THE INTERNATIONAL TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE
(C.C.I.T.T.)

IVth PLENARY ASSEMBLY

MAR DEL PLATA, 23 SEPTEMBER - 25 OCTOBER 1968

WHITE BOOK

VOLUME III

Line transmission

Published by
THE INTERNATIONAL TELECOMMUNICATION UNION
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CORRIGENDA TO VOLUME III OF THE C.C.I.T.T. *WHITE BOOK*

(English edition)

Recommendation G.111, page 4, section E, penultimate line: after "*Red Book*, volume V" insert "and reproduced in the table of the Appendix to Section 1". No change in what follows: "are not applicable... C.C.I.T.T.".

Recommendation G.134, page 1, Section B: replace "G.45" by "Q.45".

Recommendation G.163, finishes top of page 3: pages 4 and 5 belong to the Appendix.

Recommendation G.222, page 1, line 4 of text: read "composition" instead of "competition".

Recommendation G.222, page 2, line 5: read "if voice-frequency *frequency*-modulated telegraph equipment...". This is to distinguish it from the amplitude-modulated equipment referred to in G.442.

Recommendation G.232, page 1: The text of the preamble should read as follows: "... Channel terminal equipment *should provide* 12 channels in a basic group, with 4-kHz-spaced carrier frequencies, *in conformity* with the present recommendation".

Recommendation G.232, page 5, first line: replace "*Intelligible*" by "*unintelligible*".

Recommendation G.234, page 1, line 2; read: "... so that the bandwidth allocated to a channel...".

Recommendation G.241, page 6, paragraph 2, lines 6 and 11; replace "cut-off filter" by "stop filter".

Recommendation G.242, page 4, note 3, line 3; read: "... provisionally...".

Recommendation G.242, page 4, footnote 2 should read: "When supergroup contains group A in an attitude different from that of groups B to E, the limits..."

Recommendation G.333, page 2, paragraph b, 1, line 1: instead of "are recommended", read "have been earmarked".

Recommendation G.337: The title of Figure 1 should read: "Line-frequency allocation recommended for the 2.6-MHz system".

Recommendation G.356, in Figure 1, the indication "1488-kHz (12 × 124) carrier" belongs to the arrows showing the modulation in Plan 2 and not in Plan 1 B.

Note by the C.C.I.T.T. Secretariat. – Figure 1 of Recommendation G.337 (with correct title, see above) and Figure 1 of Recommendation G.423 are identical and reproduce Figure 77 of Volume III of the *Blue Book*, page 241). It has been pointed out that, in conformity with the spirit of Recommendation G.337, it is a part of Figure 1 of Recommendation G.338 and consequently supergroup No. 1 should be inverted. The attention of Administrations is drawn to this material error, which also already appeared in the *Red Book*.

Recommendation G.338, page 5, paragraph 2, line 7; read: "... of —10 dB (—1.15 Np)". Same correction on next page, line 7.

Recommendation G.423, page 3, footnote 3: delete the word "basic".

Recommendation G.423, page 4, Figure 1: Supergroup 2 should be erect, not inverted.

Recommendation G.423, page 12: The title of this table should read: "Table I (of C.C.I.R. Recommendation 380-1)".

Recommendation H.22: The order of some paragraphs was reversed during printing. Page 3 should be replaced entirely by the text attached hereto*.

Recommendation J.14: Amend the last paragraph on page 1 (before the footnotes) to read: "For example, in Figure 1 of Recommendation J.12, the station BRUXELLES carries out the equalization and line-up of the local line from the R.T.B."*.

Recommendation J.14, page 4, section d: The last sentence of the first paragraph should read: "One of the instruments of which the characteristics are summarized in the table shown on page 2 may be used".

Recommendation J.21, page 1, the penultimate line of the second paragraph should read: "... B and G in Figure 1 of Recommendation J.21".

Recommendation J.21, page 4, paragraph h, line 5: read "... (where to nominal relative level is +6.0 dB)"...

Recommendation J.21, page 5, penultimate line: read "For a programme circuit..."

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* These corrections relate to the French and English versions; they have been incorporated in the Spanish text.

2. *Links with one or more 3-kHz sections or with a mixture of 3- and 4-kHz sections*[1]

Frequency Hz	Overall loss relative to that at 800 Hz	
Below 300	Not less than −2.2 dB (−2.5 dNp); otherwise unspecified	
300- 400	−2.2 to + 4.0 dB	−2.5 to + 4.5 dNp
400- 600	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
600-2700	−2.2 to + 2.2 dB	−2.5 to + 2.5 dNp
2700-2900	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
2900-3050	−2.2 to + 6.5 dB	−2.5 to + 7.6 dNp
Above 3050	Not less than −2.2 dB (−2.5 dNp); otherwise unspecified	

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[1] *Note by the C.C.I.T.T. Secretariat.* — The Editorial Group set up by the joint LTG Working Party at its meeting in April 1967 proposed the following limits:

Links with one or more 3-kHz sections

Frequency range, Hz	Insertion loss relative to that at 800 Hz	
Below 300	Not less than −0.5 dB (0.6 dNp); otherwise unspecified	
300-2700	−0.5 to + 1.0 dB	−0.6 to + 1.2 dNp
2700-2900	−0.5 to + 2.5 dB	−0.6 to + 2.9 dNp
2900-3050	−0.5 to + 6.5 dB	−0.6 to + 7.6 dNp
Above 3050	Exceeding or equal to −0.5 dB (−0.6 dNp); upper limit unspecified	

Editorial note. — These are the limits of Figure 29 on page 119 of the *Blue Book*, Volume IV, from the Annex to Recommendation M.61.

This seems to be the result of some confusion, because the figure in question (which, below 300 Hz, differs in fact from the values shown) applies to a single telephone circuit or to a section of such a circuit.

Later, Study Group IV submitted the above table, which applies to a link and is taken from Recommendation M.81 (Volume IV, *White Book*), to the Plenary Assembly at Mar del Plata, 1968.

CONTENTS OF THE C.C.I.T.T. BOOKS
APPLICABLE AFTER THE IVth PLENARY ASSEMBLY (1968)

(WHITE BOOK)

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Volume II-A	— Recommendations (Series D) and Questions (Study Group III) relating to the lease of circuits. — Recommendations (Series E) and Questions (Study Group II) relating to telephone operation and tariffs.
Volume II-B	— Recommendations (Series F) and Questions (Study Group I) relating to telegraph operation and tariffs.
Volume III	— Recommendations (Series G, H and J) and Questions (Study Groups XV, XVI, C and D) relating to line transmission.
Volume IV	— Recommendations (Series M and N) and Questions (Study Group IV) relating to the maintenance of international lines, circuits and chains of circuits.
Volume V	— Recommendations (Series P) and Questions (Study Group XII) relating to telephone transmission quality, local networks and telephone sets.
Volume VI	— Recommendations (Series Q) and Questions (Study Groups XI and XIII) relating to telephone signalling and switching.
Volume VII	— Recommendations (Series R, S, T, U) and Questions (Study Groups VIII, IX, X, XIV) relating to telegraph technique.
Volume VIII	— Recommendations (Series V) and Questions (Special Study Group A) relating to data transmission.
Volume IX	— Recommendations (Series K) and Questions (Study Group V) relating to protection against interference. — Recommendations (Series L) and Questions (Study Group VI) relating to the protection of cable sheaths and poles.

Each volume contains, where appropriate, extracts from contributions received on the subject of the volume concerned whenever their interest is such as to warrant publication.

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TABLE 1

Summary of the main characteristics specified by the C.C.I.T.T. for international telephone circuits (†) and international connections

(This very condensed table is not a recommendation; reference should be made to the full Recommendations, the numbers of which are shown in the table)

		For an international circuit (1)	For a complete connection or for its parts (2)
Reference equivalent		G.111, B	For the connection and for the national systems G.111, G.121
Nominal four-wire equivalent (transmission plan, see G.101)		0.5 dB (G.141) Echo effects (G.131, B)	Four-wire chain national circuits G.101, B, b, G.121, G.122.
Transmission stability		G.131, A	Balance return loss of national networks (G.122)
Band of frequencies effectively transmitted	Limits in Hz	$\geqq$ 300-3400 (G.151, A) 300-3400 (G.132) [2]	From international centre to local exchange: 300-3400 (G.124)
	Additional attenuation in dB at limits of frequency	8.7 dB (G.151, A and G.132)	8.7 dB (G.151, A and G.132)
Attenuation distortion		G.151,4 A	Graph No. 1, desirable objective for 12 circuits (G.132) For data: see H.12
Group delay (t)		G.114	For the connection (G.114) $t \leqq 150$ ms, without reservation $t \leqq 400$ ms, acceptable with conditions. For data: see H.12
Phase distortion (from the group delay t) [1]		$t_m - t_{min} \leqq 30$ ms [2] $t_M - t_{min} \leqq 15$ ms [2] (G.133)	For the 4-wire chain: $t_m - t_{min} \leqq 60$ ms $t_M - t_{min} \leqq 30$ ms For each national 4-wire chain: $t_m - t_{min} \leqq 15$ ms $t_M - t_{min} \leqq 7.5$ ms (G.133)
Variation of overall loss with time		Mean deviation from nominal $\leqq \pm 0.5$ dB Std. dev. $\leqq$ 1 dB or 1.5 dB G.151, C)	Extension circuits: as (1) (G.151) For data: see H.12
Linear crosstalk between different circuits (near- or far-end crosstalk ratio Δ)		$\Delta \geqq 58.2$ dB (G.151, D)	Extension circuits: as (1) (G.151)

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† Unless otherwise stated, circuits for voice-frequency telegraphy or phototelegraphy have the same characteristics.

[1] m = nominal minimum frequency effectively transmitted.
M = nominal maximum frequency effectively transmitted.
min = frequency corresponding to minimum group-delay time.

[2] These values apply to the chain of international circuits.

TABLE 1 *(continued)*

			For an international circuit (1)	For a complete connection or for its parts (2)
Near-end crosstalk ratio between the two directions of transmission			Ordinary circuits: ≧ 43 dB (G.151, D) With speech concentrator: ≧ 58 dB With echo suppressors: ≧ 55 dB (G.151, D)	Extension circuits: as (1)
Circuit noise			See Table 1 *bis*	
Impedance of the circuit				A signle value for one trunk exchange (G.232, L)
Frequency difference at two ends of a carrier circuit			≦ 2 Hz (G.225)	G.225
Power at zero relative level point	Telephony, mean power in busy hour		Speech currents, etc. 22 μW [1] (G.223) Electric signals + tones 10 μW [1] (G.223) (see G.224 for the power of signalling pulses)	
	Voice-frequency telegraphy. Maximum power per channel for V.F.T. systems having		Amplitude modulation. Power when sending continous mark (H.23, A, a)	Frequency modulation mean power (H.23, A, b)
	24 channels		9 μW	5.6 μW
	18 channels		15 μW	7.5 μW
	12 channels or less		35 μW	11.25 μW
	Private wire telegraphy and telephony	one or other	Sending continuous mark 0.3 mW maximum (H.31) [2]	
		both	Teleg. level ≦ −13 dBm0 (H.32) [2]	
	Phototelegraphy		Amplitude modulation 1 mW, frequency modulation 0.1 mW (H.41)	
Maximum power for data transmission over leased circuits (H.51, A) [2]			1 mW on subscriber's line Frequencies ≧ 2400 Hz, see G.224	
			Frequency modulation: −10 dBm0 or −20 dBm0 Amplitude modulation: −6 dBm0 and 64 μW (mean for both directions in busy hour)	
Maximum power for data transmission over circuits in switched network (H.51, B) [2]			1 mW on subscriber's line Frequencies ≧ 2400 Hz, see G.224	
			Frequency or phase modulation: −10 dBm0 in simplex, −13 dBm0 in duplex Amplitude modulation: 64 μW (mean for both directions in busy hour)	

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[1] Calculation target value or conventional value for a hypothetical reference circuit.

[2] This recommendation contains restrictions of use.

TABLE 1 *bis*

Summary of noise objectives specified by the C.C.I.T.T. and the C.C.I.R. for telephone circuits

Notes

[1] Special objectives for telegraphy are indicated in Recommendations G.143, G.153, G.222 and G.442.

[2] For these systems, it is sufficient to check that the objective for the hourly mean is attained.

[3] See, in this recommendation, the details of the hypothetical reference circuits to be considered.

[4] The objectives for line noise, in the same column, are proportional to the length in the case of shorter lengths.

[5] Objective 3 pW/km for the worst circuits; if a real circuit has more than 40 000 pW, it should be equipped with a compandor.

[6] Except in extremely unfavourable climatic conditions.

[7] Desirable value: 500 pW. Highest value for one circuit: 2000 pW.

* Provisionally.

General comment. – All the values mentioned in this table refer to a point of zero relative level of a telephone circuit set up on the system under consideration (of the first circuit, for the chain). Furthermore (G.123), the psophometric e.m.f. of noise induced by power lines should not exceed 1 mV at the "line" terminals of the subscriber's station. The mean value of the busy-hour noise power through a four-wire national exchange: $\leq$ 200 pW0p. Limits of unweighted noise through exchange: 100 000 pW.

Types of systems				General objectives					
				Cable [2] or radio-relay link		Single-hop satellite link	Submarine cable [2]	All systems	
Telephone circuits considered [1]				National four-wire extension circuits and international circuits from 250 to 2500 km	Circuits from 2500 to about 25 000 km	Circuits from 7500 to about 15 000 km	Circuits from 2500 to about 25 000 km	Chain of six international circuits	
Recommendations	Of the C.C.I.T.T.			G.152 G.212 [3] G.222 G.226	G.153		G.153	G.143	G.143
	Of the C.C.I.R.			391, 392 393, 394, 395, 396-1, 397-1		352, 353			
Hypothetical reference circuit (H.R.C.) or typical circuit considered				H.R.C. of 2500 km [4] or similar real circuit	Circuit of 7500 km [4]	Basic H.R.C. of at least 7500 km		Chain of about 25 000 km	Chain of more than 25 000 km
Recommended objectives	Psophometric power	Hourly mean	Total power	10 000 pW				50 000 pW	
			Terminal equipment	2500 pW				About 7000 to 9000 pW	
			Line	7500 pW i.e. 3 pW/km	15 000 pW* 2 pW/km or better [5]	10 000 pW*	1 pW/km [5]	About 1.5 pW/km	1 pW/km for each section longer than 2500 km
		For one minute exceeded during 20% of the month	Line	7500 pW		10 000 pW*			
		% of a month during which the psophometric power for one minute due to the line indicated can be exceeded	47 500 pW 50 000 pW 63 000 pW	0.1	0.3 *	0.3 *			
Un-weighted power	% of the month during which 10^6 pW (5 ms) can be exceeded			0.01	0.03 *	0.03 *			

Types of systems					Special objectives								
				Noise allocation of a national system	For very short distances	Radio-relay links					Tropospheric radio-relay links in special conditions	Open-wire lines	
Telephone circuits considered [1]					Two circuits at most in each of the two terminal national networks	Circuits not very different from H.R.C. $280 < L < 2500$ km	Composition of links very different from h.r.c. $50 \leq L < 280$ km	$280 < L \leq 840$ km	$840 < L \leq 1670$ km	$1670 < L \leq 2500$ km	One or two circuits at most in one world connection	Up to 2500 km	More than 2500 km
Recommendations	Of the C.C.I.T.T.			G.123	G.125							G.311	G.153
	Of the C.C.I.R.					395	395	395	395	395	396, 397		
Hypothetical reference circuit (H.R.C.) or typical circuit considered				Total length L in km of the long-line f.d.m. carrier systems in the national chain							H.R.C. of 2500 km [4]	H.R.C. of 2500 km [4]	Circuit of 10 000 km
Recommended objectives	Psophometric power	Hourly mean	Total power	$(4000 + 4 L)$ pW or $(7000 - 2 L)$ pW	1000 pW [7] at most							20 000 pW [6]	50 000 pW [6]
			Terminal equipment									2500 pW	
			Line			$3 L$ pW	$(3 L + 200)$ pW		$(3 L + 400)$ pW	$(3 L + 600)$ pW		17 500 pW	
		For one minute exceeded during 20% of the month	Line			$3 L$ pW	$(3 L + 200)$ pW		$(3 L + 400)$ pW	$(3 L + 600)$ pW	25 000 pW		
		% of a month during which the psophometric power for one minute due to the line indicated can be exceeded	47 500 pW 50 000 pW 63 000 pW			$\frac{L}{2500} \times 0.1$	$\frac{280}{2500} \times 0.1$	$\frac{L}{2500} \times 0.1$	$\frac{L}{2500} \times 0.1$	$\frac{L}{2500} \times 0.1$	0.5		
Un-weighted power	% of the month during which 10^6 pW (5 ms) can be exceeded										0.05		

TABLE 2

Summary of the main characteristics specified by the C.C.I.T.T. for carrier terminal equipments

(This very condensed table is not a recommandation;
reference should be made to the full recommendations on the pages shown in the table)

	Systems wholly in cable (G.232, p. 3)	Systems on open-wire lines		
		3-channel (G.361, p. 3)		12-channel (G.232, p. 4)
		Nm0	dBm0	
Level of carrier leak on the line				
— per channel	−26 dBm0	−2.0	−17	−26 dBm0
— per group	−20 dBm0	−1.7	−14.5	−20 dBm0
Attenuation distortion	Figs. 1 and 2 (G.232, p. 2)			
Group delay	Table 1 (G.232, p. 3)			
Non-linear distortion	Fig. 3 (G.232, p. 5)			
Amplitude limiting	Definition (G.232, p. 4)			
Crosstalk ratio	≧ 65 dB or 7.5 Np for intelligible crosstalk (G.232, p. 4) ≧ 60 dB or 6.9 Np for unintelligible crosstalk between adjacent channels (G.232, p. 6)			
Near-end crosstalk ratio (A) between HF points	≧ 44 dB without echo suppressors (G.232, p. 7) ≧ 59 dB with echo suppressors (G.232, p. 7)			
Near-end crosstalk ratio (X) between audio points	≧ 50 dB without echo suppressors (G.232, p. 7) ≧ 65 dB with echo suppressors (G.232, p. 7)			
Impedance	600 Ω (G.232, p.7)			
Protection and suppression of pilots	(G.232, p. 7)			

Note. — See Recommendations G.234 and G.235 for 8-channel and 16-channel equipments respectively.

TABLE 3

Summary of the main characteristics specified by the C.C.I.T.T. for groups and supergroups

(This very condensed table is not a recommendation;
reference should be made to the full recommendations on the pages shown in the table)

	Group		Supergroup	
Ratio between wanted component and the following components, defined on (G.242, p. 2), after through-connection	at 84 kHz (G.242, p. 2)		at 412 kHz (G.242, p. 3)	
	(Np)	(dB)	(Np)	(dB)
– intelligible crosstalk [1]	8.0	70	8.0	70
– unintelligible crosstalk [1]	8.0	70	8.0	70
– possible crosstalk	4.0	35	4.0	35
– harmful out-of-band	4.6	40	4.6	40
– harmless out-of-band	2.0	17	2.0	17
Additional suppression to safeguard pilot frequencies (G.243, p. 1)			4.6 Np (40 dB) at 308 kHz ±8 Hz 2.3 Np (20 dB) at 308 and 556 kHz ±40 Hz (relative to 412-kHz value)	
Additional suppression to safeguard additional measuring frequencies (G.243, p. 2)			2.3 Np (20 dB) at 308 and 556 kHz ±20 Hz 1.73 Np (15 dB) at 308 and 556 kHz ±50 Hz (relative to 412 kHz) (see also Fig. 1; G.243, p. 3)	
Range of insertion loss over the pass-band for through-connection equipments	±1.2 dNp or ±1 dB relative to 84 kHz (G.242, p.3)		±1.2 dNp or ±1 dB relative to 412 kHz ≦0.35 Np (3 dB) for SG 1 and SG 3 (G.242, p. 4)	
Range of insertion loss over 10° and 40° C for through-connection equipments	±1.2 dNp or ±1 dB at 84 kHz relative to the insertion loss at 25 °C (G.242, p. 3)		±1.2 dNp or ±1 dB at 412 kHz relative to the insertion loss at 25° C (G.242, p. 4)	
Pilot frequency for (G.241, p. 2)	Frequency (kHz) [2]	Accuracy (Hz)	Absolute power leval at zero relative level point (for tolerances, see G.241, p. 3)	
			(Nm0)	(dBm0)
Basic group B [3]	84.080	±1	−2.3	−20
	84.140	±3	−2.9	−25
	104.080	±1	−2.3	−20
Basic supergroup	411.860	±3	−2.9	−25
	411.920	±1	−2.3	−20
	547.920	±1	−2.3	−20

[1] For telephony (G.242, p. 3).

[2] See (G.241, p. 2) for use of these frequencies.

[3] Also applies to 8-channel groups (G.314).

TABLE 3 *(concluded)*

Summary of the principal characteristics specified by the C.C.I.T.T. for mastergroups, supermastergroups and 15-supergroup assembly

	Mastergroup		Supermastergroup		15-supergroup assembly	
Ratio between wanted component and the following components, defined on (G.242, p. 2) after through-connection:	at 1552 kHz (G.242, p. 4)		at 11 096 kHz (G.242, p. 5)		at 1552 kHz (G.242, p. 6)	
	(Np)	(dB)	(Np)	(dB)	(Np)	(dB)
– intelligible crosstalk[1]	8.0	70	8.0	70	8.0	70
– unintelligible crosstalk [1]	8.0	70	8.0	70	8.0	70
– possible crosstalk	4.0	35	4.0	35	4.0	35
– harmful out-of-band	4.6	40	4.6	40	4.6	40
– harmless out-of-band	2.0	17	2.0	17	2.0	17
Variation of insertion loss in pass-band of through-connection equipment	±1.2 dNp or ±1 dB with respect to value at 1552 kHz (G.242, p. 5)		±1.73 dNp (±1.5 dB) with respect to value at 11 096 kHz ±1.2 dNp or ±1 dB in each mastergroup (G.242, p. 5)		±1.73 dNp (±1.5 dB) with respect to value at 1552 kHz ±1.2 dNp or ±1 dB in each supergroup (G. 242, p. 6)	
Variation of insertion loss between 10° C and 40° C of through-connection equipment	±1.2 dNp or ±1 dB at 1552 kHz relative to insertion loss at 25° C (G.242, p. 5)		±1.2 dNp or ±1 dB at 11 096 kHz relative to insertion loss at 25° C (G.242, p. 5)		±1.2 dNp or ±1 dB at 1552 kHz relative to insertion loss at 25° C (G.242, p. 6)	
Relative levels at distribution frames (G.233, p. 7-8)	(Nr)	(dBr)	(Nr)	(dBr)	(Nr)	(dBr)
– transmit	−4.1	−36	−3.8	−33	−3.8	−33
– receive	−2.6	−23	−2.9	−25	−2.9	−25
Return loss at modulator input (G.233, p. 8)	(Np) ≧ 2.3	(dB) ≧ 20	(Np) ≧ 2.3	(dB) ≧ 20	(Np) ≧ 2.3	(dB) ≧ 20
Master group, supermastergroup or 15-supergroup assembly pilots (G.241, p. 2) in:	Frequency (kHz)		Accuracy (Hz)		Level (for tolerances, see G.241, p. 3)	
					(Nm0)	(dBm0)
– Basic mastergroup	1 552		± 2		−2.3	−20
– Basic supermastergroup	11 096		±10		−2.3	−20
– Basic 15-supergroup assembly	1 552		± 2		−2.3	−20

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[1] For the telephony, see G.242, p. 3.

TABLE 4

Summary of the caracteristics specified by the C.C.I.T.T. for carrier systems on open-wire lines

(This very condensed table is not a recommendation;
reference should be made to the full recommendations ont the pages shown in the table)

	Systems acting on each pair		
	3-circuit systems	8-circuit systems	12-circuit systems
Line frequencies - for a single system	Fig. 1 (G.361, p. 2); see also (G.361, p. 1-4-5)	Fig. 1 (G.314, p. 3)	Scheme I (Fig. 1) or Scheme II (Fig. 2) (G.311, p. 3)
- for several systems on the same route	Fig. 1 (G.361, p. 2)	(G.314, p. 1)	See (Fig. 3 - G.311, p. 4) and (Fig. 4 - G.311, p. 6) for examples
Pilots - frequency	16.110 and 31.110 kHz or 17.800 kHz[1] (G.361, p. 2)	(G.314, p. 2)	(G.311, p. 3-5)
- level	-1.73 Nm0 (-15 dBm0)		-2.3 Nm0 (-20 dBm0)[2]
Terminal equipment and intermediate repeater output. Relative level per channel at 800-Hz equivalent frequency	$\leqq 2$ Nr $\leqq 17$ dBr (G.361, p. 2)	$\leqq 2$ Nr $\leqq 17$ dBr (G.314, p.1)	$\leqq 2$ Nr ± 1 dNr or $\leqq 17$ dBr ± 1 dBr (terminal equipment) $\leqq 2$ Nr ± 2 dNr or $\leqq 17$ dBr ± 2 dBr (intermediate repeater equipment) (G.311, p.2)
Frequency accuracy of pilot and carrier frequency generators	2.5×10^{-5} (G.361, p. 2-3)	1×10^{-5} (G.314, p. 2)	5×10^{-6} (G.311, p. 5-7)

[1] Used only by agreement between administrations.

[2] Provisional recommendation.

TABLE 5

Summary of characteristics specified by the C.C.I.T.T. for carrier systems on symmetric pair cables [1]

(This very condensed table is not a recommendation;
reference should be made to the full recommendations on the pages shown in the table)

	System			
	1, 2 or 3 groups	4 groups	5 groups	2 supergroups
Line frequencies	Fig. 2a (G.322, p. 4)	Fig. 2b (G.322, p. 4) Scheme 1 Scheme 1*bis* [2]	Fig. 2c (G.322, p. 4) Scheme 2 Scheme 2*bis* [2]	Fig. 4 (G.322, p. 5) Schemes 3 and 4 Scheme 3*bis* [2]
Relative level at repeater output [3] (low-gain systems) (G.322, p. 9)	−1.3 Nr or −11 dBr	−1.6 Nr or −14 dBr	−1.6 Nr or −14 dBr	−1.6 Nr or −14 dBr
Relative level at repeater output [3] (valve-type systems) (G.324, p. 2) – nominal value – tolerance	±0.5 Nr or +4.5 dBr ±0.2 Np or ±2 dB	+0.2 Nr or +1.75 dBr ±0.2 Np or ±2 dB	+0.2 Nr or +1.75 dBr ±0.2 Np or ±2 dB	+0.2 Nr or +1.75 dBr ±0.2 Np or ±2 dB
Return loss of repeater and line impedances (G.322, p. 8)	$\leqq 0.15 \sqrt{\frac{f_{max}}{f}}$ or $\leqq 0.25$	$\leqq 0.08 \sqrt{\frac{f_{max}}{f}}$ or $\leqq 0.10$	$\leqq 0.08 \sqrt{\frac{f_{max}}{f}}$ or $\leqq 0.10$ (paper-insulated cables) $\leqq 0.10 \sqrt{\frac{f_{max}}{f}}$ or $\leqq 0.17$ (cable types II*bis* and III*bis*[2] - G.321)	
Relative level at repeater input [3]	$\geqq -6.5$ Nr or $\geqq -56.5$ dBr (G.324, p. 2)			
Pilots	For alternative methods see Fig. 5 (G.322, p. 7)			60 kHz ±1 Hz and 556 kHz ±3 Hz (G.322, p. 8)
Monitoring frequencies (low-gain systems)	(G.322, p. 9)			
Harmonic distortion (low-gain systems)	See Table (G.322, p. 9)			
Harmonic distortion (valve-type systems)	See Table (G.325, p. 1)			

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[1] For 12+12 systems, see Recommendations G.325 and G.327.

[2] Used only by agreement between administrations.

[3] Not applicable to power-fed repeaters.

TABLE 6

Summary of characteristics specified by the C.C.I.T.T. for carrier systems on 2.6/9.5-mm coaxial cables

(This very condensed table is not a recommendation;
reference should be made to the full recommendations on the pages shown in the table)

	2.6-MHz systems[1] (1)	4-MHz systems (2)	12-MHz systems (3)	40- and 60-MHz systems (4)
Line frequencies	Fig. 1 (G.337, p. 2) and Fig. 1 (G.338, p. 2)	Fig. 1 (G.338, p. 2) and Fig. 3 (G.322, p. 3)	Figs. 1 to 4 (G.332, p. 2-3-4)	Figs. 1 and 2 (G.333, p. 3)
Pilot frequencies				
– line-regulating pilots	60 kHz ±1 Hz or 308 kHz ±3 Hz 2604 kHz ±30 Hz (G.337, p. 2)	60 kHz ±1 Hz or 308 kHz±3 Hz 4092 kHz ±40 Hz and see (G.338, p. 4)	4287 kHz ±42.9 Hz for valve-type systems (G.339, p. 2) 12 435 kHz ±124.3 Hz for transistorized systems (G.332, p. 5)	4287 kHz ±42.9Hz 12 435 kHz ±124.3 Hz 22 372 kHz ±223.7 Hz 40 920 kHz ±409.2 Hz 61 160 kHz[2] ±611.6 Hz (G.333, p. 2)
– auxiliary line-regulating pilots	(G.337, p. 2)	(G.338, p. 5)	308 kHz ±3 Hz and 12 435 kHz ±124.3 Hz for valve-type systems (G.339, p. 2) 308 kHz ±3 Hz and 4287 kHz ±42.9 Hz for transistorized systems (G.332, p. 5)	(G.333, p. 2)
Frequency comparison pilots				
– national	as (2)	60 or 308 kHz 1800 kHz[2] (G.338, p. 5)	300 or 308 kHz (G.332, p. 7)	
– international	as (2)	1800 kHz (G.338, p. 5)	308 and 1800 kHz 300 kHz[2] 808 kHz[2] and 1552 kHz[2] (G.332, p. 7)	4200 or 8316 kHz (G.333, p. 2)
Additional measuring frequencies	G.337, p. 2)	(G.338, p. 6)	(G.332, p. 7) and (G.339, p. 2)	

Table 6 *(continued)*

	2.6-MHz systems [1] (1)	4-MHz systems (2)	12-MHz systems (3)	40- and 60-MHz systems (4)
Level of line-regulating pilots and additional measuring frequencies – adjustment value	as (2)	-1.15 Nm0 ± 0.05 Np (-10 dBm0 ± 0.5 dB) (G.338, p. 4-6) -1.2 Nm0 for some systems (G.338, p. 5)	-1.15 Nm0 ± 0.05 Np (-10 dBm0 ± 0.5 dB) (G.332, p. 5) -1.2 Nm0 for valve-type systems (G.339, p. 2)	as (2)
– error in the level	as (3)	as (3)	± 0.01 Np or ± 0.1 dB (G.332, p. 5)	as (3)
– variation with time	as (3)	as (3)	± 0.03 Np or ± 0.3 dB (G.332, p. 5)	as (3)
Impedance match between repeaters and line N (as defined on G.332, p. 12)	$N \geq 4.6$ Np (40 dB) for $f < 300$ kHz $N \geq 5.2$ Np or 45 dB for $f > 300$ kHz (G.338, p. 8)		$N \geq 5.55$ Np (48 dB) for $300 \leq f \leq 5564$ kHz (valve-type systems G.339, p. 2) $N \geq 5.55$ Np (48 dB) for $f = 300$ kHz and $N \geq 6.3$ Np or 55 dB for $f \geq 800$ kHz (transistorized systems G.332, p. 11)	$N = 65$ dB [3] (G.333, p. 5)
Relative level on line			(G.332, p. 11) and (G.339, p. 2)	(G.333, p. 5)

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[1] Use of the 6-MHz for telephony is specified otherwise (see G.337, p. 2).

[2] Only used by agreement between administrations.

[3] Provisional recommendation.

TABLE 7

Summary of characteristics specified by the C.C.I.T.T. for carrier systems on 1.2/4.4-mm coaxial cables

(This very condensed table is not a recommendation;
reference should be made to the full recommendations on the pages shown in the table)

	1.3-MHz systems	4-MHz systems	6-MHz systems	12-MHz systems
Line frequencies	Fig. 1 (G.341, p. 2)	Schemes 1 and 2 of Fig. 1 (G.343, p. 2)	Schemes 1, 2 and 3 of Fig. 1 (G.344, p. 2)	(G.345) [1]
Pilot frequencies – line-regulating pilots	1364 kHz ±13.6 Hz (G.341, p. 1)	See (G.343, p. 1) and for Scheme 1 (G.338, p. 4); for Scheme 2 (G.332, p. 5)	308 kHz ±3 Hz (G.344, p. 3)	The provisions of this recommendation are provisionally those appearing in Recommendation G.332, with the exception of the matching (see Table 6)
– auxiliary line-regulating pilots	60 kHz ±1 Hz or 308 kHz ±3 Hz (G.341, p. 2)	4287 kHz ± 42.8 Hz [2] (G.343, p. 1)	4287 kHz ±42.8 Hz [3] 6200 kHz ±62 Hz (G.344, p. 3)	
– frequency comparison pilots	60 kHz or 308 kHz (G.341, p. 2)	Scheme 1 (G.338, p. 5) and Scheme 2 (G.332, p. 7)	Schemes 1 and 2 (G.338, p. 5) Scheme 3 (G.332, p. 7)	
Additional measuring frequencies	(G.341, p. 2)	(G.343, p. 3)	(G.344, p. 3)	
Level of line-regulating pilots and additional measuring frequencies – adjustment value	−1.15 Nm0 (−10 dBm0) or 1.2 Nm0 for some systems (G.341, p. 3)	−1.15 Nm0 (−10 dBm0) (G.343, p. 1)	−1.15 Nm0 (−10 dBm0) (G.344, p. 3)	
– tolerances		(G.343, p. 1)	(G.344, p. 3)	
Impedance match between repeaters and line	$N \geqq 6.2$ Np or 54 dB for a 6-km repeater section $N \geqq 6.0$ Np or 52 dB for a 8-km repeater section '(G.341, p. 3)	$N \geqq 50$ dB for $f = 60$ kHz $N \geqq 57$ dB for $f \geqq 300$ kHz (4-km repeater section G.343, p. 3)	$N \geqq 6.9$ Np or 60 dB for $f \geqq 300$ kHz $N = 5.7$ Np or 50 dB for f = 60 kHz (3-km repeater section G.344, p. 3)	$N = 63$ dB for a 2-km repeater section (G.345)
Relative levels on line and interconnection	(G.341, p. 4)	−9 dBr at 4028 kHz or −8.5 dBr at 4287 kHz (G.343, p. 3)	−17 dBr [1] (G.344, p. 4)	(G.332, p. 12)

[1] Provisional recommendation.

[2] Only used by agreement between administrations.

[3] Cannot be used with television transmissions.

TABLE 8

Summary of the principal characteristics specified by the C.C.I.T.T. for international circuits for programme transmissions

(This very condensed table is not a recommendation;
reference should be made to the full recommendations on the pages shown in the table)

		Normal circuits		Old-type circuits (3)
		Type A (1)	Type B (2)	
Frequency band effectively transmitted by the complete link	Limit in Hz	at least 50-10 000 (J.21, p. 2)	at least 50-6400 (J.31, p. 1)	at least 50-6400 (J.41, p. 1)
	Additional attenuation at these frequency limits	0.5 Np or 4.3 dB (J.21, p. 2)	0.5 Np or 4.3 dB (J.31, p. 1)	0.5 Np or 4.3 dB (J.41, p. 1)
Attenuation distortion		Fig. 2 (J.21, p. 2)	Fig. 1 (J.31, p. 2)	Figs. 1 and 2 (J.41, p. 2)
Phase distortion (from the group delay time t)		$t_{10000}-t_{\min} < 8$ ms $t_{100}-t_{\min} < 20$ ms $t_{50}-t_{\min} < 80$ ms (J.21, p. 3)	$t_{6400}-t_{\min} < 8$ ms $t_{100}-t_{\min} < 20$ ms $t_{50}-t_{\min} < 80$ ms (J.31, p. 2)	$t_{6400}-t_{800} < 10$ ms $t_{50}-t_{800} < 70$ ms (J.41, p. 1)
Maximum absolute voltage level at a zero relative level point		+9 dB (J.13, p. 1) peak voltage 3.1 V (J.12, p. 2)	as (1) (J.31, p. 1)	as (1)
Definition of zero relative level point (for carrier circuit)		as for telephony to within ±3 dB (J.13, p. 1)	as (1) (J.31, p. 1)	as (1)
Nominal relative voltage level at input and output of the circuit (defined on J.12, p. 1)		+0.7 Np or 6 dB (J.13, p. 1)	as (1) (J.31, p. 1)	as (1)
Variation of relative level with time		±0.2 Np or ±2 dB during a transmission (J.21, p. 4)	as (1) (J.31, p. 2)	as (1) (J.41, p. 3)
Linear crosstalk (near or far-end crosstalk ratio Δt)[1]		$\Delta \geqq 8.5$ Np or 74 dB (cables)[2] $\Delta \geqq 7.0$ Np or 61 dB (open-wire lines)[2] (J.21, p. 3)[3]	as (1)[2] (J.31, p. 2)[3]	as (1)[2] (J.41, p. 3)[3]

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[1] Between circuits for programme transmission. Also on the same pages are the limits for crosstalk with telephone circuits.

[2] Provisional recommendation.

[3] Special precautions for crosstalk between the two directions of transmission (see J.21, p. 2-4-5).

TABLE 8 *(continued)*

			Normal circuits			Old-type circuits (3)
			Type A (1)		Type B (2)	
Circuit noise (including non-linear crosstalk)	Psophometric voltage	At the end of the circuit	in cable	on open-wire	as (1) (J.31, p. 2) [1]	as (1) (J.41, p. 3-4) [1]
			6.2 mV (J.21, p. 3 [1])	15.6 mV (J.31, p. 3)		
		Relative level	+0.7 Nr	+0.7 Nr		
		Referred to zero relative level	$\frac{2.2 \text{ V}}{710} = 3\text{mV}$	$\frac{2.2 \text{ V}}{283} = 7.75 \text{ mV}$		

NOTICE TO VOLUME III OF THE WHITE BOOK

Volume III of the *White Book* fully supersedes Volume III of the C.C.I.T.T. *Blue Book* (Geneva, 1964).

It has been indicated (immediately after the titles of Recommendations or Supplements) whether the texts are new ones approved by the Plenary Assembly of Mar del Plata, 1968, or are texts amended at the same period. Texts without any such an indication date from at least as far back as the Plenary Assembly of New Delhi, 1960, when Volume III was divided into numbered recommendations; certain of these texts may be even older.

Units

Some of the recommendations in this present publication give quantities expressed in more than one system of units [1]. The following conventions apply in such cases:

1. A quantity in brackets shows a conversion to a suitable degree of accuracy.

Examples: 2500 km (1550 miles); 2.1 nepers (18.2 decibels).

2. When there is a choice of one of two values, depending on the unit used, they are given with the word « or » between them.

Examples: 9.5 mm or 0.375 inch; −10 dB or −1.2 Np.

The following abbreviations are used, particularly in diagrams and tables, and always have the following clearly defined meanings:

dBm (Nm): the absolute (power) level in decibels (in nepers);
dBm0 (Nm0): the absolute (power) level in decibels (in nepers) referred to a point of zero relative level;
dBr (Nr): the relative (power) level in decibels (in nepers);
dBm0p (Nm0p): the absolute psophometric power level in decibels (in nepers) referred to a point of zero relative level.

Graphical symbols

The graphical symbols most frequently used in Volume III are shown in an inset at the end of this book.

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[1] *Note by the C.C.I.T.T. Secretariat*

In issuing Recommendation B.4 (*White Book*, Volume I), which advocates the exclusive use of the decibel in certain cases, the IVth Plenary Assembly (Mar del Plata, 1968) recognized that this Recommendation could not be applied immediately to the present publication.

PART 1

SERIES G RECOMMENDATIONS

Telephone transmission on metallic lines, radio links, satellite and radiotelephone systems

SECTION 1

GENERAL CHARACTERISTICS FOR INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

1.0 General

RECOMMENDATION G.101 (Geneva, 1964; amended in Mar del Plata, 1968)

THE TRANSMISSION PLAN

A. PRINCIPLES

The transmission plan of the C.C.I.T.T. established in 1964 was drawn up with the object of making use, in the international service, of the advantages offered by four-wire switching. It is referred to in the recommendations appearing in Part I, Section 1, of this volume. However, the recommendations in the plan are to be considered as met if the use of technical means other than those described below gives an equivalent performance at the international exchange.

Recommendation G.122 describes the conditions to be fulfilled by a national network for this transmission plan to be put into effect.

Note 1. — From the point of view of the transmission plan, no distinction is made between intercontinental circuits and other international circuits.

Note 2. — Short trans-frontier circuits are not covered by this plan and should be the subject of agreement between the Administrations concerned.

Note 3. — The Appendix to Section 1 contains those recommendations which are now out of date or have suffered amendment as a result of the adoption of the new plan. Only those whose provisional maintenance in the C.C.I.T.T. literature might assist administrations in the change-over from the old transmission plan to the plan now recommended have been kept.

B. Definition of the constituent parts of a connection

a) *The international chain and the national systems*

A complete international telephone connection consists of three parts, as shown in Figure 1.

— *An international chain* made up of one or more four-wire international circuits. These are interconnected on a four-wire basis in the international transit centres and are also connected on a four-wire basis to national systems in the international centres.

— *Two national systems*, one at each end. These may comprise one or more four-wire national trunk circuits with four-wire interconnection, as well as circuits with two-wire connection up to the terminal exchanges and to the subscribers.

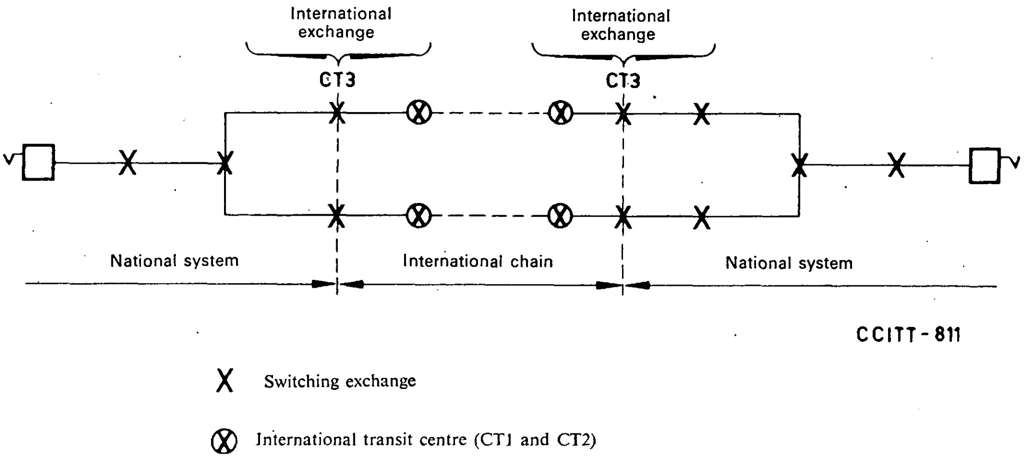


Figure 1. — **Definition of the constituent parts of an international connection**

A four-wire circuit is defined by its *virtual switching points* in an international transit exchange or an international exchange. These are theoretical points with specified relative levels (see Figure 2; for further details see Recommendation G.141).

The difference between the sending and receiving nominal relative levels at the reference frequency is, by definition, *the nominal transmission loss* of the four-wire circuit *between virtual switching points.*

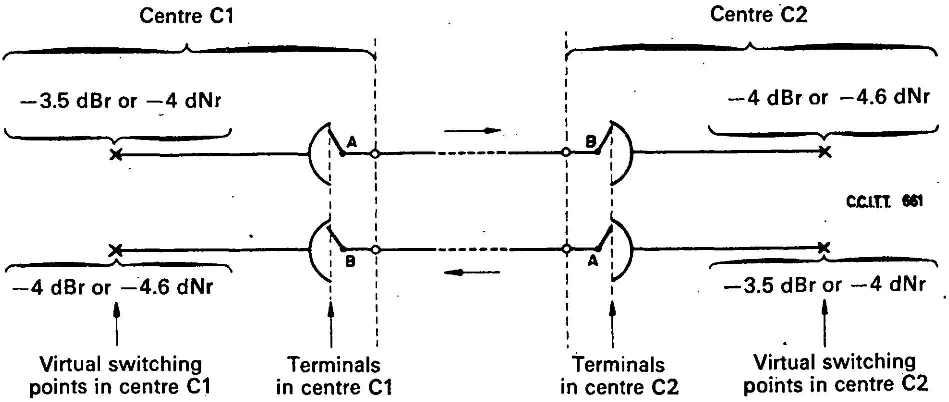
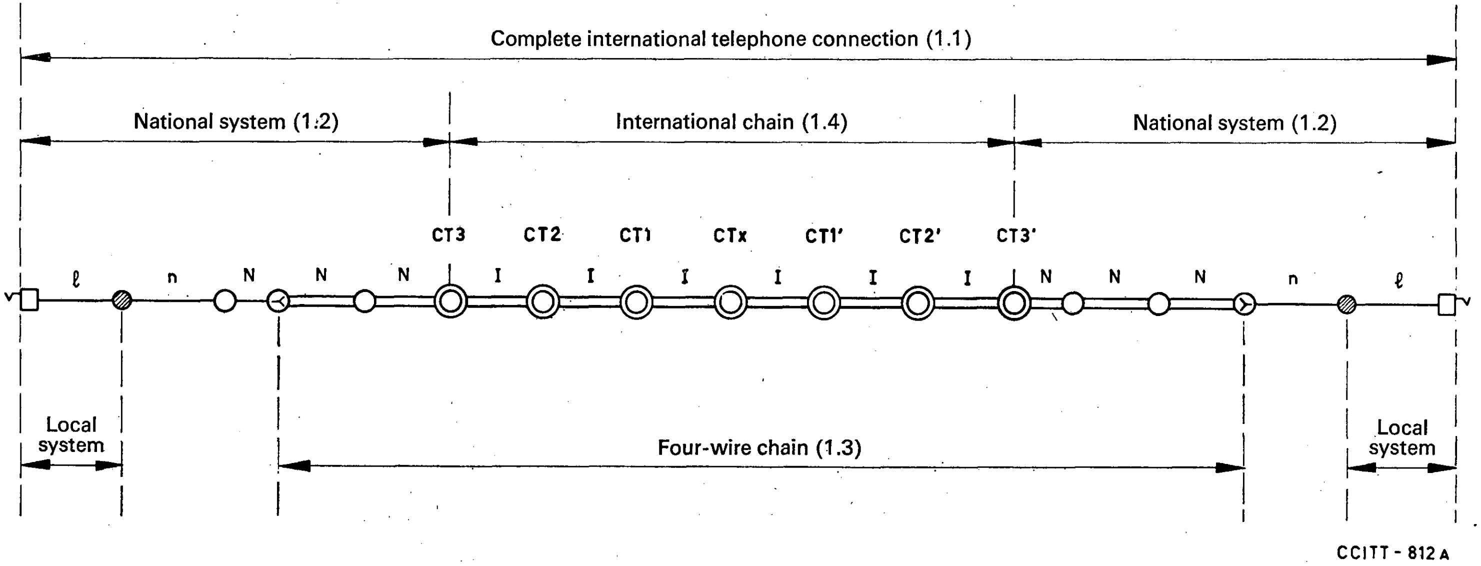


Figure 2. — **Definitions for an international circuit**



Subscriber's set
Two-wire switching exchange
Four-wire switching exchange
Exchange with terminating unit

▨ Local exchange

◎ International exchange

I = International circuits (including intercontinental circuits)
N = National extension circuits
n = Another national circuit
ℓ = Subscriber's line

Note. — The numbers in brackets are the numbers of the sub-sections in Section 1 in which the relevant recommendations appear. In addition, the circuits making up this chain must individually meet the requirements of sub-section 1.5.

FIGURE 3. — **An international connection to illustrate the nomenclature adopted**

In an international exchange, the division between the international chain and the national system is determined by the virtual switching points of the international circuit.

The virtual switching points may not be the same as the points at which the circuit terminates physically in the switching equipment. These latter points are known as the *circuit terminals*; the exact position of these terminals is decided in each case by the administration concerned.

b) *National extension circuits : four-wire chain*

When the maximum distance between an international exchange and a subscriber who can be reached from it does not exceed about 600 miles (1000 km) or, exceptionally, 1000 miles (1500 km), the country concerned is considered as of average size. In such countries, at the most three national four-wire circuits can be interconnected on a four-wire basis between each other and to international circuits. They should comply with the recommendations of paragraph 1.2.

In a large country, a fourth and possibly a fifth national circuit may be included in the four-wire chain, provided it has the nominal transmission loss and the characteristics recommended for international circuits used in a four-wire chain (see Recommendation G.141 and the recommendations in paragraph 1.5).

Note. — The abbreviation "a four-wire chain" (see Figure 3) signifies the chain composed of the international chain and the national extension circuits connected to it, either by four-wire switching or by some equivalent procedure (as understood in section A above).

C. MAXIMUM NUMBER OF CIRCUITS

a) *National circuits*

It seems reasonable to assume that in most countries any *local exchange* can be connected to the international network by means of a chain of four (or less) national circuits. Five national circuits may be needed in some countries, but it is unlikely that any country may need to use more than five circuits. Hence the C.C.I.T.T. has reached the conclusion that four circuits is a representative figure to assume for the great majority of international connections.

In most modern national networks, the four circuits will probably include three four-wire amplified circuits (usually set up on carrier systems) and one two-wire circuit, probably unamplified. In some instances, however, local exchanges will be reached by four circuits, only two of which will be four-wire circuits.

The representative maximum international connection considered by the C.C.I.T.T. for the study of transmission performance (see Figure 3 of this Recommendation and Figure 1 of Recommendation G.103) thus includes eight national circuits, besides the international ones. The cumulative distortion of these eight circuits is likely to be large, and close to the maximum allowable value. Consequently, the international circuits must not introduce any further appreciable deterioration. This principle has been borne in mind during the drafting of the recommendations dealing with such circuits.

b) *International circuits*

Implementation of the routing plan for automatic and semi-automatic international telephone traffic (Recommendation Q.13, *White Book*, Volume VI) presupposes that the transmission plan is applied. In the routing plan, the C.C.I.T.T. has defined three classes of international centres, CT1, CT2 and CT3, and has arranged to restrict the number of international circuits to five or, exceptionally, to six or seven. The CT3 connect international and national circuits; the CT2 and CT1 interconnect international circuits. In some connections, an international centre designated CTX, as well as the CT1s, may be encountered as shown in Figure 3. Certain exceptional routings, moreover, involve a seventh international circuit.

c) *Hypothetical reference connections*

See Recommendation G.103.

RECOMMENDATION G.102 (Geneva, 1964)

USE OF STANDARD COMPONENTS IN TRANSMISSION EQUIPMENT

Recommendation G.231, B, applies both to carrier systems and to voice-frequency equipment.

RECOMMENDATION G.103 (Mar del Plata, 1968)

HYPOTHETICAL REFERENCE CONNECTIONS

a) *Purpose*

A hypothetical reference connection for circuit noise studies is a model in which average and maximum noise powers contributed by circuits and exchanges may be specified.

Such a model may be used by an administration:

1) to examine the effect on transmission quality of possible changes of noise allocations and transmission losses in national networks, and
2) to test national planning rules for *prima facie* compliance with any statistical noise criteria which may be recommended by the C.C.I.T.T. for national systems.

For these purposes, several models are desirable. The three hypothetical reference connections described below should encompass most of the studies required to be undertaken.

Hypothetical reference connections for noise are *not* to be regarded as recommending particular values of loss or noise, and they are *not* intended to be used for the design of transmission systems.

b) *Composition of hypothetical reference connections*

These are defined in Figures 1, 2 and 3.

Figure 1. — The longest international connection envisaged in accordance with C.C.I.T.T. Recommendations. Such a connection would typically have high reference equivalents and high noise contributions, and the noise contribution from international circuits may be significant. Such connections are rare.

Figure 2. — A typical international connection of moderate length (say not longer than 2000 km) comprising only one international circuit.
In such a connection, the noise contribution of the national systems would be expected to predominate. Such a connection is used in a large proportion of international calls.

Figure 3. — A typical international connection within a CT1 area, between subscribers situated near terminal CT3 exchanges.
Such connections are numerous.

In the hypothetical reference connections of Figures 1, 2 and 3, maximum and average noise values have been shown separately, wherever possible, to facilitate studies.

General remarks on Figures 1, 2 and 3

1) The hypothetical reference connections show the international circuits connected together at 0 dBr and –0.5 dBr virtual switching points instead of –3.5 dBr and –4 dBr points. This was felt to be more directly useful to those who might have to use the reference connections in their studies.

It might be felt to be somewhat inconsistent that the hypothetical reference connections do not use "conventional" −3.5/−4 dBr virtual switching points. However, if the reference connections are drawn using that convention, the noise power figures appearing on the diagram can no longer be the familiar ones that appear elsewhere in other recommendations.

2) Use is made of the international routing plan nomenclature employed by the C.C.I.T.T.

3) Only one direction of transmission is shown.

4) Hourly mean noise powers are indicated according to current recommendations. For long-distance carrier circuits they are proportional to length, the appropriate noise power rate, 4 pW/km or 1 pW/km, being used according to whether the basic hypothetical reference circuit is one 2500 km long or 25 000 km long. For short-distance carrier circuits the fixed allowance recommended in Recommendation G.125 has been used.

5) The abbreviation pW0p stands for picowatts psophometric referred to a point of zero relative level. In the case of exchange noise, the point referred to is considered to be in the circuit to the immediate right of the exchange. The noise powers for circuits are referred to points of zero relative level on the circuits themselves and not to some point on the connection.

6) The pad symbols represent the nominal loss of the particular channel or circuit and the relative position of the noise generator and the pad indicates that if the noise is to be referred to the receiving end of a circuit it must be modified by the power ratio corresponding to the loss of the pad.

If it is required to refer the noise powers to some particular point on the connection (for example, the receiving local exchange or the point of zero relative level on the first international circuit) then the rule to be applied is as follows:

If a noise power is to be referred to a point to the right of its position (i.e. downstream) it is diminished by the sum of all the losses it is imagined to traverse. If it is to be referred to a point to the left of its position (i.e. upstream) it is augmented by the negative of the sum of the losses it is imagined to traverse.

7) The nominal terminal loss of the connection (i.e. the nominal overall loss less the sum of the transit losses (via net losses) of the individual circuits) is shown as one pad in the right-hand terminating set.

This artifice enables the noise powers to be indicated as if they were injected at zero relative level points on the individual circuits.

8) In Figure 1 the arbitrary value of 4.3 dB for the local exchange to primary centre loss for a circuit provided on physical line plant was arrived at in the following way. Recommendation G.111 gives a 97% limit of 20.8 dB sending reference equivalent referred to a point of –3.5 dBr on the international circuit at the CT3. Referring this to a zero relative level point at the input to the chain of national and international circuits (i.e. primary centre) gives 17.3 dB. The handbook *National telephone networks in the automatic service* indicates that a 12-dB sending reference equivalent is typical for maximum local lines, thus leaving 5.3 dB for the toll circuit and switching losses. The switching loss of the primary centre is assumed to be 1 dB leaving 4.3 dB for the toll circuit.

9) The standard deviation of transmission loss of cricuits is in accord with the objectives of Recommendation G.151,C and also with the results obtained in practice and specified in a supplement to Volume IV of the *White Book*.

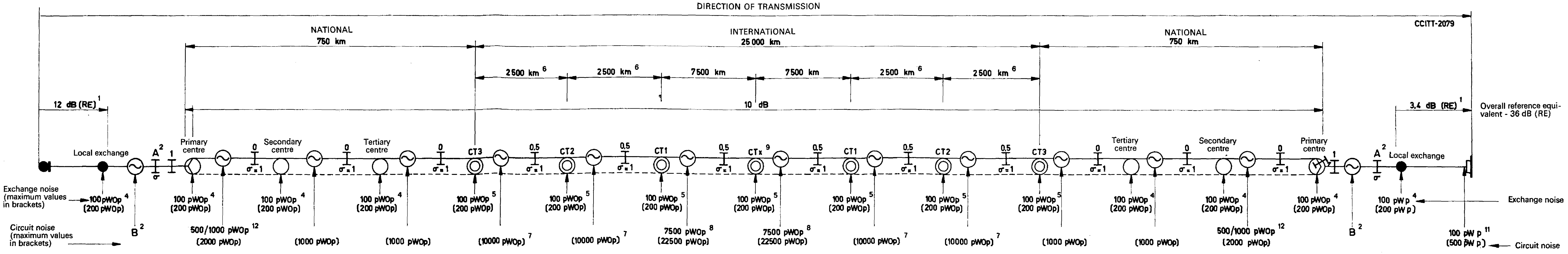


Figure. 1. — **Longest international connection envisaged in accordance with C.C.I.T.T. recommendations**

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[1] 10 bB is a typical line loss at 1600 Hz for maximum length subscriber's line. (See also general remak 8).

[2] When this circuit is a FDM or TDM short distance carrier, the value of B will be 500/1000 pW0p (2000 pW0p) - Recommendation G.125 defines these values precisely. The nominal loss A will be taken as 3 dB with $\sigma = 1$. When the circuit is provided over physical line plant, the value of B will be negligible and A will have a maximum value of 4.3 dB with $\sigma = 0$. (See general remark 8).

[3] The 1 dB pad represents the two-wire switching loss in the primary centre.

[4] The value of 200 pW0p for the maximum noise power in a national four-wire automatic exchange is taken from Recommendation G.123,C. The same value has provisionally been assumed for national two-wire exchanges. No assumption has been made concerning the position of any national zero relative level point.

[5] The value of 200 pW0p for the maximum noise power in an international exchange is that recommended in Recommendation Q.45 (*White Book*, Volume VI).

[6] The distances of 2500 km between CT3 and CT2 or between CT2 and CT1 correspond to the hypothetical reference circuits (Recommendation G.212). These distances are reasonably great but are not the maximum possible.

[7] The value of 10 000 pW0p represents the most adverse noise power during the busy hour for a circuit with the same composition as the 2500 km hypothetical reference circuit.

[8] The average value of 7500 pW0p for CT1 - CTX circuits assumes that 1 pW/km is the average value for line noise power. For the worst circuit 3 pW/km is the limit leading to the limit of 22 500 pW0p. Companders would be used to improve noise only if it exceeded 40 000 pW0p (Recommendation G.143).

[9] Exceptionally there may be an additional CTX to that shown. The overall length of the connection is not thereby affected.

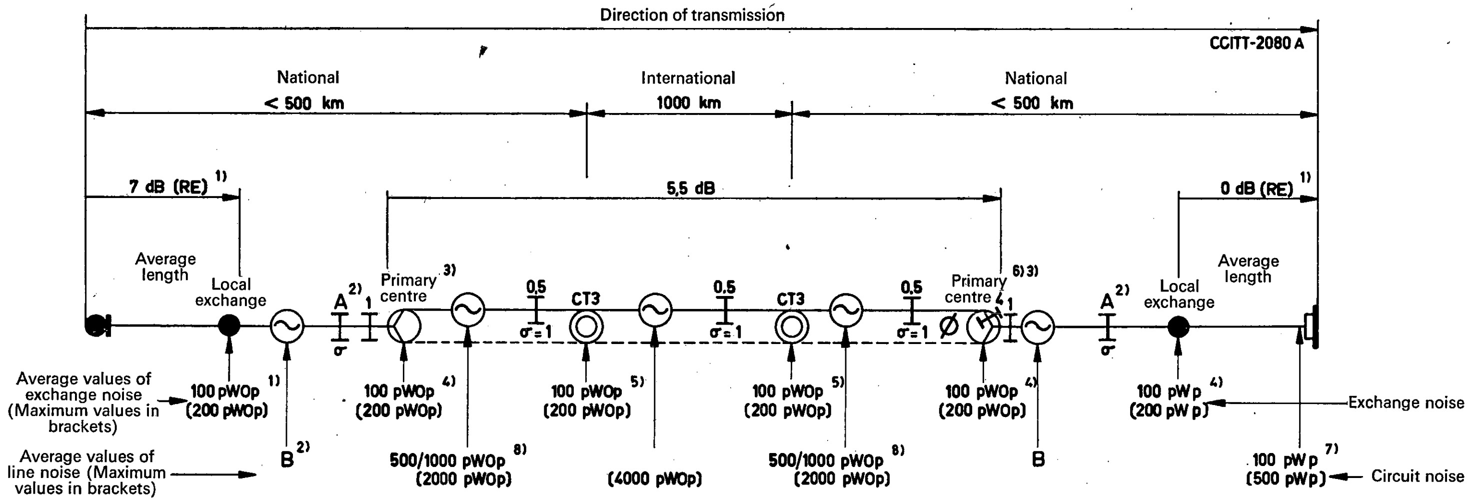
[10] The receiving country is assmed to have a 3.5 + 0 + 0 + 0 dB type plan. The nominal value of the pad in the receiving direction at the primary centre includes the loss of the terminating unit.

[11] The average value of 100 pWp due to subscriber line noise is considered to be typical and is used by at least one administration as an objective for maximum noise at the receiver.

[12] Recommendation G.125 gives a precise definition of these values as 500/1000 pW0p (2000 pW0p).

Note by the Secretariat

Footnote 4 and corresponding values have been brought up to date, together with Recommendation G.123.C, in line with Recommendations Q.31 and Q.45 (*White Book*, Volume VI).



Notes:

[1] 3 dB is a typical line loss at 1600 Hz for an average length subscriber line.

[2] See Note 2 in Figure 1.

[3] The 1 dB pad represents the two-wire switching loss in the primary centre.

[4] See Note 4 in Figure 1.

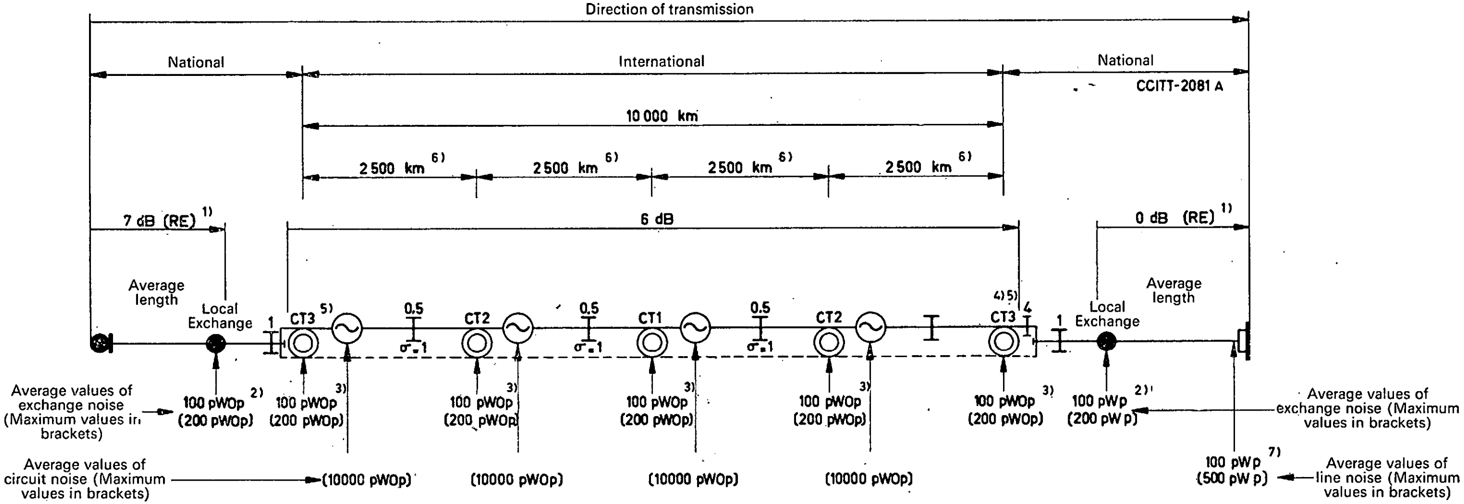
[5] The value of 200 pW0p for the maximum noise power in an international exchange is that recommended in Recommendation G.142.

[6] The receiving country is assumed to have a 2.0 + 0.5 + 0.5 + 0.5 dB type plan. The nominal value of the pad at the primary centre includes the loss of the terminating unit.

[7] See Note 11 in Figure 1.

[8] See Note 12 in Figure 1.

FIGURE 2. — **A typical international connection of moderate length comprising only one international circuit**



Notes:

[1] 3 dB is a typical line loss at 1600 Hz for an average length subscriber line.

[2] See Note 4 in Figure 1.

[3] See Note 5 in Figure 1.

[4] The receiving country is assumed to have a 2.0 + 0.5 + 0.5 + 0.5 dB type plan. The nominal value of the pad in the terminating unit includes the loss of the terminating unit.

[5] 1 dB pad represents the internal cabling losses to reach the local exchange co-sited with the CT3.

[6] See Note 6 in Figure 1.

[7] See Note 11 in Figure 1.

FIGURE 3. — **A typical international connection within a CT1 area between subscribers situated near terminal CT3 exchanges**

10) "Circuit" in these reference connections is defined in the sense of Recommendation M.70 as the whole of the line and the equipment proper to the line; it extends from the switches of one exchange to the switches of the next.

c) *Modulation and demodulation equipments*

For the study of transmission performance, the longest international connection envisaged (see Figure 1) may be considered to have the following arrangement of modulator/demodulator pairs in the four-wire chain:

	Number of modulator/demodulator pairs				
	Six national circuits	Two CT3-CT2 circuits	Two CT2-CT1 circuits	Two CT1-CTX circuits	Total
Channel	6	2	2	2	12
Group	8	4	4	6	22
Supergroup	12	4	8	12	36

Of the 12 channel modulator/demodulator pairs a maximum of three may be of the special type providing more than 12 telephone circuits per group.

GENERAL RECOMMENDATIONS ON THE TRANSMISSION QUALITY FOR AN ENTIRE INTERNATIONAL TELEPHONE CONNECTION[1]

RECOMMENDATION G.111 (P.11) (Geneva, 1964; amended in Mar del Plata, 1968)

REFERENCE EQUIVALENTS IN AN INTERNATIONAL CONNECTION

In the new transmission plan, the total nominal reference equivalent between two subscribers is not strictly limited; its maximum value results from all the various recommendations indicated below.

A. NOMINAL REFERENCE EQUIVALENTS OF THE NATIONAL SYSTEMS

a) *Definition*

National sending and receiving reference equivalents should be those calculated at the virtual switching points of the international circuit; that is to say, at points a and b of Figure 1 (for a country of average size).

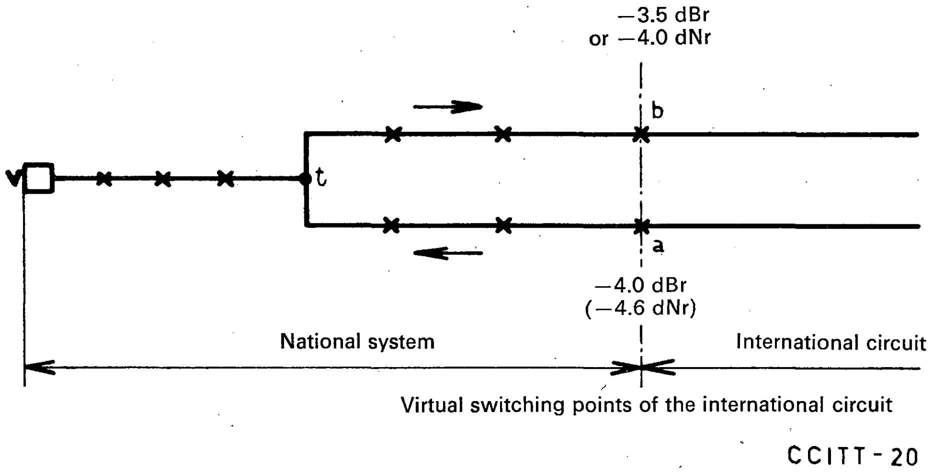


FIGURE 1. — **Definition of the virtual switching points**

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[1] The Recommendations appearing under this heading constitute sub-section 1.1. of Section 1, *White Book*, Volume III, Part I and Section 1 of Volume V, Part I.

The virtual switching points of an international four-wire telephone circuit are fixed by convention at points of the circuit where the nominal relative levels at the reference frequency are:

—3.5 dBr or —4.0 dNr, sending
—4.0 dBr (—4.6 dNr), receiving

The nominal transmission loss of this circuit at the reference frequency between virtual switching points is therefore 0.5 dB or 6 cNp.

Note. — The relative level at a given point of a four-wire circuit is determined by reference to the specifications of the transmission system on which the circuit is set up, the performance of the system (noise, crosstalk, limiting, linearity, etc.) being evaluated at a point of zero relative level. For example, the nominal mean power of signals during the busy hour, at a point of zero relative level, is indicated in Section 1 of Recommendation G.223. For further details, see Recommendation G.141, A.

b) *Maximum values*

Provisionally, the national sending and receiving system used to set up 97% of actual incoming or outgoing calls in a country of average size (see Recommendation G.101, B b) or Figure 1 of Recommendation G.121) should individually comply with both the following conditions:

- the nominal reference equivalent of the sending system between the subscriber and the first international circuit should not exceed 20.8 dB (24 dNp); and
- the nominal reference equivalent of the receiving system between the same two points should not exceed 12.2 dB (14 dNp).
  (For further details, see Recommendation G.121 (P.21).

B. NOMINAL OVERALL LOSS OF THE INTERNATIONAL CHAIN

The nominal loss between the virtual switching points of each international circuit should in principle be 0.5 dB or 6 cNp at 800 Hz or 1000 Hz. However, some circuits can be operated with higher losses (see Recommendation G.131, B a) and certain circuits may be operated at zero loss (see Note 3 of Recommendation G.141, A a)).

As far as transmission is concerned, there is no strict limit on the number of international circuits which may be interconnected in tandem, provided each of them has a nominal loss, between the virtual switching points, of 0.5 dB or 6 cNp in the transit condition and provided there is four-wire interconnection. Naturally, the fewer the number of interconnected circuits the better the transmission performance is likely to be (see Recommendation G.101, C).

C. NOMINAL REFERENCE EQUIVALENT OF A COMPLETE CONNECTION

The C.C.I.T.T. Laboratory has ascertained the loss to be inserted between a local sending and a local receiving system to obtain an overall reference-equivalent of 36 dB. In this test one, two or three A.R.A.E.N. 300-3400-Hz filters, identical with that used in the S.R.A.E.N., were inserted into the line connecting the two local commercial systems. (Recommendation P. 44, *White Book*, Volume V).

The frequency-loss characteristic of each filter meets the requirements of Graph No. 2 B of Recommendation G.232[1]; the set of three filters conforms to Graph No. 1 in Recommendation G.132 showing the objective for a chain of 12 carrier circuits in tandem.

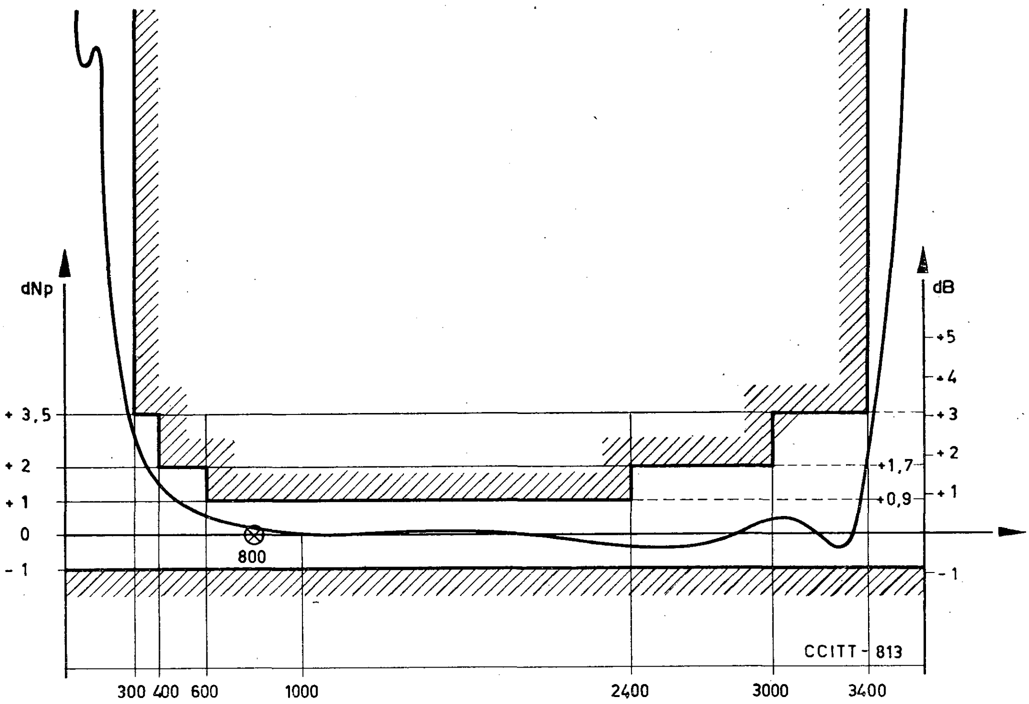

FIGURE 2. — **Characteristic of A.R.A.E.N. filter**

(The staircase diagram is Diagram No. 2 B of Recommendation G.232)

The sending and receiving reference equivalents of the local systems were also determined by the customary procedure.

In view of the results of these tests, it is recommended that administrations which use modern telephone apparatus should assume, for network planning purposes, that the reference equivalent corresponding to a complete connection is satisfactorily represented (with an error of less than 1 dB) by the sum of the sending and receiving reference equivalents of the local systems, measured separately, and of the equivalent at 800 Hz (or at 1000 Hz) of the chain of long-distance circuits.

Note: — This recommendation makes allowance for the fact that the sending and receiving reference equivalents are determined for conventional conditions in which, for example, the level of the received speech sounds is not usually that to be expected in an international connection close to the acceptable limit. In planning, moreover, allowance cannot be made for all the factors which may vary from one connection to another, such as the exact reflection loss at certain interconnection points, the effects of attenuation distortion, the level of speech sounds transmitted and received, etc.

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[1] Figure 2 shows the actual characteristic of these filters and reproduces Diagram No. 2 B of Recommendation G.232.

D. VARIATIONS IN TIME AND EFFECT OF CIRCUIT NOISE

The nominal reference equivalents given for national systems include the systematic differences between the sensitivities of the subscriber's set at the sending and receiving ends and their nominal values; however, they do not include the variations of loss with time in the various parts of the national system, nor random variations of the reference equivalents determined by subjective methods. Recommendation G.151, C sets forth the objectives recommended by the C.C.I.T.T. in connection with variations in transmission losses of international circuits and national extension circuits relative to the nominal values.

According to the results of measurements supplied by one administration the reference equivalent of its transmitting system rises by an average of 7 cNp per annum, a systematic increase due to ageing of the microphone. This point is being studied by the C.C.I.T.T. within the framework of Question 1/XII.

Annex A in the *Red Book*, Volume V *bis*, gives information on the statistical variations of reference equivalents.

Annex B in the *Red Book*, Volume V *bis*, mentions the effect on transmission performance of these variations in the equivalent and of the limits recommended for circuit noise.

E. PRACTICAL LIMITS OF THE REFERENCE EQUIVALENT BETWEEN TWO OPERATORS OR ONE OPERATOR AND ONE SUBSCRIBER

These limits are being studied for the new transmission plan; the values hitherto recommended are given in the *Red Book*, Volume V, page 10, Note 1 and in applying them Note 2 of the same text should be borne in mind.

The values for the complete connections shown in the table in the *Red Book*, Volume V, page 9, are not applicable to the transmission plan now recommended by the C.C.I.T.T.

RECOMMENDATION G.112 (P.12)

(modified in Geneva, 1964 and in Mar del Plata, 1968)

ARTICULATION REFERENCE EQUIVALENT (A.E.N.)

The transmission quality of international telephone calls will always be satisfactory if the reference equivalent limits fixed in Recommendation G.111 (P.11) are respected together with the limits fixed in Volume III of the *White Book* for noise, crosstalk, etc., and if, in addition, use is made of telephone sets of modern types which have satisfactory sensitivity/frequency characteristics and efficient anti-sidetone arrangements (see Recommendation G.121, E (P.21, E)).

Administrations wishing to make a thorough study of the transmission quality of their national sending and receiving systems could be guided by the A.E.N. method described below.

A. *Definition of the articulation reference equivalent (A.E.N.)*

Articulation reference equivalent (A.E.N.) (G.B.) [Equivalent articulation loss (Am.)—Affaiblissement équivalent pour la netteté (A.E.N.) (F)]

If articulation tests are made under specified conditions alternately on a telephone system to be tested and on the "reference system for the determination of A.E.N." (S.R.A.E.N.) with different values of line attenuation, up to the point where values of articulation on both systems are substantially reduced, then the results of these tests may be recorded in the form of curves showing the variation of sound articulation against attenuation. The value A_1 of the attenuation of the system under test, and the value A_2 of the attenuation of the S.R.A.E.N. at a fixed value 80% sound articulation can then be determined.

$(A_2–A_1)$ is by definition equal to the *articulation reference equivalent* (A.E.N.).

B. *Calculation of the nominal articulation reference equivalent of a national sending or receiving system*[1]

The nominal A.E.N. of a national sending or receiving system is the sum of the following quantities:

1. The nominal A.E.N. (average value in service) of the local system;
2. The nominal A.E.N. of the connection between the local exchange and the international exchange (average value in service).

The articulation reference equivalent, in service, of the connection between the local exchange and the international exchange is equal to the sum of the following numbers[2]:

— the equivalent of the trunk circuits between the last trunk exchange and the international exchange, measured at 800 Hz, increased by the transmission impairment due to bandwidth limitation (see Recommendation G.113 (P.13) below) when these circuits have an attenuation/frequency distortion greater than that which is allowed in the recommendations of the C.C.I.T.T.;

— the average articulation reference equivalent of the toll circuits given by the following expression:

$$i = K \times L$$

where

i = average A.E.N. in decibels or nepers,

L = length of the toll circuit in kilometres,

K = coefficient which depends on the type of toll circuit considered, in decibels per kilometre or nepers per kilometre (see the Annex below),

the mean A.E.N. of each intermediate exchange. The A.E.N. resulting from the insertion of a circuit element which, in accordance with the recommendations of the C.C.I.T.T., effectively transmits frequencies from 300 to 3400 Hz can be calculated by taking the arithmetic mean of the four values of insertion loss (or gain) of the element considered measured at 500, 1000, 2000 and 3000 Hz and expressed in decibels or nepers. Until there are more accurate values of this rating available, as will result from any measurements that administrations may make in this respect, a provisional value of 1 dB or 1 dNp for each exchange introduced into the connection will be used.

Note 1. — Circuit noise which is within the limits fixed by C.C.I.T.T. recommendations is not taken into account.

Note 2. — The "composite attenuation" of the lines connecting the international exchanges to the local exchanges should be such that the reference equivalent of the national sending system and the reference equivalent of the national receiving system remain within the limits considered compatible with good telephone transmission.

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[1] It is agreed for international purposes that the result obtained by this calculation B represents the magnitude of the articulation reference equivalent for a national transmitting or receiving system. This number is called the nominal articulation reference equivalent, to distinguish it from the articulation reference equivalent measured on the complete national sending or receiving system.

[2] Articulation tests have shown that the A.E.N. can be calculated approximately for such a link, in the manner shown above.

C. *Determination of A.E.N.*

The reference system for the determination of the A.E.N. (S.R.A.E.N.) and the method of determining the A.E.N. of commercial telephone systems at the C.C.I.T.T. Laboratory are described in Recommendations P.44 and P.45 (*White Book*, Volume V).

D. *Nominal A.E.N. values for the national sending system and the national receiving system*

By way of information, it is pointed out that administrations using the A.E.N. method consider it very desirable that national sending and receiving systems used to set up 90% of actual outgoing or incoming calls should individually meet both of the following requirements:

— the nominal A.E.N. of the national sending system should not exceed 24 dB or 2.8 Np;

— the nominal A.E.N. of the national receiving system should not exceed 18 dB or 2.1 Np.

Note 1. — The values (24 dB and 18 dB) given above for the national sending and receiving systems refer to the two-wire terminals of the international circuit, whereas the reference equivalents recommended in Recommendation P.11 refer to the virtual switching points of the international circuit. These A.E.N. values do not include the probable variations, as a function of time, of the equivalents of the trunk circuits which form part of the national system.

Note 2. — These values apply to the A.E.N. values deduced from the values measured for a local system at the C.C.I.T.T. Laboratory, as described in Recommendation P.45 with, in particular, 60 dB or 7 Np room noise at the receiving end for commercial systems and an electrical background noise (having a psophometric e.m.f. of 2 millivolts) injected into the input of the receiving system of the S.R.A.E.N.

Note 3. — The A.E.N. method does not make allowance for the effect of sidetone on subscribers' speech power.

Administrations or private operating agencies wishing to prepare transmission plans for their national network, on the basis of "transmission performance rating", will find in Annex 2 to Volume IV of the *Green Book*, information on the corrections to be made to the values of A.E.N. to allow for sidetone at the sending end.

ANNEX

(to Recommendation G.112 (P.12))

Average A.E.N. of toll circuits

A toll circuit may be considered as a quadripole inserted between the impedance of the first trunk circuit, seen through the switchboard (or switches), and the impedance of the local system (feeding bridge + subscriber's line + subscriber's apparatus).

For a given frequency, the loss introduced by such a circuit is represented by its "composite attenuation" [1] which is the sum of the image attenuation of the circuit itself and of the other terms representing all the effects due to reflections introduced by mismatch between the image impedance of the circuit and the impedances of the terminations defined above.

According to tests made by the British Administration, the A.E.N. due to the reflections can be represented by the arithmetic mean of the reflection losses measured at frequencies of 500, 1000, 2000 and 3000 Hz.

The transmission performance rating of an unloaded line is measured by its image attenuation at 1500 Hz and this is approximately equal to the arithmetic mean of the image attenuations at the four frequencies quoted above [2].

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[1] In practice, instead of using the composite attenuation, insertion loss may be used.

[2] The attenuation of a non-loaded cable circuit is proportional to the square root of the frequency. The frequencies 500, 1000, 2000, 3000 Hz are in the ratio 1, 2, 4, 6 and their square roots in the ratio 1, 1.41, 2, 2.45 of which the arithmetic mean is 1.72, i.e. almost the square root of 3; therefore this mean corresponds to a frequency of 3 × 500 = 1500 Hz.

Therefore, the A.E.N. of the toll circuit may be obtained directly, taking account not only of the effect due to the image attenuation but also of the effect of reflections, by taking the arithmetic mean of the composite attenuations measured at the four frequencies referred to above.

As the impedance of the local systems varies widely, it is not possible to define a single value for the average A.E.N. for a toll circuit, but only an average value obtained by taking the arithmetic mean of several values of the A.E.N., measured under several terminal conditions (see "C.C.I.F.—1952/1954—4th S.G.—Document No. 32", Annex).

For each type of toll circuit (defined by the electrical characteristics of the circuit), the average A.E.N. is proportional to the length of the circuit, the ratio being *easily determined* when three or four values of the A.E.N. are known. It is given by the formula:

$$i = K \times L \qquad (1)$$

where

i = average A.E.N. in decibels or nepers;

L = length of toll circuit in kilometres;

K = coefficient, which depends on the type of toll circuit considered, in decibels per kilometre or in nepers per kilometre.

To determine, once and for all, the different values of the coefficient K, the composite attenuation of three or four different lengths of each type of toll circuit used in a particular network (if necessary using artificial lines) can be measured; for this purpose the technique described in Document 32 referred to above (see also Annex 2 to Question No. 10 in the *Yellow Book* of the C.C.I.F., Volume I*ter*, page 400), and one of the methods of measuring of the composite attenuation described in the *Blue Book*, Volume IV, Part III, Supplement No. 1 can be used.

From equation (1) the value of the average A.E.N. may be calculated for any length and any type of toll circuit in the national network considered.

RECOMMENDATION G.113 (P.13) (amended in Geneva, 1964 and at Mar del Plata, 1968)

TRANSMISSION IMPAIRMENTS AND NOISE

A. TRANSMISSION IMPAIRMENT

a) *due to bandwidth limitation (cut-off impairment) effectively transmitted by the trunk circuit*

Observations have been made in the United States of America of the repetitions during conversations and articulation measurements have been made in various national laboratories as well as in the C.C.I.T.T. Laboratory. The results obtained permit the mean curve given in Figure 1 to be plotted showing the impairment due to cut-off frequency by a trunk circuit.

The equation to this curve is $y = 2(3.7 - f)^2$, where y is the transmission impairment (in decibels) due to the limitation of the frequency bandwith effectively transmitted, and f is the frequency (in kHz) for which the loss of the circuit exceeds its loss at 1000 Hz by 10 decibels.

Note. — The cut-off impairment for a chain of national trunk circuits or for a connection between two international exchanges made up of several international circuits is not obtained by adding the individual impairments. It is necessary to consider the impairment for the circuit which transmits effectively the narrowest band of frequencies.

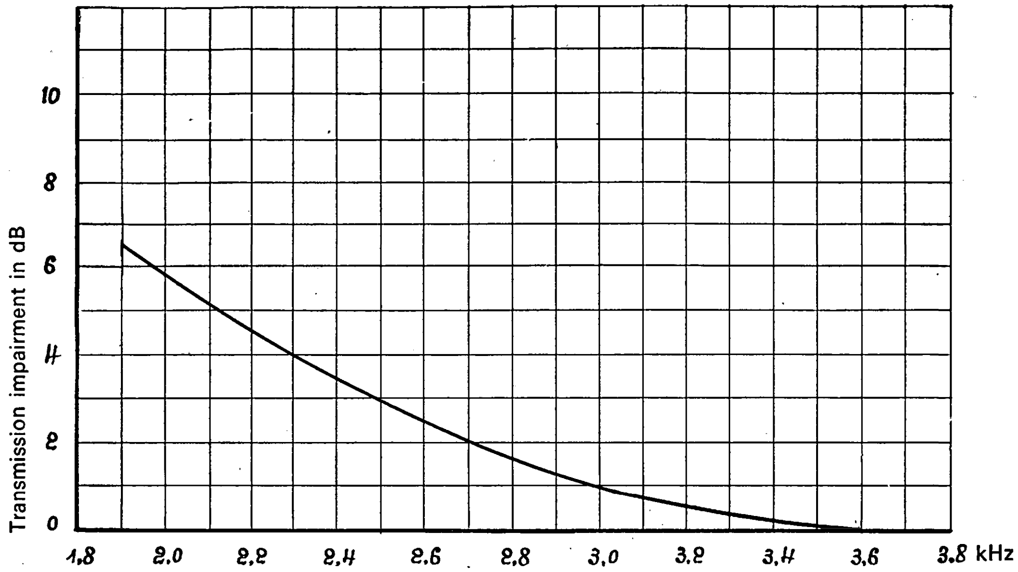

FIGURE 1. — **Transmission impairment due to bandwidth limitation (cut-off impairment)**

Note. — The frequencies shown on the abscissa are the maximum frequencies effectively transmitted according to the definition adopted in the United States of America, i.e. those for which the attenuation is greater by 10 dB than the attenuation at 1000 Hz.

b) *due to room noise*

The method of measuring A.E.N. takes account of 60 dB of room noise (Hoth spectrum) at the receiving end; information regarding the method of evaluating the "impairment due to room noise" used in the United States of America is given in Annex 3, *Red Book*, Volume V, Part II.

Although the transmission impairment values mentioned in this annex are now out of date, they show the adverse effect on speech transmission in telephony of a high level of room noise.

B. EFFECT OF CIRCUIT NOISE

The C.C.I.T.T. recommends that the mean value, expressed in decibels and taken over a large number of world-wide connections (each including six international circuits), of the distribution of one-minute mean values of noise power of the connections, should not exceed —43 dBm0p or —5 Nm0p referred to the input of the first circuit in the chain of international circuits.

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[1] The power density spectrum of the room noise used in A.E.N. measurements is given in Figure 2. The following articles give information on room noise at locations where commercial telephone sets are located:

1. A Room Noise Survey of Business Subscribers' Telephone Locations. *B.P.O. Research Report*, No. 8990—1935.
2. Room Noise at Telephone Locations. D. F. SEACORD, *Electrical Engineering*, Part 1, 58, 255, 1939.
3. Room Noise Spectra at Subscribers' Telephone Locations. D. F. HOTH, *Journal of the Acoustical Society of America*, 12, 499, 1941.

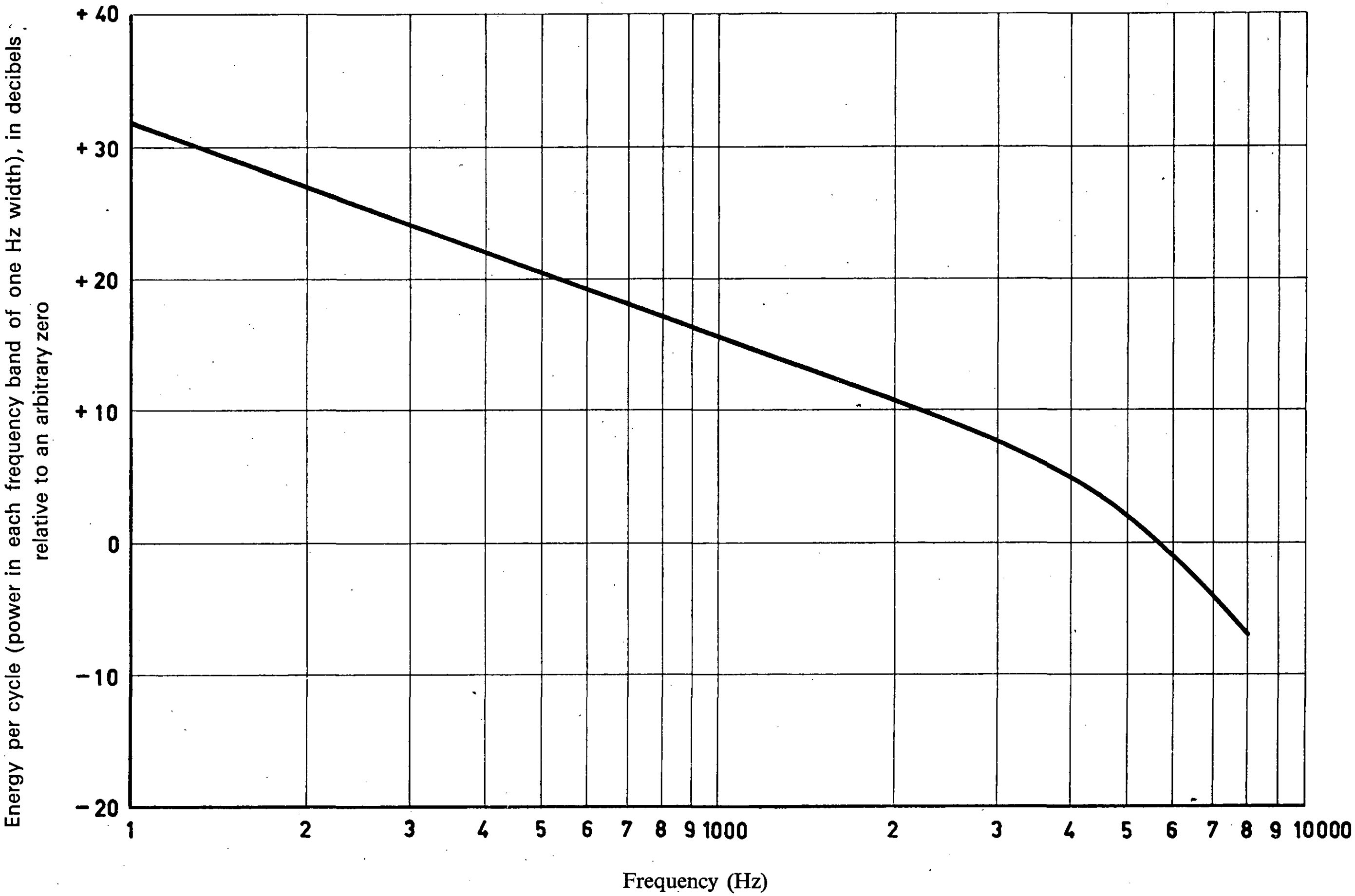

FIGURE 2. — **Power density spectrum of the room noise produced in the listening cabinet of the C.C.I.T.T. Laboratory**

This curve conforms to the mean power density spectrum of noise observed in locations where telephone sets are situated, published by Hoth.

Annexes B, C and D in the *Red Book*, Volume V*bis*, Part II, describe how the C.C.I.T.T. made allowance for the effect of noise on transmission performance in planning the international network. The procedure does not make explicit use of any transmission impairment due to circuit noise.

By way of information, the method used in the United States to fix objectives for circuit noise is described by D. A. LEWINSKI, in an article entitled: A New Objective for Message Circuit Noise (*Bell System Technical Journal*, Volume XLIII, pages 719-740, No. 2, March 1964).

Note. — Annex 2 to the *Red Book*, Volume V, Part II, is out-of-date and should be deleted.

RECOMMENDATION G.114 (P.14) (Geneva, 1964, amended in Mar del Plata, 1968)

MEAN ONE-WAY PROPAGATION TIME

A. LIMITS FOR A CONNECTION

It is necessary in an international telephone connection to limit the propagation time between two subscribers. As the propagation time is increased, subscriber difficulties increase, and the rate of increase of difficulty rises. Relevant evidence is given in the bibliography below, particularly with reference to paragraph b).

The C.C.I.T.T. therefore *recommends* the following limitations on mean one-way propagation times when echo sources exist and appropriate echo suppressors are used:

a) 0 to 150 ms, acceptable.

Note. Old-type echo suppressors may be used; they should be modified for delays above 50 ms.

b) 150 to 400 ms, acceptable, provided that increasing care is exercised on connections as the mean one-way propagation time exceeds about 300 ms, and provided that echo suppressors designed for long delay circuits are used;

c) above 400 ms, unacceptable. Connections with these delays should not be used except under the most exceptional circumstances.

Until such time as additional, significant information permits administrations to make a firmer determination of acceptable delay limits, they should take full account of the documents referred to in the bibliography in selecting, from alternatives, plans involving delays in range b) above.

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KARLIN, J. E.: Measuring the acceptability of long delay transmission circuits used during the "Early Bird" transatlantic tests in 1965; *Het P.T.T.-Bedrijf*, May 1967, pp. 25-31.

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B. VALUES FOR CIRCUITS

In the establishment of the general interconnection plan within these limits the one-way propagation time of both the national extension circuits and the international circuits must be taken into account.

a) *National extension circuits*

The main arteries of the national network should consist of high-velocity propagation lines. In these conditions, the propagation time between the international centre and the subscriber farthest away from it in the national network will probably not exceed:

$12+(0.0064\times\text{distance in miles})$ ms

or $12+(0.004\times\text{distance in kilometres})$ ms.

Here the factor 0.0064 (or 0.004) is based on the assumption that national trunk circuits will be routed over high-velocity plant (155 miles/ms or 250 km/ms). The 12-ms constant term makes allowance for terminal equipment and for the probable presence in the national network of a certain quantity of loaded cables (e.g. three pairs of channel translating equipments plus about 100 miles (160 km) of H 88/36 loaded cables). For an average-sized country the one-way propagation time will be less than 18 ms.

b) *International circuits*

International circuits will use high-velocity transmission systems; the one-way propagation times, or velocity, that should be assumed for planning purposes are:

1. *Terrestrial lines* (land lines and submarine cables)

100 miles/ms (160 km/ms).

This propagation velocity includes an allowance for terminal and intermediate multiplex equipment likely to be associated with a transmission line.

2. *Satellite links*

The mean one-way propagation times between earth stations for two illustrative single-hop communication satellite systems are:

Satellite at 8700 miles or 14 000 km altitude	110 ms
Satellite at 22 500 miles or 36 000 km altitude	260 ms

The one-way propagation times do not include any allowance for the distance from the earth stations to locations where the satellite circuits can either be extended on other international transmission systems or switched to other national or international circuits. These additional times should be taken into account for planning purposes. The practical distances between earth stations depend not only on the altitude of the satellites but also on the orbits and positions of the satellites relative to the earth stations. Exact account should be taken of these parameters in particular applications.

The magnitude of the mean one-way propagation time for circuits on high altitude communication satellite systems makes it desirable to impose some routing restrictions on their use. Details of these restrictions are given in Recommendation Q.13, Section 3.

Note. — The propagation time referred to above is the group delay as defined in the I.T.U. *List of Definitions of Essential Telecommunication Terms* (Definition No. 04-17); the numerical values are calculated at a frequency of about 800 Hz.

RECOMMENDATION P.15 (amended in Geneva, 1964)[1]

GROUP-DELAY DISTORTION

The permissible differences for a world-wide chain of 12 circuits, each on a single group connection, between the minimum group delay (throughout the transmitted frequency band) and the group delay at the lower and upper limits of this frequency band are indicated in the table below:

	Lower limit of frequency band	Upper limit of frequency band
	ms	ms
International chain	30	15
Each of the national four-wire extensions	15	7.5
On the whole four-wire chain	60	30

Typical group delays at various frequencies for a chain of 12 circuits in tandem are given in Recommendation G.232 (*White Book*, Volume III).

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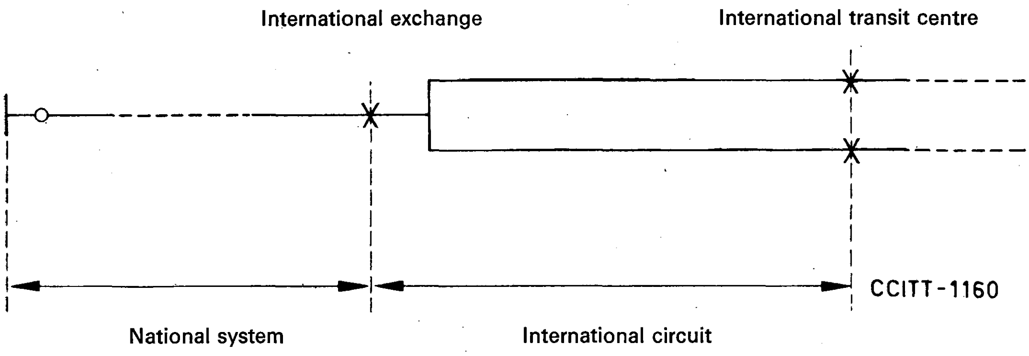
[1] Same as Recommenation G.133 (*White Book*, Volume III).

1.2 General characteristics of national systems forming part of international connections [1]

The following sub-section groups together the recommendations which national systems must conform to if international communications are to be of reasonable quality.

The principles of these recommendations also apply in cases where an international circuit is two-wire switched at one end in an international centre. This case may arise while the C.C.I.T.T. transmission plan is being implemented. The figure below illustrates the arrangement.



RECOMMENDATION G.120 (P.20) [2]

TRANSMISSION CHARACTERISTICS OF NATIONAL NETWORKS

A. APPLICATION OF C.C.I.T.T. RECOMMENDATIONS ON TELEPHONE PERFORMANCE TO NATIONAL NETWORKS

The different parts of a national network likely to be used for an international connection should meet the following general recommendations:

1. The national sending and receiving systems should satisfy the limits recommended in:

- Recommendation G.121 (P.11) as regards reference equivalent;
- Recommendation G.133 (P.15) as regards group-delay distortion;
- Recommendation G.122 as regards balance return loss and transmission loss;
- Recommendation G.123 for circuit noise.

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[1] Recommendations G.120 (P.20) and G.121 (P.21) in this sub-section also form part of Volume V.

[2] Former Recommendation P.21 of Volumes V and V*bis* of the *Red Book* amended at Mar del Plata, 1968; did not appear in Volume III of the *Blue Book*.

The Recommendations (series G) referred to in this text appear in Volume III of the *White Book*; references are also given to those Recommendations which likewise appear in Series P in Volume V of the *White Book*.

Note. — Reference should also be made to Recommendations G.112 (P.12) and G.113 (P.13).

2. Long-distance trunk circuits forming part of the main arteries of the national network should be high-velocity propagation circuits which enable the limits fixed in Recommendation G.114 (P.14) to be respected. They should conform to Recommendations G.151 and G.152.

Loaded-cable circuits should conform to Recommendation G.124 and carrier systems over very short distances to Recommendation G.125.

3. National trunk circuits should have characteristics enabling them to conform to Recommendations G.131, G.132 and G.134 in the *White Book*, Volume III, Section 1 as regards the other characteristics of the four-wire chain constituted by the international telephone circuits and the national trunk extension circuits.

4. International centres should satisfy Recommendation G.142 in the *White Book*, Volume III.

National automatic four-wire centres should observe the noise limits specified in Recommendation G.123.C.

Manual telephone trunk exchanges should satisfy Recommendation P.22.

Information on the transmission performance of automatic local exchanges is given in Part II of Chapter V (Transmission) of the handbook on "*National Telephone Networks for the Automatic Service*".

B. NATIONAL TRANSMISSION PLAN

Every administration is free to choose whatever method it considers appropriate for specifying transmission performance and to adopt the appropriate limits to ensure satisfactory quality for national calls, it being understood that in addition the C.C.I.T.T. recommendation relating to reference equivalent (Recommendation G.121 (P.21)) must be satisfied for international calls.

Note. — To meet this twofold condition with respect to national and international calls, each administration must draw up a national transmission plan, i.e. it must specify limits for each part of the national network. Supplement No. 7, *White Book*, Volume V, describes the transmission plans used in various countries. The Annex below gives some information on methods that may be applied to draw up such plans. Information on methods of planning national networks is also given for information purposes in Chapter V (Transmission) of the handbook on *National telephone networks for the automatic service.*

ANNEX

(to Recommendation G.120 (P.20))

Information on the organization of a national telephone network

a) *General organization and nomenclature* (see Chapter V (Transmission) of the handbook on *National Telephone Networks for the Automatic Service*, pp. 4-5).

b) *Choice of method for specifying transmission performance*

Different methods are used in some countries to ensure satisfactory transmission performance for national calls. For example:

- Supplement 8, *White Book*, Volume V (former Annex 1, *Red Book*, Volume V, pp. 167-173) describes the methods, based on opinion tests, employed by the United Kingdom Administration;
- "North-American practice for transmission requirements of the national network" is described under this heading in Supplement 7, *White Book*, Volume V;
- another section of the same Supplement explains how the A.E.N. method described in Recommendation P.12 (G.112) is applied in the Japanese national network.

The simplest procedure, however, which is used by many administrations, is to set reference equivalent limits for national calls since, in any case, this must be done for international calls. Once the sending and receiving reference equivalents for every type of subscriber set used in the country are known, the reference equivalent of any connection (or part of a connection) can be calculated by the methods outlined in Chapter V of the handbook on *Local Telephone Networks*, (Section 5 and Annex 3).

c) *Improvement of performance in existing networks*

Within existing telephone networks it is important to improve the transmission quality for unfavourably situated telephone sets which handle considerable traffic and especially international traffic. Several methods can be used for this purpose, for example:

1) Repeaters may be used on subscriber lines, junction circuits in the networks of large towns and toll circuits.

Note. — These repeaters may be either two-wire repeaters of the standard type or negative impedance repeaters (two- or four-wire). In each case it should be verified that the stability of the transmission remains adequate.

2) The transmitting and receiving insets may be graded in several qualities and the better insets may be fitted in the telephone sets served by lines having the greatest attenuation and vice versa.

3) Telephone sets specially designed for particularly long subscriber lines may be used. They may include an amplifier at the sending end.

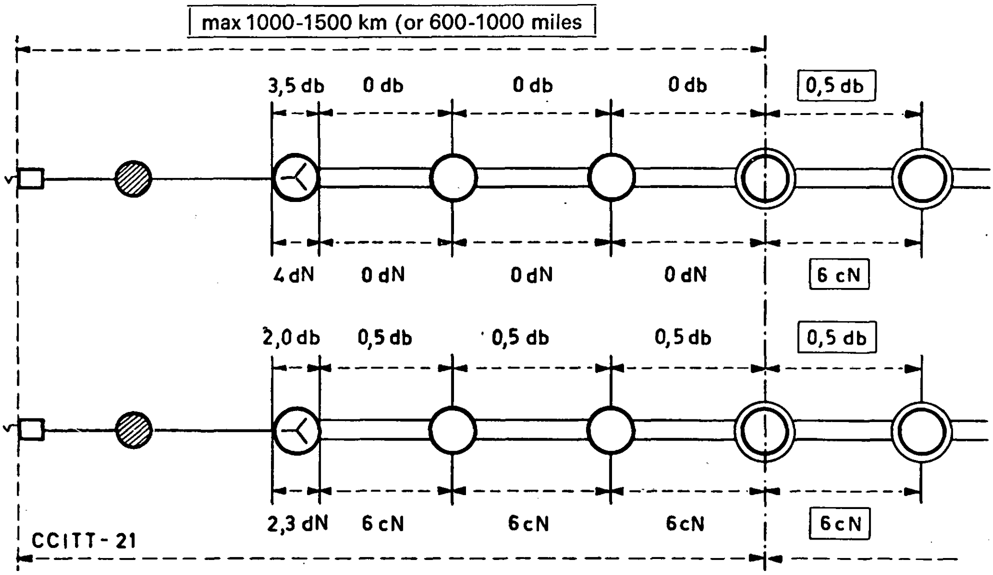
RECOMMENDATION G.121 (P.21) (Geneva, 1964; amended at Mar del Plata, 1968)

REFERENCE EQUIVALENTS OF NATIONAL SYSTEMS

A. DEFINITION

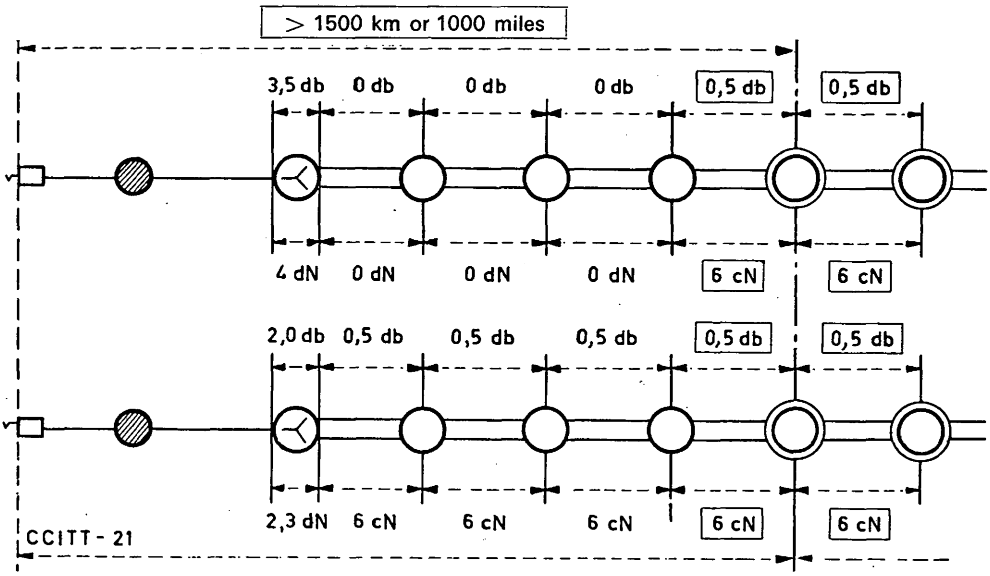
By definition, the virtual switching points of the national system are the theoretical points at which the system is interconnected to the virtual switching points of the international telephone circuits—i.e. points a and b of Figure 1 of Recommendation G.111 (P.11) and the figure appearing in Recommendation G.122.

All reference equivalents in this recommendation are referred to the virtual switching points of an international circuit at the CT3, when the country is of average size.



Maximum reference equivalents for 97% of calls		
	Sending	20.8 dB (24 dNp)
	Receiving	12.2 dB (14 dNp)

FIGURE 1. — **Distribution of equivalents for an international call, in a country of average size**



Maximum reference equivalents for 97% of calls		
	Sending	21.3 dB (24.6 dNp)
	Receiving	12.7 dB (14.6 dNp)

FIGURE 2. — **Distribution of equivalents for an international call, in a large country**

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* The division of nominal transmission losses is theoretical and can readily be achieved by means of pad-switching, for example.

B. MAXIMUM NOMINAL SENDING AND RECEIVING REFERENCE EQUIVALENTS

Provisionally, national sending and receiving systems used to set up 97% of actual outgoing or incoming calls in an average-sized country (see Recommendation G.101, B b)), should individually meet both the following requirements:

— the nominal reference equivalent of the sending system between a subscriber and the first international circuit should not exceed 20.8 dB (24 dNp);

— the nominal reference equivalent of the receiving system between the same two points should not exceed 12.2 dB (14 dNp).

In a large country, these limits shall be, respectively: 21.3 dB (24.6 dNp) and 12.7 dB (14.6 dNp) if a fourth national circuit is part of the four-wire chain, or 21.8 dB (25.2 dNp) and 13.2 dB (15.2 dNp) if five national circuits form part of the four-wire chain.

In Figures 1 and 2, the numbers in rectangles are figures recommended by the C.C.I.T.T. The others are given only as examples of possible arrangements, subject to Recommendation G.122.

Note 1. — It is possible that, in some existing networks constructed in accordance with old C.C.I.F. recommendations (see the Appendix to Section 1), the limits of 20.8 dB and 12.2 dB cannot be met immediately, but an attempt should be made to abide by them when the networks are reorganized or when telephone sets of a new type are introduced.

Note 2. — The 97% limit is provisional, and it is desirable to use a higher percentage when planning new networks.

Note 3. — The nominal reference equivalents given for national systems include the systematic differences between the performances of the subscriber set at the sending and receiving ends and their nominal values; however, they do not include the variations of loss with time in the various parts of the national system, nor fortuitous variations of the reference equivalents assessed by subjective methods.

C. MINIMUM REFERENCE EQUIVALENTS

Administrations must take care not to overload the international transmission systems if they reduce the attenuation in their national trunk network. This aspect of the problem must be studied separately before any precise recommendation can be prepared.

Legend for Figures 1 and 2

☎	Subscriber's set
—○—	Two-wire switching exchange
═○═	Four-wire switching exchange
—⊲═	Exchange with terminating unit [1]
◍	Local exchange
◎	International exchange

[1] A switchable pad may also be used at that point to compensate for losses on the two-wire side, provided that the limits given in Recommendation G.122, A for stability and attenuation are respected.

In some countries a very low sending reference equivalent may occur if unregulated telephone sets are used. Nor should the speech power applied to the international circuits by operators' sets be excessive.

D. DETERMINATION OF THE REFERENCE EQUIVALENTS OF A NATIONAL SYSTEM

Administrations and private operating agencies can use various methods to see that the limits for reference equivalents are not exceeded. Thus, for example, simulating networks can be set up representing the main combinations of a subscriber commercial telephone set, subscriber lines, junction lines and local and trunk exchange equipments, each of these networks representing a complete national sending system or receiving system, which would be compared, in a voice-ear test, with the New Master System for the determination of reference equivalents (NOSFER) or with a working standard system already compared with NOSFER or S.F.E.R.T.

Another way would be merely to measure the reference equivalent of the telephone apparatus under certain specific conditions. To this reference equivalent would be added the systematic difference between the actual sensitivity of the particular subscriber's telephone set and the nominal value of this sensitivity, the reference equivalent of the subscriber line, the image attenuation (calculated or measured at 800 Hz or at another suitable frequency) of the toll and trunk circuits connecting this set to the international centre, and the composite attenuation (measured or calculated at 800 Hz for a non-reactive resistance of 600 ohms) of the exchange equipments used in the connection between this set and the international centre (including the equipment of the exchange serving the subscriber and that of the international centre).

In any event, however, these calculations ought to be checked by a voice-ear test on the artificial networks representing the most typical complete national sending and receiving systems.

Administrations may need to calculate the reference equivalent of a subscriber line, as defined in Note 1, for local network transmission planning.

The C.C.I.T.T. advises administrations which do not possess many measurement results to apply the calculation methods described in Annex 3 to Chapter V of the handbook on *Local Telephone Networks* (the method described in paragraph 6 of this annex is also applicable to junctions and toll circuits).

It is understood that administrations which have the necessary means to assess the reference equivalent of the various types of lines used by them, with the telephone sets of the types used in their networks, may in all cases continue to apply any simple calculation methods which they may have already developed.

Note 1. — It is assumed that the reference equivalent has the same value q at the sending and receiving ends of a subscriber line, defined by

$$q = Q - Q_0 \tag{1}$$

where Q is the overall reference equivalent of the line and of a subscriber set

and Q_0 is the reference equivalent of the same set, without a line;

it is assumed that the required precautions have been taken to assess separately the effect of the variations in the feed current.

Note 2. — Part b) of Question 7/XVI relates to the possible effect of the position of the zero relative level point in a national network on the actual values of the reference equivalents of the national send and receive systems.

Note 3. — The NOSFER has replaced the Master Reference System (S.F.E.R.T.), used in the C.C.I.T.T. Laboratory before transfer to the new I.T.U. building. It, and other reference systems, are described in Recommendation P.42 (*White Book*, Volume V).

E. SIDETONE REFERENCE EQUIVALENT

Every precaution must be taken to avoid further transmission impairment in communications which reach the reference equivalent and noise limits.

Tests have shown that in these unfavourable conditions the sidetone reference equivalent (for speech) should be at least 17 dB or 2 Np.

In fact, this value cannot be achieved without additional networks, which increase line costs and are only justified when the subscriber has to exchange calls frequently in very bad conditions. In most cases, values between 7 and 10.5 dB (0.8 and 1.2 Np) are to be expected.

Note 1. — Strong sidetone (corresponding to a low value for sidetone reference equivalent) impairs transmission in two ways. At the sending end, a subscriber who hears himself clearly is tempted to lower his voice; at the receiving end, the room noise which penetrates through the acoustic leak between the earcap and the human ear is picked up by the microphone and is transmitted as sidetone to the earcap and the ear of the listener, thus increasing the total noise received.

Note 2. — Even when the value 17 dB or 2 Np is attained, administrations may consider it advisable to set a limit for room noise (see Recommendation G.113 (P.13)).

RECOMMENDATION G.122 (Geneva, 1964; amended at Mar del Plata, 1968)

INFLUENCE OF NATIONAL NETWORKS ON STABILITY AND ECHO IN INTERNATIONAL CONNECTIONS

The national portion of an international connection appears relative to the virtual switching points a and b of the first international circuit as shown in Figure 1.

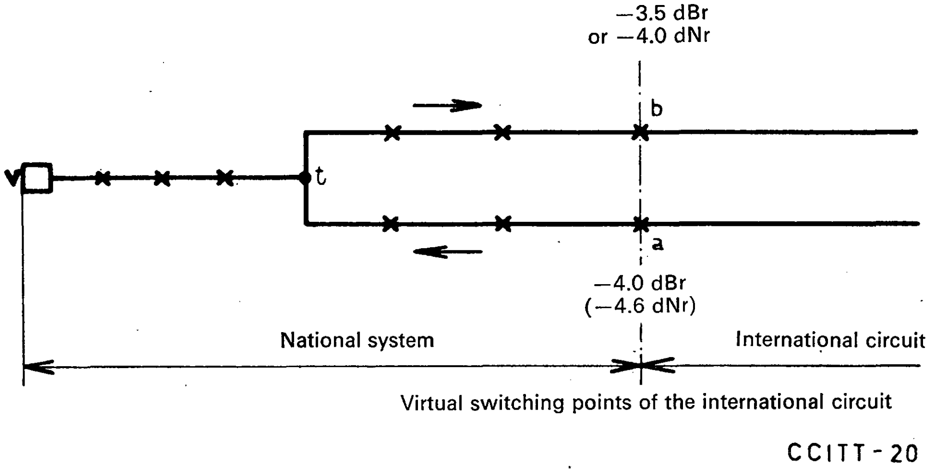

FIGURE 1. — **Definition of the virtual switching points**

The transmission loss of the path *a–t–b* (comprising the two transmission losses, *a–t* and *t–b*, and the balance return loss at the terminating set, *t*, is important from two points of view:

a) it contributes to the margin that the four-wire chain has against instability, and for this purpose the minimum value that the transmission loss *a–t–b* has in the 0 to 4-kHz band is the characteristic value;

b) it contributes to the control of echoes that can circulate in the four-wire chain, and it should be noted that the operation of echo suppressors designed for connections with long propagation times is adversely affected by low values of transmission loss *a–t–b*. From the point of view of echo, the unweighted mean power ratio over the band 500 to 2500 Hz should provisionally be taken as the quantity characterizing the transmission loss *a–t–b*.

The balance return loss exhibited at a terminating set is that portion of the total transmission loss introduced by the terminating set between the receive and the send channels which is attributable to the degree of impedance match between the impedances closing the two-wire line terminals and the balance terminals of the terminating set, Z_2 and Z_B respectively. It is given approximately by the expression in transmission units of the reciprocal of the relexion coefficient (current or voltage) between these two impedances

$$\left| \frac{Z_2 - Z_B}{Z_2 + Z_B} \right|$$

This expression is exact when the impedances closing the four-wire send and receive terminals of the terminating unit are also equal to Z_B and when the transformers are ideal.

A. TRANSMISSION LOSS OF THE PATH *a–t–b* FROM THE POINT OF VIEW OF STABILITY TRANSMISSION LOSS OF NATIONAL EXTENSION CIRCUITS

a) To ensure adequate stability of international connections, the attenuation measured or calculated between virtual switching points *a* and *b* in Figure 1 along the path *a–t–b* in the national network should have a value not less than $(6 + n)$ dB or $(7 + 1.2\,n)$ dNp, where n is the number of four-wire circuits in the national chain.

This requirement should be observed at any frequency in the band 0 to 4 kHz.

In making this measurement or calculation, it may be assumed that the circuits have their nominal values of transmission loss at 800 Hz. Account should be taken of all the terminal conditions encountered in normal operation.

Note. — The stability of international telephone connections at frequencies outside the band of effectively transmitted frequencies (i.e. below 300 Hz and above 3400 Hz) is governed by the following transmission losses at the frequencies of interest:

- the balance return loss at the terminating units;
- the transmission losses of the terminating units;
- the transmission losses of the four-wire circuits.

An estimate of the minimum additional transmission loss likely to be introduced at frequencies above and below the band 300-3400 Hz is given in the table below:

Minimum nominal transmission loss of the path a–t–b for all normal conditions of operation likely to be encountered outside the effectively transmitted band

Frequency range, Hz	Loss relative to that at 800 Hz
Below 100	Not less than 4 dB (4.6 dNp)
100–200	Not less than 1 dB (1.1 dNp)
200–300	Not less than 0 dB (0 dNp)
Above 3400	Not less than 0 dB (0 dNp)

It should be noted that these minima assume:

- zero balance return loss at the terminating unit, i.e. no balance return *gain.* A balance return gain might occur in practice, for example, if a telephone instrument presenting an inductive impedance were connected via a short subscriber line to a terminating unit equipped with a capacitive balance network;
- transformer-type terminating sets which exhibit a high-pass filter characteristic. This might not be so in the case of resistive terminating sets;
- national four-wire extension circuits which introduce no relative gain above or below the 300-3400 Hz. This may not be so in the case of physical circuits uncorrected at the low-frequency end or equalized circuits.

b) For the purposes of calculation (e.g. in order to verify if a particular transmission plan is acceptable) it may be assumed that the mean value of the attenuation of the path *a–t–b* for the distribution of actual calls is $(10 + n)$ dB or $(11.4 + 1.2)\,n$ dNp in the band 300-3400 Hz (this value may be increased by the amounts given in the table in the note to a) above for frequencies outside this band), and that the values of attenuation over the whole band are distributed about the mean value with a standard deviation of $(6.25 + 4\,n)^{1/2}$ dB or $(8.3 + 5.3\,n)^{1/2}$ dNp. The actual distribution is not normal, but to facilitate calculations it may be assumed to be so. This assumption errs on the safe side. The graphs in the figure in Recommendation G.131—A were calculated on this assumption.

The mean and standard deviation mentioned above make allowance for:

1) the sum of the nominal values of the transmission losses *a–t* and *t–b;*
2) variation of these losses with time assuming unity correlation between the variations in the two directions of transmission for the same circuit;
3) the departure from nominal of the mean values of the transmission loss of the circuits;
4) the mean and standard deviation of the distribution of stability balance return loss at the terminating set, *t*, this distribution being in principle determined for all the actual calls established over the national network.

c) When formulating new national plans for the routing and transmission of international calls administrations are encouraged to aim at a mean value for the attenuation of the path *a–t–b* of the distribution of actual calls of at least $10 + n$ dB or $11.4 + 1.2\,n$ dNp.

d) The limit recommended in a) above may be met for instance by imposing the following simultaneous conditions on the national network:

1) The sum of the nominal transmission losses in both directions of transmission *a–t* and *t–b* measured between the two-wire input of the terminating set, *t*, and one or other of the virtual switching points on the international circuit, a or b, should not be less than $4 + n$ dB or $4.4 + 1.2\,n$ dNp. There is no need for the two quantities *a–t* and *t–b* to be equal, so that differential gain can be used in the national network. This practice may be needed to meet the requirements of Recommendation G.121—B, but it implies that the transmission loss in terminal service of the four-wire chain plus the terminating sets may be different according to the direction of transmission. The choice of the nominal value of the transmission loss *t–b* should in all cases be made with an eye to Recommendation G.121—C dealing with the minimum sending reference equivalent to be imposed in each national chain, to avoid any risk of overloading in the international network.

2) The balance return loss from the point of view of stability at the terminating set, *t*, should have a value not less than 2 dB or 2.4 dNp for all the terminal conditions encountered during normal operation.

e) The target recommended in c) above could be attained if in addition to meeting the condition of d). 1, the mean value of the balance return loss from the point of view of stability at the terminating set were not less than 6 dB or 7 dNp, this figure referring to the distribution of actual calls.

Note 1. — Annex 5 to Chapter V of the C.C.I.T.T. handbook on *National Automatic Networks* describes some of the methods proposed, and in some cases successfully applied, by some administrations to improve balance return losses.

Note 2. — Recommendation G.131—A indicates the risk of instability of international connections if the above recommendations are complied with. It will be seen that, even in the present interim period in which distributions of balance return loss from the point of view of stability can only attain a mean value of 3 dB or 3.5 dNp and a standard deviation of 1.5 dB or 1.7 dNp, the stability of international connections is still acceptable and hence the transmission plan described in Part I, section 1, of this book can be implemented without waiting for a general improvement in balance return loss in national networks.

Note 3. — Attention is drawn to Note 3 of Recommendation G.141—A concerning the nominal transmission loss of short four-wire circuits.

Note 4. — Attention is drawn to Recommendation Q.32 (Volume VI) concerning measures to be adopted to ensure the stability of international connections during the periods of setting-up and clearing a call.

B. TRANSMISSION LOSS OF THE PATH *a–t–b* FROM THE POINT OF VIEW OF ECHO

a) Provisionally, the transmission loss of the path *a–t–b* from the point of view of echo has been assumed to have a mean value of not less than $15 + n$ dB or $17.3 + 1.2\,n$ dNp with a standard deviation from the mean of $(15.25 + 4\,n)^{\frac{1}{2}}$ dB or $(20.13 + 5.3\,n)^{\frac{1}{2}}$ dNp where n is the number of four-wire circuits in the national chain.

b) The transmission loss of the path *a–t–b* from the point of view of echo is provisionally defined as the expression in transmission units of unweighted mean of the power ratios in the band 500-2500 Hz.

A convenient and sufficiently accurate method of calculating the mean of the power ratios over this band is to divide the band by five equally-spaced ordinates and apply the trapezoidal rule for numerical integration. This implies calculating a quarter of the sum of the ratios at the following frequencies multiplied by the indicated coefficients:

500 Hz, coefficient = ½
1000 Hz, coefficient = 1
1500 Hz, coefficient = 1
2000 Hz, coefficient = 1
2500 Hz, coefficient = ½

c) An example of how the provisional limit quoted in paragraph a) above can be achieved would be for the mean value of the sum of the transmission losses *a–t* and *t–b* from the point of view of echo to be not less than $4 + n$ dB or $4.4 + 1.2\,n$ dNp with a standard deviation from the mean, not exceeding $(6.25 + 4\,n)^{\frac{1}{2}}$ dB or $(8.3 + 5.3\,n)^{\frac{1}{2}}$ dNp accompanied by a balance return loss from the point of view of echo at the terminating set, *t*, of not less than 11 dB or 12.7 dNp with a standard deviation from the mean, not exceeding 3 dB or 3.5 dNp.

RECOMMENDATION G.123 (Geneva, 1964; amended at Mar del Plata, 1968)

CIRCUIT NOISE IN NATIONAL NETWORKS

A. NOISE INDUCED BY POWER LINES

The psophometric e.m.f. of the noise produced by magnetic and/or electrostatic induction from all the power lines affecting one or more parts of a chain of telephone lines joining a subscriber's set to its international centre should not exceed 1 millivolt, this being the value at the line terminals of the subscriber's set (when receiving) it being assumed that the telecommunication installations inserted in that chain are balanced to earth as perfectly as possible, in conformity with the most modern equipment construction.

It should be noted that, even in the case of perfectly balanced lines, the insertion of equipment having too great a degree of unbalance to earth may cause unacceptable noise at the terminals of a subscriber's receiver.

In every national networks, it is usually possible, in practice, to find switching centres such that some of the lines that terminate at those centres (lines in cable, conforming to C.C.I.T.T. specifications) are free from noise arising from neighbouring power lines. It is then sufficient to determine the psophometric e.m.f.s. arising from all the power lines affecting one or more parts of the chain of lines joining such a centre to the subscriber's set.

B. NOISE CONTRIBUTED BY TRANSMISSION SYSTEMS

a) *National extension circuits forming part of the four-wire chain*

1. *Very-long-distance circuits* (about 2500-25 000 km)

If an extension circuit more than 2500 km long is used in a large country, it will have to meet all the recommendations applicable to an international circuit of the same length (Recommendation G.153).

2. *Long-distance circuits* (about 250-2500 km)

These circuits should meet the requirements of Recommendation G.152. Since in a country of average size they are not very long, their contribution to the overall noise will be limited (for example, see the hypothetical reference connection in Figure 1, Recommendation G.103).

b) *National medium-distance circuits*

These circuits (about 25 to 250 km long) may form part of the four-wire chain, or may be connected to it by two-wire switching. The noise objectives applicable to systems specially designed to provide such circuits are under study (Question 24/XV).

c) *Very-short-distance circuits*

See Recommendation G.125.

C. NOISE IN A NATIONAL FOUR-WIRE AUTOMATIC EXCHANGE [1]

a) *Definition of a "connection through an exchange"*

Noise conditions in a national four-wire automatic exchange are defined by reference to a "connection" through this exchange. By "connection through an exchange" is to be understood the pair of wires corresponding to a direction of transmission and connecting the input point of a circuit incoming in the exchange to the output point of a different circuit outgoing from the exchange. (These input or output points are often taken at the test-jack frame.)

b) *Mean noise power over a long period*

1) Limits of *psophometrically* weighted noise introduced when passing through a national four-wire exchange.—The value of the busy-hour mean psophometric noise power measured on a "connection" through a national four-wire automatic exchange and referred to a point of zero relative level should not exceed 200 picowatts (i.e. a level of —67 dBm0).

2) Limits of *unweighted* noise introduced when passing through a national four-wire exchange.—The limits of busy-hour unweighted noise measured in the same conditions as in paragraph 1) are defined thus:

The unweighted noise power at a point of zero relative level should not exceed 100 000 picowatts (a level of —40 dBm0 or —4.6 Nm0).

Note. — Unweighted noise should be measured with a device possessing a uniform response curve throughout the band between 30 and 20 000 Hz.

c) *Impulsive noise*

(Being studied under Question 8/XI.)

D. NOISE ALLOCATION FOR A NATIONAL SYSTEM

Network planning should be such that the noise power entering the international network and attributable to national sending systems meets the limits of the following rule.

The psophometric noise power introduced by the national sending system at a point of zero relative level on the first international circuit must not exceed either $4000 + 4L$ or $7000 + 2L$ pWp, whichever is less, and where L is the total length in kilometres of the long-

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[1] In accordance with Recommendation Q.31, the limits recommended are the same as in Recommendation Q.45 (*White Book*, Volume VI).

line f.d.m. carrier systems in the national chain. The corresponding quantities referred to the send virtual switching point are $1800 + 1.8\,L$ and $3100 + 0.9\,L$ pWp.

The derivation of this rule is explained in the Annex.

Note. — The question of a corresponding rule in respect of the noise power generated in national receiving systems is under study (Question 9/C). A problem, which has already arisen in some national networks, as regards the receiving direction, is that when losses are reduced the circuit noise becomes more noticeable, particularly during periods of no conversation. This is particularly relevant in the case of large countries in which the noise contribution from line systems is high. Hence if an administration complies with a recommendation concerning national noise power levels and then subsequently improves transmission, perhaps by introducing four-wire switching in lower-order exchanges, it may find itself in a worse situation as regards noise. It follows that it is important to preserve a proper balance between noise and loss.

ANNEX

(to Recommendation G.123)

Noise allocation for a national system

1. It is desirable that the noise power arising in national networks be limited in terms of the level appearing at the virtual switching points—the agreed interface between the national and the international network. In order to do this, some particular distribution of losses within the national network must be assumed. The solution is to adopt an agreed reference connection in order to specify maximum noise power levels from national sources referred to the virtual switching point on the international circuit.

2. Having regard to the way in which national networks are constructed, it is appropriate to express the noise allowance in the form $A + B\,L$ where A is a fixed allowance resulting from noise in exchanges and from short-haul multiplex systems, B is an allowance for a noise rate per unit length from long-haul multiplex systems and L is the total length of these latter systems in the national portion of the international connection. Two such expressions are necessary—one for countries of average size and another for large countries (in the sense of Recommendation G.121).

3. This approach is comparatively straightforward in the national sending system and serves to limit the amount of noise injected into the international connection.

4. *Average-sized countries* (i.e. not greater than 1500 km from the CT3 to the most remote local exchange).

The relevant hypothetical reference chain for the national sending system is given in Figure 1[1]. The circuit between the local exchange and the primary centre is assumed to be routed on a short-haul f.d.m. carrier system and is operated at a nominal loss of 3 dB. In accordance with Recommendation G.125, the noise power on this circuit is taken to be the maximum value of 2000 pW0. The circuit between the primary centre and the secondary centre is also assumed to be routed on a short-haul f.d.m. carrier system, as envisaged in Recommendation G.125.

The line noise power rate of the two long-distance trunk circuits is assumed to be 4 pW/km and the total line length of these two circuits ($L_1 + L_2$ in Figure 1) approaches the limit of 1500 km arbitrarily defining "a country of average size" in Recommendation G.121. It is thus assumed that

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[1] *Note by the C.C.I.T.T. Secretariat.* — The noise values shown in this figure are maximum values; see also the corresponding part of Figure 1 of Recommendation G.103.

NOISE ALLOCATION FOR A NATIONAL SYSTEM

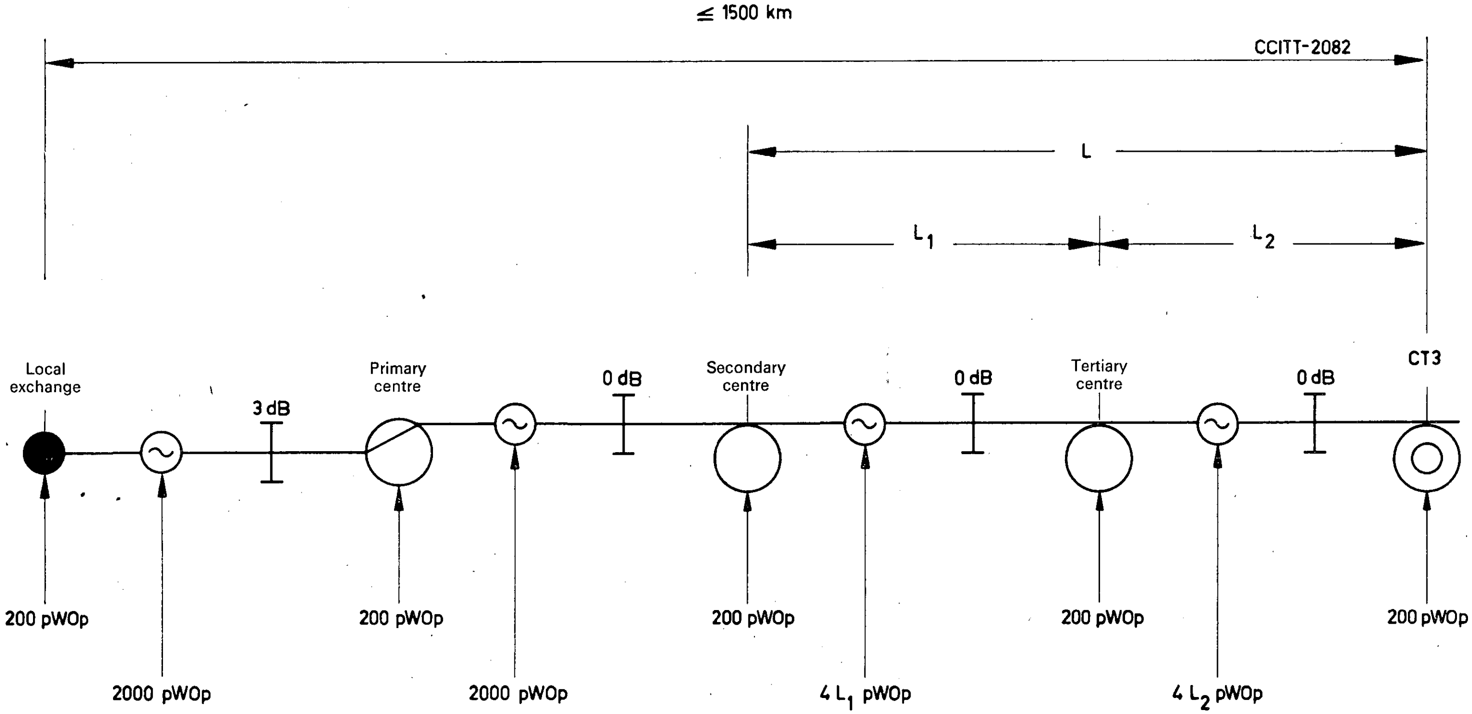

FIGURE 1

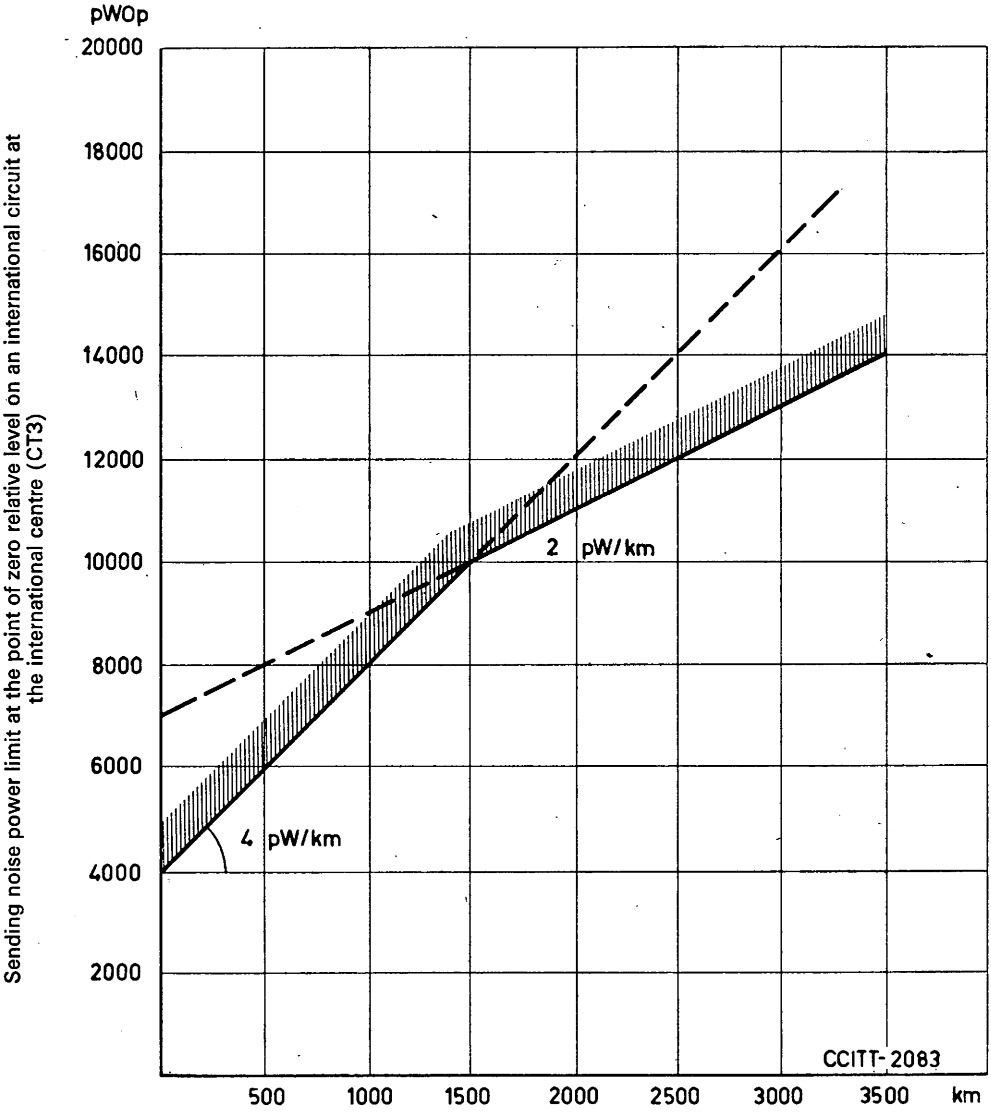
pW0p
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
Sending noise power limit at the point of zero relative level on an international circuit at the international centre (CT3)
2 pW/km
4 pW/km
CCITT-2083
500
1000
1500
2000
2500
3000
3500
km
Total length of national long-distance f.d.m. carrier system

FIGURE 2

the distance covered by the two short-haul systems is a very small proportion of the total length of the complete national sending system.

Each exchange is assumed to contribute 200 pW0 in accordance with Recommendation G.123—C or Q.31.

The total noise power level referred to a point of zero relative level on the first international circuit at the CT3 is (moving from right to left and adding in each successive noise contribution encountered):

$200 + 4\,L_2 + 200 + 4\,L_1 + 200 + 2000 + 200 + \frac{1}{2}(2000) + \frac{1}{2}(200) = 3900 + 4\,L$ pW0 where $L = L_1 + L_2$. This may be conveniently rounded off to $4000 + 4\,L$ pW0.

This expression is valid for L not exceeding 1500 km leading to, at that distance, 10 000 pW0.

5. *Large countries.*

When L is in excess of 1500 km the additional long-distance circuits in the national network should in principle be engineered to international standards, and in particular some large countries have found it necessary to plan national systems with noise power rates lower than 4 pW/km.

A convenient value to assume is 2 pW/km; this is in rough agreement with the practice of one such large country and is also in line with Recommendation G.153.

The rule for large countries has been established as shown in Figure 2 in which the $4000 + 4\,L$ rule is shown passing through the point (1500 km, 10 000 pW). A line with a slope of 2 pW/km is constructed to pass through the same point and its intercept is seen to be 7000 pW. Hence the rule for large countries is $7000 + 2\,L$ pW0. (The 0.5-dB nominal loss of the last national circuit has been ignored for simplicity's sake.)

RECOMMENDATION G.124 (Geneva, 1964)

CHARACTERISTICS OF LONG-DISTANCE LOADED-CABLE CIRCUITS LIABLE TO CARRY INTERNATIONAL CALLS

A. CONSTITUTION OF NATIONAL LONG-DISTANCE CIRCUITS: GROUP DELAY

The main routes in a national network should be made up of lines with a high propagation velocity, if the limits laid down in Recommendation G.114 are to be respected. This recommendation nevertheless makes allowance for the probability that there will be a number of loaded cables in a national system, for example, about 100 statute miles (160 kilometres) of H 88/36 loaded cable.

B. ATTENUATION DISTORTION

Plans for future networks should provide for circuits capable of effectively transmitting the band 300-3400 Hz to connect international and local exchanges.

The attenuation distortion of these circuits should not appreciably increase the attenuation distortion of the international chain. Hence, if these circuits are loaded, a sufficiently high cut-off frequency should be chosen.

C. CABLE CHARACTERISTICS

National long-distance circuits liable to carry international calls may be four-wire circuits or (sometimes) two-wire ones. The C.C.I.T.T. recommends that, in planning networks of loaded long-distance cables for internal use, administrations and private operating agencies should, for preference, follow the indications given in Recommendation G.543.

RECOMMENDATION G.125 (Geneva, 1964; amended at Mar del Plata, 1968)

CHARACTERISTICS OF NATIONAL CIRCUITS ON CARRIER SYSTEMS OVER VERY SHORT DISTANCES

Very short carrier circuits (of about 3 to 25 km) which are likely to form part of international connections should meet the requirements of Recommendation G.132 as far as attenuation distortion is concerned. These circuits should transmit all types of signal (e.g. speech, data, facsimile) which might normally be expected, according to C.C.I.T.T. Recommendations over this part of the connection.

A. ANALOGUE SYSTEMS [1]

a) *Circuit noise*

1) *Objective*

Assuming that the circuits in an international connection which make use of carrier systems over very short distances can be limited to four—that is to say, two for each of the terminal additional networks—the C.C.I.T.T. considers that the following objective would be satisfactory so far as the quality of international connection is concerned.

The mean (for all the channels of a system) of the mean psophometric power at a zero relative level point should not exceed 500 pW during any hour.

2) *Values which can be achieved now*

In the present stage of technique and for economic consideration the C.C.I.T.T. can do no more than issue the following recommendation:

The mean (for all the channels of a system) of the mean psophometric power at a zero relative level point should not exceed 1000 pW during any hour. In no case should this mean power per hour exceed a maximum of 2000 pW for any of the channels of the system.

These figures allow for crosstalk effects.

Note. — As far as possible, no use should be made of systems satisfying only the noise clauses in paragraph a).2 in international connections, particularly when the circuit nearest to the subscriber (toll circuit, G.B.; toll connecting trunk, Am.) from the primary centre to the local exchange, is concerned.

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[1] These are conventional frequency-division multiplex systems and time-division systems without coding.

Systems satisfying the objective in paragraph a). 1 might be used to establish either the toll circuit or one of the four-wire long-distance circuits, or both.

B. DIGITAL SYSTEMS

The question of these systems is under study.

1.3 General characteristics of the "four-wire chain" formed by the international circuits and national extension circuits

This sub-section gives the overall characteristics recommended for the four-wire chain defined in Recommendation G.101—B.

RECOMMENDATION G.131 (Geneva, 1964; amended in Mar del Plata, 1968)

STABILITY AND ECHO

A. STABILITY OF TELEPHONE TRANSMISSION

The nominal transmission loss of international circuits having been fixed, the principal remaining factors which affect the stability of telephone transmission on switched connections are:

— the variation of transmission loss with time and among circuits (Recommendation G.151—C);

— the attenuation distortion of the circuits (Recommendation G.151—A);

— the distribution of stability balance return losses (Recommendation G.122—A).

The stability of international connections has been calculated and the results are displayed graphically in Figure 1, which shows the proportion of connections (out of all the possible connections) likely to exhibit a stability of less than or equal to 0 dB or 3 dB (3.5 dNp) as a function of the number of circuits comprising the four-wire chain and the mean values of stability balance return loss that may be assumed. Of course the proportion of connections actually established which exhibit a stability lower than or equal to the values considered will be very much smaller.

When interpreting the significance of the curves showing the proportion of calls likely to have a stability of 3 dB (3.5 dNp) or less it should be borne in mind that the more complicated connections will undoubtedly incorporate a circuit equipped with an echo suppressor, in which case the stability during conversation is very much higher.

The simplifying assumptions underlying the calculations are:

a) National circuits are added to the international chain in compliance with Recommendation G.122—A.

b) The standard deviation of transmission loss among international circuits routed on groups equipped with automatic regulation is 1 dB or 12 cNp. This accords with the assumptions used in Recommendation G.122—A.b., and the results of the 10th series of tests by Study Group IV indicate that this target is being approached in that 1.1 dB or 13 cNp was the standard deviation of the recorded data and the proportion of unregulated international groups in the international network is significantly decreasing.

c) The variations of transmission loss in the two directions of transmission are perfectly correlated.

d) The departure of the mean value of the transmission loss from the nominal value is zero. As yet there is little information concerning international circuits maintained between four-wire points.

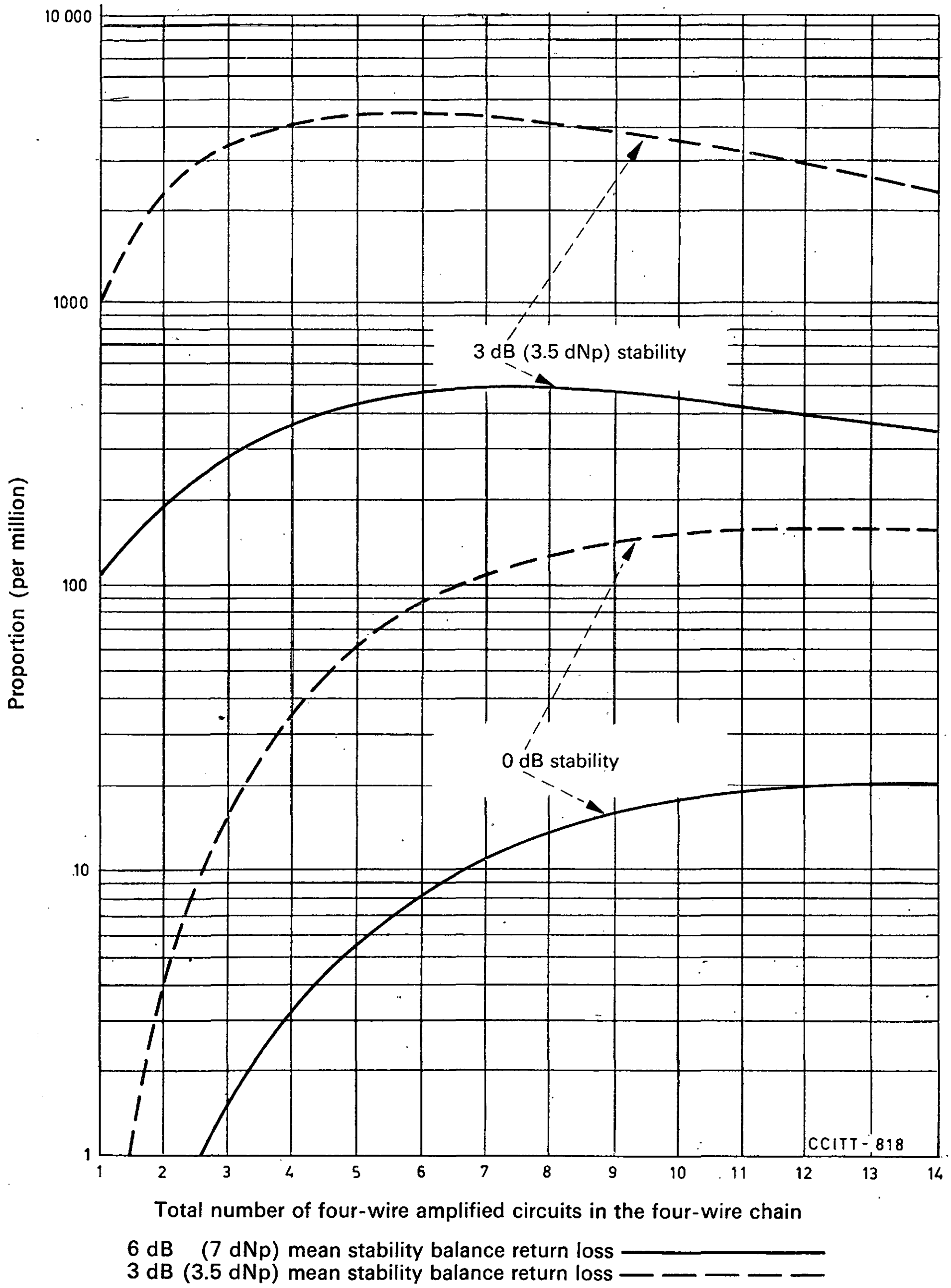


FIGURE 1. — **Proportion of possible connections with a stability equal to or less than 0 dB or 3 dB**

e) No allowance has been made for the variations and distortions introduced by the national and international exchanges.

f) The variation of transmission loss of circuits at frequencies other than the test frequency is the same as that at the test frequency.

g) No account has been taken of attenuation distortion. This is felt to be justifiable because low values of balance return loss occur at the edges of the transmitted band and are thus associated with higher values of transmission loss.

h) All distributions are Gaussian.

Bearing in mind these assumptions the conclusion is that the recommendations made by the C.C.I.T.T. are self-consistent and that if these recommendations are observed and the maintenance standard set for variation of loss among circuits is achieved, there should be no instability problems in the transmission plan. It is also evident that those national networks which can exhibit no better stability balance return loss than 3 dB mean, 1.5 dB standard deviation (3.5 dNp; 1.7 dNp) are unlikely to seriously jeopardize the stability of international connections as far as oscillation is concerned. However, the near-singing distortion and echo effects that may result give no grounds for complacency in this matter.

Details of the calculations are set out in Supplement No. 1 to this Volume

B. LIMITATION OF ECHOES

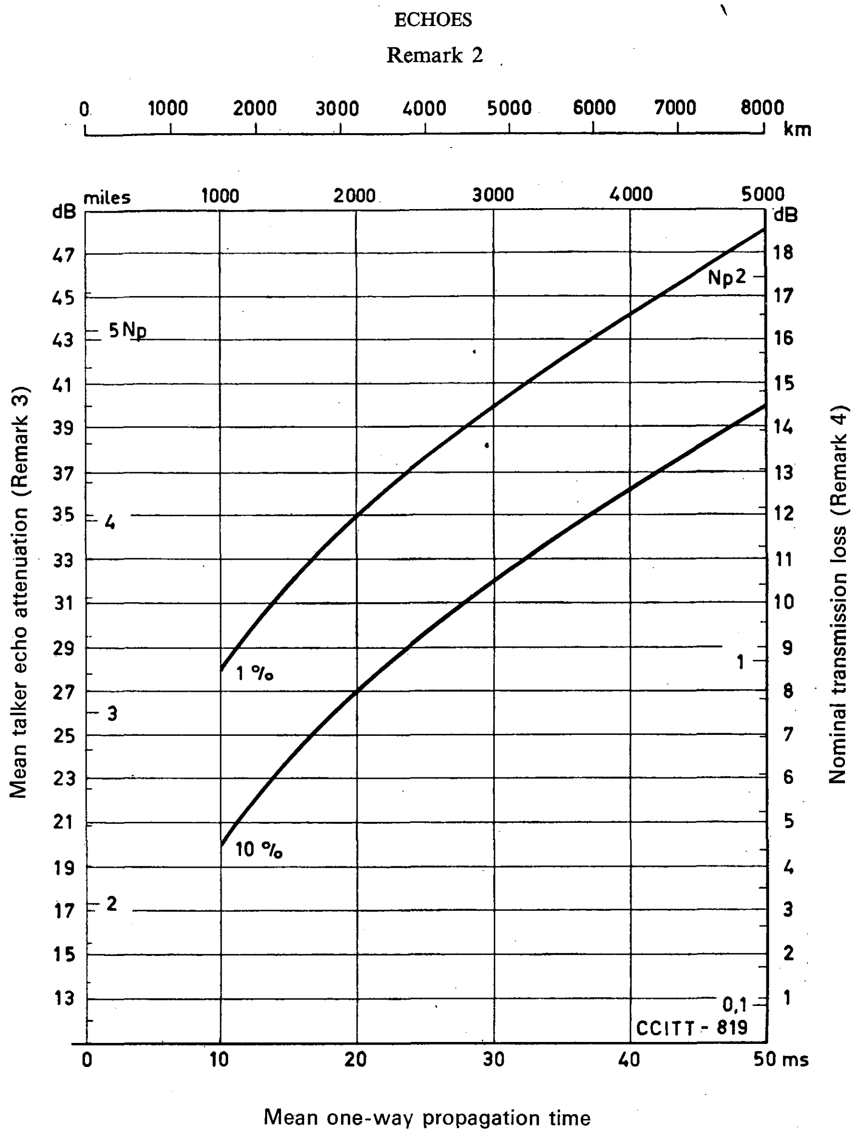
The main circuits of a modern telephone network providing international communications are high-velocity carrier circuits on symmetric or coaxial pairs or radio-relay systems and echo suppressors are not normally used except on connections involving very long international circuits. There is often no general need for echo suppressors in national networks but they may be required for the inland service in large countries. Echo suppressors may also be needed on loaded-cable circuits (low-velocity circuits) used for international calls.

Echoes may be controlled in one of two ways; either the overall loss of the four-wire chain of circuits may be adjusted so that echo currents are sufficiently attenuated (which tacitly assumes a particular value for the echo return loss) or an echo suppressor can be fitted.

a) *Transmission loss adjustment*

The curves of Figure 2 indicate the minimum value of the overall transmission loss of a connection, measured or calculated between the two-wire ends of the subscribers' lines in the terminal local exchanges that must be introduced if no echo suppressor is to be fitted. The transmission loss is shown as a function of the mean one-way propagation time. A distance scale has been added which assumes a velocity of propagation of 100 statute miles/ms (160 km/ms); if low velocity plant is used in any part of the connection then the propagation-time scale should be used. Supplement No. 2 to this Volume explains how these curves have been derived.

The curves are applicable to a chain of circuits which are connected together four-wire, but they may also be used for circuits connected together two-wire if precautions have been taken to ensure good return losses at these points, for example, a mean value of 27 dB or 31 dNp with a standard deviation of 3 dB or 3.5 dNp.



Remark 1. — The percentages refer to the probability of encountering objectionable echo.

Remark 2. — The distance scales assume a velocity of propagation of 100 statute miles/ms or 160 km/ms.

Remark 3. — The mean talker echo attenuation is here defined as the sum of the mean values of the transmission loss in the two directions of transmission between the two-wire ends of the subscribers'lines in the terminal local exchanges, together with the mean value of the echo return loss at the listener's end.

Remark 4. — The nominal transmission loss is here defined as the nominal transmission loss between the two-wire ends of the subscribers'lines in the terminal local exchanges assuming: a) that there is no difference between the nominal value and the mean value; b) that the nominal transmission loss is the same in both directions of transmission, and c) the mean value of the echo return loss at the listener's end is 11 dB (12.7 dNp).

Remark 5. — In constructing the tolerance curves, nine four-wire circuits were assumed for the four-wire chain.

FIGURE 2. — **Echo tolerance curves**

In the case of international circuits reserved for traffic between terminal countries (see the Appendix describing the old plan), the C.C.I.T.T. recommends only a maximum value of nominal overall transmission loss. The minimum value to ensure freedom from intolerable echo can be ascertained from the curves. Should this be greater than the recommended maximum, an echo suppressor should be fitted.

When an international circuit is used only for comparatively short and straightforward international connections the nominal transmission loss between virtual switching points may be increased in proportion to the length of the circuit according to the following rule if the use of echo suppressors can thereby be avoided:

up to 300 miles (500 km) nominal transmission loss:	0.5 dB or 6 cNp
between 300 and 600 miles (500 and 1000 km) nominal transmission loss:	1.0 dB or 12 cNp

and 0.5 dB or 6 cNp for every additional 300 miles (500 km) or part thereof.

However, such a circuit may not form part of multi-circuit connections unless the nominal transmission loss is restored to 0.5 dB or 6 cNp.

b) *Echo suppressors*

The preferred type of echo suppressor is a terminal, differential, half-echo suppressor operated from the far end. There are two types of half-echo suppressors in use in the international network, one suitable only for use in connections with mean one-way propagation times not exceeding 50 ms, referred to as a short-delay echo suppressor, and the other suitable for use in connections with any mean one-way propagation time especially times well over 50 ms, referred to as a long-delay echo suppressor like those used on circuits routed on communication—satellite systems. It will quite clearly be of advantage in future to retain only a single type of echo suppressor in service throughout the whole international network. The characteristics of such an echo suppressor which can be used on connections with either short or long propagation times are given in Recommendation G.161—B and C, *White Book*, Volume III. The characteristics of the short-delay echo suppressor are given in the *Blue Book*, Volume III, Recommendation G.161—B.

c) *Rules governing the use of echo suppressors*

Only telephony is considered here. Echo suppressors are an embarrassment to data and other telegraph-type transmission. Use of echo suppressors with tone disablers is recommended for data transmission. (See Recommendation G.161—C.)

1. *Ideal rules*

The fundamental requirements that an *ideal* scheme should comply with are given in rules A to D below.

Rule A. — The probability that an international connection between any two subscribers will exhibit an objectionable echo should not be greater than 1 %. If the probability is greater, an echo suppressor must be provided.

Rule B. — Not more than the equivalent of one full echo suppressor (i.e. two half-echo suppressors) should be included in any connection needing an echo suppressor.

When there is more than one full echo suppressor the conversation is liable to be clipped; lockout can also occur.

Rule C. — Connections that do not require echo suppressors should not be fitted with them, because they increase the fault rate and are an additional maintenance burden.

Rule D. — The half-echo suppressors should be associated with the terminating sets of the four-wire chain of the complete connection. This reduces the chance of speech being mutilated by the echo suppressors because the hangover times can be very short.

2. *Practical rules*

It is recognized that no practical solution to the problem could comply with rules so exclusive and inflexible as the ideal rules A to D above. Some practical rules, E to L, are suggested below in the hope that they will ease the switching, signalling and economic problems. They should not be invoked unless rules A to D cannot reasonably be complied with.

Rule E. — For connections involving the longest national four-wire extensions of the two countries, a probability of encountering objectionable echo not of 1% (rule A) but of 10% can, by agreement between the administrations concerned, be tolerated. This rule E[1] is valid only in those cases where it would otherwise be necessary, according to rule A[1], to use an echo suppressor solely for these connections, and where there is no need for echo suppressors on connections between the regions in the immediate neighbourhood of the two international centres concerned.

Rule F. — If, as is appreciated, rule D above cannot be complied with, the echo suppressor may be fitted at the international exchange or at an appropriate national transit centre. Should it prove impracticable to fit the echo suppressor at the international exchange (CT3) on multi-circuit connections then it may be fitted at an international transit centre (CT2 or CT1).

For either of these arrangements the hangover time should normally be 50 ms. Exceptionally it may be increased to 70 ms when there is a long chain of circuits extending the connection beyond the point where the echo suppressor is situated. The values of hangover time are provisional in respect of long-delay echo suppressors.

Rule G. — In isolated cases a full short-delay echo suppressor may be fitted at the outgoing end of a transit circuit (instead of two half-echo suppressors at the terminal centres) provided that neither of the two hangover times exceeds 70 ms. This relaxation may reduce the number of echo suppressors required and may also simplify the signalling and switching arrangements. It is emphasized that full echo suppressors must not be used indiscriminately; the preferred arrangement is two half-echo suppressors as near the terminating sets as possible. A full echo suppressor should be as near to the "time-centre" of the connection as possible, because this will require lower hangover times.

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[1] Annex 2 to Question 2/XI (*Blue Book*, Volume VI) is a study of the application of rules A and E to the United Kingdom-European network relations.

Whether a full long-delay echo suppressor can be used in this circumstance is under study.

Rule H. — In exceptional circumstances, such as breakdown, an emergency route may be provided. The circuits of this route need not be fitted with echo suppressors if they are usable without them for a short period. However, if the emergency routing is to last more than a few hours, echo suppressors must be fitted according to rules A or E above.

Rule J. — It is accepted that a connection that does not require an echo suppressor may in fact be unnecessarily equipped with one or two half-echo suppressors, or a full echo suppressor. (The presence of an echo suppressor in good adjustment on a circuit with modest delay times can hardly be detected.)

Rule K. — On a connection that requires an echo suppressor, up to the equivalent of two full echo suppressors (e.g. three half-echo suppressors or two half-echo suppressors and a full one) may be permitted. Every effort should be made to avoid appealing to this relaxation because the equivalent of two or more full echo suppressors, with long hangover times, on a connection can cause severe clipping of the conversation and considerably increases the risk of lockout.

Rule L. — In general it will not be desirable to switch out (or disable) the intermediate echo suppressors when a circuit equipped with long-delay echo suppressors is connected to one with short-delay echo suppressors. However, it would be desirable to switch out (or disable) the intermediate echo suppressors if the mean one-way propagation time of that portion of the connection which would now fall between the terminal half-echo suppressors is not greater than 50 ms, since the different types are likely to be compatible.

d) *Insertion of echo suppressors in a connection*

Ways of doing this which have been considered are:

1. Provide a pool of echo suppressors common to several groups of circuits, and arrange for an echo suppressor to be associated with any circuit that requires one (see Annex 2 to Question 2/XI, *Blue Book,* Volume VI).

2. Arrange for the circuits to be permanently equipped with echo suppressors but switch them out (or disable them) when they are not required (see Annex 3 to Question 2/XI, *Blue Book,* Volume VI).

3. Divide the circuits of an international route into two groups, one with and one without echo suppressors and route the connection over a circuit selected from the appropriate group according to whether the connection merits an echo suppressor. However, it is recognized that circuits may not be used efficiently when they are divided into separate groups. This must be borne in mind.

4. It is possible to conceive schemes in which the originating country and the terminal country are divided into zones at increasing mean radial distances from the international centre and to determine the nominal lengths of the national extensions by examining routing digits and circuits-of-origin.

As far as telephone transmission is concerned there is nothing to distinguish one method from another and the economic solution to the problem may well be found in the judicious use of all these methods. The nature and volume of the traffic carried by a particular connection will also influence the economics of the methods and hence the choice among them.

The C.C.I.T.T. is currently studying what recommendations are necessary to ensure that the insertion of echo suppressors in international connections complies, overall, with the practical rules of c. 2 above.

It should be appreciated that different continents need not use the same method although the methods must be compatible to permit intercontinental connections. There appears to be no great difficulty in arranging this.

RECOMMENDATION G.132 (Geneva, 1964; amended at Mar del Plata, 1968)

ATTENUATION DISTORTION

The objectives for the variation with frequency of transmission loss in terminal condition of a world-wide four-wire chain of 12 circuits (international plus national extensions), each one routed over a single group link, are shown in Figure 1, which assumes that no use is made of high-frequency radio circuits or 3-kHz channel equipment.

Note 1. — The conditions laid down in Recommendation G.232—A, for carrier terminal equipments guarantee that, for a chain of 12 circuits in tandem (six national circuits and six international circuits), each circuit being equipped with one pair of channel-translating equipment, the attenuation distortion will be limited to 9 dB or 1 Np only between about 400 and 3000 Hz. As far as the international chain is concerned, see Recommendation G.141—C.

Note 2. — It is only in a small proportion of international connections that the four-wire chain will in fact comprise 12 circuits.

Note 3. — The assessment by subjective tests of the transmission performance of connections made up of long and complicated circuits is being studied under Question 2/XII.

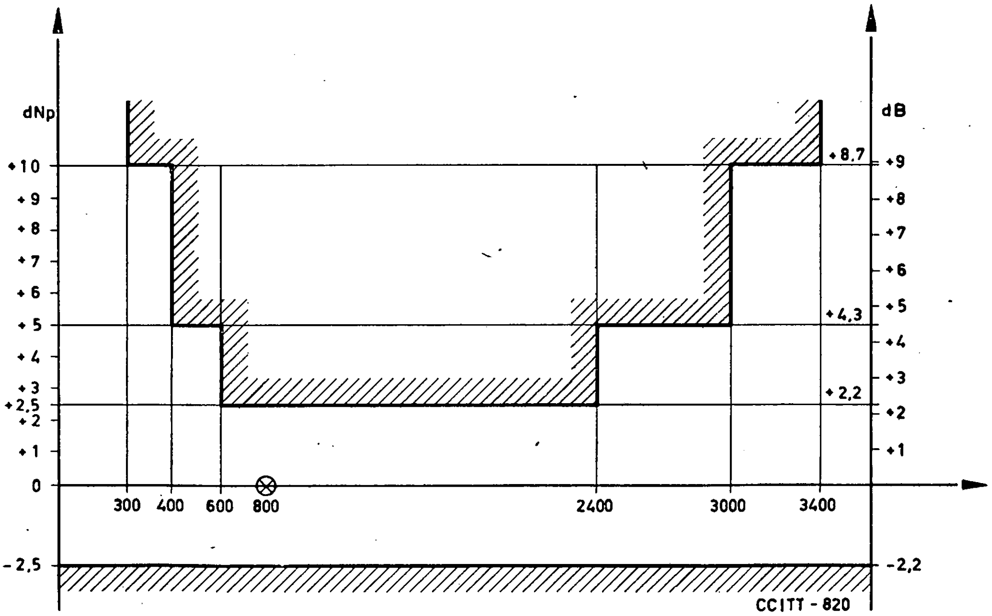

FIGURE 1. — Diagram No. 1 — Permissible attenuation variation with respect to its value measured at 800 Hz (objective for world-wide four-wire chain of 12 circuits in terminal service)

RECOMMENDATION G.133 (Geneva, 1964)

GROUP-DELAY DISTORTION

The permissible differences for a world-wide chain of 12 circuits each on a single 12-channel group link, between the minimum group delay (throughout the transmitted frequency band) and the group delay at the lower and upper limits of this frequency band are indicated in the table below:

	Lower limit of frequency band	Upper limit of frequency band
	ms	ms
International chain	30	15
Each of the national four-wire extensions	15	7.5
On the whole four-wire chain	60	30

Typical group delays at various frequencies for a chain of 12 circuits in tandem are given in Recommendation G.232.

RECOMMENDATION G.134 (Geneva, 1964; amended at Mar del Plata, 1968)

LINEAR CROSSTALK [1]

A. LINEAR CROSSTALK BETWEEN DIFFERENT FOUR-WIRE CHAINS OF CIRCUITS

The signal-to-crosstalk ratio which may exist between two four-wire chains of circuits comprising international and national circuits is restricted by Recommendation G.151—D.a as regards circuits, and by Recommendation Q.45 (*White Book*, Volume VI) as regards international centres.

B. LINEAR CROSSTALK BETWEEN GO AND RETURN CHANNELS OF THE FOUR-WIRE CHAIN OF CIRCUITS

The signal-to-crosstalk ratio between the two directions of transmission of a four-wire chain of circuits is restricted by Recommendation G.151—D. b) as regards circuits and by Recommendation G.45 as regards international centres.

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[1] Recommended methods for the measurement of crosstalk are described in the following Annex.

ANNEX

(to Recommendation G.134)

Methods for measuring crosstalk in exchanges, on international circuits and on a chain of international circuits

1. The method used for measuring crosstalk will depend on the type of crosstalk. In general the one or the other of the following two situations will be encountered:

a) Crosstalk in an exchange arising mainly from a single source or from several nearby sources.

b) Crosstalk measured at the end of a circuit or chain of circuits and which is the result of multiple sources of crosstalk occurring at points along the circuit or chain of circuits. The total crosstalk will depend on the relative phases of the individual contributions and may accordingly vary greatly with frequency. On long circuits or chains of circuits, difficulties may arise when making crosstalk measurements at a single frequency, owing to small variations in the frequency of the master oscillators supplying translating equipment at various points along the circuit or chain of circuits.

2. Available methods for measuring crosstalk are as follows [1]:

a) Single-frequency measurements, e.g. at 800 Hz or 1000 Hz.

b) Measurements made at several frequencies, e.g. at 500, 1000 and 2000 Hz, the results being averaged on a current or voltage basis.

c) Measurements made using a uniform spectrum random noise or closely-spaced harmonic series signal shaped in accordance with a speech power density curve. Such measurements should be made in accordance with paragraph J, b), of Recommendation G.232.

d) Voice/ear tests, in which speech is used as the disturbing source and the crosstalk is measured by listening and comparing its level with a reference source whose level can be adjusted by some form of calibrated attenuating network.

3. Pending further study, the following methods are provisionally recommended for "type tests" and "acceptance tests" involving crosstalk measurement.

a) *Crosstalk in exchanges*

Crosstalk should be measured at 1100 Hz which, in the experience of some administrations is equivalent to a measurement made with a conventional telephone signal generator (Recommendation G.227) and a psophometer.

b) *Crosstalk on an international circuit or chain of international circuits*

Crosstalk should be measured using a uniform spectrum random noise or closely-spaced harmonic series signal shaped in accordance with a speech power density curve. The measurements should be made in accordance with paragraph J, b), of Recommendation G.232.

Note 1. — In cases of difficulty with a) and b) voice/ear tests are recommended.

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[1] It is a question here of the measurement of the frequency (or frequencies) to be used; the measure of the crosstalk for a given frequency is described in a supplement to Volume IV of the *White Book*.

Note 2. — In the case of telephone circuits used for voice-frequency telegraphy the near-end signal-to-crosstalk ratio between the two directions of transmission should be measured at each of the telegraph channel carrier frequencies, i.e. at each odd multiple of 60 Hz from 420 Hz to 3180 Hz inclusive. However, difficulty can arise in practice because of the effect mentioned in 1, b), above.

RECOMMENDATION G.135 (Mar del Plata, 1968)

ERROR ON THE RECONSTITUTED FREQUENCY

As the channels of any international telephone circuit should be suitable for voice-frequency telegraphy, the accuracy of the virtual carrier frequencies should be such that the difference between an audio-frequency applied to one end of the circuit and the frequency received at the other end should not exceed 2 Hz, even when there are intermediate modulating and demodulating processes.

To attain this objective, the C.C.I.T.T. recommends that the channel and group carrier frequencies of the various stages should have the accuracies specified in the corresponding clauses of Recommendation G.225.

Experience shows that, if a proper check is kept on the *operation* of oscillators designed to these specifications, the difference between the frequency applied at the origin of a telephone channel and the reconstituted frequency at the other end hardly ever exceeds 2 Hz if the channel has the same composition as the 2500-km hypothetical reference circuit for the system concerned.

Calculations indicate that, if these recommendations are followed, in the four-wire chain forming part of the hypothetical reference connection defined in Figure 1 of Recommendation G.103[1] there is about 1 % probability that the frequency difference between the beginning and the end of the connection will exceed 3 Hz and less than 0.1 % probability that it will exceed 4 Hz.

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[1] In fact, the chain considered for these calculations comprised 16 (instead of 12) modulator-demodulator pairs to allow for the possibility that submarine cables with equipments in conformity with Recommendation G.235 might form part of the chain. No allowance was made, however, for the effects of Doppler frequency-shift due to inclusion of a non-stationary satellite; values for this shift are given in C.C.I.R. Report 214-1, Volume IV (2) (Oslo, 1966).

1.4 General characteristics of the four-wire chain of international circuits; international transit

RECOMMENDATION G.141 (Geneva, 1964; amended at Mar del Plata, 1968)

TRANSMISSION LOSSES, RELATIVE LEVELS AND ATTENUATION DISTORTION

A. CONVENTIONS AND DEFINITIONS

a) *Relative levels specified at the virtual switching points of international circuits*

The virtual switching points of an international four-wire telephone circuit are fixed by convention at points of the circuit where the nominal relative levels at the reference frequency are:

—3.5 dBr or —4.0 dNr, sending
—4.0 dBr (—4.6 dNr), receiving

The nominal transmission loss of this circuit at the reference frequency between virtual switching points is therefore 0.5 dB or 6 cNp.

Note 1. — See the definitions in section b). The position of the virtual switching points is shown in Figure 2 of Recommendation G.101 and in the figure in Recommendation G.122.

Note 2. — Since the four-wire terminating set forms part of national systems and since its actual attenuation may depend on the national transmission plan adopted by each administration, it is no longer possible to define the relative levels on international four-wire circuits by reference to the two-wire terminals of a terminating set. In particular, the transmission loss in terminal service of the chain created by connecting a pair of terminating sets to a four-wire international circuit cannot be fixed at a single value by C.C.I.T.T. recommendations. The virtual switching points of circuits might therefore have been chosen at points of arbitrary relative level. However, the values adopted above are such that in general they permit the passage from the old plan to the new to be made with the minimum amount of difficulties.

Note 3. — If a four wire circuit forming part of the four-wire chain contributes negligible delay and variation of transmission loss with time, it may be operated at zero nominal transmission loss between virtual switching points. This relaxation refers particularly to short four-wire tie-circuits between switching centres—for example, circuits between a CT3 and a CT2 in the same city.

b) *Definitions*

1. *Transmission reference point*

A hypothetical point used as the zero relative level point in the computation of nominal relative levels. Such a point exists at the sending end of each channel of a four-wire switched circuit preceding the virtual switching point; on an international circuit it is defined as having a level + 3.5 dB above that of the virtual switching point.

With the C.C.I.T.T. transmission plan this point does not necessarily coincide with the two-wire termination point as was the case with the old plan. The level of transmitted load at this point is the subject of Recommendation G.223.

2. *Relative (power) level*

The expression in transmission units of the ratio $\frac{P}{P_0}$, where P represents the power at the point concerned and P_0 the power at the transmission reference point.

3. *Circuit test access point*

Study Group IV has defined circuit test access points as being "four-wire test-access points so located that as much as possible of the international circuit is included between corresponding pairs of these access points at the two centres concerned". These points, and their relative level (with reference to the transmission reference point), are determined in each case by the administration concerned. They are used in practice as points of known level to which other transmission measurements will be related. In other words, for measurement and lining-up purposes, the level at the appropriate circuit test access point is the level with respect to which other levels are adjusted.

4. *Measurement frequency*

For all international circuits 800 Hz is the recommended frequency for single-frequency maintenance measurements. However, by agreement between the administrations concerned, 1000 Hz may be used for such measurements.

A frequency of 1000 Hz is in fact now widely used for single-frequency measurements on some international circuits.

Multifrequency measurements made to determine the loss/frequency characteristic will include a measurement at 800 Hz and the frequency of the reference measurement signal for such characteristics can still be 800 Hz.

Note. — Definitions 1 and 2 are used in the work of Study Group XVI. Definitions 3 and 4, taken from Recommendation M.64—B and M.58 (*White Book*, Volume IV), are included for information. Further explanation is given in the Annex below.

B. INTERCONNECTION OF INTERNATIONAL CIRCUITS IN A TRANSIT CENTRE

In a transit centre, the virtual switching points of the two international circuits to be interconnected are considered to be connected together directly without any intermediate pad or amplifier.

In this way a chain of *n* international circuits has a nominal transmission loss in transit of *n* times 0.5 dB or 6 cNp in each direction of transmission which contributes to the stability of the connection; see Recommendation G.131.A.

C. ATTENUATION DISTORTION

The conditions laid down for carrier terminal equipment by Recommendation G.232—A guarantee that a chain of six circuits, each equipped with a single pair of channel-translating equipments in accordance with that Recommendation, will exhibit an attenuation distortion in terminal service that will meet the limits of Figure 1 in Recommendation G.132, including the distortion contributed by the seven international centres traversed.

Note. — To assess the attenuation distortion of the international chain, the limits indicated for international circuits in Recommendation G.151—A must not be added to the limits for international centres mentioned in Recommendation Q.45. In fact, on the one hand, some exchange equipment would be counted twice if this addition were made; on the other, the specification limits of Recommendation Q.45 apply to the worst possible connection through an international exchange, while the maintenance limits of Recommendation G.151—A apply to the poorest international circuit. The specifications of the various equipments are such that the mean performance will be appreciably better than could be estimated by the above-mentioned addition.

ANNEX

(to Recommendation G.141)

Explanatory texts supplementing the definitions in A.b

1. *Relative level at a point in a transmission equipment* (Contribution by the French Administration)

The recommendations of the C.C.I.T.T. are drafted in such a way that the absolute power level of the test signals to be applied at the input of a particular transmission equipment to check whether it conforms to these recommendations is clearly defined as soon as the "relative level" at this point is fixed.

It is therefore for the manufacturer to specify for the benefit of the user the value of this relative level for each specific type of equipment. When a transmission system is set up, equipments must be assembled so as to ensure compatibility between the relative levels imposed by individual equipments. The diagram showing the levels of the circuit set up within a system is thus defined by the equipments used in it.

2. *Conventional load at zero relative level point* (contribution by Siemens and Halske)

In the design of a national network the C.C.I.T.T. conventions concerning the load produced by a multiplex signal referred to a point of zero relative level (Recommendation G.223) must be respected.

It can be assumed that this is the case if the reference equivalents of national sending systems (from the subscriber set to the virtual switching point) have values of between 7 and 24 dNp or 6 and 21 dB (with a mean of about 16 dNp or 14 dB) in all the connections. It must, of course, be understood that the conventional load also includes the components deriving from a certain percentage of circuits used as bearers for v.f. telegraphy, in data, facsimile, etc., transmission, or deriving from signalling and tones produced by the exchanges, carrier leaks and reference pilots.

RECOMMENDATION G.142 (Geneva, 1964; amended at Mar del Plata, 1968)

TRANSMISSION CHARACTERISTICS OF AN INTERNATIONAL CENTRE (CT)

Recommendation Q.45 (*White Book*, Volume VI) gives the transmission characteristics to be respected for acceptance tests in an international centre. Study Group XVI is studying the effect of these characteristics on the transmission plan.

RECOMMENDATION G.143 (Geneva, 1964; amended at Mar del Plata, 1968)

CIRCUIT NOISE AND THE USE OF COMPANDORS

A. Noise objectives for telephony

a) *Principle*

Taking into account the noise allowed in national networks (Recommendation G.123), it is desirable that, when the new transmission plan takes effect, the mean psophometric power in any hour of the total noise generated by a chain of six international circuits, some of which may exceed 2500 km in length, on a connection used for international telephone calls, should not exceed 50 000 picowatts referred to a zero relative level point of the first circuit in the chain (level —43 dBm0 or —5 Nm0).

Of course, a lower value of the total noise will be obtained when the international chain consists of only a small number of international circuits, not exceeding 2500 km in length and conforming to Recommendation G.152 (in particular, such circuits do not introduce a mean psophometric power in any hour with a level greater than −50 dBm or −58 dNm at a zero relative point on the circuit).

However, as connections longer than 25 000 km will be set up, the C.C.I.T.T. recommends, as an objective, that on sections longer than 2500 km used for international traffic line equipment be supplied which gives rise to noise not greatly exceeding L picowatts on a circuit L km long (see Annexes B and C, *Red Book*, Volume V*bis*). There is obvious advantage in working to the same standard on short sections when this can reasonably be done.

Note. — Strictly speaking, the noise objective for communication-satellite systems (see Recommendation G.153—C) cannot be expressed in the form of a given number of picowatts per km.

b) *Noise produced by equipment*

The noise produced by the modulating equipment in the international chain of circuits in the longest hypothetical reference connection[1] can be estimated on the assumption that such equipment comprises:

- 6 channel-modulation pairs, or 8 to 10 if 3-kHz-spaced channel equipment is used on transoceanic routes,
- 12 to 14 group-modulation pairs,
- 18 to 24 supergroup-modulation pairs,

for all of which a total psophometric power of 5000 to 7000 pW (at a point of zero relative level on the first circuit of the international chain of four-wire circuits) is an ample allowance.

The objective — 67 dBm (7.7 Nm) for the hourly-mean psophometric power level at each international switching point quoted in Recommendation Q.45 — is equivalent to about 2000 pW at a point of zero relative level on the first circuit in the four-wire chain.

It may thus be seen that the noise produced by the equipment does not constitute a substantial contribution to the total noise generated by the international chain.

c) *Division of the overall objective*

The land sections in the international chain, set up on cable carrier systems or on radio-relay links, should in principle afford circuits of the quality defined above. In practice, by agreement between administrations, the noise objective could be shared between the submarine and overland systems in such a way that the submarine cable systems contribute at a somewhat lower rate, e.g. 1 pW/km, and the overland systems contribute at a somewhat higher rate, e.g. a maximum of 2 pW/km. This result may be achieved either by setting up special systems, or by a proper choice of channels in systems designed to the 3 pW/km objective.

Note. — In some countries, overland systems forming part of a circuit substantially longer than 2500 km (e.g. 5000 km or more) have been constructed with the same noise objectives as the submarine cable system, i.e. 1 pW/km.

d) *Circuits operated with speech concentrators*[2]

It would be desirable for all the circuits making up a group for use with a concentrator system to have approximately the same noise power level.

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[1] See Figure 1 in Recommendation G.103.

[2] For example, TASI (Time Assignment Speech Interpolation) of CELTIC (Concentrateur exploitant les temps d'inoccupation des circuits); see Recommendation G.163.

B. USE OF SYLLABIC COMPANDORS[1]

The limit recommended in Section A of this Recommendation for the noise power level at the zero relative level point of the first circuit in a chain of six international circuits is an objective to guide the designers of line and radio systems, and in consequence the noise objective is usually re-expressed in terms of a noise rate per unit length, a concept more suited to the needs of system designers.

However, for very many years, international (and national) circuits will continue to be provided on existing transmission systems which have been designed to other standards, e.g. 4 pW/km, as given in Recommendation G.152. Furthermore, the circuit noise produced by transmission systems can increase above the values originally achieved because of ageing effects, and changes of system loading. There is therefore a need for a simple practical criterion that can be applied for planning purposes to an international circuit to determine if, as far as noise power is concerned, it is suitable for establishing multi-circuit world-wide telephone connections or whether it can be made suitable by fitting compandors[2].

It is recommended that, for the present, the systematic use of compandors conforming to Recommendation G.162 in the long-distance national and international network be restricted.

It must be pointed out that the action of a compandor doubles the effect of any variations in the transmission loss occurring in that part of the circuit which lies between the compressor and the expander and for this reason compandors, if needed, should be fitted at the ends of circuit sections provided by inherently stable line transmission systems such as submarine cable systems.

The following planning rule is recommended by the C.C.I.T.T. as a guide for deciding whether an international circuit requires a compandor:

If the hourly-mean psophometric circuit noise power level of an international circuit substantially longer than 2500 km (e.g. 5000 km or more) is less than —44 dBm or —5 Nm (at a point of zero relative level on the circuit) no compandor is necessary.

If the circuit noise power level is greater than —44 dBm or —5 Nm, a compandor should be fitted.

If the circuit noise power level is greater than —36 dBm (—4.15 Nm), the circuit, even though fitted with a compandor, should not be allowed to form part of a six-circuit connection. It is, of course, to be understood that circuits of length 2500 km or less will always meet the appropriate general noise objectives (Recommendation G.222) without the need for compandors.

Note 1. — This rule has been devised to make possible the planning of the international telephone network, using presently available circuits. It should in no way be interpreted as relaxation of the design objectives recommended in Section A of this Recommendation, nor should it be applied for maintenance purposes.

Note 2. — The compandors used should conform to the limits proposed in Recommendation G.162.

C. NOISE LIMITS FOR TELEGRAPHY

The mean psophometric noise power referred to a point of zero relative level should not exceed 80 000 pW (—41 dBm0p or —4.7 Nm0p) for frequency modulation voice-frequency

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[1] The instantaneous compandors that are associated with certain transmission systems are considered to be an integral part of these systems.

telegraphy at the 50, 100 or 200 baud rate and the sending power recommended by the C.C.I.T.T., namely 135 pW at a point of zero relative level.

This limit is specified in Recommendation H.22 in the second part of the present volume. Naturally, the noise values on many connections will meet the objectives specified in Section A of the present Recommendation and will thus be better than this limit.

Note. — If recourse be had to synchronous operation, a higher noise level can be tolerated (such as —30 dBm0p or —3.5 Nm0p for a particular telegraph system).

D. Noise objectives for data transmission

The following objectives are acceptable for data transmission at data signalling rates not exceeding 1200 bits per second. Naturally, the values on many circuits and connections will meet the objectives of Section A of the present Recommendation and will thus be better than the following objectives.

a) *Leased circuits for data transmission*

A reasonable objective for uniform spectrum random noise for a data transmission *leased* circuit, assuming that plant liable to impulsive noise interference is avoided, and as high a modulation rate as possible is to be used without significant error rate, would appear to be —40 dBm0p (—4.6 Nm0p).

b) *Switched connections*

For switched connections a design objective of, say, —36 dBm0p (—4.15 Nm0p) without compandors may be taken for intercontinental circuits on which compandors may be used.

1.5 General characteristics of international telephone circuits and national extension circuits

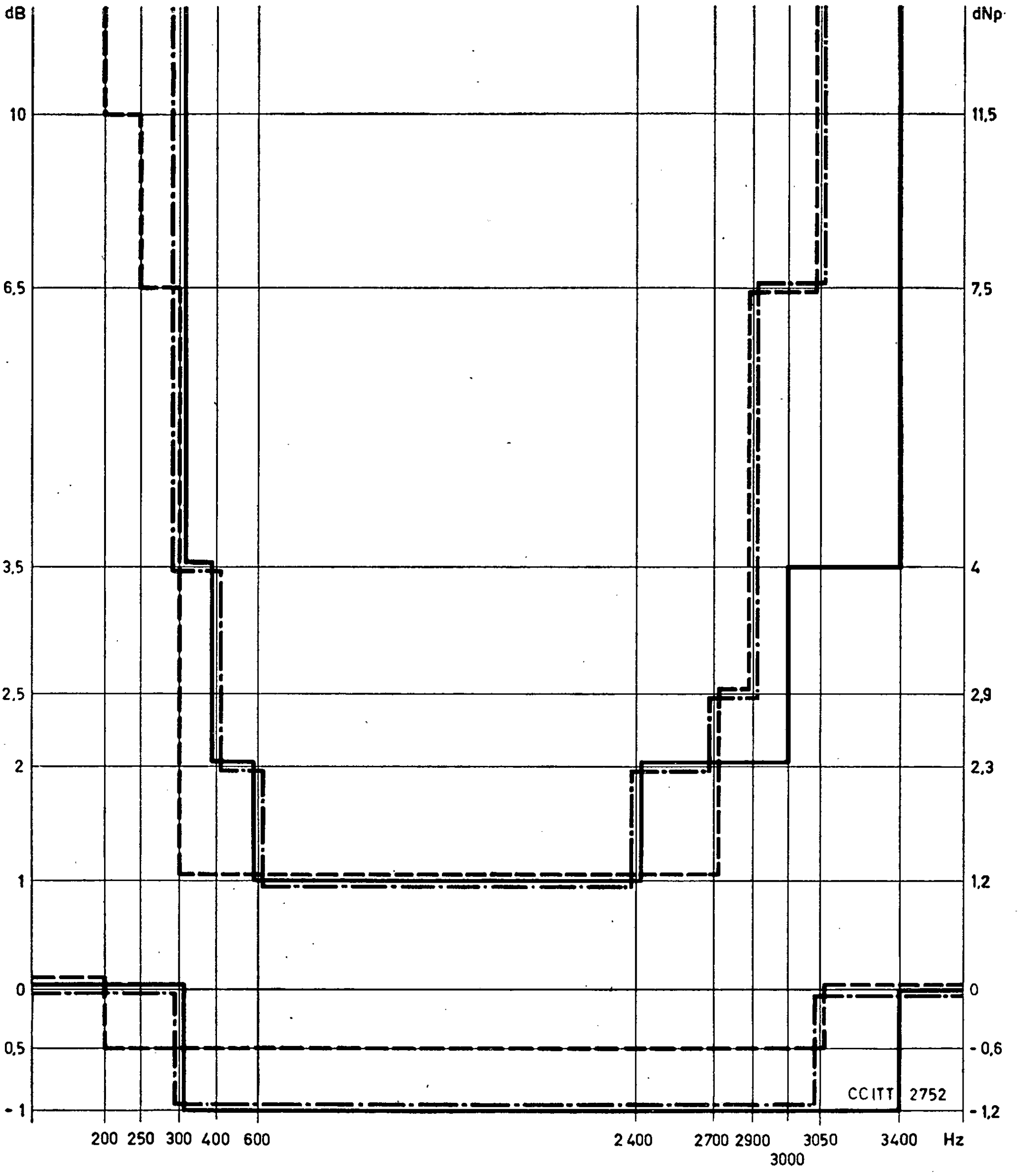
RECOMMENDATION G.151 (Geneva, 1964; amended at Mar del Plata, 1968)

GENERAL CHARACTERISTICS APPLICABLE TO ALL MODERN INTERNATIONAL CIRCUITS AND NATIONAL EXTENSION CIRCUITS

A. Attenuation distortion

International circuits and national extension circuits should individually have an attenuation distortion characteristic such that the provisions of Recommendation G.132 are complied with. Recommendation G.232 gives recommendations for channel modulation terminal equipment at carrier frequencies with 4-kHz spacing, whereby this aim can be achieved.

It follows from the Recommendations mentioned above that, as a rule, the frequency band effectively transmitted by a telephone circuit, according to the definition adopted by the C.C.I.T.T. (i.e. the band in which the attenuation distortion does not exceed 9 dB or



——— Circuits with equipment having 4-kHz spacing (Recommendation G.232)

– – – – Circuits with equipment having 3-kHz spacing (Recommendation G.235)

—·—·— Circuits with mixture of equipment with 3- and 4-kHz spacing

FIGURE 1. — **Attenuation-frequency characteristics of circuits with 3-kHz and 4-kHz channel equipment**

1 Np compared with the value for 800 Hz), will be a little wider than the 300-3400-Hz band, and for a single pair of channel terminal equipments of this type, the attenuation distortion at 300 Hz and 3400 Hz should never exceed 3 dB (3.5 dNp) and in a large number of equipments should not average more than 2 dB or 2 dNp (see Graphs No. 2A and No. 2B in Recommendation G.232). Even more complex circuits, and circuits using terminal equipments with 3-kHz-channel spacing in accordance with Recommendation G.235, should satisfy the limits in Figure 1; to ensure that these limits are respected, equalizers are inserted, if necessary, when the circuits are set up (Recommendation M.58, *White Book*, Volume IV).

Note 1. — The C.C.I.T.T. examined the possibility of recommending a specific frequency below 300 Hz as the lower limit of the frequency band effectively transmitted, taking the following considerations into account:

1. The results of subjective tests carried out by certain administrations show that it is possible to improve transmission quality if the lower limit of the transmitted frequency band is reduced from 300 Hz to 200 Hz. These tests show a definite increase in the loudness of the received speech, and also in the quality of the transmission as judged by opinion tests; the improvement in articulation is, on the other hand, very slight.

2. However, such an extension would probably have the following disadvantages:
   - 2.1 it would slightly increase the cost of equipment;
   - 2.2 it would introduce some difficulties in balancing the terminating sets at the ends of the four-wire chain, if it were desired to use four-wire circuits without exceeding the values of nominal transmission loss recommended in the new transmission plan;
   - 2.3 it would increase the possible susceptibility to noise, especially at 250 Hz;
   - 2.4 the additional energy transmitted in consequence of extending the band could increase the loading of carrier systems;
   - 2.5 the out-of-band signalling systems recognized by the C.C.I.T.T. could not be used.

In view of the above, the C.C.I.T.T. has issued the aforementioned recommendations concerning signals transmitted at frequencies between 300 and 3400 Hz.

Note 2. — In applying the C.C.I.T.T. recommendations, administrations may mutually agree to transmit signals at frequencies below 300 Hz over international circuits. Every administration may, of course, decide to transmit signals at frequencies below 300 Hz over its national extension circuits, provided it is still able to apply the new C.C.I.T.T. transmission plan to international communications.

B. GROUP DELAY

The group-delay characteristics of international circuits and national extension circuits should enable the requirements of Recommendations G.114 and G.133 to be met.

C. VARIATIONS OF TRANSMISSION LOSS WITH TIME

The C.C.I.T.T. recommends the following objectives (objective a) has been used to assess the stability of international connections—see Recommendation G.131—A):

a) The standard deviation of the variation in transmission loss of a circuit should not exceed 1 dB or 12 cNp. This objective can be obtained already for circuits on a single group link equipped with automatic regulation and should be obtained for each national circuit, whether regulated or not.

The standard deviation should not exceed 1.5 dB or 17 cNp for other international circuits.

b) The difference between the mean value and the nominal value of the transmission loss for each circuit should not exceed 0.5 dB or 6 cNp.

D. LINEAR CROSSTALK [1]

a) *Between circuits*

The near-end or far-end crosstalk ratio (intelligible crosstalk only) measured at audio-frequency at trunk exchanges between two complete circuits in terminal service position should not be less than 58 dB or 6.7 Np. This value may be modified as a result of the study of Question 11/XII.

b) *Between the go and return channels of a four-wire circuit*

1. *Ordinary telephone circuits (see Note 1 below)*

Since all ordinary telephone circuits may also be used as v.f. telegraph bearers, the near-end crosstalk ratio between the two directions of transmission should be at least 43 dB (5 Np).

2. *Circuits used with a speech concentrator*

For circuits and circuit-sections used to interconnect terminal speech concentrator equipments, near-end crosstalk between any two channels will appear in the form of crosstalk between circuits and hence the total near-end crosstalk ratio introduced between speech concentrators should not be less than 58 dB (6.7 Np). (See Notes 2 and 4 below.)

3. *Circuits used with modern echo suppressors, for example, high-altitude satellite circuits*

The near-end crosstalk ratio of any circuit equipped with terminal far-end operated, half-echo suppressors of modern design should not be less than 55 dB (6.3 Np). This is to avoid nullifying the effect of the suppression loss introduced by modern echo suppressors. (See Notes 2, 3 and 4 below.)

Note 1. — Paragraph 1 above refers to telephone circuits which are not equipped with (or used in conjunction with) modern echo suppressors designed for long propagation times. Circuits which can form part of switched connections with a long propagation time and which then lie between terminal half-echo suppressors of modern design should, wherever possible, conform to the higher standards given in paragraph 3 above.

Note 2. — The channel-translating equipment provides the principal go-to-return crosstalk path on circuits or circuit-sections routed on carrier systems with modern translating and line transmission equipment (but see Note 4 below). It should be noted that crosstalk paths between the high-frequency input and the high-frequency output and also between the voice-frequency input and voice-frequency output on channel-translating equipments contribute to the go-to-return crosstalk ratios of circuits and circuit-sections. Both these paths must be taken into account when considering circuits or circuit-sections used between terminal speech concentrator equipments or modern echo suppressors. The following cases arise:

Speech concentrators

Both the high-frequency path and the voice-frequency path contribute to the crosstalk ratio.

Echo suppressors

1 A circuit comprising one circuit-section between far-end operated, half-echo suppressors: the high-frequency path is dominant.

2) A circuit comprising more than one circuit-section between the suppressors: at points where channel-translating equipments are connected together at voice-frequency, the voice-frequency crosstalk path of one equipment is effectively in parallel with the high-frequency crosstalk path of the other so that both must be taken into account.

3) More than one circuit between the suppressors: this occurs when intermediate adjacent half-echo

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[1] The methods recommended for measuring crosstalk are described in the Annex to Recommendation G.134.

suppressors are switched out (or disabled) and the go-to-return crosstalk arises in a fashion analogous to that described in 2) above, circuits replacing circuit-sections.

Note 3. — If channel-translating equipments conforming to the requirements of Recommendations G.232 or G.235 are used for circuits or circuit-sections there should ordinarily be no difficulty in achieving the limit of 55 dB (6.3 Np) even on a circuit with three circuit-sections (i.e. a circuit with three pairs of channel-translating equipment). However, there is little margin and in order to cater for the condition described in Note 2 above, a somewhat higher value of near-end crosstalk ratio for circuits is required.

Note 4. — Some types of symmetrical-pair line transmission systems introduce significantly low go-to-return crosstalk ratios on the derived circuits and wherever possible such systems should not be used to provide circuits or circuit-sections for use with speech concentrators or modern echo suppressors.

E. NON-LINEAR DISTORTION

Experience has shown that telephone circuits set up on systems for which the C.C.I.T.T. has issued recommendations (the elements of which systems, taken separately, meet the relevant non-linearity requirements) are equally suitable, as far as non-linearity is concerned, for telephone and voice-frequency telegraph transmission.

Note. — In carrier telephone circuits, the non-linear distortion produced by the line amplifiers and by modulation stages other than the channel-translating equipment can be ignored. Hence the above remarks are applicable to circuits of any length.

F. ERROR ON THE RECONSTITUTED FREQUENCY

See Recommendation G.135.

RECOMMENDATION G.152 (Geneva, 1964; amended at Mar del Plata, 1968)

CHARACTERISTICS APPROPRIATE TO LONG-DISTANCE CIRCUITS OF A LENGTH NOT EXCEEDING 2500 KM

This Recommendation applies to all modern international circuits not more than 2500 km in length. It also applies to national trunk circuits in an average-size country, and which may be used in the four-wire chain of an international connection.

It is understood that, should an extension circuit more than 2500 km long be used in a large country, it will have to meet all the recommendations applicable to an international circuit of the same length.

A. CIRCUITS ON LAND OR SUBMARINE CABLE SYSTEMS OR ON LINE-OF-SIGHT RADIO-RELAY SYSTEMS

The circuits in question are mostly set up in cable or radio-relay link carrier systems, such that the noise objectives of Recommendation G.222 are obtained for a circuit with the same make-up as the hypothetical reference circuit 2500 km long.

A consequence of Recommendation G.222 is that, for a circuit *L*-km long (where *L* is 2500 km or less), the mean psophometric noise power during any hour should be of the order of 4 *L* picowatts, excluding very short circuits and those with a very complicated composition, this latter case being dealt with in Recommendation G.226.

B. CIRCUITS ON TROPOSPHERIC-SCATTER RADIO-RELAY SYSTEMS

The C.C.I.R. has defined a hypothetical reference circuit and fixed noise limits in its Recommendations 396-1 and 397-1 respectively, which are reproduced in C.C.I.T.T. Recommendations G.433 and G.444.

C. CIRCUITS ON OPEN-WIRE CARRIER SYSTEMS

Recommendation G.311, paragraph h), contains relevant noise objectives.

RECOMMENDATION G.153 (Geneva, 1964; amended at Mar del Plata, 1968)

CHARACTERISTICS APPROPRIATE TO INTERNATIONAL CIRCUITS MORE THAN 2500 KM IN LENGTH

These circuits should meet the general requirements set forth in Recommendation G.151 and should, in addition, according to the kind of system on which they are set up, meet the particular provisions of Sections A, B, C or D below.

Note. — Some circuits which do not meet the noise objectives specified in the present Recommendation can nevertheless be used for telephony (if they are fitted with compandors), telegraphy or data transmission (sections B, C and D of Recommendation G.143; the table below summarizes these Recommendations).

Noise objectives or limits[1] *for very long circuits providing various services*[2]

Psophometric power		Type of objective or limit	
pW0p	dBm0p	for a connection, a chain of circuits, or a leased circuit	for a circuit which may form part of a switched connection
40 000	−44		Limit for a telephone circuit used without a compandor (Recommendation G. 143—B).
50 000	−43	Objective for a chain of 6 international circuits,-obtained in practice by a combination of circuits of 1, 2 or 4 pW/km (Recommendation G. 143—A).	
80 000	−41	Limit for FM v.f. telegraphy, in accordance with C.C.I.T.T. standards (Recommendation G. 143—C).	
100 000	−40	Objective for data transmission over a leased circuit (Recommendation G. 143—D.a).	
250 000	−36		Tolerable for data transmission over the switched network (Recommendation G. 143—D. b). A circuit exceeding this limit without a compandor cannot be used in a chain of 6 telephone circuits even if it is equipped with a compandor (Recommendation G. 143—B).
10^6	−30	Tolerable for a certain system of synchronous telegraphy (Recommendation G. 143—C).	

[1] Only the mean psophometric power over one hour has been indicated, referred to a point of zero relative level of the international circuit, or of the first circuit of the chain.

[2] Limits or objectives determined according to the minimum requirements of each service. The objectives (which are often better) for various transmission systems are recapitulated in Table *1bis*, *White Book*, Volume III.

A. CIRCUITS MORE THAN 2500 KM IN CABLE OR RADIO-RELAY SYSTEMS, WITH NO LONG SUBMARINE CABLE SECTION

It seems certain that circuits of this kind, between 2500 km and about 25 000 km long, will throughout most of their length be carried in land-cable systems or radio-relay systems, already used to give international circuits not more than 2500 km long, and designed on the basis of the objectives already recommended for such systems in Recommendation G.222.

Moreover, it is unlikely that the number of channel demodulations will exceed that envisaged in the corresponding part of the longest international connection referred to in Recommendation G.103.

This being so, the C.C.I.T.T. issues the following recommendations:

a) *Variations in transmission loss with time*

Automatic level adjustment should be used on each group link on which the circuit is routed. In addition, all possible steps should be taken to reduce changes of transmission loss with time.

b) *Circuit noise*

It is provisionally recommended that systems to provide such international circuits not more than 25 000 km long should be designed on the basis of the noise objectives at present recommended for 2500-km hypothetical reference circuits.

Accordingly, the mean psophometric power during any hour of the noise due to the line should not exceed 3 pW per kilometre of line with respect to a zero relative level point. Whenever possible, a lower figure should be obtained (2 pW/km, or preferably even less) by a suitable choice of the telephone channels making up the circuits. Furthermore, as mentioned above, it is possible that the modulation equipments used in making up such a circuit will be relatively fewer (in relation to length) than for a hypothetical reference circuit 2500 km long.

Note. — In some countries, overland systems forming part of a circuit substantially longer than 2500 km (e.g. 5000 km or more) have been constructed with the same noise objectives as the submarine cable system, i.e. 1 pW/km.

The foregoing values are hourly means. Provisionally the short-term noise objectives for circuits of this kind of length up to about 7500 km are as follows:

The one-minute mean noise power shall not exceed 50 000 pW (—43 dBm0p or —5 Nm0p) for more than 0.3% of any month and the unweighted noise power, measured or calculated with an integrating time of 5 ms, shall not exceed 10^6 pW (—30 dBm0 or —3.5 Nm0) for more than 0.03% of any month. It is to be understood that these objectives are derived pro rata from the objectives for circuits of 2500 km length (Recommendation G.222); for lengths between 2500 and 7500 km proportionate intermediate values should apply.

The C.C.I.T.T. is not yet able to recommend objectives for short-time noise on circuits of the above type which exceed 7500 km in length.

B. CIRCUITS WITH A LONG SUBMARINE CABLE SECTION

a) *Attenuation distortion*

A circuit of this kind may, for reasons of economy, comprise terminal equipments with carriers spaced 3 kHz apart, in accordance with Recommendation G.235.

If terminal equipment be used with carrier spacing of 4 Hz, it must at least meet the requirements of Recommendation G.232. As is pointed out in a Remark appended to this Recommendation, some countries use improved terminal equipment in circuits permanently used for intercontinental operation.

b) *Circuit noise attributable to the submarine cable section*

1. *Without compandor*

A very long submarine-cable system designed for use without compandors and with no restrictions for telephony, voice-frequency telegraphy and data transmission should be designed with a view to ensuring that the mean noise per hour does not exceed 3 pW/km on the worst channel. The mean noise power for each direction of transmission, extended over all the channels used for the longest circuits, should not exceed 1 pW/km.

Note. — However, it would be desirable that the circuits in a group to be operated with a speech concentrator system[1] should all have more or less the same noise level.

2. *With compandor*

At present, the C.C.I.T.T. does not propose to study systems which, by relying on the *systematic* use of compandors, have noise objectives which are greatly different from those of paragraph b) 1 above.

c) *Circuit noise attributable to other sections*

The other sections of the circuit should comply with the recommendations given in Section A of this Recommendation; the note of paragraph A.b) still applies to this case.

C. CIRCUITS ON COMMUNICATION-SATELLITE SYSTEMS

The C.C.I.R. and the C.C.I.T.T. are considering the extent to which circuits set up on communication-satellite systems may be integrated into the world-wide network; some of the limitations on the use of such circuits are outlined in Recommendation Q.13 (*White Book*, Volume VI).

The C.C.I.R. has made recommendations so far as circuit noise is concerned and has defined a hypothetical reference circuit (C.C.I.R. Recommendation 352) and the allowable noise power in this reference circuit (C.C.I.R. Recommendation 353-1). These recommendations are reproduced in C.C.I.T.T. Recommendations G.434 and G.445 respectively.

D. CIRCUITS MORE THAN 2500 KM IN LENGTH SET UP ON OPEN-WIRE LINES

In the present state of the art, modern carrier systems on open-wire lines meet all practical requirements for long-distance land lines, provided special precautions are taken concerning, in particular:

- regularity of construction of the line;
- accurate operation of automatic line regulators;
- the possibility of modifying, if necessary, the level diagram of the telephone circuits, to take account of special climatic conditions (ice, etc.).

Further, it is necessary to consider noise carefully in each particular case and to choose the repeater spacing so as to have an acceptable signal/noise ratio during most of the time.

In designing such systems, the objective should be that the mean psophometric power, during any hour, at a point of zero relative level, at the end of a circuit of about 10 000 km, taking account of all noise which exists, with the exception of noise due to ratio transmitters, should not exceed 50 000 pW (level of —43 dBm0p or —5 Nm0p).

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[1] See footnote 2, page 2 of Recommendation G.143.

Note 1. — The objective given above is for a reasonable distribution of wet weather over the territory crossed by the circuit. The value of 50 000 pW may be exceeded when climatic conditions are very unfavourable.

Note 2. — This objective might seem to be more severe, in proportion to the length, than that given in paragraph g) of Recommendation G.311. It should be noted that for circuits considerably longer than 2500 km, fitted with equipment designed on the basis of the hypothetical reference circuit, the noise and crosstalk values may increase less rapidly than the length of the circuit. Moreover, it is recommended above that special precautions be taken in the construction of the line and in the adjustment of the levels on the system, and also it is not very likely that, on a 10 000-km circuit, the same climatic conditions will exist throughout its length.

Note 3. — If Recommendation G.143—B were strictly adhered to, any circuit of this type which barely met the 50 000 pW objective would have to be fitted with a compandor. In practice, since a 10 000-km circuit is involved, this noise value is tolerable without a compandor.

1.6 Apparatus associated with long-distance telephone circuits

RECOMMENDATION G.161 (Geneva, 1967; amended at Mar del Plata, 1968)

ECHO SUPPRESSORS SUITABLE FOR CIRCUITS HAVING EITHER SHORT OR LONG PROPAGATION TIMES

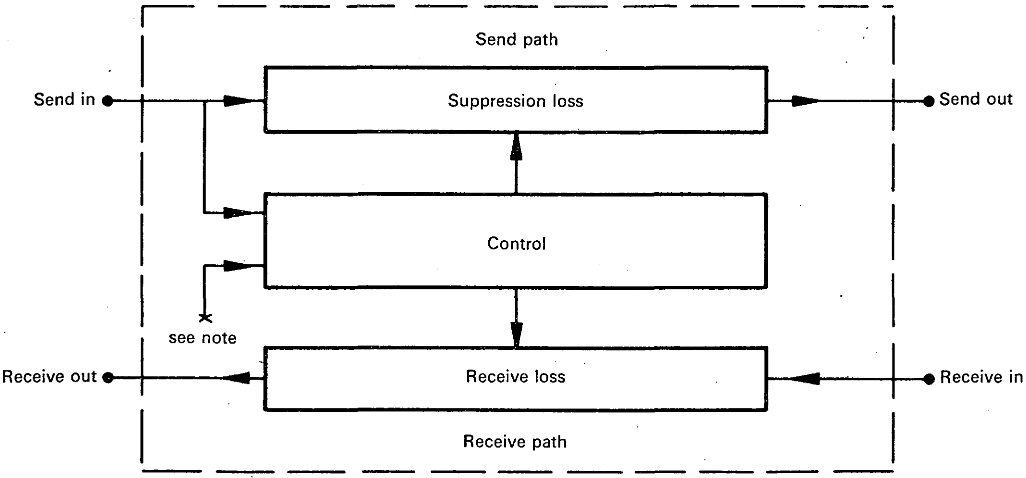
A. DEFINITIONS RELATING TO ECHO SUPPRESSORS

a) *Echo suppressor* (see Figure 1)

A voice-operated device placed in the four-wire portion of a circuit and used for inserting loss in the echo path to suppress echo.

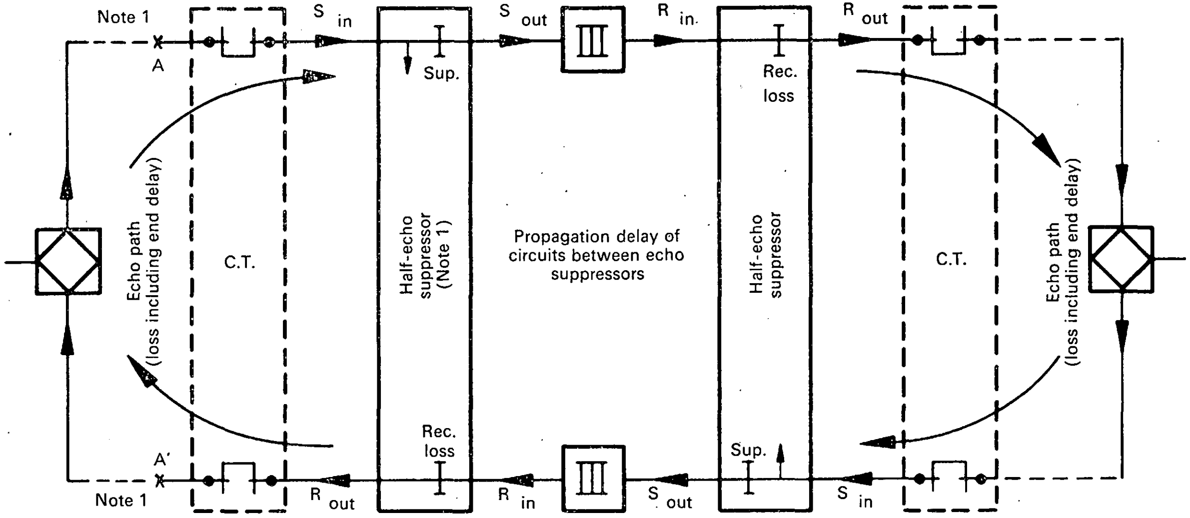
b) *Full echo suppressor*

An echo suppressor in which the speech signals on either path control the suppression loss in the other path.



Note. — This input may be connected to either side of the receive loss, depending on the control circuitry.

FIGURE 1



Note 1. — In some applications the echo suppressor is inserted at point A, A′.

FIGURE 2

c) *Half-echo suppressor*

An echo suppressor in which the speech signals of one path control the suppression loss in the other path but in which this action is not reciprocal.

d) *Differential echo suppressor*

An echo suppressor in which the action is controlled by the difference in level between the signals on the two speech paths.

e) *Suppression loss*

The specified minimum loss which an echo suppressor introduces into the send path (of the echo suppressor) to reduce the effect of echo currents.

f) *Receive loss*

The specified loss which an echo suppressor introduces into the receive path (of the echo suppressor) to reduce the effect of echo currents during break-in.

g) *Terminal echo suppressor* (see Figure 2)

An echo suppressor designed for operation at one or both terminals of a circuit.

h) *Suppression operate time*

The time interval between the instant when defined test signals, applied to the send and/or receive input ports, are altered in a defined manner and the instant when the suppression loss is introduced into the send path of the echo suppressor.

i) *Suppression hangover time*

The time interval between the instant when defined test signals applied to the send and/or receive input ports are altered in a defined manner, and the instant when the suppression loss is removed from the send path.

j) *Break-in operate time*

The time interval between the instant when defined test signals, applied to the send and/or receive ports, are altered in a defined manner such as to remove suppression and the instant when suppression is removed. Insertion of loss in the receive path will occur practically simultaneously.

k) *Break-in hangover time*

The time interval between the instant when defined test signals, applied to the send and/or receive ports, are altered in a defined manner such as to restore suppression and the instant when suppression is restored. Removal of loss in the receive path will occur practically simultaneously.

l) *Differential sensitivity*

The difference, in dB, between the level of the test signals applied to the send path and receive path when break-in occurs.

B. CHARACTERISTICS OF ECHO SUPPRESSORS SUITABLE FOR CIRCUITS HAVING EITHER SHORT OR LONG PROPAGATION TIMES

a) *General*

This specification is applicable to the design of terminal half-echo suppressors for use on circuits having long propagation times (e.g. synchronous satellite circuits). Echo suppressors so designed are also suitable for circuits having shorter propagation times and employing half-echo suppressors. All designs of echo suppressors, for use on circuits having long propagation times, should comply with the requirements given in the following sections.

Freedom is permitted in design details not covered by the requirements. Echo suppressors so designed will be compatible. *Compatibility* is defined as follows:

Given: 1) that a particular type of echo suppressor (say type A) has been designed so that satisfactory performance is achieved when any practical single- or multi-link connections are equipped throughout with one or more pairs of half-echo suppressors of identical type;

and: 2) that another particular type of echo suppressor (say type B) has likewise been designed;

then: type B is said to be *compatible* with type A if it is possible to replace any one or more of the half-echo suppressors at any point in the connection by that or those of the other type without appreciably degrading the performance of the connection.

The degradation has been studied and its extent determined by tests involving the reactions of users under service conditions or involving devices or methods that permit an equivalent laboratory evaluation of the degradations due to the two different echo suppressors. Two of these methods are given in Supplements Nos. 3 and 4 to this Volume.

Echo suppressors manufactured in accordance with former Recommendation G.161 (*Blue Book*, Volume III) are in service and are suitable only for circuits having a one-way propagation time less than 50 milliseconds. It should be noted that only on circuits having one-way propagation times less than 50 milliseconds will these old echo suppressors be compatible with the new ones. Thus the following typical arrangements (Figure 3) are acceptable on grounds of compatibility.

Objective test methods are very important to permit measurement of essential operating characteristics of echo suppressors suitable for circuits having long propagation times. Suitable test arrangements for these measurements are given in the Annex to this Recommendation.

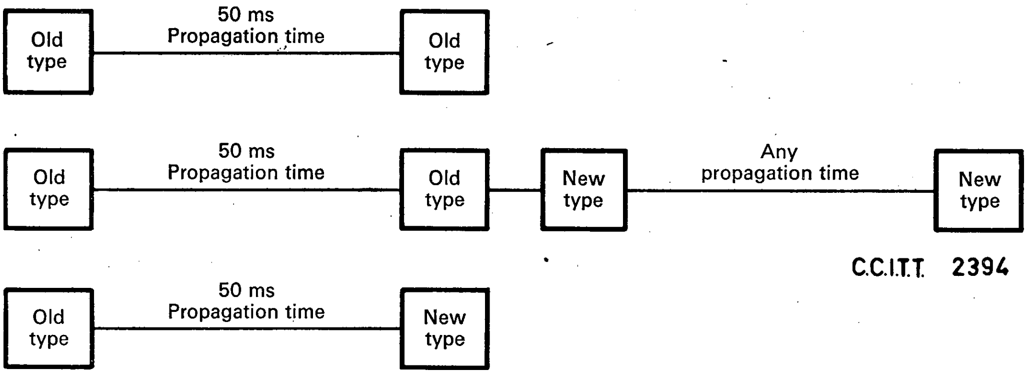


FIGURE 3. — **Typical arrangements for echo suppressors**

b) *Purpose, operation and environment*

Echo in any two-wire or combination two- and four-wire telephone circuit is caused by impedance mismatches. Normally, most of the echo is produced by reflections within the two-wire portion of the national network. Echo can be made tolerable by providing loss in the circuit if the one-way propagation time (delay) of the echo is less than about 25 milliseconds (ms). For delays longer than this, too much circuit loss is needed to suppress echo, and echo suppressors are required.

When an echo suppressor is in its suppression mode, it places a large loss in the return path which, besides suppressing echo, prevents the speech of the second party of the conversation from reaching the first party when both parties are talking simultaneously (termed "double-talking"). To reduce this effect (called "chopping") during double-talking, the echo suppressor must be able to operate in a second mode when both parties are talking simultaneously. The terminology usually used is that the second party must be able to "break-in" or remove suppression when he interrupts during an utterance by the original talker.

The result of break-in is to transform the circuit from one permitting speech in one direction to one permitting speech in both directions simultaneously, and a necessary consequence of this action is to permit echo to return unsuppressed. If the break-in action is adjusted to minimize the echo, the speech of one or both double-talking parties will still be chopped to some extent as the control of the echo suppressor transfers from one party to the other. The basic requirements in the design of an echo suppressor are therefore two:

1) To provide adequate suppression of echo when speech from one talker only is present;

2) To provide ease and unobtrusiveness of break-in during double-talking.

The second requirement involves two mutually exclusive functions:

1) Avoidance of chopping of double-talking speech;

2) Elimination of echo during and after double-talking.

A differential circuit is used to detect the condition when break-in should take place. The level of the speech in the send path is compared with the level of the speech in the receive path to determine whether the send speech is echo of the first party, or speech of the second party. Echo is reduced in level by the echo path loss and is delayed by twice the propagation time between the echo suppressor to the point of reflection. (The round-trip delay in the echo path is called "end-delay".) The minimum echo path loss and the maximum end-delay must be considered in the design of the differential circuit. If speech in the send path is below the level of the expected echo (considering the worst case of echo path-loss and end-delay), suppression will not be removed. If speech in the send path is above the level of the expected echo, break-in will occur and the suppression will be removed.

Echo suppressors are placed in the voice-frequency portion of a four-wire circuit which is nominally of 600-ohms impedance. The send (transmit or office-to-line) and the receive (line-to-office) paths are at different relative levels in different national networks; two such sets of levels are:

1) Send, −16 dBr; Receive, +7 dBr.

2) Send, − 4 dBr; Receive, +4 dBr.

The loss of the echo path (taken as the average value of loss in the frequency band from 500 to 2500 Hz) is likely to be such that the minimum loss from receive out-port to send in-port of an echo suppressor will be equal to the difference between the relative levels at these two points plus 6 dB, for example, 29 dB for case 1 or 14 dB for case 2. Echo suppressors must be designed to perform in a satisfactory manner under such conditions.

Echo suppressors for circuits having long propagation times will be terminal half-echo suppressors and protection from end-delays of up to about 25 ms (round-trip) is achieved in designs which meet the requirements given below.

The level of circuit noise entering the send or receive path of an echo suppressor may, in unfavourable circumstances, be as high as −40 dBm0p.

Speech volumes at the send in-port and at the receive in-port are likely to be about −15 dBm0 with a standard deviation of 6 dB.

c) *Requirements for performance with steady-state input signals independently applied to the send and receive paths*

1. *Transmission performance*

The values given in paragraphs 1.1 to 1.11 are provisional.

The performance characteristics apply to both the send and receive paths separately, except as noted.

1.1 *Insertion loss*

The insertion loss at 800 Hz (or 1000 Hz) of an echo suppressor in an unoperated condition shall be 0 ± 0.3 dB, for test tone levels $\leqq$ 0 dBm0.

These limits shall be observed over the temperature range + 10° C to + 40° C and also over the permitted power supply variations.

1.2 *Frequency characteristic*

The loss-frequency characteristic shall be such that if Q dB is the loss at 800 Hz (or 1000 Hz) the loss shall be within the range $Q + 0.3$ dB to $Q - 0.2$ dB at any frequency in the band 300-3400 Hz.

1.3 *Delay distortion*

The delay distortion shall not exceed 100 μs measured between any two frequencies in the band 500-3000 Hz.

1.4 *Impedance*

1) The nominal value of the inputs and outputs shall be 600 ohms (non-reactive).

2) The return loss with respect to the nominal impedance shall not be less than 20 dB over the frequency range 300 to 3400 Hz.

3) The impedance unbalance to earth of each port shall not be less than 40 dB over the frequency range 300 to 3400 Hz.

1.5 *Overload*

The insertion loss at 800 Hz (or 1000 Hz) shall not increase by more than 0.2 dB, relative to the loss at 0 dBm0, for a test tone level of + 10 dBm0.

1.6 *Harmonic distortion*

The total harmonic distortion power, for a pure 800-Hz (or 1000-Hz) sine wave at a level of 0 dBm0, shall not exceed —34 dBm0.

1.7 *Intermodulation*

If loss devices inserted in the receive path operate at syllabic rate, the intermodulation products produced by such devices should conform to clause e)2 of Recommendation G.162, which relates to the overall compandor.

1.8 *Transient response*

If loss devices which are inserted in the receive path operate at syllabic rate, the transient performance of such devices should conform to clause g) of Recommendation G.162 covering the overall transient response of a compandor.

1.9 *Noise*

The mean weighted psophometric power introduced by an echo suppressor shall not exceed —70 dBm0p.

The mean unweighted noise power in a band of 300-3400 Hz introduced by an echo suppressor shall not exceed —50 dBm0.

1.10 *Crosstalk*

The crosstalk attenuation between the send path and the receive path shall not be less than 70 dB.

1.11 *Spurious outputs produced by the echo suppressor*

The various operations of the echo suppressor must not result in any appreciable spurious outputs such as internally generated impulses due to transient conditions. In particular, these must not be of such magnitude as would be likely to operate falsely the suppression or break-in feature of any other echo suppressor that might be in the connection. Consideration must include that of multi-link connections having several pairs of echo suppressors in tandem.

To prevent false operation of other echo suppressors in a built-up connection, the zero-to-peak voltage of any transient output produced in the receive or transmit paths (terminated in 600 ohms) due to echo suppressor operation caused by signals in the opposite path should not exceed 20 millivolts at a point of zero relative level (—34 dBV0) after first filtering the transient to a 500 to 3000 Hz bandwidth. Additionally, the duration of any such transient should be such that it is not audible in the presence of normal levels of noise (e.g. —50 dBm0p).

2. *Steady state echo suppressor performance*

The action of an echo suppressor which incorporates the general features described in paragraph b) is explained below with the aid of the idealized operational diagram shown in Figure 4. The significant combinations of input signals are represented by the areas X, Y, Z, W and V.

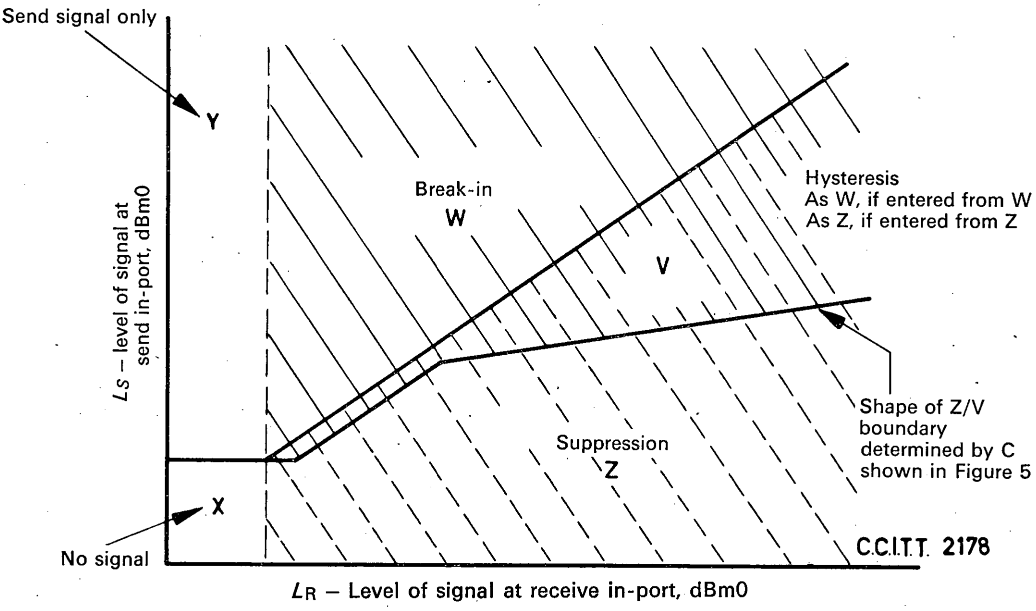


FIGURE 4. — **Conceptual diagram showing operational states of echo suppressors under ideal conditions**

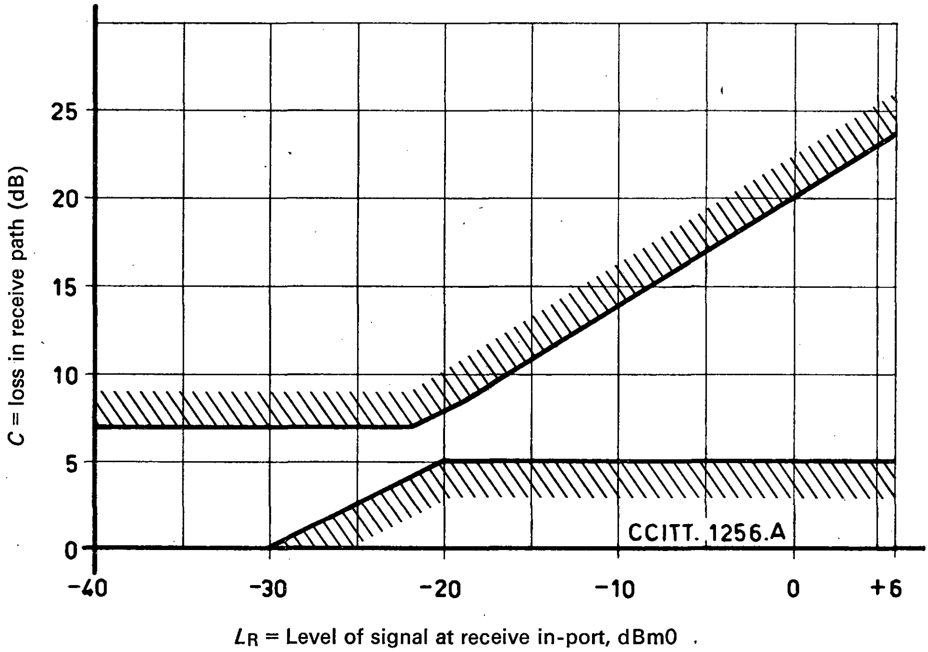
TABLE 1

Key to operational diagram Figure 4

Area	Loss in send path (dB)	Loss in receive path (dB)
X	0	0
Y	0	7 maximum
W	0	Within limits for *C* shown in Figure 5
Z	50 minimum	0
V	As W if entered from W As Z if entered from Z	

The area X corresponds to the absence of any appreciable signal on either the send or the receive path. Y corresponds to the presence of signal only on the send path. The area Z represents those combinations of signal levels for which the echo suppressor should provide suppression in the send path. The area W corresponds to break-in when the suppression should be absent. The area V corresponds to hysteresis that is provided to ensure that the break-in condition is retained when the signal on the send path has fallen slightly below the minimum level at which break-in would be initiated; the area V therefore represents a bistable condition. Table 1 shows the losses that should be inserted in the two paths, when each of the five areas X, Y, Z, W and V is occupied continuously. Figure 5 shows the boundaries for the receiving loss, C, that should be inserted in the receive path during break-in. The information given in Figures 4 and 5 and in Table 1 applies for steady-state signals with the inter-area boundaries being crossed very slowly.

The features shown in Figure 4 are concerned only with characteristics that can be determined without knowledge of, or access to, the internal circuits of echo suppressors. These characteristics are determined by application of test signals to the external terminals of the echo suppressor and observation of its state by external measurements. Test methods for measurements to verify compliance with the requirements are given in the Annex to this Recommendation.



The recommended values are those enclosed in the non-shaded area

FIGURE 5. — **Recommended loss *C*, to be inserted in receive path during break-in**

d) *Dynamic characteristics when signals are applied, removed or changed in the send and receive paths independently*

The dynamic characteristics can be specified by stating the time that elapses when the conditions of the signals pass from a point in one area to one in another before the state appropriate to the second area is established (Figures 4 and 9). When passing from X to Z, this is termed the suppression operate time and when passing in the opposite direction is termed suppression hangover time. When passing from the Z area through V to W (or Y) it is termed the break-in operate time and when passing from W through V to Z it is termed the break-in hangover time. The V/W and V/Z boundaries may, in practice, be crossed at any angle; the requirements in Table 3 deal with vertical and horizontal directions.

When sudden changes are made in the levels of sinusoidal test signals at a frequency of 1000 Hz, the maximum times of operation given in Table 3 apply and the recommended values of hangover given in Table 4 apply. The right-hand part of each table refers to tests described in the Annex.

The signal levels that define the various thresholds are give in Table 2.

TABLE 2

Inter-area threshold levels

Boundary	Symbol	At 1000 Hz dBm0 at 20 ± 5°C	At 1000 Hz dBm0 between 10 and 40°C	Variation with frequency
Suppression				
X to Z	Txz	$-33 \leqq Txz \leqq -29$		
		For $L_S = -40$	$T'xz = Txz \pm 1$	Figure 6
Z to X	Tzx_{max}	$Txz - 0$ dB	$T'xz - 0$ dB	
	Tzx_{min}	$Txz - 3$ dB	$T'xz - 3$ dB	
X to Y	Txy	$-36 \leqq Txy \leqq -29$	$T'xy = Txy \pm 1$	
		For $L_R = -40$		
Y to X	Tyx_{max}	$Txy - 0$ dB	$T'xy - 0$ dB	Figure 7
	Tyx_{min}	$Txy - 3$ dB	$T'xy - 3$ dB	
Break-in				
V to W (previous input Z)	Tvw	$L_S = L_R \pm 1.5$ dB $(-26.5 \leqq L_R \leqq +4.5)$		$T'vw = Tvw \pm 1.5$ dB between 500 and 3000 Hz (Note 2)
V to Z (previous input W)	Tvz_{max} Tvz_{min}	$Tvw - C$ dB $Tvw - C - 3$ dB (Note 1) $(-26.5 \leqslant L_R \leqslant +4.5)$		$T'vz = Tvz \pm 1.5$ dB between 500 and 3000 Hz (Note 2)

L_S = level (dBm0) at send in-port.
L_R = level (dBm0) at receive in-port.
C = the loss inserted in the receiving path during break-in. This characteristic must conform with the limits shown in Figure 5.

Note 1. — The vertical extent of the area V in dB should not exceed by more than 3 dB the loss inserted in the receive path, when break-in is established.

Note 2. — Tolerances in the attenuation/frequency characteristics of the two filters of the break-in detector must be taken into account, but it is desirable that the break-in threshold should be as independent of frequency as possible; a tolerance of ± 1.5 dB should apply if L_S and L_R are varied together over the frequency range 500-3000 Hz.

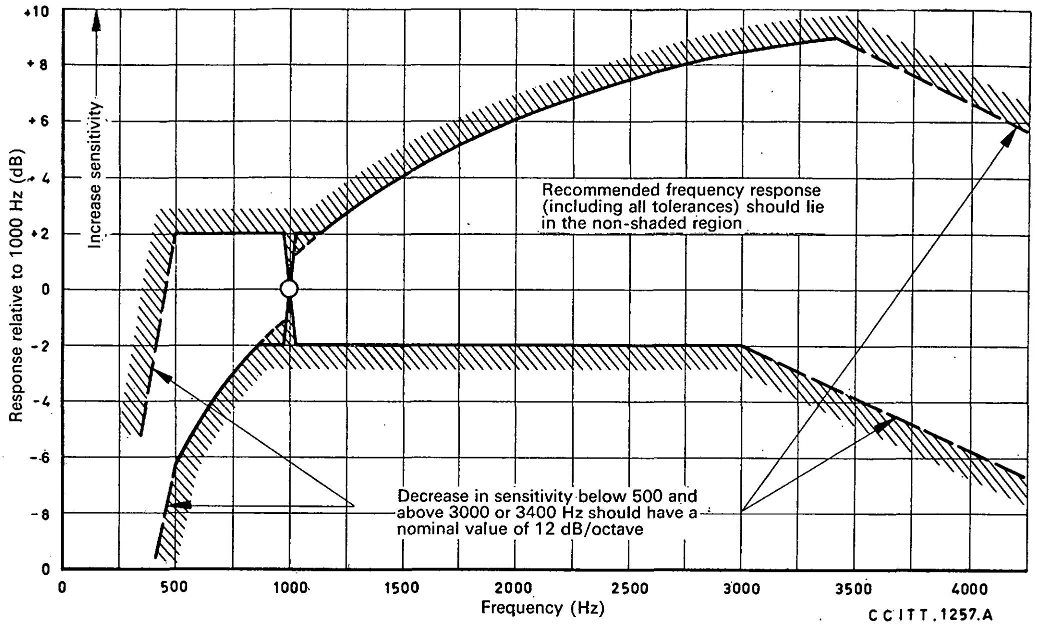


FIGURE 6. — Recommended frequency response of suppression control path of echo suppressor

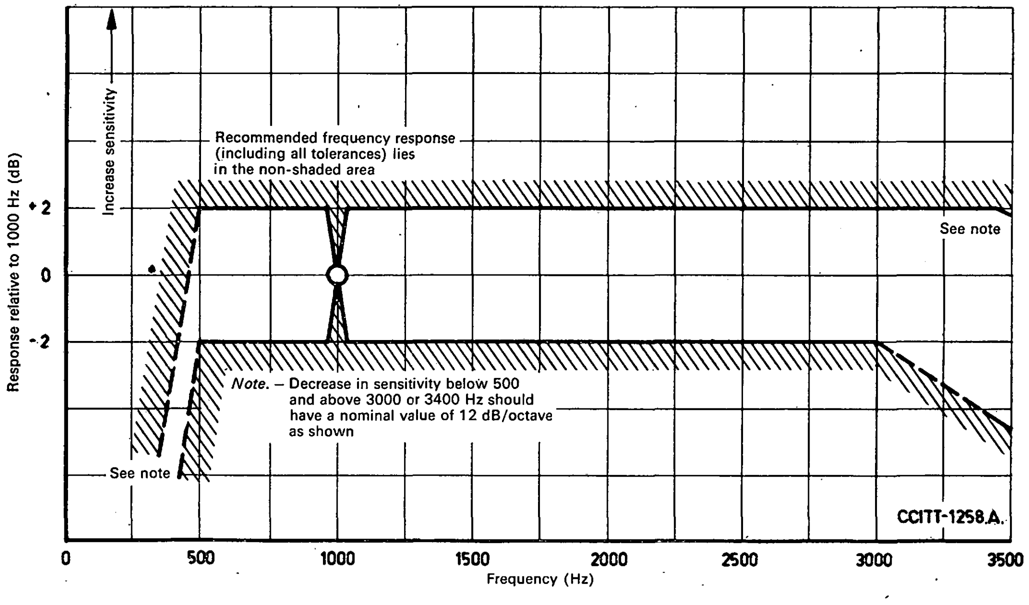


FIGURE 7. — Recommended frequency response of each control path of break-in detector of echo suppressor

TABLE 3

Maximum operate times

Boundary	Initial signals		Final signals		Recommended value, ms (maximum) (see Note 1)		Test No.	Excursion (see Fig. 9)	Test circuit Fig. No.	Oscilloscope trace Fig. No.
	Send L_S dBm0	Receive L_R dBm0	Send L_S dBm0	Receive L_R dBm0						
Suppression X/Z	−40 −40	−40 −40	−40 −40	−25 −11	5 5		4	a → b a → d	11	14
Break-in Z/V/W L_R constant	−40 −40	−25 −15	−19 − 9	−25 −15	30 30	Note 2	6	b → k c → j	13	16
Break-in Z/V/W/Y L_S constant	−25 −25 −25 −25	−22 −19 −16 − 9	−25 −25 −25 −25	−40 −40 −40 −40	40 60 70 75	Note 3	5	h → i g → i f → i e → i	11 or 12	15

Note 1. — Operation of suppressors by signals of short duration, such as circuit impulse noise, is undesirable.

Note 2. — From theoretical considerations it is apparently desirable that this time be short. In some echo suppressors this is of the order of 10 ms. With conversations in the English language, no deleterious effect has been observed when echo suppressors with an operate time of 30 ms have been used.

Note 3. — It is desirable that these values be as low as possible consistent with the need to protect against false break-in on echo for the case of maximum end delay and minimum echo path loss as described in section e). Some administrations feel that 30 and 50 ms can be achieved instead of 40 and 60 ms respectively.

TABLE 4
Hangover times
(Note 3)

Boundary	Initial signals		Final signals		Recommended value, ms	Test No.	Excursion (see Fig. 9)	Test circuit Fig. No.	Oscilloscope trace Fig. No.
	Send L_S dBm0	Receive L_R dBm0	Send L_S dBm0	Receive L_R dBm0					
Suppression Z/X	−40	−25	−40	−40	40 to 75	4	b ⟶ a	11	14
	−40	−11	−40	−40	40 to 75 (Note 2)		d ⟶ a		
Break-in W/V/Z L_R constant	−19	−25	−40	−25	Within range 150 - 350 (Note 1)	6	k ⟶ b	13	16
	− 9	−15	−40	−15			j ⟶ c		

Note 1. — The amount of break-in hangover that is necessary depends upon the value of hysteresis (width of the V region) used under break-in conditions (see Figure 1). For low values of hysteresis, the hangover time should be toward the upper end of the range. For higher values of hysteresis, the hangover time may be towards the lower end of the range.

Note 2. — The upper limit for the suppression (Z/X) hangover time may be as great as 240 ms *provided* the requirements for break-in operate time (Z/V/W/Y) for L_S constant are met (Table 3).

Note 3. — Although it is not considered necessary to measure the Y/X hangover time, it is desirable that echo-suppressors should be so designed that this hangover time is not unnecessarily long, for example, not greatly in excess of that applicable for break-in.

e) *Performance under conditions of small echo-path loss and when end-delay may be present*

The foregoing requirements apply when the echo suppressor is tested under conditions such that the signals in the send and receive paths are independent. In practice, satisfactory performance must also be maintained when the send path is connected to the receive path through an echo path that may have end-delay and low loss. Three features of the dynamic performance must be checked under these conditions. The Annex to this Recommendation describes test arrangements suitable for measuring these conditions. The three conditions are described as follows:

1) An echo (leakage through the echo path) must not cause false operation of the break-in condition when the echo-path loss is low and the end-delay is zero. The trouble could be caused by inappropriate design of the control path time constants. When a signal is suddenly applied to the receive in-port, this trouble would show itself as a temporary false operation of the break-in condition, persisting for the duration of the break-in hangover time. (See test No. 7.)

2) If insufficient protection against end-delay is incorporated in the echo suppressor, the break-in circuit may operate on the trailing edge of the echo. This can occur with the sudden removal of a signal at the receive in-port when the echo-path loss is low and the end-delay is large. (See test No. 8.)

3) In certain designs it can happen that the hysteresis represented by the bistable area V (see Figure 4) is excessive in relation to the amount of loss inserted in the receive path. This can result in the false retention of break-in by echo occurring under the following conditions: A steady-state signal is present at the receive in-port and is coupled to the send in-port via the echo path. A signal of sufficient amplitude and duration to cause break-in is then applied to the send in-port. Upon cessation of this signal, the echo of the receive signal falsely maintains the break-in condition. (See test No. 9.)

f) *External enabling*

An option should be included in the echo suppressor to provide for enabling or disabling by an externally derived ground (earth) from the trunk circuit. The enabler should function to permit or prevent normal echo suppressor operation.

C. CHARACTERISTICS OF ECHO-SUPPRESSOR TONE DISABLERS

a) *General*

Each echo suppressor should be equipped with a tone disabler which functions to prevent the introduction of the suppression and receive loss when data or other specified tone signals are transmitted through the suppressor. Thus it should disable for specified tones but should not disable on speech.

b) *Disabling characteristics* — see Figure 8

The disabling tone transmitted is 2100 Hz ± 15 Hz at a level of −12 ± 6 dBm0. The frequency of the tone applied to the disabler is 2100 Hz ± 21 Hz (see Recommendation V.21, Volume VIII). The disabling channel bandwidth should be chosen wide enough to encompass this tone (and other disabling tones used within national networks). At the same time, the

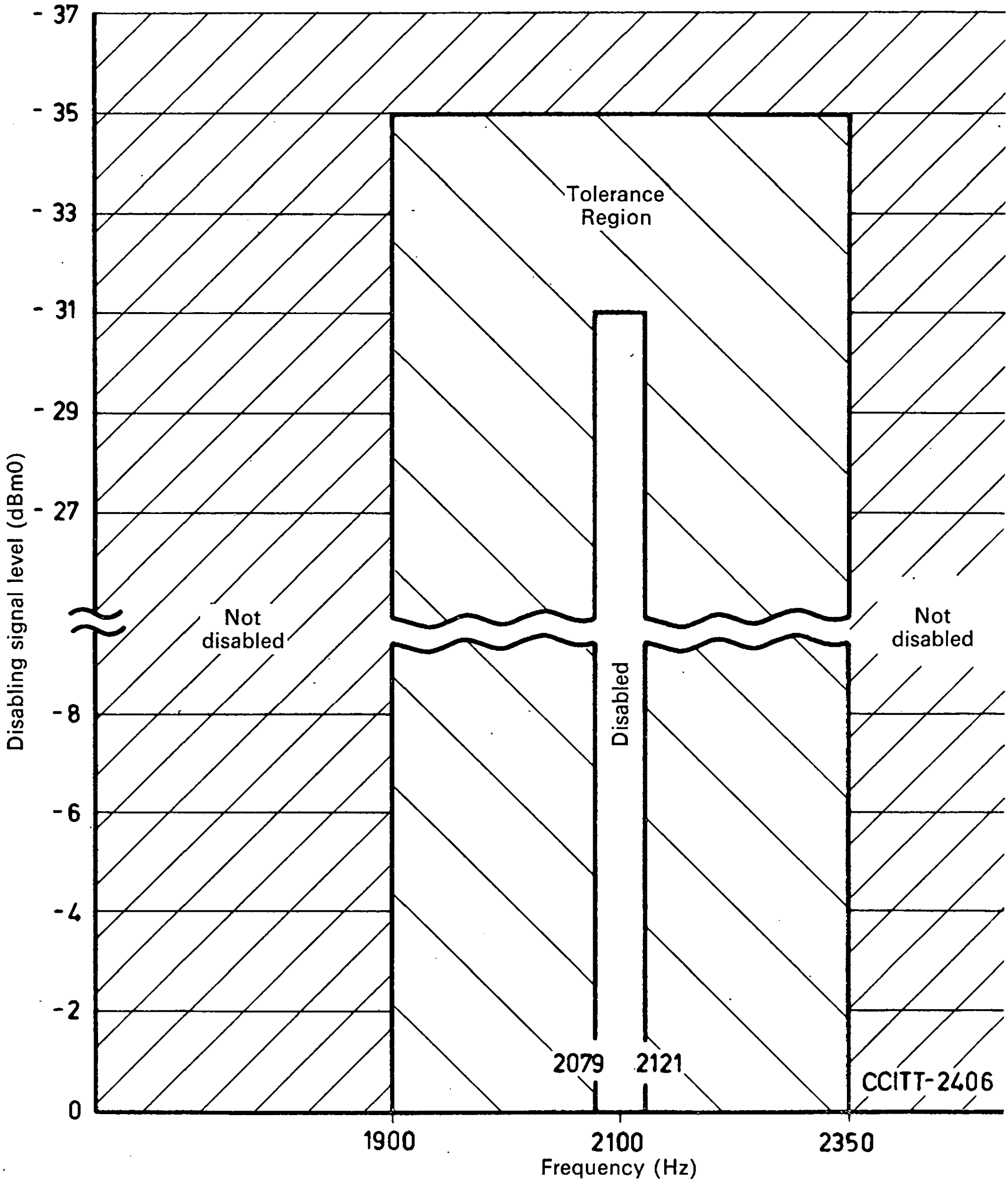


FIGURE 8. — Required disabling band characteristics

disabling channel bandwidth should be such that, in conjunction with guard action and timing, adequate protection is provided against false operation of the disabler by speech signals. The disabling channel sensitivity (threshold level) should be such that the disabler will operate on the lowest expected power of the disabling tone. The band characteristics shown in Figure 8 will permit disabling by the 2100-Hz disabling tone as well as others used in North America. Providing that only the recommended 2100-Hz disabling tone is used internationally, interference with signalling equipment will be avoided. Unintentional disabling of the echo suppressor by signalling tones is not considered detrimental, since the echo suppressor serves no needed functions during the time when signalling tones are present on the circuit.

c) *Guard band characteristics*

Energy in the voice band, excluding the disabling band, must be used to oppose disabling so that speech will not falsely operate the tone disabler. The guard band should be wide enough and with a sensitivity such that the speech energy outside the disabling band is utilized. The sensitivity and shape of the guard band must not be such that the maximum idle or busy circuit noise will prevent disabling. In the requirement, white noise is used to simulate speech and circuit noise. Thus, the requirement follows:

Given that white noise (in a band of approximately 200-3400 Hz) is applied to the tone disabler simultaneously with a 2100-Hz signal. The 2100-Hz signal is applied at a level 3 dB above the midband disabler threshold level. The white noise energy level required to inhibit disabling should be no greater than the level of the 2100-Hz signal and no less than a level 5 dB below the level of the 2100-Hz signal. As the level of the 2100-Hz signal is increased over the range of levels to 30 dB above the midband disabler threshold level, the white noise energy level required to inhibit disabling should always be less than the 2100-Hz signal level.

These values are provisional.

d) *Holding-band characteristics*

The tone disabler, after disabling, should hold in the disabled state for tones in a range of frequencies. The bandwidth of the holding mode should encompass all present or possible future data frequencies. The release sensitivity should be sufficient to maintain disabling for the lowest level data signals expected, but should be such that the disabler will release for the maximum idle or busy circuit noise. Thus the requirement follows:

The tone disabler should hold in the disabled mode for any single-frequency sinusoid in the band from 390-3000 Hz having a level of —27 dBm0 or greater. The tone disabler should release in the presence of the maximum expected circuit noise. The sensitivity required to ensure release in the presence of the maximum circuit noise is under study. Specification of the shape of the holding-band characteristic should be studied further.

e) *Operate time*

The operate time must be sufficiently long to provide talk-off protection, but less than the C.C.I.T.T. recommended limit of 400 ms. Thus the requirement is that the disabler should operate within 300 ± 100 ms after a receipt of a disabling signal having a level in the range between a value 3 dB above the midband disabler threshold level and a value of 0 dBm0.

f) *Recycle time*

Talk-off protection should also be provided by recycling. That is, if speech which simulates the disabling signal is interrupted, because of inter-syllabic periods, before disabling has taken place, the operate timing mechanism should reset. However, momentary absence or change of level in a true disabling signal should not reset the timing.

Thus, the disabler should recycle for loss of the disabling signal for periods exceeding 60 ms, which occur at any time prior to the operate time of the disabler. This implies that, after recycling, the duration of the disabling signal required to disable is equal to the operate time.

For loss of the disabling signal for periods less than 3 ms, the disabler should not completely recycle. This implies that, after the signal loss, the duration of the disabling signal required to disable is less than the operate time.

The above requirements should hold for disabling signals in the level range from a value 3 dB above the midband disabler threshold level to a value of 0 dBm0.

The values given in this section are provisional.

g) *Release time*

The disabler should not release for signal drop-outs less than the C.C.I.T.T. recommended value of 100 ms. To cause a minimum of impairment upon accidental speech disabling, it should release within 250 ± 150 ms after a signal in the holding band falls at least 3 dB below the maximum holding sensitivity.

h) *Methods for testing tone disablers*

The methods are under study.

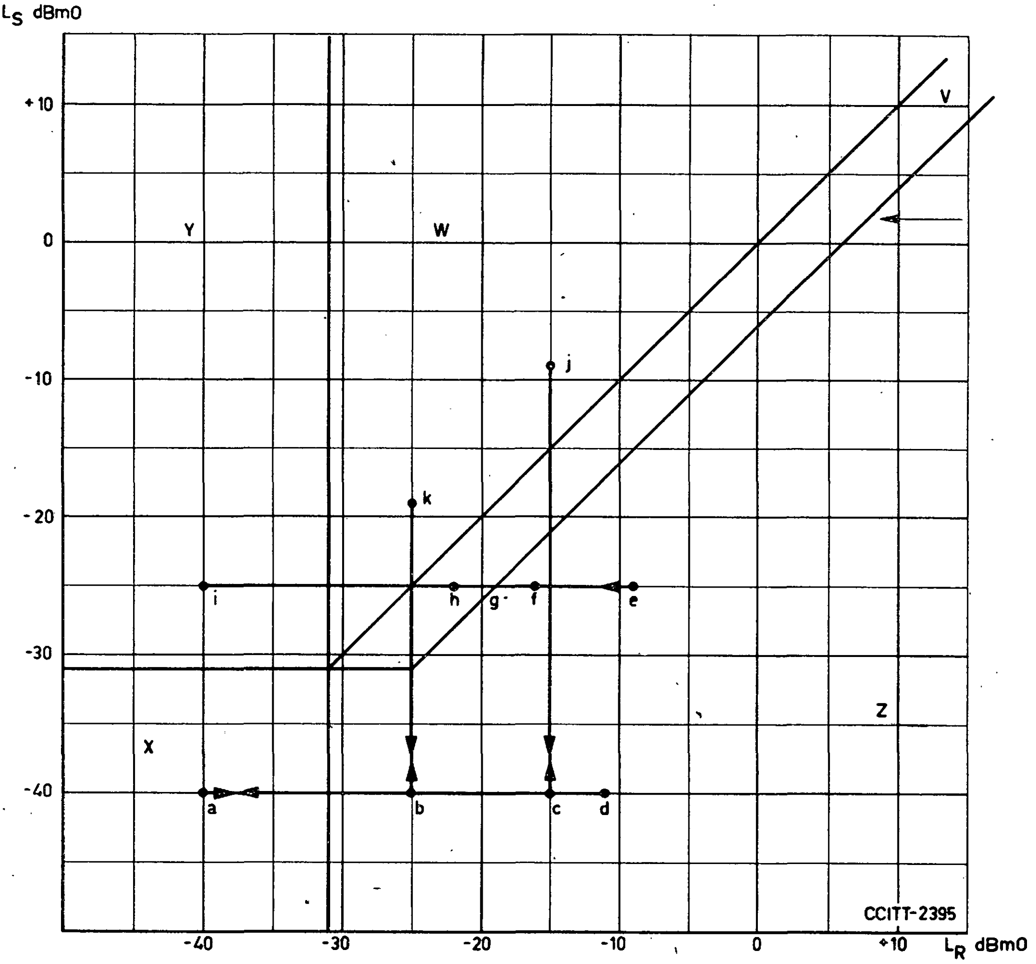
ANNEX

(to Recommendation G.161, Section B)

Test arrangements to measure essential operating characteristics of echo suppressors

a) *General considerations*

An echo suppressor with sinusoidal signals applied to its send and receive in-ports will assume one of a number of states depending on the relative levels of the two signals. Any given combination of levels of the two input signals may be represented by a point on a typical operational diagram (Figure 9). Each area on this diagram corresponds (under steady conditions) to a particular state identified by the losses in the two speech paths and the internal organization of its logic.



Note. The boundaries shown are typical only.

FIGURE 9. — **Operational diagram showing levels used in dynamic tests (see Tables 3 and 4)**

The *static* characteristics of an echo suppressor are specified by stating the inter-area boundaries and the losses in the two speech paths when signals pass slowly from one area to another.

The *dynamic* characteristics are specified by stating the time that elapses when a signal passes suddenly from a point in one area to one in another, before the state appropriate to the second area is established.

b) *Measurement of static characteristics*

The static characteristics measured are losses in the send and receive paths and the inter-area threshold levels (Tables 1 and 2). The equipment required is:

— one oscillator with 600-ohm balanced output impedance;
— two 600-ohm balanced attenuators;
— one 600-ohm mixing pad;

— two level-measuring sets with 600-ohm balanced input impedance.

The diagram of connections is shown in Figure 10.

Test No. 1 — Suppression threshold and loss

1. Set the oscillator to 1000 Hz.
2. Adjust *A* so that $L_S = -40$ dBm0.
3. Adjust *B* so that $L_R = -40$ dBm0.
4. Increase L_R until suppression occurs and note the value of L_R and the suppression loss.
5. Decrease L_R until suppression releases and note the value of L_R.
6. Set the oscillator to appropriate frequencies to check for conformity within the bounds shown in Figure 6 and repeat steps 2 to 5.

Test No. 2 — X/Y threshold and loss (if any) in receive path

1. Set the oscillator to 1000 Hz.
2. Adjust *A* so that $L_S = -40$ dBm0.
3. Adjust *B* so that $L_R = -40$ dBm0.

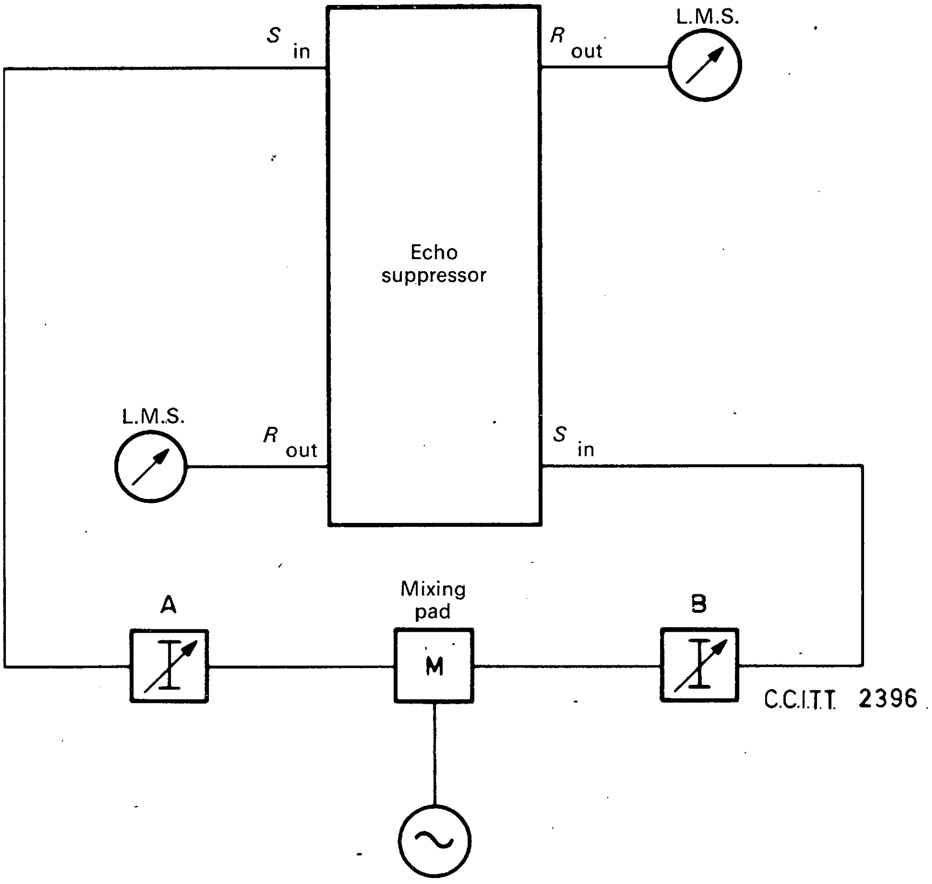


FIGURE 10. — Test circuit for measurement of static characteristics

4. Increase L_S until the loss in the receive path (if any) is inserted and note the value of L_S and the receive loss.

5. Decrease L_S until the loss is removed and note the value of L_S.

6. Set the oscillator to appropriate frequencies to check for the conformity within the bounds shown in Figure 7 and repeat steps 2 to 5.

Test No. 3 — Break-in differential sensitivity and receive loss

1. Set the oscillator to 1000 Hz.
2. Adjust A so that $L_S = -40$ dBm0.
3. Adjust B so that $L_R = -26.5$ dBm0.
4. Increase L_S until suppression is removed and loss is inserted in the receive path. Note the value of L_S and the receive loss.
5. Decrease L_S until suppression is inserted and loss is removed from the receive path. Note the value of L_S.
6. Increase L_R in appropriate steps up to $+ 4.5$ dBm0 and repeat steps 4 and 5.
7. Set the oscillator to appropriate frequencies to check for the conformity within the bounds shown in Figure 7 and repeat steps 2 to 6.

c) *Measurement of dynamic characteristics when L_S and L_R are applied independently*

The dynamic characteristics measured are the suppression and break-in operate and hangover times (Tables 3 and 4). The equipment required is:

- one oscillator with 600-ohm balanced output impedance, set to 1000 Hz;
- three 600-ohm balanced attenuators;
- three 600-ohm mixing pads;
- two tone-burst generators having a maximum of at least 400 ms ON time and 400 ms OFF time and also capable of being held in either state by manual control. The input and output impedances in both states should be 600 ohms. One burst-tone generator is driven by the other and has 100 ms delay such that it turns ON 100 ms after the other turns ON. An alternative method, using only one tone-burst generator, is also described;
- two 600-ohm terminating resistors;
- one dual beam oscilloscope, preferably with long-persistence screen.

c.1) *Tests in which L_S is maintained constant*

Test No. 4 — Suppression operate and hangover times

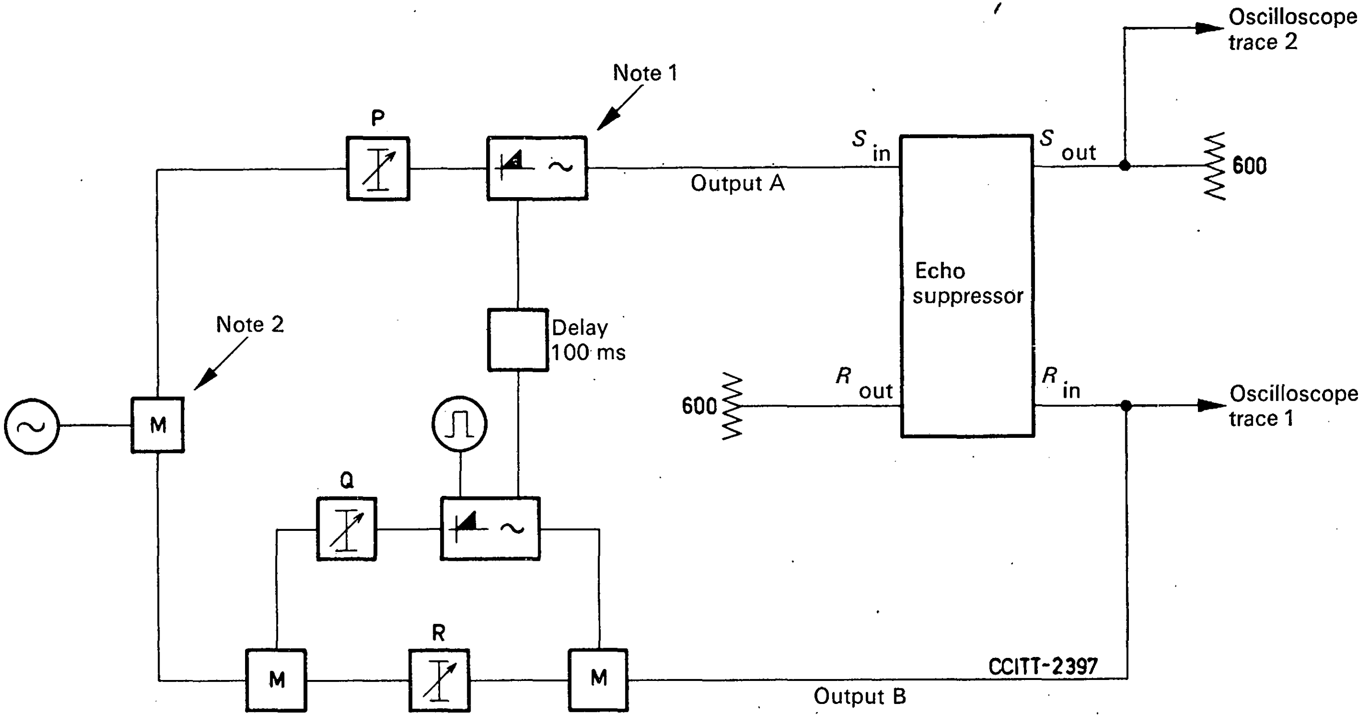
1. Adjust attenuators P, Q and R shown on Figure 11 to produce the L_R and L_S values of Tables 3 and 4.
2. Read times as shown on Figure 10.

Test No. 5 — Break-in operate time, L_S constant

1. Adjust attenuators P, Q and R shown on Figure 11 to produce the L_R and L_S values of Table 3.
2. Read times as shown on Figure 11.

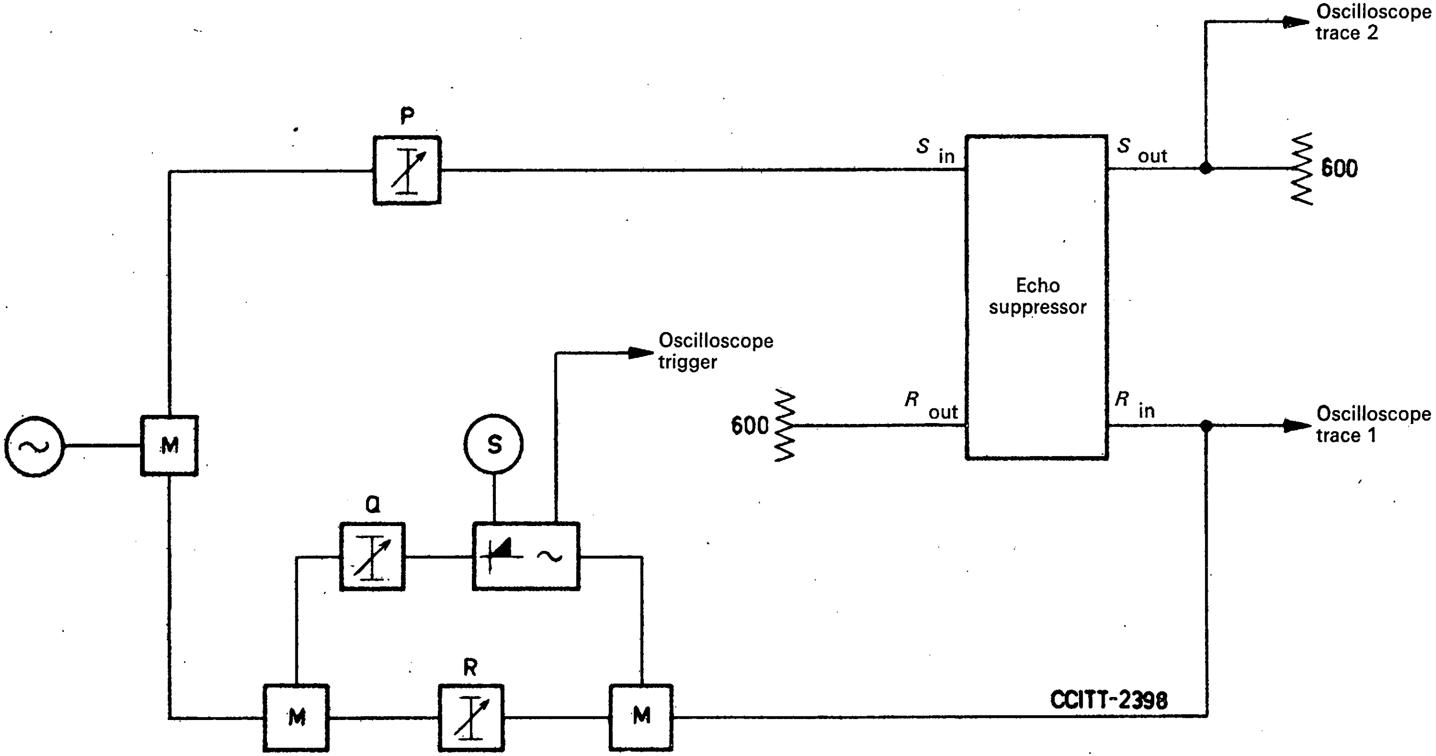
Test No. 5 — Alternative method

The circuit diagram is shown in Figure 12. The equipment required is the same as in the foregoing Test No. 5, but only one tone-burst generator is required. This is controlled manually by



Note 1. — For suppression operate and hangover times, this modulator is maintained in the conducting state.
Note 2. — *M* denotes mixing pad.

FIGURE 11. — **Test circuit for measurement of dynamic characteristics (Suppression, X/Y and break-in, Z/V/W/Y, Ls constant)**



Note 1. — Switch *S* permits the following conditions to be selected:

a) repetitive tone burst
b) continuous tone
c) no tone.

Note 2. — *M* denotes mixing pad.

FIGURE 12. — **Alternative test circuit for measurement of dynamic characteristics (Break-in, Z/V/W/Y, Ls constant)**

switch *S*. The oscilloscope must possess a long-persistence screen, or facilities for obtaining an oscillogram provided. The order in which the following adjustments are made is important.

1. Set *P* so that L_S is less than −40 dBm0.
2. Set *R* so that L_R = final value specified in Table 3.
3. Set *Q* so that L_R = initial value specified in Table 3.
4. Set *P* so that L_S = value specified in Table 3.
5. Operate *S* to make tone-burst generator non-conducting.
6. Read break-in operate times as shown in Figure 15.
7. Repeat steps 1 to 6 for initial values of L_R given in Table 3.

c.2) *Test in which L_R is maintained constant*

Test No. 6 — Break-in operate and hangover time, L_R constant

1. Adjust attenuators *P*, *Q* and *R* shown on Figure 13 to produce the L_S and L_R values of Tables 3 and 4.
2. Read times as shown on Figure 16.

d) *Measurement of echo-suppressor operation when the send in-port is connected to the receive out-port through an echo path loss that may include delay as well as loss.*

In these tests, the echo suppressor is checked for false break-in on returning echo.

Test No. 7 — False operation of break-in when end-delay is zero

The diagram of connections is shown in Figure 17, and the equipment required is:

— one oscillator with 600-ohm balanced output impedance;
— two 600-ohm balanced attenuators;
— one 600-ohm terminating resistor;
— one tone-burst generator;
— one dual beam oscilloscope;

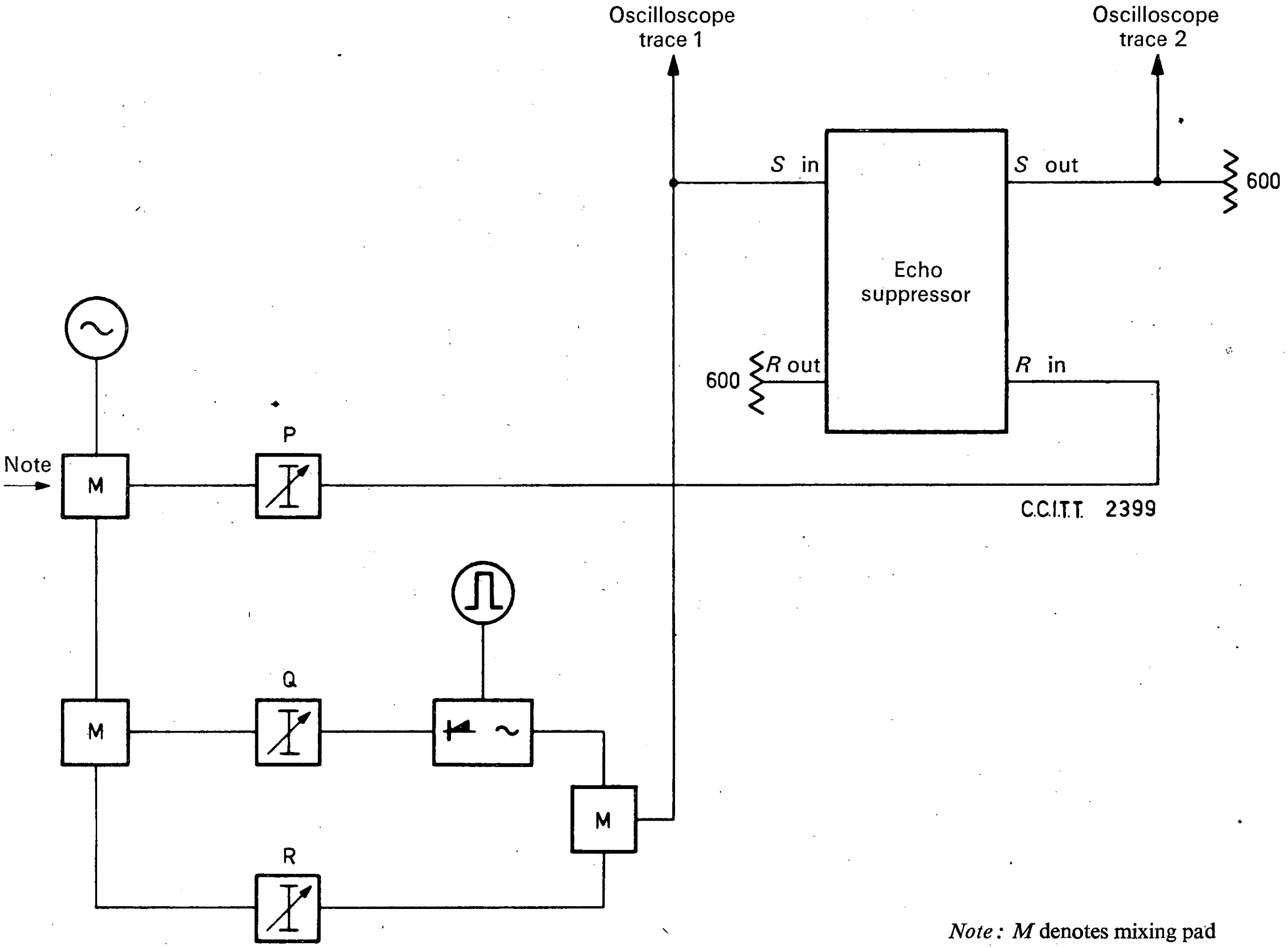
1) Set the oscillator to 1000 Hz.
2) Adjust *Y* so that L_R = −28 dBm0.
3) Set *X* to the difference in test levels on receive and send paths, plus 6 dB.
4) Check the absence of a signal on trace 2 of the oscilloscope, denoting non-occurrence of false break-in. Reduce *X* until false break-in occurs, and note margin.
5) Repeat steps 2 to 4 for values of L_R of −16 and 0 dBm0.

Test No. 8 — False operation of break-in when end-delay is present

The diagram of connections is shown in Figure 18: the equipment required comprises the same items as for Test No. 7, together with an adjustable audio-frequency delay device.

Note. — As an alternative to the use of an adjustable audio-frequency delay device, a variable delay logic element can be used in lieu as shown in Figure 19. An additional tone-burst generator is then required.

1) Set the oscillator to 1000 Hz.
2) Adjust *Y* so that L_R = −28 dBm0.
3) Set delay to 25 ms.



Note : *M* denotes mixing pad

FIGURE 13. — **Test circuit for measurement of dynamic characteristics (Break-in, Z/V/W, L_R constant)**

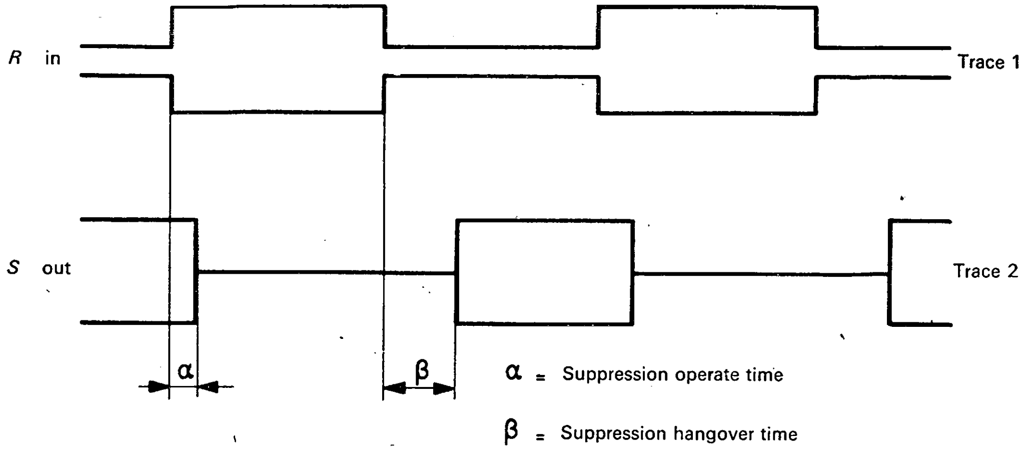


FIGURE 14. — Trace for suppression operate and hangover

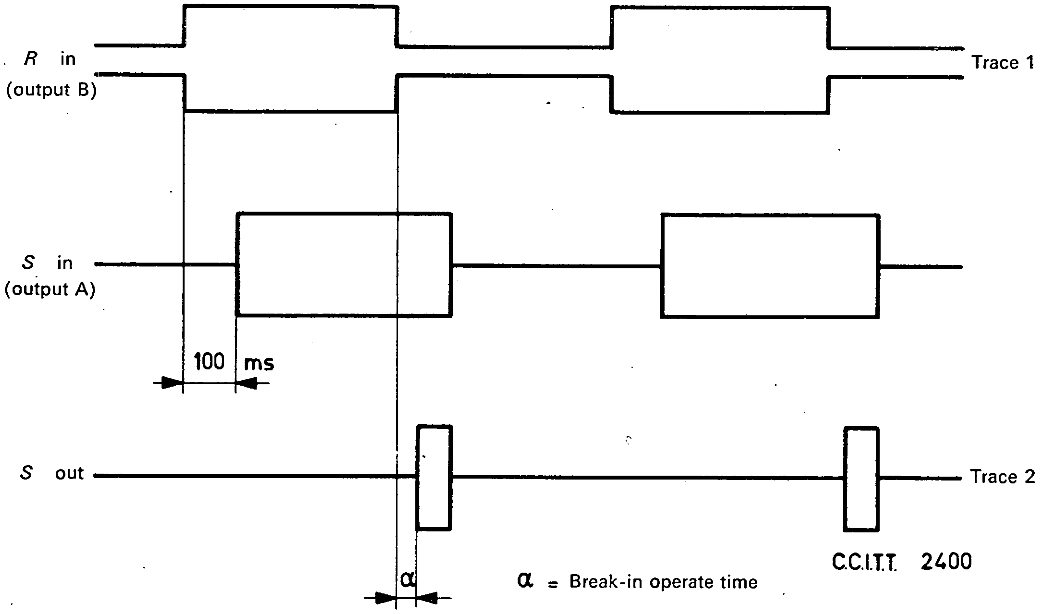


FIGURE 15. — Trace for break-in operate time, Ls constant

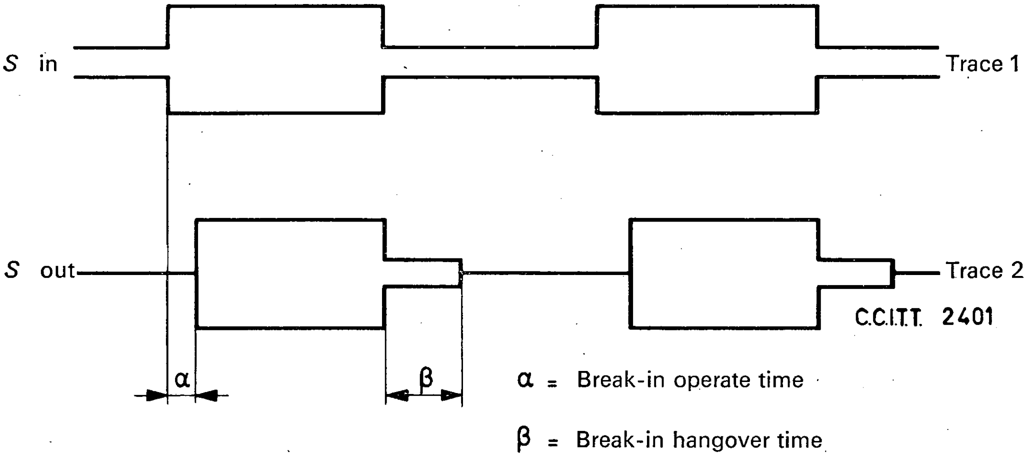


FIGURE 16. — **Trace for break-in operate and hangover times, L_R constant**

4) Set X to the difference in test levels on receive and send paths, plus 6 dB. (Any basic loss of the delay device must be deducted from the value of X, or compensated for by equivalent amplification.)
5) Check the absence of a signal on trace 2 of the oscilloscope, denoting non-occurrence of false break-in. Reduce X until false break-in occurs, and note margin.
6) Repeat steps 1 to 5 for values of L_R of -16 and 0 dBm0.

Test No. 9 — False retention of break-in due to provision of excessive hysteresis

The diagram of connections is shown in Figure 20 and the equipment required is:
- one oscillator with 600-ohm balanced output impedance;
- three 600-ohm balanced attenuators;
- two 600-ohm mixing pads;
- one 600-ohm terminating resistor;
- one tone-burst generator;
- one amplifier (used as buffer);
- one dual beam oscilloscope.

1) Set the oscillator to 1000 Hz.
2) Adjust Q so that the path loss between R_{out} and S_{in} is equal to the difference in test levels at these points, plus 6 dB.
3) Adjust R so that $L_R = -28$ dBm0.
4) Adjust P so that $L_S = L_R + 3$ dB.
5) Check that the signal on trace 2 of the oscilloscope is proper (see Figure 21) denoting non-occurrence of false retention of break-in.
6) Repeat steps 3 to 5 for values of L_R of -16 and 0 dBm0.

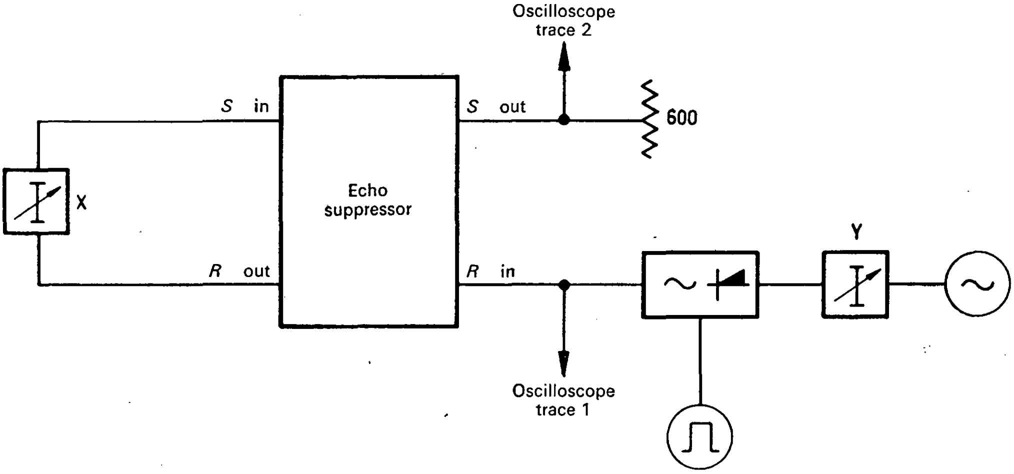


FIGURE 17. — Test circuit for false break-in with no end delay

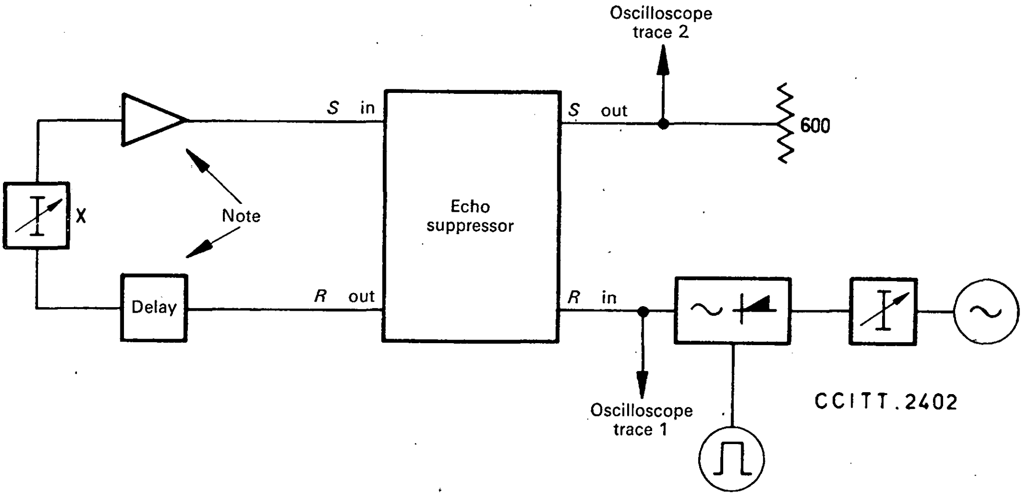


FIGURE 18. — Test circuit for false break-in with end delay present

Note. — Basic loss of the delay device may be compensated or allowed for in the setting of *X*.

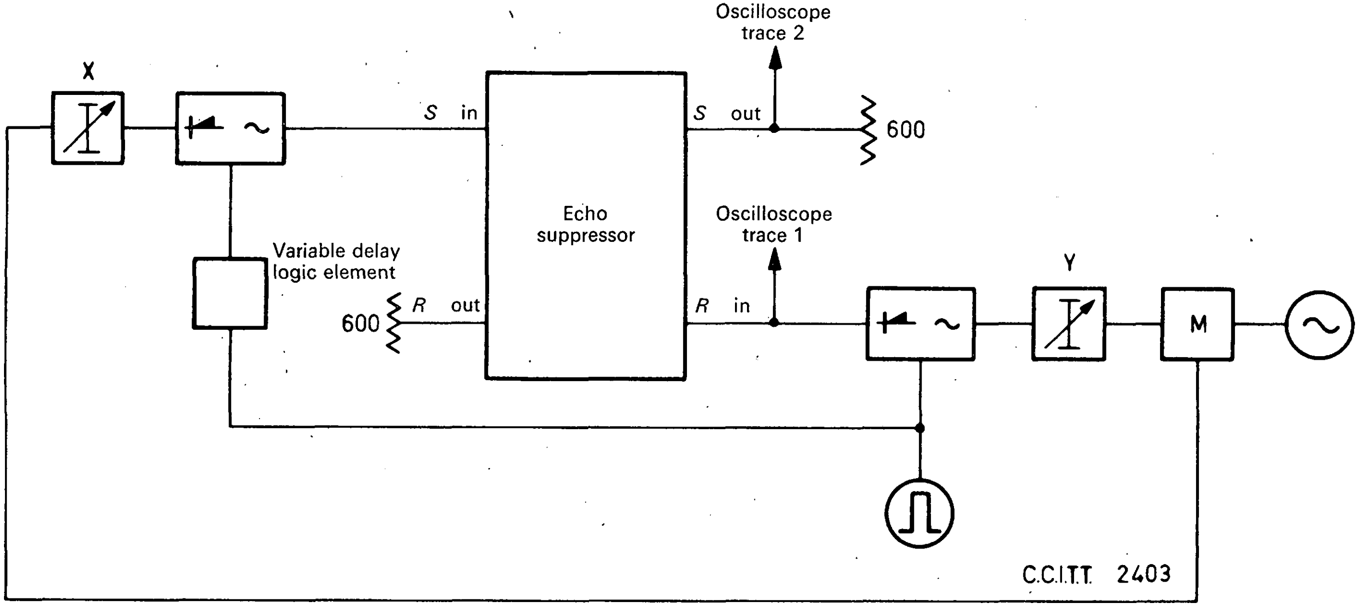


FIGURE 19. — Alternative test circuit for false break-in with end delay present

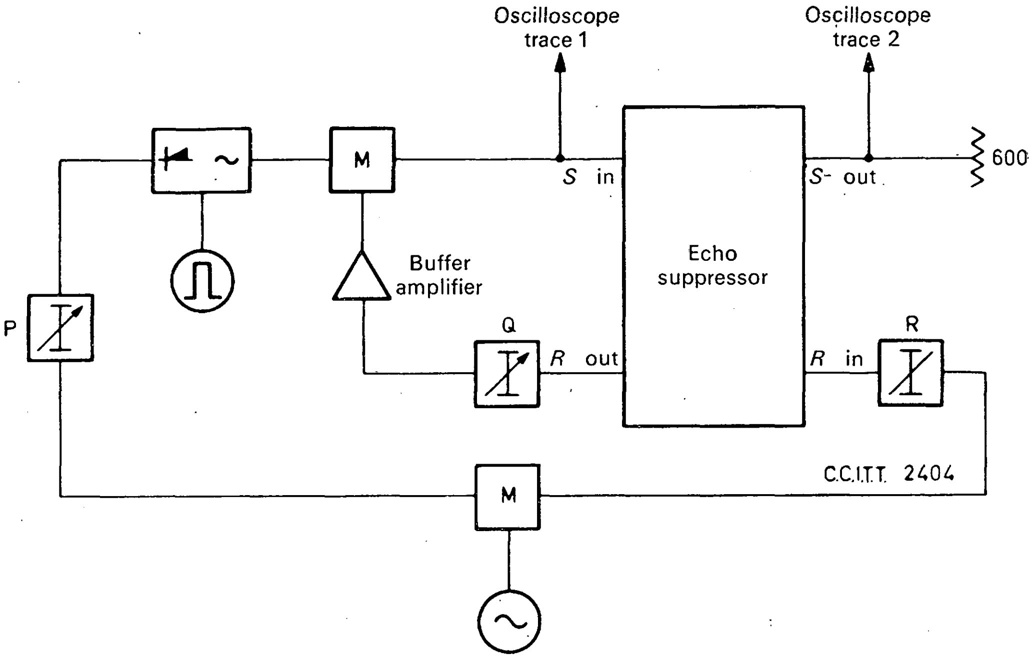
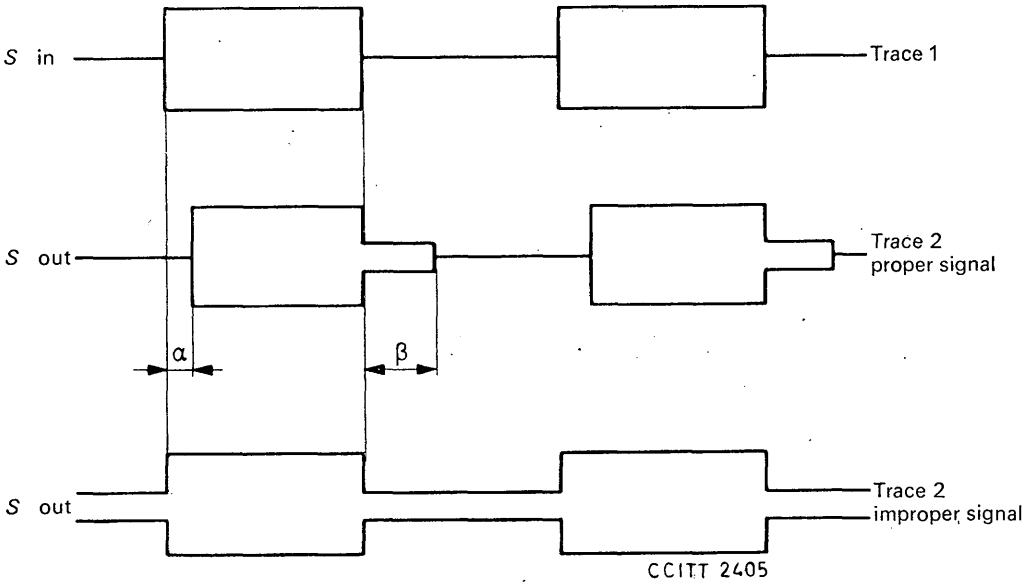


FIGURE 20. — Test circuit for false retention of break-in due to provision of excessive hysteresis



α = Break-in operate time

β = Break-in hangover time

FIGURE 21. — Traces for false retention of break-in due to provision of excessive hysteresis

RECOMMENDATION G.162 (Geneva, 1964; amended at Mar del Plata, 1968)

CHARACTERISTICS OF COMPANDORS FOR TELEPHONY

These characteristics are applicable to compandors of modern design for use either on very long international circuits or on national and international circuits of moderate length.

Some of the clauses given below specify the joint characteristics of a compressor and an expander in the same direction of transmission of a four-wire circuit. The characteristics specified in this way can be obtained more easily if the compressors and expanders are of similar design; in certain cases close co-operation between administrations may be necessary.

It should also be noted that the equipment produced so far for circuits of moderate length may be completely satisfactory for those circuits and yet not quite meet the clauses of this Recommendation.

a) *Definition and value of the "unaffected level"*

The *unaffected level* is the absolute level, at a point of zero relative level on the line between the compressor and the expander of a signal at 800 Hz, which remains unchanged whether the circuit is operated with the compressor or not.

The unaffected level is defined in this way in order not to impose any particular values of relative level at the input to the compressor or the output of the expander.

The unaffected level should be, in principle, 0 dBm0 (0 dNm0). Nevertheless, to make allowances for the increase in mean power introduced by the compressor, and to avoid the risk of increasing the intermodulation noise and the overload which might result, the unaffected level may, in some cases, be reduced by perhaps as much as 5 dB (5.8 dNp). However, this reduction of unaffected level entails a diminution of the improvement in signal-to-noise ratio provided by the compandor. This possible reduction should be made by direct agreement between the administrations concerned. No reduction is necessary, in general, for systems with less than 60 channels.

Note. — The increase in the mean power in the transmitted band determined by the compressor in the telephone channel depends on the value of the unaffected level, the attack and recovery times, the distribution of the speech volumes and the mean power level of transmitted speech. When 0 dBm0 (0 dNm0) is adopted for the unaffected level, it appears that the effective increase in the mean power level is of the order of 2 or 3 dB (2.3 or 3.5 dNp).

b) *Ratio of compression and expansion*

1. *Definition and preferred value of the ratio of compression.* — The ratio of compression of a compressor is defined by the formula:

$$a = \frac{n_e - n_{e0}}{n_s - n_{s0}}$$

where: n_e is the input level;
n_{e0} is the input level (corresponding to 0 dBm0 (0 dNm0);
n_s is the output level;
n_{s0} is the output level corresponding to an input level of n_{e0}.

The preferred value of a is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between + 10° C and + 40° C.

2. *Definition and preferred value of the ratio of expansion.* — The ratio of expansion of an expander is defined by the formula:

$$\beta = \frac{n'_s - n'_{s0}}{n'_e - n'_{e0}}$$

where: n'_e is the input level;
n'_{e0} is the input level corresponding to 0 dBm0 (0 dNm0);
n'_s is the output level
n'_{s0} is the output level corresponding to an input level of n'_{e0}.

The preferred value of β is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between + 10° C and + 40° C.

3. *Range of level.* — The range of level over which the recommended value of α and β should apply should extend at least:

from + 5.8 to −52 dNm0 (+ 5 to −45 dBm0) at the input of the compressor and
from + 5.8 to −58 dNm0 (+ 5 to −50 dBm0) at the nominal output of the expander.

4. *Variation of compressor gain.* — The level at the output of the compressor, measured at 800 Hz, for an input level of 0 dBm0 (0 dNm0), should not vary from its nominal value by more than ± 0.5 dB or ± 6 cNp for a temperature range of + 10° C to + 40° C and a deviation of the supply voltage of ± 5% from its nominal value.

5. *Variation of expander gain.* — The level at the output of the expander, measured at 800 Hz for an input level of 0 dBm0 (0 dNm0), should not vary from its nominal value by more than ± 1 dB or ± 12 cNp for a temperature range of + 10° C and + 40° C and a deviation of the supply voltage of ± 5% from its nominal value.

Note. — It is desirable, especially for compandors intended for very long circuits, to set stricter limits than the values of + 0.5 dB and +1 dB given under b) 4 and b) 5; + 0.25 dB and + 0.5 dB respectively are preferable.

6. *Conditions for stability.* — The insertion of a compandor shall not appreciably reduce the margin of stability. To ensure this, for the combination of an expander and a compressor on the same four-wire circuit and at a given station, the error of the output level of the compressor with respect to any value of expander input level shall not exceed + 0.5 dB or + 6 cNp. This error is referred to the level obtained at the compressor output when the input level is 0 dBm0. This limit shall be observed at all frequencies between 200 and 4000 Hz, within the temperature range + 10° C to + 40° C. No negative limit is specified for the error. In this test an attenuator shall be inserted between the expander and the compressor, the value of which is to be set in accordance with the following note:

Note 1. — This clause concerns the influence of a compandor on the loop gain of a four-wire circuit and on the margin of stability.

In examining this problem, a connection was considered made up of three four-wire circuits, *AB*, *BC* and *CD*, which link the terminal stations *A* and *D* (at which the terminating sets are located) through the intermediate stations *B* and *C*. It is assumed that the circuit *BC* is equipped with compandors. It is desired to determine the tolerances for the gain of the combination of expander and compressor at *C* in order to limit the reduction in the margin of stability caused by their insertion. To facilitate study of this question, it is assumed that, in normal use, the expander output and compressor input are points of the same relative level.

The following expression then gives the loss between the output of the expander at *C* and the input of the compressor at *C*:

$$a_s = a_0 + a_r + a_x + a_y \text{ dB}$$

Where

a_0 = nominal transmission loss of the chain of circuits between the two-wire terminals at *A* and *D*;
a_r = balance return loss at the terminating set at *D*;
a_x = departure of transmission loss of channel *CD* from its nominal value;
a_y = departure of transmission loss of channel *DC* from its nominal value.

The two latter values may be positive or negative.

It may be concluded that, in order that the measurement of the gain of the combination of an expander and a compressor at the same station may satisfactorily determine the total effect on the margin of stability, the following conditions must be observed:

The expander must be connected to the compressor via an attenuator, the loss of which should cover the entire range of values for a_s which actually occur when there is a risk of instability. To take account of all practical conditions, it would probably be necessary to consider a very wide range.

However, considering only the important example of a terminal compandor and zero balance return loss, then $a_s = a_0$ and this is the value which is generally recommended for the loss of the attenuator between expander and compressor in this test.

Nevertheless, when it is possible to determine the exact values of a_r, a_x and a_y, corresponding to the most probable condition of instability, the exact value of a_s can be specified.

It has been assumed that the expander output and the compressor input are normally points of the same relative level. If this is not the case, and if the relative level at the expander output is a_c dB higher than the relative level at the compressor input, the loss in the attenuator should be increased by a_c (which may be positive or negative).

Note 2. — Cross-connection between the control circuits of the compressor and expander may have advantages from the point of view of circuit echoes; hence, its use should be allowed. On the other hand, its use, which has some disadvantages from the point of view of signalling-to-voice break-in, will certainly be confined to exceptional cases. In consequence, there seems no need for any special C.C.I.T.T. recommendations on the subject.

7. *Tolerances on the output levels of the combination of compressor and expander in the same direction of transmission of a four-wire circuit.* — The compressor and expander are connected in tandem. A loss (or gain) is inserted between the compressor output and expander input equal to the nominal loss (or gain) between these points in the actual circuit in which they will be used. Figure 1 shows, as a function of level of 800 Hz input signal to the compressor, the permissible limits of difference between expandor output level and compressor input level. (Positive values indicate that the expander output level exceeds the compressor input level.)

The limits shall be observed at all combinations of temperature of compressor and temperature of expander in the range + 10° C to + 40° C. They shall also be observed when the test is repeated with the loss (or gain) between the compressor and expander is increased or decreased by 2 dB (2.3 dNp).

Note. — The change of gain (or loss) of 2 dB (2.3 dNp) mentioned in clause 7 above is equal to twice the standard deviation of transmission loss recommended as an objective for international circuits routed on single group links in Recommendation G.151, C.

c) *Impedances and return loss*

The nominal value of the input and output impedances of both compressor and expander should be 600 ohms (non-reactive).

Provisionally the return loss with respect to the nominal impedance of the input and the output of both the compressor and the expander should be not less than 14 dB (16 dNp)

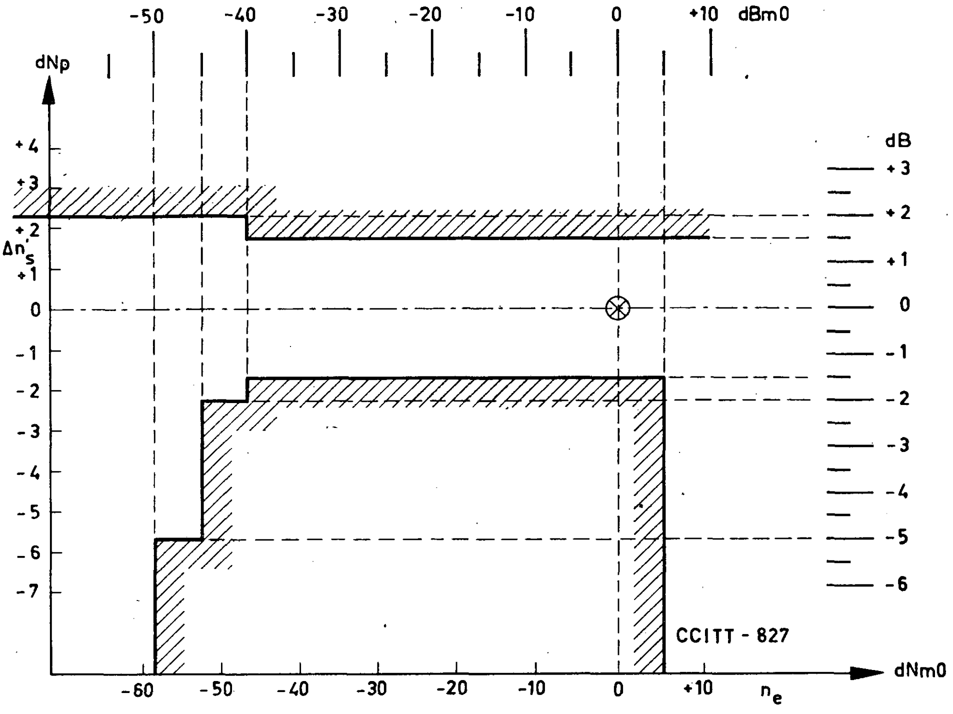


FIGURE 1

over the frequency range 300 to 3400 Hz and for any measurement level between + 5 and —45 dBm0 (+ 5.8 and —52 dNm0) at the compressor input or the expander output.

d) *Operating characteristics at various frequencies*

1. *Frequency characteristic with control circuit clamped.*

The control circuit is said to be clamped when the control current (or voltage) derived by rectification of the signal is replaced by a constant direct current (or voltage) supplied from an external source. For the purpose of this clause, the value of this current (or voltage) should be equal to the value of the control current (or voltage) obtained when the input signal is 0 dBm0 (0 dNm0) at 800 Hz.

For the compressor and the expander taken separately, the variations of loss or gain with frequency should be contained within the limits of a diagram that can be deduced from the figure in Recommendation G.132 by dividing the tolerance shown by 8, the measurement being made with a constant input level corresponding to a level of 0 dBm0 (0 dNm0).

These limits should be observed over the temperature range + 10° C and + 40° C.

2. *Frequency characteristic with control circuit operating normally.* — The limits given in d) 1 should be observed for the compressor, when the control circuit is operating normally, the measurement being made with a constant input level, corresponding to a level of 0 dBm0 (0 dNm0).

For the expander, under the same conditions of measurement, the proposed limits can be deduced from the figure in Recommendation G.132, by dividing the tolerances shown by 4.

These limits shall be observed over the range + 10° C to + 40° C.

e) *Non-linear distortion*

1. *Harmonic distortion.* — Harmonic distortion, measured with an 800-Hz sine wave, at a level of 0 dBm0 (0 dNm0) should not exceed 4 % for the compressor and the expander taken separately.

Note. — Even in an ideal compressor, high output peaks will occur when the signal level is suddenly raised. The most severe case seems to be that of voice-frequency signalling, although the effect can also occur during speech. It may be desirable, in exceptional cases, to fit the compressor with an amplitude limiter to avoid disturbance due to transients during voice-frequency signalling.

2. *Intermodulation tests.* — It is necessary to add a measurement of intermodulation to the measurements of harmonic distortion, whenever compandors are intended for international circuits (regardless of the signalling system used) as well as in all cases where they are provided for national circuits over which multifrequency signalling, or data transmission using similar types of signals, is envisaged.

The intermodulation products of concern to the operation of multifrequency telephone signalling receivers are those of the third order, of type $(2f_1\text{-}f_2)$ and $(2f_2\text{-}f_1)$, where f_1 and f_2 are two signalling frequencies.

Two signals at frequencies 900 Hz and 1020 Hz are recommended for these tests.

Two test conditions should be considered, the first in which each of the signals at f_1 and f_2 is at a level of -5 dBm0 (-5.8 dNm0) and the second in which they are each at a level of -15 dBm0 (-17 dNm0). These levels are to be understood to be at the input to the compressor or at the output of the expander, i.e. the uncompressed levels.

The limits for the intermodulation products are defined as the difference between the level of either of the signals at frequencies f_1 or f_2 and the level of either of the intermodulation products at frequencies $(2f_1\text{-}f_2)$ or $(2f_2\text{-}f_1)$.

A value for this difference which seems adequate for the requirements of multifrequency telephone signalling (including end-to-end signalling over three circuits in tandem, each equipped with a compandor) is 26 dB (30 dNp) for the compressor and the expander separately.

Note 1. — These values seem suitable for C.C.I.T.T. signalling system No. 5, which will be used on some long international circuits.

Note 2. — It is inadvisable to make measurements on a compressor plus expander in tandem, because the individual intermodulation levels of the compressor and of the expander might be quite high, although much less intermodulation is given in tandem measurements since the characteristics of compressor and expander may be closely complementary. The compensation encountered in tandem measurements on compressor and expander may not be encountered in practice, either because there may be phase distortion in the line or because the compressor and expander at the two ends of the line may be less closely complementary than the compressor and expander measured in tandem.

Hence the measurements have to be performed separately for the compressor and the expander. The two signals at frequencies f_1 and f_2 must be applied simultaneously, and the levels at the output of the compressor or expander measured selectively.

f) *Noise*

The effective value of the sum of all noise voltages, referred to a zero relative level point, the input and the output being terminated with resistances of 600 ohms, shall be less than or equal to the following values:

at the output of the compressor	(10 mV	unweighted	—38 dBm0	or —44 dNm0)
	(7 mV	weighted	—41 dBm0p	or —47 dNm0p)
at the output of the expander	(0.5 mV	weighted	—84 dBm0p	or —97 dNm0p)

It is not considered useful to specify a value of unweighted noise voltage for the expander.

g) *Transient response*

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission of a four-wire circuit fitted with compandors shall be checked as follows:

The compressor and expander are connected in tandem, the appropriate loss (or gain) being inserted between them as in clause b) 7.

A 12-dB or 14-dNp step signal at a frequency of 2000 Hz is applied to the input of the compressor, the actual values being a change from —16 to —4 dBm0 or —18.5 to —4.5 dNm0 for attack, and from —4 to —16 dBm0 or —4.5 to —18.5 dNm0 for recovery. The envelope of the expander output is observed. The overshoot (positive or negative), after an upward 12-dB or 14-dNp step expressed as a percentage of the final steady-state voltage, is a measure of the overall transient distortion of the compressor-expander combination for attack. The overshoot (positive or negative) after a downward 12 dB or 14 dNp step, expressed as a percentage of the final steady-state voltage is a measure of the overall transient distortion of the compressor-expander combination for recovery. For both these quantities the permissible limits shall be ± 20%. These limits shall be observed for the same conditions of temperature and of variation of loss (or gain) between compressor and expander as for the test in clause b) 7.

In addition, the attack and recovery times of the compressor alone shall be measured as follows:

Using the same 12-dB or 14-dNp steps as above for attack and recovery respectively, the attack time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 1.5 times its steady-state value. The recovery time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 0.75 times its steady-state value.

The values proposed are:

not greater than 5 ms for attack;
22.5 ms for recovery.

The following additional test is proposed to check the effect of the compandor on certain signalling systems which may be sensitive to envelope distortion immediately following the sudden application of a signal.

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission on a four-wire circuit is measured with an "infinite" upward input step, i.e. with a signal applied after a period with no input.

The level of the signal to be applied is —5 dBm0 (—5.8 dNm0).

Provided the measurement is effected with an interval of at least 50 ms between the pulses, the limits shown by an unbroken line in Figure 2 should be observed for the overshoot of the final voltage V_1; in most cases an attempt should be made if possible to observe the narrower limits, indicated in the figure by a broken line.

These limits shall be observed for the same conditions of temperature loss (or gain) between compressor and expander as for the tests with 12-dB or 14-dNp steps.

Note 1. — The tests of transient distortion described involve the measurement of the overshoot or undershoot of the envelope of the applied sinusoidal signal. It may happen that, due to small unbalances in the variable loss device, very-low-frequency components of the control current appear at the output. These are not a modulation of the signal frequency, but they produce an unsymmetrical waveform and render it difficult to determine the overshoot or undershoot of the envelope. While it is undesirable that these low-frequency components should be so large as to increase significantly the risk of overload of the line equipment, they are of no importance for speech transmission and will not affect tuned signalling receivers. However, it is desirable to consider whether these components may affect the guard circuits of some signalling receivers. If so, it may be necessary to specify a maximum value for these components and to include an appropriate test in this recommendation.

To simplify the measurement of the true envelope amplitude in the presence of these unbalance components, it is admissible and convenient to insert at the input to the measuring oscillograph a high-pass filter having a cut-off of about 300 Hz. However, a filter which is effective in removing unbalance components may itself introduce additional transient distortion in the signal envelope. To avoid this difficulty, the following method of calculation may be adopted which does not require a filter.

If at any instant the amplitude of the envelope in a positive direction is $+ E_1$, and in the negative direction is $-E_2$ then the two-envelope amplitude is given by

$$\frac{1}{2}\left[(+E_1) - (-E_2)\right] \equiv \frac{1}{2}\left[|E_1| + |E_2|\right]$$

and the unbalance component is given by

$$\frac{1}{2}\left[(+E_1) + (-E_2)\right] \equiv \frac{1}{2}\left[|E_1| - |E_2|\right]$$

This method is not only simple and free of the transient distortion problem which occurs with a filter, but it also provides direct information on the unbalance, which, as indicated above, may be important.

Note 2. — The time constants of the expander control circuit should in principle be equal to those of the compressor control circuit so as to avoid any overshoot (positive or negative) in the transient response.

Note 3. — If an administration prefers to use a direct method of measuring expander attack and recovery times, the following might be adopted:

To define the attack and recovery times of the expander, a sudden change in level from —8 to —2 dBm0 (—9.2 to —2.3 dNm0) should be applied to its input for measurement of the attack time, and from —2 to —8 dBm0 (—2.3 to —9.2 dNm0) for measurement of the recovery time. The attack time is represented by the time between the moment when the abrupt variation is applied and the moment when the output voltage reaches a value x times its final value. The recovery time is represented by the time between the moment when the abrupt variation is applied and the moment when output voltage reaches a value y times its final value. The times thus measured should lie between the same limits as those shown for the compressor. Bearing in mind detailed differences in the construction of the various compandors now in use, specific figures for x and y cannot be given. Hence, each administration will have to determine the correct values of x and y for the type of compandor concerned.

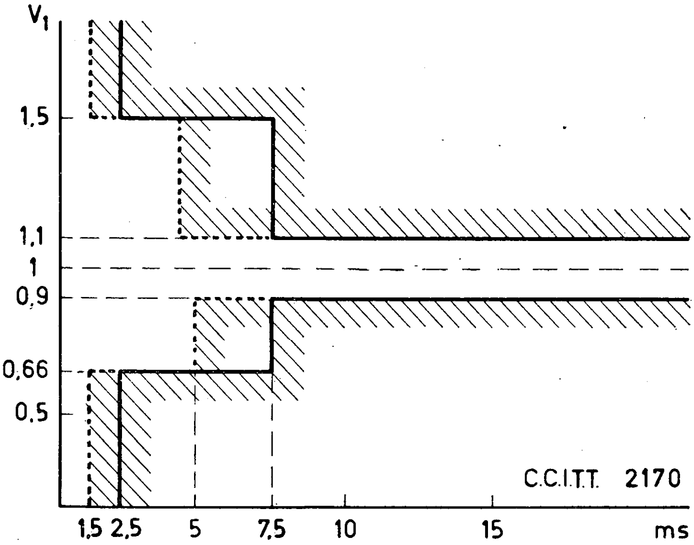


FIGURE 2

For an ideal expander, 0.57 and 1.51 are valid for x and y; by way of example, the Italian Administration has found 0.65 for x and 1.35 for y for a certain type of construction.

Some administrations have said that it might be preferable to specify fixed values of x and y, for all types of expander, leaving administrations free to choose the limit values for attack and recovery times, according to the different types of expander. Values of 0.75 and 1.5 are proposed for x and y in this method of measurement.

Note 4. — The infinite step transient response measurements refer to a compressor-expander combination connected in tandem; moreover, several administrations have investigated the possibility of meeting the limits shown in the figure, even for a chain of three compandors in tandem, by bringing also the channel modulating and demodulating equipment into the connection. This modem equipment may cause an undesirable transient phenomenon in the step at the expander output; this phenomenon, and the intermodulation of the third order associated with it, may influence the multi-frequency signalling.

RECOMMENDATION G.163 (Mar del Plata, 1968)

CALL CONCENTRATING SYSTEMS

a) *Characteristics*

The characteristics of the TASI system which is now in operation on submarine cable systems are given in references [1] and [2].

The characteristics of the CELTIC system are given in reference [3].

ATIC (Time Assignment with Sample Interpolation) is a time assignment system for pulse code transmission.

A description of the basic function is given in reference [4] and another article on its statistical efficiency is quoted in reference [5].

Note. — The use of these concentrating systems involves various restrictions; for example, they may call for a special signalling system.

b) *Possibility of interconnection*

To ensure satisfactory speech quality when call concentrating systems of the TASI type are operated in tandem, it is necessary that each concentrator introduce only a very small speech impairment at the peak of the busy hour. The present TASI concentrators were designed with the objective that the average speech lost during the peak of the busy hour will be approximately 0.5 %. In addition, the interpolation process in TASI is designed so that there is a very small probability that the amount of speech lost in any speech spurt will be greater than the length of an average syllable (about 250 ms). Subjective tests [6] have been made on individual working TASI systems and the results, obtained by interviewing customers, show that the impairment due to a properly loaded and maintained TASI is essentially undetectable by the customer. No such tests have been carried out on call-concentration systems in tandem.

Because of the subjective problems involved, estimates made of the speech impairment that would result from tandem call-concentration systems must be qualitative without subjective tests. The probability of excessive clipping, even in a system of three concentrators in tandem with each having the same busy hour, can be kept to a satisfactory level by arranging the system so that the impairment introduced by each concentrator is small, as in the case of the present TASI system. If the tandem concentrators are located in different time zones or in areas with different peak traffic hours, the lighter loaded concentrators will cause negligible additional impairment.

Assuming that present and future concentrators will be operated and designed so as to meet the criterion of very small speech impairment during the peak of the busy hour, it is recommended that no restrictions be imposed on tandem operation of concentrators at this time. In addition, it is recommended that no test on tandem operation should be made until tandem operation of concentrators is a reality. At such time, tests could be made under working conditions to determine the effects of tandem concentrators on speech and to establish whether any adjustment of the ratio of number of simultaneous calls to the number of channels would be required to keep speech clipping to a negligible amount.

The estimated probability that the forward-transfer pulse for the C.C.I.T.T. No. 5 signalling system will be clipped for a certain length of time in one, two, and three TASIs in tandem has been incorporated in Supplement No. 2, *White Book*, Volume VI.

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[2] H. Midema and M. G. Schachtman: TASI quality-effect of speech detectors and interpolation. *B.S.T.J.*, same issue.

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[5] M. Bonatti and F. Motolese: Probabilità di attività delle giunzioni di un doppio fascio telefonico. *Telecommunicazioni*, No. 23, June 1967, pp. 24-28.

[6] G. K. Helder: Customer evaluation of telephone circuits with delay. *B.S.T.J.*, Vol. XLV, No. 7, September 1966.

APPENDIX TO SECTION 1

The old transmission plan

Grouped together in this appendix are the texts of those recommendations which have been rendered out of date or which have been modified as a result of the adoption of the transmission plan described in Section 1 of Volume III of the *White Book*. Only those passages that will help administrations to pass from the old C.C.I.T.T. plan to the new have been retained.

These texts are drawn from paragraphs 1.1.1, 1.2.6, 1.2.7 and 1.3.2 of Volume III *bis* of the C.C.I.F. *Green Book*.

Interconnection of international and national trunk circuits

a) *Method of interconnection*

The interconnection of two four-wire circuits should be made in such a way that the overall equivalent and stability are practically the same as if there were a single direct four-wire circuit, having its terminals at the two end international exchanges.

Circuits for semi-automatic working

To avoid reflections at the point of interconnection of two international four-wire circuits (which reflections could interfere with signalling), it is recommended that the interconnection of these circuits should always be done by direct connection of the line wires. Also any low-pass filters, which may be fitted for reasons of stability when one of the international circuits is used on its own, should be cut out.

This recommendation does not relate to the interconnection of two national circuits in international calls. Administrations and private operating agencies concerned may make suitable arrangements to connect these circuits. Similarly, the method of connection between a national and international circuit may be chosen by national administrations or private operating agencies, it being understood that the signal receiver is connected to the four-wire end of the international circuit and that the connection with the national network does not cause reflections during the time when signals are liable to be transmitted between two registers.

b) *Use of terminal repeaters associated with line building-out networks*

The C.C.I.T.T.

considering

that the use of terminal repeaters and of automatically switched pads is markedly superior to the use of cord circuit repeaters as regards transmission, and has some advantage in respect of ease of operation,

unanimously recommends

that terminal repeaters and pads be used in future transit trunk circuits, whenever this is economical.

Note. — Cord circuit repeaters are still in use in certain countries.

Impedance of international and trunk circuits

All circuits, whether international circuits or national two-wire or four-wire trunk circuits, terminating at the same trunk exchange, should have the same nominal value of impedance as seen from the switchboard (or from the switches). For any particular exchange, this should be either 800 ohms or 600 ohms.

Nominal equivalent

For all international circuits, the nominal equivalent should be the same for the two directions of transmission.

For manually operated international circuits, the nominal equivalent (insertion loss between non-reactive resistances of 600 ohms) between the switchboard jacks at the end international exchanges, including the line transformers, measured at 800 Hz should not exceed 7 dB or 0.8 Np. This limit includes the insertion loss of the connecting circuits between the two international circuits at an international transit exchange.

For semi-automatic international circuits, it is necessary to standardize the nominal equivalent, and the value recommended by the C.C.I.F. in the present state of knowledge is 7 dB or 0.8 Np in each direction of transmission. This value includes the insertion loss of the incoming and outgoing switching equipments and also of pads included in the circuit in terminal service.

As in the future it may be considered desirable to reduce the nominal value of 7 dB or 0.8 Np, it is necessary to arrange the equipments so that it is readily possible to change this value.

The interconnection of two semi-automatic international circuits on a four-wire basis in a transit centre should be effected in such a way that the overall equivalent has the same nominal value as the equivalent of a single circuit.

This equivalent is measured under the same conditions as for a single circuit; it includes the insertion loss of the transit switching equipments, as well as any pads included in the connection.

Reference equivalents

Practical limits for the reference equivalent between two subscribers, the reference equivalent of the national sending system and the reference equivalent of the national receiving system

In all international telephone connections between two subscribers within the same continent, the reference equivalent between the two subscribers should not exceed 40 dB (4.6 Np).

The reference equivalent of the national sending system (from the ends of the international circuit) should not exceed 18.2 dB (2.1 Np).

The reference equivalent of the national receiving system (from the ends of the international circuit) should not exceed 13 dB (1.5 Np).

If gain is introduced at the international exchange (for example, by adding a repeater to compensate for the attenuation of the circuit between the international exchange and the final local exchange), this gain will be included in the above-mentioned reference equivalents of the national systems.

If, in certain connections, the nominal equivalent of the international circuits is reduced by a certain amount at the international exchange concerned, this reduction will be considered as equal to a corresponding gain introduced into the national systems.

Note 1. — Efforts should be made to ensure that the maximum of 4.6 Np (40 dB) for the reference equivalent between the two subscribers is met for all international connections. All types of variation should be taken into account including variations with time and tolerances with respect to the nominal values of reference equivalents of lines and equipments. Administrations or private operating agencies should allow for the fact that it is possible to have variations of about 3 dB (0.35 Np) in the values of the reference equivalents measured in the Laboratory of the C.C.I.T.T., but for the present it is thought that no tolerances can be specified for possible variations due to such causes in the preparation of plans for national telephone networks.

Note 2. — The limiting conditions for transmission shown above concern only the reference equivalent (4.6 Np for the whole of the transmission system) and do not take into account reductions in quality of transmission due to the effects of noise and bandwidth limitation.

Note 3. — In the old C.C.I.T.T. transmission plan, the transmission reference point (defined in Recommendation G.141) was called the "origin" of the circuit and by convention it coincided with, for example, the two-wire test jack. The reference equivalent values recommended above were referred to the *two-wire* switching points of an international circuit.

Practical limits for the reference equivalent between two operators or between one operator and a subscriber

In an international telephone communication, the reference equivalent between two operators or between an operator and a subscriber should not exceed the values given in the following table:

Communications between two operators		Communications between one operator and a subscriber			
Reference equivalent of the connection between two operators		Reference equivalent of the connection between an operator and a subscriber at the same end of the international line		Reference equivalent of the connection between an operator and a subscriber at opposite ends of the international line	
Subscribers' lines disconnected	Subscribers' lines connected	Internationa circuit disconnected	International circuit connected	Subscriber's line disconnected	Subscriber's line connected
21.8 dB (2.50 Np)	28.7 dB (3.30 Np)	22.2 dB (2.55 Np)	25.7 dB (2.96 Np)	30.9 dB (3.55 Np)	34.4 dB (3.95 Np)

Note. — To ensure that the limits indicated for reference equivalents are not exceeded, administrations and private operating agencies may use various methods. For example, models could be made representing the principal combinations of commercial subscribers' instruments, subscribers' lines, auxiliary lines and units of the local and trunk exchanges, each of these models representing a complete national sending system or a complete national receiving system which may be compared by a voice/ear test with the Master Telephone Transmission Reference System (S.F.E.R.T.) without distortion or with a working standard which has already been compared with S.F.E.R.T. It might be enough to measure the reference equivalent of the subscribers' apparatus under certain specified conditions; to this reference equivalent should be added the factory tolerances of the subscribers' apparatus considered, the image attenuation (calculated or measured at 800 Hz) of the subscribers' lines, auxiliary lines and circuits connecting this apparatus to the international exchange, and the composite attenuations (measured or calculated at 800 Hz and terminated with a non-reactive resistance of 600 ohms) of the parts of the telephone exchanges used in the connection, between the subscribers' apparatus and the international exchange (including the parts of the exchange serving the subscriber and the parts of the international exchange). But in all cases it is necessary to verify the results of the calculations by means of a voice/ear test made on models representing the typical complete national sending and receiving systems.

SECTION 2

GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS

2.1 Definitions and general considerations

RECOMMENDATION G.211 (amended in Geneva, 1964, and in Mar del Plata, 1968)

MAKE-UP OF A CARRIER LINK

In the international telephone network, provision must be made for the interconnection of various sorts of carrier-transmission systems using symmetric cable pairs, open-wire lines, coaxial cable pairs or radio-relay links. It is thus desirable for the carrier equipment used in these various systems, and which is not confined to a particular sort of line, to meet general C.C.I.T.T. recommendations.

Basically, these equipments comprise translating equipment and through-connection filters.

a) *Translating equipment*

These equipments are classified below according to the procedure used to make up the large-capacity systems from the basic supergroup.

Two procedures are in use:

Procedure 1 : the mastergroup and supermastergroup procedure;

Procedure 2 : the 15-supergroup assembly procedure; their use is described in the Recommendations concerning the various line systems.

For international links, procedure 2 can be used above 4 MHz only by agreement between the administrations concerned, including the agreement of the administration(s) of the transit country or countries, if any.

In the Recommendations of the C.C.I.T.T., the names of the equipments defined above are also used for equipments which translate a basic group, supergroup or mastergroups or a basic (No. 1) 15-supergroup assembly into the line-frequency band and vice versa.

The translating equipments used in procedure 1 are:

— channel-translating equipment, for translating the audio-frequency band into basic group B[1] and vice versa (see Recommendations G.232, G.234 and G.235);

— group-translating equipment for translating 5 basic groups B into the basic supergroup and vice versa;

— supergroup-translating equipment for translating 5 basic supergroups into the basic mastergroup and vice versa;

— mastergroup-translating equipment for translating 3 basic mastergroups into the basic supermastergroup and vice versa;

— supermastergroup-translating equipment for translating the basic supermastergroup into the line-frequency band and vice versa.

Note. — Figure 1, a) and b), recapitulates the basic frequency bands used in procedure 1; the through-connection possibilities described in Recommendation G.242 are provided for in these bands.

The translating equipments used in procedure 2 are:

— channel-translating equipment and group-translating equipment, as defined for procedure 1;

— supergroup-translating equipment for translating 15 basic supergroups into the basic assembly No. 1 of 15 basic supergroups and vice versa;

— 15-supergroup assembly equipment for translating basic assembly No. 1 of 15 supergroups into the frequency band of the 15-supergroup assembly No. 3 and vice versa;

— supermastergroup-translating equipment for translating 15-supergroup assembly No. 3 into the line-frequency band and vice versa.

Note 1. — When a basic 15-supergroup assembly is translated into the band of 15-supergroup assembly No. 3, it lies within the frequency limits of the basic supermastergroup.

Note 2. — Figure 1, a) and c), gives a recapitulation of the basic frequency bands used in procedure 2 in which the through-connection facilities described in Recommendation G.242 are provided.

Note 3. — The frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 336 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 388 kHz). The equipments which are used for translating into the line-frequency band and vice versa may therefore be the same.

For this reason, these equipments carry the same name of "supermastergroup-translating equipment".

b) *Through-connection filters*

Through group, supergroup, etc., filters and direct through-connection filters (see Recommendation G.242).

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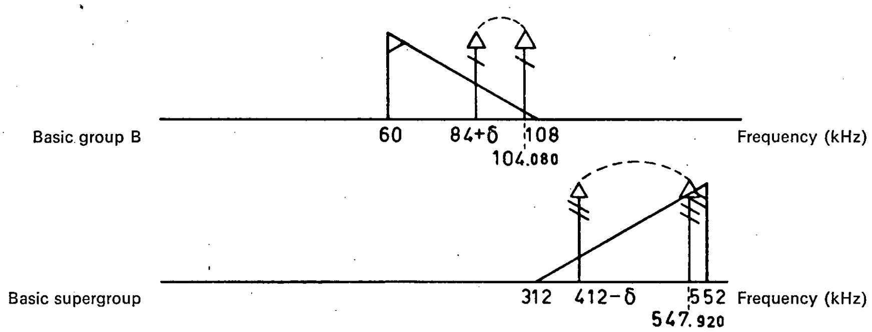
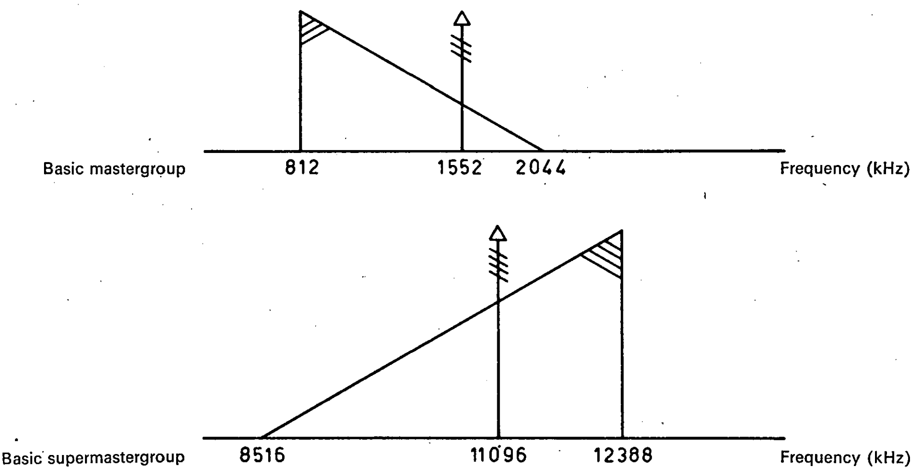
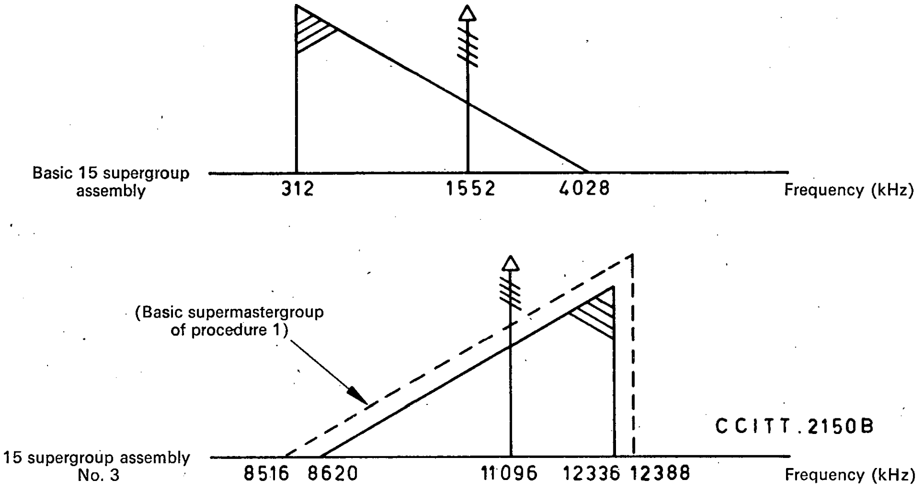
[1] The IVth Plenary Assembly (Mar del Plata, 1968) decided that basic group A (12-60 kHz) should no longer be mentioned in C.C.I.T.T. Recommendations.



a) *Frequency bands occupied by basic groups and supergroup*



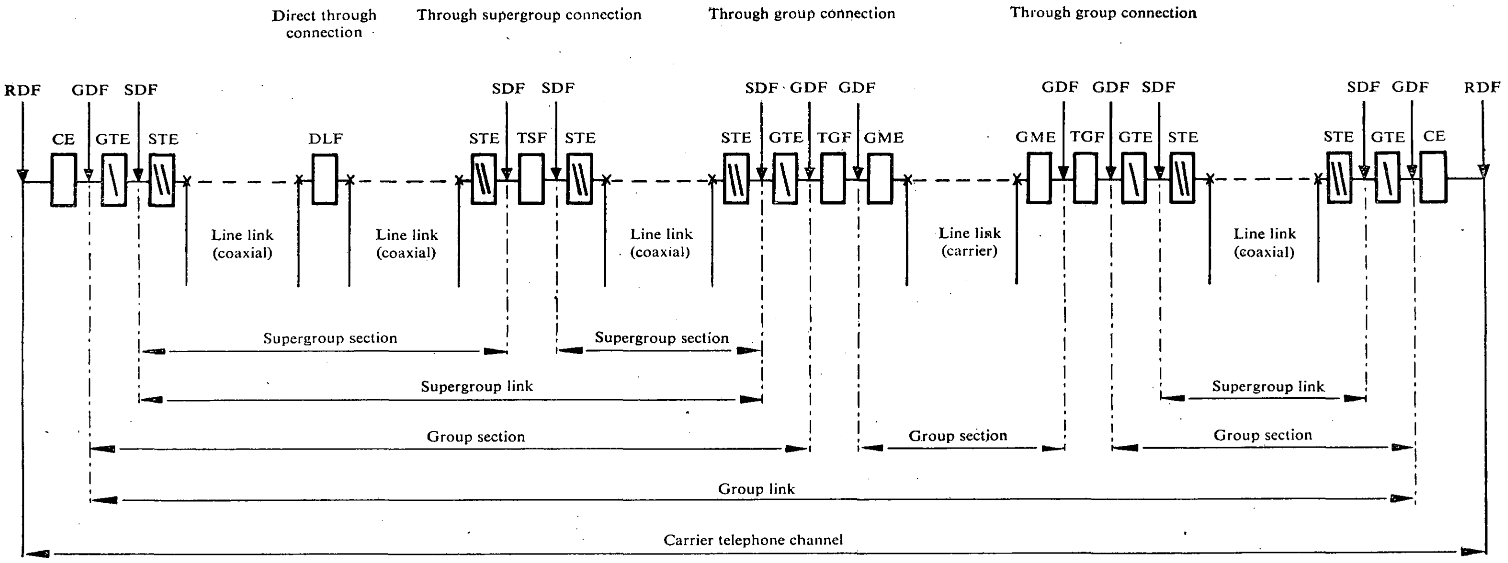
b) *Frequency bands occupied by basic mastergroup and supermastergroup in procedure 1 (mastergroup working)*



c) *Frequency bands occupied by basic 15-supergroup assemblies and by 15-supergroup assembly No. 3*

FIGURE 1. — **Frequency bands occupied by basic groups, supergroups, mastergroups and supermastergroups, by the basic 15-supergroup assembly and the 15-supergroup assembly No. 3, together with the associated pilots**

MAKE-UP OF A CARRIER LINK



CE — Channel-translating equipment (translation of the audio band into the basic group and vice versa)
GTE — Group-translating equipment (translation of the basic group into the basic supergroup)
STE — Supergroup-translating equipment (translation of the basic supergroup into the line frequency on coaxial cable, and vice versa)
GME — Group-modulating equipment
DLF — Direct line filter
TSF — Through-supergroup filter
TGF — Through-group filter
RDF — Repeater distribution frame
GDF — Group distribution frame
SDF — Supergroup distribution frame

(This diagram shows only one direction of transmission)

FIGURE 2

The equipment listed under a) and b) above can be interconnected for setting-up long groups, supergroups, etc., over several carrier systems. An example of such a link is shown in Figure 2 together with the expressions defined below that are recommended for describing the various parts of a circuit on such a group or supergroups, etc.[1]

Figure 3 refers to definitions 2 to 11.

1. *Line link (using symmetric pairs, coaxial pairs, etc.)*

A transmission path, however provided, together with all the associated equipment, such that the bandwidth available, while not having any specific limits, is effectively the same throughout the length of the link.

There is no frequency translation nor direct line filtration of groups, supergroups, etc., within the link, and the terminal stations for the link are those where the transmitted signals are changed in some way.

2. *Group link*

The whole of the means of transmission, using a frequency band of specified width (48 kHz) connecting two group distribution frames (or their equivalent). It extends from the point where the group is formed to the point where it is broken down. This expression is usually applied to the combination of "go" and "return" channels.

3. *Supergroup link*

The whole of the means of transmission, using a frequency band of specified width (240 kHz) connecting two supergroup distribution frames (or their equivalent). It extends from the point where the supergroup is formed to the point where it is broken down. This expression is usually applied to the combination of "go" and "return" channels.

4. *Mastergroup link*

The whole of the means of transmission using a frequency band of specified width (1232 kHz) connecting two mastergroup distribution frames (or their equivalent). It extends from the point where the mastergroup is formed to the point where it is broken down. This expression is usually applied to the combination of "go" and "return" channels.

Note. — As translating procedure 2 described under a) above does not enable mastergroups to be set up, the "mastergroup link" concept applies only in procedure 1.

5. *Supermastergroup link*

The whole of the means of transmission using a frequency band of specified width (3872 kHz) connecting two supermastergroup distribution frames (or their equivalent). It extends from the point where the supermastergroup is formed to the point where it is broken down. This expression is usually applied to the combination of "go" and "return" channels.

Note. — As the frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 336 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 388 kHz), the basic supermastergroup link can transmit one supermastergroup or an assembly of 15-supergroups.

6. *15-supergroup assembly link*

The whole of the means of transmission using a frequency band of specified width (3716 kHz) connecting two 15-supergroup assembly distribution frames (or their equivalent). It extends from

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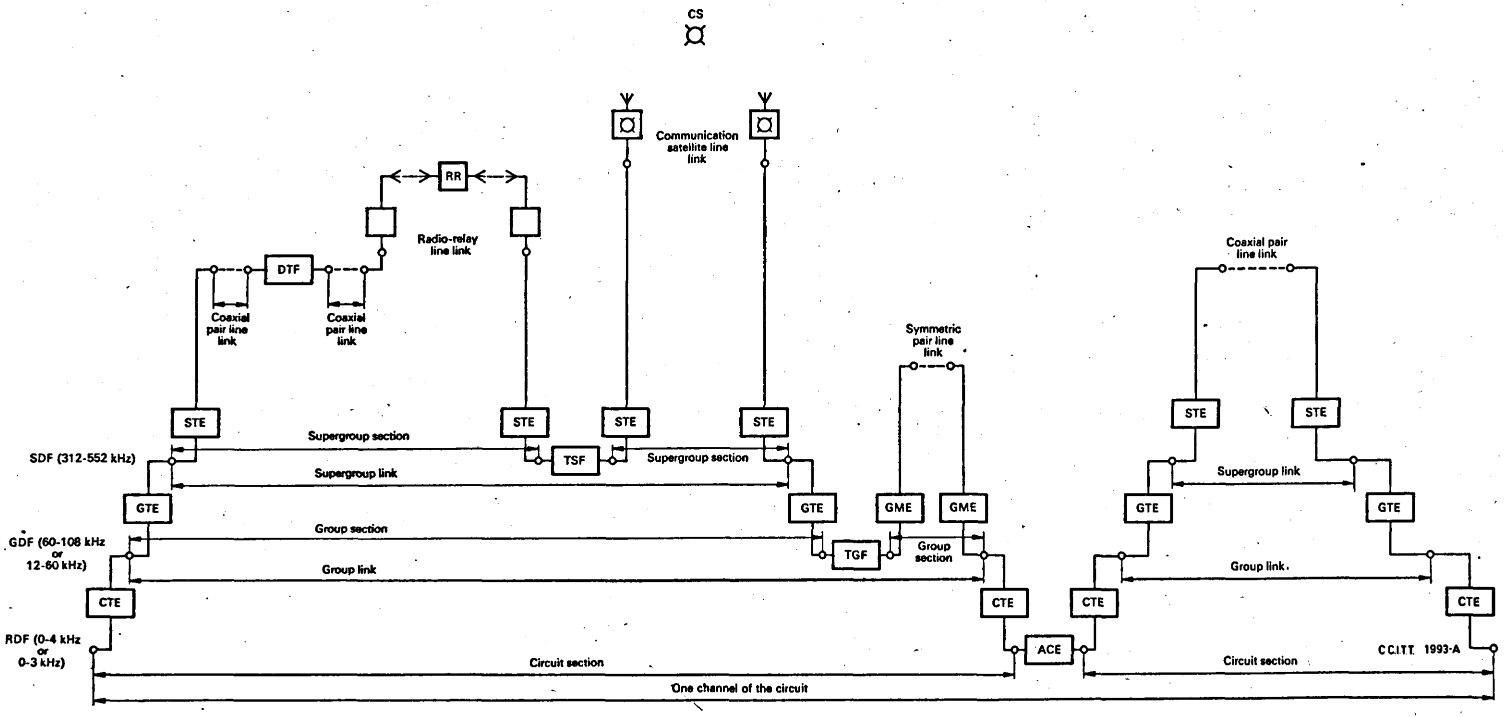
[1] As somewhat different definitions are given in Volume IV of the *White Book*, a question is under study to eliminate the differences (Question 27/XV).



ACE — Audio-connecting equipment
CTE — Channel-translating equipment (translation of the audio band into the basic group or vice versa)
GTE — Group-translating equipment (translation of the basic group into the basic supergroup)
STE — Supergroup-translating equipment (translation of the basic supergroup into the line frequencyon coaxial cable, or radio-relay system or vice versa)

CS — Communication satellite
GME — Group-modulating equipment
DLF — Direct through-connection filter
TSF — Through-supergroup filter
TGF — Through-group filter
RDF — Repeater distribution frame
GDF — Group distribution frame
SDF — Supergroup distribution frame

FIGURE 3. — Channel of a group set-up on several systems in tandem

the point where the 15-supergroup assembly is formed to the point where it is broken down. This expression is usually applied to the combination of "go" and "return" channels.

Note. — The notion of 15-supergroup assembly link relates to translating procedure 2 described in a) above. It is the equivalent of the "supermastergroup link" concept of the translating procedure 1 (900 telephone channels).

7. *Group section*

Part of a group link between two adjacent group distribution frames (or their equivalent).

A group link is generally made up of several "group sections", connected in tandem by means of "through-group filters".

8. *Supergroup section*

Part of a "supergroup link" between two adjacent supergroup distribution frames (or their equivalent).

A supergroup link is, in general, made up of several "supergroup sections" connected in tandem by means of "through-supergroup filters".

9. *Mastergroup section*

Part of a "mastergroup link" between two adjacent mastergroup distribution frames (or their equivalent).

A mastergroup link is, in general, made up of several "mastergroup sections" connected in tandem by means of "through mastergroup filters".

Note. — As translating procedure 2 described in a) above does not enable mastergroups to be set up, the "mastergroup section" concept applies only in procedure 1.

10. *Supermastergroup section*

Part of a "supermastergroup link" between two adjacent supermastergroup distribution frames (or their equivalent).

A supermastergroup link is, in general, made up of several "supermastergroup sections" connected in tandem by means of "through-supermastergroup filters".

Note. — As the frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 336 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 388 kHz), the supermastergroup section can transmit one supermastergroup or an assembly of 15-supergroups.

11. *15-supergroup assembly section* (applicable to operation by procedure 2)

Part of a "15-supergroup assembly link" between two adjacent 15-supergroup assembly distribution frames or between two equivalent points. At the 15-supergroup assembly distribution frame, interconnection is effected in the frequency band of the basic 15-supergroup assembly (No. 1) (312-4028 kHz).

A "15-supergroup assembly link" is generally composed of several 15-supergroup assembly sections connected in tandem via 15-supergroup assembly through-connection filters.

Note. — In a country which uses procedure 1, a 15-supergroup assembly can be through-connected without difficulty at the supermastergroup distribution frame. In this case, the 15-supergroup assembly is through-connected to position *3* (8620-12 336 kHz) instead of position *1* (312-4028 kHz) as required by the definition of the through-connection point of such an assembly (see Recommendation G.242, f). This through-connection point does not therefore answer this definition and is not at the end of a 15-supergroup assembly section.

12. *Through-group connection point*

When a "group link" is made up of several "group sections", they are connected in tandem by means of "through-group filters" at points called "through-group connection points".

13. *Through-supergroup connection point*

When a "supergroup link" is made up of several "supergroup sections", they are connected in tandem by means of "through-supergroup filters" at points called "through-supergroup connection points".

14. *Through-mastergroup connection point*

When a "mastergroup link" is made up of several "mastergroup sections", they are connected in tandem by means of "through-mastergroup filters" at points called "through-mastergroup connection points".

15. *Through-supermastergroup connection point*

When a "supermastergroup link" is made up of several "supermastergroup sections" they are connected in tandem by means of "through-supermastergroup filters" at points called "through-supermastergroup connection points".

16. *Through-15-supergroup assembly connection point*

When a "15-supergroup assembly link" is made up of several "15-supergroup assembly sections", these sections are interconnected in tandem by means of "through-15-supergroup assembly filters" at points called "through-15-supergroup assembly connection points".

As an alternative when the 15-supergroup assembly equipment provides sufficient filtering (corresponding to the definition of through-connection equipments - see paragraph f of Recommendation G.242) "through 15-supergroup assembly filters" can be dispensed with.

Note. — When a 15-supergroup assembly is connected by means of through-supermastergroup filters, the point of interconnections is "through-supermastergroup connection point" and not a "through-15-supergroup assembly connection point".

17. *Regulated line section* (symmetric pairs, coaxial pairs or radio-relay links, etc.)

In a carrier transmission system, a line section on which the line-regulating pilot or pilots are transmitted from end to end without passing through an amplitude-changing device peculiar to the pilot or pilots.

18. *Main repeater station*

A station, always the terminal of a line link (see 1 above), where direct line filtering or demodulation or both together may take place. As a consequence, in such a station there are equalizers and it is possible to find points which are of uniform relative level independent of frequency ("flat points").

Such a station, where all the supergroups, for example, are demodulated and brought into the basic supergroup position, is called a "main terminal station" and is of necessity at the end of a regulated line section. A "main intermediate station" is a station within a regulated line section where a direct through-connection takes place.

RECOMMENDATION G.212

HYPOTHETICAL REFERENCE CIRCUITS

General definitions

Hypothetical reference circuit. — This is a hypothetical circuit of defined length and with a specified number of terminal and intermediate equipments, this number being sufficient but not excessive.

It forms a basis for the study of certain characteristics of long-distance circuits (noise, for example).

Hypothetical reference circuit for telephony. — This is a complete telephone circuit (between audio-frequency terminals) established on a hypothetical international telephone carrier system and having a specified length and a specified number of modulations and demodulations of the groups, supergroups and mastergroups, these numbers being reasonably great but not having their maximum possible values.

Various "hypothetical reference circuits for telephony" have been defined to allow the co-ordination of the different specifications concerning the constituent parts of the multichannel carrier telephone systems, so that the complete telephone circuits set up on these systems can meet C.C.I.T.T. standards.

The C.C.I.T.T. has defined the following hypothetical reference circuits for telephony:

- on symmetric pair cable (see Recommendation G.322),
- on coaxial pair cable for 4-MHz systems (see Recommendation G.338) and for 12-MHz systems (see Recommendation G.332)
- on open-wire lines (see Recommendation G.311).

The C.C.I.R. also has defined the following hypothetical reference circuits for telephony:

1) In line-of-sight radio-relay systems;
   using frequency-division multiplex, with a capacity of 12 to 60 telephone channels or of more than 60 telephone channels (see Recommendation G.431);
   - using time-division multiplex, with a capacity less than or equal to 60 telephone channels (see Recommendation G.432).
2) On tropospheric-scatter radio-relay systems (see Recommendation G.433).
3) For satellite systems (see Recommendation G.434).

Each of these various hypothetical reference circuits has the same total length[1] and they are all used in the same way. They are only a guide for planning carrier systems.

In addition, because of the use of three pairs of channel modulators and demodulators[2], these hypothetical reference circuits for telephony can be used to study not only the case

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[1] With the exception of the hypothetical reference circuit for satellite systems.

[2] Except in the case of the hypothetical reference circuit for radio-relay links using time-division multiplex, which has six pairs of channel modulators.

of a circuit of 2500 km, set up on a carrier system or systems, but also that of an international connection having the same total length and made up of three circuits set up on channels of different carrier systems, and interconnected at two international transit exchanges.

A homogeneous section is a section without diversion or modulation of any one of the mastergroups, supergroups, groups or channels established on the system which is being considered except for those modulations or demodulations defined at the ends of the section.

All the hypothetical reference circuits defined above consist of homogeneous sections of equal length (6 or 9 sections [1] as the case may be).

It is assumed that at the end of each homogeneous section, the channels, groups, supergroups and mastergroups, as appropriate, are connected through at random.

Psophometric power. — Where square law addition (power addition) of noise can be assumed, it has been found convenient for calculations and design of international circuits to use the idea of "psophometric power" as defined below:

$$\text{psophometric power} = \frac{(\text{psophometric voltage})^2}{600}$$

or

$$\text{psophometric power} = \frac{(\text{psophometric e.m.f.})^2}{4 \times 600}$$

A convenient unit is the micro-microwatt or picowatt (pW), and this equation can then be given as follows:

$$\begin{array}{l}\text{psophometric power} \\ \quad\text{(in picowatts)}\end{array} = \frac{(\text{psophometric e.m.f. in mV})^2}{0.0024}$$

RECOMMENDATION G.213 (Geneva, 1964, amended in Mar del Plata, 1968)

INTERCONNECTION OF SYSTEMS IN A MAIN REPEATER STATION

The C.C.I.T.T. finds it necessary to define separation points between various types of equipment, both in cable systems and in radio-relay systems. These separation points are defined in the following paragraphs and the C.C.I.R. has adopted the same definitions when preparing its Recommendation 380-1 (see also Recommendation G.423).

a) *Definitions of telephony input and output points for the line link* [2]

These are points (marked *T* and *T′* in Figure 1) located in principle in a main repeater [2] station where the standard conditions given below are found at the input and output of a

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[1] The number is not specified for the tropospheric-scatter radio-relay systems.

[2] See definitions of Recommendation G.211.

line link (comprising a cable system or radio link). These standard conditions permit interconnection with other line links or with telephony equipment (including, where appropriate, direct through-connection filters as well as translating equipment).

At such a point, *T*, on the receiving side, the following conditions apply:

1. All the telephony groups (groups, supergroups, mastergroups, etc.) are still assembled in the positions in the frequency spectrum which they occupy on the line.

2. All the line-regulating, monitoring or frequency-comparison pilots on the H.F. line are, or can be, suppressed, according to whether the station is at the end of a regulated-line section or not[1].

3. The relative level of all the telephony channels is independent of frequency, i.e. any de-emphasis network is included in the line equipment.

4. No special suppression of additional measuring frequencies is foreseen (C.C.I.T.T. Recommendation G.423 for cable systems, C.C.I.R. Recommendation 381-1 for radio-relay systems).

A similar point *T'* is defined for the sending side, where the following conditions are met:

1. All the telephony groups (groups, supergroups, mastergroups, etc.) are still assembled in the positions in the frequency spectrum which they occupy on the line, except where use is made of direct through-connection filters provided as part of the line equipment.

2. (Follows from the situation at *T* according to condition 2 above.)

3. The relative level of all the telephony channels is independent of frequency, i.e. any pre-emphasis network is included in the line equipment.

4. The additional measuring frequencies are transmitted.

General remarks

1. Figure 1 gives an example only.

2. If the station is within a regulated line section, provision must be made for the line-regulating pilots to be passed through, either by means of the telephony direct through-connection filter itself or by means of a special pilot through-connection filter. To cater for this case, and for the case where the station forms a boundary between two regulated line sections, a pilot input to, and output from, the line link, separate from the telephony input and output points *T* and *T'*, should be provided; these are points *P* and *P'* in the figure.

3. (Applicable to all systems, irrespective of the number of channels):
When there is direct through-connection of part of the supergroups and mastergroups with the aid of direct through-connection filters fitted into the line equipment for this purpose, it is up to each administration to fix the relative levels at the filter access points (which are different from the access point *T* and *T'* mentioned above).

4. The levels at points *T* and *T'* have been chosen so as to permit the insertion of the various direct through connecting and translating equipments which may be necessary in the main station. The difference in level between points *R* and *T* and between points *T'* and *R'* allows for the cabling interconnecting these points, which may be at some distance from each other and, in favourable circumstances, for a blocking filter having only a small loss in the passband.

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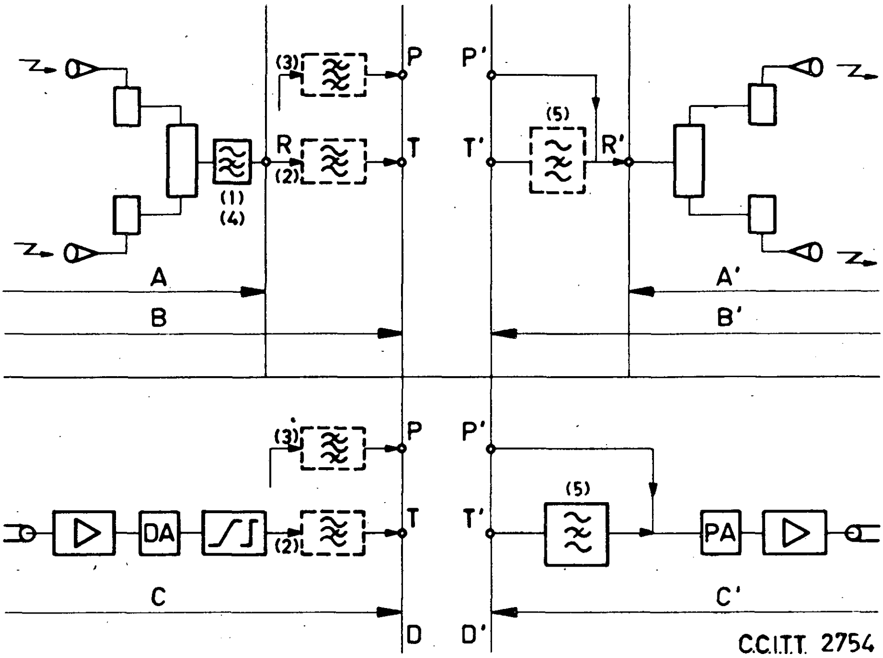
[1] The interconnecting point between a radio-relay system and a long cable system is always the terminal of a regulated line section (C.C.I.R. Recommendation 381-1) and hence all these pilots are suppressed at that point.

INTERCONNECTION IN A MAIN STATION



A, A′	:	radio equipments
B, B′	:	radio system
C, C′	:	cable system
D, D′	:	boundary of the high-frequency line equipment
Point P	:	provided for possible injection of regulating pilots
Between T and T′	:	telephony translating equipment and/or direct through-connection equipment
DA	:	de-emphasis network
PA	:	pre-emphasis network
(1)	:	blocking of continuity pilots and, if necessary, of regulation pilots
(2)	:	blocking, if necessary, of regulating pilots, and pilots that must not go beyond the line link
(3)	:	through-connection filter for regulating pilots, if necessary, a direct through-connection filter for telephone groups can, if necessary, be inserted
(4)	:	blocking of unspecified pilots or supervisory signals
(5)	:	filter for blocking any unwanted frequency before injecting a pilot, ensuring with (2) the requisite protection against a pilot (or other) frequency coming from another regulated-line section (system B or C, as the case may be).

FIGURE 1

b) *Definitions of the radio equipment baseband input and output points*

These are points (marked *R* and *R'* in Figure 1) forming the output and input terminals of radio equipment conforming to C.C.I.T.T. Recommendation G.423 and C.C.I.R. Recommendation 380-1.

At the output point of the radio equipment (point *R*), the following conditions are found in the baseband of the radio link:

1. All the telephony groups (groups, supergroups, mastergroups, etc.) and the pilots, i.e. line regulating, frequency comparison and monitoring pilots included in the baseband, are assembled in the positions in which they are transmitted, as defined in the C.C.I.T.T. and C.C.I.R. Recommendations mentioned above.

2. All the continuity and switching pilots special to the radio equipment and transmitted outside the baseband are suppressed, conforming to C.C.I.R. Recommendation 381-1.

3. Any radio standby and diversity switching is on the radio equipment side with respect to point *R*.

4. The relative levels of the telephony channels are independent of frequency, i.e. any de-emphasis networks are part of the radio equipment.

A similar point *R'* is defined for the baseband input where similar conditions, with due alteration of detail, are met.

c) *Relative levels recommended by the C.C.I.T.T. at the telephony input and output* (Points *T* and *T'* in Figure 1)

At the interconnection points *T* and *T'* for telephony defined in a) above, the following table shows the relative levels which are recommended for cable systems, each of which is defined by the maximum number of telephone channels that it can provide. (Similar levels are recommended by the C.C.I.T.T. for radio systems of corresponding capacity — see Recommendation G.423.)

The cable systems to which this recommendation applies are modern systems with transistor equipment and to new versions of other systems previously standardized by the C.C.I.T.T.

The recommended levels at *T* and *T'* make it possible to insert all the translating or direct through-connecting equipment which may be necessary; this does not define the relative levels in translating and direct through-connecting equipment, which depend on other considerations.

TABLE

Recommended relative levels for interconnection of various cable systems

Maximum number of telephone channels	Impedance (ohms)	Relative power level per channel at a main station				Remarks
		Receiving (point *T*)		Sending (point *T′*)		
		dBr	Nr	dBr	Nr	
24, 36, 48	150 (bal.)	−23	−2.6	−36	−4.1	
60 120	150 (bal.) or 78 (unbal.)	−23	−2.6	−36	−4.1	
300	75 (unbal.)	−23	−2.6	−36	−4.1	
600, 960, 1200, 1260	75 (unbal.)	−23 or −33	−2.6 or −3.8	−36 or −33	−4.1 or −3.8	Note 1
2700	75 (unbal.)	−33	−3.8	−33	−3.8	See also Rec. G.333 and J.73
10 800	75 (unbal.)	−33	−3.8	−33	−3.8	Provisionally

Note 1. — 600, 960, 1200 and 1260 channel systems.

Administrations have the choice between the alternative pairs of levels shown for points *T* and *T′* which apply in the following circumstances:

1) The following levels apply where conformity with well-established equipment using similar levels is necessary:

−23 dBr or −2.6 Nr at point *T*
−36 dBr or −4.1 Nr at point *T′*.

2) The following levels apply in other cases, for example, to new stations wholly equipped with transistor equipment:

−33 dBr (−3.8 Nr) at each of the points *T* and *T′*.

RECOMMENDATION G.214 (Mar del Plata, 1968)

LINE STABILITY OF CABLE SYSTEMS

Line regulation has a threefold purpose:

a) to keep actual line relative levels within such limits that thermal or intermodulation noise never exceeds acceptable values;

b) to keep levels at the ends of regulated-line sections within such limits that the group regulators are able to function;

c) to ensure that regulation is precise enough to make it generally unnecessary to provide an automatic group regulator and/or supergroup regulator for the group, supergroup, etc., links set up on a single regulated-line section.

It appears that all three objectives will be secured if levels at the end of the longest regulated section envisaged are stabilized to ± 1 dB (± 0.115 Np) at any frequency in the band transmitted.

The C.C.I.T.T. therefore *unanimously recommends that:*

Designers of line-regulating systems take account of the daily and seasonal variations in temperature to which the cables and repeaters are likely to be subjected, the predictable ageing of components, for example vacuum tubes, and also the nominal range of variation of power supplies, assuming that appropriate precautions are taken in the placing of the cable, in the design of buildings and in regulation of power supplies.

As a design objective for the residual effects of sustained power and temperature variations, and the predictable ageing of components, for example the vacuum tubes, over the ranges expected in any period between two successive manual adjustments, the change in insertion gain of a regulated-line section at any frequency in the transmitted band should not exceed 1 dB (0.115 Np).

For the purposes of this Recommendation, it is assumed that a regulated-line section will not be longer than a homogeneous section of the hypothetical reference circuit applicable to the type of system considered and that the interval between two successive manual adjustments will be not less than a fortnight.

The variations in gain of a regulated-line section in service is also affected by tube failure and replacements, maintenance operations and adjustments. The design objective excludes these effects.

Moreover, the dynamic stability of the regulating system should be such that any swinging of the gain is damped and at a suitable rate as a result of an abrupt change in pilot level. If, for example, the pilot level is suddenly increased by 2 dB at the origin of the regulated-line section, the pilot level must not increase or diminish by more than 2 dB at the end of the regulated-line section. The resulting fluctuations in pilot level must fall off progressively.

Note 1. — It may be desirable to specify immunity of the regulating system to interference from components of television signals when transmitted.

Note 2. — The dynamic stability of a regulating system is under study by the C.C.I.T.T. (Question 26/XV).

2.2 General recommendations

RECOMMENDATION G.221

OVER-ALL RECOMMENDATIONS RELATING TO CARRIER-TRANSMISSION SYSTEMS

a) *Characteristics of complete circuits*

The characteristics of complete circuits, measured between audio-frequency terminals (overall loss in terminal service and in transit service, frequency bands effectively transmitted and attenuation distortion, variation of overall loss with time, phase distortion, stability, crosstalk, etc.) should meet the general conditions for four-wire telephone circuits indicated in Section 1.

b) *Linear crosstalk*

The near-end crosstalk ratio between the two directions of transmission at all frequencies used for the regulating and measuring pilots on carrier systems should be not less than 40 dB (4.6 Np).

RECOMMENDATION G.222 (amended in Geneva, 1964, and in Mar del Plata, 1968)

NOISE OBJECTIVES FOR DESIGN OF CARRIER-TRANSMISSION SYSTEMS OF 2500 KM

a) *Design objectives in respect of noise produced by the line and the frequency division modulating equipment on hypothetical reference circuits of 2500 km for telephony*

In order to ensure that multichannel carrier systems on cable and on radio-relay links shall comply with a common standard of performance in respect of noise, the following design objectives should apply to the noise *at a zero relative level point* in any telephone channel having the same competition as the hypothetical reference circuit on such systems.

1. To ensure adequate performance in respect of telephone speech and signalling:

1.1 the mean psophometric power during any hour shall not exceed 10 000 pW,[1]

1.2 the mean noise power over one minute shall not exceed 10 000 pW for more than 20% of any month,

1.3 the mean noise power over one minute shall not exceed 50 000 pW for more than 0.1% of any month.

1.4 the unweighted noise power, measured or calculated with an integrating time of 5 ms shall not exceed 1 000 000 pW (10^6 pW) for more than 0.01% (10^{-4}) of any month.

2. But if it is intended to use voice-frequency amplitude-modulated telegraph equipment for 50 bauds conforming to Series R Recommendations of the C.C.I.T.T. (Volume

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[1] This clause, which does not give any statistical distribution in time, is well suited to cable systems but it presents difficulties when applied to radio-relay systems. For this reason, some administrations have so far taken no account of this clause in the design of radio-relay systems. Its interpretation and practical application to radio-relay systems are accordingly under study.

VII of the *White Book*) and to obtain the quality shown in Recommendation F.10 of the C.C.I.T.T. (Volume II-B of the *White Book*), the mean non-weighted noise power over 5 ms must not exceed 10^6 pW during more than 0.001% (10^{-5}) of any month, nor more than 0.1% of any hour.

If voice-frequency modulated telegraph equipment operating at 50 bauds is used it is to be expected that the quality specified in paragraph 1 above will be satisfactory as far as the telegraph transmission is concerned.

The conditions under which the above design objectives should apply are given in paragraph b) below.

b) *Conditions in which the design objectives for hypothetical reference circuits apply*

1. The values mentioned in paragraph a) of this Recommendation are design objectives and it is not intended that they should be quoted in specifications for equipment or used for acceptance tests. The noise on a homogeneous section of an actual carrier system is dealt with in Reccommendation G.226.

The following Recommendations specify the conditions in which these general objectives apply to different types of system, account being taken of the special characteristics of each system:

- symmetric pair cable systems using transistors (Recommendation G.322);
- symmetric pair cable systems using thermionic valves (Recommendation G.324);
- symmetric pair cable "12 + 12" systems using transistors (Recommendation G.326);
- 4-MHz systems (Recommendation G.338), 12-MHz systems (Recommendation G.332) and 40-60 MHz systems (Recommendation G.333) on 2.6/9.5-mm coaxial pairs;
- systems on 1.2/4.4-mm coaxial pairs (Recommendation G.341);
- radio-relay links using frequency-division multiplex (Recommendation 393-1 of the C.C.I.R., reproduced in Recommendation G.441 below) and time-division multiplex (Recommendations 300 and 394 of the C.C.I.R., see Recommendation G.443).

In particular, Recommendation G.442 lays down objectives for the use of amplitude-modulation voice-frequency telegraphy used in line-of-sight radio-relay systems.

Tropospheric-scatter radio-relay systems should meet the objectives of this recommendation, or other objectives, according to the circumstances of operation (see C.C.I.R. Recommendation 397-1, reproduced in Recommendation G.444).

Other objectives are recommended for systems providing 12 carrier circuits on an open-wire pair (see Recommendation G.311)

2. Designers are expected to fit their distribution curves to fall below both points given in paragraph a), sub-paragraphs 1.2 and 1.3 of this present recommendation.

3. In connection with sub-paragraph 1.3 of the recommendation, the C.C.I.T.T. would have preferred to indicate a figure of 100 000 pW (average psophometric power over one minute at a zero relative level point), not to be exceeded during more than 0.01% of any month. On account of difficulties in measurement, a figure of 50 000 pW for 0.1% of any month has been shown.

4. Within each homogeneous section of a hypothetical reference circuit, the telephone channels will occupy the same position in relation to each other. Within these sections, certain intermodulation products (those of odd order) tend to add on the basis of linear

addition of voltages, but between sections it may be considered that in respect of noise a power-additive law applies exclusively.

In a part of a hypothetical reference circuit consisting of one or more equal homogeneous sections, the mean noise power in any hour [1] and the one-minute mean noise power not exceeded during 20% of any month shall be considered to be proportional to the number of homogeneous sections involved.

5. In parts of a hypothetical reference circuit consisting of one or more equal homogeneous sections, the small percentages of any month in which the one-minute-mean power may exceed the design objective for 0.1% of the time or less shall be regarded as proportional to the number of homogeneous sections involved. This principle also applies to the objective mentioned in sub-paragraph 1.4 of paragraph a) of this present recommendation.

6. Although in principle it is to be understood that the general noise objectives are all-embracing, in practice it is recognized that there will be abnormalities from time to time which will result in additional noise sources becoming evident. Often, such extra contributions can be accommodated within the margin available within the system design. In other cases, no concern need be felt provided that such additional contributions are small compared to the general objective, for example, less than 10% of the power or probability of occurrence respectively.

In any case, all necessary precautions should be taken during the installation and putting into service of the systems so that noises of external origin are reduced to a negligible value of, at the most, 10% of the limits fixed as objectives.

7. Recommendation G.223 below gives the other hypotheses which it is recommended to make for the calculation of the noise on the hypothetical reference circuits for telephony.

c) *Circuits more than 2500 kilometres long*

The basic hypothetical reference circuit for satellite systems is defined, and the appropriate provisional noise objectives recommended, in C.C.I.R. Recommendations 352 and 353-1 (reproduced in Recommendations G.434 and G.445).

For the other systems likely to provide very long circuits, it has been considered that there was no point in defining further hypothetical reference circuits. Noise objectives are recommended in Recommendation G.153. The world-wide hypothetical reference connection is defined in Recommendation G.103.

d) *Design objectives for noise produced by modulating equipments*

The general objectives mentioned in paragraph a) include the noise produced by modulating equipment[2]. The mean psophometric power, which corresponds to the noise produced

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[1] Where the mean noise power in any hour varies, as on radio-relay systems, the subdivision of this noise objective between sections on the basis of length is inappropriate because the worst hours of all the various sections will be uncorrelated. More suitable bases for subdivision are under study.

[2] Called, in C.C.I.R. recommendations, "frequency-division multiplex equipments". It is evident that paragraph d) does not apply to radio-relay links using time-division multiplex.

by all modulating equipment mentioned in the definition of the hypothetical reference circuit in question, should not exceed 2500 picowatts at a zero relative level point. This value of power refers to the whole of the noise due to various causes (thermal noise, intermodulation, crosstalk, power supplies, etc.). Its allocation between the various equipments can to a certain extent be left to the discretion of design engineers. However, to ensure a measurement of agreement in the allocation chosen by different administrations, the following values are given as a guide to the target design values:

for 1 pair of channel modulators:	200 to 400 pW
for 1 pair of group modulators:	60 to 100 pW
for 1 pair of supergroup modulators:	60 to 100 pW

The following values are recommended on a provisional basis:

for 1 pair of mastergroup modulators:	40 to 60 pW
for 1 pair of supermastergroup modulators:	40 to 60 pW
for 1 pair of basic 15-supergroup assembly modulators:	40 to 60 pW

The allocation of a large part of the noise to channel-modulating equipment is justified because these equipments are the most numerous in a network and it is better that they should be as low-priced as possible.

RECOMMENDATION G.223 (Remark of Recommendation G.222, Volume III of the *Red Book*, amended in Geneva, 1964, and in Mar del Plata, 1968)

ASSUMPTIONS FOR THE CALCULATION OF NOISE ON HYPOTHETICAL REFERENCE CIRCUITS FOR TELEPHONY

1. *Nominal mean power during the busy hour*

To simplify calculations when designing carrier systems on cables or radio links, the C.C.I.T.T. has adopted a *conventional* value to represent the *mean absolute power level* (at a zero relative level point) of the speech plus signalling currents, etc., transmitted over a telephone channel in one direction of transmission during the busy hour.

The value adopted for this mean absolute power level corrected to a zero relative level point is −15 dBm0 (−1.73 Nm0) (mean power = 31.6 microwatts); this is the mean with time and the mean for a large batch of circuits.

Note 1. — This conventional value was adopted by the C.C.I.F. in 1956 after a series of measurements and calculations had been carried out by various administrations between 1953 and 1955. Annex 6 (Part 4 of Volume III, *Blue Book*) reproduces the documentation assembled at the time. The adopted value of about 32 microwatts was based on the following assumptions:

- mean power of 10 microwatts for all signalling and tones;
- mean power of 22 microwatts for other currents, namely:
  - speech currents, including echoes, assuming a mean activity factor of 0.25 for one telephone channel in one direction of transmission,

— carrier leak,

— telegraph signals, assuming that few telephone channels are used for v.f. telegraphy or phototelegraphy.

On the other hand, the power of pilots in the load of modern carrier systems has been treated as negligible.

Note 2. — The question of reconsidering the assumptions leading to this conventional value arose in 1968 for the following reasons:

— changes in the r.m.s. power of speech signals, due to the use of more modern telephone sets, to a different transmission plan, and perhaps also to some change in subscriber habits.

— Change in the mean activity factor of a telephone channel due, *inter alia*, to different operating methods.

— Increase in the number of v.f. telegraphy bearer circuits and sound programme circuits.

— Introduction of circuits used for data transmission, and rapid increase in their number.

A limited study of measurements of speech signal power was carried out by various administrations in 1966 and 1967; it produced the results shown in Supplement 5 to this Book. These results are too fragmentary to warrant a change in the conventional value of −15 dBm0. The IVth Plenary Assembly of the C.C.I.T.T. (Mar del Plata, 1968) agreed to keep this value, since it was considered that the increase in the load of carrier systems due to the growth of uses other than telephony (for which the permissible levels are generally higher than −15 dBm0) will probably be compensated by a reduction in the speech current power and that the margin with which carrier systems are calculated in practice will enable a slight increase in the mean power transmitted per channel to be tolerated without serious inconvenience.

However, this favourable situation may not last indefinitely or may not apply for all systems. Question 11/C has therefore been set for study with a view to dealing with all aspects of this problem.

Note 3. — Pending the results of the study mentioned at the end of Note 2 above, the C.C.I.T.T. has agreed to the following rules concerning the maximum permissible number of v.f. telegraph bearer circuits:

1. For a *12-channel system*, both the load capacity and the intermodulation requirements are determined by the statistics of speech, hence there is no reason to limit the number of channels in a 12-channel system which may be used as v.f. telegraphy bearer channels.
2. For a *60-channel system*, the load capacity is determined by the statistics of speech but the intermodulation requirements for a mixed v.f. telegraph and speech loading become controlling when the v.f. telegraph bearers exceed about 30% of the total. Hence it is possible, without change of specifications, to allow up to 20 channels in this system to be used for v.f. telegraphy.
3. For a *120-channel system*, about 12% of the total could be allowed for v.f. telegraph bearers.

   The number of reserve circuits for v.f. telegraphy is excluded from these limits for both 60- and 120-channel systems. The number of channels mentioned in 2) and 3) should be distributed more or less uniformly throughout the line-frequency band.
4. For *systems with 300 or more channels*, the C.C.I.T.T. is not yet able to define any specific limit, owing to the many complicated factors such as mean power, peak power, overload capacity, intermodulation, noise-performance and pre-emphasis, which have to be taken into consideration.
5. For *groups and supergroups* no conclusion could be obtained. From information available, it would be unwise, without special consideration, to exceed two v.f. telegraph systems per supergroup in a wideband system.

2. *Conventional load*

2.1 It will be assumed for the calculation of intermodulation noise below the overload point that the multiplex signal during the busy hour can be represented by a uniform-spectrum random noise signal, the mean absolute power level of which, at a zero relative level point $10 \log_{10} \overline{P}(n)$, is given by the following formulae:

$$10 \log_{10} \overline{P}(n) = -15 + 10 \log_{10} n \text{ dB for } n \geqq 240$$
$$\text{and } 10 \log_{10} \overline{P}(n) = -\ 1 + \ 4 \log_{10} n \text{ dB for } 12 \leqq n < 240,$$

n being the total number of telephone channels in the system.

Examples are shown in Table 1 of the results given by these formulae for some typical values of n:

TABLE 1

n	12	24	36	48	60	120	...
$10 \log_{10} \overline{P}(n)$	3.3	4.5	5.2	5.7	6.1	7.3	
...	240	300	600	960	1800	2700	
	8.8	9.8	12.8	14.8	17.5	19.3	

These results apply only to systems without pre-emphasis and using independent amplifiers for the two directions of transmission.

2.2 For two-wire systems having common amplifiers for the two directions of transmission ($n + n$ systems), it is necessary to assume a different conventional loading. When the relative levels are the same for both directions of transmission the conventional load is given by the following formulae:

$$10 \log_{10} \overline{P}(n) = -15 + 10 \log_{10} 2n \text{ dB for } n \geqq 120$$
$$\text{and } 10 \log_{10} \overline{P}(n) = -\ 1 + \ 4 \log_{10} 2n \text{ dB for } 12 \leqq n < 120$$

where $10 \log_{10} \overline{P}(n)$ is defined as in paragraph 2.1 above and n is the number of channels in each direction of transmission.

Note 1. — The mean absolute power level of a uniform-spectrum random noise test signal deduced from these formulae may be used in calculating the intermodulation noise on a hypothetical reference circuit, when there is no overloading. It is considered that these formulae give a good approximation in calculating intermodulation noise when $n \geqq 60$. For small numbers of channels, however, tests with uniform-spectrum random noise are less realistic owing to the wide difference in the nature of actual and test signals.

Note 2. — In view of the conventional character of these calculations, it was not considered useful to take into account the power transmitted for programme transmissions over carrier systems. Moreover, the mean value of 0.25 was assumed for the activity factor of a telephone channel and it was not deemed useful to study any deviations from this mean.

Note 3. — Care must be taken in interpreting the results of tests with uniform-spectrum random noise loading, especially in systems in which the dominant noise contribution in certain channels arises from a particular kind of intermodulation product (e.g. A-B). In such cases, the weighting factor used in relating the performance of the channel to that under real traffic conditions must be carefully determined. The curve given by the transfer function of the network used to define the conventional telephone signal (see Recommendation G.227) may be used in this case to determine the weighting factor for the wideband signal.

Note 4. — The formulae in paragraph 2.2 above for (n+n) type 12-channel systems are the same as those given in paragraph 2.1 (four-wire systems), assuming that the number of channels is doubled but that there is no correlation between the channel activities in each direction of transmission. For the purposes of this assumption, the fact that in an (n+n) system the two directions of transmission of a telephone circuit are not active at the same moment is ignored. Calculations have shown that the resultant error is negligible and in any case is on the safe side.

3. *Component characteristics and levels*

The values of the characteristics of circuit components and the levels to be used in calculations will be the nominal values.

Note. — When specifying equipments, a reasonable margin should be allowed for the ageing of components and for tolerances on levels, supply voltages, temperature, etc.

4. *Psophometric weight and weighting factor*

For calculating psophometric power, use should be made of the *Table of psophometer weighting for commercial telephone circuits* which is given at the end of this present recommendation.

If uniform-spectrum random noise is measured in a 3.1-kHz band with a flat attenuation/frequency characteristic, the noise level must be reduced by 2.5 dB to obtain the psophometric power level. For another bandwidth, B, the weighting factor will be equal to:

$$2.5 + 10 \log_{10} \frac{B}{3.1} \text{ dB};$$

when $B = 4$ kHz for example, this formula gives a weighting factor of 3.6 dB (4.1 dNp).

5. *Calculating noise in modulating (translating) equipments*

5.1 For group, supergroup, etc. *modulating equipments*, in calculating *intermodulation noise* (below the overload point), the following conventional values, already accepted, will be assumed for the load at a zero relative level point:

for 12-channel group modulators	3.3 dB (0.38 Np)
for 60-channel supergroup modulators	6.1 dB (0.70 Np)
for 300-channel mastergroup modulators	9.8 dB (1.12 Np)

5.2 The mean noise power in channel translating equipments due to interference from channels adjacent to the disturbed channel will be calculated as follows. In all the terminal equipment of the hypothetical reference circuit there are six exposures to adjacent-channel disturbance. Five of these disturbing channels will be assumed to carry speech-like loading signals each having a mean power of 32 μW, i.e. an absolute power level of −15 dB (−1.73 Np) per channel at a zero relative level point, while the sixth disturbing channel will be assumed to carry telegraphy, phototelegraphy or data transmission with a conventional loading of 135 μW applied at the zero relative level point, i.e. an absolute power of −8.7 dbm0 (−1.0 Nm0) uniformly distributed over the frequency range 380 to 3220 Hz.

The conventional telephony signal defined in Recommendation G.227 may be used to simulate the speech signals transmitted on the disturbing channels.

Note. — Limitation of crosstalk caused by channels adjacent to the disturbed channel is governed by an additional clause in the channel equipment specification (see paragraph J. b. of Recommendation G.232). In addition, the power of signalling pulses is restricted by Recommendation G.224.

5.3 In all cases, allowance should, of course, be made for thermal noise.

6. *Overload point of amplifiers and the equivalent r.m.s. power of the peak of a multiplex signal*

6.1 *Overload point. — The overload point or overload level of an amplifier* is at that value of absolute power level (referred to 1 milliwatt) at the output, at which the absolute power level of the third harmonic increases by 20 dB (2.3 Np) when the input signal to the amplifier is increased by 1 dB or 1 dNp.

This first definition does not apply when the test frequency is so high that the third harmonic frequency falls outside the useful bandwidth of the amplifier. The following definition may then be used:

Second definition. — The overload point or overload level of an amplifier is 6 dB or 0.7 Np higher than the absolute power level in dBm, at the output of the amplifier, of each of two sinusoidal signals of equal amplitude and of frequencies A and B respectively, when these absolute power levels are so adjusted that an increase of 1 dB or 1 dNp in both of their separate levels at the input to the amplifier causes an increase, at the output of the amplifier, of 20 dB (2.3 Np) in the intermodulation product of frequency 2 A-B.

6.2 *Equivalent r.m.s. sine wave power of the peak of a multiplex signal.* — This is the power of a sinusoidal signal whose amplitude is that of the peak voltage of the multiplex signal. Figure 24 shows the equivalent peak power level in terms of the number of channels in the system. It is derived from Curve B, Figure 7 of the Holbrook and Dixon article[1] taking into account the conventional value (−15 dBm0, i.e. −1.73 Nm0) allowed by the C.C.I.T.T. for the mean power per channel instead of −16 dBm0, i.e. an increase of 1 dB. Table 2 gives corresponding numerical values for a few typical numbers of channels.

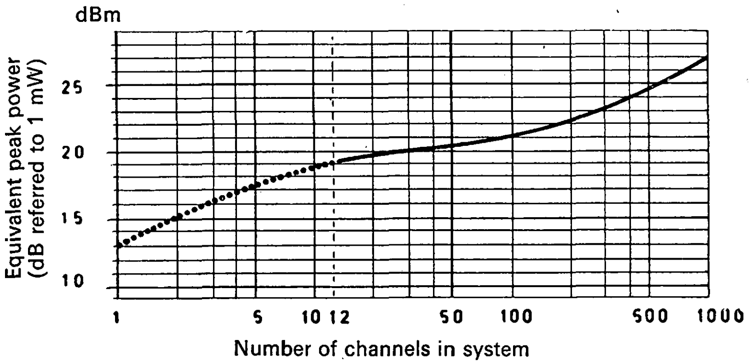

Figure 1. — Equivalent r.m.s. sine wave power of the peak of a multiplex signal at the zero relative level point, as a function of the number of telephony channels in a system, without pre-emphasis or peak limiting assuming a mean power per channel of −15 dBm0 (−1.73 Nm0), with a standard deviation of 5.8 dB (6.7 dNp)

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[1] B. D. Holbrook and J. T. Dixon: Load Rating Theory for Multichannel Amplifiers. *Bell System Technical Journal*, 18, 1939, No. 4, October, pages 624 to 644.

TABLE 2

Number of channels	12	24	36	48	60	120	300	600	960	1800	2700
Equivalent peak power dBm0	19	19.5	20	20.5	20.8	21.2	23	25	27	30	32

This curve is for use when there is no amplitude limiter at the channel input and when there is no pre-emphasis in the overall band of the multiplex signal; other cases are being studied. For an example with limiting only, see Annex.

6.3 *Margin against saturation.* — In planning, a margin of a few decibels or decinepers will be maintained between the absolute level of the equivalent power of the peak of the multiplex signal and the amplifier saturation point, to allow for level variations, ageing, etc.

7. *Methods of calculating noise*

The methods proposed by several administrations for effecting such a calculation are described in Supplement 6 to this volume.

Table of commercial telephone circuit psophometer weighting coefficients

Frequency (Hz)	Weight			
	Numerical value	Numerical value squared	Value in decibels	Value in nepers
16.66	0.056	0.003136	−85.0	−9.79
50	0.71	0.5041	−63.0	−7.25
100	8.91	79.3881	−41.0	−4.72
150	35.5	1 260 .25	−29.0	−3.34
200	89.1	7 938.81	−21.0	−2.42
250	178	31 684	−15.0	−1.73
300	295	87 025	−10.6	−1.22
350	376	141 376	− 8.5	−0.98
400	484	234 256	− 6.3	−0.73
450	582	338 724	− 4.7	−0.54
500	661	436 921	− 3.6	−0.41
550	733	537 289	− 2.7	−0.31
600	794	630 436	− 2.0	−0.23
650	851	724 201	− 1.4	−0.16
700	902	813 604	− 0.9	−0.10
750	955	912 025	− 0.4	−0.046
800	1 000	1 000 000	0.0	0.000
850	1 035	1 071 225	+ 0.3	+0.034
900	1 072	1 149 184	+ 0.6	+0.069
950	1 109	1 229 881	+ 0.9	+0.103
1 000	1 122	1 258 884	+ 1.0	+0.115
1 050	1 109	1 229 881	+ 0.9	+0.103
1 100	1 072	1 149 184	+ 0.6	−0.069
1 150	1 035	1 071 225	+ 0.3	+0.034
1 200	1 000	1 000 000	0.0	0.000
1 250	977	954 529	− 0.20	−0.023
1 300	955	912 025	− 0.40	−0.046
1 350	928	861 184	− 0.65	−0.075
1 400	905	819 025	− 0.87	−0.100
1 450	881	776 161	− 1.10	−0.126
1 500	861	741 321	− 1.30	−0.150
1 550	842	708 964	− 1.49	−0.172
1 600	824	678 976	− 1.68	−0.193
1 650	807	651 249	− 1.86	−0.214
1 700	791	625 681	− 2.04	−0.234
1 750	775	600 625	− 2.22	−0.255
1 800	760	577 600	− 2.39	−0.275
1 850	745	555 025	− 2.56	−0.295
1 900	732	535 824	− 2.71	−0.311
1 950	720	518 400	− 2.86	−0.329
2 000	708	501 264	− 3.00	−0.345
2 050	698	487 204	− 3.12	−0.359
2 100	689	474 721	− 3.24	−0.373
2 150	679	461 041	− 3.36	−0.386
2 200	670	448 900	− 3.48	−0.400
2 250	661	436 921	− 3.60	−0.414
2 300	652	425 104	− 3.72	−0.428
2 350	643	413 449	− 3.84	−0.442

Table of commercial telephone circuit psophometer weighting coefficients (contd.)

Frequency (Hz)	Weight			
	Numerical value	Numerical value squared	Value in decibels	Value in nepers
2 400	634	401 956	− 3.96	−0.456
2 450	626	390 625	− 4.08	−0.470
2 500	617	380 689	− 4.20	−0.484
2 550	607	368 449	− 4.33	−0.499
2 600	598	357 604	− 4.46	−0.513
2 650	590	348 100	− 4.59	−0.528
2 700	580	336 400	− 4.73	−0.544
2 750	571	326 041	− 4.87	−0.560
2 800	562	315 844	− 5.01	−0.576
2 850	553	305 809	− 5.15	−0.593
2 900	543	294 849	− 5.30	−0.610
2 950	534	285 156	− 5.45	−0.627
3 000	525	275 625	− 5.60	−0.645
3 100	501	251 001	− 6.00	−0.691
3 200	473	223 729	− 6.50	−0.748
3 300	444	197 136	− 7.05	−0.812
3 400	412	169 744	− 7.70	−0.886
3 500	376	141 376	− 8.5	−0.979
3 600	335	112 225	− 9.5	−1.09
3 700	292	85 264	−10.7	−1.23
3 800	251	63 001	−12.0	−1.38
3 900	214	45 796	−13.4	−1.54
4 000	178	31 684	−15.0	−1.73
4 100	144.5	20 880.25	−16.8	−1.93
4 200	116.0	13 456	−18.7	−2.15
4 300	92.3	8 519.29	−20.7	−2.38
4 400	72.4	5 241.76	−22.8	−2.62
4 500	56.2	3 158.44	−25.0	−2.88
4 600	43.7	1 909.69	−27.2	−3.13
4 700	33.9	1 149.21	−29.4	−3.38
4 800	26.3	691.69	−31.6	−3.64
4 900	20.4	416.16	−33.8	−3.89
5 000	15.9	252.81	−36.0	−4.14
>5 000	<15.9	<252.81	<−36.0	<−4.14

Note. — If, for the planning of certain telephone transmission systems, calculations are made on a basis of the psophometric weighting values and if it appears useful to adopt, for frequencies above 5000 Hz, more precise values than those given in the above table, the following values may be used:

5 000 à 6 000	<15.9	<252.81	<−36.0	<−4.14
>6 000	< 7.1	< 50.41	<−43.0	<−4.95

ANNEX

(to Recommendation G.223)

(supplied by the United Kingdom Administration)

This Annex shows, as an example, the power of a sine wave with the same peak voltage as the multiplex signal, with an amplitude limiter of specified characteristic.

The probability of occurrence of this peak voltage is 10^{-5}, which agrees fairly well with Holbrook and Dixon's assumptions.

Number of channels (*n*)	Power of the equivalent sine wave dBm0
12	12.7
24	14
50	15.9
100	18
200	20.4
500	23.6
1000	26.6

For calculation of the above values it was assumed that the transmission channel was fitted with a limiter having the following characteristics as regards the sine wave loading and the increase in the equivalent attenuation:

Load, dBm0	Additional attenuation, dB
+ 4	negligible
+ 5.5	0.5
+ 6.5	1
+ 8	2
+ 9.5	3
+13	6

RECOMMENDATION G.224

MAXIMUM PERMISSIBLE VALUE FOR THE ABSOLUTE POWER LEVEL (POWER REFERRED TO ONE MILLIWATT) OF A SIGNALLING PULSE[1]

The C.C.I.T.T. recommends that, for crosstalk reasons, the absolute power level (referred to 1 mW) of each component of a short duration signal should not exceed the values given in the following table:

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[1] This recommendation is the same as Recommendation Q.16 (Volume VI of the *White Book*); it applies both to national and to international signalling systems.

TABLE 1

Maximum permissible value, at a zero relative level point

Signalling frequency (Hz)	Maximum permissible power for a signal at a zero relative level point (microwatts)	Corresponding absolute power level	
		Decibels referred to 1 mW	Decinepers referred to 1 mW
800	750	−1	−1.1
1200	500	−3	−3.5
1600	400	−4	−4.5
2000	300	−5	−5.7
2400	250	−6	−7
2800	150	−8	−9
3200	150	−8	−9

Note 1. — If the signals are made up of two different frequency components transmitted simultaneously, the maximum permissible values for the absolute power levels are 3 dB or 3.5 dNp below the above figures.

Note 2. — The values given in this table result from a compromise between the characteristics of various channel filters now in existence.

RECOMMENDATION G.225 (amended in Geneva, 1964, and in Mar del Plata, 1968)

RECOMMENDATIONS RELATING TO THE ACCURACY OF CARRIER FREQUENCIES

a) *Accuracy of the virtual carrier frequencies on an international circuit or on a chain of circuits*

As the channels of any international telephone circuit should be suitable for voice-frequency telegraphy, the accuracy of the virtual carrier frequencies should be such that the difference between an audio-frequency applied to one end of the circuit and the frequency received at the other end should not exceed 2 Hz, even when there are intermediate modulating and demodulating processes.

To attain this objective, the C.C.I.T.T. recommends that the channel and group carrier frequencies of the various stages should have the following accuracies:

Virtual channel carrier frequencies in group	$\pm 10^{-6}$
Group and supergroup carrier frequencies	$\pm 10^{-7}$

Mastergroup and supermastergroup carrier frequencies

— for the 12-MHz system	$\pm 5 \cdot 10^{-8}$
— for the 60 MHz-system (above 12 MHz)	$\pm 10^{-8}$

Experience shows that, if a proper check is kept on the operation of oscillators designed to these specifications, the difference between the frequency applied at the origin of a telephone channel and the reconstituted frequency at the other end hardly ever exceeds 2 Hz if the channel has the same composition as the 2500-km hypothetical reference circuit for the system concerned.

Calculations indicate that, if these recommendations are followed, in the four-wire chain forming part of the hypothetical reference connection defined in Figure 1 of Recommendation G.103[1] there is about 1% probability that the frequency difference between the beginning and the end of the connection will exceed 3 Hz and less than 0.1% probability that it will exceed 4 Hz.

Note 1. — In small stations, i.e. in stations which do not need supergroup carrier frequencies, the accuracy of the group carrier may be ± 10^{-6}, which is the same as for channel carrier frequencies.

Note 2. — The modulating frequencies appropriate to (n+n) systems should have the accuracies recommended in the relevant recommendations:

Recommendation G.311 for 12-channel open-wire systems;
Recommendation G.361 for 3-channel open-wire systems;
Recommendations G.326 and G.327 for (12+12) cable systems.

b) *Measure of alignment of the master oscillators*

Recommendation a) above cannot be met without some measure of alignment of the master oscillators at the various stations in which modulation occurs.

Carrier-transmission systems are formed into "partial networks" extending over the whole or a part of a country. Synchronization of the master oscillators of a partial network is ordinarily based on national frequency comparisons; international comparisons may be made if necessary.

National frequency comparisons. — It is necessary that, within the same partial network of coaxial carrier systems, the master oscillators in stations where frequencies are generated should be "co-ordinated". This "co-ordination" can consist of a control of one oscillator with respect to another to give one of the following three conditions:

1) synchronization, i.e. identical frequency and fixed phase relationship;
2) isochronization, i.e. identical frequency only;
3) differential control to correct differences between the frequencies at intervals.

Also, automatic devices can be used to give an alarm if the difference in frequency between the checking pilot and a local oscillator exceeds a certain fixed value.

The C.C.I.T.T. has not recommended any particular method of comparing or controlling the master oscillators at different stations, and "routine frequency comparison" of the master oscillators may be thought sufficient, this comparison being followed if necessary

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[1] In fact, the chain considered for these calculations comprised 16 (instead of 12) modulator/demodulator pairs to allow for the possibility that submarine cables with equipments in conformity with Recommendation G.235 might form part of the chain. No allowance was made, however, for the effects of Doppler frequency-shift due to inclusion of a non-stationary satellite; values for this shift are given in C.C.I.R. Report 214-1, Volume IV(2) (Oslo, 1966).

by automatic or manual regulation, the master oscillators in each partial network being compared periodically with a national frequency standard, if possible.

The routine comparison of the frequencies generated by the master oscillators is made by means of a "frequency check pilot" transmitted to line for this purpose. It is not necessary to compare phases.

International frequency comparisons. — The case may arise, either of a country that has a national frequency standard with no facilities for distributing it throughout the country (particularly in an area in which a coaxial carrier system is to be set up) or of a country that has no national frequency standard. Recommendation M.54 (Volume IV of the *White Book*) describes methods by which such countries may obtain a standard frequency by radio, or may have a controlled frequency sent over a telephone circuit.

RECOMMENDATION G.226 (Recommendation G.223, Volume III of the *Red Book*)

NOISE ON A REAL LINK

a) *Cable systems*

It should be appreciated that designers are usually concerned, not with particular circuits or links, but with plant that will be used for the establishment of many links. It is not practicable for the C.C.I.T.T. to specify the performance of every real link that may be established, or for the designer to contemplate changing his design to suit the various lengths or other conditions on different real links. The C.C.I.T.T. has therefore defined hypothetical reference circuits, so that designers can be sure that, if their particular design of plant is used throughout a real circuit made up in the same way as a hypothetical reference circuit, the performance specified by the C.C.I.T.T. for the hypothetical reference circuit will be realized on that real circuit.

A real international link usually has a different make-up from that of the hypothetical reference circuit, and often includes equipments of different design. For each of these two reasons the performance to be expected from real links cannot be deduced uniquely from the recommendations relative to hypothetical reference circuits.

However, on a real homogeneous section it must be expected that the noise power measured at the time of commissioning, and with a conventional load as defined in paragraph 2 of Recommendation G.223, will be about the same as that calculated taking into account the particular composition of the real homogeneous section and the real parameters. There should be no cause for anxiety unless the measured noise power exceeds the calculated power by an appreciable amount, which might indicate a fault somewhere in the equipment. In such a case, every effort should be made to reduce the measured noise power to a value of the same order as that calculated.

b) *Radio links*

See C.C.I.R. Recommendation 395-1 (reproduced at the end of Recommendation G.441).

RECOMMENDATION G.227 (Geneva, 1964; amended in Mar del Plata, 1968)

CONVENTIONAL TELEPHONE SIGNAL

a) *Principle*

For the calculation or measurement of crosstalk noise between adjacent channels, and, generally speaking, when it is desired to simulate the speech currents transmitted by a telephone channel, the C.C.I.T.T. recommends that a conventional telephone signal be used, the main characteristic of which is a weighting network as a function of the frequency.

This network is defined by the following transfer coefficient as a function of the frequency:

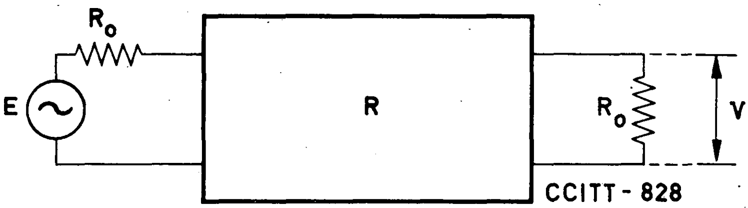


FIGURE 1

$$\frac{E}{2V} = \frac{18\,400 + 91\,238\,p^2 + 11\,638\,p^4 + p\,[67\,280 + 54\,050\,p^2]}{400 + 4001\,p^2 + p^4 \qquad + p\,[36\,040 + 130\,p^2]}$$

where $p = \mathrm{j}\,\frac{f\,(\mathrm{Hz})}{1000}$, *E and V* are defined by Figure 1.

The response curve of the network is shown in Figure 2, and an example of the design is given in Figure 3 and by the following values :

b) *Example of network design*

The network is made up of three bridged *T* sections with a constant characteristic impedance equal to R_0 ohms.

Figure 3 represents the network and indicates the values of the various components normalized to R_0.

A tolerance of ± 1 % can be allowed on the value of each component.

Note. — If θ_1, θ_2, θ_3 are the "composite" transfer coefficients of sections 1, 2 and 3 respectively, we have:

$$\frac{E}{2\,V} = e^{\theta} = e^{\theta_1 + \theta_2 + \theta_3}$$

with

$$e^{\theta_1} = \frac{46 + 90p + 46p^2}{1 + 90p + p^2}$$

$$e^{\theta_2} = \frac{20 + 11p}{20 + p}$$

$$e^{\theta_3} = \frac{20 + 23p}{20 + p}$$

with

$$p = \mathrm{j}\,\frac{f\,(\mathrm{Hz})}{1000}$$

The minimum "composite loss" of the complete network lies in the vicinity of 600 Hz and equals $a_0 \simeq 0.34$ neper for this example.

The curve in Figure 2 represents, as a function of frequency, the "composite loss" of the network in Figure 3 relative to the minimum loss a_0.

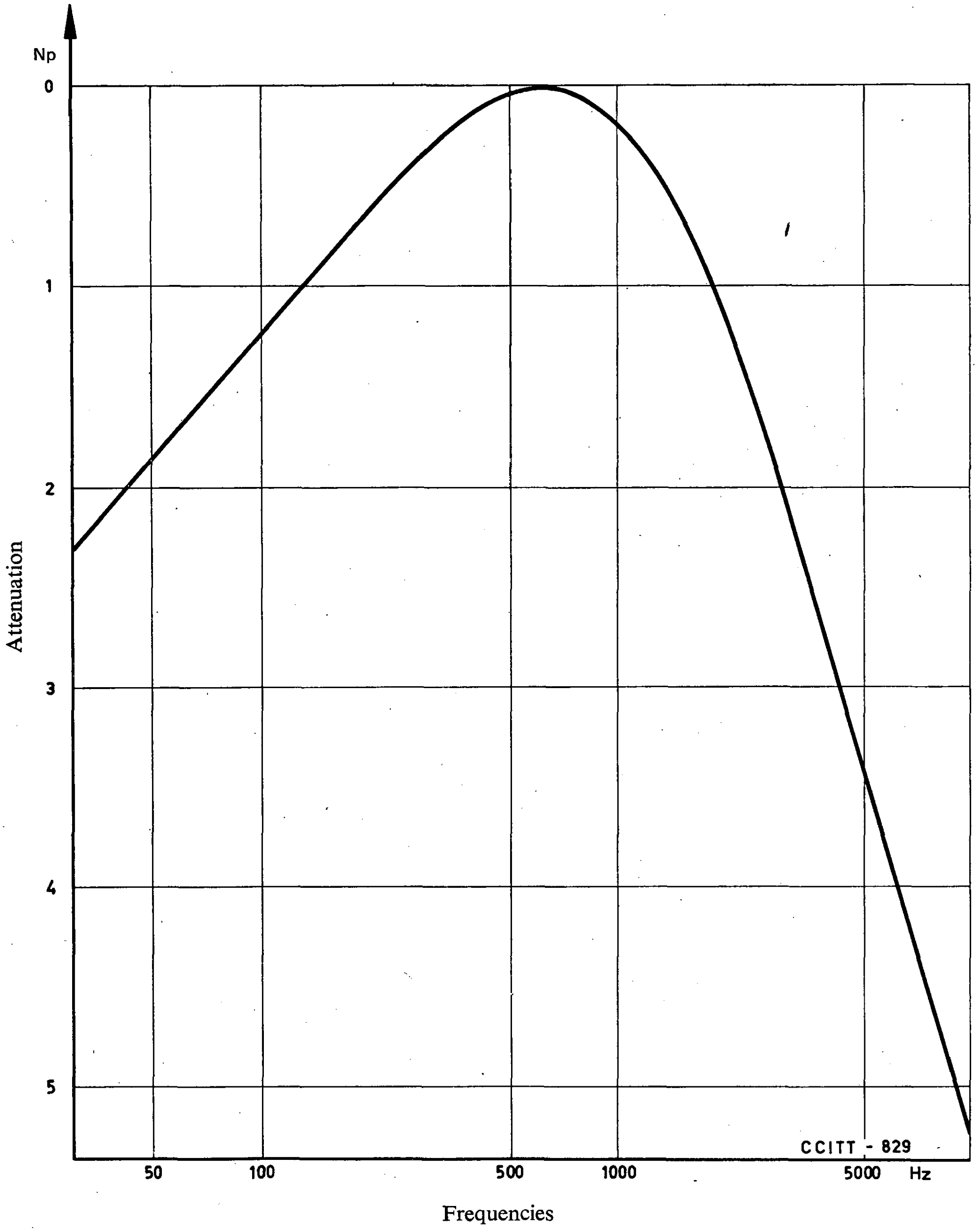
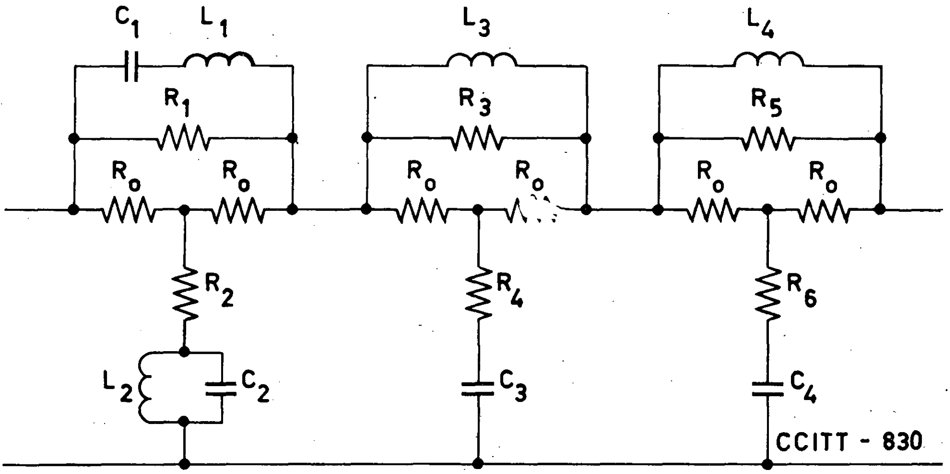


Figure 2. — **Relative response curve of the weighting network of the conventional telephone signal generator**



Section 1	Section 2	Section 3
$\frac{R_1}{R_0} = 45$	$\frac{L_1\,\omega_0}{R_0} = 0.5$	$R_0C_1\,\omega_0 = 2$
$\frac{R_2}{R_0} = 0.0222$	$\frac{L_2\,\omega_0}{R_0} = 2$	$R_0C_2\,\omega_0 = 0.5$
$\frac{R_3}{R_0} = 10$	$\frac{L_3\,\omega_0}{R_0} = 0.5$	$R_0C_3\,\omega_0 = 0.5$
$\frac{R_4}{R_0} = 0.1$	$\frac{L_4\,\omega_0}{R_0} = 1.11$	$R_0C_4\,\omega_0 = 1.11$
$\frac{R_5}{R_0} = 22$		
$\frac{R_6}{R_0} = 0.0455$		

with $\omega_0 = 2\pi \times 10^3 \times \text{second}^{-1}$

FIGURE 3. — **Weighting network of the conventional telephone signal generator**

c) *Signal at the network input*

The network may be energized either by a uniform-spectrum random noise signal or by a closely-spaced harmonic series. In the latter case, the following precautions are necessary:

1) spacing of the harmonics should not exceed 50 Hz;

2) the measuring instrument must have an adequate integrating time with respect to the fundamental period of the harmonic series. Types of C.C.I.T.T. instruments in general use, such as the psophometer, are believed to be satisfactory in this respect;

3) the peak/r.m.s. ratio of the signal should not exceed 3.5. This requirement may be achieved, in the case of a particular generator, by means of an associated phase-changing network;

4) the two methods (uniform-spectrum random noise and harmonic series) would give different results on subjective, e.g. aural, measurements, and such measurements should not, therefore, involve the use of the conventional telephone signal generator. That apparatus would be used solely for objective measurements, in which a psophometer served as measuring instrument.

RECOMMENDATION G.228 (Geneva, 1964, amended in Mar del Plata, 1968)

MEASUREMENT OF CIRCUIT NOISE IN CABLE SYSTEMS USING A UNIFORM-SPECTRUM RANDOM NOISE LOADING

a) *Principle*

The principle of the method of measurement described in C.C.I.R. Recommendation 399-1 (reproduced below) is of considerable interest also to the C.C.I.T.T., because it corresponds closely to the assumptions for calculation of noise (see Recommendation G.223) and because it has been applied successfully to radio-relay links.

The overall accuracy objective of the measuring equipment when used for routine maintenance measurements is ±2 dB. A higher accuracy is desirable when measurements are made for the purpose of assessing the noise performance of a system in relation to required performance.

The following measuring procedures and corrections are recommended for these types of measurement.

b) *Procedures*

1. *Signal load adjustment*

The loading power should be adjusted to the nominal value by means of a true r.m.s. level measuring device. The maximum error, including reading error, should not exceed ±0.15 dB.

2. *Receiver calibration*

The receiver should be calibrated with reference to the received signal immediately before insertion of a band elimination filter.

3. *Insertion of band elimination filters*

Only one band elimination filter should be inserted at a time. This limits errors in measurement of intermodulation noise.

4. *Readjustment of signal load*

Normally, the signal load should be readjusted to the nominal value after the insertion of a band elimination filter. When measurements are specifically to investigate second-order intermodulation, or when this is known to dominate, greater accuracy is obtained by readjusting only for the specified pass-band insertion loss of the band elimination filter.

5. *Measurement at receiver*

The noise density ratio is now measured as the change required in the setting of an attenuator to restore the pointer of an indicating instrument to the calibration value.

The foregoing is repeated for each measuring frequency.

c) *Corrections*

1. *Receiver calibration*

This should be corrected for the following effects:

Irregularity of the noise source. — The tolerance for the spectrum regularity is ±0.5 dB. A calibration table (or curve) should be available for each noise generator.

Errors of effective bandwidth. — This correction allows firstly for the difference between nominal occupied bandwidth of the systems under test and actual bandwidth between band-limiting filter effective cut-off frequencies, secondly for the difference between nominal occupied bandwidth and the total bandwidth actually occupied by telephone channels (i.e. 4 N kHz).

Pass-band discrimination of band-limiting filters at the measuring frequency. — These corrections should ensure calibration to an accuracy of ±0.2 dB.

2. *Band elimination filter effects*

The effective width of the band elimination filter causes a low reading in this measurement of third-order intermodulation noise. This error is proportional to the effective width (approximately the 3 dB points) of the filter relative to the system bandwidth. For a system using no pre-emphasis a slot of 1 % system bandwidth causes a low reading of about 0.05 dB. When pre-emphasis is used but total signal power is unchanged the error is increased in proportion to the increase of signal power density at the measuring frequency. Approximate corrections for this error are thus possible when the proportion of third-order intermodulation noise has been determined.

3. *Noise attributable to test equipment*

Corrections may be necessary if the signal-noise density ratio being measured is greater than about 55 dB (assuming a signal load corresponding to the conventional value) or if the relative level at the measuring point is very low.

d) *Overall accuracy*

After application of the corrections specified in C.1 measurements of pure thermal noise may be made with high accuracy (better than ±0.5 dB).

Assuming that corrections for effective slot width (paragraph C.2) are also made the overall measuring accuracy should be better than ±1 dB.

e) *Limitations of the noise loading measurement technique*

Although the measurements made at the specified frequencies may have an accuracy as defined above, the noise performance of a system between these frequencies cannot always be inferred accurately from these measurements. Whether this interpolation is justified or not has to be established for the system under consideration.

Intermodulation noise, notably that of the second-order type, on certain cable systems can vary by several dB as a function of this frequency, particularly at the low end of the transmitted band of frequencies. The total noise performance of a system may be evaluated, when necessary, by carrying out measurements and continuously varying the frequency, using additional test equipment.

C.C.I.R. RECOMMENDATION 399-1

RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION MULTIPLEX

Measurement of performance with the help of a signal consisting of a uniform spectrum

The C.C.I.R., (1956 — 1959 — 1963 — 1966)

Considering

a) that it is desirable to measure the performance of radio-relay systems for frequency-division multiplex telephony under conditions closely approaching those of actual operation;

b) that a signal with a continuous uniform spectrum (white noise) has statistical properties similar to those of a multiplex signal, when the number of channels is not too small;

c) that the use of a signal with a continuous uniform spectrum to measure the performance of such radio-relay systems is already widespread;

d) that it is necessary to standardize the frequencies and bandwidths of the measuring channels to be used for such tests;

e) that it is necessary to standardize the minimum attenuation and the bandwidth of the stop filters which may have to be used in the white noise generator;

f) that the C.C.I.T.T. has indicated, for the planning of telephone circuits, a mean value of speech power in a telephone channel to be taken into consideration during the busy hour (C.C.I.T.T. Recommendation G.222, *Red Book*, Vol. III);

Unanimously recommends

1. that the performance of frequency-division multiplex radio-relay systems should be measured by means of a signal of a continuous uniform spectrum in the frequency band used for the telephone channels;

2. that the nominal power level of the test signal with a uniform spectrum should be in accordance with the conventional load, specified in C.C.I.T.T. Recommendation G.222. If applied at the point of interconnection of the system corresponding to T' of C.C.I.R. Recommendation 380 the absolute power levels of interest are shown in column 4 of Table I;

TABLE I

1	2	3	4
Number of telephone channels	Relative power level at point *T'* (dBr)	Level of the conventional load (dBm0)	Nominal power level of the test signal at point *T'* (dBm)
60	−36	6.1	−29.9
120	−36	7.3	−28.7
300	−36	9.8	−26.2
600	−36 −33	12.8	−23.2 −20.2
960	−36 −33	14.8	−21.2 −18.2
1260	−33	16.0	−17.0
1800	−33	17.5	−15.5
2700	−33	19.3	−13.7

2.1 that the sending equipment should be capable of providing, at the output of an inserted band eliminating filter, a loading level at least up to + 10 dB relative to the nominal power level defined above;

2.2 that, within the bandwidth corresponding to the baseband of the system under test, the r.m.s. voltage of the white noise spectrum measured in a band of about 2 kHz should not vary by more than ± 0.5 dB. This degree of spectrum regularity should be met in the level range up to + 6 dB relative to the power level indicated in Table I, column 4. This is to ensure reliable calibration of the receiver by means of the test signal;

2.3 that the white noise test signal should be available at the output of the sending equipment with a peak factor of about 12 dB with respect to the r.m.s. value;

3. that the nominal effective cut-off frequencies (the cut-off frequencies of hypothetical filters having ideal square cut-off characteristics and transmitting the same power as the real filters) and tolerances, for the band-limiting filters proposed for the various bandwiths of systems to be tested, should be as specified in Table II. (To reduce the number of filters required, compromises have been made between the nominal effective cut-off frequency and the system bandwidth-limiting frequency in some cases. The tolerances ensure that consequent calibration errors do not exceed ± 0.1 dB and errors in measurement of intermodulation noise do not exceed ± 0.2 dB assuming system pre-emphasis conforming to Recommendation 275-1);

3.1 that the discrimination of a low-pass filter should be at least 20 dB at a frequency more than 10% above nominal cut-off and at least 25 dB at frequencies more than 20% above nominal cut-off. The discrimination of a high-pass filter should be at least 25 dB at frequencies more than 20% below nominal cut-off;

3.2 that to limit discrimination against measuring-channels, the spread of losses introduced by any pair of high-pass and low-pass filters should not exceed 0.2 dB over a range of frequencies which includes the outer measuring channels;

3.3 that in place of the measuring-channel frequencies previously recommended (8002 and 12 150 kHz) or proposed (5450 kHz) new frequencies of 5340, 7600 and 11 700 kHz are suggested. This is to ensure the highest accuracy consistent with reasonable spacing of the measuring channels and economy of design;

TABLE II

System capacity (channels)	Limits of band occupied by telephone channels (kHz)	Effective cut-off frequencies of band-limiting filters (kHz)		Frequencies of available measuring channels (kHz)
		High-pass	Low-pass	
60	60-300	60 ± 1	300 ± 2	70 270
120	60-552	60 ± 1	552 ± 4	70 270 534
300	60-1300 64-1296	60 ± 1	1296 ± 8	70 270 534 1248
600	60-2540 64-2660	60 ± 1	2600 ± 20	70 270 534 1248 2438
960	60-4028 64-4024	60 ± 1	4100 ± 30	70 270 534 1248 2438 3886
900	316-4188	316 ± 5	4100 ± 30	534 1248 2438 3886
1260	60-5636 60-5564	60 ± 1	5600 ± 50	70 270 534 1248 2438 3886 5340
1200	316-5564	316 ± 5	5600 ± 50	534 1248 2438 3886 5340
1800	312-8120 312-8204 316-8204	316 ± 5	8160 ± 75	534 1248 2438 3886 5340 7600
2700	312-12 336 316-12 388 312-12 388	316 ± 5	12 360 ± 100	534 1248 2438 3886 5340 7600 11 700

4. that values of the provisional characteristics for the discrimination in each stop band at the output of a sending equipment are given in Table III; these characteristics are intended to apply over a temperature range from 10°C to 40°C;

5. that when connected directly to a transmitting equipment provided with band elimination filters which only just meet the requirements of § 4 a minimum signal-noise density ratio of 67 dB shoult be indicated by the receiving equipment; this requirement applies when a nominal conventional load is applied :

5.1 that the minimum effective bandwidth of the receiver should be 1·7 kHz;

6. that additional measuring channels may be provided by agreement between the Administrations concerned.

Note. — An overall accuracy of ± 2 dB or better is assumed for the measurement of radio-relay systems in operation. Attention is also drawn to C.C.I.T.T. Recommendation G.228 which discusses the method of measurement.

TABLE III

Centre frequency f_c (kHz)	Bandwidth (kHz) in relation to f_c, over which the discrimination should be at least			Bandwidth (kHz), in relation to f_c, outside of which the discrimination should not exceed	
	70 dB	55 dB	30 dB	3 dB	0.5 dB
70	± 1.5	± 2.2	± 3.5	± 12	
270	± 1.5	± 2.3	± 2.9	± 8	
534	± 1.5	± 3.5	± 7.0	± 15	
1248	± 1.5	± 4.0	± 11.0	± 35	
2438	± 1.5	± 4.5	± 19.0	± 60	
3886	± 1.5	± 15.0	± 30.0	± 110	
		± 1.8	± 3.5	± 12	± 100
5340	± 1,5	± 2.2	± 4.0	± 14	± 140
7600	± 1.5	± 2.4	± 4.6	± 16	± 200
11 700	± 1.5	± 3.0	± 7.0	± 20	± 300

Note 1. — The discrimination values quoted are relative values referred to the attenuation of the band-stop filters at the lowest baseband frequency.

Note 2. — The characteristics recommended for the filters 70 kHz to 2438 kHz inclusive are based on coil-capacitor type filters. Those characteristics recommended for the filters at 5340 kHz and above are based on crystal-type filters. Optional characteristics are recommended for the 3886 kHz filter to permit a choice of design between a coil-capacitor type or crystal-type filter.

Note 3. — The design of the receiver selectivity of 3886 kHz should be related to the characteristic of the crystal-type band-stop filter.

2.3 Translating equipment used on various carrier-transmission systems

RECOMMENDATION G.231 (amended in Geneva, 1964, and in Mar del Plata, 1968)

ARRANGEMENT OF CARRIER EQUIPMENT

A. CARRIER-SYSTEM RACKS

The C.C.I.T.T.,

considering

that countries not having a national industry for the construction of carrier systems must obtain them from different factories, and that the variations of the dimensions of the racks between different sources of supply do not allow of a simple and economical lay-out of the cables and efficient use of accommodation,

unanimously recommends

that in future the dimensions of carrier-system racks should meet these requirements as follows:

Space between suites. — The minimum space between suites should be such that it is possible to move test trolleys from place to place (between two suites), and also for maintenance staff to be able to work comfortably between two suites. A spacing of 75 centimetres (29½ in.) at least seems reasonable.

Overall height. — The overall height of a rack above the floor (not including the space provided for overhead cable runs) should not exceed 320 centimetres (126 in.).

In principle, 30 centimetres (11.8 in.) should be allowed for overhead cable runs, and also about 30 centimetres (11.8 in.) for access to these cables, which makes at the most 60 centimetres (23.6 in.) between the top of the rack and the ceiling; nevertheless, some administrations consider that a total height of 40 centimetres (15.8 in.) between the top of the rack and the ceiling is sufficient in certain cases. In main repeater stations (or terminal equipment stations), where, in addition to cables connecting one rack to another, general distribution cables have to be allowed for, it is recommended that the height of the building between the floor and the ceiling should be at least 4 metres (13 ft 2 in.) to facilitate access to the various cables.

Thickness. — The thickness of a rack should not be greater than 45 cm (17.7 in.)

B. USE OF STANDARD COMPONENTS IN TRANSMISSION EQUIPMENT[1]

While acknowledging that the International Electrotechnical Commission (I.E.C.) is competent to device standards for components or devices generally used in electrical engineering, the C.C.I.T.T. nevertheless reserves the right to issue recommendations dealing with such equipment and with transmission systems which, if components standardized by the I.E.C. were used, may prove impossible to create.

Furthermore, manufacturers and administrations wishing to use components specified by the I.E.C. or by another body will still be responsible for ensuring that the recommendations issued by the C.C.I.T.T. are met.

Hence the C.C.I.T.T. recommends:

That administrations and manufacturers should ensure that all components used in transmission systems and equipments (even if such components have been standardized by some other national or international body) are such that the requirements of C.C.I.T.T. recommendations will be complied with in the conditions of use envisaged, throughout the life of the equipment or systems, i.e. twenty years or more.

C. POWER SUPPLY

For modern carrier system equipment fitted with transistors, it is recommended that power supply equipment should provide a no-break supply when the power mains fail.

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[1] This recommendation applies both to carrier systems and to audio equipment.

D. REPEATER STATION CABLING [1]

The administrations mentioned in the list kept by the C.C.I.T.T. Secretariat are prepared to supply other administrations and technical assistance experts working under the I.T.U. with information on the national standards they apply to the wiring of repeater stations. However, they would warn users that cable specifications and wiring diagrams are not always the best way of giving them the information they desire. The documentation available is very bulky and requests for information should be reasonably precise, since it is essential to know exactly on what point information is required in order to decide what form the reply should take.

A proper understanding of how wiring is done in repeater stations cannot be acquired from documents alone and the persons concerned should get in touch with the administrations on the list in order to see the methods put into practice.

Administrations are invited to supply information to keep this list, which is deposited with the C.C.I.T.T. Secretariat, constantly up to date.

RECOMMENDATION G.232 (modified in Geneva, 1964, and in Mar del Plata, 1968)

12-CHANNEL TERMINAL EQUIPMENTS

The C.C.I.T.T. recommends that, except in the particular cases cited in Recommendations G.234 and G.235, channel terminal equipments forming 12 channels in a basic group, with 4-kHz spaced carrier frequencies, should conform to the present recommendation.

A. ATTENUATION DISTORTION

The following three conditions should be satisfied simultaneously:

1. The variation with frequency of the mean of the overall losses of the 12 pairs of channel transmitting and receiving equipments of one terminal equipment should not exceed the limits shown in Graph No. 2 A of Figure 1.

2. For each pair of channel transmitting and receiving equipments of one terminal equipment, the variation of overall loss with frequency should not exceed the limits shown in Graph No. 2 B of Figure 1.

3. For the transmitting equipment of any channel, the attenuation frequency distortion should not exceed the limits in Graph No. 2 C of Figure 2 where:

- the frequencies shown as abscissae are audio frequencies, before modulation,
- the ordinates give the limits of relative power level measured at carrier frequency.

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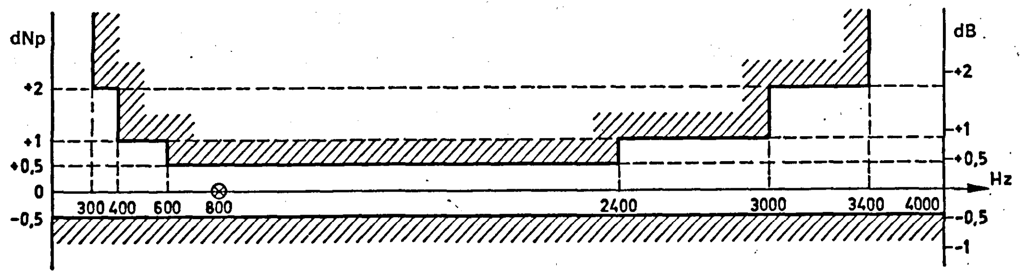
[1] This recommendation applies both to carrier systems and to audio equipment.

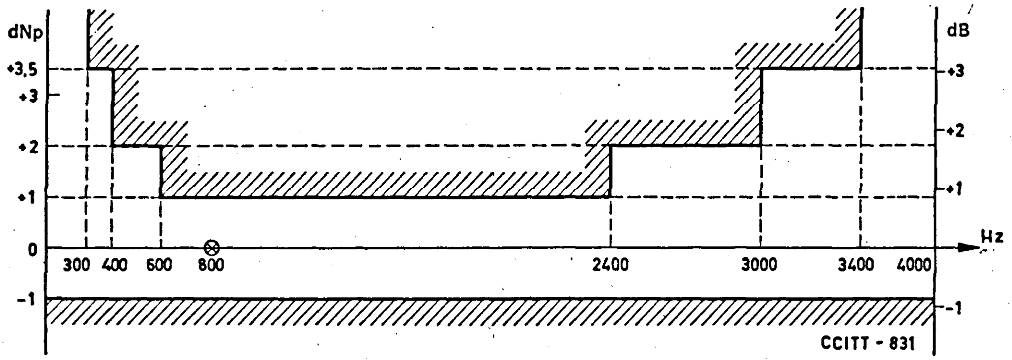
For the receiving equipment of any channel, the attenuation frequency distortion should not exceed the limits of this same Graph No. 2 C where, this time:

— the frequencies shown as abscissae are audio frequencies after demodulation,

— the ordinates give the limits of relative power level measured at each frequency, at the audio output terminals.



Graph No. 2 A. — **Limits for the average variation of overall loss of 12 pairs of equipments of one 12-channel terminal equipment**



Graph No. 2 B. — **Limits for any pair of channel transmitting and receiving equipments**

Figure 1. — **Permissible limits for the variation with frequency of the overall loss of one pair of channel transmitting and receiving equipments of one 12-channel terminal equipment**

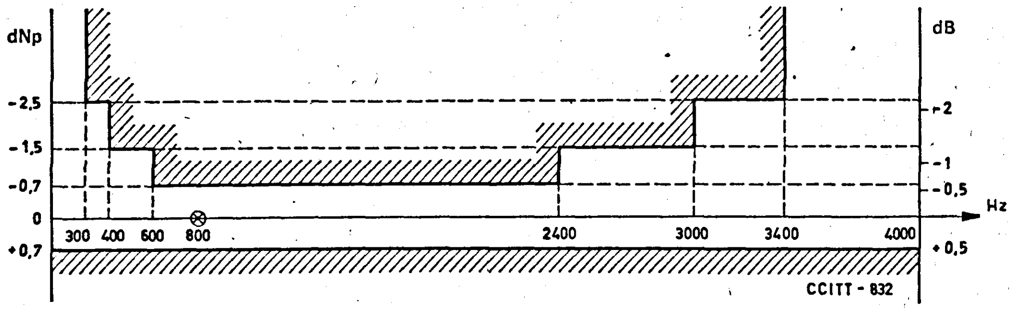


Figure 2. Graph No. 2 C. — **Allowable limits for the variation, as a function of frequency, of the relative power level at the output**

— of the sending equipment of any channel,

— of the receiving equipment of any channel of a 12-channel terminal

This last recommendation (paragraph 3) is based on the assumption that the transmitting and receiving equipments will be treated on an equal footing, and that the overall tolerances will be equally shared between the transmitting and receiving sides.

Note. — Some countries use, for circuits interconnecting international centres of the higher orders, i.e. CTIs and CT2s (international transit centres), channel-translating equipment that gives an improved loss-frequency response by comparison with equipment meeting the above recommendation. (See Supplement No. 7 of this volume.) Such equipment does not incorporate out-band signalling.

B. LIMITS FOR THE RESPONSE OUTSIDE THE BAND 300 TO 3400 Hz

This question is being studied by the C.C.I.T.T. (Question 3/XV).

C. GROUP DELAY

The C.C.I.T.T. does not recommend limiting values for the group delay at different frequencies. For information, the following Table 1 indicates typical values for equipments of four administrations as well as the values which should be met on a chain of 12 circuits.

TABLE 1

	Frequency (Hz)	300	400	2000	3000	3400
Readings (in ms) measured on a pair of equipments	Belgium (b)	4	2.7	1	1.3	2.6
	France (b)	4.2	2.9	1	1.4	2.8
	F. R. of Germany (b)	3.9	2.7	1.2	1.6	3
	United Kingdom (a) (b)	2.6 4.2	2.2 2.7	1 1.2	1.4 1.8	2.6 3.4
Typical values (in ms) for 12 pairs of equipments		50	35	14	22	41

(a) With in-band signalling
(b) With out-band signalling

D. STABILITY OF VIRTUAL CARRIER FREQUENCIES

See Recommendation G.225.

E. CARRIER LEAK TRANSMITTED TO LINE

The carrier leaks are measured at the group distribution frame (or an equivalent point).

The absolute power level of these leaks, referred to a point of zero relative level, should be lower than the following values:

Carrier leak measured on one channel: —26 dBm0

Sum of carrier leak powers of the various channels, measured within a group: —20 dBm0

However, if the group is transmitted via open-wire lines over the whole or part of its length, and if it is desired to guard against the risk of conversations exchanged over the open-wire line being picked-up by an ordinary wireless receiver, the carrier leak must be further reduced.

The place and method to be used for the supplementary suppression of carrier leak, when a group on a cable is transferred to an open-wire line, should be agreed by the administrations concerned.

F. PROTECTION AGAINST HARMFUL VOLTAGE SURGES, CLICKS, ETC.

Experience has shown that it may be necessary to protect carrier equipment against harmful voltage surges arising, for example, from clicks caused by switching equipment or by low-frequency ringing currents.

Some protection against these harmful voltage surges derives from the use by various administrations of terminations giving a high-pass filter effect and having a high loss for frequencies below 300 Hz, or from limiting devices which are either normally fitted in their carrier systems or which can be inserted in the termination. Other arrangements can also be used.

G. LINEARITY

The curve representing the variation (as a function of power), of the overall loss per channel of a combination of sending and receiving terminal equipments should be within the limits of Figure 3 (Graph No. 3), the measurements of the output power being made by means of a square law device.

H. AMPLITUDE LIMITING

The sending equipment of an individual channel, with the addition of a limiter where necessary, must produce the limiting effect defined as follows: for any sine wave signal, at any frequency between 300 and 3400 Hz applied at the input at any level not exceeding 20 dBm0 (2.3 Nm0), the level of the high-frequency output signal, measured by means of a quadratic law aperiodic device and referred to zero relative level, should not exceed 12 dBm0 or 1.4 Nm0.

J. CROSSTALK

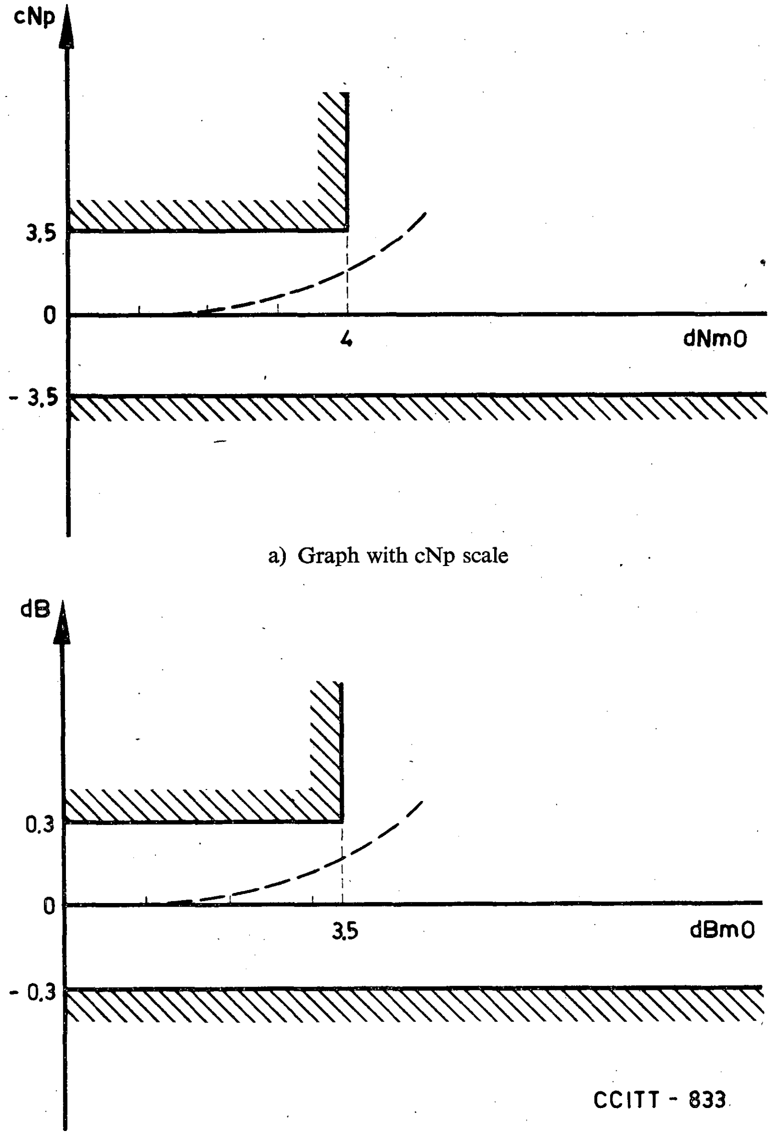
a) *Intelligible inter-circuit crosstalk*

The crosstalk ratio (intelligible crosstalk only) measured between two carrier channels of the same group should not be less than 65 dB or 7.5 Np.

To check that this limit is met, measurement can be restricted to testing with a frequency of 800 Hz with a power of 1 milliwatt at a point which would be at zero relative power level under normal working conditions. The measurement can also be made by means of a wave analyser.

b) *Intelligible crosstalk between adjacent channels*

The crosstalk produced in an adjacent channel by an unwanted sideband, as a result of imperfect suppression by the channel filter, is inverted and is thus unintelligible. However, such crosstalk may have speech-like rhythm and the annoyance produced by a loud talker be limited.



a) Graph with cNp scale

b) Graph with dB scale

FIGURE 3. Graph No. 3. — **Permissible limits for the variation with applied audio power level, of the overall loss of the combination of sending and receiving 12-channel terminal equipments. The curve shows the variation of overall loss as a function of the power level applied to the audio input terminals of one channel and referred to the overall loss when the applied power is 1 mW**

To check that the suppression is adequate the following method is applied. The disturbed circuit is terminated at its sending end and the disturbing channel is loaded with a uniform spectrum-random-noise signal shaped in accordance with the speech power density curve given in Recommendation G.227.

The power applied to the channel should not exceed 1 mW at a zero relative level point, so as to avoid the influence of the channel limiter.

Using a psophometer, the noise produced in the disturbed channel is then compared with the signal applied to the disturbing channel and the result is expressed as a crosstalk power ratio. The value obtained (making allowance, where necessary, for basic or other noise present on the disturbed channel, independently of the crosstalk being measured) should be at least 60 dB or 6.9 Np.

c) *Go-to-return intelligible crosstalk of any channel within a group*

This recommendation will relate only to intelligible crosstalk measured between the audio-frequency distribution frame and the group distribution frame, including the station wiring (although it is thought that the crosstalk under consideration comes chiefly from the channel terminal equipments).

The near-end crosstalk ratio measured between the "Audio in" point of each channel and the correspondingly numbered "Audio out" point (see Figure 4) should be at least *X* dB when the high-frequency access points are suitably terminated.

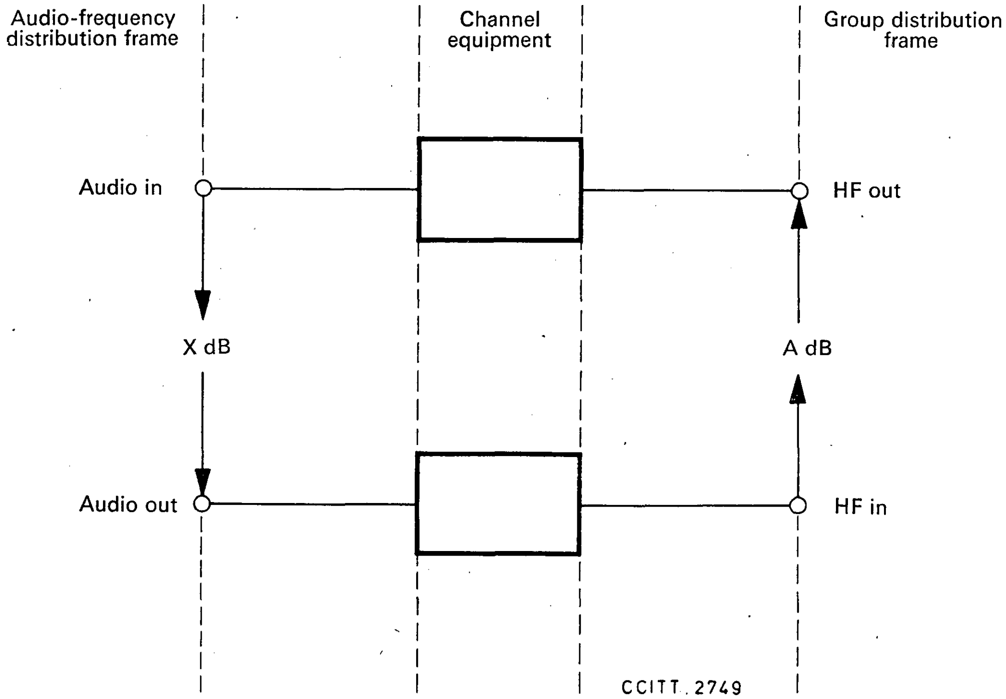


FIGURE 4

In addition, the near-end crosstalk ratio measured between the "h.f. in" and the "h.f. out" points shall be at least A dB when the audio points are appropriately terminated.

For the values defined in this way, the C.C.I.T.T. provisionally recommends the following figures which are minimum values to be included in specifications (not objectives):

For all channels $X = 50$, $A = 44$ dB.

Between the channels of circuits which may be used with echo suppressors or call concentrators, $X = 65$ dB, $A = 59$ dB.

Note. — Some administrations consider that better values than those indicated above for all channels can be satisfied in all cases without additional complications.

K. NOISE

Recommendation G. 222 refers to the noise produced by channel translating equipments.

L. IMPEDANCE SEEN FROM THE SWITCHBOARD JACKS

The nominal values of the impedance of the trunk circuits (seen from the manual switchboard jack or from the automatic selector) should be the same for all circuits connected to the same trunk exchange. It is recommended that, if possible, future carrier system terminal equipments should be designed to have a value of 600 ohms for the impedance of national or international trunk circuits.

M. PROTECTION AND SUPRESSION OF PILOTS

With the use of group and supergroup pilots certain problems arise from mutual interference between pilots and between pilots and telephony.

Group and supergroup pilots have been treated separately in the paragraphs below where forms of interference, excluding effects of out-band signalling, are covered and recommendations made.

Specific recommendations on out-band signalling have been excluded owing to a lack of detailed standardization of signalling characteristics; however, certain general principles and their application to particular out-band systems have been included as a guide for an approach to the problem.

Note. — Throughout this section M, and in Annexes 1 and 2 at the end of it, it is assumed that the pilots used are, on the one hand, at the frequencies 84.080 and 84.140 kHz, and, on the other, at 411.920 and 411.860 kHz. If the pilots 104.080 kHz and 547.920 kHz are used, the same provisions apply with the following changes:

Channels 1 and 2 are associated with the group pilot at 104.080 kHz (just as channels 6 and 7 are associated with the pilot at 84.080 kHz).

The interference frequency at 64.080 kHz in group 5 and channels 11 and 12 are associated with the supergroup pilot at 547.920 kHz (just as the interference frequency at 104.080 kHz in group 3 and channels 1 and 2 are associated with the pilot at 411.920 kHz).

a) *Protection and suppression of the group reference pilot*

In view of the various possibilities of interference indicated in Annex 1 to this recommendation, it is recommended that the terminal equipment of a 12-channel group should conform to the attenuation/frequency requirements of Table 2.

TABLE 2

Pilot frequency (kHz)	Channel No.	Interference frequency (Hz)	Minimum loss (relative to 800-Hz loss)			
			Send equipment		Receive equipment	
			dB	Np	dB	Np
(1)	(2)	(3)	(4)		(5)	
84.080	6	3920	20	2.3	40	4.6
	7	-80	20	2.3	20	2.3
84.140	6	3860	20	2.3	35	4.0
	7	-140	30	3.4	20	2.3

The required attenuation at the equivalent frequencies of −80 and 3920 Hz or −140 and 3860 Hz may be obtained by a combination of audio filters, h.f. channel filters and bandstop filters at the discretion of the administration concerned. It is, however, noted that, when there is a non-linear device (such as a channel modulator operated as a limiter) (see section H in this recommendation) between a.f. and h.f., filtration on the a.f. filters could have a much reduced effect on high level a.f. interference signals compared with the effect on low level signals. The relative losses quoted in columns (4) and (5) of table 2 are the total effective losses required after the inclusion of a limiter.

All the attenuation values indicated above should be obtained over a band of at least ±3 Hz relative to the nominal pilot frequency for the pilot at 84.080 kHz and ±5 Hz for the pilot at 84.140 kHz for both send and receive sides. This bandwidth allows for the tolerances on the pilot (Recommendation G.241, c) and for the possible frequency variations on an international circuit (Recommendation G.225, a).

In addition, on the send side, the attenuation over a band of ±25 Hz relative to the nominal frequency of the pilot should be such that the total energy of a white noise signal occupying that bandwidth is attenuated by at least 20 dB (2.3 Np) (see Annex 1). Any unwanted signals falling within this band are liable to be within the passband of the pilot pick-off filter and may cause interference with an automatic gain regulator, measuring equipment, etc.

b) *Protection and suppression of the supergroup reference pilots*

Considerations analogous to those outlined in the previous paragraph lead to the recommending of identical values but now applying to channels 1 and 2 of the terminal equipments (instead of channels 6 and 7 respectively). However, the total attenuation required may be obtained, at the discretion of the administration concerned, either in the channel terminal equipment or in the group-translating equipment (using blocking filters either at 104.140 kHz or 104.080 kHz in group 3 of the group-translating equipment or at 411.860 kHz or 411.920 kHz), or as a combination of the two equipments. The precautions to be taken against such interference in the channel equipment have therefore to be determined in relation to the precautions taken in the group equipment (Recommendation G.233, i).

The total attenuation required is indicated in the following Table 3.

TABLE 3

Pilot frequency. (kHz)	Disturbing frequency in the basic group 3 (kHz)	Channel No.	Disturbing frequency in the channel (Hz)	Minimum attenuation relating to 800 Hz			
				Sending		Receiving	
				dB	Np	dB	Np
(1)	(2)	(3)	(4)	(5)		(6)	
411.920	104.080	1	3920	20	2.3	40	4.6
		2	–80	20	2.3	20	2.3
411.860	104.140	1	3860	20	2.3	35	4.0
		2	–140	30	3.4	20	2.3

Remarks, the same as in the previous paragraph, relative to the frequency bands in which these values of attenuation are necessary remain valid in the present case. However, the attenuation in the sending side, within a band of ±25 Hz relative to the nominal frequency of the supergroup pilot, may with difficulty be obtained at other than voice frequency.

c) *Mutual interference between pilots and out-band signalling*

In the specification of equipment intended for use with out-band signalling, account should be taken of the mutual disturbance between signalling and pilots, and calculation made for each case of the protection necessary as a function of the parameters of the signalling system, according to the following principles:

1. *Protection of pilots*

When the signalling current is interrupted at the different speeds determined by the signalling code, the level of the signalling interference resulting in a band of ± 25 Hz on either side of the pilot frequency should remain at least 20 dB (2.3 Np) below the level of the pilot.

If the transmission of the signalling current is of very short duration compared with the time constant of the regulator, a higher level of interference could be tolerated. Precautions should nevertheless be taken to protect the pilot against continuous transmission of signals under fault conditions.

2. *Protection of signalling*

It is necessary to ensure that signalling requirements in respect of such factors as signalling, distortion, etc, are met for all out-band signalling channels, even when adjacent to a reference pilot frequency.

Note. — When an out-band signalling system is used, consideration should also be given to the mutual interference of both speech and signalling. In general the attenuation required from this aspect is in itself sufficient to afford protection for pilots.

An example of the application of these rules, where it is assumed that the level of the pilot residue should be no higher than 10 dB or 1.2 Np below the threshold of sensitivity of the signalling receiver, is considered in Annex 2.

ANNEX 1

(to Recommendation G. 232)

Calculation of the attenuation necessary for protection or suppression of pilots

A. INTERFERENCES AT THE END OF A GROUP LINK DUE TO THE USE OF A GROUP REFERENCE PILOT

1. *Disturbance of telephone by group reference pilots*

It is assumed that the maximum level of interference permissible in a telephone channel due to a group reference pilot is –73 dBm0p or –8.4 Nm0p. The disturbed channels are Nos. 6 and 7.

Table 4 below gives the total minimum additional suppression necessary in the receiving channel equipment, between the carrier-frequency input and the audio-frequency output, relative to the nominal loss of the telephony signal.

TABLE 4

Pilot frequency (kHz)	Pilot level	Channel No.	Interfering frequency in the channel (Hz)	Psophometric weighting at the interfering frequency		Minimum attenuation	
				dB	Np	dB	Np
84.080	–20 dBm0 (– 2.3 Nm0)	6 7	3920 –80	13 48	1.5 5.5	40 5	4.6 0.6
84.140	–25 dBm0 (– 2.9 Nm0)	6 7	3860 –140	13 31	1.5 3.6	35 17	4.0 1.9

Note. — Psophometric weights have been rounded off, allowance being made for the tolerances set forth in Recommendation P.53, Volume V of the *White Book.*

2. *Disturbance of group reference pilots by telephone channels*

Interference may be caused to the G.R.P. from signals close to or at 80 Hz (84.080-kHz pilot) or 140 Hz (84.140-kHz pilot) in channel 7 and 3920 Hz or 3860 Hz in channel 6. The difficulty here is in defining the character of the interfering signal and that of the instrument suffering from the interference. Certain test have shown that the major source of interference is sporadic interference (key clicks, mechanical disturbance of microphone, etc.) at low frequencies in channel 7.

However, 20 dB of suppression at 80 Hz from an audio high-pass filter was quite adequate when considering the effect on a gain regulator having a long-time constant. The regulator characteristics were as follows:

84.080-kHz pick-off filter ± 25 Hz (3-dB points).

Operation of automatic gain regulator (according to r.m.s. value): 4-dB step change in pilot level controlled to 0.2 dB of final value in 45 seconds.

When considering interference on a recorder chart this 20 dB of suppression was found inadequate and 64 dB at 80 Hz was needed with the particular recorder equipment used to ensure interference "spikes" of less than 0.02 dB due to the telephony interference. Nevertheless, as a general working figure, 20 dB of suppression at 80 Hz (for a pilot frequency of 84.080 kHz) is thought suitable for general recommendation. 3920-Hz interference from channel 6 (again considering the 84.080-kHz pilot) has caused no difficulty with 20 dB suppression, and, while less would probably be adequate from the aspect of regulator interference, this figure is nevertheless recommended as one that is readily achieved in channel terminal equipment.

Corresponding figures have been derived for the suppression of interference with the 84.140-kHz pilot from telephony channels. It is assumed here that the energy frequency distribution of the telephony interference accords with the curve of Recommendation G.227. Further, the bandwidth of the pilot measuring filter is assumed to be ± 25 Hz about the pilot frequency, and the permissible interference is the same as that recommended above.

Table 5 gives the total minimum additional attenuation necessary in the sending side of channel terminal equipments, between the audio-frequency input and the carrier-frequency output, relative to the nominal attenuation of the telephony signal.

TABLE 5

Pilot frequency (kHz)	Pilot level	Channel No.	Disturbing frequency in the channel (Hz)	Minimum attenuation	
				dB	Np
84.080	−20 dBm0 (− 2.3 Nm0)	6 7	3920 -80	20 20	2.3 2.3
84.140	−25 dBm0 (− 2.9 Nm0)	6 7	3860 -140	20 30	2.3 3.4

3. *Interference between two-group reference pilots*

a) At the end of a group link where the 60-108 kHz band is broken down to 12 speech channels, the group pilot will give rise to an audio signal in channels 6 and 7 as indicated in paragraph 2 above. If either of these channels is used in the same channel position of a further group link the audio-interference signal will be translated to the frequency of the group pilot and will interfere with the group pilot associated with the second group link.

A total of 40 dB (4.6 Np) is required to suppress the interference to a tolerable level and this must be obtained in both channels 6 and 7. This loss may from some aspects preferably be all in the "receive", and from others all in the "send" side.

A generally acceptable working rule, however, is that at least 20 dB (2.3 Np) be provided in both transmission directions.

b) A further possible source of interference between one group pilot and another is the interconnection between the receive and send sides of a channel 6 or of a channel 7, although only the latter is likely to be significant and need be considered. If the balance return loss of the two-four-wire termination of channel 7 and the losses of associated circuitry are low at 80 Hz, the 80-Hz or 140-Hz signal derived from the incoming group pilot will be reconverted to 84.08 kHz or 84.14 kHz in the send side and beat with the locally generated outgoing group pilot. The total attenuation in the receive-to-send loop should exceed 40 dB (4.6 Np).

B. INTERFERENCE AT THE END OF A SUPERGROUP LINK OR A GROUP LINK DUE TO THE USE OF A SUPERGROUP REFERENCE PILOT

Similar considerations apply when a supergroup pilot is used as are set out in part A of this Annex in respect of the use of a group pilot, the channels concerned in the case of a supergroup pilot being channels 1 and 2 of group 3. The disturbing frequencies in these channels are 3930 Hz and −80 Hz for the 411.920-kHz pilot, and 3860 Hz and −140 Hz for the 414.860-kHz pilot.

1. *Interference with telephony channels by the supergroup reference pilot*

Following the calculations in paragraph A-1 of the present Annex, the minimum necessary attenuations are, according to the pilot used:

Channel 1 (receiving):	40 dB (4.6 Np) at 3920 Hz
	35 dB or 4.0 Np at 3860 Hz
Channel 2 (sending) :	5 dB or 0.6 Np at −80 Hz
	17 dB or 1.9 Np at −140 Hz

2. *Interference with supergroup reference pilots by telephone channels*

Following the calculations in paragraph A-2 of the present Annex, the minimum necessary attenuations are, according to the pilot used:

Channel 1 (sending) :	20 dB (2.3 Np) at 3220 Hz
	20 dB (2.3 Np) at 3860 Hz
Channel 2 (receiving):	20 dB (2.3 Np) at −80 Hz
	30 dB or 3.4 Np at −140 Hz

3. *Interference between two supergroup reference pilots*

Following the considerations of paragraph A-3 a total attenuation of at least 40 dB (4.6 Np) is necessary at the frequency of a residual signal from a received supergroup reference pilot which, after modulation, is transposed to the frequency of the supergroup reference pilot emitted at the origin of the next supergroup section.

The total attenuation (sending plus receiving) concerns channels 1 and 2.

Moreover, in the case of tandem connection of two groups each occupying position 3 in two supergroups, interference may be produced between the two supergroup reference pilots; hence a total attenuation of at least 40 dB or 4.6 Np is necessary in the translating equipment of group 3 (sending plus receiving).

ANNEX 2

(to Recommendation G. 232)

Example of reciprocal protection of pilots and out-band signalling

The following three cases may be considered (see Recommendation Q.21, Volume VI of the *White Book*):

- — Virtual carrier frequency signalling, at level −3 dBm0 (−0.35 Nm0)
- — 3825-Hz high level: −5 dBm0 (−0.6 Nm0)
- — 3825-Hz low level: −20 dBm0 (−2.3 Nm0)

A pilot at 84.140 kHz (at a level of −25 dBm0 (−2.9 Nm0)) is associated with virtual carrier frequency signalling and a pilot at 84.080 kHz (at a level of −20 dBm0 (−2.3 Nm0)) with 3825-Hz signalling.

1. *Protection of pilots*

Assuming that the signalling current is interrupted at 10 Hz (50-50 ms) one finds that the attenuation necessary in the send side of channel 6 in the signalling or channel equipment is:

— Virtual carrier frequency signalling: 21 dB or 2.4 Np at 3860 ± 25 Hz
— 3825-Hz high level: 17 dB or 2.0 Np at 3920 ± 25 Hz
— 3825-Hz low level: 2 dB (0.2 Np) at 3920 ± 25 Hz

2. *Protecting of signalling*

Assuming that the threshold of sensitivity of the receiver is 11 dB (1.3 Np) below the nominal level of the signalling, one finds that the attenuation required in the receiving side of channel 6 in the signalling or channel equipment is:

— Virtual carrier frequency signalling: zero
— 3825-Hz high level: 6 dB (0.7 Np) at 3920 ± 3 Hz
— 3825-Hz low level: 21 dB or 2.4 Np at 3920 ± 3 Hz.

RECOMMENDATION G.233 (amended in Geneva, 1964, and in Mar del Plata, 1968)

RECOMMENDATIONS CONCERNING TRANSLATING EQUIPMENTS

This Recommendation concerns translating equipments with the exception of:

— channel-translating equipment, in respect of which Recommendations G.232, G.234 and G.235 should be consulted;
— equipment for translation into the line frequency band; the recommendations relating to the various line systems should be consulted.

a) *Translating procedure*

The procedures whereby the translating equipments defined in Recommendation G.211 translate basic groups, supergroups and mastergroups or a basic 15-supermastergroup assembly (No. 1) are represented by the following figures:

1. Figure 1 for group-translating equipments (procedures 1 and 2);
2. Figure 2 for supergroup-translating equipments (procedure 1);
3. Figure 3 for mastergroup-translating equipments (procedure 1);
4. Figure 4 for supergroup-translating equipments (procedure 2);
5. Figure 5 for translating equipments for basic 15-supergroup assembly (No. 1) (procedure 2).

Note. — Equipments 4 and 5 above are peculiar to procedure 2 described in Recommendation G.211. The conditions in which this procedure is used are described in that recommendation.

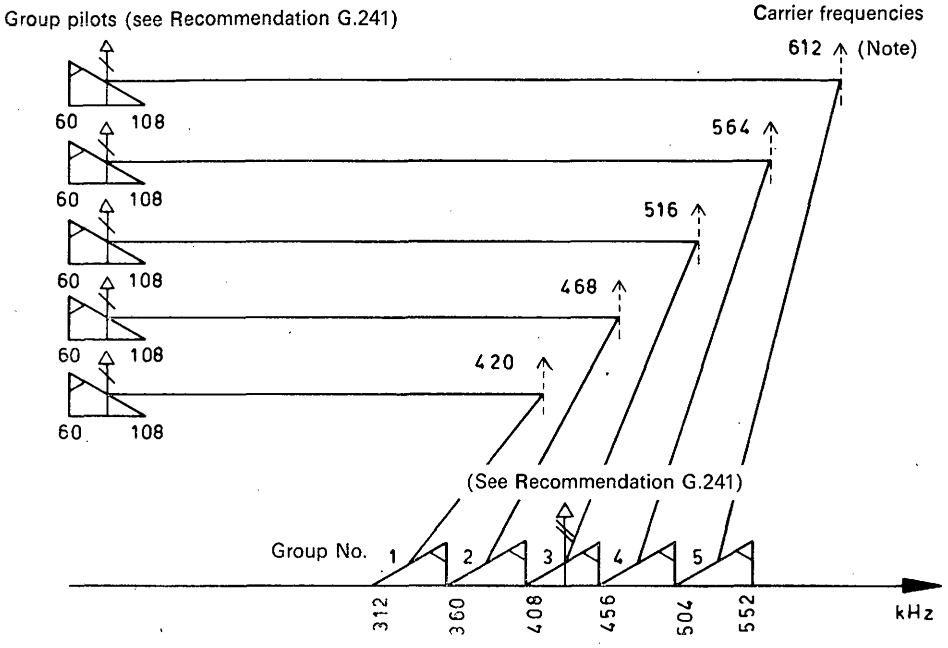


FIGURE 1. — Constitution of the basic supergroup

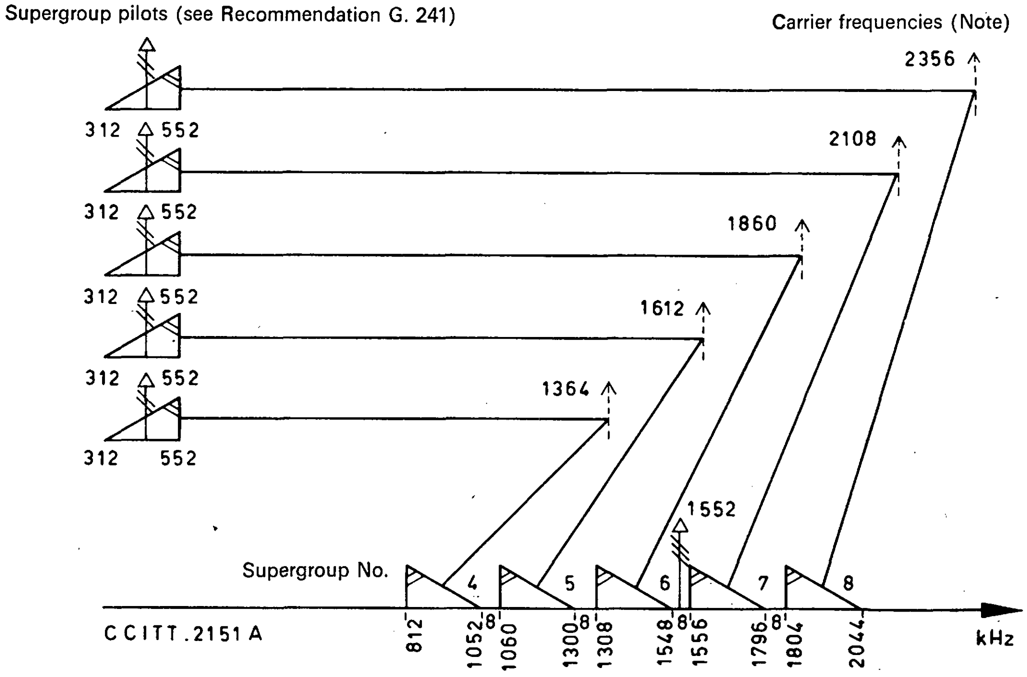


FIGURE 2. — Constitution of the basic mastergroup

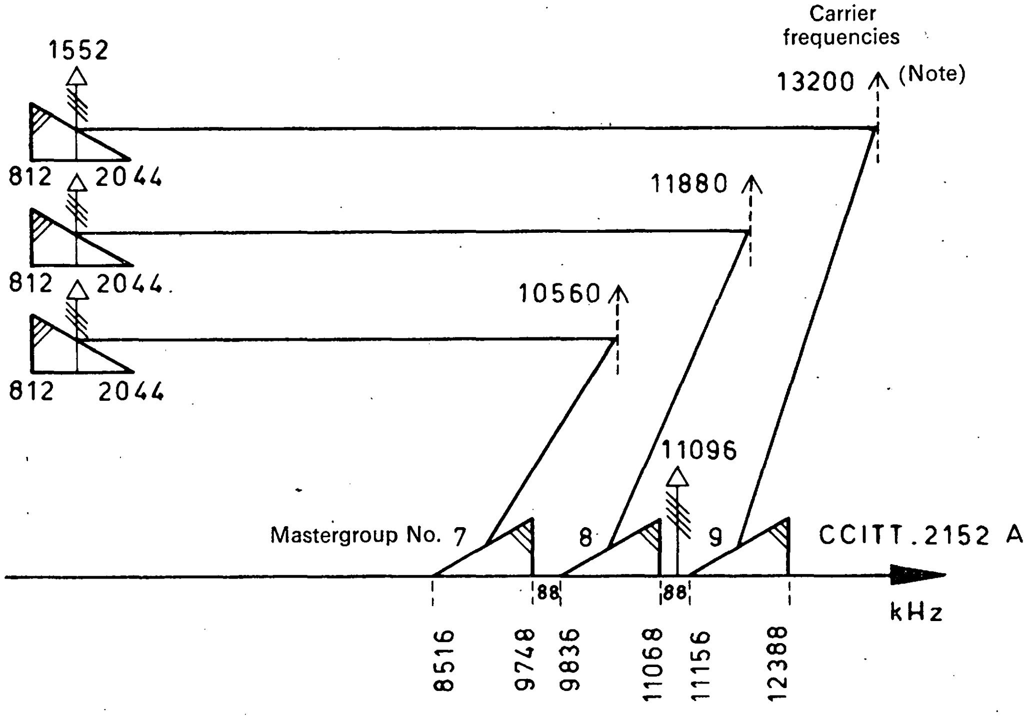


FIGURE 3. — **Constitution of the basic supermastergroup**

Note to Figures 1 to 5. — The virtual carrier frequencies shown in Figures 1 to 5 will normally be the frequencies actually used. However, they are all shown as virtual frequencies to allow for the possibility of using cheaper ways of constituting basic groups, supergroups, etc., in future.

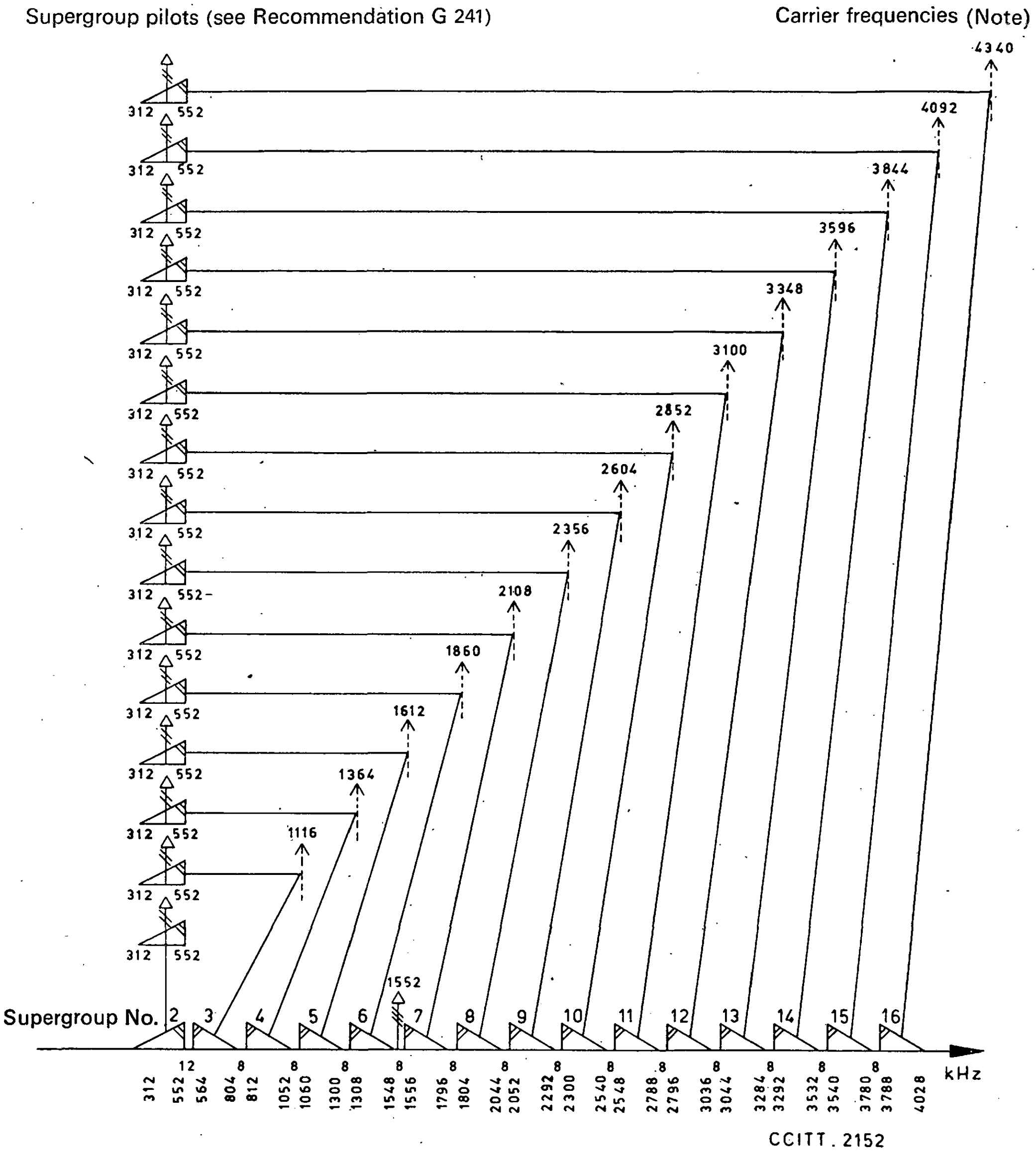


FIGURE 4. — Constitution of the basic 15-supergroup assembly

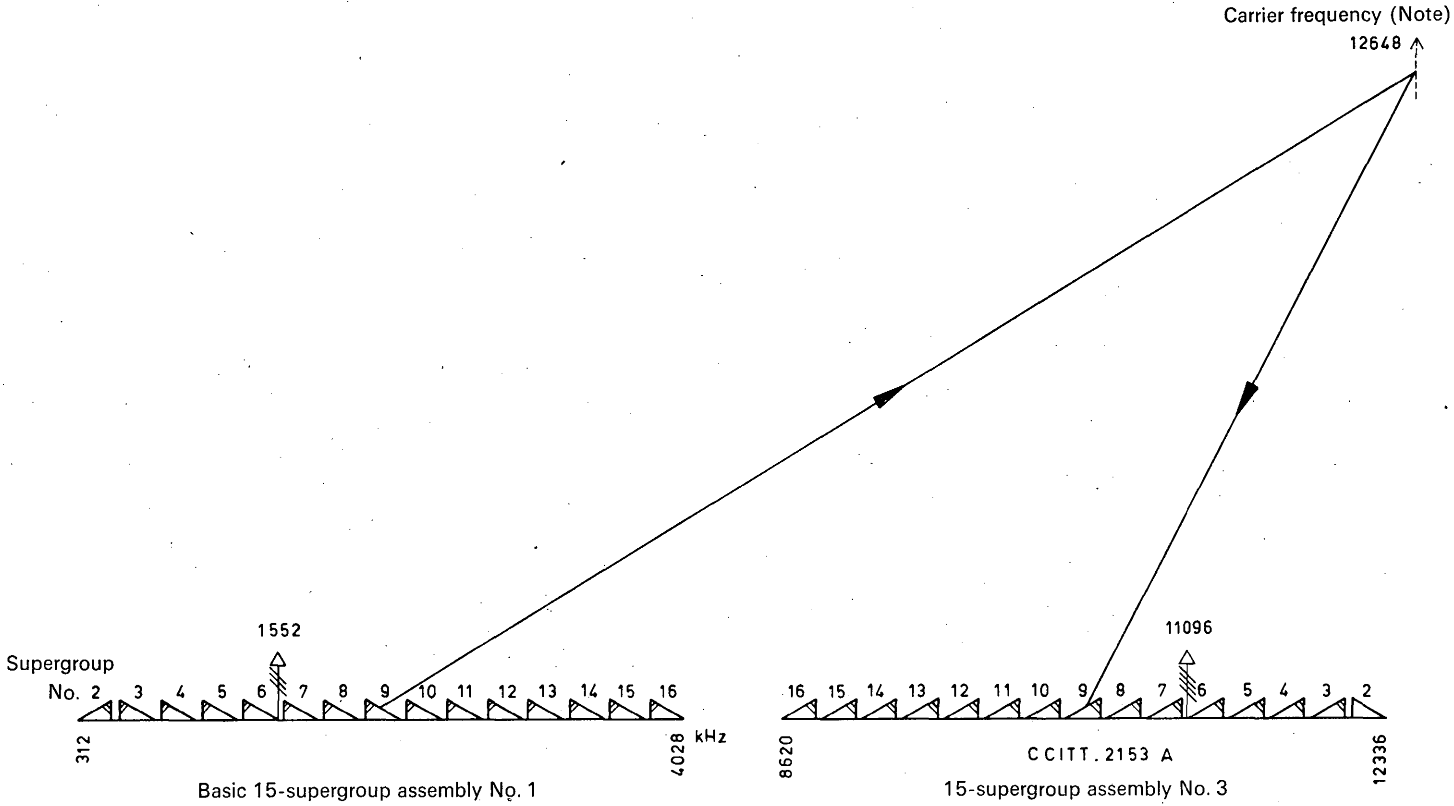


FIGURE 5. — **Constitution of 15-supergroup assembly No. 3**

b) *Adjustment of level at basic group-frequency points*

When a group passes through different carrier systems, it is necessary to provide for an adjustment of level: for example, between the limits of ± about 4 dB (± 0.4 Np), wherever the group passes through the basic frequency range.

c) *Relative power levels at group distribution frames and supergroup distribution frames*

Although the standardization of the relative power levels at group distribution frames and supergroup distribution frames would be desirable to facilitate the setting-up and maintenance of international carrier systems and routing changes of groups or supergroups from one system to another, it does not seem possible to recommend such a standardization internationally, because of the diversity of carrier systems already in service. The following table shows, for information, the level used in different countries.

d) *Relative power levels at mastergroup distribution frames*

The relative power levels at mastergroup distribution frames (see Figure 6) should be adjusted to the following values:

- transmit: —36 dB or —4.1 Np
- receive: —23 dB or —2.6 Np

across a 75-ohm impedance, unbalanced to earth.

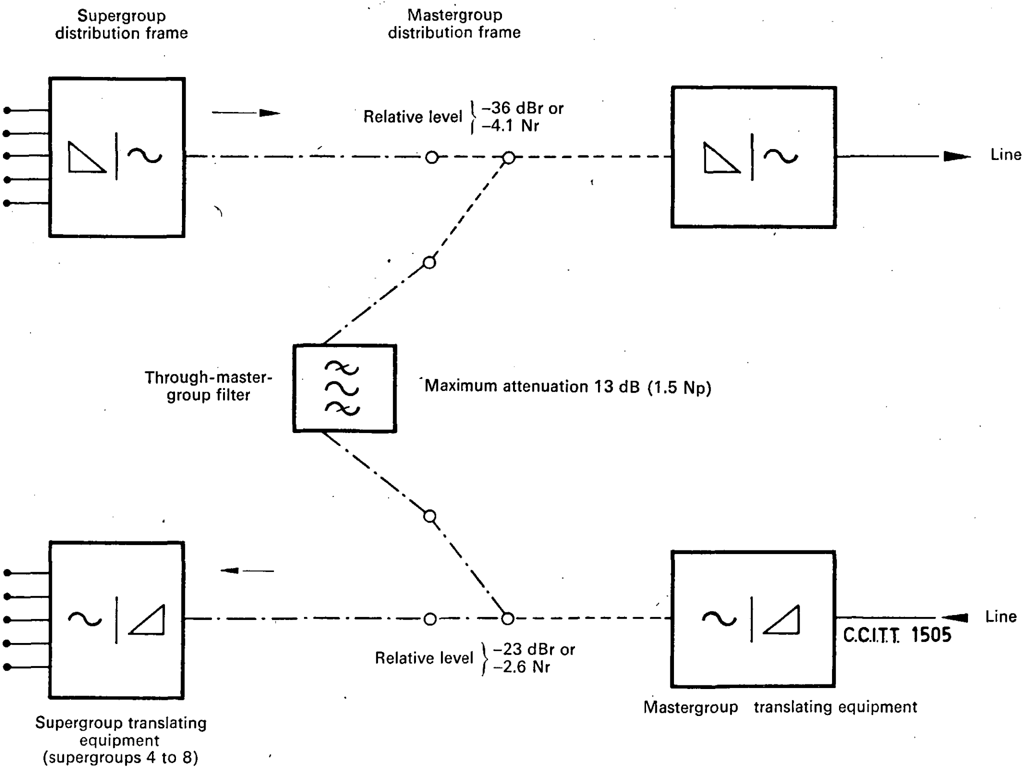


FIGURE 6. — **Relative levels at mastergroup distribution frame**

Relative power levels at the group and supergroup distribution frames in the carrier systems of various countries

Country		Relative power level at group distribution frame				Basic group at distribution frame	Impedance at group distribution frame	Relative power level at supergroup distribution frame				Impedance at supergroup distribution frame
		Transmit		Receive				Transmit		Receive		
		Nr	dBr	Nr	dBr			Nr	dBr	Nr	dBr	
Federal Republic of Germany		−4.2		−3.5		B	150 ohms, balanced	−4.0		−3.5		75 ohms, unbalanced
Australia	System 1		−36.5		−30.5	B	150 ohms, balanced		−35		−30.5	id.
	System 2		−42		− 5	B	135 ohms, balanced		−35		−30	id.
Belgium			−37		− 8	B	150 ohms, balanced		−35		−30	id.
Denmark, Spain, Ireland, Norway, United Kingdom of Great Britain and Northern Ireland			−37		− 8	B	75 ohms, unbalanced		−35		−30	id.
United States of America (American Telephone and Telegraph Company)			−42		− 5	B	135 ohms, balanced		−25		−28	id.
France		−6		−1.7		B	150 ohms, balanced	−5.2		−4.1		id.
Italy, Netherlands			−37		−30	B	150 ohms, balanced		−35		−30	id.
Japan (Nippon Telegraph and Telephone Public Corporation)			−36		−18	B	75 ohms, balanced		−29		−29	id.
Mexico (Teléfonos de México)		−5.4	−47	−1.1	−10	B	150 ohms, balanced	−5.4	−47	−2.8	−24	id.
People's Republic of Poland		−4.2		−3.5		B	150 ohms, balanced	−4.1		−2.6		id.
Sweden									−35		−30	id.
Switzerland		−4.7		−0.9		A or B	75 ohms, unbalanced	−4.0		−3.0		id.
U.S.S.R.		−4.1		−2.6		B	150 ohms, balanced	−4.1		−2.6		id.

e) *Relative levels at supermastergroup distribution frames*

Relative power levels at supermastergroup distribution frames should be adjusted to the following values:

- transmit: —33 dB (—3.8 Np)
- receive: —25 dB or —2.9 Np

across a 75-ohm impedance, unbalanced to earth.

f) *Relative levels at the distribution frame of 15-supergroup assembly (No. 1)*

The relative power levels at the 15-supergroup assembly distribution frame should be adjusted to the following values:

send: —33 dB (—3.8 Np)
receive: —25 dB or —2.9 Np

across a 75-ohm impedance, unbalanced to earth.

g) *Return loss*

The return loss against 75 ohms of the input and output of mastergroup and supermastergroup modulators and of the basic 15-supergroup assembly modulators should not be less than 20 dB (2.3 Np).

h) *Noise*

Paragraph c) of Recommendation G.222 gives information on the noise produced by group, supergroup, mastergroup and 15-supergroup assembly translating equipment.

i) *Interference related to supergroup reference pilot*

Interference from or with supergroup reference pilots may be avoided by taking suitable precautions in channel terminal equipments or group-translating equipment (see Recommendation G.232, M, b) and Recommendation G.234, f), 2).

1) *Pilots at 411.860 and 411.920 kHz*

1.1 For the protection of pilots at a through-connection point (see Recommendation G.243), should group 3 at the receive end of a supergroup link be through-connected without demodulation, for example, to another supergroup link, the modulating equipment for group 3 should present an attenuation of at least 20 dB (2.3 Np) at the frequency of the supergroup pilot.

1.2 Moreover, when an administration wishes to route 8- or 12-channel groups freely between one supergroup link and another with no restrictions on routing of group 3, then the group 3 modulating and group 3 demodulating equipment should each provide in all cases at least 20 dB (2.3 Np) suppression at the frequency of the supergroup reference pilot.

2) *Pilot at 547.920 kHz*

If this pilot is used in a supergroup transmitting five groups (regardless of the use made of these groups) and not a wideband signal (for data, etc.) occupying most of the frequency band, the arrangements mentioned in paragraph i.1 above for the group 3 equipment should be adopted in the modulating and demodulating equipment of group 5.

j) *Accuracy of carrier frequencies*

See Recommendation G.225, a).

k) *Carrier leak*

The carrier leak level for a modulation stage of a modulating or demodulating equipment should not exceed —40 dBm0 (—4.6 Nm0). This is a provisional value and forms the subject of a question under study.

RECOMMENDATION G.234 (Geneva, 1964, amended in Mar del Plata, 1968)

8-CHANNEL TERMINAL EQUIPMENTS

The transmission of less than 12 telephony channels per standard C.C.I.T.T. group link should be provided for, so that the channel bandwidth can be more than 4 kHz. Such an arrangement, however, would probably be useful only over a restricted working distance. In adopting this view, the C.C.I.T.T. has taken account of the disadvantages of such an arrangement, including the reduced number of channels available per group, the additional demand imposed on manufacturers by the adoption of a further type of equipment and the possibility of increased cost of equipment already standardized if the demand for these latter should decrease.

If, by mutual agreement, administrations find it useful to use channel terminal equipments with increased (greater than 4 kHz) spacing for international links over short distances, a system of the following type is recommended, it being understood that other solutions are possible. In the same way as with the equipment described below, any such solution must not result in greater interference on international routes. If the use of some other solution becomes general, it should be submitted to the C.C.I.T.T. for standardization.

The attention of administrations is drawn to the fact that this equipment has been studied only in connection with its use on systems on cable. Its use on open-wire lines is also possible (see Recommendation G.314).

a) *General recommendation*

The technical characteristics of 8-channel terminal equipment should not in any way limit the length of the routes on which it is used; other factors, of an economical nature, for example, have this effect; as a consequence it should meet the recommendations for equipments with 4-kHz spacing (see Recommendation G.232) except for those that are replaced by the following recommendations.

b) *Frequency arrangement within the group*

The number of channels to be included in such a group should be eight. When the group occupies the basic group B frequency band, for example, the frequency arrangement should be as shown in Figure 1.

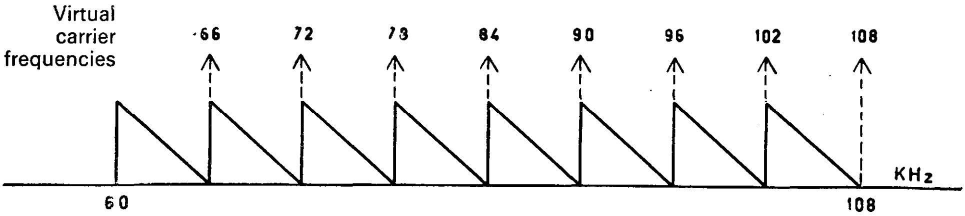


FIGURE 1. — **Arrangement of telephony channels in an 8-channel group**

c) *Out-band signalling channel*

Each telephone channel in an 8-channel group may include an out-band signalling channel using a mean frequency of 4.3 kHz ± 10 Hz.

The signal levels in terms of absolute power level (ref. 1 mW) at a zero relative level point should be:

discontinuous signals:	−6 dBm0 (−0.7 Nm0)
semi-continuous signals:	Value between −20 dBm0 (−2.3 Nm0) and −17.4 dBm0 (−2.0 Nm0).

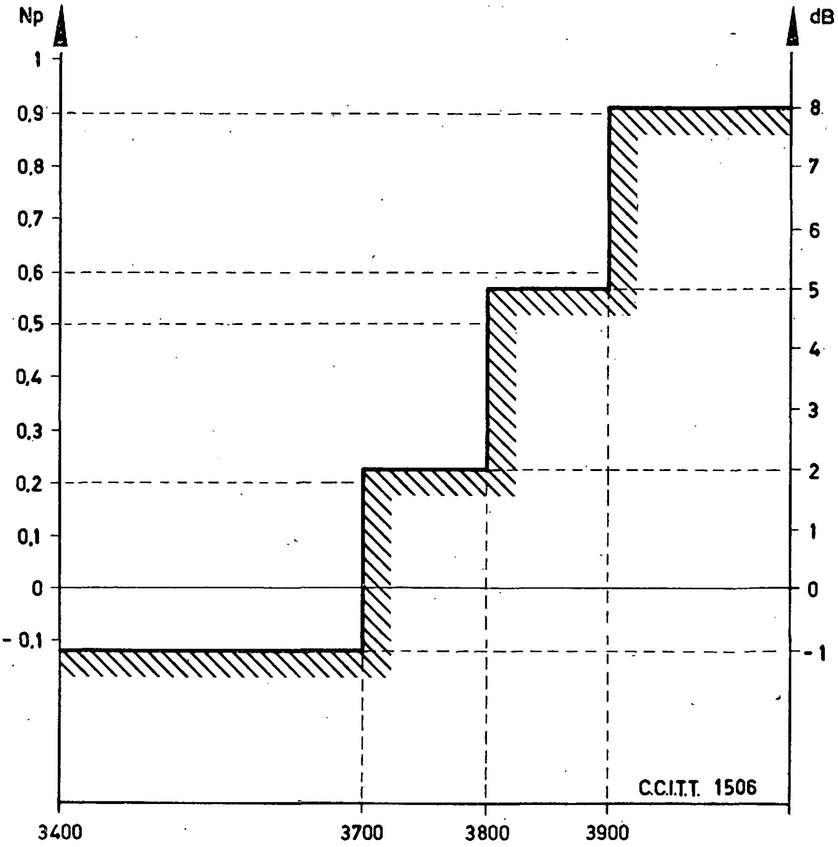


FIGURE 2. Diagram No. 2 bis. — **Lower limit for the variation with frequency of the overall loss of a channel above 3400 Hz referred to the value at 1800 Hz**

d) *Attenuation distortion*

The condition shown in paragraph A of Recommendation G.232 has to be met. In addition, in order to avoid singing in the four-wire loop when the two-wire end is terminated by a coil-loaded line, and also to avoid the transmission to line of interfering signals above 3.4 kHz, it is necessary to impose limits on the attenuation/frequency response at frequencies above 3.4 kHz. The limits recommended are as shown in Diagram No. 2 *bis* of Figure 2.

e) *Constitution of supergroups; group and supergroup pilots*

The group pilots to be used should be the same as for groups having 4-kHz spacing.

With regard to the constitution of supergroups from 8-channel groups, it is recommended that only uniform supergroups should be set up, i.e. supergroups comprising only five 8-channel groups, 12-channel groups with 4-kHz spacing being excluded. Only the pilots at 411.860 and 411.920 kHz can be used as supergroup pilots; the pilot at 547.920 kHz cannot be used since it would be situated at 1920 Hz in channel 8 of group 5.

f) *Protection and suppression of pilots*

The general problems concerning the protection and suppression of group and supergroup reference pilots are similar to those with 12-channel equipments as covered in section M of Recommendation G.232 according to calculations analogous to those of Annex 1 to Recommendation G.232.

1) *Protection and suppression of the group reference pilot*

It is recommended that 8-channel terminal equipments should conform to the attenuation/frequency requirements of the table below:

Pilot frequency (kHz)	Channel No.	Interference frequency in the channel (Hz)	Minimum loss (relative to 800-Hz loss)			
			Sending		Receive	
			dB	Np	dB	Np
84.08	4	5920	20	2.3	20	2.3
	5	−80	20	2.3	20	2.3
84.14	4	5860	20	2.3	20	2.3
	5	−140	30	3.4	20	2.3

The same qualifications apply in this case also regarding bandwidth over which these values of attenuation are necessary as are quoted in Recommendation G.232, M, a).

2) *Protection and suppression of the supergroup reference pilot*

The same considerations as are outlined in Recommendation G.232, M, b), are valid in the present case also, although only channel 1 of group 3 is concerned (interfering frequencies 3920 or 3860 Hz).

3) *Mutual interference between pilots and out-band signalling*

The considerations of Recommendation G.232, M, c) apply in the present case, taking account of the characteristics of the out-band signalling system for 8-channel terminal equipments recommended in paragraph c) of the present recommendation.

RECOMMENDATION G.235 (Geneva, 1964)

16-CHANNEL TERMINAL EQUIPMENTS

In the exceptional cases where this presents a very important economical advantage, for example in submarine cable systems where the line equipment is very costly by comparison with the terminal equipment, the C.C.I.T.T. recognizes the use of channel terminal equipments, giving 16 telephone channels in a group with 3-kHz channel spacing, conforming to the detailed requirements of the present recommendation as well as to the compatible requirements of Recommendation G.232.

It is pointed out that carrier systems over lines on land which are the subject of C.C.I.T.T. recommendations have been drawn up on the assumption that they will be used with 4-kHz-spaced terminal equipments; it is not always possible to use such systems with 3-kHz-spaced terminal equipments.

a) *Allocation of frequencies in a group*

16 channels should appear in the basic group band 60-108 kHz, the channels being numbered 1 to 16 in order of decreasing frequency. The relative channel position and the virtual carrier frequencies should be:

Lower sidebands of:

105.15 99.15 93.15 87.15 81.15 75.15 69.15 63.15 kHz

Upper sidebands of:

104.85 98.85 92.85 86.85 80.85 74.85 68.85 62.85 kHz

Note 1. — It should be noted that this frequency allocation does not permit the transmission of the 16-channel group in the normal through-group equipment without cutting off the high frequencies of the extreme channels.

Note 2. — Transmission of such a group within a supergroup, and in a wideband system, calls for special elimination of the leaks from certain neighbouring group and supergroup carrier currents which, having frequencies that are multiples of 4 kHz fall within certain channels.

b) *Attenuation distortion*

The transmit and receive sides should each meet the characteristics of Figure 1 with a reference frequency of 800 Hz or 1000 Hz.

c) *Group delay*

The following conditions should be met both by sending and receiving equipments:

— group delay at 1000 Hz, $\leqq$ 1 millisecond.

- over the band 565-2550 Hz the difference between the maximum and minimum group delay should not exceed 0.75 millisecond.
- over the band 300-565 Hz on the one hand, and over the band 2550-3000 Hz on the other hand, the group delay should not exceed the value at 1000 Hz by more than 2 milliseconds.

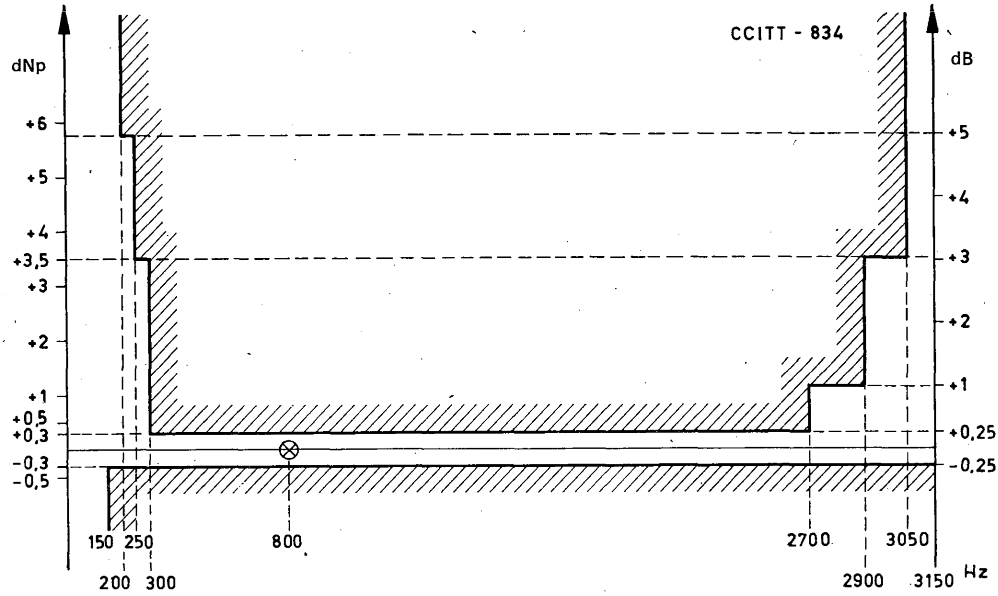


FIGURE 1. Diagram No. 2 D. — **Permissible limits for the variation, as a function of the frequency, in the attenuation**

- **of the sending equipment of any channel,**
- **of the receiving equipment of any channel in a 16-channel terminal**

d) *Stability of virtual carrier frequency*

The channel carrier oscillators should be within ± 0.1 Hz of nominal. The carriers of sub-groups (if such are used) should be multiples of 4 kHz derived from the central carrier generators and will therefore have the same good frequency stability as the latter.

e) *Carrier leak*

The level of each carrier leak should not exceed

—70 dBm0 or —8 Nm0 for each channel carrier current;

—60 dBm0 (—6.9 Nm0) for each sub-group carrier current.

f) *Limiting and linearity*

When a 1000-Hz signal is applied to a channel, the variation in sending equipment gain as the signal level is changed should lie within the limits below, the reference gain being 0 with a 0 dBm0 input:

−60 to +4 dBm0 (−6.9 to + 0.46 Nm0) input; gain: 0 ± 0.1 dB or 0 ± 1 cNp

+15 dBm0 (+ 1.73 Nm0) input; gain: between −3 and −5 dB (−3.45 dNp and −5.75 dNp).

g) *Crosstalk*

1. Crosstalk ratio (corresponding only to intelligible crosstalk) between the two directions of transmission of each circuit should not be less than 65 dB or 7.5 Np.

2. If random noise at a level of 0 dBm0, weighted in accordance with the figure in Recommendation G.227, is applied to a channel on the sending side, the resulting interference on other channels should not exceed −60 dBm0p (−6.9 Nm0).

h) *Noise*

The basic noise in each transmit and receive channel should not exceed −73 dbm0 (−8.4 Nm0) psophometrically weighted.

j) *Group and supergroup pilots*

Use of group and supergroup pilots as envisaged by Recommendation G.241 is impossible. An 84-kHz pilot is normally used; other pilots can be used by agreement among administrations.

2.4 Utilization of groups, supergroups, etc.

RECOMMENDATION G.241 (amended in Geneva, 1964, and in Mar del Plata, 1968)

PILOTS ON GROUPS, SUPERGROUPS, ETC.

a) *Use of pilots*

Experience has shown that, without the use of a group pilot transmitted throughout a group link, adequate stability of the channels of individual group links cannot be guaranteed, in spite of the care given to the maintenance of the carrier systems on which they are routed.

It may be necessary, in the first place, to place an automatic regulator, controlled by the pilot, at the end of some of the group sections forming the group link, to compensate for inevitable variations in attenuation on each of the sections. This regulator is not, of course, designed to correct automatically for faults.

It is desirable for the regulator to have a range of ± 4 dB or ± 4 dNp. An alarm should be given when the amplitude of the pilot at the input of the regulator departs from its nominal value by more than ± 4 dB or ± 4 dNp.

The conditions governing the use of these regulators are given in Recommendation M.18 (Volume IV of the *White Book*).

It is also necessary to provide for measuring the level of the group pilot at the ends of group sections where it is not planned to use a regulator. In these cases, too, an alarm should be given when the level of the pilot departs from its nominal value by more than ± 4 dB.

Precisely similar considerations apply to the use of supergroup, mastergroup and supermastergroup pilots, and also to the use of basic 15-supergroup assembly pilots.

Note. — When a group is through-connected from a cable section (on coaxial or symmetric pairs) to an open-wire line, transmission of the group pilot over the open-wire line, which is an advantage as regards maintenance of the complete group, can, to a certain extent, facilitate "tapping" of conversations by means of radio receivers of a particular type in the territory traversed by the open-wire line. However, this risk of "tapping" is less than the similar risk arising from inadequate suppression of the carrier, because the frequency of the group pilot is more remote from the near-by carrier frequency, so that the quality of the overheard conversation would be necessarily degraded.

b) *Nominal characteristics of pilots (group, supergroup, etc.)*

When group, supergroup, etc. pilots are considered necessary, they should be permanently transmitted.

The frequency and the level of these pilots are shown in the following table:

Frequency and level of pilots

Pilot for	Frequency (kHz)	Absolute power level at a zero relative level point
Basic group B	84.080 [1] 84.140 [1] 104.080 [1,2,3]	−20 dB (−2.3 Np) −25 dB (or −2.9 Np) −20 dB (−2.3 Np)
Basic supergroup	411.860 [1] 411.920 [1,3] 547.920 [1,2]	−25 dB (or −2.9 Np) −20 dB (−2.3 Np) −20 dB (−2.3 Np)
Basic mastergroup	1 552	−20 dB (−2.3 Np)
Basic supermastergroup	11 096	−20 dB (−2.3 Np)
Basic 15-supergroup assembly (No. 1)	1 552 [4]	−20 dB (−2.3 Np)

Notes to the table:

[1] The group pilots 84.080 kHz and the supergroup pilots 411.860 and 411.920 kHz are used over groups and supergroups transmitting telephone channels and in some cases, wide spectrum signals (data, facsimile, etc.). For each group (or supergroup) the two pilots at 84.080 and 84.140 kHz (or 411.860 and 411.920 kHz) should be transmitted simultaneously. However, only one of these two pilots need be used if there is agreement between the administrations concerned (including the administrations of transit countries).

It is now apparent that transmission of wide spectrum signals (data, facsimile, etc.) may demand use of the pilots 104.080 kHz and 547.920 kHz instead of those previously used. These latter pilots may also be used on groups and supergroups carrying only telephone channels. The choice of pilots to be used is a matter of agreement between the administrations concerned (including the administrations of transit countries).

[2] However, the use of the pilots at 104.080 and 547.920 kHz might lead to the following difficulties:

1. The group pilot at 104.080 kHz is incompatible with the line pilots situated at 4 kHz from one end of a group, which are to be found in the following systems:

- open-wire systems using frequency allocation I as shown in Figure 1 of Recommendation G.311;
- symmetric-pair systems using variant B as shown in Figure 5 of Recommendation G.322, especially the transistorized system described in Recommendation G.323.

2. If the frequency allocation in the supergroup comprises groups A-E in accordance with Figures 2 *c* and 3 of Recommendation G.322, a supergroup pilot at 547.92 kHz will appear at frequency 103.92 kHz in group A. This frequency is liable to cause difficulties when group A is used for telephony. To avoid any disturbance, it might be necessary to introduce new routing restrictions.

3. Difficulties would arise if these pilots were used on groups having terminal equipment with carrier frequency spacing of 6 kHz in accordance with Recommendation G.234, unless one further channel is abandoned in some groups.

   Remark. — These difficulties have already arisen in some cases with the pilots recommended at present.

4. The choice of these frequencies would make it very difficult to use signalling at the virtual carrier frequency of a telephone channel in conformity with Recommendation Q.21 (Volume VI of the *White Book*). However, this point (and the preceding one) can be considered to be of purely national interest.

[3] The supergroup pilot at 411.920 kHz may also be used when the supergroup contains one or more groups transmitting wideband signals. It is impossible to route a group equipped with a pilot at 104.080 kHz in the position of group 3 in a supergroup with a pilot at 411.920 kHz.

[4] This pilot after modulation appears at frequeney 11.096 kHz, which is the frequeney of the 15-supergroup assembly No. 3 pilot.

c) *Tolerances on the sent-level of pilots*

The following values are recommended for the frequency accuracy of the various pilots:

Pilot frequency 84.080 kHz and 411.920 kHz:	± 1 Hz
Pilot frequency 84.140 kHz and 411.860 kHz:	± 3 Hz
Pilot frequency 104.080 kHz and 547.920 kHz:	± 1 Hz
Pilot frequency 1552 kHz: [1]	± 2 Hz
Pilot frequency 11 096 kHz:	± 10 Hz

Note. — These tolerances can be taken as a basis for the specifications of the associated pilot receiving filters and stop filters, allowance also being made for C.C.I.T.T. recommendations concerning the accuracy of master oscillators.

The following recommendations are made concerning the tolerances for the sent pilot level:

1. The design of equipment should be such as to allow the sum of errors in the level of any group, etc., pilot as transmitted, due to finite level adjustment steps, change in number of groups supplied, and lack of adjustment facilities in individual groups, to be kept within ± 0.1 dB or ± 1 cNp.

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[1] This pilot after modulation appears at frequency 11.096 kHz, which is the frequency of the 15-supergroup assembly No. 3 pilot.

2. The change in output level of the pilot generator with time (which is a factor included in equipment specifications) must not exceed ± 0.3 dB or ± 3 cNp during the interval between two maintenance adjustments, e.g. in one month.

3. To reduce pilot level variations with time, it is advisable to have a device to give an alarm when the variation at the generator output exceeds ± 0.5 dB or ± 5 cNp, the zero of the warning device being aligned as accurately as possible with the lining-up level of the transmitted pilot.

The attention of administrations is drawn to the difficulty which could result from an appreciable reduction in the absolute power level of the pilot sent to line; such a reduction is liable to cause "near singing", resulting from the operation of the automatic gain-control amplifiers. It would be desirable to make arrangements for overcoming this difficulty if it should arise.

d) *Protection of group, supergroup, etc. pilots against interference by noise*

Automatic regulators operated by group, etc., reference pilots should be so designed that the interfering effect of noise does not exceed 0.02 dB for any significant period. If, for example, the regulator operates on the mean signal voltage, this corresponds to a long-term interfering signal of —20 dB relative to the pilot level. When the interference is of short duration compared with the time constant of the regulator, high levels of interference may be experienced without causing an error in regulation exceeding 0.02 dB.

Group and supergroup pilots. — If the pilot pick-off filter has a bandwidth of 50 Hz (25 Hz on each side of the nominal pilot frequency) the ratio between pilot and noise will always be considerably greater than 20 dB in the case of carrier systems over land-lines. This ratio is still respected if the unweighted power of the noise in a telephone channel reaches 10^6 pW at zero relative level (level of —30 dBm0), which very rarely occurs on radio-relay links conforming to the conditions of Recommendation G.441.

In the case of very long group or supergroup links on such radio-relay links, the pilot-to-noise ratio will be smaller than 20 dB only for a period of less than some ten-thousandths of any month. In that case the resultant error in regulation will be negligible, as the duration of the very high-level noise will be short compared with the necessarily long time-constant of the regulator. In any case, such high-level bursts are not expected to occur with any significant frequency and the chief factor limiting the interference caused to a pilot by noise is therefore the effective bandwidth of the pick-off filter.

Other pilots. — Similar consideration applies also to mastergroup, supermastergroup and basic 15-supergroup assembly pilots. However, the bandwidth of the pick-off filter will certainly be greater than 50 Hz and more reliance will have to be placed on the relatively long-time constant of the regulator to minimize the effect of short-duration high-level noise.

Note 1. — Recommendations concerning the protection and suppression of pilots at certain points appear in Recommendation G.243.

Note 2. — When use is made of procedure 1, described in Recommendation G.211, the spacing between the 11 096 kHz supermastergroup pilot and the audio-frequencies transposed in the adjacent channels is 28 kHz and 60 kHz.

This same spacing is only 4 kHz with procedure 2, described in Recommendation G.211.

In view of this, a supermastergroup regulator is not necessarily suitable for the transmission of a 15-supergroup assembly over a supermastergroup link.

e) *Protection of group or supergroup pilots against signals transmitted in telephone channels*

This protection is ensured in the channel and group translating equipment, in accordance with Recommendations G.232 M and G.234 f).

f) *Protection of group or supergroup link pilots transmitting wide-spectrum signals*

1. To protect the group or supergroup link pilots (used to establish wideband circuits against other wide-spectrum signals (data, facsimile, etc.)), it is recommended that the power spectrum emitted about the pilot frequency be limited in the equipment which transmits these signals.

This limitation is so calculated that the group of supergroup regulators installed on the link will not receive interference of more than 0.1 dB, and the values to be specified therefore depend on the characteristics of the regulators (passband of the pilot filters, regulation operating time constant).

The limits to be set are provisionally fixed by the graph in Figure 1 which allows for the existing characteristics of regulators activated by pilots at 84 + *d* or 412 − *d* kHz. When

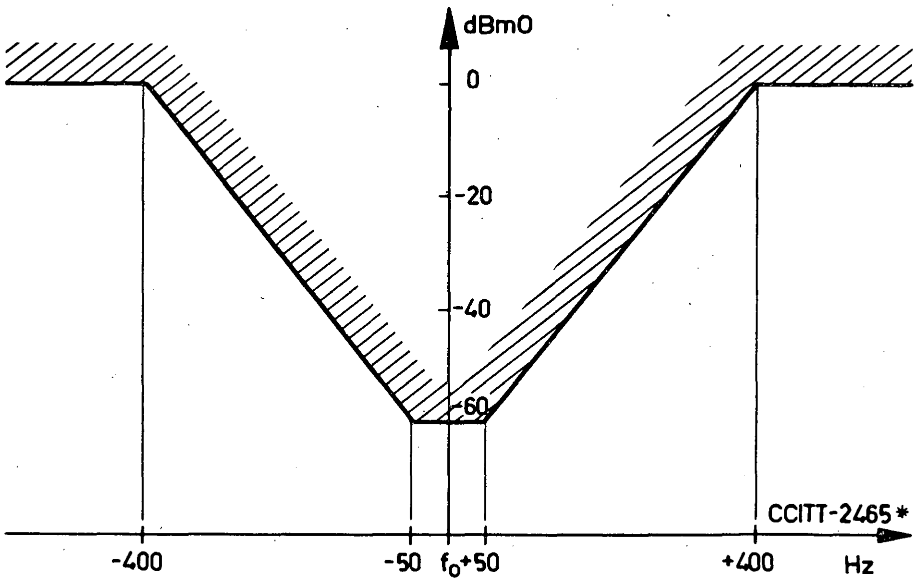

FIGURE 1. — **Maximum permissible level of each frequency in the spectrum of a wideband signal, about the frequency f_0 of the group or supergroup pilot**

a study is made of regulators activated by the new pilots at 104.080 and 547.920 kHz, or of new regulators activated by pilots at 84 + d or 412 — d kHz, special consideration should be given to their frequency-pass filter so that their passband will be as narrow as possible. It will then be possible to adopt a new graph. This point forms the subject of a question under study.

Such a limitation of the transmitted spectrum, obtained by a suitable choice of modulation characteristics, dispenses with the need to insert a band-stop filter to protect the pilot (such a filter would introduce harmful distortion of the group delay). However, if it is not possible to impose such a limitation on the emitted spectrum by this method, or if no guarantee can be secured that this limitation will be respected, the administrations operating the transmission networks should — to protect the group regulators against interference caused by the wideband signals — insert band-stop filters (which would produce the smallest possible distortion to the group delay) at the input of the group or supergroup links under consideration, producing the limitation indicated by Figure 1. The characteristics of these filters form the subject of a question which is under study.

Note. — The general problem of protecting the reference pilots from interference when a group or supergroup is used for the transmission of wide-spectrum signals arises because the protection of these pilots is not always secured by means of a band-clearing filter connected immediately before injection of the pilot. In normal telephone use such protection may depend upon the existence of filters in telephony channel or group translating equipment; however, these may not be in circuit when a wideband transmission path is set up.

Special precautions ought to be considered when a group carrying a supergroup reference pilot is used for wide-spectrum transmission (although such a choice should be avoided when possible) e.g., when group 3 is used in a supergroup carrying the 412 - d kHz pilot or when group 5 is used in a supergroup carrying the 547.92 kHz pilot. Disturbance of this pilot will affect not only the wide-spectrum signal but may also affect the other groups in the supergroup. Administrations may, in some circumstances, feel obliged to protect the supergroup pilot immediately before injection by means of a band-clearing filter conforming to the requirements indicated above.

2. *"Delayed transfer"*

It may be imagined that some data-processing devices record the wideband signal in the form in which it reaches them from the network, and then retransmit this recorded signal over the network on a group or supergroup link. On this assumption, the pilot will be recorded at the same time as the signal; it will therefore be retransmitted with it and will then interfere with the pilot injected on the new link. In this case, the recording or retransmitting device should be equipped with a frequency cut-off filter providing an attenuation of at least 40 dB (or 4.6 Np) at the pilot frequency under consideration, and contributing as little distortion as possible to the group delay. The characteristics of this filter form the subject of a question under study. However, if administrations have inserted, at the input of wideband links, the cut-off filter for protection of the pilot as mentioned in 1) above, the aim sought in the present paragraph will have been reached and the frequency cut-off filter will be superfluous.

3. *Multipoint links*

In the case of multipoint links on tree-shaped networks, the pilot should be blocked at each confluence point on all the confluent links except one, by means of a filter like the one mentioned in 2) above, leaving only one pilot protected against interference from the other pilots. It is also possible to block the pilots on all the confluent links and to transmit a locally produced pilot beyond that point of the link.

RECOMMENDATION G.242 (amended in Geneva, 1964, and in Mar del Plata, 1968)

THROUGH-CONNECTION OF GROUPS, SUPERGROUPS, ETC.

a) *General considerations* [1]

It may be found desirable from both the technical and the economical points of view to provide facilities at the end of certain sections such that the channels routed over one section do not all have to be extended to the next section, this being done without demodulating all the channels to voice frequency, whole batches of channels being extended to different line sections.

At such points, which are at the ends of the *line links* concerned, the through-connection of batches of telephone channels should be possible from one line link to another. This can be achieved by means of the following two methods which, though basically different, can nevertheless be used in association at a given point for different batches of channels. In both cases arrangements are necessary to ensure that the through-connected frequency band is "clear", that is to say, so far as possible the channel vestiges on the two sides of the through-connected batch of channels should be suppressed by means of a through-connection filter.

1. *Through group, supergroup, mastergroup, supermastergroup or 15-supergroup assembly.* — It is assumed that the batch of through-connected channels occupies the frequency band of a group, supergroup, mastergroup, supermastergroup or 15-supergroup assembly, or that it can be split into several such bands. Each of the groups, supergroups, mastergroups, supermastergroups or 15-supergroup assemblies is then brought into the basic frequency band and is filtered in that band by means of a through-group filter, or through-supergroup, through-mastergroup, through-supermastergroup or through-15-supergroup assembly filter.

Note. — The frequency band occupied by the basic 15-supergroup assembly No. 3 (8620 to 12 336 kHz) is within the frequency band occupied by the basic supermastergroup (8516 to 12 388 kHz).

Hence, when 15-supergroup assemblies are used in the conditions specified in Recommendation G.211 (procedure 2), basic 15-supergroup assembly No. 3 can be through-connected by means of through-supermastergroup filters.

2. *Direct through-connection.* — It is also possible to through-connect a group, supergroup, mastergroup, supermastergroup or 15-supergroup assembly or a batch of them by direct line filtration without demodulation and passage via the basic frequency band. It is

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[1] This Recommendation does not consider certain precautions necessary for the protection of various pilots and additional measuring frequencies. Such precautions are given in Recommendation G.243.

then necessary to have direct through-connection filters connected to the line equipment to effect the necessary separation. The facilities provided in this respect by 4 MHz, 12 MHz and 40/60 MHz coaxial systems are mentioned in Recommendations G.337, G.332 and G.333.

In fixing the degree of suppression of unwanted components, it is convenient to use the following definitions:

Intelligible crosstalk components. — Transferred speech currents which can introduce intelligible crosstalk into certain channels at the point considered.

Unintelligible crosstalk components. — Transferred speech currents which can introduce unintelligible crosstalk into certain channels at the point considered.

Possible crosstalk components. — Transferred speech currents which, at the point considered, do not intrude into the channels of other systems but which may do so elsewhere.

Harmful out-of-band components. — Transferred currents arising from speech, or pilots, or additional measuring frequencies, and of frequencies such that they will always lie outside the useful frequency band (corresponding to speech frequencies) of the carrier systems, but which may interfere with pilots or additional measuring frequencies.

Harmless out-of-band components. — Transferred currents arising from speech or pilots, which, at all translation points, have frequencies outside the useful frequency band corresponding to audio frequencies of pilot frequencies.

The term "wanted component" is applied below, in respect to the speech band, to an 800-Hz signal with a power of 1 milliwatt sent to a zero relative level point, and in respect of pilots or additional measuring frequencies, to the signal of specified frequency and level at the point where it is normally injected.

b) *Through-group connection*

In the case of through-connection of a group, the ratio between the wanted components and the various unwanted components defined above should be:

1. intelligible crosstalk components	70 dB or 8.0 Np;
2. unintelligible crosstalk components	70 dB or 8.0 Np;
3. possible crosstalk components	35 dB or 4.0 Np; wherever possible components appear;
4. harmful out-of-band components	40 dB (4.6 Np);
5. harmless out-of-band components	17 dB or 2.0 Np.

All these separations must be provided by the transfer filter itself. They relate to the nominal level, 84 kHz which is the reference frequency (close to the group pilots) at which the loss of the group transfer filter is set. At the other frequencies, account should be taken of the tolerance allowed for the distortion loss of this filter.

At any temperature between 10° and 40° C, insertion loss for all the through-group connection equipment[1] at any frequency of the passband (60.6 to

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[1] This equipment comprises the group demodulation equipment, the through-group filter proper and a group modulation equipment.

107.7 kHz [1]) should not depart from the loss at 84 kHz [2] by more than ± 1 dB or ± 1.2 dNp.

The loss between 10° and 40° C at 84 kHz should not differ by more than ± 1 dB or ± 1.2 dNp from the loss at 25° C.

Note 1. — It would be technically difficult for the C.C.I.T.T. to recommend a distribution of these overall limits among the equipments mentioned in footnote 1 below.

Note 2. — The question of likewise referring all the levels and attenuations mentioned to the level and attenuation at 104 kHz, and not only 84 kHz, forms the subject of a question under study.

The value of 70 dB or 8.0 Np given at b) 1 and 2 above for the intelligible or unintelligible crosstalk components is the minimum standard value for telephony. A value of 80 dB or 9.2 Np is provisionally recommended, for future designs of equipment, within the band of each group adjacent to the through-connected group which corresponds to the band 84 to 96 kHz in the basic group B and which may be used for programme transmission.

This condition should be fulfilled both when the adjacent group is erect or inverted.

Note. — As a consequence of this latter condition, in each through-connected group, the value recommended will also be achieved in the band corresponding to the band 72 to 84 kHz in the basic group B.

c) *Through-supergroup connection*

In the case of through-connection of a supergroup, the ratio between the wanted components and the various unwanted components defined above should be:

1. intelligible crosstalk components	70 dB or 8.0 Np;
2. unintelligible crosstalk components	70 dB or 8.0 Np;
3. possible crosstalk components	35 dB or 4.0 Np wherever possible components appear;
4. harmful out-of-band components	40 dB (4.6.Np) [3];
5. harmless out-of-band components	17 dB or 2.0 Np

All these separations must be provided by the transfer filter itself. They relate to the nominal level, 412 kHz which is the reference frequency (close to the supergroup pilots), at which the loss of the supergroup transfer filter is set. At the other frequencies, account should be taken of the tolerance allowed for the distortion loss of this filter.

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[1] If 16-channel groups be used, the passband must be extended from 60.1 to 107.9 kHz or, by agreement between the administrations concerned, the band indicated in the present recommendation must be kept, in which event note 1 to Recommendation G.235 will have to be carefully borne in mind.

[2] Slightly different loss limits apply outside the band occupied by the telephone channels when out-of-band signalling is used; this point can be settled on the national level or by agreement between the administrations concerned.

[3] The specified attenuation should be met at the nominal frequencies of the pilots and additional measuring frequencies involved (at a point where these are 308 kHz or 556 kHz) in accordance with the definition of harmful out-of band components.

At any temperature between 10° and 40° C, insertion loss for all the through-supergroup connection equipment [1] at any frequency of the passband (312.3 to 551.4 kHz[2]) should not depart from the loss at 412 kHz[3] by more than ± 1 dB or 1.2 dNp.

The loss between 10° and 40° C at 412 kHz should not differ by more than ± 1 dB or ± 1.2 dNp from the loss at 25°C.

Note 1. — It would be technically difficult for the C.C.I.T.T. to recommend a distribution of these overall limits among the equipments mentioned in footnote 1.

Note 2. — The question of likewise referring all the levels and attenuations mentioned to the level and attenuation at 548 kHz, and not only 412 kHz, forms the subject of a question under study.

Note 3. — The ratio of 70 dB or 8.0 Np. shown under 1 and 2 for the intelligible or unintelligible crosstalk components is a minimum standard value for telephony. For the future design of equipment, a separation of 80 dB (9.2 Np) is provisionnally advocated for the bands liable to be used for programme transmission in each supergroup adjacent to the transferred supergroup.

Note 4. — In the case of through-connection of supergroup 1 or 3, the range of insertion loss of the combined through-supergroup equipment can reach 3 dB (0.35 Np) in the passband of the filter around 312 kHz or 552 kHz.

d) *Through-mastergroup connection*

For the through-mastergroup connection, the ratio between wanted components and the various unwanted components defined above should be:

1. intelligible crosstalk components	70 dB or 8.0 Np;
2. unintelligible crosstalk components	70 dB or 8.0 Np;
3. possible crosstalk components	35 dB or 4.0 Np; wherever possible components appear;
4. harmful out-of-band components	40 dB (4.6 Np) [4];
5. harmless out-of-band components	17 dB or 2.0 Np.

All these ratios should be achieved by the through-mastergroup filter itself. They refer to the nominal level of the 1552-kHz reference frequency (mastergroup pilot) by which the loss of the through-mastergroup filter is fixed. At other frequencies, the attenuation/frequency distortion tolerance allowed for this filter should be taken into consideration.

At any temperature between 10° and 40° C, the loss at any frequency within the passband (812 to 2044 kHz) of the combined through-mastergroup equipment [1] should not deviate by more than ± 1 dB or ± 1.2 dNp from the loss at 1552 kHz.

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[1] This equipment comprises the supergroup demodulation equipment, the through-group filter proper and a group modulation equipment.

[2] When supergroups contain group 5 in a direction different from that of groups 1 to 4, the limits of the passband are: 312.3 and 551.7 kHz.

[3] Slightly different loss limits apply outside the band occupied by the telephone channels, when out-of-band signalling is used; this point can be settled on the national level or by agreement between the administrations concerned.

[4] The specified attenuation should be met over a band extending for 600 Hz above and 600 Hz below the nominal frequencies of the pilots or the additional measuring frequencies involved (where these are 768 or 2088 kHz) in accordance with the definition of harmful out-of-band components.

The loss between 10° and 40° C, at 1552 kHz, should not deviate by more than ± 1 dB or ± 0.1 Np from the loss at 25° C.

Within each supergroup the total variation of the insertion loss should not exceed ± 1 dB or ± 1.2 dNp relative to the loss at the frequency of the supergroup reference pilot.

Note. — The ratio of 70 dB or 8.0 Np, shown in 1 and 2 for intelligible or unintelligible crosstalk components, is a minimum standard value for telephony. For the future design of equipment, a separation of 80 dB or 9.2 Np is provisionally advocated for the bands liable to be used for programme transmission in each mastergroup adjacent to the transferred mastergroup.

e) *Through-supermastergroup connection*

For the through-supermastergroup connection, the ratio between wanted components and the various unwanted components defined above should be:

1. intelligible crosstalk components:	70 dB (8.0 Np);
2. unintelligible crosstalk components:	70 dB (8.0 Np);
3. possible crosstalk components wherever possible components appear	35 dB (4.0 Np);
4. harmful out-of-band components	40 dB (4.6 Np); [1]
5. harmless out-of-band components	17 dB (2.0 Np)

All these ratios should be achieved by the through-supermastergroup filter itself. They refer to the nominal level of the 11096 kHz reference frequency (supermastergroup pilot) by which the loss of the combined supermastergroup equipment [2] is fixed. At other frequencies the attenuation/frequency distortion tolerance allowed for this filter should be taken into consideration.

At any temperature between 10° and 40° C, the insertion loss at any frequency within the passband 8516 to 12 388 kHz of the combined through-supermastergroup equipment should not deviate by more than ± 1.5 dB (± 1.73 dNp) from the loss at 11096 kHz. Within each mastergroup the total variation in insertion loss should not exceed ± 1 dB (± 1.2 dNp) relative to the loss at the frequency of the mastergroup pilot.

The loss between 10° and 40° C, at 11096 kHz, should not deviate by more than ± 1 dB (± 1.2 dNp) from the loss at 25° C.

Note. — The ratio of 70 dB (8.0 Np) shown in 1 and 2 for intelligible or unintelligible crosstalk components, is a minimum standard value for telephony. For the future design of equipment, a separation of 80 dB (9.2 Np) is provisionally advocated for the bands liable to be used for programme transmission in each mastergroup adjacent to the transferred mastergroup.

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[1] The specified attenuation should be met over a band extending for 600 Hz above and 600 Hz below the nominal frequencies of the pilots or the additional measuring frequencies involved (after frequency translation of the supermastergroup into the basic 8516-12.388 kHz band) in accordance with the definition of harmful out-of-band components.

[2] This equipment comprises the supermastergroup demodulation equipment, the through-supermastergroup filter proper and supermastergroup translating equipment.

f) *Through-15-supergroup assembly connection*

For through-15-supergroup assembly (No. 1) connection, the ratio between wanted components and the various unwanted components defined above should be:

1. intelligible crosstalk components	70 dB (8.0 Np);
2. unintelligible crosstalk components	70 dB (8.0 Np);
3. possible crosstalk components wherever possible components appear	35 dB (4.0 Np);
4. harmful out-of-band components	40 dB (4.6 Np); [1]
5. harmless out-of-hand components	17 dB (2.0 Np)

All these ratios should be achieved by the through-15-supergroup filter itself. They refer to the nominal level of the 1552-kHz reference frequency (frequency of the basic 15-supergroup assembly pilot) by which the loss of the through basic 15-supergroup assembly No. 1 filter is fixed. At other frequencies, the attenuation/frequency distortion tolerance allowed for the filter should be taken into consideration.

Alternatively, the above ratios may be provided by a through-connection equipment [2] that incorporates the necessary filtering within the 15-supergroup assembly demodulator and the 15-supergroup assembly modulator.

At any temperature between 10° and 40° C, the loss at any frequency within the pass-band (312 to 4028 kHz) of the combined through-15-supergroup equipment [2] should not deviate by more than ± 1.5 dB or ± 1.73 dNp from the loss at 1552 kHz.

The loss between 10° and 40°C at 1552 kHz should not deviate by more than ± 1 dB or ± 1.2 dNp from the loss at 25° C.

Within each supergroup, the total variation of the insertion loss should not exceed ± 1 dB (± 1.2 dNp) relative to the loss at the frequency of the supergroup reference pilot.

Note. — The ratio of 70 dB (8.0 Np) shown in 1 and 2 for intelligible or unintelligible crosstalk components is a minimum standard value for telephony. For the future design of equipment, a separation of 80 dB (9.2 Np) is provisionally advocated for the bands liable to be used for programme transmission in each 15-supergroup assembly adjacent to the transferred 15-supergroup assembly.

g) *Direct through-connection*

The values recommended for the attenuation of the various crosstalk components are the same as those given in paragraphs b) to f) above for through-connection of groups, supergroups, etc.

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[1] The specified attenuation should be met over a band extending for 600 Hz above and 600 Hz below the nominal frequencies of the pilots or the additional frequencies involved (after frequency translation of the supermastergroup into the basic 312-4028 kHz band) in accordance with the definition of harmful out-of-band components.

[2] This equipment comprises the 15-supergroup assembly demodulation equipment, the through-connection filter (if any) and the 15-supergroup assembly-translating equipment.

RECOMMENDATION G.243 (amended in Geneva, 1964, and in Mar del Plata, 1968)

PROTECTION OF PILOTS AND ADDITIONAL MEASURING FREQUENCIES AT POINTS WHERE THERE IS A THROUGH-CONNECTION

A. INTERCONNECTION OF TELEPHONE CIRCUITS AT AUDIO FREQUENCY

It is necessary that the interconnection of telephone circuits at audio frequency may be made without restriction and without causing interference between the sent and received group and supergroup pilots. It is therefore recommended that Recommendations G.232,M and G.234 be met, which specify an attenuation of at least 20 dB (2.3 Np) in both modulating and demodulating equipments for the leaks of group pilots (channels 6 and 7 or 1 and 2) and supergroup pilots (channels 1 and 2 or 11 and 12).

B. THROUGH-GROUP CONNECTION

a) *Group routed on a supergroup equipped with pilots 411.860 and 411.920 kHz*

To permit unrestricted through-group connection without causing interference between the sent and received supergroup pilots the recommendations of G.233,i, 1.2, have to be followed. Otherwise, it is necessary at least to follow the recommendation of G.233, i, 1.1, and moreover, to avoid routing a through group in position 3 in two successive supergroup links.

b) *Group routed on a supergroup equipped with pilot 547.920 kHz*

The same provisions as in a) apply, but to the group in position 5 and not in position 3 (in accordance with G.233, i, 1.2.)

C. THROUGH-SUPERGROUP CONNECTION

a) *Protection of a line-regulating pilot against additional measuring frequencies*

To prevent interference with a line-regulating pilot lying adjacent to a through-connected supergroup, arising from an additional measuring frequency on an adjacent line link, it is recommended that the combined through-supergroup equipment, plus any additional blocking filter (e.g. associated with the through-supergroup equipment or provided as a pilot supression filter immediately proceding the point on the line at which the line-regulating pilot is injected) should provide the following discrimination (relative to 412 kHz):

- over the range 308 kHz ± 8 Hz not less than 40 dB (4.6 Np);
- over the range 308 kHz ± 40 Hz, and the range 556 kHz ± 40 Hz, not less than 20 dB (2.3 Np).

Note 1. — In making this recommendation, it has been assumed that the addition of the various frequency components within pilot-operated line regulators will follow a square or average law of addition.

Note 2. — If, by mutual agreement, administrations use an auxiliary line-regulating pilot at one of the frequencies indicated at the end of paragraph c) 1 of Recommendation G.332, an additional attenuation giving a discrimination of at least 40 dB (4.6 Np) relative to the attenuation at 412 kHz should be provided over a suitable frequency range around 556 kHz and in particular in the range 556 kHz ± 10 Hz in the case of a 2792-kHz pilot, for which the C.C.I.T.T. has recommended that the frequency variations should not exceed ± 5 Hz.

Note 3. — When the synchronizing or frequency-checking pilot is also a line-regulating pilot (multi-purpose pilot), then where it passes from one regulated-line section to another, the pilot should be blocked and reintroduced (after filtration) on the following regulated-line section after its amplitude has been corrected.

b) *Protection of additional measuring frequencies*

To minimize interference between additional measuring frequencies on adjacent line sections and to prevent interference between additional measuring frequencies on non-adjacent line sections, it is recommended that through-supergroup equipment should provide the following discrimination (relative to 412 kHz):

- over the range 308 kHz ± 50 Hz and the range 556 kHz ± 50 Hz, not less than 15 dB (1.73 Np);
- over the range 308 kHz ± 20 Hz and the range 556 kHz ± 20 Hz, not less than 20 dB (2.3 Np).
- at frequencies of 308 kHz and 556 kHz, not less than 40 dB (4.6 Np).

c) *Protection of the mastergroup or 15-supergroup pilot against additional measuring frequencies*

To prevent interference with the mastergroup or 15-supergroup pilot arising from additional measuring frequencies, it is recommended that the through-supergroup equipment, plus any necessary additional blocking filter, should provide the following discrimination relative to 412 kHz:

- over the range 308 kHz ± 7 Hz and the range 556 Hz ± 7 Hz, 50 dB (5.75 Np);
- over the range 308 kHz ± 40 Hz and the range 556 kHz ± 40 Hz, 30 dB (3.45 Np).

Any necessary additional blocking filter should be provided in association with the equipment where the 1552 kHz pilot is injected, that is, in the supergroup translating equipment on the sending side where the mastergroup or 15-supergroup assembly is formed.

Note. — Figure 1 recapitulates all the attenuations recommended over the range 308 kHz and 556 kHz.

D. END OF A SUPERMASTER-GROUP LINK

The supermastergroup pilot should be blocked at the end of a supermastergroup link, unless otherwise agreed between administrations. The end of a supermastergroup link shall be considered as any point where basic supermastergroup working is no longer used, even though the supermastergroup may not be broken up into mastergroups at that point.

For example, in the case described in Figure 2, point M is the end of a supermastergroup link, at which point the supermastergroup pilot should not be transmitted to country

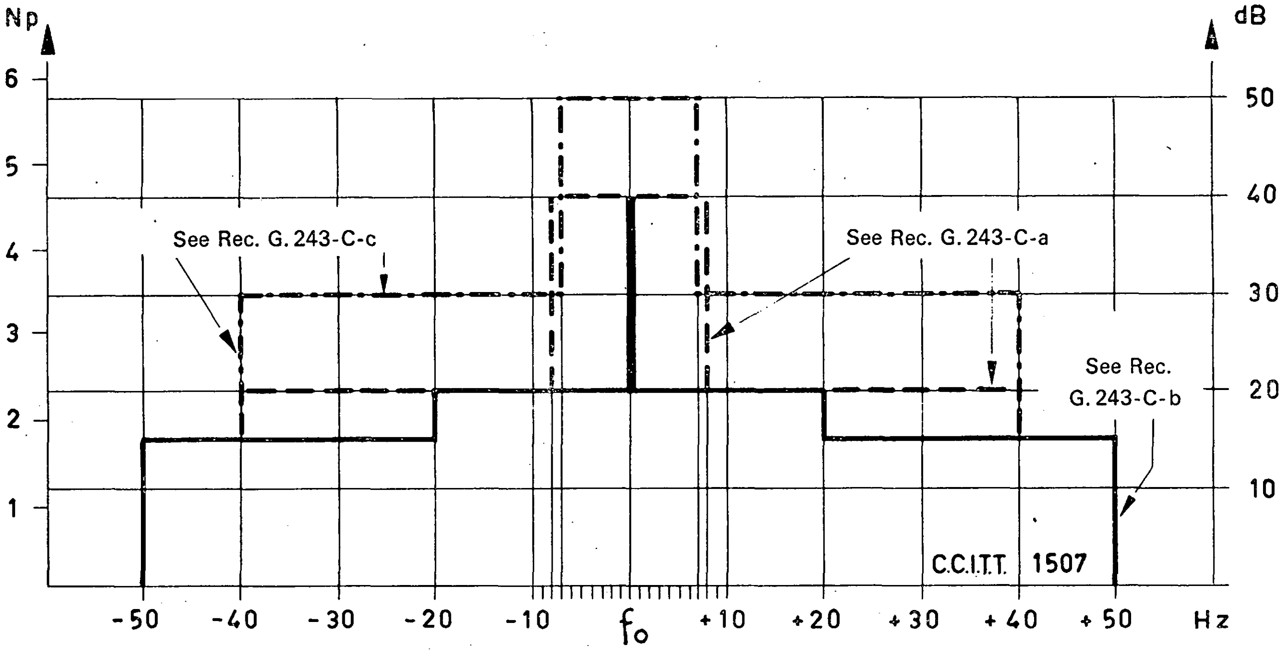

FIGURE 1. — **Minimum recommended relative attenuation around 308 kHz and 556 kHz for various cases of through-supergroup connection**

Notes. — 1. The ordinates of this graph give the minimum recommended relative attenuation (referred to the attenuation at 412 kHz):

— for through-connection equipment alone in all cases ▬▬▬▬▬▬

— for through-connection equipment (filters and translating equipment, together with any supplementary filters) when it is necessary to safeguard:

a line-regulating pilot — — — — —
a mastergroup pilot —·—·—·—

2. This graph applies both to $f_0 = 308$ kHz and to $f_0 = 556$ kHz.

B (even though the supermastergroups continue to be transmitted to line without demodulation), unless country B agrees to depart from this rule. Moreover, country B, which does not use the basic supermastergroup, is not required to transmit this supermastergroup pilot over the circuit PM.

In any case, the supermastergroup pilot is considered as blocked when it undergoes an additional attenuation of 40 dB (4.6 Np).

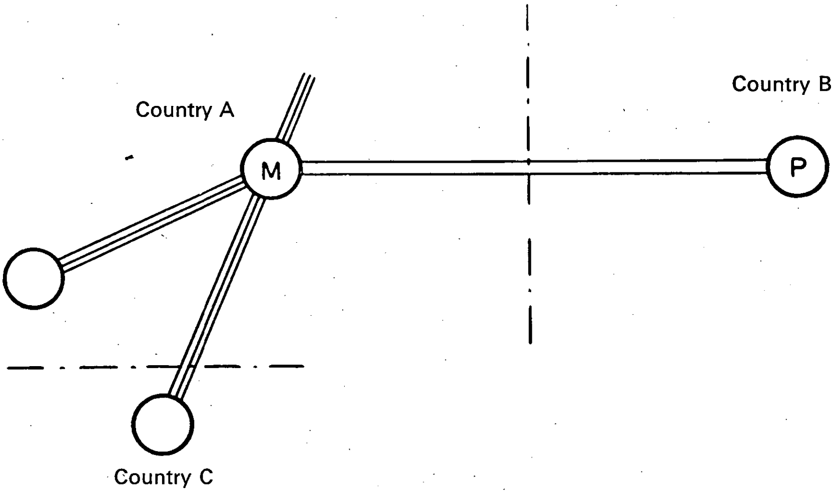

FIGURE 2. — **Definition of a supermastergoup link**

○ Exchange containing carrier equipment.

≡ Link with basic supermastergroup working.

= Link with mastergroup working, not using basic supermastergroups.

—.—. Frontier.

Note. — It is assumed that countries A and C use the basic supermastergroup and that country B does not.

E. DIRECT-THROUGH CONNECTION

Let B be a repeater station where one or several supergroups, mastergroups, supermastergroups or 15-supergroup assemblies are through-connected by direct filtering[1] from a line section AB on to another line BC (see Figure 3). At point B special precautions should be taken with respect to pilots and additional measuring frequencies, so that these signals are transmitted to certain line sections where it is desired to route them but, on the other hand, do not interfere with pilots of the same type transmitted on other sections.

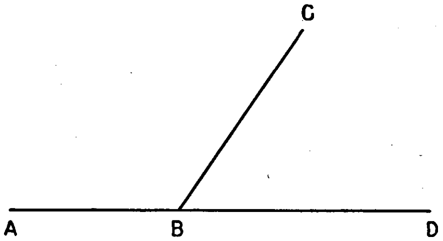

FIGURE 3

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[1] If the supergroups are in the basic supergroup frequency band, this becomes the case dealt with in part C.

a) *Precautions to be taken in the use of pilot signals and additional measuring frequencies where there is direct through-connection within a regulated line section*

Line-regulating pilots. — When there is interconnection between two distinct regulated-line sections to the left and right of the Figure in Recommendation G.213 (which is always the case if there is a radio-relay link) the sum of the suppression of (2) and (5), (see legend) at the frequency of any received line-regulating pilot, should be at least 40 dB. This is so whether or not there is an outgoing line-regulating pilot sent on the same frequency[1]. The two filters are in the same station; this is not an international interconnection problem, but one of industrial standardization for countries which order systems from several manufacturers.

It may be considered preferable, in order to facilitate network arrangements, to make (2) = 40 dB if the lines liable to be interconnected do not all have line-regulating pilots of the same frequency. If a filter (5) is also considered necessary for the suppression of unwanted signals from other equipments, there will sometimes be a suppression of a received line-regulating pilot very much greater than this. There is no technical objection to this.

If it is considered necessary always to have a filter (5) before the point of injection of an outgoing line-regulating pilot, and there is a pilot of the same frequency on the interconnected regulated-line section, the division may be made in the following way:

(2) = 20 dB (5) = 20 dB

Referring to Figure 3 in this Recommendation, if it is not desired to associate the line regulation of section AB with that of the other sections, point B is, by definition, the end of a regulated-line section in section AB and the line-regulating pilots of this section AB should be stopped in such a way that, on the sections BC and BD, they are at least 40 dB (4.6 Np) below the pilots used on these sections.

Additional measuring frequencies. — At a station where there is direct through-connection and which is within a regulated-line section (station B of section AD in the preceding example) the additional measuring frequencies within all the diverted frequency bands are diverted with the supergroups.

It may not be possible to use additional measuring frequencies at the edges of a through-connected frequency band because the amplitudes of these frequencies are affected by the direct through-connection filters. It might therefore be desirable in certain cases to specify "measuring sections" over which these additional measuring frequencies would be used. The choice of such measuring sections is left to the discretion of the administrations concerned.

Other pilot frequencies. — In each particular case, the administrations concerned should decide on the points where the synchronizing or frequency-checking pilot and any switching pilot should be blocked so as not to interfere with other parts of the link. However, should

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[1] The question of the circumstances in which a higher pilot residue might be permitted is under study.

one of these pilots also be a line-regulating pilot (multipurpose pilot) the rules defined above for line-regulating pilots should be applied.

b) *Precautions to be taken at a direct through-connection point at the end of a regulated-line section*

Line-regulating pilots. — If it is not desired to associate the line regulation of section AB with that of the other sections, point B is, by definition, the end of a regulated line in section AB and the line-regulating pilots of this section AB should be stopped in such a way that, on the sections BC and BD, they are at least 40 dB (4.6 Np) below the pilots used on these sections.

Additional measuring frequencies. — The additional measuring frequencies within the frequency band occupied by all the through-connected supergroups are normally transmitted without special blocking [1]. The level of the additional measuring frequencies at the edges of this band may be affected by the sections of the through-connection filters.

There is no need in such cases for equipments to include methodical provision of blocking filters for protecting line-regulating pilots against additional measuring frequencies sent over a preceding section.The arrangements to be made by the maintenance staff when such blocking filters are not provided are shown in Recommendation M.50 (Volume IV of the *White Book*).

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[1] Such special blocking attenuation would in any case be both expensive and technically difficult to achieve.

SECTION 3

INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES

3.1 Systems providing a group on an open-wire pair

RECOMMENDATION G.311 (amended in Geneva, 1964; and at Mar del Plata, 1968)

GENERAL CHARACTERISTICS OF SYSTEMS PROVIDING 12 CARRIER TELEPHONE CIRCUITS ON AN OPEN-WIRE PAIR

The C.C.I.T.T.,

considering

that in the international telephone service, it is very desirable to standardize as far as possible 12-channel carrier telephone systems on open-wire lines using one of the basic groups already employed in carrier systems on symmetric cable-pairs or coaxial cables for which systems the standardization is already much more advanced,

unanimously recommends

that multichannel carrier systems on open-wire lines constructed in the future for the provision of international telephone circuits should satisfy the following conditions:

a) *Frequency band effectively transmitted by each telephone circuit.* — The audio-frequency band effectively transmitted by each telephone circuit should extend from 300 Hz to 3400 Hz.

b) *Basic group.* — The basic group should be that standardized for carrier systems on unloaded symmetric cable-pairs and coaxial cables, i.e.:

Group B : In each direction of transmission 12 channels in the band between 60 and 108 kHz transmitting the lower sideband for each individual channel.

c) *Relative levels.* — The relative power level at the output of the terminal equipment and the intermediate repeaters should be, on each channel and at the frequency on this channel, which corresponds to an audio-frequency of 800 Hz equal to the nominal level with the following tolerances:

Terminal equipment: ± 1 dB or ± 1 dNp.

Intermediate repeater equipment: ± 2 dB or ± 2 dNp for a route of length comparable to a typical homogeneous section—i.e., some 450 km (280 miles) or comprising about four repeater sections.

The maximum value of the nominal level should be + 17 dBr or + 2 Nr at the input to the open-wire line.

The inherent physical characteristics of open-wire line routes result in significant deviations from a regular attenuation/frequency characteristic and the relatively large and varied changes of line attenuation with weather conditions may not always permit the tolerances recommended above for the output of intermediate repeater stations to be met, either when the route is newly commissioned or in subsequent maintenance.

To achieve the tolerances recommended at the output of intermediate repeaters while retaining reasonable design and maintenance standards, it will be necessary for the open-wire line and the repeater equipment to comply with the following standards of performance and tolerances:

1. The attenuation/frequency characteristic of the open-wire line repeater section should be as near as possible to a smooth curve, which for each 48-kHz bandwidth corresponding to a direction of transmission will be substantially a straight line, i.e. a linear frequency characteristic. Deviations from this straight line should not exceed 0.5 dB or 6 cNp in any repeater section (see Recommendation G.313).

2. In each direction of transmission and under dry weather conditions the attenuation/frequency characteristic of any repeater section, comprising an open-wire line and a repeater at the receiving end, should be within ± 0.3 dB or ± 3.5 cNp of the straight line representing the best approximation to the measured attenuation/frequency characteristic of the line. These tolerances require a high standard of design, construction and maintenance of the open-wire line and may also necessitate equalization of the residual attenuation distortion of the repeater section.

3. The gain regulation characteristic of the repeater should be such that the change in gain to compensate for a change in weather conditions is a linear function of the frequency and should correct a linear line attenuation/frequency characteristic with tolerances not exceeding the following:

for all conditions between dry and normal wet weather conditions, i.e. where Recommendation G.312 recommends a maximum repeater gain of about 43 dB or 5 Np, a tolerance of ± 0.5 dB or ± 6 cNp;

when there is an appreciable deposit of ice on the wires, i.e. where Recommendation G.312 suggests a maximum repeater gain of about 64 dB or 7.4 Np, a tolerance of ± 1 dB or ± 1.1 dNp.

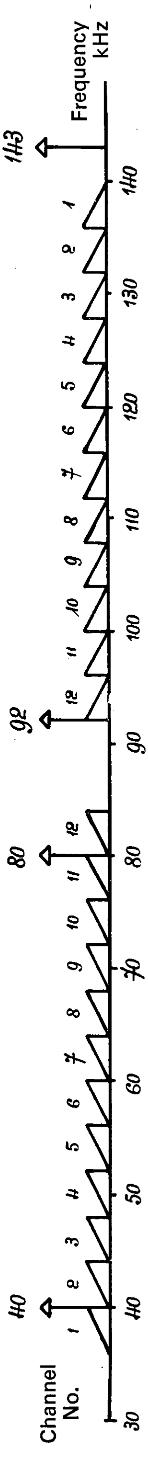

FIGURE 1. — Frequency allocation for a 12-channel open-wire carrier telephone system—Scheme I

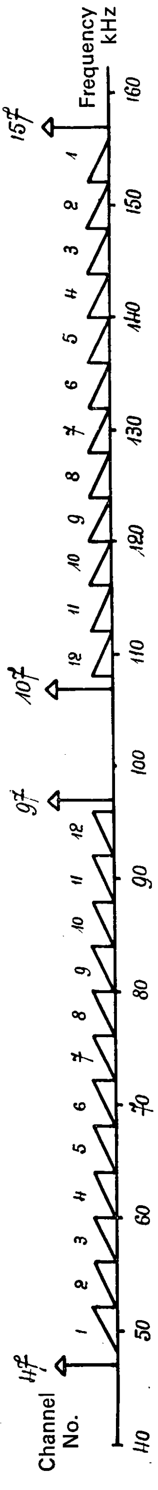

FIGURE 2. — Frequency allocation for a 12-channel open-wire carrier telephone system—Scheme II

d) *Frequencies transmitted to line.* — The system should have 12 carrier telephone circuits.

The system should use one pair of open-wire lines. The lowest frequency transmitted to line should be high enough to allow the use of a three-channel carrier telephone system, at the same time as the system giving 12 carrier telephone channels.

Figures 1 and 2 show two methods of dividing the line-frequency spectrum and the corresponding pilot frequencies available (Schemes I and II). In order to ensure some measure of uniformity in the international telephone network, it is recommended that administrations or private operating agencies concerned with an international carrier system should always choose one or the other of these systems, if possible.

The C.C.I.T.T. does not specially recommend either Scheme I or Scheme II. The administrations or private operating agencies concerned in setting up a 12-channel carrier telephone system on international open-wire lines must judge in each case which of the two schemes is technically and economically more suitable.

Further, the use on different pairs of the same route of several 12-channel carrier systems would involve careful positioning of the modulated groups in the line-frequency spectrum. As an example, Figures 3 and 4 show two methods used in some countries.

e) *Pilot frequencies.* — Each system will have an automatic gain regulator controlled by two pilots having different frequencies for each of the two directions of transmission. It is not possible to standardize frequencies of the pilots to be used on international open-wire carrier systems throughout the international telephone service, because agreement has

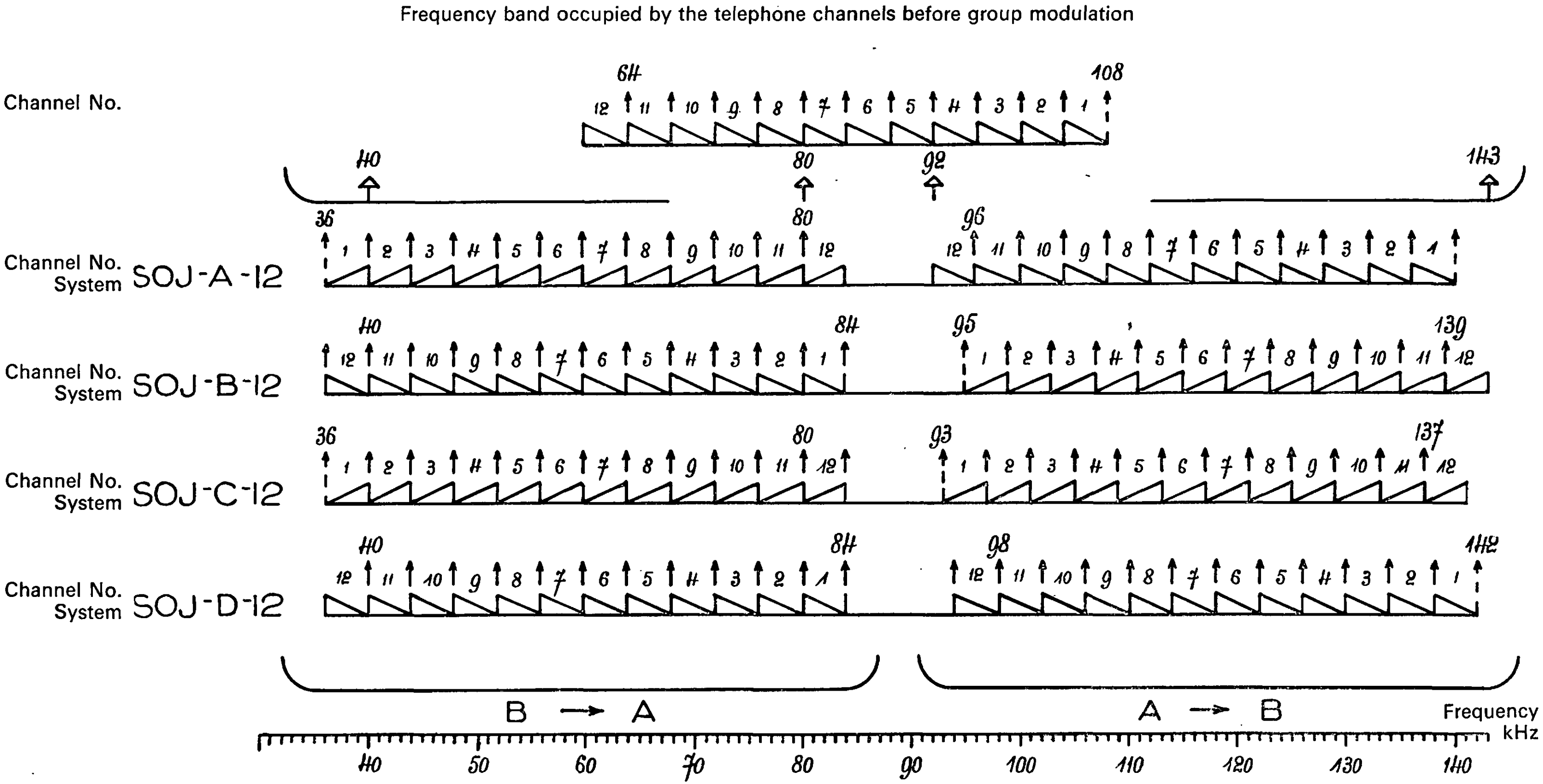

FIGURE 3. — **Frequency allocation for a 12-channel open-wire carrier telephone system, using Scheme I** *(continued on following page)*

System	B → A carrier frequency of		A → B carrier frequency of	
	1st group modulation	2nd group modulation	1st group modulation	2nd group modulation
	kHz	kHz	kHz	kHz
SOJ-A-12	340	484	340	308
SOJ-B-12	340	364	340	543
SOJ-C-12	340	484	340	541
SOJ-D-12	340	364	340	306

FIGURE 3 *(continued)*. — **Table showing carrier frequency allocation**

not been reached on the choice of a particular division of the line-frequency spectrum. It is left to administrations or private operating agencies concerned in such an international connection to take a decision on this subject. *It is extremely desirable* that agreement should be reached between them to use the *same* method of division of the line-frequency spectrum, and the same pilot frequencies (i.e. either Scheme I of Figure 1 or Scheme II of Figure 2), in order to avoid intermediate modulating and demodulating equipments at the frontier repeater stations, or any other method of changing from one system to another. If agreement cannot be reached, one of two things can be done:

1. Consider the frontier repeater station where two different systems are interconnected at the end of a regulated-line section—i.e., stop the pilot of each country at the frontier and introduce there the pilot used by the other country, which should be reintroduced into the line on the other side of the frontier.

2. Choose pilots which, in the two systems, have exactly the same relative positions with reference to the centre of the group of telephone channels transmitted to line and the same relative levels, because it is then possible to translate the pilots together with the groups.

At a point of zero relative level, the nominal absolute voltage level of each pilot should be as low as possible, having regard to the type of system used. It is provisionally recommended that in all cases this absolute level should not exceed —20 dB (—2.3 Np). The stability of the pilots should be such that their frequency is always accurate to within less than 5×10^{-6}.

f) *Stability of the carrier frequency generators.* — So that the effect of the modulations or demodulations shall never produce a difference greater than 2 Hz between the audio-frequency applied at the input of a channel and that which is received at the corresponding

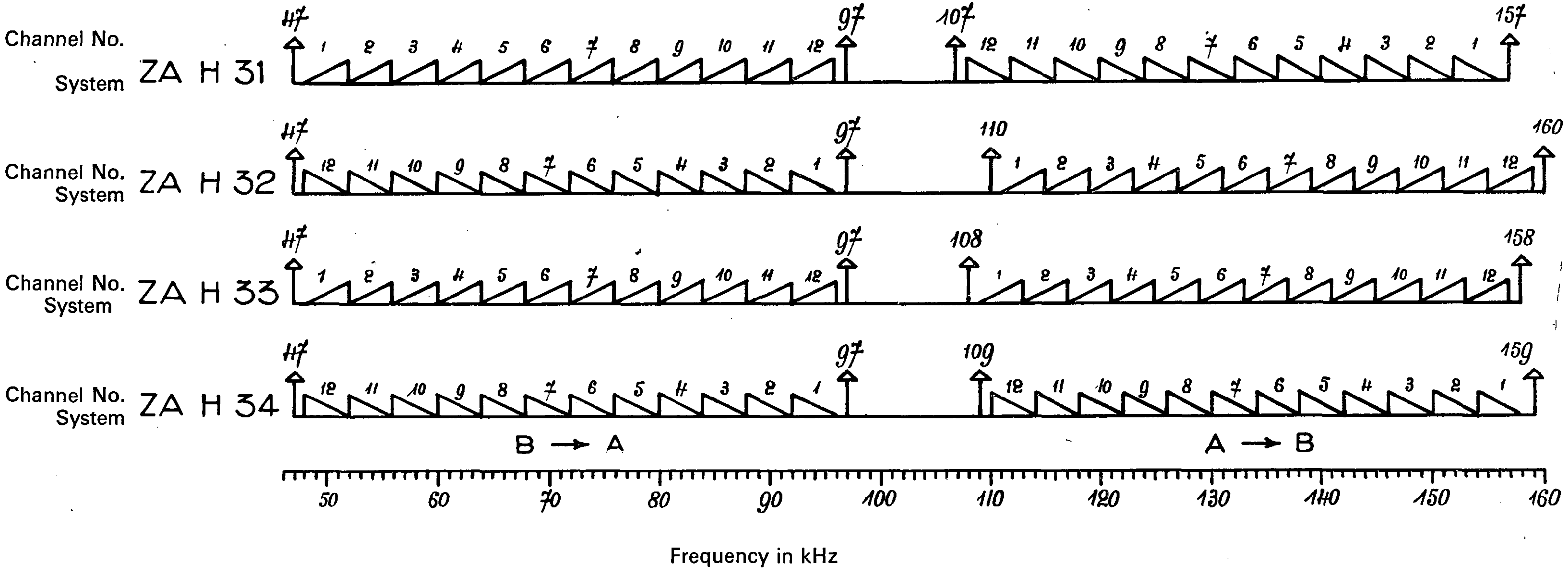

FIGURE 4. — **Frequency allocation for a 12-channel open-wire carrier telephone system, using Scheme II**

end (where there is not intermediate demodulation and remodulation), the stability of the carrier generators must be such that their frequency is always accurate to within less than 5×10^{-6}.

g) *Hypothetical reference circuit over open-wire lines.* — This hypothetical reference circuit is 2500 km long and is set up on a carrier system providing 12 circuits on open-wire pairs.

For each direction of transmission, this hypothetical reference circuit has a total of:

3 pairs of channel modulators and demodulators,

6 pairs of group modulators and demodulators.

Figure 5 shows a diagram of this hypothetical reference circuit. It will be seen that there is a total of 9 modulations and 9 demodulations for each direction of transmission, supposing that each modulation or demodulation is effected in a single stage [1].

The assumptions regarding the numbers of pairs in different homogeneous sections of the hypothetical reference circuit, the lengths of the homogeneous sections, the interconnections of channels and groups at the ends of sections and the law of addition of noise arising in different sections, that apply to the hypothetical reference on symmetric pairs (see paragraph A a) of Recommendation G.322) should also apply to the hypothetical reference circuit on open-wire lines.

Moreover, the line-frequency arrangements recommended in paragraph d) of this present recommendation (giving relative "staggering" and/or "inversion" of channels) are applied to each section of the circuit in equal numbers.

h) *Design objectives for circuit noise.* — The following objective shall be used in the design of 12-circuit carrier systems on open-wire lines.

Each telephone channel conforming to the definitions of the hypothetical reference circuit on open-wire lines must be so designed that the mean psophometric noise power at the end of the hypothetical reference circuit, referred to a point of zero relative level, does not exceed 20 000 pW during any hour.

The same assumptions apply for the calculation of noise as are indicated in Recommendation G.223, due allowance being made for the make-up of the hypothetical reference circuit on open-wire lines.

Note. — The psophometric power of 20 000 pW corresponds to normal conditions in rainy weather; this figure may be exceeded only in very unfavourable weather conditions.

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[1] It is not possible on a single 12-circuit open-wire carrier system to set up a telephone circuit having the same constitution as given by the hypothetical reference circuit, since at a group derivation point all the telephone channels transmitted to line are extracted *en bloc* from the system concerned. However, the hypothetical reference circuit defined above, with a certain number of modulations, is useful in designing equipment such that the circuits set up on these systems may satisfy C.C.I.T.T. recommendations.

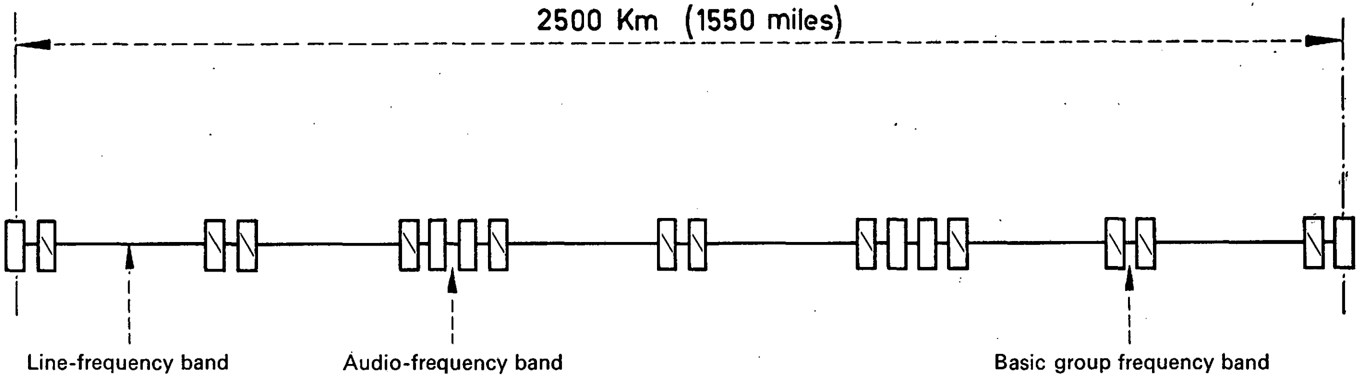

FIGURE 5. — Diagram of the hypothetical reference circuit on open-wire lines

It is recommended that this overall limit be subdivided among the main components of total noise as follows:

Line noise	17 500 pW
Noise due to terminal equipment	2 500 pW

The distribution of total noise between:

basic noise,
intermodulation noise, and
crosstalk noise

is left entirely to the designer of the system, within the limits of 2500 pW for the terminal equipment and 17 500 pW for the line.

Note. — As a simple example, a detailed distrib ution amongthe various components of total line noise is shown in Supplement No. 6 of this volume.

i) *Characteristics of an actual 2500-km circuit.* — If the lines are carefully built (taking into account the information given in the note to Recommendation G.313), and if the design has been drawn up in accordance with C.C.I.T.T. recommendations, it is probable that circuits having a constitution comparable to that of the hypothetical reference circuit will satisfy the recommendations of the C.C.I.T.T. during most of the time.

Note. — Since open-wire lines are exposed to weather variations, it is to be expected that, if a large part of a circuit is exposed to very unfavourable weather, certain conditions will not be satisfied (e.g. crosstalk, line relative levels and noise conditions).

RECOMMENDATION G.312

INTERMEDIATE REPEATERS FOR OPEN-WIRE CARRIER SYSTEMS

a) *Maximum gain.* — Where icing of lines is exceptional, the repeaters (in the direction in which the highest frequencies are transmitted) must have a gain of at least 43 dB (5 Np) at the upper frequency transmitted to line, this gain being measured between the line terminals of the repeater station equipment (which includes directional filters, equalizers, etc.), the level regulators being in the position of maximum gain.

In countries where icing of lines is a very serious problem, it is possible to use repeaters having a maximum gain of 64 dB (7.4 Np) at the upper frequency transmitted to line, these repeaters also being designed to deal with the greater slope of the attenuation/frequency characteristic, under icing conditions.

b) *Impedance.* — Experience shows that because of different methods of construction the nominal values of the impedance of open-wire lines vary from 530 ohms to 630 ohms.

The impedance of the repeater station equipment, seen from the terminals to which the line is connected, should be adjusted at the highest frequency transmitted to line in such a way that the modulus of the return current coefficient at the junction between this equipment and the line is not greater than 0.05 in the upper part of the line-frequency spectrum, and not greater than 0.075 in the lower part.

c) *Minimum value of harmonic margin.* — The harmonic distortion of a repeater should not exceed a value corresponding to the following limits:

When a power of 1 milliwatt is applied at the input to a telephone circuit, the second order harmonic margin (ratio of the second harmonic to the fundamental) should be not less than 70 dB or 8.1 Np; the third order harmonic margin (ratio of the third harmonic to the fundamental) should be not less than 80 dB or 9.2 Np.

d) *Overload point.* — The overload point of a repeater should be not less than 33 dB (3.8 Np).

This overload point is the value of the total power at the output for which an increase of 1 decineper or 1 decibel would be accompanied by an increase of 20 dB (2.3 Np) in the level of the third harmonic.

e) *Stability.* — Near singing should not occur if the line terminals are closed at each side with any impedance (from a very small value to a very high value and with any angle).

f) *Minimum crosstalk ratio between repeaters in the same station.* — If a disturbing voltage is applied to a repeater in a station (so as to include all station wiring and auxiliary apparatus) and the input to another repeater in the same station is closed with an impedance equal to the nominal impedance of the line, then the voltages at the output of these two repeaters, when compared (again including all station wiring and auxiliary apparatus), should give a crosstalk ratio of not less than 74 dB or 8.5 Np, the two repeaters being in their normal working conditions.

RECOMMENDATION G.313

OPEN-WIRE LINES FOR USE WITH 12-CHANNEL CARRIER SYSTEMS

a) *Attenuation of a repeater section.* — The maximum level to be transmitted on open-wire lines has been fixed at + 17 dB or + 2 Np. The lowest level on an open-wire line should not be allowed to fall below — 17 dB or — 2 Np during normal wet weather conditions.

These conditions are all that need to be observed if only one 12-circuit carrier system is to be used on an open-wire route. (See Annex below).

Where it is desired to use several systems, there are additional requirements to be met. The attenuation/frequency characteristic should be as near as possible to a smooth curve.

For example, on a new 12-circuit carrier route, deviations from a regular curve not exceeding 0.5 dB, in any repeater section and throughout the frequency band transmitted to line, should be obtainable.

b) *Crosstalk.* — Far-end crosstalk ratio between two pairs of wire allocated to carrier systems using the same line-frequency band should not be less than 65 dB or 7.5 Np in any repeater section (the length being about 100 km), at any frequency in the frequency band effectively transmitted.

Near-end crosstalk attenuation, measured at the terminal equipments or in repeater stations, should not be less than 42 dB or 4.8 Np at any frequency in the band of frequencies effectively transmitted to line.

Note. — It is considered that the conditions shown above can be met if sufficient care is taken in the construction of the line. Open-wire routes intended to carry several 12-circuit carrier systems should be transposed in the normal way for the frequency band concerned.

Information about crosstalk between circuits on open-wire lines and transposition systems for routes ntended to carry several 12-circuit carrier systems will be found in the following publications:

1. Methods for increasing crosstalk attenuation between open-wire lines, by M. Vos and C. G. Aurel (*Ericsson Technics* No. 6, 1936). (The French translation of this article is contained in duplicated Document No. 10 of the 3rd C.E.—C.C.I.F.—1947/1948).
2. Crosstalk on open-wire lines (Bell Telephone System Monograph 2520).
3. Replies to Question 40 of the 3rd C.E. of the C.C.I.F. given in the following documents:
   Document No. 13 of the 3rd C.E.—C.C.I.F.—1955/1956 (Cuban Telephone Company),
   Document No. 33 of the 3rd C.E.—C.C.I.F.—1955/1956 (Italian Administration),
   Document No. 71 of the 3rd C.E.—C.C.I.F.—1955/1956 (U.S.S.R. Administration),
   Document No. 73 of the 3rd C.E.—C.C.I.F.—1955/1956 (Australian Administration).

Administrations intending to work a single 12-circuit carrier system on an existing route will find relevant information in the Annex below.

c) *Underground cable sections.* — When it is necessary to use sections of underground cable, either at the terminal repeater stations or as an intermediate section in the open-wire route, consideration should be given to matching the impedance of the open-wire pairs to that of the underground cable pairs,

1. by using a low capacity cable loaded appropriately to match its impedance to that of the open-wire line,
2. by means of matching transformers and/or separating filters mounted on or at the foot of the poles at the ends of the section.

d) *Precautions for the elimination of crosstalk in repeater stations.* — It is recommended that over a distance of some 30 yards from a repeater station, separate underground cables be provided to extend the open-wire line into the station. It may also be necessary to insert longitudinal chokes in other pairs, with or without crosstalk suppression filters.

e) *Protection against external voltage surges.* — The French Administration uses the following methods of protection which are given for information:

The line filters should be protected on the line side by fuses and lightning arrestors.

Where the output of the audio-frequency circuit is connected directly to an open-wire line, the output of the audio filter should be protected in the same way.

Audio-frequency filters should be balanced and should be built to withstand a test voltage of 3000 volts d.c. to frame.

High-frequency filters may have a balanced first half-section connected to the other filter sections by a transformer. The first half-section should be capable of withstanding a test voltage of 3000 volts to frame. The remainder of the filter may be unbalanced if it immediately precedes the terminal equipment. If there is a cable in between, two transformers should be used to preserve the balance and, if necessary, to correct for impedance.

Also for information, the Cuban Telephone Company uses the following protective methods:

α) Carbon arrestors are fitted:

1. On the terminal pole (with a breakdown voltage of 750 volts);
2. Between the leading-in cable and the equipment (with a breakdown voltage of 350 volts).

In very unfavourable conditions, these arrestors fuse and connect the line to earth.

β) Thyrite arrestors are placed in the line filters to afford protection against voltages which are not high enough to operate the carbon arrestors.

γ) Protection by line discharge coils is also used where necessary in areas with severe lightning.

ANNEX

(to Recommendation G.313)

Special case of a single 12-circuit carrier system to be worked over an existing open-wire line

When an administration or private operating agency intends to work a single 12-circuit carrier system over existing open-wire lines, it would be well advised to take the following considerations into account:

The attenuation/frequency characteristic of the pair which it is proposed to use should be measured, and also that of the reserve pair. Factors affecting the attenuation of a particular pair are: the distance between conductors, the diameter and type of conductor, insulation methods and transposition schemes. If the distance between wires is constant, if the pair consists of uniform conductors throughout its length and if the transposition scheme used gives frequent and regularly spaced transpositions, the pair can be considered suitable for 12-circuit carrier working.

When routes are transposed to allow working up to 30 kHz there will generally be no difficulty in working a single 12-circuit carrier system, provided attention is given to matching the impedance between open-wire and underground cable sections, including terminal sections at repeater stations, by using transformers or correctly loaded cable.

On routes transposed for only voice-frequency working, it is feasible to erect two additional pairs for use by a 12-circuit carrier system, by fixing an arm to an extension at the top of the pole and by suitably transposing the additional pairs. The additional arm should be at least 24 inches (61 cm) away from the highest existing arm. Alternatively, if there is no need for extra conductors, a transposition scheme suitable for working up to 30 kHz can be introduced, which should make it possible to work a single 12-circuit carrier system. Whether a route should be rebuilt will depend on the rate of growth of traffic and it might be more economical to use from the outset a transposition scheme suitable for several 12-circuit carrier systems. In such a case the residual life of the route is an important factor.

Comments in paragraphs c), d) and e) above also apply to this special case.

RECOMMENDATION G.314 (Geneva, 1964)

GENERAL CHARACTERISTICS OF SYSTEMS PROVIDING EIGHT CARRIER TELEPHONE CIRCUITS ON AN OPEN-WIRE PAIR

a) *Frequency band of each circuit, out-band signalling*

The general requirements for 8-channel terminal equipments given in Recommendation G.234 should be met by the circuits set up on each channel of an 8-channel open-wire system. However, administrations should note that low-level semi-continuous signalling may present some difficulty when weather conditions are bad.

b) *Line relative levels*

Normally, the nominal relative levels and tolerances should be those recommended for 12-channel systems (Recommendation G.311, paragraph c) refers). However, when a 6-kHz system is used on short lines (e.g. less than 100 km) and there are no 4-kHz systems on the open-wire route, a lower sending level is permissible provided that the minimum level at the receiving end does not fall below the value of — 17 dB or — 2 Np, already recommended for 12-channel systems (Recommendation G.313, paragraph a) refers).

c) *Frequencies transmitted to line*

The system should have eight telephone circuits and should use one pair of open-wire lines. The frequency arrangement should be compatible with the line-frequency arrangement used for existing 3-channel and 12-channel routes. Either of the arrangements shown in Figure 1 is suitable.

Note 1. — These line-frequency allocations may be obtained either from the basic 8-channel group defined in Recommendation G.234, using the modulation equipments to place it in line which, in respect of 12-channel systems, produce the frequency allocation Scheme I in Recommendation G.311, or directly from the audio-frequencies, using special modulation equipments. The C.C.I.T.T. does not propose to recommend either of those modulation procedures in preference to the other.

By way of information, when two systems are to be installed on the same route, the frequency allocations mentioned below may be used. In that case, however, it is doubtful whether four systems can be operated on a route where simplified transposition plans are applied such as those which are permissible when operation is confined to two systems with the frequency allocation recommended above.

One possible arrangement which would give staggering advantages between the four 8-channel allocations similar to those obtaining between the 12-channel allocations recommended by the C.C.I.T.T., and which would give reasonable compatibility, would be to adopt for the 8-channel system the following frequency allocations in the upper frequency group:

Allocation A: lower sidebands of 98, 104-134, 140 kHz
Allocation B: upper sidebands of 93, 99-129, 135 kHz
Allocation C: upper sidebands of 95, 101-131, 137 kHz
Allocation D: lower sidebands of 100, 106-136, 142 kHz

In the lower frequency group, allocations A and C could be as for the normal plan in Figure 1 and allocations B and D as for the staggered version.

Alternative arrangements giving improved staggering advantages might be proposed after further study.

Note 2. — If an 8-channel system is used on the same open-wire route as a 12-channel system employing the frequency arrangement shown in Figure 3 of Recommendation G.311, there is risk that voice-frequency signals in channels 1 and 8 of the 8-channel system may interfere with the pilot channels at 40 and 80 kHz in the 12-channel system or vice versa. Administrations planning to use systems in this way should take account of this risk in locating the different systems on the available pairs.

d) *Line pilots*

When either of the two frequency arrangements shown in Figure 1 is used, the frequencies of the line pilots should be 84 and 92 Hz.

However, when 12-channel modulation equipment in accordance with Scheme I, Figure 1 of Recommendation G.311, is used to place the 8-channel groups in the line-frequency spectrum, the line pilots normally used for the 12-channel open-wire system may be used (see Recommendation G.311).

In regions where the weather conditions do not have an extreme effect on the attenuation of a repeater section, one level-regulating pilot will suffice for each direction of transmission. Only on very long lines (e.g. of length greater than 800 km where climatic conditions are favourable) and for those regions with considerable climatic variations (e.g. where an appreciable deposit of ice on the wires is possible) will it be necessary to use additional pilots. In such cases the following are recommended:

1. In the direction of transmission using the lower frequency allocation, a pilot frequency of 48 kHz. This corresponds with a virtual carrier frequency of both the 12-channel and the 8-channel systems, and also as this pilot frequency is not adjacent to the edge of the passband of the line system filters (normally used to separate the 3-channel from the 8-channel (or 12-channel) systems on the same line pair), the use of such a gain-regulating pilot will not impose unnecessarily stringent requirements on the attenuation-frequency distortion of the filters.

2. In the direction of transmission using the upper frequency allocation, a pilot frequency of either 143 kHz or 144 kHz is recommended.

Note. — 143 kHz has the advantage of compatibility with 12-channel systems, whereas 144 kHz, being a multiple of 6 kHz, may be more convenient to obtain, e.g. from the carrier generating equipment.

The stability of the pilot frequency source should be such that the frequency is always accurate to within 1 part in 10^{-5}.

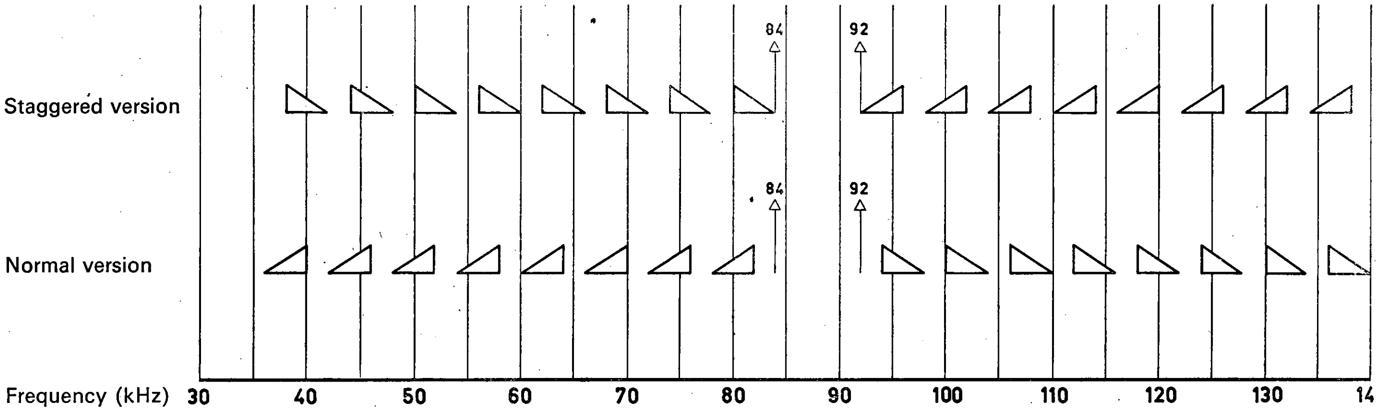

FIGURE 1. — Line-frequency allocation of 8-channel open-wire system

3.2 Carrier telephone systems on unloaded symmetric cable pairs, providing groups or supergroups

The Recommendations of this sub-section refer to systems which provide groups of 12 long-distance telephone circuits using symmetric pairs in two different cables for each direction of transmission. Recommendations G.325, G.326 and G.327 refer to (12 + 12) cable systems.

The Plenary Assembly of Mar del Plata (1968) rearranged these Recommendations to place more emphasis on modern transistor systems and introduced a number of drafting changes. The following list shows those Recommendations which have had their numbers changed as a result of this rearrangement.

Former No. [1]	Subject	New No.
G.321	General characteristics for valve-type systems	G.324
G.322	Intermediate and terminal repeaters for valve-type systems	
G.323	Characteristics of symmetric cable pairs	G.321
G.324	Valve-type (12 + 12) systems	G.327
G.325	Transistorized systems	G.322
G.326	Typical transistorized systems	G.323
G.327	Transistorized (12 + 12) systems	G.325
G.328	Typical transistorized (12 + 12) systems	G.326

RECOMMENDATION G.321 (former Recommendation G.323, amended in Geneva, 1964)

CHARACTERISTICS OF SYMMETRIC CABLE PAIRS

A. Cable specification

Examples of the electric characteristics of a star-quad cable designed to provide 12, 24, 36, 48, 60 or 120 carrier telephone channels on each quad pair

a) *Types of cable*

Administrations which decide to equip their symmetric pair cable network should, wherever possible, choose those which conform to the types of cable defined below.

New cables laid in the European and North-African international telephone network include unloaded symmetric pairs, designed to be used for 12, 24, 36, 48, 60 or 120 carrier telephone channels on each pair. These pairs are laid up in star quads and all unloaded pairs of the same cable are one of the types whose nominal characteristics are shown in the table below:

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[1] In Volume III of the *Blue Book*.

	Type I	Type II	Type II *bis*	Type III	Type III *bis*
Diameter of conductors, mm	0.9	1.2	1.2	1.3	1.3
Effective capacity, nF/km	33	26.5	21	28	22
Characteristic impedance (in ohms)					
at 60 kHz	153	178	206	170	196
at 120 kHz	148	174	203	165	193
at 240 kHz	—	172	200	163	190
at 550 kHz	—	—	198	—	188
Attenuation per unit length at 10° C (in cNp/km)					
at 60 kHz	26	—	—	—	—
at 120 kHz	36	23	17	21	16
at 240 kHz	—	33	24	31	23
at 552 kHz	—	55	36	51	34

It is essential that a repeater section crossing a frontier should be of a uniform type throughout its length. When a frontier section is between a large and a small country, the administration of the larger country should do everything possible to use whichever of the three types has been adopted by the smaller country, so as not to oblige the administrations of small countries to use sections of international cable of a different type from that of their national cables.

Note 1. — Some administrations, by paying special attention to crosstalk balance and adopting appropriate repeater spacing, have been able to set up systems with 2 supergroups, in accordance with Recommendation G.322, on paper-insulated symmetric pairs conforming with this present specification.

Note 2. — It is also possible to set up 2 supergroup systems that conform with Recommendation G.322 on pairs of type II *bis* and type III *bis*. Type II *bis* pairs are insulated by polythene and type III *bis* pairs by styroflex.

b) *Regularity of factory lengths*

The regularity may be characterized by one or other of the equivalent methods below, the choice of which is left to the administrations concerned.

1. *Effective capacity*

The "effective capacity" is measured between the two conductors of the pair, all other cable conductors being connected together and to the sheath.

Ratios of the effective capacity

Type I cable. — The average of the effective capacities of all the pairs in any factory length should not differ from the nominal value by more than ±5%.

In any factory length, the difference between any individual value of effective capacity and the average value obtained for this factory length should not exceed ± 7.5%; the arithmetic mean of the magnitudes of these differences should not exceed 2.5%.

Types II, II bis, III and III bis cables. — The average effective capacity of any length should not differ by more than ± 3% from the nominal value.

In any length, the difference between the effective capacity of any pair and the average capacity for the cable length should not exceed ± 5%.

2. *Impedance* (type II, II *bis*, III and III *bis* cables)

The real part of the characteristic impedance of any circuit, measured with a frequency of 120 kHz, should not depart by more than ± 5% from the mean value of all the pairs of the first manufacturing batch of each type. This mean value should not depart by more than ± 5% from the nominal value at 120 kHz.

The impedance will be measured on the factory lengths using a bridge, the circuits being terminated by an impedance equal to that which is measured by the bridge.

c) *Crosstalk*

The quality of the cable from the point of view of crosstalk may be characterized by one or other of the two equivalent methods below, the choice of which is left to the administrations concerned.

1. *Direct measurements of crosstalk*

For a factory length of 230 metres the crosstalk between any two side circuits should satisfy the following conditions:

— far-end crosstalk ratio should be greater than 68 dB or 7.8 Np,

— near-end crosstalk attenuation should be greater than 56 dB or 6.4 Np.

For cables to be used with 5 groups or 2 supergroups these values should hold up to 240 kHz; and for cables with two groups, up to 120 kHz.

During these measurements, the circuits will be terminated by the real part of the nominal impedance for the frequency considered.

For factory lengths greater than 230 metres (750 feet), the above limits will be reduced by

$$20 \log_{10} \frac{L}{230} \text{ dB or } \ln \frac{L}{230} \text{ Np}$$

L being the length in metres. Lengths shorter than 230 metres should satisfy the same conditions as a length of 230 metres.

2. *Capacity unbalance and mutual inductances*

All the capacity unbalance measurements should be made with an alternating current of 800 Hz. The mutual impedance measurements should be made with an alternating current of 5000 Hz. All the measurements should be made at the ambient temperature, without applying corrections; but in case of dispute, the results obtained at 10 °C will be considered as final. All the conductors, other than those under test, should be connected to the cable sheath.

For a factory length of 230 metres (750 feet), the capacity unbalance should not exceed the values given in Table 1 and the mutual inductances should not exceed the values given in Table 2. These tables show different values for type I cables in one column, and for types II, II *bis*, III and III *bis* in the other.

TABLE 1

Capacity unbalance

	Mean of all readings (ignoring signs)		Maximum individual reading	
	Type I	Types II, II *bis*, III and III *bis*	Type I	Types II, II *bis*, III and III *bis*
Capacity unbalance:				
between pairs of the same quad	33	17	125	60
between pairs of adjacent quads in the same layer	10	5	60	25
between pairs in non-adjacent quads in the same layer	mean value not specified because all possible combinations are not measured		20	10
between pairs in quads in adjacent layers	10	5	60	25
between any pair and earth	100	100	400	400

Note. — The limits shown for the mean values do not apply to cables which have four or less quads.

TABLE 2

Mutual inductances

	Mean of all readings (ignoring signs)		Maximum individual reading	
	Type I	Types II, II *bis*, III and III *bis*	Type I	Types II, II *bis*, III and III *bis*
Mutual inductances in microhenrys:				
between pairs of the same quad	0.150	0.125	0.600	0.500
between pairs of adjacent quads in the same layer	0.100	0.040	0.400	0.150
between pairs in non-adjacent quads . . .	0.050	0.020	0.350	0.150
between pairs in quads in adjacent layers .	0.100	0.040	0.600	0.250

Note. — The limits shown for the mean values do not apply to cables which have four or less quads.

For lengths greater than 230 metres, it is necessary to apply the following rules:

The average values from pair to pair given in the preceding tables should be multiplied by the square root of the ratio between the length in question and 230 metres.

All the maximum values, as well as the average values between a pair and earth, should be multiplied by the ratio between the length in question and 230 metres.

Lengths shorter than 230 metres should satisfy the same conditions as the length of 230 metres.

d) *Dielectric strength*

When specially requested, cables will have a construction such that the insulation of any cable length should be capable of withstanding, without breakdown, a potential difference, specified in each particular case, but not exceeding 2000 volts r.m.s., applied for at least 2 seconds between all the conductors connected together and the earthed sheath. The test is to be made with a 50-Hz alternating current. The value of the test voltage should not exceed by more than 10% the maximum value of a sinusoidal voltage having the same r.m.s. value.

The test can also be carried out using direct current (see Annex 19, *Blue Book*, Volume III, Part 4 entitled "Tests of dielectric strength"). In such a case the limit for the voltage will be 1.4 times the r.m.s. value of the voltage when using alternating current[1].

e) *Insulation resistance*

In a length of cable, the insulation resistance measured between a conductor and all the other conductors connected together, and to the earthed sheath, should not be less than 10 000 megohm-kilometres (approximately 6200 megohm-miles), the potential difference used being at least 100 volts and not greater than 500 volts. The reading shall be made after electrification for one minute, the temperature being at least 15 °C (59 °F).

B.1 SPECIFICATION OF A REPEATER SECTION TO BE EQUIPPED WITH TRANSISTOR REPEATERS

a) *Maximum attenuation in a repeater section*

The maximum attenuation at the highest frequency transmitted to line of a normal repeater section shall be 41 dB or 4.7 Np for low-gain systems with 1, 2 or 3 groups and 36 dB or 4.1 Np for low-gain systems with 4 or 5 groups or 2 supergroups.

b) *Crosstalk*

The far-end crosstalk ratio between circuits in the same direction, measured on the repeater sections of a carrier system on unloaded symmetric pairs, terminated at their two ends by impedances equal to their characteristic impedance, should not be less than the values shown below (which allow for the existence of any crosstalk balancing networks).

1. For the classical method of balancing, the repeater section far-end crosstalk for low-gain transistorized systems up to 120 channels on type II and III cables (or similar cables) or low-gain 120-channel systems on type II *bis* or III *bis* cables should not be less than 69.5 dB (8.0 Np).

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[1] Paragraph 4 of Annex 19 does not recommend a formula for general application for tests on mixed dielectrics. However, for tests of telephone cables, the C.C.I.T.T. recommends the use of the factor 1.4 as representative of current commercial practice.

2. When a "balancing section" comprises several repeater sections, an equivalent result can be obtained from the formula 69.5 — 10 $\log_{10} n$ (dB), where n is the number of repeater sections in the "balancing section".

c) *Regularity of impedance*

The impedance of any circuit in a repeater section forming part of a carrier system on unloaded symmetric pairs should not differ from the nominal value by more than the values shown below:

± 5% (value measured at 60 kHz) for a repeater section forming part of a 12-channel system;

± 8% (value measured at 108 kHz) for a repeater section forming part of a 24-channel system;

± 8% (value measured at 120 kHz) for a repeater section forming part of a 36- or 48-channel system;

± 8% (value measured at 240 kHz) for a repeater section forming part of a 60-channel system;

± 8% (value measured at 552 kHz) for a repeater section forming part of a 120-channel system.

d) *Dielectric strength*

If it is desired to check the dielectric strength of a repeater section after laying, direct current will be applied to the cable at a voltage equal to the specified r.m.s. alternating current test voltage for tests on factory lengths (see paragraph A.d. above).

e) *Insulation resistance*

The insulation resistance measured at the end of the cable between any one conductor and all the other conductors bunched and connected to the earthed sheath (excluding internal repeater station wiring) should not be less than 10 000 megohm-kilometres (approximately 6200 megohm-miles) measured at a potential difference of at least 100 volts and not more than 500 volts. The reading shall be made after electrification for one minute, the temperature being at least 10 °C (50 °F).

B.2 SPECIFICATION OF A REPEATER SECTION WHERE VALVE-TYPE REPEATERS ARE TO BE USED

a) *Maximum attenuation of a repeater section*

The total cable attenuation of a repeater section should not normally exceed 56.5 dB (6.5 Np) for the highest frequency. For 20% of the sections, a maximum value of 61 dB or 7.0 Np.

b) *Crosstalk*

The far-end crosstalk ratio between circuits in the same direction, measured on the repeater sections of a carrier system on unloaded symmetric pairs, terminated at their two ends by impedances equal to their characteristic impedance, should not be less than the values shown below (which allow for the existence of any crosstalk balancing networks).

69.5 dB (8.0 Np) for repeater sections of 12-channel systems;

65 dB or 7.5 Np for repeater sections of 24, 36, 48, 60 or 120-channel systems.

c) *Impedance regularity* (apply the corresponding clauses in section B.1).

d) *Dielectric strength* (apply the corresponding clauses in section B.1).

e) *Insulation resistance* (apply the corresponding clauses in section B.1).

RECOMMENDATION G.322 (former Recommendation G.325, amended in Geneva, 1964)

GENERAL CHARACTERISTICS RECOMMENDED FOR TRANSISTOR-TYPE SYSTEMS ON SYMMETRIC PAIR CABLES

This Recommendation applies to systems using types of cable so far recommended by the C.C.I.T.T. (see Recommendation G.321) and providing 1, 2, 3, 4 or 5 groups or 2 supergroups.

A. General recommendations

a) *Hypothetical reference circuits*

1. The "hypothetical reference circuit on symmetric pairs" is 2500 km long, and is set up on a symmetric pair carrier system. For each direction of transmission, it has a total of:

3 pairs of channel modulators and demodulators,
6 pairs of group modulators and demodulators,
6 pairs of supergroup modulators and demodulators [1].

Figure 1 shows a diagram of the "hypothetical reference circuit on symmetric pairs". It will be seen that there is a total of 15 modulations and 15 demodulations for each direction of transmission supposing that each modulation or demodulation is effected by a single stage [1].

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[1] Where systems provide 1, 2, 3 or 4 groups, it is possible to have a smaller number of modulations, but this does not detract from the usefulness of the idea of a "hypothetical reference circuit on symmetric pairs".

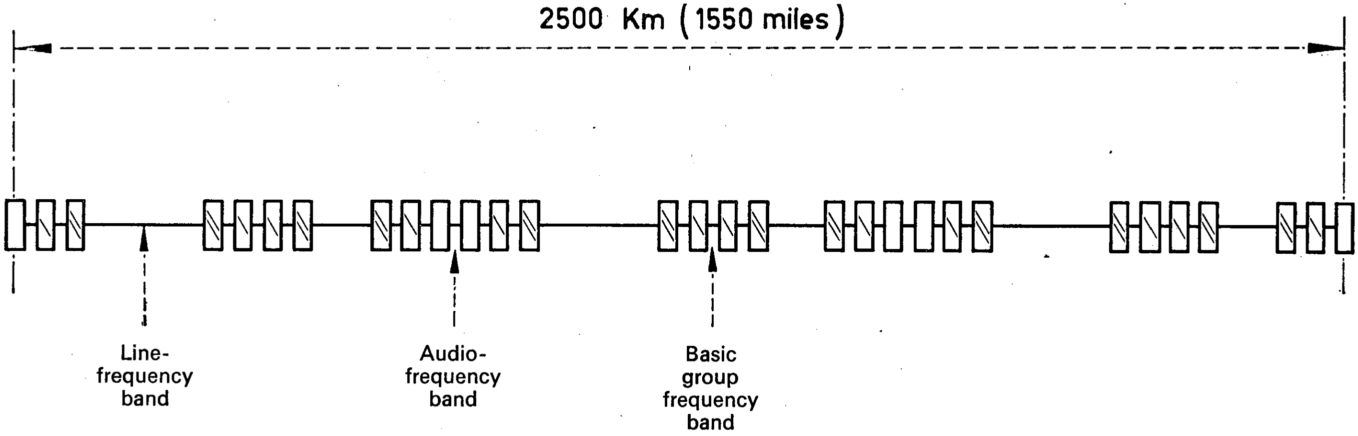


FIGURE 1. — **Diagram of the hypothetical reference circuit on symmetric cable pairs**

This hypothetical reference circuit consists of 6 homogeneous sections of equal length (see Recommendation G.212).

The number of pairs in the cable is assumed to be the same in all sections.

The hypothetical reference circuit on symmetric pairs thus defined is used for systems providing 1, 2, 3, 4 or 5 groups.

2. The composition of the hypothetical reference circuit for a 10-group (2-supergroup) carrier system should be the same as that of the hypothetical reference circuit for a 16-supergroup coaxial cable system (see paragraph c) of Recommandation G.338).

b) *Design objectives for circuit noise*

The objectives mentioned in Recommendation G.222 are applicable to hypothetical reference circuits in the circumstances indicated in Recommendation G.223.

In practice, it is sufficient to check by calculation that, for every telephone channel as defined by the hypothetical reference circuit on symmetric pairs, the mean psophometric power at the end of the channel, referred to a point of zero relative level does not exceed 10 000 pW during any period of one hour.

The subdivision of the total noise between:

— basic noise,
— intermodulation noise,
— noise due to crosstalk

is left entirely to the designer of the system, within the limits of 2500 pW for the terminal equipment and 7500 pW for the line.

Note. — In planning a carrier system on symmetric cable pairs, calculation of the noise due to crosstalk could be carried out by the methods described in Annexes 14, 15 and 16, *Blue Book*, Volume III, Part 4.

c) *Line-frequency spectrum*

1. *Systems providing 1, 2 or 3 groups*

The line-frequency spectrum should be in accordance with the scheme shown in Figure 2*a*).

2. *Systems providing 4 groups*

The frequency spectrum transmitted to line should be in accordance with scheme 1 of Figure 2*b*).

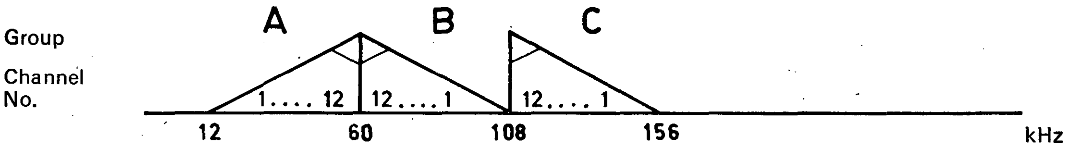
Note. — By agreement between the administrations concerned, it is possible to omit one group of supergroup 1* shown in scheme 2 of Figure 2*c*) for systems with 5 groups; if this is done, scheme 1 *bis* of Figure 2*b*) is obtained.

3. *Systems providing 5 groups*

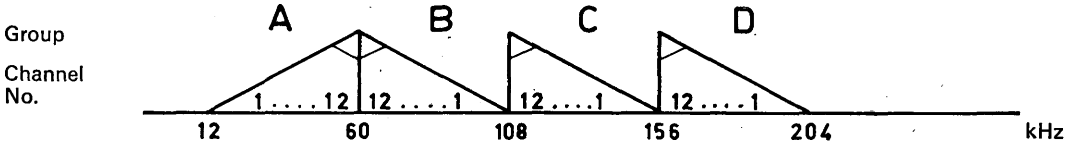
The frequency spectrum transmitted to line should be in accordance with scheme 2 of Figure 2c).

Note 1. — Where there is direct interconnection between a system with 5 groups on symmetric pairs and systems with a smaller number of groups, by agreement between the administrations and private operating agencies concerned, the system with 5 groups, shown in scheme 2 *bis* of Figure 2c), may be used.

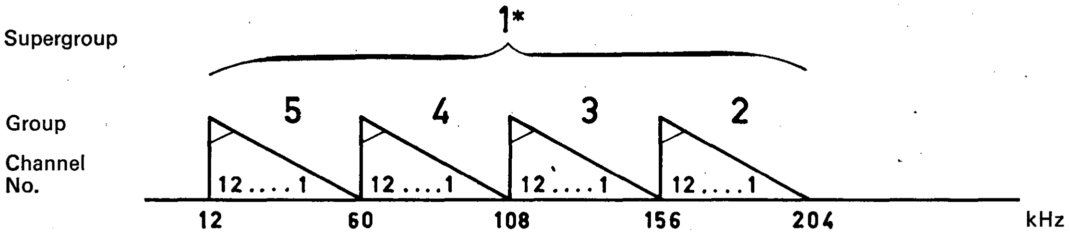
SYMMETRIC PAIRS—TWO GROUPS



a) Systems providing 1, 2 or 3 groups

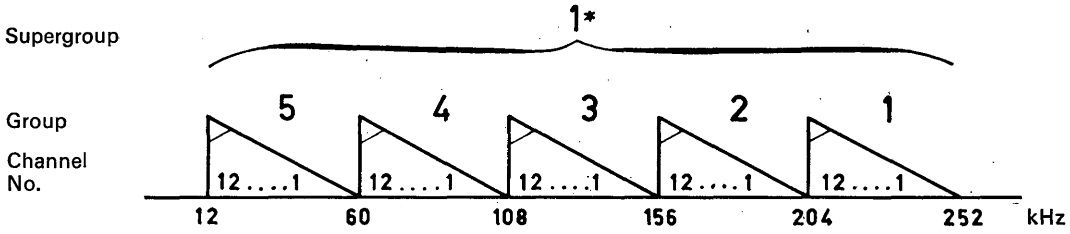


Scheme 1 (recommended)

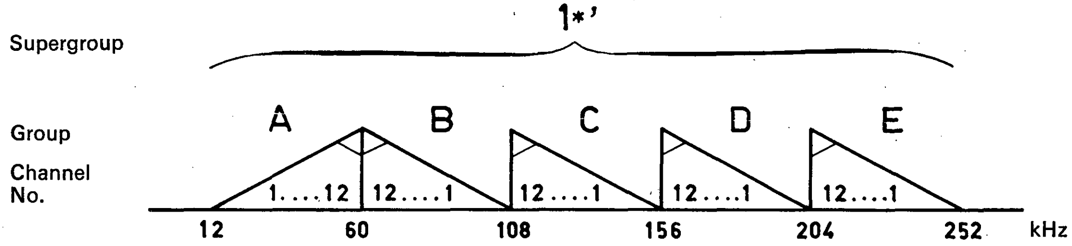


Scheme 1 bis (which may be used by agreement between administrations)

b) Systems providing 4 groups



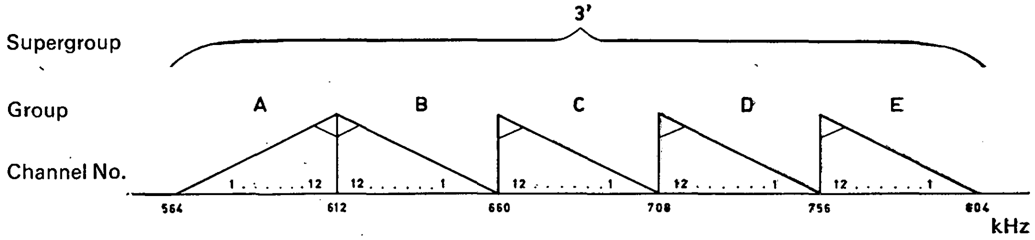
Scheme 2 (recommended)



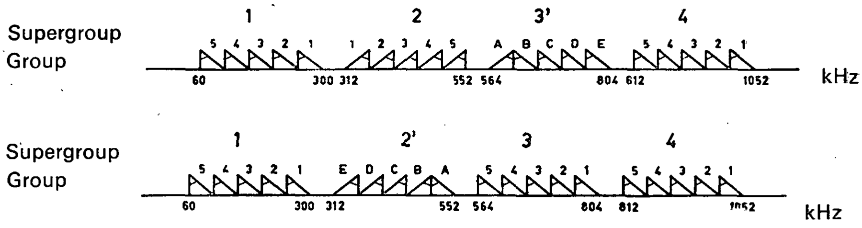
Scheme 2 bis (which may be used by agreement between administrations)

c) Systems providing 5 groups

FIGURE 2. — **Line-frequency allocation for international carrier systems on symmetric cable pairs**

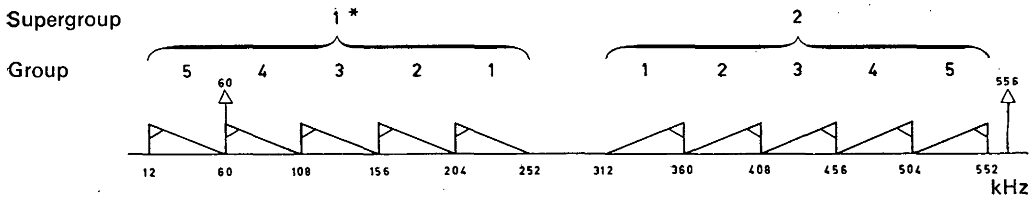


a) Arrangement of groups and channels (supergroup 3′ has been shown as an example)

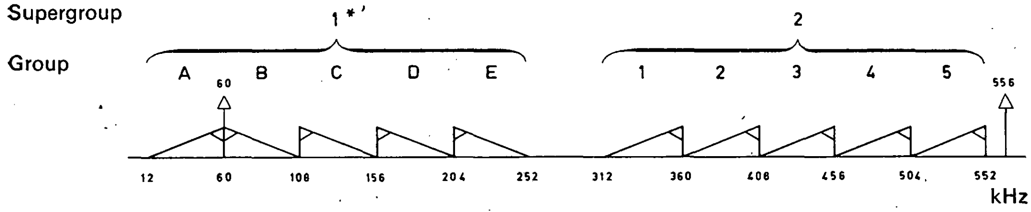


b) Example of possible positions, in the coaxial line-frequency band of the supergroup corresponding to Scheme 2 *bis* of Figure 2*c*

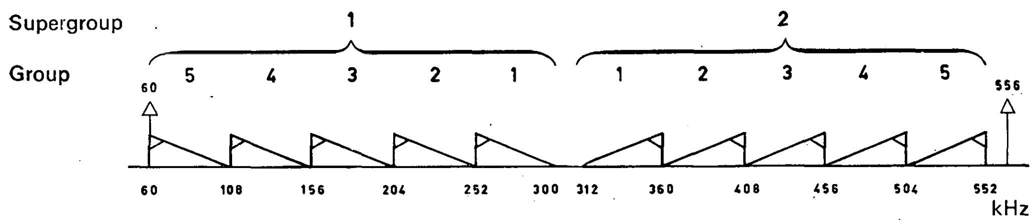
FIGURE 3. — **Arrangement of groups in a supergroup, which may be used in coaxial carrier systems interconnected with systems on symmetric pairs**



Scheme 3 (recommended)



Scheme 3 bis (may be used by agreement between administrations)



Scheme 4 (recommended)

FIGURE 4. — **Line-frequency allocation for international carrier systems providing 2 supergroups on symmetric pair cables**

Note 2. — By agreement between the administrations and private operating agencies concerned, the arrangement in Figure 3 can be used for a supergroup on a coaxial cable system which is to be interconnected at basic supergroup frequencies (312-552 kHz) with either a 5-group system on symmetric pairs using scheme 2 *bis* (Figure 2c)) or with a 4-group system using scheme 1 (Figure 2b)).

Supplement No. 8 of this volume shows a simple way of assembling basic groups B into a supergroup in accordance with one of the schemes shown in Figure 3 above and in Figure 1 of Recommendation G.338 and vice versa.

4. *Systems providing 2 supergroups*

The frequency spectrum transmitted to line should be in accordance with either scheme 3 or scheme 4 of Figure 4, whichever the administration decides.

Supergroups 1 and 2 are the same as those in coaxial cable carrier systems. Supergroup 1* is the same as that normally recommended for 5 group systems on symmetric cable pairs.

Note. — By agreement between the administrations and private operating agencies concerned, for 5 group systems on symmetric cable pairs, instead of supergroup 1*, supergroup 1*′ may be used (scheme 2 *bis*, Figure 2c), which gives the arrangement shown in scheme 3 *bis* of Figure 4.

d) *Line-regulating pilots*

1. *Systems providing 1, 2, 3, 4 or 5 groups*

Either of the following methods can be used (see Figure 5).

Either of these methods can be chosen by the administrations concerned and can be used without difficulty, provided the pilots are efficiently suppressed at the end of a regulated-line section.

Method A

1. A pilot at 60 kHz with an absolute power level of —15 dB (—1.73 Np) at a point of zero relative level, this frequency being in the gap between groups A and B and it being understood that this pilot would be used for regulation of the line on all regulated-line sections, whatever their length, and also for synchronization or checking of frequencies.

2. Where necessary, and especially for long regulated-line sections, an additional line-regulating pilot 4 kHz above the maximum frequency transmitted to line and with an absolute power level of —15 dB (—1.73 Np) at a point of zero relative level.

Note. — There are in existence systems with 5 groups in which this pilot is only 1 kHz above the maximum frequency transmitted.

Point 2 does not apply to systems with a single group.

The recommended accuracy for these pilot frequencies is:

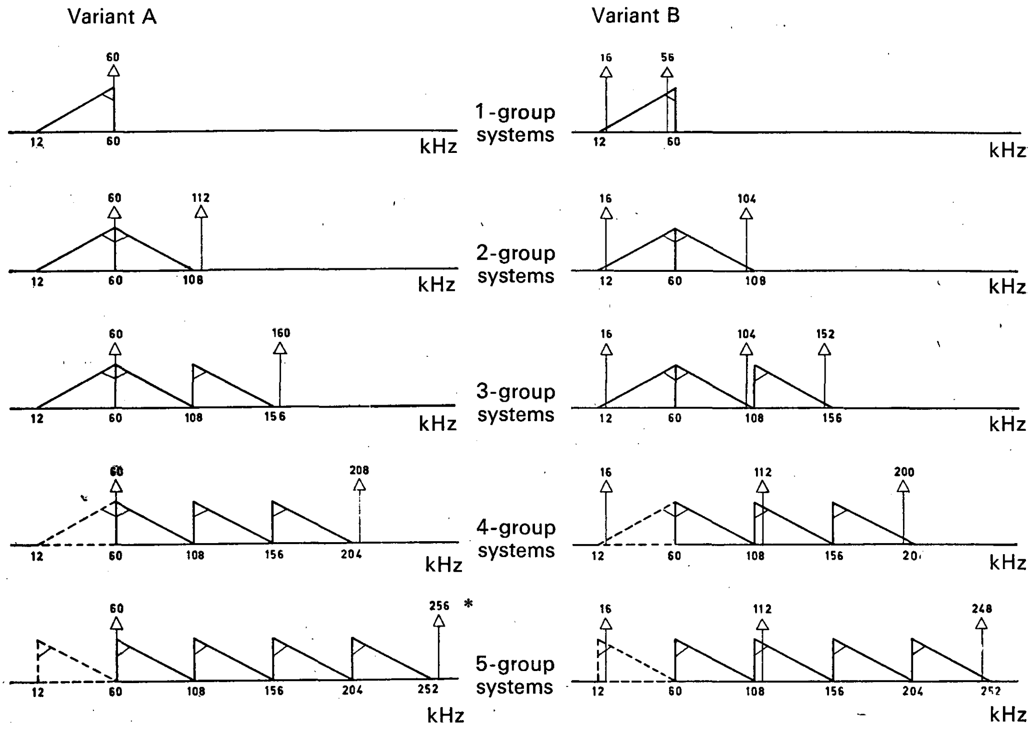
± 1 Hz for the 60-kHz pilot;

± 3 Hz for auxiliary pilot located 4 kHz above the maximum frequency of the channel group concerned.

Method B

Two pilots situated in the basic group B at 64 kHz and at 104 kHz transmitted with an absolute power level of —17 dB or —2 Np at a point of zero relative level.

On the high-frequency line, it is possible to have two pilots per 48 kHz of transmitted band and, from amongst these pilots, 16 kHz and the maximum transmitted frequency less 4 kHz are selected.



Absolute power level (at a zero relative level point)

−15 dB (−1.73 Np)

−17 dB or −2.0 Np

Note. — The group shown dotted can be inverted without changing the frequencies recommended for pilots.

* Recommended frequency; there are systems using 253 kHz.

FIGURE 5. — **Line-regulating pilots for carrier systems on symmetric pairs**

For systems having two or more groups, a third line-pilot is used, located between the top and bottom pilots, 64 kHz is the frequency used in 2-group systems, and 112 kHz in 5-group systems.

2. *System providing 2 supergroups*

The following frequencies and levels are recommended (as shown in Method A of paragraph d) 1 above):

lower pilot: 60 kHz absolute power level of −15 dBm (−1.73 Np) at a zero relative level point;

upper pilot: 4 kHz above the highest transmitted frequency, i.e. 556 kHz absolute power level of −15 dBm (−1.73 Np) at a zero relative level point.

The recommended accuracy for the frequencies of these pilots is as follows:

± 1 Hz for the 60-kHz pilot,
± 3 Hz for the 556 kHz pilot.

Note. — If a supergroup is through-connected from a coaxial-pair system to occupy the position of the upper supergroup in the band of line frequencies, there can be a residue from a line pilot or additional measuring frequency. The recommendations for through-supergroup equipment (Recommendation G.243) ensure that this residue will be sufficiently attenuated to cause no interference with the line-regulating pilots or additional measuring frequencies of another coaxial-pair system when these are sent at an absolute power level of −10 dB or −1.2 Np at a zero relative level point. So that there will be no interference with the 120-circuit system line-regulating pilot sent at −15 dBm0 (−1.73 Npm0), this system should incorporate its own additional protection of 5 dB (5.75 dNp) at 556 kHz for a through-connected supergroup.

e) *Matching of repeater and line impedances*

It is desirable to limit the return-current coefficient at the ends of a repeater section so that the effect of the reflected near-end crosstalk does not contribute excessively to the total far-end crosstalk.

For example, in a cable which has a near-end crosstalk ratio of 56.5 dB (6.5 Np) and which meets the limit for far-end crosstalk ratio (direct far-end crosstalk) of at least 69.5 dB (8 Np) (the cable being between impedances equal to its characteristic impedances), the contribution of the reflected near-end crosstalk would be insignificant compared with the effect of the far-end crosstalk at the maximum frequency transmitted, if the return current coefficients between repeaters and line have the following values.

The modulus of the return-current coefficient between the input (or output) impedance of the repeater (in its normal operating condition and including line transformers and equalizers) measured between the line terminals at the frequency f, and the nominal value of the impedance at the frequency f of the cable pair connected to the input (or output) of the repeater, should not exceed the value given by the formula:

$0.15 \sqrt{\frac{f_{\max}}{f}}$ or 0.25 for systems with 1, 2 and 3 groups;

$0.08 \sqrt{\frac{f_{\max}}{f}}$ or 0.10 for systems with 4 and 5 groups or systems with 2 supergroups on paper-insulated cables (types II and III in Recommendation G.321);

$0.10 \sqrt{\frac{f_{\max}}{f}}$ or 0.17 for systems with 5 groups or systems with 2 supergroups on styroflex or polyethylene-insulated cables (types II *bis* and III *bis* in Recommendation G.321).

Note. — The values of the return-current coefficient recommended for systems with 1, 2 or 3 groups would in general be unsatisfactory if they were tolerated on all the sections of a line link; but they have been accepted as limits for a frontier section because, first, an international circuit will usually comprise only one such frontier interconnection and, second, the matching conditions at such a point may be complicated by the fact that one of the repeaters of this section may not have been specified for the exact type of cable to which it is connected.

B. SPECIAL RECOMMENDATIONS

B.1 *Systems to be used simultaneously with valve-type systems in the same cables*

In those exceptional cases when some pairs in a repeater section are already equipped with valve-type systems in accordance with present recommended practice, and it is desired to equip the free pairs with new transistor systems without changing the existing installations, the new system using transistors must meet the recommendations of Section A of this Recommendation and also the provisions of Recommendation G.324 relating to valve-type systems. However, it may depart from those recommendations specifying permissible values for amplifier harmonic margin and overload point (paragraphs B-c and B-d of Recommendation G.324).

Note. — Recommendation G.323 gives an example of a 60-channel high-gain transistor system.

B.2 *"Low-gain" systems*

a) *Relative level at the output of the repeaters*

The relative level per channel, at any frequency, at the output of each repeater shall be:

—11 dB or —1.3 Np for systems with 1, 2 or 3 groups;
—14 dB or —1.6 Np for systems with 4 or 5 groups or 2 supergroups.

b) *Monitoring frequencies*

If a monitoring (or fault-locating) frequency is sent over a normally operating system, it may for example be in the band 560-600 kHz for a 2-supergroup system.

Note. — Frequencies sent only over a system already withdrawn from service because of a fault can be selected by each administration on the national level.

c) *Harmonic distortion*

The harmonic distortion repeater does not exceed a value corresponding to the limits shown in the following table:

Limits for	Systems providing		
	1, 2 or 3 groups	4 or 5 groups	2 supergroups
2nd-order harmonic margin[a]. . . .	79 dB or 9.1 Np	82 dB or 9.4 Np	85 dB or 9.8 Np
3rd-order harmonic margin[a]. . . .	92 dB (10.6 Np)	98 dB (11.3 Np)	104 dB or 12 Np

[a] See *List of Definitions of Essential Telecommunication Terms*, page 69, definition 06.48.

Note. — These values are measured for a power of 1 mW applied at a point of zero relative level on any channel.

d) *Noise factor*

The noise factor of a complete repeater (taking into account noise due to the transistors, the input network and the line-matching network) does not exceed 10 dB or 1.2 Np.

e) *Overload point*

The overload point, defined in paragraph 6.1 of Recommendation G.223, is at least 14 dB or 1.6 Np for the intermediate repeaters.

Note. — For determination of this overload point, account has been taken of a margin of a few decibels for level variations due to geographical differences with respect to the theoretical site of a repeater, to temperature variations of the cable, to equalization inaccuracies, etc. In stations where this margin is unnecessary, a repeater overload point that is slightly lower may therefore be chosen.

f) *Crosstalk ratio between repeaters in the same station*

A typical figure for the crosstalk ratio between repeaters in the same station is 87 dB or 10 Np. With this figure it is possible to use repeater stations regardless of the cable-balancing method adopted.

Note. — If, however, the cable is balanced by repeater sections in the conventional way, a figure of 80 dB (9.2 Np) is adequate.

The figures given above apply to all the equipment at the repeater station, from the input transformer to the output transformer.

g) *Power feeding*

In the absence of a special agreement between the administrations concerned in a power-feeding section crossing a frontier, it is recommended that each administration power-feed only the repeater stations on its own territory.

RECOMMENDATION G.323 (former Reccommendation G.326, Geneva, 1964)

TYPICAL TRANSISTORIZED SYSTEMS ON SYMMETRIC PAIRS IN CABLE

This Recommendation defines typical transistorized systems on symmetric pairs in cable (differing for the two directions of transmission) which comply with Recommendation G.321. These systems must meet the requirements set forth in Recommendation G.322. They have been defined for the benefit of administrations which do not themselves devise specifications for the supply of cables and equipment. They must not be considered as recommended by the C.C.I.T.T. in preference to other systems which would also meet the requirements of Recommendation G.322. Administrations and manufacturers which contemplate designing such systems are asked to adhere, so far as possible, to the characteristics of one of the typical systems defined below. This will enable the C.C.I.T.T. to direct future studies in such a way as to restrict the number of differing systems, to facilitate inter-connection between equipments of different manufacture and, if necessary, to prepare for standardization at some future date.

The following is a description of a high-gain system.

Principal parameters of a 60-channel transistorized system ("high-gain" system)

This system has been specified because it can be used simultaneously with 60-channel valve-type systems in the same cables.

Principal parameters of the system

1. Frequencies transmitted to line:12-252 kHz

2. Transmission levels:

without pre-emphasis		— 0.55 Np
with pre-emphasis	at 12 kHz	— 1.3 Np
	at 252 kHz	— 0.1 Np

3. Line-pilot frequencies

— for amplification regulation independent of frequency	248 kHz
— for linear regulation with frequency	16 kHz
— for supplementary regulation ((curvilinear)	112 kHz

4. Repeater station amplication (with average regulator positions of the automatic amplification regulation) 5.75 ± 0.60 Np

5. Limits of the automatic amplification regulation:

a) in unattended stations depending on the soil temperature	at 12 kHz	± 0.13 Np
	at 252 kHz	± 0.24 Np
b) in pilot-regulated stations		
— for amplification regulation independent of frequency	248 kHz	± 0.50 Np
— for linear regulation with frequency	16 kHz	± 0.40 Np
— for supplementary regulation (curvilinear)	112 kHz	± 0.35 Np

6. Absolute thermal noise level at the repeater input in the 248-252 kHz spectrum — 15.2 Np

7. Non linearity attenuation of the repeaters at zero output absolute level according to the main frequency power

— for the second harmonic	10.0 Np
— for the third harmonic	12.5 Np

8. Reflection coefficient at the station input and output in relation to the input resistances of the cable $P \leq \sqrt{0.1 \frac{f_{\max}}{f}}$ and less than 0.2

9. Absolute overload point of the amplifiers above 2.65 Np

10. Signal-to-crosstalk ratio between the two transmission directions in the station with 6.0 nepers gain at 252 kHz:

for 25% combinations above	10.0 Np
for 75% combinations above	11.0 Np

11. *Power feeding*

Up to 12 unattended repeater stations are placed between the attended repeater stations Direct current power is fed to six stations on each side of the attended repeater station by an earth-wire system, the repeaters of a system on the power-feed section being inserted in series in a power circuit.

If the induced outside voltages are more than 75 volts, the supply can be two-wire without earth return.

The number of unattended repeater stations on the section between the two attended repeater stations does not exceed 6. The maximum power-feed is 500 volts.

A study of the effect of induced voltages, raising of the earth potential in the neighbourhood of electric installations, and surges due to lightning is to be carried out by the C.C.I.T.T. (Question 21/V).

12. *Remote control of repeaters*

In this system the efficiency of the repeaters is checked from the amplification and non-linearity attenuation in the $2 f_1 - f_2$ type.

RECOMMENDATION G.324 (Corresponds to former Recommendations G.321 and G.322)

GENERAL CHARACTERISTICS FOR VALVE-TYPE SYSTEMS ON SYMMETRIC CABLE PAIRS

A. GENERAL RECOMMENDATIONS

a) *Hypothetical reference circuit*

b) *Noise objectives*

c) *Line-frequency spectrum*

d) *Line-regulating pilots*

The corresponding paragraphs of Section A of Recommendation G.322 apply in their entirety.

e) *Matching of repeater and line impedances*

The general considerations set forth in Recommendation G.322, section A, paragraph e) apply. However, the maximum value of the modulus of the return-current coefficient is uniformly $0.15 \sqrt{\frac{f_{\max}}{f}}$ or 0.25 for all systems.

B. SPECIFIC RECOMMENDATIONS

In addition to the general recommendations set forth above, the following conditions relating to valve-type repeaters shall apply:

a) *Maximum gain*

The complete equipment of an intermediate repeater station should have a maximum gain of 61 dB or 7 Np measured at the highest frequency transmitted.
The above value is a nominal value and a factory tolerance of ± 1 dB or ± 0.1 Np, throughout the band of effectively transmitted frequencies, is allowed.

b) *Relative levels* [1]

Nominal values. — At the various measuring frequencies selected, the relative power level measured at the input to the repeater at the far end of a repeater section crossing the frontier should always be greater than —56.5 dB or —6.5 Np when, at the terminal equipment, a power of one milliwatt is applied at the origin of each audio-telephone circuit. (Any equalizers are considered to be a part of the repeater.)
The nominal value of the relative power level, measured at the input of the repeater, under the same conditions as above, is as follows:

— systems providing 1, 2 or 3 groups: + 4.5 dB or + 0.5 Np
— systems providing 4 or 5 groups or 2 supergroups: +1.75 dB or + 0.2 Np.

Interconnection conditions at frontier repeaters. — For lining-up and for "reference" (see Maintenance Instructions, *White Book*, Volume IV), well-defined frequencies have been chosen which can be used to obtain the attenuation/frequency characteristic of the line. As a guide, frequencies that may be used are spaced at:

4 kHz between 12 and 60 kHz,
8 kHz between 60 and 108 kHz,
12 kHz between 108 and 252 kHz.

In frontier stations, at the output of each line repeater, the value measured at each of these frequencies should normally be + 4.5 dB or + 0.5 Np for systems with 1, 2 or 3 groups and + 1.75 dB or + 0.2 Np for systems with 4 or 5 groups or 2 supergroups (except where special cables are concerned, such as submarine cables, or where a special method of equalization is used, for example, pre-equalization). No value of the relative power level thus measured should depart from the nominal value given above by more than ± 2 dB or ± 0.2 Np.

c) *Harmonic distortion*

The harmonic distortion of a repeater should not exceed a value corresponding to the limits shown in the following table:

---

[1] Not applicable to power-fed repeaters.

Limits for	Systems providing		
	1, 2 or 3 groups	4 or 5 groups	2 supergroups
2nd-order harmonic margin [a]. . . .	77 dB or 8.9 Np	80 dB (9.2 Np)	83 dB or 9.5 Np
3rd-order harmonic margin [a]	84 dB or 9.7 Np	90 dB (10.4 Np)	100 dB (11.5 Np)

[a] See the *List of Definitions of Essential Telecommunication Terms*, page 69, definition 06.48.

Note. — These values apply when the repeater gain is set to 56.5 dB (6.5 Np) and for a fundament al power of 1 mW at a point of zero relative level, and assuming that valves with average characteristics are use d.

d) *Overload point*

The overload point is defined in paragraph 6.1 in Recommendation G.223. For the repeaters of systems providing 1, 2, 3, 4 or 5 groups it should be at least 28 dB or 3.2 Np and for the repeaters of systems providing two supergroups it should be at least 29 dB or 3.3 Np.

e) *Minimum value of the crosstalk ratio between repeaters in the same repeater station*

The crosstalk ratio between two repeaters in the same station should be no less than 74 dB or 8.5 Np.

This value applies to the whole of the repeater station equipment from the input transformer to the output transformer.

RECOMMENDATION G.325 (former Recommendation G.327, Geneva, 1964)

GENERAL CHARACTERISTICS RECOMMENDED FOR TRANSISTORIZED SYSTEMS PROVIDING 12 TELEPHONE CARRIER CIRCUITS ON A SYMMETRIC PAIR IN CABLE (12 + 12 SYSTEMS)

Transistorized systems of the 12 + 12 type on symmetric pairs in cable are used for carrier working either on old deloaded cables or on cables specially constructed for the purpose (without a second cable being required). These systems may be used in regional or local relations, or in long-distance relations, trunk or international.

This Recommendation applies to systems for long-distance relations making use of the kinds of cable at present recommended by the C.C.I.T.T. (see Recommendation G.321) and to multiple-twin quad cables with conductors of 0.9 mm diameter, with an effective capacitance of 35 to 40 nF/km or other kinds of deloaded cables of equivalent quality. For systems used for local or regional relations, some clauses of the present recommendation may be made less stringent.

a) *Frequency spectrum transmitted to line*

The C.C.I.T.T. recommends that the line-frequency spectrum should be in accordance with Scheme 1 or 2 of Figure 1.

Administrations or private operating agencies concerned in setting up such an international system should agree to use either one or the other of the two schemes.

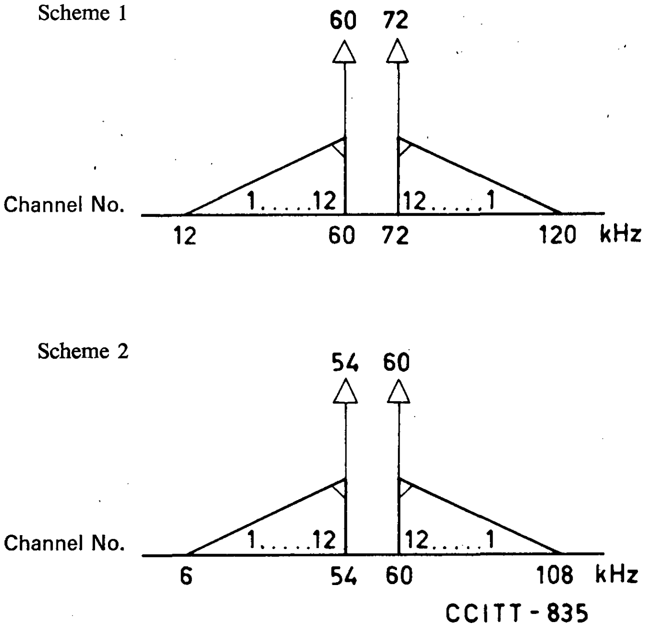


FIGURE 1. — **Arrangement of line-transmitted frequencies for international 12+12 cable systems using transistors**

b) *Line-regulating pilots*

The following frequencies are recommended:

with Scheme 1: 60 kHz and 72 kHz
with Scheme 2: 54 kHz and 60 kHz.

The recommended accuracy is ± 1 Hz for the 60-kHz pilot. The frequency tolerance for other pilots will be decided by agreement between the administrations concerned.

All these pilots should be transmitted at an absolute power level of —15 dB (—1.73 Np) at a zero relative level point.

c) *Hypothetical reference circuit for 12 + 12 symmetric-pair systems*

This is 2500 kilometres long, and for each direction of transmission comprises a total of:

— three channel translation pairs,

— nine special translation pairs translating a basic group into the band transmitted to line, and vice versa.

This circuit is carried on a 12 + 12 symmetric-pair system in cable. We shall assume that we are dealing with pairs of conductors of 0.9 mm diameter, with an effective capacitance of 35 to 40 nF/km.

Figure 2 shows one of the three identical parts of which this hypothetical reference circuit is made up. All in all, it has 18 homogeneous sections, each 140 kilometres long.

Note 1. — There are only half as many translation pairs as there are homogeneous sections, because one of the two bands transmitted to line corresponds to a basic group (see Figure 2).

Note 2. — With systems using frequency-frogging in the repeaters, the appropriate modulators form part of the high-frequency line.

d) *Design objectives for circuit noise*

The objectives set forth in Recommendation G.222 apply to the hypothetical reference circuit for symmetric-pair 12 + 12 systems, in the circumstances described in Recommendation G.223.

In practice, it will suffice to check by calculation that the mean psophometric power at the end of every telephone channel as defined by the hypothetical reference circuit, at zero relative level, does not exceed 10 000 picowatts during any hour.

Provisionally, it is recommended that this overall limit be apportioned between the total noise components as follows:

Line noise (including noise due to special translation equipment)	9000 pW
Noise due to channel translating equipment	1000 pW

Apportionment of total noise inherent in the system among:

— basic noise,

— intermodulation noise,

— noise due to crosstalk,

is left entirely to the discretion of the carrier system designer, up to 1000 pW for channel translating equipment and 9000 pW for the line.

Note. — In accordance with all recommendations on cable systems in the G series recommendations, the design objective as regards noise power does not take into consideration noise from external sources; it is assumed that this is negligible compared with the figure of 10 000 pW.

With regard to real circuits, administrations must take whatever steps are required in each individual case to ensure that clicks arising on audio-frequency pairs in the same cable as a (12 + 12) system and transmitted by crosstalk do not create excessive noise on the circuits of that system which may be used for international communications.

e) *Error on the reconstituted frequency*

The difference between a frequency sent at the origin of a homogeneous section 140 km long (see paragraph c) and Figure 2) and the frequency received at the end of that section,

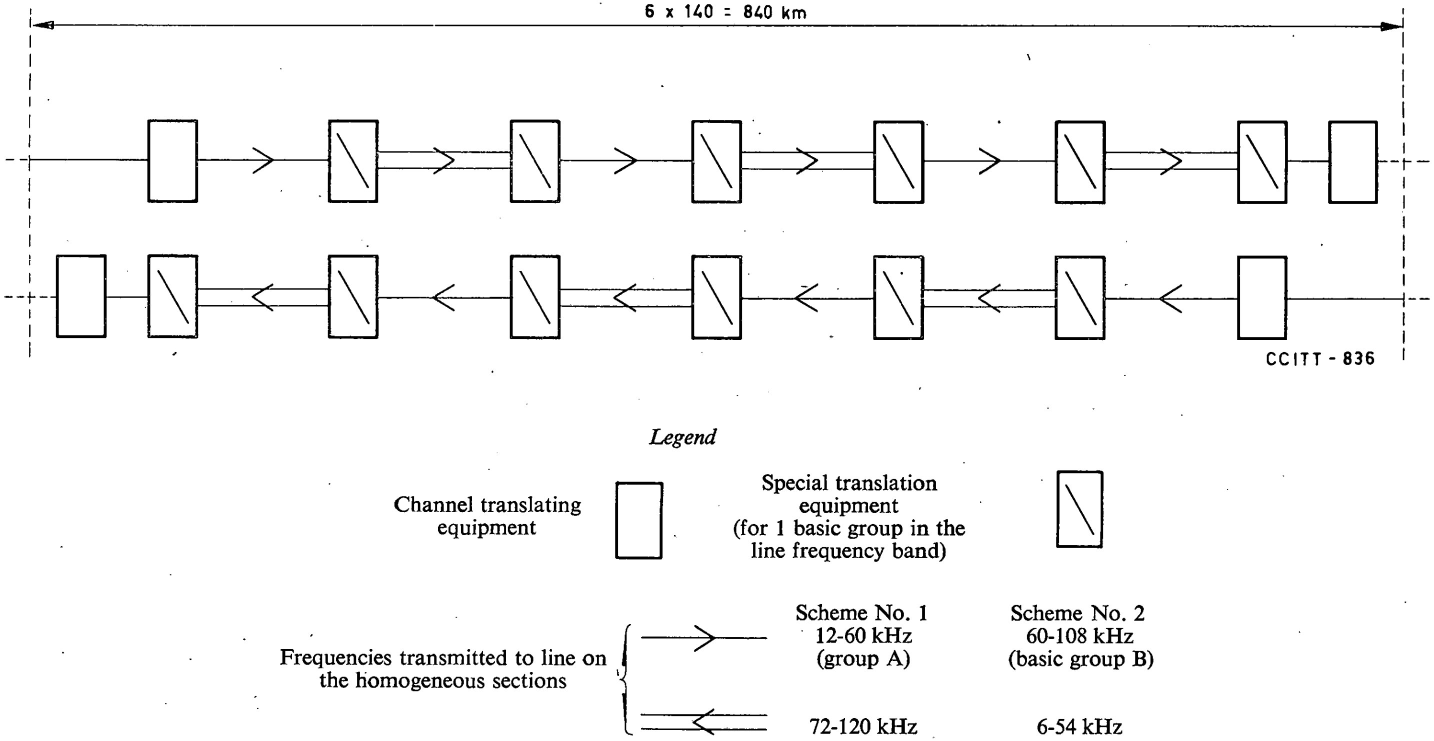


FIGURE 2. — **Basic diagram of one-third of the hypothetical reference circuit for symmetric pair 12+12 systems**

should not exceed a figure provisionally fixed at 0.3 Hz; this figure is the same whether there is frequency-frogging in the intermediate repeaters or not.

f) *Direct line interconnection*

When administrations desire the direct line interconnection of two systems (with, of course, the same allocation of line-transmitted frequencies) it is recommended that each of these systems should meet the following requirements on the interconnection section (except where agreed otherwise between the administrations concerned):

1. Relative level per channel, at all frequencies, at the output of the frontier repeaters: −15 dB or −1.7 Np [1].

2. Attenuation of the frontier repeater section at the highest frequency transmitted to line:
   25 dB or 2.9 Np [1].

Note. — For composite cables, agreement should be reached between the two administrations concerned to fix the attenuation of the frontier section in such a way that the repeaters of the symmetric pairs and those of the coaxial cables can be housed in the same frontier stations.

3. Matching of the impedances of the frontier repeaters and the line. The modulus of the return-current coefficient between the input (or output) impedance of a repeater and the characteristic impedance of the line should not exceed the lower of the two values:

$$0.15 \sqrt{\frac{f_{\max}}{f}} \text{ or } 0.25.$$

g) *Interconnection in a main station*

If such interconnection is necessary, either for operating reasons, or because the two systems to be interconnected use different allocations of frequencies transmitted to line, one of the following procedures may be followed:

1. Interconnection at a group distribution frame, with use of the basic group, levels and impedance applied normally by the administration to which the frame belongs.

2. Direct interconnection between the two systems. If they use different allocations of frequencies transmitted to line, the two administrations concerned shall reach agreement on which of them shall install the necessary demodulators (the line of separation between the two types of equipment will then be CC′ or DD′ on Figure 3).

In the absence of such an agreement, each incoming system must comprise equipment required for the outgoing system, in each direction of transmission (the separating line in Figure 3 would then be the oblique DC′).

Unless there is a specific agreement, the relative power level will be −36 dB or −4.1 Np at sending (input of each system—points C′ and D in the case of Figure 3). The points

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[1] These values apply to low-gain systems. High-gain systems (i.e. substantially above 30 dB) are still under study.

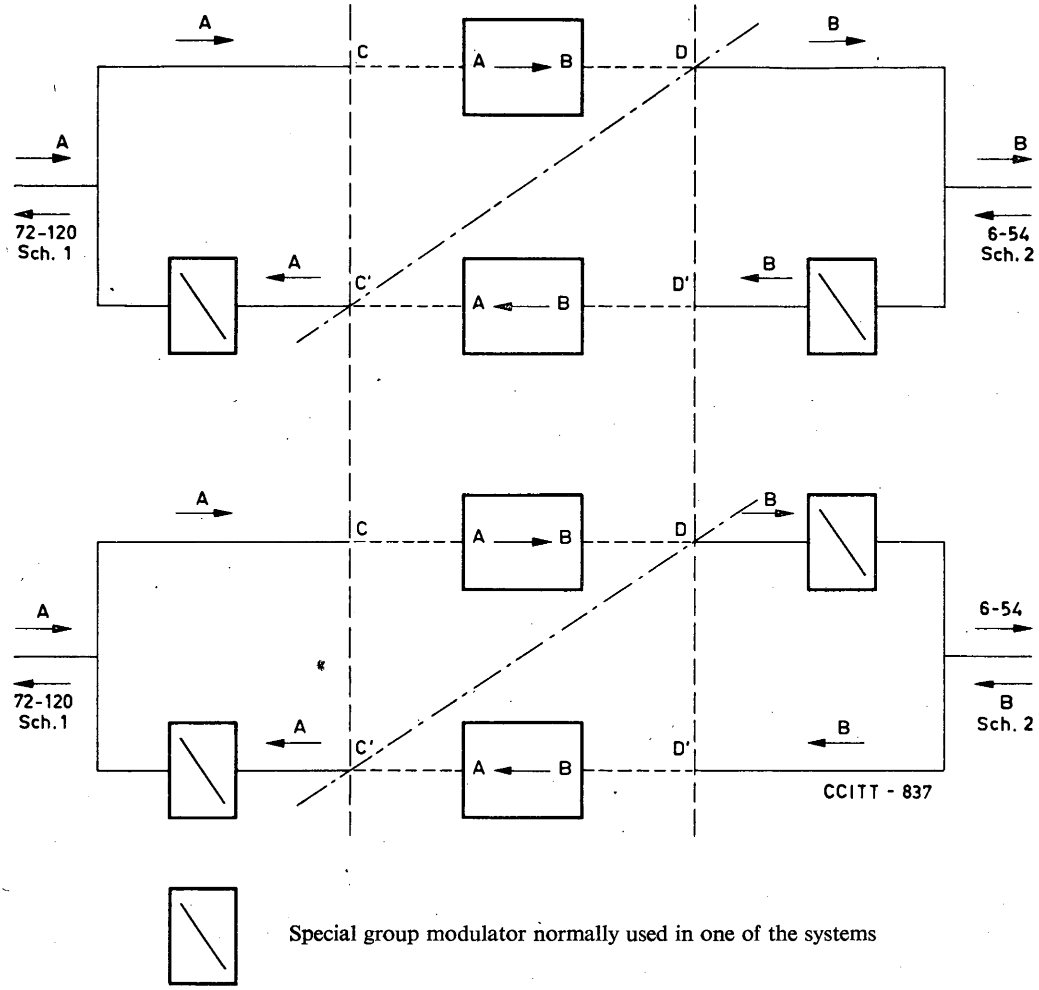

FIGURE 3. — **Direct interconnection of two 12+12 systems using different allocations of frequencies transmitted to line**

considered do not correspond to points T and T′ defined in Recommendation G.213. In particular, a translating equipment of any type cannot be connected to it without precautionary measures (see the levels indicated in the table of Recommendation G.233).

By agreement between administrations, interconnection can be effected as indicated in Figure 4, a method whereby it is possible to replace three modulators by one.

h) *Essential clauses for a model specification*

See Recommendation G.326.

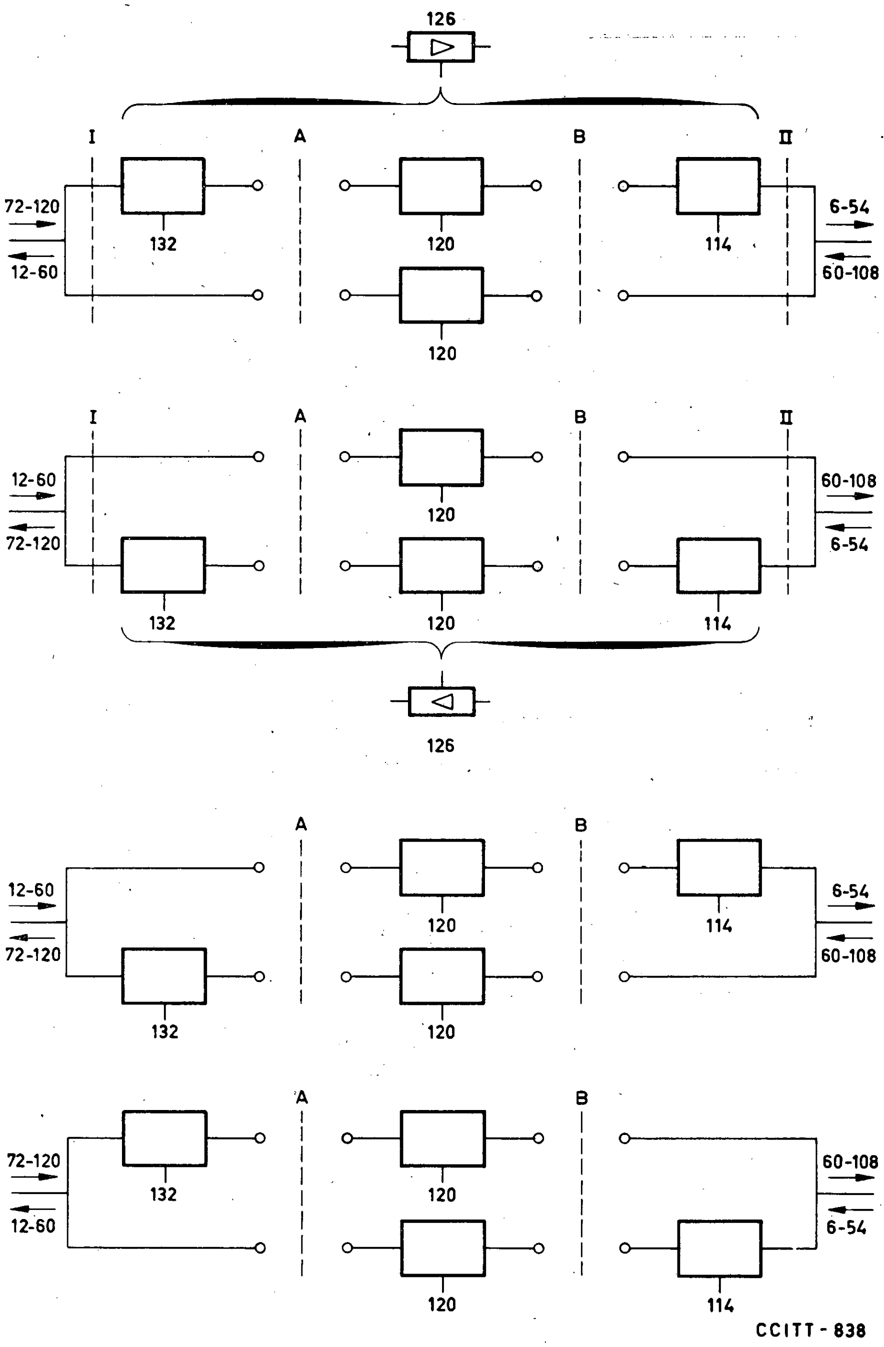

FIGURE 4. — **Method of interconnection that can be used by agreement between administrations (the numbers on this diagram show frequencies in kHz ; A and B indicate the basic group concerned)**

RECOMMENDATION G.326 (former Recommendation G.328, Geneva, 1964)

TYPICAL TRANSISTORIZED SYSTEMS ON SYMMETRIC PAIRS OF THE (12 + 12) TYPE

This Recommendation defines typical transistorized systems using one symmetric cable pair for the two directions of transmission. These systems must meet the requirements set forth in Recommendation G.325. They have been defined for the benefit of administrations which do not themselves study specifications for the supply of cables and equipment. They must not be considered as recommended by the C.C.I.T.T. in preference to other systems which would also meet the requirements of Recommendation G.325. Administrations and manufacturers which contemplate designing such systems are asked to adhere, so far as possible, to the characteristics of one of the typical systems defined below. This will enable the C.C.I.T.T. to direct future studies in such a way as to restrict the number of differing systems, to facilitate interconnection between equipments of varying manufacture and, if necessary, to prepare for standardization at some future date.

The following abbreviations will be used:

— A low-gain systems;

— B high-gain systems without frequency-frogging;

— C high-gain systems with frequency-frogging in each line repeater.

A. General characteristics

a) *Relative levels*

Crosstalk restricts the gain of low-gain systems to about 30 dB or 3.5 Np. Further, the exact length of a repeater section is often determined with respect to a loading step. The result is a maximum attenuation of about 27 to 30 dB, or 3.1 to 3.5 Np for a repeater section and a repeater output level of —10 to —13 dB, or —1.2 to —1.5 Np, at least in the upper frequency band transmitted to line.

In high-gain systems, frequency-frogging is in general use, with or without pre-emphasis; in this case, the siting of the loading coils has no effect on the placing of repeaters. Typical values are: 56 to 60 dB, or 6.5 to 7 Np, attenuation for a repeater section and either 0 dB or +0.8 Np, or + 7 dB as the repeater output level for systems without frequency-frogging, or with frequency-frogging but without pre-emphasis. Other values are applicable for systems with frequency-frogging and with pre-emphasis.

b) *Matching of repeater and line impedances*

The same values are applied in a normal section as those recommended for a frontier section in Recommendation G.325, f).

B. CHARACTERISTICS OF REPEATERS

a) *Non-linear distortion*

The harmonic margin and intermodulation products are not less than the figures in the following table:

System	Harmonic margin [1]		3rd order intermodulation products
	2nd order	3rd order	
Low-gain			
without frequency-frogging (A) .	78 dB (9 Np)	92 dB (10.6 Np)	
High-gain			
without frequency-frogging (B) .	74 dB or 8.5 Np	78 dB (9 Np)	
with frequency-frogging (C)			
(1)	70 dB or 8 Np	90 dB or 10.3 Np	
(2)			75 dB or 8.6 Np

[1] See *List of Definitions of Essential Telecommunication Terms*, page 69, definition 06.48.
(1) Lower-band amplifiers (12-60 kHz or 6-54 kHz)
(2) Upper-band amplifiers (72-120 kHz or 60-108 kHz)

Note. — The figures in this table are typical values. All systems should satisfy the requirements of Recommendation G.325, d).

b) *Noise factor*

The noise factor of a complete repeater (including the equalizers or other passive networks, if any) does not exceed 10 dB or 1.2 Np at the highest frequencies transmitted.

Note. — In low-gain systems, this figure is not critical and may be exceeded.

c) *Overload point*

The peak factor taken from Table 2 of Recommendation G.223 having been added to the relative level, a margin of a few decibels, as for four-wire systems, is still required.

d) *Crosstalk ratio repeaters in the same station*

The crosstalk ratio between repeaters in the same station is not less than:

82 dB or 9.5 Np in type A systems
80 dB (9.2 Np) in type B and C systems.

These values are valid for all the equipment at the repeater station, from the input transformer to the output transformer.

C. TYPES OF CABLE USED

12 + 12 systems can be established:

1. on deloaded old cables, or
2. on new cables, comprising quads reserved for high-frequency operation.

The equipments defined in this recommendation may be used on both types of cable, but when they are used on deloaded old cables there are other conditions which should be met, apart from those indicated in this recommendation. In particular, if the disturbance caused by other pairs in the same cable is too great, the noise objectives in Recommendation G.325, d) cannot be achieved.

RECOMMENDATION G.327

(former Recommendation G.324 replacing Recommendation G.352, *Red Book* Volume III, amended in Geneva, 1964)

VALVE-TYPE SYSTEMS OFFERING 12 TELEPHONE CARRIER CIRCUITS ON A SYMMETRIC PAIR IN CABLE (12 + 12) SYSTEMS

Valve-type (12 + 12) systems on symmetric cable pairs are used for carrier working (without the need for laying a second cable) either on old deloaded cables, or (in special cases) on cables specially laid (these generally being short). Therefore, it is very unlikely that, in the international network, these systems will be used for long distances or will involve more than two countries.

a) *Frequency spectrum transmitted to line*

The C.C.I.T.T. recommends that the line-frequency spectrum should be in accordance with Scheme 1 or 2 of Figure 1.

Administrations or private operating agencies concerned in setting up such an international system should agree to use either one or the other of the two schemes.

b) *Line-regulating pilots*

For valve-type (12 + 12) channel carrier telephone systems on symmetric pairs where

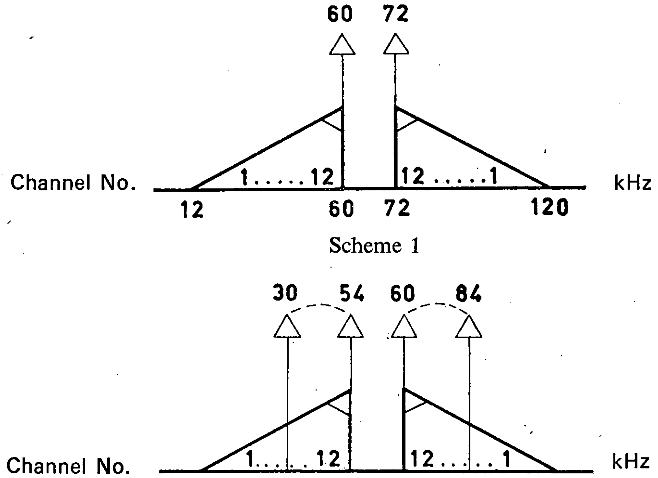

FIGURE 1. — **Line-frequency arrangements for international (12+12) cable systems using valves**

it is necessary to use pilots, the following frequencies are recommended:

With Scheme 1: 60 kHz and 72 kHz,
With Scheme 2: 54 kHz and 60 kHz or 30 kHz and 84 kHz.

These pilots should be transmitted with an absolute power level of —15 dB (—1.73 Np) at a point of zero relative level.

The recommended accuracy is ± 1 Hz for the 60-kHz pilot. The frequency tolerance for other pilots will be decided by agreement between the administrations concerned.

All these pilots should be transmitted at an absolute power level of —15 dB (—1.73 Np) at a zero relative level point.

Note. — Administrations which have agreed to use Scheme 2 should agree to choose between the two groups of line-regulating pilots shown above. When the frequencies 30 kHz and 84 kHz are used, and a group is to be extended on another carrier system, administrations concerned with the (12 + 12) system should take the necessary steps to ensure that this line-regulating pilot does not interfere with the other system.

Also, it is necessary to ensure that the carrier leaks (30 or 84 kHz) do not interfere with the regulation of the line.

3.3 Carrier systems on 2.6/9.5-mm coaxial cable pairs

The Plenary Assembly (Mar del Plata, 1968) rearranged the Recommendations in this sub-section so as to place more emphasis on modern transistor systems and grouped the Recommendations common to all coaxial pair systems (2.6/9.5 mm and 1.2/4.4 mm) and the Recommendations dealing with certain special cases in a new sub-section 3.5.

The following table shows the coaxial pair systsms to which the various Recommendations in sub-sections 3.3, 3.4 and 3.5 apply. The numbers of the former Recommendations in sub-section 3.3 of the *Blue Book*, Volume III, are shown in parentheses. The numbering of the Recommendations in sub-section 3.4 remains unchanged.

Type of coaxial pair	2.6/9.5 mm—Recommendation G.331 (G.334)				
Nominal repeater spacing (km)	9-9.7	9-9.7	4.5-4.8	4.5-4.8	1.5 approx.
	Valve-type systems			Transistorized systems	
	2.6 and 6 MHz	4 MHz	12 MHz	12 MHz	40/60 MHz
Former Recommendations *(Blue Book)*	(G.331)	(G.332)	(G.333)		
New Recommendations *(White Book)*	G.337	G.338	G.339	G.332	G.333

Type of coaxial pair	1.2/4.4 mm—Recommendation G.342				Special
Nominal repeater spacing (km)	6 or 8	4	3	2 approx.	
	Transistorized systems				
	1.3 MHz	4 MHz	6 MHz	12 MHz	(120+120) system
Former Recommendations *(Blue Book)*	(G.341)	(G.343)	(G.344)		
New Recommendations *(White Book)*	G.341	G.343	G.344	G.345	G.356

Note. — See also Recommendations G.351 (G.335) and G.352 (G.336).

RECOMMENDATION G.331 (former Recommendation G.334, amended at Mar del Plata, 1968)

CHARACTERISTICS OF COAXIAL CABLE PAIR, TYPE 2.6/9.5-mm OR 0.104/0.375-in.[1]

A. CABLE SPECIFICATION

a) *Type of coaxial pair*

It is very desirable to have throughout the European network the same type of coaxial pair and having the following characteristics:

The centre conductor should be a solid copper wire of 0.104 in. or 2.6 mm diameter. The outer conductor should be a soft copper tape, formed into a cylinder around the insulation, the axis of this cylinder being the axis of the centre conductor; the thickness of the copper tape used for the outer conductor should be 0.010 in. or 0.25 mm; the interior diameter of the outer conductor should be 0.375 in. or 9.5 mm. The insulation should be such that the mean dielectric constant of the combination of gas and low-loss solid dielectric material is low enough to meet the requirements of this specification.

It is desirable, for crosstalk reasons, to surround each outer copper conductor with two open helical soft steel tapes.

b) *Average impedance*

The real component of the best balance against the impedance of the coaxial cable at 2.5 MHz should not differ by more than one ohm from the nominal value of 75 ohms.

c) *Impedance regularity*

Measurements of impedance regularity are carried out by means of pulses sent over the coaxial cable, echoes of these pulses being observed at the sending end.

Measurements can be made from either or both of the ends of a factory length, and the pulse used should be an approximate sine-squared pulse having a half-amplitude width less than 0.1 microsecond. The results are expressed in terms of "echo attenuation". This, for a peak in the response curve, is the logarithmic ratio in dB or Np of the amplitude of the transmitted pulse to that of the peak concerned.

The corrected echo attenuation of the highest peak in the echo curve as measured on all factory lengths should not be less than the following values:

50 dB or 5.8 Np for all coaxial pairs;
54 dB or 6.2 Np for at least 95% of all coaxial pairs measured.

Moreover, not more than 20% of the coaxial pairs constituting a repeater section on one direction of one system should have corrected echo attenuations less than 54 dB or 6.2 Np.

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[1] These coaxial pairs may be used for the following system: 2.6 MHz, 4 MHz, 6 MHz, 12 MHz, 40 MHz or 60 MHz (see Recommendations G.332 to G.339).

It should also be checked that one of the following two conditions is met:

1. The arithmetic mean of the three smallest echo attenuations for a coaxial pair should be at least 55 dB or 6.3 Np.

2. The "equivalent ratio" should not exceed 0.6 ohm for lengths of less than 300 metres or 0.8 ohm for lengths of 300 metres or more. The "equivalent ratio" is that single value of resistance irregularity which, when placed in series at the sending end, would produce the same reflected energy as all the faults in the coaxial pair being measured.

d) *Dielectric strength*

The insulating material should withstand for two minutes a voltage of 2000 volts r.m.s. 50 Hz (or 2800 V, d.c.) applied between the centre conductor and the outer conductor connected to the sheath. This dielectric strength test should be made on each factory length.

e) *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 volts, should not be less than 5000 megohm-kilometres after electrification for one minute, at a temperature not lower than 15 °C (59 °F). The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on each factory length.

B. REPEATER SECTION SPECIFICATION

a) *Average impedance*

The mean real component of the impedance of a standard coaxial pair, measured on a complete repeater section at 2.5 MHz, should not differ by more than one ohm from the nominal value of 75 ohms.

There is no point in specifying values at other frequencies because the impedance characteristic of the standard coaxial pair follows a well-defined law, depending on frequency.

An approximate formula which is accurate enough for transmission calculations at frequencies above 1 MHz is as follows:

$$Z = 74.4 + \frac{0.95}{\sqrt{f}} (1 - \mathrm{j}) \text{ ohms,}$$

where f is the frequency in megahertz per second.

It can be checked that this condition is met by making either steady-state measurements or pulse measurements. By the mean real component of the impedance at 2.5 MHz is meant:

- for steady-state measurements, the value at 2.5 MHz of the resistive component of the impedance, as taken from the smooth curve giving the change of the resistive component of the impedance with frequency;
- for pulse measurements, the resistive component of the impedance, at 2.5 MHz, of the test balance against the coaxial pair being measured.

b) *Impedance regularity*

The impedance regularity of a repeater section can be checked by making either steady-state measurements or pulse measurements.

b 1) *Steady-state measurements.* — The impedance over the whole frequency band to be transmitted is measured from each end of the repeater section, the distant end being terminated with an impedance such that no appreciable reflection is produced at the termination.

The points are then plotted, with frequency on the 0X axis and the resistive component of the frequency on the 0Y axis.

A smooth curve is drawn through these points. For all types of coaxial pair used for telephony, the difference between the measured impedance and this smooth curve should not exceed ± 3%.

For coaxial pairs used for television transmission, the frequency band concerned should range from at least 0.5 MHz to 6.2 MHz for 405-line and 625-line television systems on coaxial cable with about 6 miles (9 km) repeater spacing, though, in providing for the future, administrations may wish to make measurements at higher frequencies.

b 2) *Pulse measurements.* — These measurements should be made from each end of the repeater section using an approximately sine-squared pulse. The half amplitude width of this pulse should be less than 0.2 microsecond. The results of these measurements are expressed in terms of "echo attenuation".

This, for a peak in the response curve, is the logarithmic ratio in dB or Np of the amplitude of the transmitted pulse to that of the peak concerned.

Distortion of the pulse during transmission over the cable can be corrected by calculations, or by manual or automatic correction by means of networks.

The results of these measurements should meet the following limits, whether the coaxial pairs are for telephony or television.

1. After correction for the distortion introduced by the coaxial pair, the echo attenuation of the largest reflection should not be less than 48 dB or 5.5 Np.

2. Either 2.1 or 2.2 below should also be met.

2.1. The echo attenuation of the largest reflection, before correction should not be less than 54 dB or 6.2 Np.

The echo attenuation for the mean square value of the three largest reflections after correction should not be less than 51 dB or 5.9 Np.

2.2. The uncorrected "equivalent ratio" should not exceed one ohm. (The "equivalent ratio" is that single value of resistance irregularity which, when placed in series at the sending end, would produce the same reflected energy as all the faults in the coaxial pair being measured.)

When energy correction is carried out, the equivalent ratio should be reduced to terms of one kilometre of cable by dividing the observed value by $\sqrt{L}$, where L is the length in km of the half repeater section concerned. The equivalent ratio thus reduced should be less than 0.8 ohm.

Note. — The impedance of cable manufactured by modern methods is normally so uniform that the above values are approached only rarely. It might be, however, that if each of a number of repeater sections produced reflections approaching these limits, transmission over a complete 2500-km circuit would be unsatisfactory.

c) *Attenuation*

The attenuation coefficient of a coaxial pair measured at 15 °C (59 °F) and at a frequency of 2.5 MHz should not exceed 6.8 dB per mile (4.1 dB or 0.47 Np per kilometre).

The measured value of attenuation should be corrected for the mean temperature of the cable, using a coefficient of attenuation-change with a temperature of 0.0021 per °C at 2.5 MHz.

d) *Crosstalk*

The far-end crosstalk ratio between two coaxial pairs of a cable should be at least 85 dB or 9.8 Np at any frequency in the band of frequencies effectively transmitted and for a repeater section of about 9 kilometres.

Note 1. — Existing cables that meet this condition in the frequency band from 60 kHz to about 4 MHz will give satisfactory results with the 12-MHz system.

For new cables laid with a view to using 12-MHz systems, the far-end crosstalk ratio, measured at 60 kHz, on a repeater section of about 4.5 km, should be at least 91 dB or 10.5 Np.

Note 2. — It is not considered necessary to specify a limit for the near-end crosstalk ratio, because recent tests have shown that the near-end crosstalk ratio, under service conditions, is greater than the far-end crosstalk ratio.

In a repeater section (of about 9 kilometres), a near-end-crosstalk ratio E, corresponding to the empirical formulae below, will be obtained:

$$E = 80 + 50.5 \times \sqrt{f} \text{ dB} \quad f \text{ in MHz}$$

or

$$E = 9.2 + 5.8 \times \sqrt{f} \text{ Np} \quad f \text{ in MHz}$$

up to a maximum of 135 dB or 15.5 Np.

e) *Dielectric strength*

The insulating material should withstand for two minutes a d.c. voltage of 2000 volts applied between the centre conductor and the outer conductor connected to the sheath. This dielectric strength test should be made on each repeater section on completion of laying.

f) *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 volts, should not be less than 5000 megohm-kilometres after electrification for one minute at a temperature not lower than 10 °C (50 °F). The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every repeater section.

RECOMMENDATION G.332 (amended at Mar del Plata, 1968)

12-MHz TRANSISTORIZED SYSTEMS ON STANDARDIZED 2.6/9.5-mm OR 0.104/0.375-in. COAXIAL PAIR

a) *Arrangement of line frequencies for telephony*

In the systems transmitting a frequency band of about 12 MHz on a C.C.I.T.T. standard (2.6/9.5-mm or 0.104/0.375-in.) coaxial cable (see Recommendation G.331) with a nominal repeater station spacing of about 3 miles or 4.5 km, the arrangement of line frequencies for telephony should conform to one of the Plans 1A, 1B and 2 described below.

It seems that in future Plan 1A is to be preferred to Plan 1B. However, in international connections between countries which use different modulation procedures (see Recommendation G.211) and in the absence of any special arrangements between the interested administrations including, if necessary, the administrations of transit countries, Plans 1 are to be preferred.

1. *Frequency arrangement of Plan 1A*

Plan 1A uses the first modulation procedure described in Recommendation G.211.

The telephone channels should first be assembled into basic supermastergroups. Three supermastergroups are transmitted to line in accordance with the frequency arrangement of Figure 1.

In this figure the virtual carrier frequencies of the two lower supermastergroups are shown.

2. *Frequency arrangement of Plan 1B*

Frequencies below 4287 kHz. — For frequencies below 4287 kHz, Plan 1B uses the second modulation procedure described in Recommendation G.211.

The telephone channels should first be assembled into supergroups. Fifteen supergroups are transmitted to line in accordance with the frequency arrangement of Figure 2 (frequencies below 4287 kHz). These fifteen supergroups comprise the basic 15-supergroup assembly (No. 1) described in Recommendation G.233; the carrier frequencies are shown in that Recommendation. Figure 3 gives further details of the frequency arrangement below 4287 kHz.

Frequencies above 4287 kHz. — For frequencies above 4287 kHz, Plan 1B uses the first modulation procedure described in Recommendation G.211.

For frequencies above 4287 kHz, the frequency arrangement of Figure 2 is identical with that of Figure 1.

3. *Frequency arrangement of Plan 2*

This plan uses the second modulation procedure described in Recommendation G.211.

The telephone channels should be assembled into basic (No. 1) 15-supergroup assemblies. Three 15-supergroup assemblies are transmitted to line in accordance with the frequency arrangement shown in Figure 4. In this figure, the virtual carrier frequencies of 15-supergroup assemblies Nos. 2 and 3 are shown.

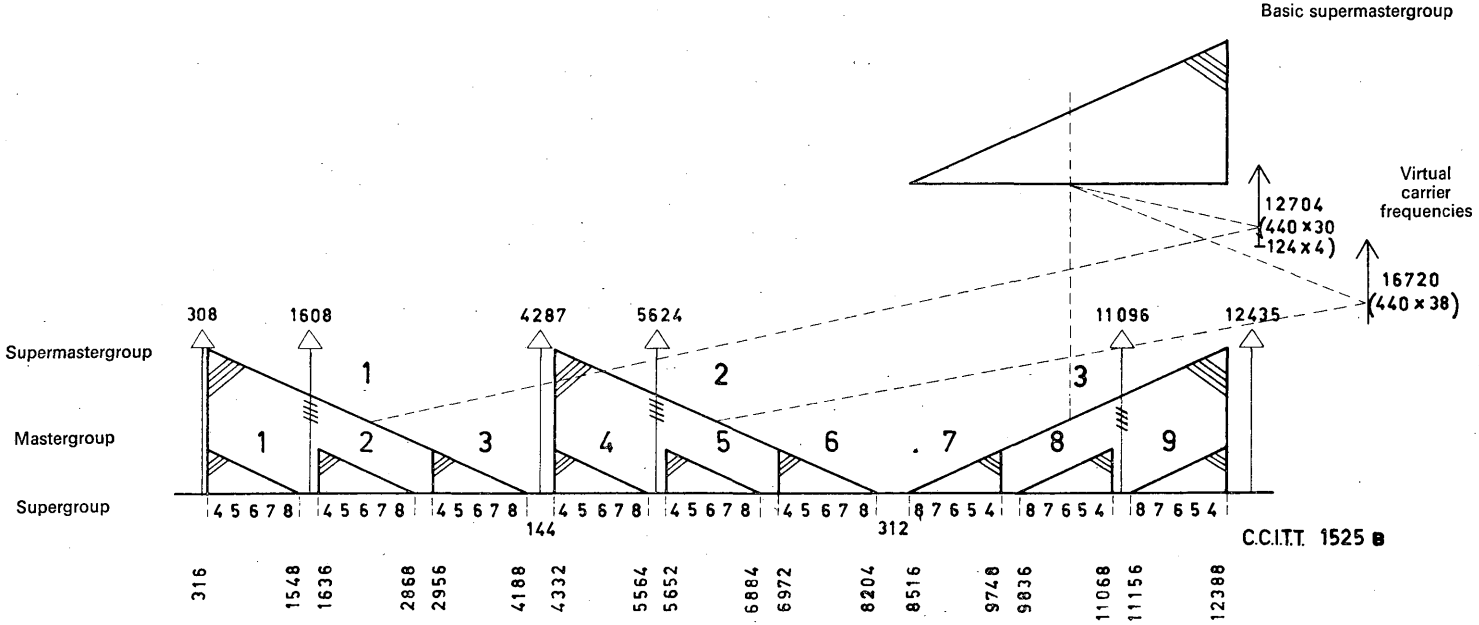


FIGURE 1. — Plan 1A frequency arrangement for 12-MHz systems

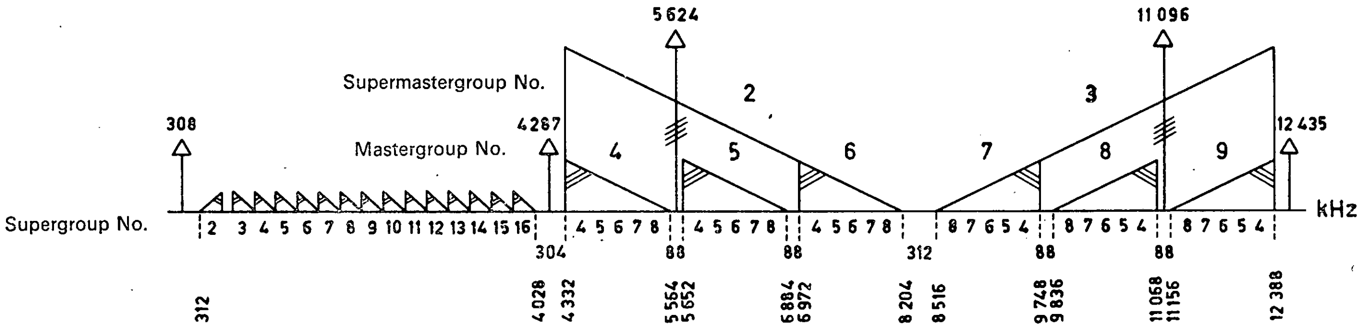


FIGURE 2. — Plan 1B frequency arrangement for 12-MHz systems

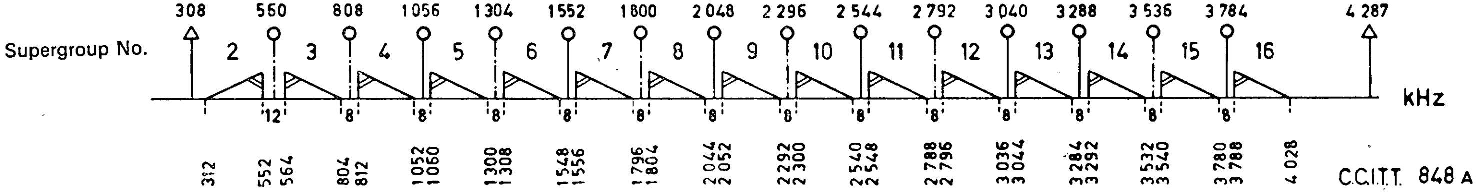


FIGURE 3. — Plan 1B frequency arrangement for 12-MHz systems : frequencies below 4287 kHz

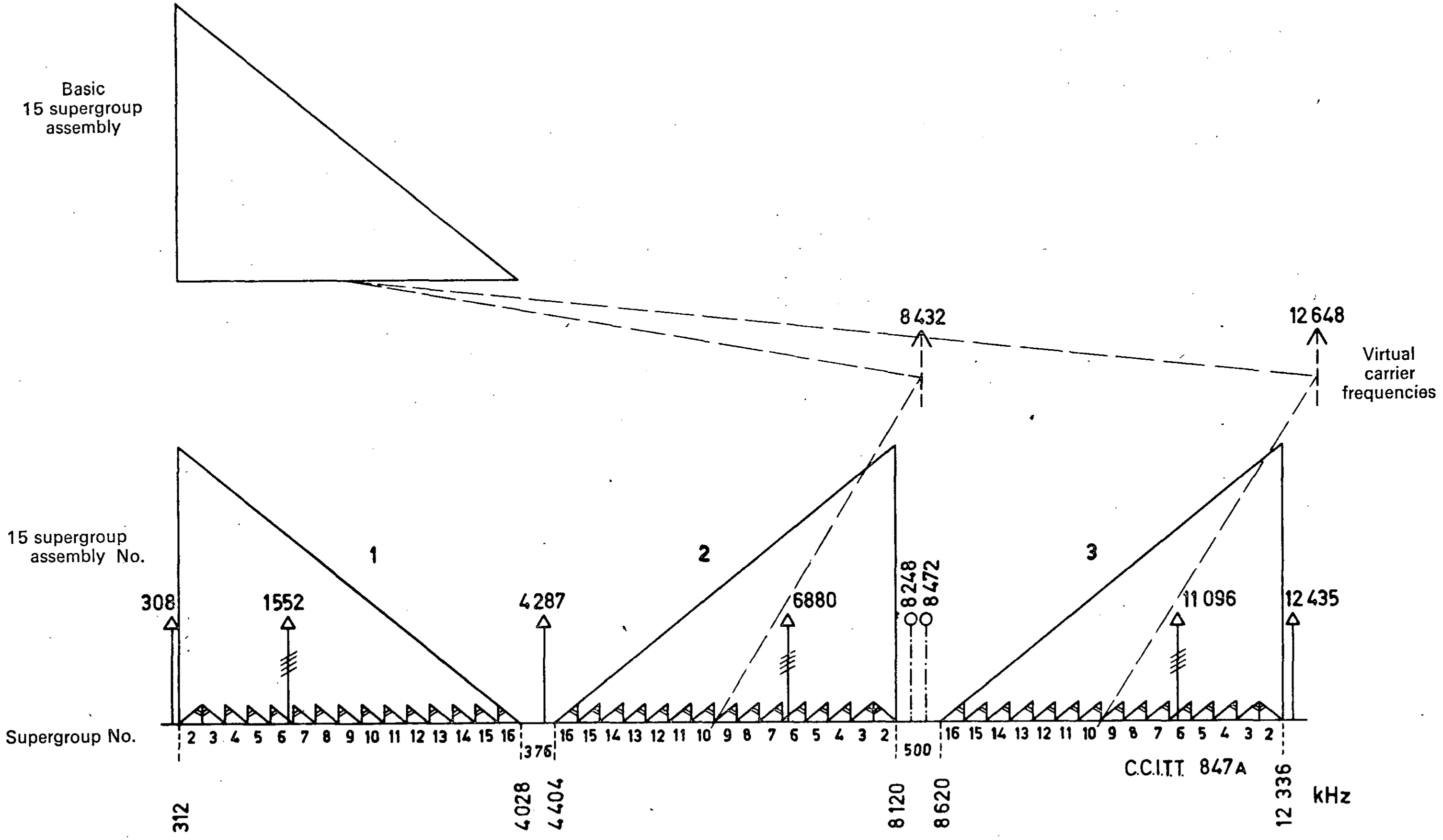


FIGURE 4. — **Plan 2 frequency arrangement for 12-MHz systems**

b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The C.C.I.T.T. recommends that 12 435 kHz be used for the main line-regulating pilot.

In any regulated-line section crossing a frontier, it is recommended that in both directions of transmission the administration on the sending side should permanently transmit one or two auxiliary line-regulating pilots at 308 and/or 4287 kHz, at the choice and request of the administration on the receiving side so as to provide for additional regulation, for example.

The frequency accuracy recommended for the pilots is $\pm 10^{-5}$.

The absolute power level of the main and auxiliary line-regulating pilots (referred to a zero relative level point, deduced from the level diagram of the telephone circuits set up on the coaxial cable system considered) should be adjusted at the point of injection to have a value of —10 dB or —1,15 Np.

Equipment should be designed in such a way that these pilots may be blocked at the end of a regulated-line section, so that their level shall be at least 40 dB (4.5 Np) below that of the pilots used on other sections.

The following tolerances for the level of these pilots are recommended.

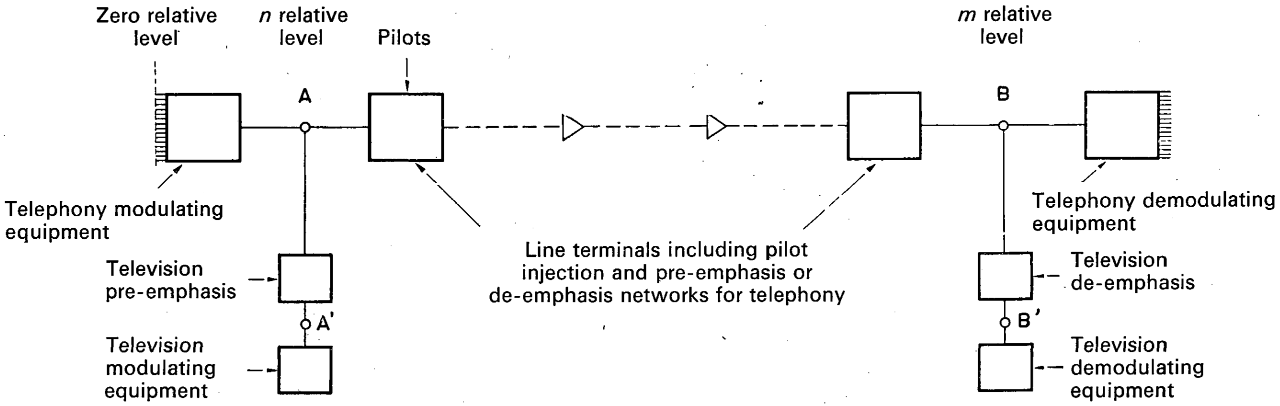
1.1. The design of equipment should be such as to allow the error in the level of any pilot as transmitted, due to finite level adjustment steps, to be kept within ± 0.1 dB or ± 1 cNp.

1.2. The change in output level of the pilot generator with time (which is a factor included in equipment specifications) must not exceed ± 0.3 dB or ± 3 cNp during the interval between two maintenance adjustments, e.g. in one month.

1.3. To reduce pilot level variations with time, it is advisable to have a device to give an alarm when the variation at the generator output exceeds ± 0.5 dB or ± 5 cNp, the zero of the warning device being aligned as accurately as possible with the lining-up level of the transmitted pilot.

The attention of administrations is drawn to the difficulty which could result from an appreciable reduction in the absolute power level of the pilot sent to line; such a reduction is liable to cause "near singing", resulting from the operation of the automatic gain-control amplifiers. It would be desirable to make arrangements for overcoming this difficulty if it should arise.

Note. — When pre-emphasis and de-emphasis is applied on the line link, it is necessary to define the line pilot level with reference to a point, possibly hypothetical, at the input to or output from the line, at which the relative levels of all telephone channels are equal over the whole of the line-frequency band. When a part of the line-frequency band is to be used to provide a television channel, different pre-emphasis and de-emphasis networks may be required but this will not affect the definition of line pilot levels. Figures 5 and 6 show two hypothetical arrangements for the purpose of this definition.



Note. — Between points A and B, the gain/frequency response of the high-frequency line is uniform for telephony. At these points, all telephone channels are at equal relative level. Between points A′ and B′, the gain/frequency response of the high-frequency line is uniform for television.

FIGURE 5. — **To illustrate the definition of line-regulating pilot levels on a line suitable for carrying both telephony and television**

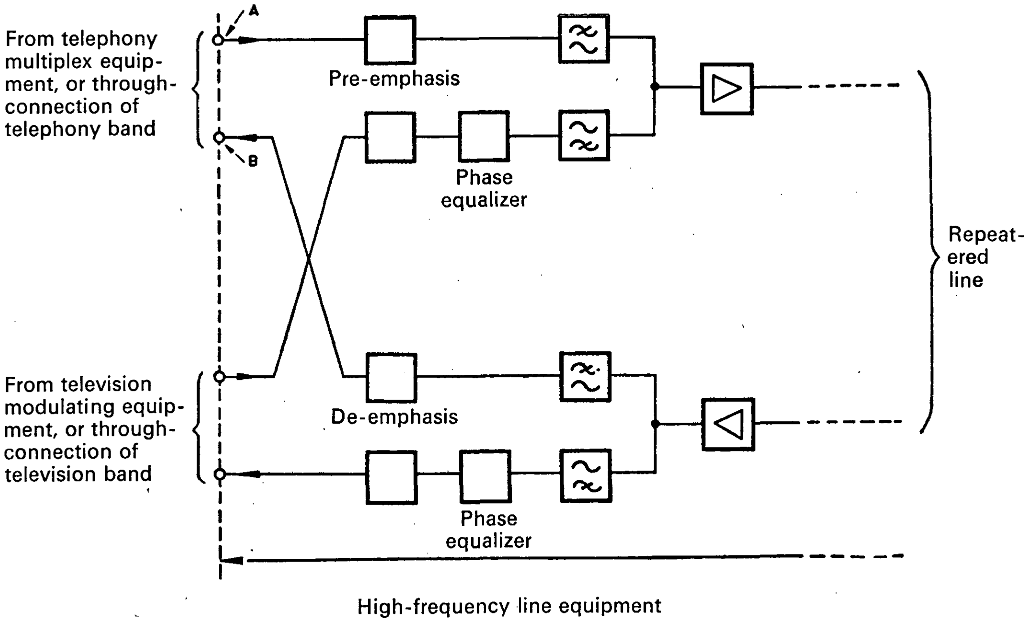


FIGURE 6. — **An example of high-frequency line equipment for a 12-MHz "mixed" system for simultaneous telephony and television transmission. The relative levels for telephony would be defined for the points A and B**

2. *Frequency comparison pilots*

Administrations wishing to make an international frequency comparison shall choose the frequency 300, 808 or 1552 kHz for this purpose, when it is impossible to use 308 or 1800 kHz. International comparison of national standards is comparatively rare. During a specified period of time, it will always be possible to use for such comparisons one of the frequencies mentioned above, even though it may normally be used as an additional measuring frequency.

A frequency of 300 kHz can be used for national comparisons when administrations do not wish to use the 308 kHz pilot for this purpose. In this case, it is recommended that the 300 kHz be transmitted at an absolute power level of —10 dB (—1.15 Np) at a point of zero relative level.

3. *Additional measuring frequencies.* — If the frequency allocation without mastergroups is used at frequencies below 4 MHz (Figures 3 and 4), the following frequencies *may* be used for additional measuring frequencies:

560, 808, 1056, 1304, 1552, 1800, 2048, 2296,
2544, 2792, 3040, 3288, 3536 and 3784 kHz.

Any administration using 12-MHz working on a line crossing a frontier should, at the request of any other administration concerned, transmit or measure the measuring frequencies appearing in the following preferred list:

560, 808, 1304, 1800, 2296, 2792 and 3536 kHz.

Administrations should likewise transmit or measure, at the request of corresponding administrations, any measuring frequency which may be used in other circumstances, namely:

1. at frequencies below 4 MHz, if frequency allocation with mastergroups indicated in plan 1A (Figure 1) is used:

   560, 808, 1304, 1592 and 2912 kHz.

2. at frequencies above 4 MHz: if plan 1B (Figure 1) or 1B (Figure 2) is used:

   5608, 6928, 8248 [1], 8472, 9792 and 11 112 kHz.

If plan 2 (Figure 4) is used under the conditions described in Recommendation G.211 for the application of the second modulation process, the additional frequencies above 4 MHz are:

5392 [2], 7128 [2], 8448, 8472, 8864 [2], 9608 [2] and 11 344 [2] kHz

All these frequencies are recapitulated in the following table:

Frequencies that are available for use as additional measuring frequencies on 12-MHz systems

Frequency band	Frequency arrangement	Additional measuring frequency to be sent or measured on request	Other additional measuring frequencies which can be sent
<4 MHz	in supergroups (Figures 3 and 4)	560, 808, 1304, 1800, 2296, 2792 and 3536 kHz	1056, 1552, 2048, 2544, 3040, 3288 and 3784 kHz
	all mastergroups (Figure 1)	560, 808, 1304, 1592 and 2912 kHz	
>4 MHz	in mastergroups (Figures 1 and 2)	5608, 6928, 8248 [1], 8472, 9792 and 11 112 kHz	
	in 15-supergroup assemblies (Figure 4)	5392 [2], 7128 [2], 8248, 8472, 8864 [2], 9608 [2] and 11 344 kHz	

The absolute frequency variation of additional measuring frequencies below 4 MHz should never be outside limits of ± 40 Hz from their nominal value. For frequencies above 4 MHz, the relative frequency variation referred to the nominal value should never exceed $\pm 1 \times 10^{-5}$.

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[1] A frequency of 8248 kHz can be used as a radio-relay link line-regulating pilot. In such a case, the precautions shown in Recommendation G.423 should be applied.

[2] *Secretariat Note.* — These frequencies are not shown on Figure 4, as approved by the 1968 Plenary Assembly. For lack of precise indications, the Secretariat has taken them from Figure 68 (*Blue Book*, Volume III, page 201) which is not reproduced in the *White Book*.

The absolute power level of the additional measuring frequencies (referred to a zero relative level point, deduced from the level diagram of the telephone circuits set up on the coaxial cable system considered) [1] should be adjusted at the point of injection to have a value of —10 dB or —1.15 Np.

The additional measuring frequencies should not be permanently transmitted. They will only be transmitted for so long as is necessary for actual measurement purposes.

Arrangements should be made in equipment for the 12-MHz system, so that the 308-kHz line-regulating pilot is protected from disturbances from a pilot or additional measuring frequency of the same frequency coming from a 4-MHz system when this protection is not already provided by the equipment of the 4-MHz system.

Note. — Some administrations use new manual or automatic methods of equalizing attenuation distortion, e.g. equalizers based on the Cosine function, using frequencies which do not appear in the list of additional measuring frequencies recommended by the C.C.I.T.T.

Obviously, no additional measuring frequency which might leave the national network should be sent at the same frequency as one of the pilots recommended by the C.C.I.T.T.

c) *Hypothetical reference circuit for 12-MHz* [2] *systems on coaxial cable*

This hypothetical reference circuit is 2500 km (1550 miles) long and is set up on a 12-MHz carrier system on coaxial cable. It has, for each direction of transmission, a total of:

three pairs of channel modulators, each pair including translation from the audio-frequency band to the basic group and vice versa;

three pairs of group modulators, each pair including translation from the basic group to the basic supergroup and vice versa;

six pairs of supergroup modulators, each pair including translation from the basic supergroup to the frequency band of the basic mastergroup and vice versa;

nine pairs of mastergroup modulators, each pair including translation from the basic mastergroup to the frequency band transmitted on the coaxial cable and vice versa.

Figure 7 shows the principle of the hypothetical reference circuit for 12-MHz systems on coaxial cable.

This hypothetical reference circuit consists of nine homogeneous sections of equal length (see Recommendation G.212).

d) *Design objectives for circuit noise*

The objectives given in Recommendation G.222 are applicable to the hypothetical reference circuit for 12-MHz systems on coaxial cable, in the circumstances indicated in Recommendation G.223.

In practice, it is sufficient to check, for each telephone channel, as defined by the hypothetical reference circuit, that the mean psophometric power at the end of the channel,

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[1] Note of paragraph b 1 still applies.

[2] This hypothetical reference circuit is also used for systems transmitting one mastergroup on 1.2/4.4-mm-coaxial pair.

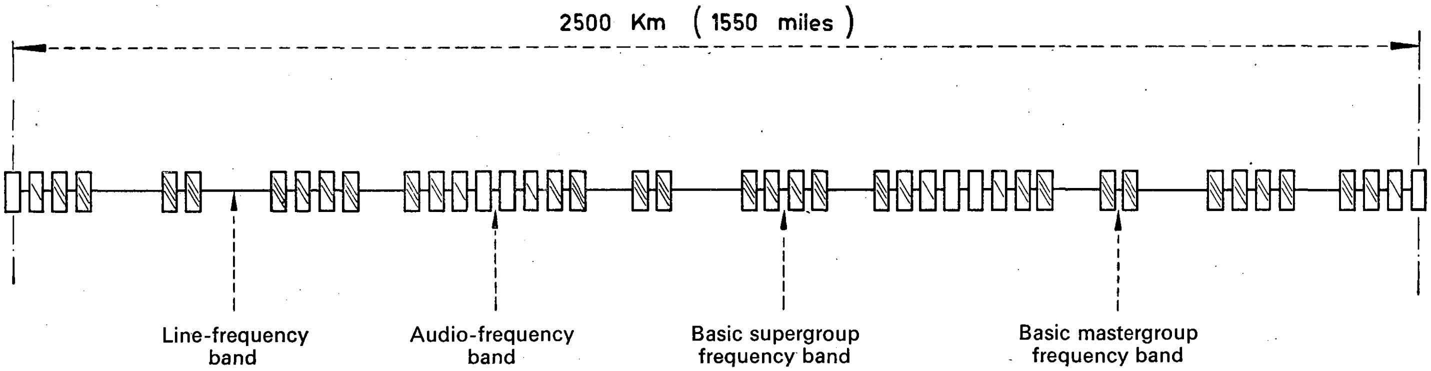


FIGURE 7. — **Diagram of a hypothetical reference circuit for 12-MHz coaxial-pair systems**

referred to a zero relative level point, does not exceed 10 000 pW during any period of one hour.

The subdivision of the total noise between basic noise and intermodulation noise is left entirely to the designer of the system, within the limits of 2500 pW for the terminal equipment and 7500 pW for the line.

e) *Matching of the impedance of a coaxial pair and the impedances of the repeaters*

Z_L is the characteristic impedance of the line (for any frequency f effectively transmitted), this impedance being the ordinate for the frequency f of a smooth curve, agreed by the administrations (or private operating agencies) concerned as being representative of the average "impedance/frequency" characteristic of the type of coaxial cable concerned;

Z_R is the worst value of the input impedance (for the frequency f) of the equipment of a repeater station, as seen from the line (see Figure 8);

Z_E is the worst value of the output impedance (for the frequency f) of the equipment of a repeater station, as seen from the line;

$A = al$ the total image attenuation (at the frequency f) of the line between two adjacent repeater stations, a being the average attenuation of the coaxial cable per unit length and l the average length between two adjacent repeater stations.

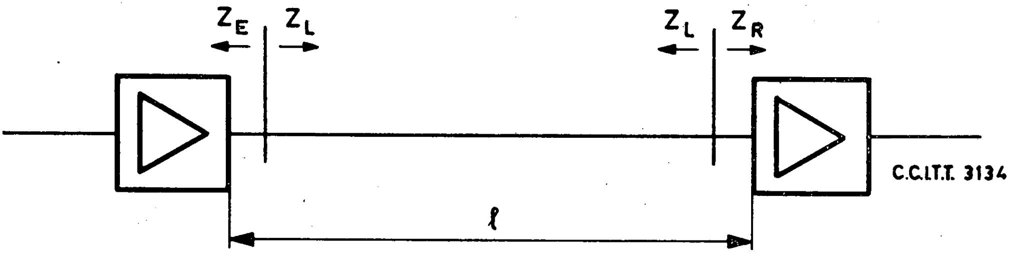


FIGURE 8. — **Repeater section of coaxial cable**

Then N (in decibels or nepers) is defined by the formulae:

$$N = 2A + 20 \log_{10} \left| \frac{Z_E + Z_L}{Z_E - Z_L} \right| + 20 \log_{10} \left| \frac{Z_L + Z_R}{Z_L - Z_R} \right| \text{(decibels)}$$

or

$$N = 2A + \log_e \left| \frac{Z_E + Z_L}{Z_E - Z_L} \right| + \log_e \left| \frac{Z_L + Z_R}{Z_L - Z_R} \right| \text{(nepers)}$$

The present Recommendation refers only to 12-MHz systems on 2.6/9.5-mm coaxial pairs in which the nominal spacing between repeaters is approximately 4.5 to 4.8 km (Recommendation G.337).

The sum N of the three terms defined above must in this case be equal to at least 48 dB (5.55 Np) at 300 kHz and to at least 55 dB (6.3 Np) at all frequencies above 800 kHz. Between 300 and 800 kHz the permissible limit in nepers or dB varies linearly with the frequency.

Note. — The C.C.I.T.T. has defined the permissible limits for N, for a sum of the three terms (see above formulae). It is recommended that administrations and private operating agencies concerned with a coaxial cable section crossing a frontier should agree on permissible values in this particular case for each of these three terms, to meet the above condition, that is to say, agree on the use of as good a match as possible or of a methodical mismatch at the ends of the repeater section.

f) *Relative levels and interconnection in a frontier section*

1. *Interconnection in a frontier section*

In a repeater section which crosses a frontier, the relative level at the input of the cable section (output of the repeater equipment) should be equal to —13 dB (—1.5 Np) at 12 435 kHz.

Note 1. — This recommendation is based on the assumption that the attenuation in the frontier section is approximately 37 to 38 dB (4.3 Np). This should be taken into consideration in determining the actual length of the frontier section.

Note 2. — When the pre-emphasis curves of the two systems are different, Recommendation G.352 should be applied.

2. *Relative levels in any repeater section*

It has not been possible to standardize a single value.

3. *Pre-emphasis*

From the information supplied by various administrations, the pre-emphasis generally lies between 9 and 12 dB.

g) *Power-feeding and alarm systems*

1. *Power feeding across a frontier*

2. *Power-feeding systems*

The text of Recommendation G.341 g.1 and g.2, applicable to all 1.2/4.4-mm pair systems, still applies for 12-MHz transistor systems on 2.6/9.5-mm pairs.

3. *Supervision and alarms in a frontier section (see the Annex below)*

ANNEX

(to Recommendation G.332)

Frequencies used for supervision or fault location

The frequencies or frequency bands used in various countries for supervising or for locating faults are given below for information.

Country	Band (kHz)
Belgium	280 and 12 700 and 170 to 210 for regulation
Japan	13 000 to 13 180
France	12 700 to 12 800
Netherlands	280 and 170 to 210 for regulation
F. R. of Germany	269 and (13 300 ± 75)
United Kingdom	13 500 + 12.5
Sweden	12 700 to 13 000

Note. — The Chile Telephone Company employs a fault-tracing system using direct currents transmitted over interstitial pairs of the cable, which obviates any risk of interference with the systems mentioned above.

RECOMMENDATION G.333 (Mar del Plata, 1968)

40 AND 60 MHz TRANSISTORIZED SYSTEMS ON STANDARDIZED 2.6/9.5-mm COAXIAL PAIRS

Introduction

The amplifier design technique employed now or in the next few years will permit the transmission of frequencies up to 60 MHz on a 2.6/9.5-mm coaxial pair.

The experience of certain administrations shows that it is now possible to manufacture without great difficulty cables for possible operation up to frequencies of the order of 60 MHz. However, for cables already operated up to 4 or 12 MHz, certain difficulties (especially regarding the equalization of attenuation variations with frequency) might arise, due in particular to:

- the spread of the values of attenuation per unit length;
- attenuation anomalies over long distances, if the cable should incorporate significant impedance irregularities; such irregularities, which are found especially at splicing points, can be detected by using shorter pulses, which are a function of the frequency bandwidth to be transmitted.

The C.C.I.T.T. has therefore defined a 60-MHz system which can be obtained, for example, by dividing the repeater section of a 12-MHz system into three. It is recommended to any administrations which, by mutual agreement, use 40-MHz systems in the international service that they apply the clauses relating to the 60-MHz system, with alterations where necessary.

a) *Line frequencies*

The distribution scheme for line frequencies must be extended to approximately 60 MHz, on the understanding that in practice some systems will be able to use only a part of this frequency band.

It is also desirable to facilitate the interconnection of these systems with the other coaxial-pair systems.

In view of these considerations the C.C.I.T.T. recommends the following:

Plan 1. — Line-frequency allocation and modulation stages for 40-MHz and 60-MHz systems (Figure 1)

In this plan, the basic block for interconnection is the supermastergroup of 8516 and 12 388 kHz recommended by the C.C.I.T.T. in Recommendation G.211. It thus contains the three mastergroups constituting the basic supermastergroup, but the same frequency band could contain a 15-supergroup assembly (see Plan 2).

All modulation and demodulation between the basic supermastergroup and the line-frequency band is carried out in one modulation step. The carrier frequencies for this modulation are shown in Figure 1. They are all low multiples of 440 kHz, or multiples of 2200 kHz. These two fundamental frequencies are both closely related to frequencies normally used in the 12-MHz systems.

The extraction of blocks directly from the line-frequency band can be carried out individually for the four lowest supermastergroups. Higher supermastergroups can only be extracted in the form of an assembly of four supermastergroups. This method is chosen to save frequency bandwidth.

The two lowest supermastergroups are identical with supermastergroups Nos. 2 and 3 shown in Figure 1 of Recommendation G.332.

Plan 2. — Line-frequency allocation and modulation stages for 40-MHz and 60-MHz systems (Figure 2)

According to Plan 2, eleven assemblies of 15 supergroups are translated into the frequency band 8620 to 12 336 kHz which lies within the frequency band of the basic supermastergroup.

The 15-supergroup assemblies transmitted to line and numbered 3 to 13, are obtained in the same way as the corresponding supermastergroups of Plan 1 above. The assembly of 15 supergroups numbered 2 is obtained by modulation of a 15-supergroup assembly in the band 312-4028 kHz, the carrier frequency being 68 × 124 = 8432 kHz.

The facilities for extracting blocks directly from the basic-frequency band are identical to those of Plan 1.

The two lowest 15-supergroup assemblies are identical with the second and third 15-supergroup assemblies in Figure 4 of Recommendation G.332.

Note. — It is understood that Plan 1 would be chosen in those countries whose national networks are based upon the use of basic mastergroup and supermastergroups, whereas Plan 2 could be adopted in those countries whose national networks are based upon the use of supergroup assemblies only.

In international connections between countries using the same plan in their national networks, i.e. both using Plan 1 or both using Plan 2, the plan common to these two countries would naturally be used.

However, in international connections between countries which use different plans in their national networks and in the absence of any special agreement between the interested administrations, including administrations of transit countries, use of Plan 1 is recommended.

b) *Pilots*

1. *Line-regulating pilots*

The following frequencies are recommended for line-regulating pilots of the 60-MHz system: 4287 kHz, 12 435 kHz, 22 372 kHz, 40 920 kHz and 61 160 kHz, with a frequency accuracy of $\pm 1 \times 10^{-5}$ and a level of -1.15 Nm0 (-10 dBm0). All these frequencies, except the highest, can also be used with the 40-MHz system. A further study is to be made of the main line-regulating pilot to be chosen from this list.

2. *Frequency comparison pilots*

Since international comparison of frequencies is rarely carried out, the C.C.I.T.T. recommends that administrations choose one of the following two frequencies:

- — 4200 kHz, which is a multiple of 300 kHz and a neighbouring value of 4400 kHz,
- — 8316 kHz (27 × 308 kHz) which can easily be included in the free intervals of the two frequency arrangements proposed (Figures 1 and 2).

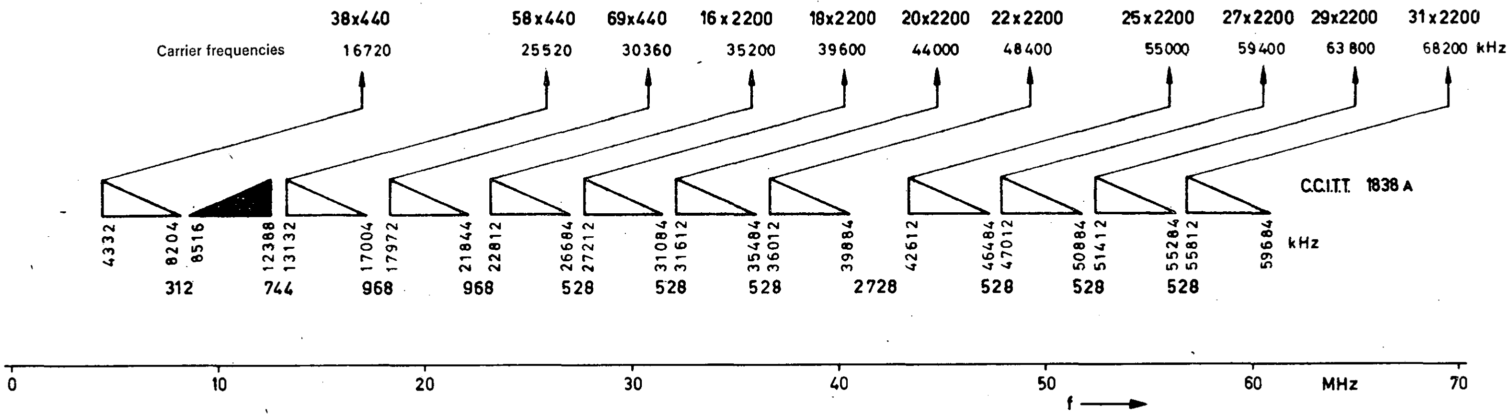


FIGURE 1. — Line-frequency allocation recommended for 40-MHz and 60-MHz systems on 2.6/9.5-mm coaxial cable pairs using Plan 1

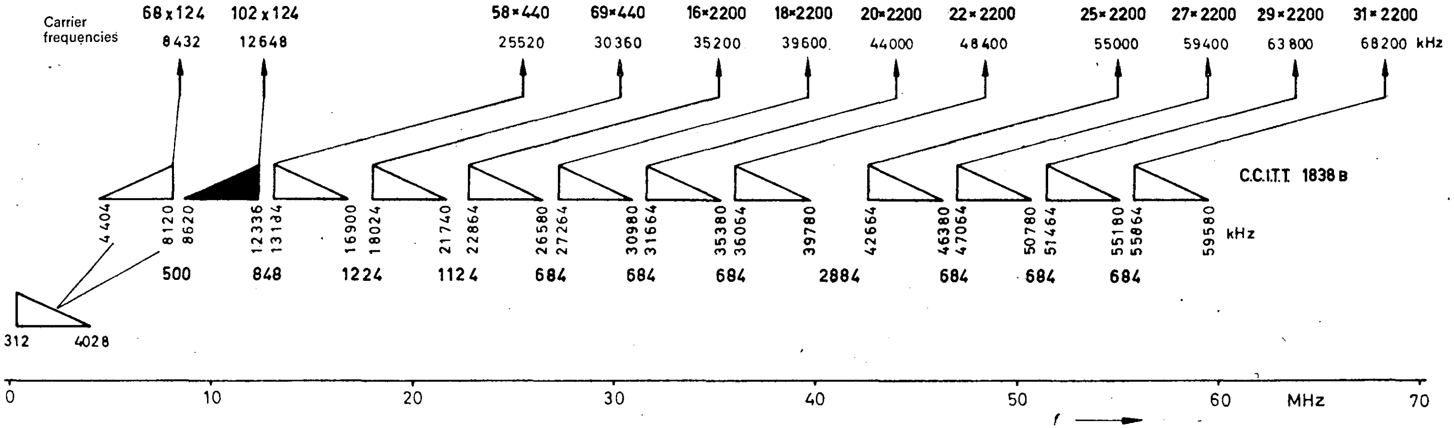


FIGURE 2. — Line-frequency allocation recommended for 40-MHz and 60-MHz systems on 2.6/9.5-mm coaxial cable pairs using Plan 2

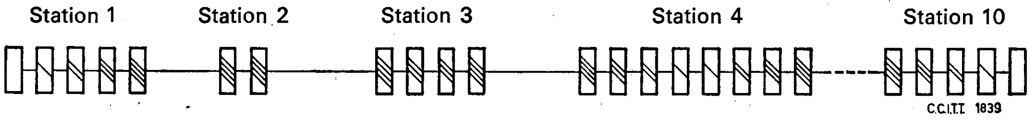
c) *Hypothetical reference circuit*

1. *General considerations*

The reference circuit has to reflect what is expected to be the practical application of the system. The spacing of main stations is expected to be substantially the same as in earlier systems, e.g. the 12-MHz system. A length of 2500 km, divided into 9 sections of 280 km with a total of 10 main stations, has therefore been adopted. It was thought that because of the wide band available and the reduced cost per kHz of bandwidth, fewer demodulations to the basic frequency bands of lower order may be expected.

2. *Modulation*

With either of the line-frequency allocations recommended in paragraph a), five modulation stages are generally needed to place a particular channel in its position in the line-frequency band:



Note. — Stations 5 and 8 are identical with Station 2 — Stations 6 and 9 are identical with Station 3 — Station 7 is identical with Station 4

FIGURE 3. — **Diagram of a hypothetical reference circuit for 60-MHz systems on 2.6/9.5-mm coaxial cable pairs**

Symbols

1) Channel translation to form a basic group

2) Group translation to form a basic supergroup

Alternatively

3) Supergroup translation to form a basic mastergroup — Supergroup translation to form a 15-supergroup assembly in the band 312-4028 kHz

Alternatively

4) Mastergroup translation to form a basic supermastergroup — Modulation of the 15-supergroup assembly to place it within the frequency band of the basic supermastergroup

5) Supermastergroup translation to the line-frequency allocation (except for supermastergroup 2).

As certain mastergroups in the 12-MHz system already require double modulation to place them in their position in the line band, it is probable that the noise performance specification of existing modulation equipment will prove adequate, which is of course highly desirable.

On the above basis, the hypothetical reference circuit shown in Figure 3 is provisionally recommended by the C.C.I.T.T.

d) *Circuit noise*

It is recommended that the system be designed on the basis of Recommendation G.222, i.e. in such a way as to obtain a mean psophometric power of about 3 pW per km of line, on the worst telephone channel having the same composition as the 2500-km hypothetical reference circuit.

e) *Matching of repeater impedances and line impedance*

A value of 65 dB (7.5 Np) is provisionally recommended for the magnitude *N* defined in paragraph e) of Recommendation G.332.

f) *Interconnection*

Levels in a main station (see Recommendation G.213)

When one part of the frequency band is transmitted without demodulation, the same value of —33 dB (—3.8 Np) is provisionally recommended at the output of the direct through-connection filter.

RECOMMENDATION G.337 (former Recommendation G.331, amended in Mar del Plata, 1968)

GENERAL CHARACTERISTICS OF SYSTEMS ON 2.6/9.5-mm OR 0.104/0.375-in. COAXIAL CABLE PAIRS

The various systems which can be set up on standard C.C.I.T.T. 2.6/9.5-mm or 0.104/0.375-in. coaxial cable pair (see Recommendation G.331) are defined as follows:

1. *2.6-MHz system.* — A coaxial cable system with about 6-mile or 9-km repeater spacing, providing 10 supergroups in the frequency band 60 kHz to 2540 kHz (see section A of this recommendation).

2. *4-MHz system.* — A coaxial cable system with about 6-mile or 9-km repeater spacing, providing 16 supergroups in the frequency band 60 kHz to 4028 kHz (see Recommendation G.338) which can alternatively transmit a vestigial sideband television signal with an effectively transmitted video-frequency band of 3 MHz (see Recommendation J.71).

3. *6-MHz system.* — A coaxial cable system with about 6-mile or 9-km repeater spacing, providing at least 15 supergroups in the band 60 kHz (or 300 kHz) to about 6 MHz (see paragraph B of this recommendation), which can alternatively transmit a vestigial sideband television signal with an effectively transmitted video-frequency band of 5 MHz (see Recommendation J.72).

4. *12-MHz system.* — A coaxial cable system with about 3-mile or 4.5-km repeater spacing, providing 40 to 45 supergroups in the frequency band 0.3 MHz to about 12 MHz (see Recommendation G.332 for transistorized systems and G.339 for valve-type systems) which can alternatively transmit at least 15 telephony supergroups plus a vestigial sideband television signal with an effectively transmitted video-frequency band of 5 MHz (see Recommendation J.73).

5. *60-MHz system.* — A coaxial cable system with about 1-mile or 1.5-km repeater spacing, providing up to 180 supergroups for telephony (see Recommendation G.333).

SYSTEMS ON 2.6/9.5-mm COAXIAL PAIRS

A. 2.6-MHz VALVE-TYPE SYSTEM

This system can be used only by agreement between the administrations or private operating agencies concerned. In such a case, application of the clause for the 4-MHz system (Recommendation G.338) is recommended, with the following special features:

a) *Arrangement of line frequencies*

The scheme shown in Figure 1 (derived from Figure 1 of Recommendation G.338) applies, but using only supergroups 1 to 10.

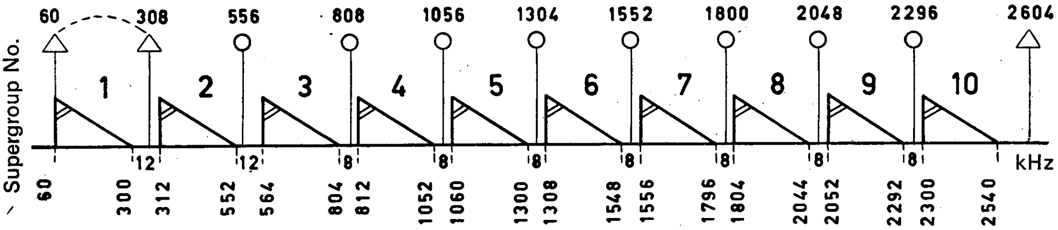


FIGURE 1. — **Line-frequency allocation recommended for the 10-MHz system**

b) *Line-regulating pilots*

For the upper line-regulating pilot, 2540 + 64 = 2604 kHz can be used, in other words, a frequency 64 kHz above the top frequency of the tenth supergroup. The recommended frequency accuracy is ± 30 Hz.

Any frequencies used for additional line-regulating pilots should be chosen from the following list:

60, 308, 556, 808, 1056, 1304, 1552, 1800, 2048 and 2296 kHz.

c) *Additional measuring frequencies*

Frequencies which can be used are:

60, 308, 556, 808, 1056, 1304, 1552, 1800, 2048 and 2296 kHz.

B. 6-MHz VALVE-TYPE SYSTEM

This system is primarily intended for television transmissions and it is described under this heading in Recommendation J.72 (Part 3 of this volume).

It is possible to use the high-frequency line of a 6-MHz system for telephony transmission, though it seems unlikely that on such a system there would be frequent changing from telephony to television, or vice versa.

The following recommendations apply to telephony transmission under such circumstances.

a) *Arrangement of line frequencies*

A 6-MHz system on coaxial cable should be capable of transmitting at least supergroups Nos. 2 to 16 in the frequency arrangement recommended by the C.C.I.T.T. for 4-MHz systems, with the transmission quality recommended by the C.C.I.T.T. and based on the hypothetical reference circuit for 4-MHz systems (see Recommendation G.338, a and d).

The possible use of supergroup No. 1 for international traffic should be the subject of agreement between the administrations concerned.

It seems that such supergroups or mastergroups as it is possible to transmit above 4028 kHz will not give circuits having the quality defined above. Such circuits could not therefore be used in international service unless for short-length circuits restricted to terminal traffic.

b) *Pilots*

The pilots used for telephony in the two existing systems have frequencies and levels indicated in Recommendation J.72. As a result, the pilot levels for telephony will be as follows:

1st system. — At point B′ or point E′ of Figure 1 of Recommendation J.72 the relative level of the telephone channels is —15 dB (—1.73 Np).

The 4142-kHz and 308-kHz line pilots are transmitted at levels of —6 dBm0 (—0.69 Nm0) and —15.1 dBm0 (—1.74 Nm0) respectively (absolute power levels at a zero relative level point).

2nd system. — The sent levels of the pilots are —13.1 dBm0 (—1.5 Nm0) (absolute power levels at a zero relative level point).

RECOMMENDATION G.338 (former Recommendation G.332, amended in Geneva 1964)

4-MHz VALVE-TYPE SYSTEMS ON STANDARDIZED 2.6/9.5-mm OR 0.104/0.375-in. COAXIAL CABLE PAIRS

a) *Arrangement of line frequencies*

The arrangement of line frequencies between 60 kHz and about 4 MHz should be as shown in Figure 1 [1].

It is very desirable to be able to set up large groups of long-distance international circuits, on carrier systems on coaxial cable, with a minimum of intermediate demodulations and remodulations, by avoiding intermingling these groups with those used for setting up shorter circuits.

Therefore, the C.C.I.T.T. recommends preferably the use of supergroups 4 to 12 (inclusive) to set up these large groups of long-distance international circuits.

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[1] However, if it is desired to use mastergroups, adoption of the line-frequency allocation in Figure 2 is recommended.

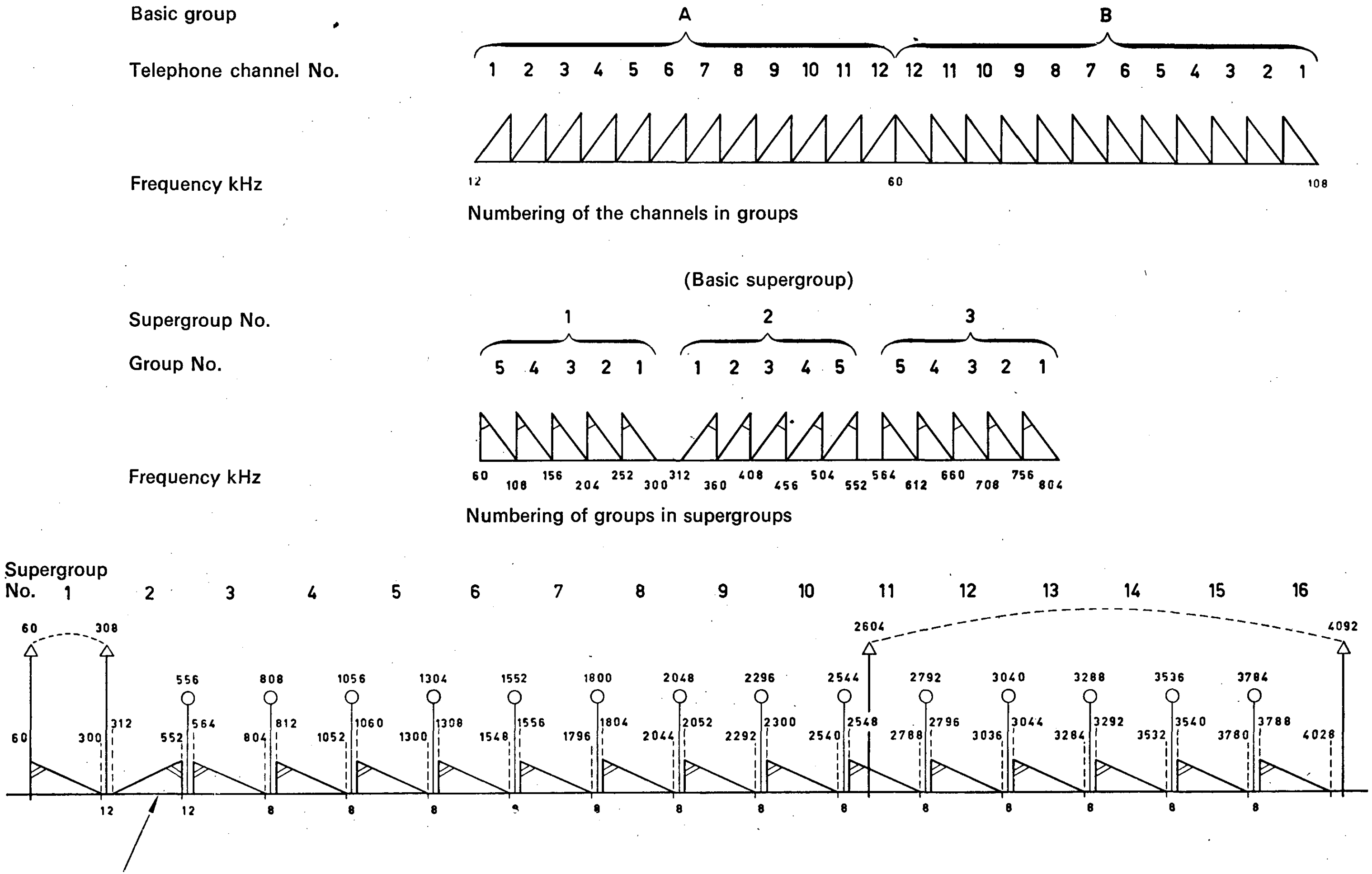

FIGURE 1. — **Line-frequency spectrum from 60 kHz to about 4 MHz for international 2.6/9.5-mm coaxial cables used for multichannel carrier telephony**

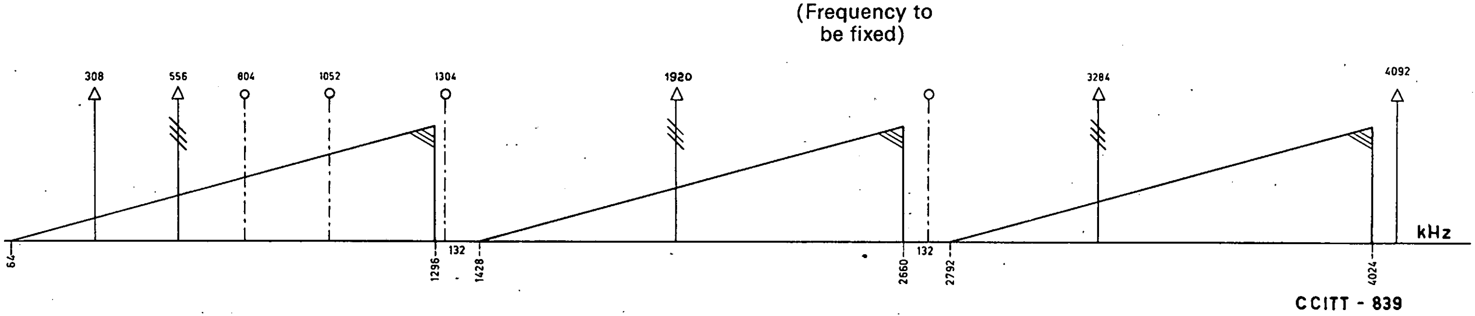

FIGURE 2. — **Allocation of line frequencies in international 4-MHz carrier system on 1.2/4.4-mm coaxial pairs, in the case of the use of mastergroups**

It is convenient to use supergroups 1 to 3 for short circuits. Administrations or private operating agencies needing a greater number of shorter circuits should agree to omit one of the supergroups higher than 12, in order to facilitate the derivation of the others.

Note. — Supergroups 1 to 3 and 13 to 16 have the same quality as the other supergroups and may well be used for long-distance circuits. Their use is recommended for these short circuits because they can be extracted from the line (or reintroduced) by simple filters (assuming in the present state of the art, the sacrifice of a supergroup when the higher supergroups are used), without demodulation or remodulation of the supergroups which are not derived.

b) *Pilots*

1. *Line-regulating pilots.* — In order to reduce overall variations of level and of overall loss on long routes, it is very desirable that the regulated-line sections, which have their levels and attenuation equalization controlled by end-to-end pilots, should be as long as possible.

In practice, a large number of regulated-line sections will terminate at international exchanges. Administrations or private operating agencies concerned will mutually agree upon the terminal points of all regulated-line sections for each particular case.

There should be two line-regulating pilots; these pilots could, for example, be used to change the "gain-frequency" characteristic of the repeater, in order to compensate for variations of attenuation in the preceding cable section, and to readjust the attenuation equalization as necessary. There are also other methods of regulation, using two pilots.

The standard arrangements for international 2.6/9.5-mm or 0.104/0.375-in. coaxial cables (see Recommendation G.334) allow the use of 16-carrier telephone supergroups with suitable repeater spacing, and a line-frequency spectrum as indicated in Figure 1. These 16 supergroups occupy the band of frequencies from 60 kHz to 4028 kHz. To achieve the required regulation, it is necessary to have one pilot in the lower part and one in the upper part of this frequency band.

The C.C.I.T.T. recommends the use of the following frequencies:

α) 60 kHz or 308 kHz for the lower line-regulating pilot;

β) $4028 + 64 = 4092$ kHz for the upper line-regulating pilot.

It is recommended that these pilot frequencies be accurate to the following limits:

± 1 Hz for the 60-kHz pilot

± 3 Hz for the 308-kHz pilot

± 40 Hz for the 4092-kHz pilot

The absolute power level of these pilots (referred to a point of zero relative level deduced from the level diagram of the telephone circuits set up on the carrier system considered) should be adjusted at the output of the transmit amplifier to have a nominal value of −10 dB (−1.15 Np).

The tolerances for this level are the same as in paragraph b.1 of Recommendation G.332.

Note. — Some systems in use employ a pilot at −1.2 Np.

The frequencies to be used as auxiliary line-regulating pilots should be chosen from the following:

60, 308, 556, 808, 1056, 1304, 1552, 1800, 2048,
2296, 2544, 2792, 3040, 3288, 3536 and 3784 kHz.

It is recommended that when, by agreement between the administrations concerned, 2792 kHz is used as an auxiliary line-regulating pilot, the frequency should be stable to ± 5 Hz.

2. *Frequency-checking pilots.* — For a national routine frequency check as described in Recommendation G.225, a frequency of either 60 kHz or 308 kHz may be used for the frequency-checking pilot.

The absolute power level of a frequency-checking pilot (referred to a zero relative level point deduced from the level diagram of the telephone circuit set up on the carrier system considered) should be adjusted at the output of the transmit amplifier, to a nominal value of −10 dB or −1.15 Np.

Note. — Some systems in use employ a pilot at −1.2 Np.

The frequency 1800 kHz is provisionally reserved for international frequency comparisons, as required. However, if the administrations concerned so desire, this frequency 1800 kHz may be used for the frequency-checking pilot.

3. *Multipurpose pilots.* — Administrations or private operating agencies concerned with an international carrier system on coaxial cable may agree to use (if they consider it desirable) one of the lower line-regulating pilots (either 60 or 308 kHz) for level control as well as for frequency checking.

In any case, it is desirable that one of the following two solutions should always be applied, so as to allow the line-regulating pilots to be used at the same time for frequency checking:

- provide, in each regulated-line section, a master oscillator which is regularly compared, directly or indirectly, with a national frequency standard;
- if there is no master oscillator in a regulated-line section, then beyond the junction between the two regulated-line sections considered, reintroduce the lower line-regulating pilot coming from the previous section, after its level has been stabilized.

Generally speaking, it is possible for one pilot to have two or more functions if the administrations or private operating agencies concerned so decide.

4. *Additional measuring frequencies.* — For routine maintenance measurements of a carrier system on coaxial cable, it is necessary, in addition to the pilots mentioned above, to have signals of specified frequency and level, called "additional measuring frequencies". The frequencies which may be used for these are the following:

60, 308, 556, 808, 1056, 1304, 1552, 1800, 2048,
2296, 2544, 2792, 3040, 3288, 3536 and 3784 kHz.

The recommended accuracy for the frequency of these signals is ± 40 Hz.

The absolute power level of these additional measuring frequencies (referred to a point of zero relative level deduced from the level diagram of the telephone circuits set up on the carrier system considered) should be adjusted at the output of the transmit amplifier to have a nominal value of −10 dB or −1.15 Np.

Note. — Some systems in use employ a pilot at −1.2 Np.

The additional measuring frequencies should not be permanently transmitted. They will be transmitted only for so long as is necessary for actual measurement purposes.

c) *Hypothetical reference circuit for 4-MHz*[1] *systems on coaxial cable*

This hypothetical reference circuit is 2500 kilometres (1550 miles) long and is set up on a 4-MHz carrier system on coaxial cable. It has, for each direction of transmission, a total of:

— three pairs of channel modulators, each pair including translation from the audio-frequency band to the basic group and vice versa;

— six pairs of group modulators, each pair including translation from the basic group to the basic supergroup and vice versa;

— nine pairs of supergroup modulators, each pair including translation from the basic supergroup to the frequency band transmitted on the coaxial cable and vice versa.

A diagram of the hypothetical reference circuit for 4-MHz systems on coaxial cable is shown in Figure 3. It will be seen that there is a total of 18 modulations and 18 demodulations for each direction of transmission, assuming that each modulation or demodulation is carried out in a single stage.

This hypothetical reference circuit consists of nine homogeneous sections of equal length (see Recommendation G.212).

d) *Design objectives for circuit noise*

The objectives stated in Recommendation G.222 are applicable to the hypothetical reference circuit for 4-MHz[1] systems on coaxial cable, in the circumstances indicated in Recommendation G.223.

In practice, it is sufficient to check by calculation that, for every telephone channel, as defined by this hypothetical reference circuit, the mean psophometric power at the end of the channel, referred to a zero relative level point, does not exceed 10 000 pW during any period of one hour.

The subdivision of the total noise between basic noise and intermodulation noise is left entirely to the designer of the system, within the limits of 2500 pW for the terminal equipment and 7500 pW for the line.

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[1] The hypothetical reference circuit is also used for 2.6-MHz systems, for systems transmitting supergroups on 1.2/4.4-mm coaxial pairs and for systems providing two supergroups on symmetric pairs.

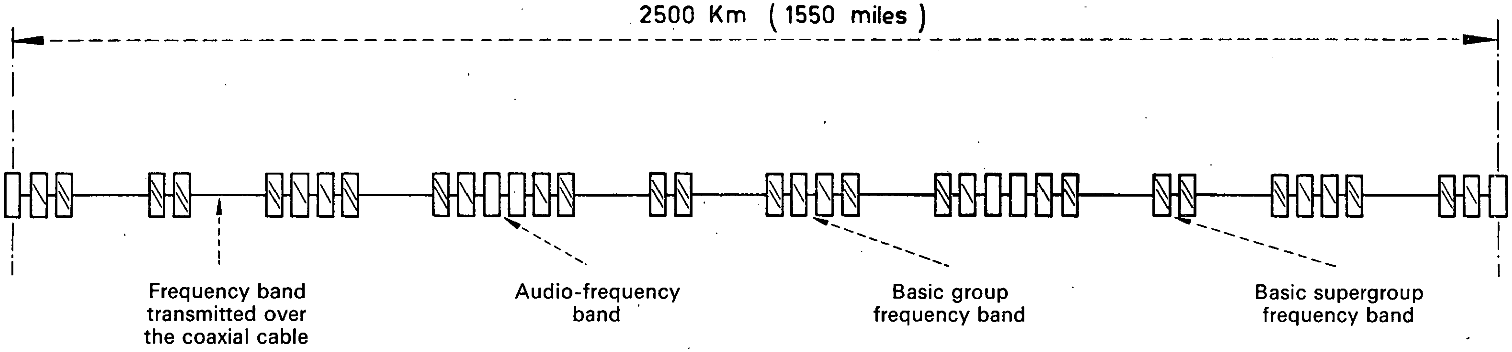


FIGURE 3. — **Diagram of the hypothetical reference circuit for 4-MHz systems on coaxial cable**

e) *Matching of the coaxial pair impedance and the repeater impedances*

Let *N* be the sum of the three terms defined in paragraph e) of Recommendation G.332.

In the case of a 4-MHz coaxial carrier system, *N* should be at least equal to 40 dB (4.6 Np) for all frequencies below 300 kHz, because at these frequencies, where the cable attenuation is relatively small, it is difficult to obtain higher values for *N* with the values at present obtained for the reflection coefficient at the amplifier input, if it is assumed that the amplifier output impedance is completely mismatched to the line impedance. With this value of *N* it is hoped that at the end of a line section of about 700 km, no irregularities in the equivalent/frequency characteristic greater than 1 dB or 0.1 Np (this being considered a reasonable limit) will arise. This seems sufficient, if it is considered very improbable that very long international circuits will be set up throughout on channels of supergroup 1 (60-300 kHz) since it is particularly easy to extract this supergroup at intermediate points, making its use preferable for relatively short circuits.

In order to obtain an equivalent/frequency characteristic having rolls not greater than 1 dB or 0.1 Np at the end of a 2500 km (1550 miles) circuit based on the hypothetical reference circuit, it is recommended that for supergroups having line frequencies greater than 300 kHz, the value of *N* should be 45 dB or 5.2 Np.

Note 1. — If a 2500-km hypothetical reference circuit on coaxial cable is set up on the channels of supergroup No. 1 in some of the nine line sections between the successive modulation points (see Figure 3) it may be hoped that the condition that irregularities in the equivalent/frequency characteristic should not exceed 1 dB or 0.1 Np will still be satisfied, since in the amplifier sections of other line sections where this hypothetical reference circuit uses channels of other supergroups, there will be values of *N* greatly above the limit of 45 dB or 5.2 Np.

Note 2. — The C.C.I.T.T. has defined only the permissible limits for *N*, for the sum of the three terms (see the formulae in paragraph e) of Recommendation G.332). It is recommended that the administrations and private operating agencies concerned with a coaxial cable section crossing a frontier should agree on permissible values in this particular case for each of these three terms, to meet the above condition, that is to say, agree on the use of as good a match as possible or for a methodical mismatch at the ends of the amplifier section.

RECOMMENDATION G.339

(former Recommendation G.333, amended at Geneva, 1964, and at Mar del Plata, 1968)

12-MHz VALVE-TYPE SYSTEMS ON STANDARDIZED 2.6/9.5-mm COAXIAL PAIRS

The paragraphs in this Recommendation correspond to those in Recommendation G.332, which applies to transistorized systems.

For valve-type systems, the C.C.I.T.T. had already made the following specific recommendations.

a) *Arrangement of line frequencies for telephony*

Recommendation G.332—unchanged.

b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The C.C.I.T.T. recommends the following frequencies for line-regulating pilots:

308 kHz, 4287 kHz and 12 435 kHz

with a relative frequency accuracy of ± 1×10^{-5}.

The pilot 4287 kHz is the main line-regulating pilot.

For the level of these pilots and the corresponding tolerances, see Recommendation G.332; however, some systems in use employ a pilot at -1.2 Np.

2. *Frequency comparison pilots* and

3. *Additional measuring frequencies*

See Recommendation G.332; however, some systems in use employ pilots or additional measuring frequencies at -1.2 Np.

c) *Hypothetical reference circuit*

Recommendation G.332—unchanged.

d) *Design objectives for circuit noise*

Recommendation G.332—unchanged.

e) *Matching of the coaxial pair impedance and the repeater impedances*

Let N be the sum of the three terms defined in paragraph e) of Recommendation G.332. Within the frequency band between 300 kHz and 5564 kHz, the value recommended for N is 48 dB (5.55 Np).

Note 1. — When using the whole of the line-frequency band for telephony, this condition is generally met in practice at frequencies above 5564 kHz.

Note 2. — The Note to paragraph a) of Recommendation G.332 still applies.

f) *Relative power levels and interconnection in a frontier section*

It is not possible to recommend relative power levels at the output of intermediate repeaters since they are very closely linked to the inherent design of each administration's system.

When interconnection between two telephone systems is effected via a cable section that crosses a frontier each administration, in accordance with Recommendation G.336, should accept, on the receiving side, the level conditions which normally apply to the incoming system used in the other country. It may be possible to comply with this condition simply by inserting a correcting network at the receiving end. The repeater section crossing the frontier should then be less than 4.5 km long, the details being agreed directly between the administrations concerned before the repeater stations are sited.

Where the cable systems on the two sides of a frontier differ greatly in design (especially where a line is to be used alternatively for "all-telephony" or for "telephony-plus-television") such a solution is not generally applicable. In this case, one of the frontier stations may act as a main station having the necessary types of pre-emphasis and de-emphasis networks to permit interconnection at "flat" points. The recommended levels at such interconnection points are as follows for the "all-telephony" case:

—32 dB or —3.7 Np at the output of the de-emphasis network;
—35 dB or —4.0 Np at the input of the pre-emphasis network.

Interconnection of pilots, e.g. blocking and re-injecting or by-passing, should be agreed between administrations.

For "telephony-plus-television" transmission, more complicated arrangements are necessary or differential pre-emphasis and de-emphasis can be used (see Recommendation J.73, especially Figures 1 and 2 of that Recommendation).

3.4 Carrier 1.3-MHz systems on 1.2/4.4-mm coaxial cable pairs

All the systems described in this sub-section are transistorized (see the table at the head of sub-section 3.3).

RECOMMENDATION G.341 (amended at Geneva, 1964, and at Mar del Plata, 1968)

1.3-MHz SYSTEMS ON STANDARDIZED 1.2/4.4-mm COAXIAL CABLE PAIRS

Preliminary remark

The C.C.I.T.T. recommends that administrations laying 1.2/4.4-mm coaxial cables should do so with a view to the eventual operation of these pairs with 4-MHz (Recommendation G.343) or 6-MHz (Recommendation G.344) systems.

If administrations wish to equip a coaxial pair line with a smaller number of channels before the complete installation is effected, they are advised to use, in conformity with the present recommendation:

- a system with 6-km repeater sections, if they wish to go on later to operation with 1200 or 1260 telephone channels;
- a system with 8-km repeater sections, if they wish to go on to operation with 900 or 960 telephone channels.

a) *Line frequencies*

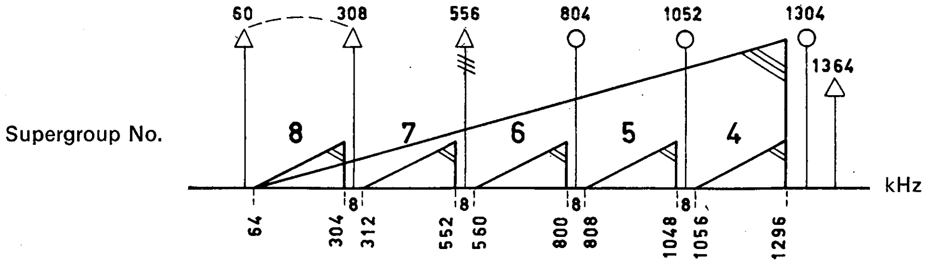
The system will carry 300 telephony channels, transmitted to line:

- either between 60 kHz and 1300 kHz as supergroups Nos. 1-5 of the 4-MHz system (Figure 1 a),
- or between 64 kHz and 1296 kHz as a mastergroup with erect channel sidebands (Figure 1 b).

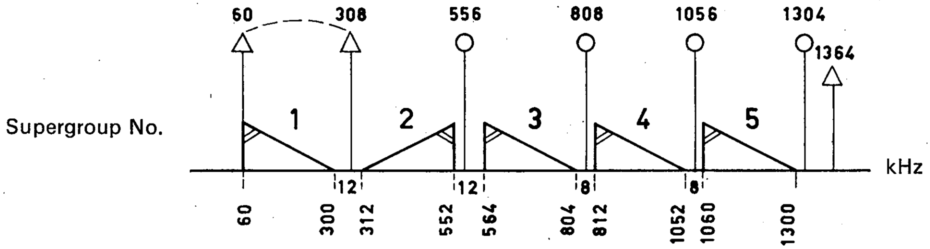
b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The C.C.I.T.T. recommends that 1364 kHz be used for the main line-regulating pilot on all regulated-line sections crossing a frontier. The main line-regulating pilot is used for automatic correction of cable attenuation with the temperature.



a) Supergroups Nos. 1 to 5 arrangement



b) Mastergroup arrangement

FIGURE 1. — **Line-frequency arrangements for international carrier 1.3-MHz systems on 1.2/4.4-mm coaxial pair**

In any regulated-line section crossing a frontier, it is recommended that in both directions of transmission the administration on the transmitting side permanently transmit an auxiliary line-regulating pilot at 60 or 308 kHz, as the administration on the receiving side may choose, so as to provide for additional regulation, for example.

The frequency accuracy recommended for the pilots is 10^{-5}.

The absolute power level of these pilots (referred to a point of zero relative level, deduced from the level diagram of the telephone circuits set up on the carrier system considered) should be adjusted at the output of the transmit amplifier to have a nominal value of −10 dB or −1.15 Np.

The tolerances for this level are the same as in paragraph b.1 of Recommendation G.332.

Note. — Some systems in use employ a pilot at −1.2 Np.

2. *Frequency comparison pilots*

For national frequency comparisons, it is recommended that a 60- or 308-kHz pilot be used. Should international frequency comparison appear desirable, the administrations concerned will reach agreement on which of these two frequencies they will use.

3. *Additional measuring frequencies*

Frequencies that can be used for additional measuring frequencies are as follows:

— supergroups Nos. 1 to 5 frequency allocation: (60), (308), 556, 808, 1056, 1304 kHz;
— mastergroup frequency allocation: (60), (308), 804, 1052, 1304 kHz.

Note. — One of the two frequencies in brackets will be used for the auxiliary line-regulating pilot.

The absolute power level of these additional measuring frequencies (referred to a point of zero relative level deduced from the level diagram of the telephone circuits set up on the carrier system considered) should be adjusted, at the output of the transmit amplifier, to have a nominal value of −10 dB or −1.15 Np.

Note. — Some systems in use employ additional pilots at −1.2 Np.

The additional measuring frequencies should not be permanently transmitted. They will be transmitted only for so long as is necessary for actual measurement purposes.

c) *Hypothetical reference circuit*

For calculation purposes, the hypothetical reference circuit for 4-MHz systems (Recommendation G.338, paragraph c)) will be used when supergroups Nos. 1-5 are transmitted to line, and the hypothetical reference circuit for 12-MHz systems (Recommendation G.332, paragraph c)) will be used when a mastergroup is transmitted to line.

d) *Circuit noise*

The general target noise values for cable systems (see Recommendation G.222) apply also to systems on 1.2/4.4-mm coaxial pairs, with the conditions given in Recommendation G.223.

In practice, it is sufficient to check by calculation that, for every telephone channel as defined by the relevant hypothetical reference circuit, the mean psophometric power at the end of the channel, referred to a zero relative level point, does not exceed 10 000 pW during any period of one hour.

e) *Matching of the coaxial pair impedance and the repeater impedances*

The sum *N* of three terms defined in Recommendation G.332, paragraph e), must be at least equal to:

54 dB or 6.2 Np for a 6-km repeater section;
52 dB or 6.0 Np for a 8-km repeater section.

These figures have been calculated so as to get a roll in the attenuation-frequency characteristic not exceeding 0.09 Np at the end of a homogeneous section 280 km long. It has been assumed that the reflected currents add in phase in all the repeater sections of this homogeneous section (the spacing of the buried repeaters, on a small coaxial pair, generally being very regular). In addition, it has been assumed that it is highly improbable that a telephone channel will be on more than one homogeneous section of the hypothetical reference circuit in the lower part of the band of line frequencies. At higher frequencies, *N* should be well above the limit.

f) *Relative levels and interconnection*

1. *Relative levels and cabling loss for any repeater section.* — 1.1 The loss on any 6-km repeater section should be 35 dB or 4.1 Np at 1300 kHz. The level at the input of the cable section (output of the repeater equipment) should be −13 dB (−1.5 Np) at 1300 kHz. Each administration may so select the pre-emphasis characteristic that the level at the same point and at frequency 60 kHz lies in the range between −18 dB and −28 dB (−2.1 and −3.2 Np).

1.2 The nominal loss on any 8-km repeater section should be 49 dB (5.6 Np) at 1300 kHz. The relative levels at the input of any cable section are not strictly standardized, values of −3.5 dBr (−0.4 Nr) and −4.3 dBr (−0.5 Nr) at the top channel are being used in connection with pre-emphasis values of 9 dB and 10 dB respectively.

2. *Frontier section.* — For interconnection between two systems using different pre-emphasis characteristics, unless there are special arrangements between the administrations concerned, the following recommendation will be applied:

2.1 In a 6-km repeater section crossing a frontier, the level at the end of the cable section (input of the repeater equipment) should be equal to −48 dB (−5.55 Np) at 1300 kHz.

As it may be necessary to insert equipment at the frontier crossing to eliminate the monitoring or fault-locating frequencies used in each country or to terminate the remote power supply section, it is possible that the sending level at 1300 kHz may be less than −13 dB (−1.5 Np). It is then necessary that the frontier section should be less than 6 km long. If the difference between the pre-emphasis characteristics used in both countries in accordance with paragraph 1 is small, it may be compensated for by the fact that the frontier section is shorter than a normal repeater section. If the difference between the pre-emphasis characteristics used in both countries is too great to be compensated for in this way, one of the administrations concerned, chosen by mutual agreement, will have to make up for this difference at the attended receiving station on its territory which lies closest to the frontier.

2.2 For interconnection between two different systems of this type with 8-km repeater sections, the relative level at the frequency 1300 kHz should be −4.0 dBr (−0.46 Nr) at the input of the frontier cable section. According to Recommendation G.352 one of the administrations concerned, chosen by mutual agreement, will have to make up for the slight differences in relative level and pre-emphasis at the attended repeater station which lies closest to the frontier.

3. *Relative levels in a terminal station; interconnection with other systems.* — Recommendation G.213 explains the general principles to be adopted to facilitate interconnection of different systems in terminal stations.

g) *Power-feeding and alarm systems*

1. *Power feeding across a frontier.* — In the absence of a special agreement between the administrations or private operating agencies concerned with a power-feeding section crossing a frontier, it is recommended that each administration power-feed only those repeater stations in its own country. Many administrations use looped power-feeding on the

two sides of a power-feeding station, half of each of the sections between this station and the adjacent power stations being so fed; they can close the loop at their frontier stations. Agreements will be necessary if, for example, the frontier is very far from the mid-point between the two nearest feeding stations, or if the administrations concerned use looped power-feeding on the entire section between two feeding stations.

If the repeater stations in a country are fed from another country, special precautions will be required to protect the staff working on the cables.

2. *Remote power-feeding systems.* — The C.C.I.T.T. is studying these systems from the following viewpoints:

- — precautions to be taken to protect staff against normal voltages and remote power-feed currents, or the use of voltages and currents which are innocuous to persons working in repeater stations or on lines;
- — protection of staff and equipment against induced voltages and currents;
- — trouble in remote power-feeding operation caused by induced voltages and currents.

3. *Supervision and alarms in a frontier section.* — This should be governed by agreement between the administrations concerned. In particular, it is necessary at the points of interconnection between two systems that if frequencies are used for monitoring or for locating faults they be attenuated to a level of −50 dbm0 on the receiving sides to prevent any disturbance to similar frequencies used in the system further down the line.

Note 1. — Frequencies sent only over a system already withdrawn from service because of a fault may be selected by each administration on the national level.

RECOMMENDATION G.342 (amended in Geneva, 1964, and at Mar del Plata, 1968)

CHARACTERISTICS OF 1.2/4.4-mm COAXIAL CABLE PAIRS [1]

A. CABLE SPECIFICATION

a) *Coaxial pairs*

The small-diameter coaxial pair recommended by the C.C.I.T.T. for the international service has copper conductors and is defined by the following nominal dimensions:

- — diameter of inner conductor in solid copper: 1.2 mm;
- — internal diameter of outer conductor: 4.4 mm;
- — thickness of outer conductor: either 0.15 mm or 0.18 mm.

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[1] These coaxial pairs can be used with 1.3-MHz systems (Recommendation G.341), with 4-MHz systems (Recommendation G.343), with 6-MHz systems (Recommendation G.344), or with 12-MHz systems (Recommendation G.345).

When the possibility of television transmissions has been envisaged, this has been expressly mentioned in each clause.

b) *Nominal characteristic impedance*

The nominal characteristic impedance is 75 ohms at 1 MHz.

c) *Mean impedance*

The mean real part of the impedance of a coaxial pair at 1 MHz must not differ from the nominal figure by more than 1.5 ohms (provisional figure) for telephony or 1 ohm (provisional figure) for pairs that may be used for television transmissions.

A check can be made to see that this is so by pulse measurements. The "mean real part of the impedance at 1 MHz" is to be taken as meaning the resistive component of the impedance at 1 MHz of the best balance against the coaxial pair being measured.

d) *Impedance regularity*

Measurements of impedance regularity are carried out by means of pulses sent over the coaxial cable, echoes of these pulses being observed at the sending end.

Measurements can be made from either or both of the ends of a factory length, and the pulse used should be an approximate sine-squared pulse having a half-amplitude duration not greater than 0.1 microsecond. The results are expressed in terms of "echo attenuation". This, for a peak in the response curve, is the logarithmic ratio in dB or Np of the amplitude of the transmitted pulse to that of the peak concerned.

Distortion of the pulse during transmission over the cable can be corrected by calculation, or by manual or automatic correction by means of networks.

The results of these measurements should meet the following limit: the corrected value of pulse echo attenuation should be at least 45 dB or 5.2 Np. This value should be achieved on 100% of factory lengths.

Note. — The figure recommended above is adequate for telephony. If there is to be a possibility of using the cable for television at some future date, an attempt must be made to approach the figures specified for the 2.6/9.5-mm coaxial pair in Recommendation G.331. At the present time, the following corrected figures might be recommended for echo attenuation:

not less than 48 dB or 5.5 Np for all coaxial pairs,
not less than 54 dB or 6.2 Np for 80% of the coaxial pairs measured.

e) *Dielectric strength*

The pair should withstand 1000 volts r.m.s. (a.c., 50 Hz) (or 1500 volts d.c.) applied for at least one minute between the centre and outer conductors.

If, in normal use, the external conductors of the coaxial pairs are not earthed, a test of dielectric strength is made between the external conductors and the earthed metallic sheath. The conductors of the quads or pairs are connected to the external conductors of the coaxial pairs or to the sheath, according to the kind of system used for these quads or pairs. Under these conditions, a 50-Hz a.c. r.m.s. voltage of 2000 volts or more will be applied (or a d.c. voltage of 2800 volts or more).

Note. — The test voltages recommended take account of the normal margins of safety applied in the various countries. Polythene insulation, however, might reasonably withstand considerably higher test voltages. In any case, some other dielectric might conceivably be used in the future.

f) *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 volts, should not be less than 5000 megohm-kilometres after electrification for one minute, at a temperature not lower than 15 °C (59 °F). The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on each factory length.

B. SPECIFICATION FOR A REPEATER SECTION

a) *Mean impedance*

The mean real part of the impedance of a coaxial pair at 1 MHz must not differ from the nominal figure by more than 1.5 ohms (provisional figure) for telephony or 1 ohm (provisional figure) for pairs that may be used for television transmissions.

A check can be made to see that this is so by pulse measurements. The "mean real part of the impedance at 1 MHz" is to be taken as meaning the resistive component of the impedance at 1 MHz of the best balance against the coaxial pair being measured.

By way of information, the impedance values in Table 1 were obtained at various frequencies on coaxial pairs manufactured by different processes.

TABLE 1

Mean real part of the impedance of coaxial pairs measured at different frequencies

Frequency (kHz) . . .	60	100	200	500	1000	1300	4500
Impedance (ohms) . .	79.8	78.9	77.4	75.8	75	74.8	74

b) *Impedance regularity*

The "corrected value" of pulse echo attenuation shall be as in paragraph A d) of this present recommendation, with the following differences: the measurement in this case is made using a sine-squared pulse having a half-amplitude duration not more than 0.2 microsecond for a 3-km repeater section; not exceeding 0.4 microsecond for a 6-km repeater section. Also, there is correction of amplitude and phase. This corrected value should be at least 42 dB or 4.85 Np.

Note. — The figure recommended above is adequate for telephony. If there is to be a possibility of using the cable for television transmissions, an attempt must be made to approach the figures specified for the 2.6/9.5-mm coaxial pair in Recommendation G.331 on most of the repeater sections. At the present time, a corrected figure of at least 44 dB or 5.1 Np might be recommended for the worst section. In addition, an echo attenuation of roughly 52 dB, or 6 Np, might at present be recommended for the worst non-corrected echo.

c) *Attenuation*

The nominal value of the attenuation per unit length, at 10° C and at 1 MHz, is equal to 5.3 dB/km (61 cNp/km). The real value must not differ from this nominal value by more than ± 0.2 dB (± 2.3 cNp).

For all the types of pairs which were measured, the coefficient of attenuation variation with temperature is about 2×10^{-3} at frequencies of 500 kHz or more and 2.8×20^{-3} at 60 kHz.

Table 2 shows the general trend of the variation of the attenuation per unit length as a function of frequency, for all pairs which conform to the present specification.

TABLE 2

Nominal values, at various frequencies, of the attenuation per unit length of a small-diameter coaxial pair

Frequency (kHz) . . .	60	100	300	500	1000	1300	4500
Attenuation (dB/km) .	1.5	1.8	2.9	3.7	5.3	6.0	11

Note. — By way of information, the Annex hereto shows the values measured or specified in various countries, with the corresponding deviations or tolerances. In any case, amplifier design must be based on the values measured on the type of cable which will actually be used.

d) *Crosstalk*

The far-end crosstalk ratio between two coaxial pairs in a cable at any frequency in the band actually transmitted must be not less than the values given in the following table.

TABLE 3

Minimum far-end crosstalk ratio between two 1.2/4.4-mm coaxial pairs

Length of repeater section (km)	Far-end crosstalk ratio			
	without phase inversion		with phase inversion at repeaters	
	Np	dB	Np	dB
8	10.0	87		
6	10.2	89	9.2	80
4	10.7	93		
3	10.9	95	9.5	83

There is no need to specify a near-end crosstalk ratio when the former limits are chosen for the far-end crosstalk ratio.

When phase inversion is used, the near-end crosstalk ratio must be at least 84 dB, or 9.7 Np, for a repeater section about 6 kilometres long, and 87 dB, or 10 Np, for a repeater section about 3 kilometres long.

Note. — These limits are based on 58 dB or 6.7 Np for the far-end crosstalk ratio on the worst homogeneous 280-km section, assuming that the far-end and near-end crosstalk is equally divided between the cable and the equipment. To estimate the former limits (far-end crosstalk without phase inversion), it is assumed for the time being that the difference between the mean and minimum values of the crosstalk ratio is 5 dB.

e) *Dielectric strength*

The pair must withstand a d.c. voltage of at least 1000 volts applied during at least one minute between the internal and the external conductors.

In addition, a test of dielectric strength between the coaxial pair and earth shall be made as described in paragraph A.e) of this recommendation, using a d.c. voltage of at least 2000 volts applied for one minute.

Note. — The recommended test voltages take account of the normal margins of safety applied in the various countries. Polythene insulation, however, might reasonably withstand considerably higher test voltages. In any case, some other dielectric might conceivably be used in the future.

f) *Insulation resistance*

The insulation resistance between the centre and outer conductors of the coaxial pair, measured with a perfectly steady voltage of between 100 and 500 volts, should not be less than 5000 megohm-kilometres after electrification for one minute at a temperature not lower than 10 °C (50 °F). The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every repeater section.

ANNEX

(to Recommendation G.342)

Examples of attenuation per unit length of a small-diameter coaxial pair measured or specified in some countries

TABLE 4

Values measured on a type of pair the outer conductor of which is 0.15 mm thick

Frequency (kHz)	60	100	200	300	500	1000	1300	4000
Mean attenuation (dB/km)	1.56	1.88	2.46	2.93	3.70	5.26	6.0	10.6
Maximum deviation (dB/km)	± 0.10	± 0.10	± 0.15	± 0.15	± 0.15	± 0.15	± 0.15	± 0.15

TABLE 5

Values specified in certain countries for a type of pair the outer conductor of which is 0,18 mm thick

Frequency (kHz)	60	100	200	300	500	700	1000	1300	4500
Specified attenuation (dB/km) . .	1.49	1.80	2.42	2.91	3.73	4.43	5.30	6.05	11.2
Toleranz (dB/km)	± 0.1	± 0.1	*	*	*	*	± 0.2	± 0.2	± 0.2

* Not specified.

RECOMMENDATION G.343 (Geneva, 1964, amended at Mar del Plata, 1968)

4-MHz SYSTEMS ON STANDARDIZED 1.2/4.4-mm COAXIAL PAIRS

Preliminary note

The present Recommendation describes a system, equipped with transistorized repeaters, designed to carry a maximum of 960 carrier telephone channels on a 1.2/4.4-mm coaxial pair (see Recommendation G.342).

A system of this kind is produced by halving the length of the repeater section of a 1.3-MHz system (as described in Recommendation G.341) if this length is 8 km, corresponding to a nominal repeater spacing of 4 km.

a) *Line frequencies*

In order to simplify interconnection with existing systems and especially with the 4-MHz system on standardized 2.6/9.5-mm coaxial pairs the frequency arrangement already standardized in Recommendation G.338 a) should be used.

However, the line equipment (repeaters, etc.) should transmit a frequency band going up at least to 4287 kHz.

This arrangement is shown in Plan 1 in Figure 1.

It is desirable to make provision for the through-connection of entire mastergroups to this system: this can be effected in accordance with the frequency arrangement of Plan 2 in Figure 1.

Plan 2 uses the three lowest mastergroups in the 12-MHz system on a 2.6/9.5-mm coaxial pair. It permits in particular direct interconnection with a 12-MHz coaxial system using the 1.A frequency allocation shown in Figure 1 of Recommendation G.333, and with a radio-relay link of 900 or 1800 channels operated according to Recommendation G.423, Figures 4 and 8.

b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The frequencies recommended for the various cases indicated in paragraph a) above and shown in Figure 1 are as follows:

Plan 1. — The line-regulating pilots recommended in Recommendation G.338 for the 4-MHz system on a 2.6/9.5-mm coaxial pair should be used. However, each administration, when so requested by another administration, should permanently send a line-regulating pilot at 4287 kHz.

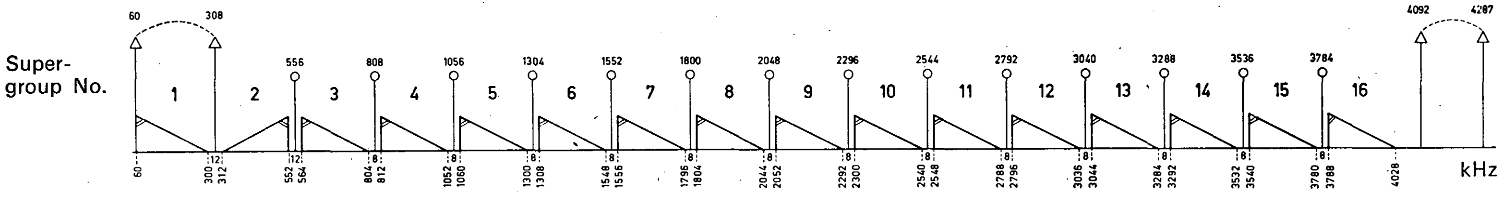
Plan 2. — The line-regulating pilots recommended in Recommendation G.332 for the 12-MHz system in the same frequency band.

In every instance, the recommended stability is $\pm 10^{-5}$, the absolute power level recommended is —10 dB (—1.15 Np) at a point of zero relative level, while the tolerances at this level are the same as in paragraph b.1 of Recommendation G.332.

2) *Frequency comparison pilots*

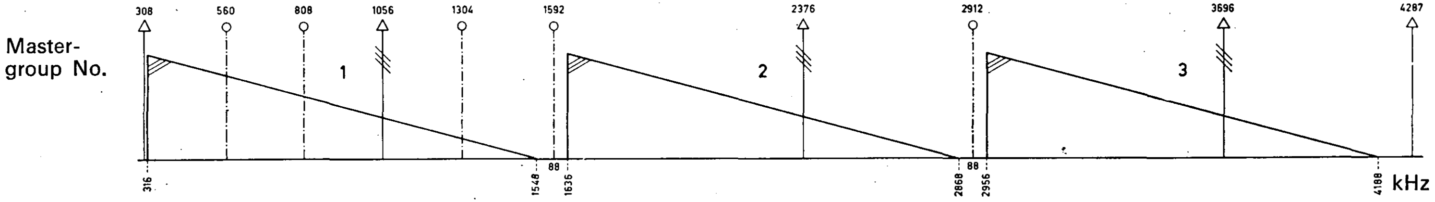
Plan 1. — The same recommendation as for the 4-MHz system (Recommendation G.338, paragraphs b.2 and b.3).

Plan 2. — The same recommendation as for the 12-MHz system (Recommendation G.332, paragraph b.2).



Plan 1

a) Supergroup allocation



Plan 2

b) Mastergroup allocation

FIGURE 1. — **Allocation of line frequencies in international 4-MHz carrier system on 1.2/4.4-mm coaxial pairs**

3) *Additional measuring frequencies*

Plan 1. — When the allocation according to Recommendation G.338 (supergroups) is used, all the additional measuring frequencies given in that recommendation should be used.

Plan 2. — The additional measuring frequencies recommended for the 12-MHz system in the same frequency band should be used (Recommendation G.332).

c) *Hypothetical reference circuits* and d) *noise*

Paragraphs c) and d) of Recommendation G.341 apply.

e) *Matching of the coaxial-pair impedance* and *repeater impedances*

For a repeater section above 4 km in length the sum N of the three terms defined in paragraph e) of Recommendation G.332 must be at least equal to the following:

50 dB at 60 kHz
57 dB above 300 kHz
with linear variation from 50 dB to 57 dB in the 60-300 kHz band, in the case of a linear frequency scale.

Note. — These values are based on the assumption that the attenuation-frequency characteristic does not show any ripple exceeding ± 1 dNp at the end of a homogeneous section 280 km long. A released condition was applied at 60 kHz, as it may be difficult, at low frequencies, to obtain a reflection coefficient for the repeater input and output impedances which is sufficiently small in relation to the impedance of the cable.

f) *Relative levels and interconnection*

1. *Relative level at amplifier output*

— 9 dBr at 4028 kHz or
— 8.5 dBr at 4287 kHz.

2. *Pre-emphasis characteristic*

This is defined by the formula:

$$A = 10 \log_{10} \left[1 + \frac{a}{1 + \dfrac{b}{\left(\dfrac{f}{f_r} - \dfrac{f_r}{f}\right)^2}} \right] \text{dB}$$

in which the constants are so selected as to give between 9 and 11 dB of pre-emphasis.

Both of the series below meet this requirement:

1. $+a = 10$ $b = 3$ $f_r = 4.7$ MHz
2. $+a = 11.25$ $b = 1.56$ $f_r = 4.4$ MHz

3) *Interconnection in a frontier section of two systems in which the repeater sections are of the same nominal length* (this is true of two 4-MHz systems, and also of two 6 MHz-systems)

As the relative line levels and the pre-emphasis characteristic are already covered by recommendations, the interconnection of two systems in a frontier section will not give rise to any great difficulty in this case. The country on the receiving side can receive the other country's line levels provided minor adjustments are made in the first main repeater station (for details, see Recommendation G.352).

4) *Interconnection of a 4-MHz and a 6-MHz system in a frontier section*

In the absence of a special agreement between Administrations, the method described in Recommendation G.352 should be applied in this case.

5) *Interconnection at a main station*

See Recommendation G.213.

g) *Power-feeding and alarm systems*

Recommendation G.341 g) also applies to systems conforming to the present recommendation.

RECOMMENDATION G.344 (Geneva, 1964, amended at Mar del Plata, 1968)

6-MHz SYSTEMS ON STANDARDIZED 1.2/4.4-mm COAXIAL PAIRS

Preliminary note

The present Recommendation describes a 6-MHz system with transistorized repeaters.

It may be used for transmitting a maximum of 1260 telephone channels or television signals having a video bandwidth of about 5 MHz.

A system of this kind can be produced by halving the length of the repeater section of a 1.3-MHz system (as described in Recommendation G.341) if this length is 6 km, corresponding to a nominal repeater spacing of 3 km for the 6-MHz system.

a) *Line frequencies*

1. *Telephony transmission*

The C.C.I.T.T. recommends the three plans in Figure 1, each plan forming a whole within the line-frequency band.

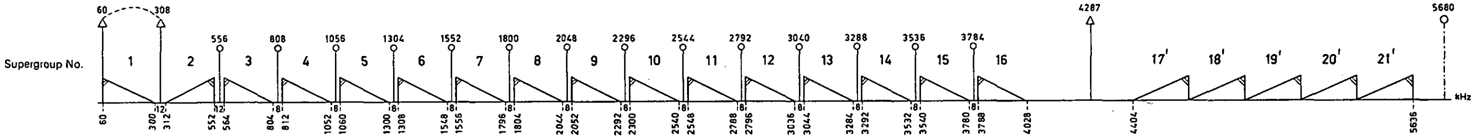
Plans 1 and 2 show the supergroup allocations, and Plan 3 the mastergroup allocations.

In *Plan 1*, the groups are assembled by means of carriers produced from a single frequency at 124 kHz.

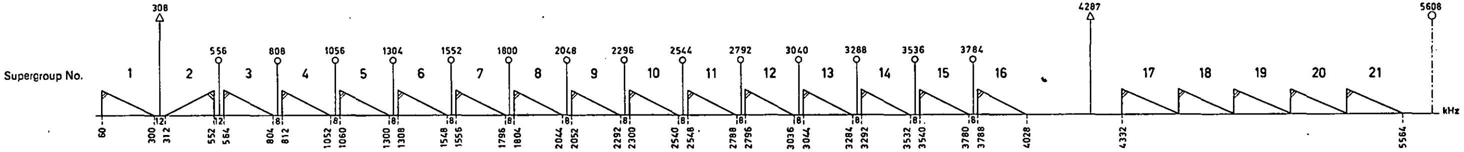
The supergroups in the band 4404 to 5636 kHz are assembled as upper sidebands with the aid of carrier frequencies corresponding to supergroups in the range Nos. 15 to 19. They may alternatively be assembled by translation of an assembly of supergroups Nos. 4 to 8 using a carrier frequency of 6448 kHz, which is obtained by multiplying by 4 the carrier frequency of 1612 kHz corresponding to supergroup No. 5.

In *Plan 2*, the five inverted supergroups in the 4332 to 5564 kHz band correspond to mastergroup 4 in the 12-MHz line allocation, but they also represent an arrangement conveniently obtained from group and supergroup carrier frequencies.

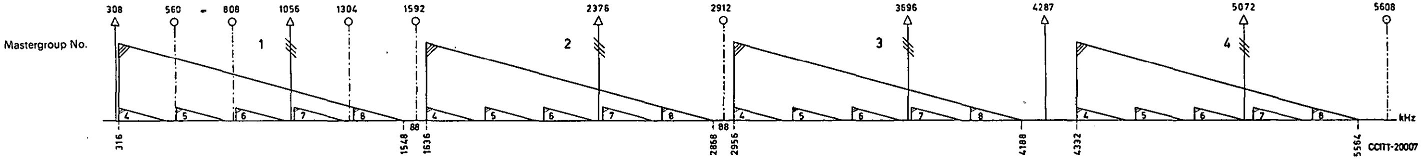
Plan 3 is formed from mastergroups 1 to 4 in the 12-MHz system (Recommendation G.332 a)).



PLAN 1



PLAN 2
a) *Supergroup allocations*



PLAN 3
b) *Mastergroup allocation*

2. *Transmission of television signals*

Administrations considering such transmission should refer provisionally to Recommendation J.72[1].

b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The frequencies recommended are 308 kHz on the one hand, and 4287 kHz or 6200 kHz on the other.

Note. — The pilot at 4287 kHz cannot be used with television transmissions.

In every instance, the recommended stability is ± 10^{-5}, the absolute power level recommended is —10 dB (—1.15 Np) at a point of zero relative level, while the tolerances at this level are the same as in paragraph b.1 of Recommendation G.332.

2) *Frequency comparison pilots*

Plans 1 and 2. — The same recommendation as for the 4-MHz system (Recommendation G.338, paragraphs b.2 and b.3).

Plan 3. — The same recommendations as for the 12-MHz system (Recommendation G.332, paragraph b.2).

3) *Additional measuring frequencies*

Plans 1 and 2. — All the additional measuring frequencies given in Recommendation G.338 (supergroups) should be used. In addition, in the frequency band above 4287 kHz, the following additional measuring frequencies are recommended:

Plan 1: 5680 kHz,
Plan 2: 5608 kHz.

Plan 3. — The additional measuring frequencies recommended for the 12-MHz system in the same frequency band (Recommendation G.332) should be used.

c) *Hypothetical reference circuits* and d) *noise*

Paragraphs c) and d) of Recommendation G.341 apply.

e) *Matching of the coaxial-pair impedance and repeater impedances*

For a repeater section about 3 km in length the sum N of the three terms defined in paragraph e) of Recommendation G.332 must be at least equal to 60 dB (6.9 Np) at all frequencies above 300 kHz.

A figure of 50 dB (5.7 Np) is recommended at 60 kHz. Between 60 and 300 kHz the acceptable limit varies progressively.

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[1] The C.C.I.T.T. is now considering whether the provisions in Recommendation J.72 (which was drafted for transmission on 2.6/9.5-mm coaxial pairs) can be applied without change to the transmission of black-and-white television signals on 1.2/4.4-mm coaxial pairs.

f) *Relative levels and interconnection*

1. *Relative levels at repeater output at 4287 kHz :*

   -17 dBr provisionally.

2. *Pre-emphasis characteristics for telephony*

   The values considered for the constants a, b, f_r in the formula:

$$A = 10 \log_{10} \left[1 + \frac{a}{1 + \dfrac{b}{\left(\dfrac{f}{f_r} - \dfrac{f_r}{f}\right)^2}} \right] \text{dB}$$

are:

1. $a = 10$ $b = 2.20$ $f_r = 5.75$ kHz
2. $a = 24$ $b = 8.50$ $f_r = 6.40$ kHz

g) *Interconnection in a frontier section*

All the various possibilities are indicated in Recommendation G.343, paragraphs h.3 to h.5.

h) *Power-feeding and alarm systems*

Recommendation G.341 also applies to systems conforming to the present Recommendation.

RECOMMENDATION G.345 (Mar del Plata, 1968)

12-MHz SYSTEMS ON STANDARDIZED 1.2/4.4-mm COAXIAL PAIRS

The provisions of this Recommendation are provisionally those appearing in Recommendation G.332 for transistorized systems on 2.6/9.5-mm coaxial pair, with the exception of the following provision:

e) *Matching of the coaxial-pair impedance and repeater impedances*

For a repeater section about 2 km in length, it is desirable to specify a value of N equal to 63 dB throughout the transmitted frequency band, N being defined as in Recommendation G.332 e). Studies are continuing to ascertain whether such a value is feasible in the lower part of this band.

RECOMMENDATION G.351 (former Recommendation G.335, amended at Mar del Plata, 1968)

DESIGN, SUPERVISORY ARRANGEMENTS AND POWER FEEDING OF A CARRIER SYSTEM ON COAXIAL CABLE[1]

a) *Definitions of the constituent parts of a carrier system on coaxial cable*

Repeater stations of a carrier telephone system on coaxial cable can be classified as follows:

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[1] This Recommendation applies to 2.6-MHz, 4-MHz, 6-MHz and 12-MHz systems, but at present only to valve-type systems. Its extension to transistorized systems is under study (Question 23/XV).

1. Stations are classified as *attended* or *unattended*, according to whether they are normally staffed or not.

2. *Power-feeding stations* have a local electricity supply and feed power over the cable conductors to other stations. *Power-fed stations* receive power from other stations over the cable conductors. There are other stations having a local power supply which do not feed power to other stations (autoalimentées).

3. As regards regulation of levels and equalization, a station having a local regulator (automatic or manual) is called a *regulated* station (station régulée), whilst a station which has a regulator remotely controlled from another station is called *remotely regulated* (télérégulée) and a station having no regulation is called *non-regulated* (non régulée).

Amongst regulated stations, there is one which controls the regulation of one or several remotely controlled stations; this is called a *regulating station.*

It is possible to classify coaxial line sections as follows:

A *repeater section* (section élémentaire d'amplification) is a section of line between any two adjacent stations.

A *major repeater section* (section principale d'amplification) is a section of line (with intermediate amplifiers) between any two adjacent attended stations.

A *regulated-line section* (section de régulation de ligne) is defined under 10 in Recommendation G.211.

b) *Supervisory arrangements*

Alarms. — Administrations having considerable experience in the use of carrier systems on coaxial pairs have found that it is necessary to transmit the following information to all interested stations:

1. Failure of an amplifier or amplifier valve and effective substitution of a reserve amplifier or valve.
2. Failure of the normal source of power and effective substitution by a reserve source.
3. Indication of the repeater section in which a fault has occurred on the conductors of the coaxial pair.

To transmit this information, interstice pairs in the coaxial cable should be used.

It is recommended that this information should be transmitted *automatically* (by interstice pairs in the cable) to the attended station responsible for clearing the type of fault in question.

Speaker circuits (service circuits) : — Provision of two speaker circuits is recommended.

The first circuit, called an *omnibus speaker*, should serve as an omnibus line between all attended stations. The second line, called a *through speaker*, is used to inform the control station (or sub-control station) concerned when one of the three faults above has been automatically signalled to an attended station.

c) *Power feeding*

Use of mains supply. — The *advantages of alternating current* for power feeding over a coaxial cable system are the following:

1. There is in all countries a widespread alternating current power distribution network which can be used to supply the coaxial cable network.

2. Power may be transmitted at the most suitable voltage, which can be stepped up if necessary at an intermediate repeater station before transmission to the next station.

3. Apart from the need for having indirectly heated valves, there are no other special requirements for the valves used in repeater stations.

4. In repeater stations any suitable anode voltage can be produced.

5. There is no risk of electrolytic corrosion, even if earth return is used.

The *disadvantages of alternating current* are the following:

1. The transmission efficiency is less than with direct current.

2. The filtering of the power supply to each repeater station is more difficult than with direct current.

3. For a given maximum voltage, the effective voltage is lower.

4. Another point to consider when using alternating current is the noise produced on any voice-frequency circuits in the same cable.

After having weighed these advantages and disadvantages, the C.C.I.T.T. recommends the use of alternating current at the normal supply frequency (in Europe 50 Hz).

Voltage and current. — The C.C.I.T.T. recommends the following values for modern cables and components not having a gas-filling for increasing dielectric strength:

a) Maximum working voltage between centre and outer conductor, 1000 volts r.m.s. 50 Hz alternating current.

b) Maximum permissible r.m.s. alternating current, 5 amperes.

If it is wished to increase the voltage above 1000 volts r.m.s., it is possible:

1. To use a gas-filling to increase the dielectric strength, in which case the specification for a standard 2.6/9.5-mm or 0.104/0.375-in. coaxial pair still applies (Recommendation G.334).

2. To modify the construction of the coaxial pair, in which case a new specification will be needed, suitable for the voltage concerned.

Power-feeding systems and earthing of coaxial cables. — Supplement 10 to this volume describes the methods used in various countries.

The C.C.I.T.T. considers that it is unnecessary to recommend one or other of these methods exclusively, as the "power-feeding sections" will always be relatively short, and as a result their construction and maintenance are primarily a national question. In the absence of special agreement between the Administrations (or private operating agencies) concerned in a power-feeding section crossing a frontier, it is recommended that each Administration power-feed only the repeater stations on its own territory.

Stand-by power supply

For modern carrier system equipment fitted with transistors, it is recommended in Recommendation G.231, C that power supply equipment should provide an uninterrupted supply when the power mains fail.

Note. — Much existing equipment has been designed in accordance with the old Recommendation in Volume III of the *Blue Book*, which is reproduced below:
" In countries where the main power supply is unreliable and where it is the normal source of supply for the coaxial system, it is recommended that in each power-feeding station there should be equipment to transfer from the normal source of supply to a stand-by source or vice versa in such a manner that breaks in transmission on voice-frequency telegraph circuits or on telephone circuits with automatic signalling carried by the system do not exceed about 150 milliseconds."

d) *Spacing of power-feeding stations and attended stations*

A power-feeding station is not necessarily an attended station if there is an adequate alarm and remote control system. In this case the location of the attended station will be determined by local telephone requirements.

RECOMMENDATION G.352 (former Recommendation G.336, amended at Mar del Plata, 1968)

INTERCONNECTION OF COAXIAL CARRIER SYSTEMS OF DIFFERENT TYPES [1]

In every case of interconnection of coaxial carrier systems of different types at frontiers, some special arrangements are required to enable the systems to interwork satisfactorily.

The following points require special attention:

a) *Pilots*

Each line-regulating pilot should be transmitted on the two systems to be interconnected, at the same absolute power level (referred to a point of zero relative level). If the two systems do not use the same frequencies for the pilots, each of the stations situated at the ends of the regulated-line section crossing the frontier should be equipped to send all the pilots needed by both systems.

b) *Transmission conditions*

For interconnecting systems using different pre-emphasis values and output levels at national boundaries, administrations can agree to equalize the level differences by shortening

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[1] This Recommendation applies to 2.6-MHz, 4-MHz, 6-MHz and 12-MHz systems.

the frontier cable section and adding suitable passive equalizer networks as indicated in Annex 1.

There may be cases in which even shortening the cable section to zero is not sufficient to equalize completely the level differences. It is recommended in these cases that the residual small level differences be finally corrected in the next main repeater station.

In some cases it may be feasible to maintain the normal repeater spacing in the frontier cable section and to accept some level differences at some intermediate repeaters near the frontier, ancillary gain and correcting networks being provided in the nearest main station (see Annex 2).

c) *Power feeding*

In the absence of a special agreement between the administrations or private operating agencies concerned in a power-feeding section crossing a frontier, it is recommended that each administration power-feed only the repeater stations on its own territory.

d) *Supervision and alarms*

In each particular case, these points should be agreed by administrations concerned.

e) *Conditions for the repeater section*

The C.C.I.T.T. has standardized the dimensions of the coaxial pairs to be used in the international European telephone network (see Recommendations G.331 and G.342). Nevertheless, this standardization allows certain variations, so that the coaxial pairs manufactured by different contractors in different countries may not have exactly the same characteristics. To ensure uniformity throughout the frontier repeater section, it is strongly recommended that, by agreement between the two administrations or private operating agencies concerned the manufacture of the whole section should be entrusted to the same firm. If the same contractor does not supply the whole section, the two administrations or private operating agencies concerned must *very carefully* co-ordinate their detailed specifications and their methods of laying and jointing, to ensure that the conditions recommended by the C.C.I.T.T. for the complete repeater section are met.

As regards matching of the impedance of this repeater section to the impedances of the two adjacent amplifiers, in the general case of a coaxial cable section between two adjacent repeaters and used for telephony only, the C.C.I.T.T. has defined only the permissible limits for the sum N of the three terms defined in paragraph e) of Recommendation G.332.

It is recommended that administrations or private operating agencies concerned in a coaxial cable section crossing a frontier agree on the values for each of these three terms permissible in this case to meet the above condition—that is to say, agree on the use of as good a match as possible. It is also very desirable that, throughout a coaxial system, the administrations or private operating agencies concerned should agree always to use the same methods, particularly in impedance matching, so as to simplify system maintenance.

ANNEX 1

(to Recommendation G.352)

The interconnection of systems using different pre-emphasis values and output levels, at additional boundaries, can be achieved by the method shown in Figure 1. Repeater locations are designated I to IV, the different systems used in the two countries are indicated by repeater types A and B; the dotted lines w, x, y and z show the possible locations of the actual frontier. The correcting networks shown between repeater points II and III are designed in conjunction with the cable length between II and III to compensate for the differences in level and pre-emphasis of systems A and B. The correcting networks may be mounted in the repeater boxes at II or at III or may be mounted one in each box. Alternatively, they could be mounted in a separate box between II and III. The distance between II and III will normally be less than the repeater spacing of system A or system B and could in the limit be zero, with the repeater boxes II and III adjacent to one another, the frontier would then be at *w* or *z*.

Interconnection of two systems can be established by this method, using only passive interconnecting networks, if the following condition is met: The repeater input level at any frequency of one system is lower than the output level of the other system at the same frequency, by a small amount (say 1 dB) to allow for the loss of the interconnecting circuit.

The repeaters of type A could be fed with power and supervised from the nearest power feeding station in country A and similarly for type B repeaters. If the frontier were located at x or y, neither of the power-feeding and supervisory systems need cross the boundary.

With this method all repeaters could be of standard types and output and pilot levels could be normal. Special correcting networks would be required.

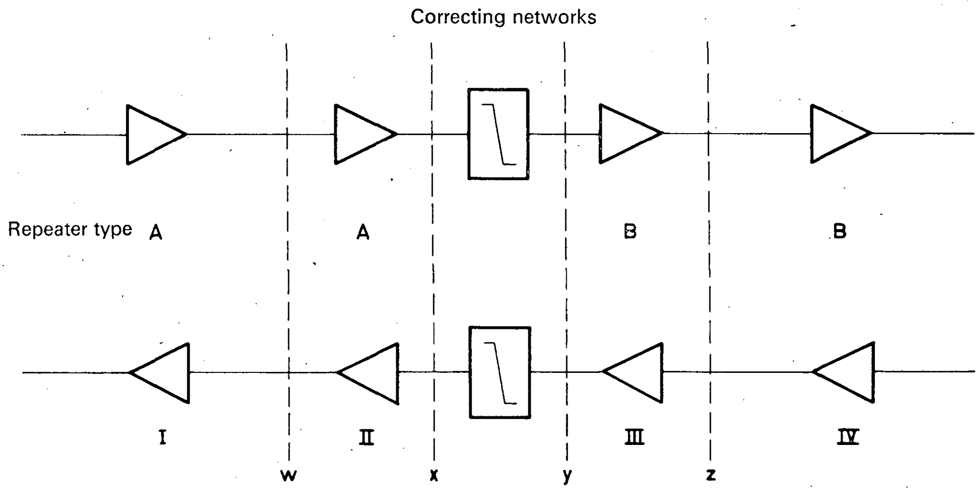

FIGURE 1

ANNEX 2

(to Recommendation G.352)

An alternative method is shown in Figure 2, in which the ordinary length of repeater spacing with the nominal loss a is maintained in the frontier cable section. The normal relative sending level of system I is n_I and that of system II is n_{II}. The difference of the relative levels is defined as the differential pre-emphasis

$$\Delta_{\text{pre}} = n_I - n_{II}$$

It shall be assumed that Δ_{pre} is positive over the whole transmission band and that at the highest transmitted frequency, the sending levels of the two systems are almost equal. For the adaptation of the relative levels between system I and system II it is necessary to introduce an additional passive correction network Δ_{pre} in the direction I⟶II and an additional active correction network $-\Delta_{\text{pre}}$ in the direction II⟶I.

For reasons associated with the size of the repeater housing and power supply, it may be desirable to avoid additional amplification in the frontier section, which usually has underground repeaters with a remote power supply. There is no great drawback in using the pre-emphasis of the foreign incoming system up to the following attended repeater station and to accommodate only in this latter the requisite gain for transformation of the pre-emphasis. In the attended repeater station, there will be no special difficulty in getting the necessary space and current for the additional equipment. The requisite gain in the direction II⟶I (for $-\Delta_{\text{pre}}$) and in the direction I⟶II (because of a possible basic loss in the Δ_{pre} network) is supplied by additional amplifiers which are usually already provided for in attended stations, to compensate for the basic attenuation of precision equalizers.

As indicated in Figure 2, it may be well to use differential pre-emphasis for both directions in the same repeater station, for example on that side of the frontier where there is the system using the smallest pre-emphasis (higher sending relative level). If we assume as is shown in Figure 2 that this is system I, the few underground repeaters of system I between the frontier and the attended repeater station will (in lower channels) be operated with the lower level of system II and will affect the overall noise performance of the whole system less critically than if the situation were reversed, such that system II were operated at a higher level.

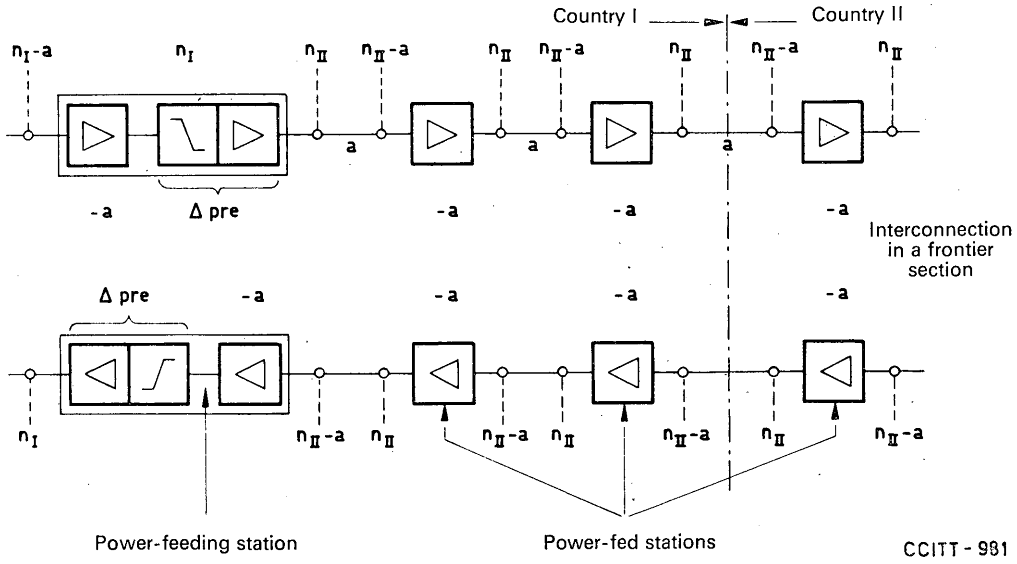

FIGURE 2

RECOMMENDATION G.356 (Mar del Plata, 1968)

(120 + 120)-CHANNEL SYSTEMS ON A SINGLE COAXIAL PAIR

A. MAIN CHARACTERISTICS OF THE SYSTEMS

The proposed systems provide 120 + 120 channels on a single coaxial pair, with two-way repeaters power-fed via the cable.

These systems belong to two categories: one with two supergroups (120 channels), the other with two supergroups + one group (120 + 12 channels).

The choice between these systems depends on the conditions of use.

a) *Line frequencies*

In systems of the first category, the two supergroups are transmitted to line in the position of supergroups Nos. 1 and 2 for one direction of transmission and in the 812-1304-kHz band for the other direction. In systems of the second category, the two supergroups are transmitted to line in the position of supergroups Nos. 4 and 5 for one direction of transmission and in the 188-676-kHz band for the other direction; the group is transmitted in the position of the basic group (60-108 kHz) for one direction of transmission and in the 1380-1428-kHz band for the other direction.

The two frequency plans concerned are shown in Figure 1 (Plans 1A and 1B for the first category, Plan 2 for the second category).

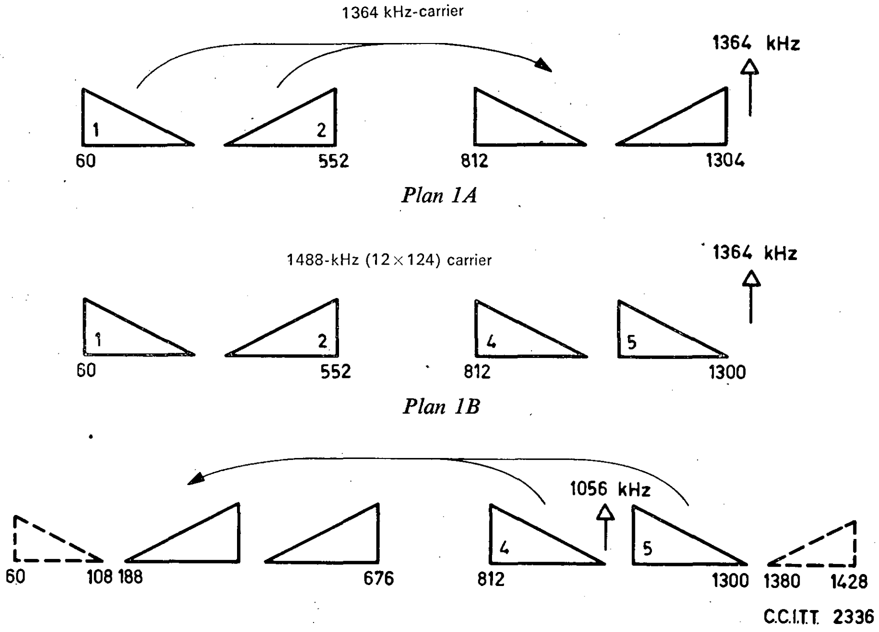

FIGURE 1. — Frequency allocation plans

All these systems permit interconnection at frequencies of the basic supergroup.

The system using Plan 1A needs less carrier frequencies than the other systems; it permits simple interconnection in the 60-552-kHz band.

The system using Plan 1B makes use of supergroup translation frequencies standardized for other systems (e.g. 300-circuit four-wire systems) and equipment widely available.

The system using Plan 2 enables 12 circuits to be set up in addition along the main transmission path, independently of the 120 long-distance channels. Moreover, it provides better protection in regions where a great deal of induced noise is to be feared.

In the case of interconnection at a frontier crossing of systems using different frequency plans, the administrations concerned should agree on the arrangements to be adopted. In case of difficulty, the C.C.I.T.T. recommends that Plan 1A be adopted to connect the two stations located on either side of the frontier.

	1st category 120 channels Plans 1A and 1B	2nd category (120+12) channels Plan 2
b) *Pilots*		
regulating pilots	1364 kHz	432 and 1056 kHz
monitoring	52 or 60 kHz	
Additional measuring frequencies :		
(if required) Lower band	60 and 308 kHz	124 and 677 kHz
Upper band	808, 1056 and 1304 kHz	811 and 1364 kHz
Stability and level of pilots and additional frequencies	Rec. G.341	Rec. G.341
c) *Hypothetical reference circuit*	Rec. G.338	Rec. G.338
d) *Conventional load* (provisional recommendation)	Rec. G.223 for a 240-channel four-wire system	Rec. G.223 for (240 +24)-channel four-wire systems

e) *Matching of the coaxial-pair impedance and the repeater impedances*

The most important "roll" effect arising from reflections within the cable is caused by the interaction of these reflections with the mismatches at the repeater section terminals. In order to minimize the effects of internal cable reflections the repeater section terminal mismatches should be such that the roll effect attributable to interaction between terminal mismatches alone is only about half the permitted objective, i.e. 0.5 dNp roll amplitude for a 280-km section. For a 120-channel system this is quite feasible.

f) *Relative levels and interconnection*

1. Interconnection: in the main stations [1] in supergroups 1 and 2 or supergroups 4 and 5

		1st category 120 channels Plans 1A and 1B	2nd category (120+12) channels Plan 2
Input	Send	−36 dB	−4.1 Np or −36 dB
Output	Receive	−23 dB	−2.6 Np or −23 dB

2. Interconnection in line: Recommendation G.352.

g) *Regulation*

As with other standardized C.C.I.T.T. systems, designers of the line-regulating equipment must take account of the daily and seasonal variation in temperature to which the cables and repeaters are likely to be subjected. In the case of aerial cables, particularly, large temperature changes may be encountered, for example ± 35 °C.

B. CABLES

The line is a single coaxial pair, the specification of which is suited to the external medium, the underground or overhead conditions of use, stresses caused by lightning strokes or the neighbourhood of power lines, the method of laying, etc.

The internal conductor may either be insulated by the customary methods for coaxial pairs standardized by the C.C.I.T.T. or—in order to increase the dielectric strength or the mechanical strength—it may be insulated with solid polythene, or polythene and air (discs surrounded by a tube made of polythene, foamed polythene, polythene cylinder with longitudinal channels, etc.).

The external conductor may be of copper or aluminium.

The cable lengths may be joined together either by splicing or by means of a connector.

The characteristic impedance at 1 MHz is 75 ohms in principle, unless the cost of a cable with this impedance would be too high for the purpose in view.

Specifications of impedance regularity should take into account the final capacity of any system that may use the cable.

The standardized 4.4-mm and 9.5-mm coaxial pairs have close limits on impedance and internal reflections, partly to allow for possible use for television. For a 120-channel system the C.C.I.T.T. objective for the variation of level with frequency of the line spectrum at the end of a regulated-line section (maximal "roll" amplitude 1.0 dNp) can be met using cables

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[1] Corresponding to points T and T′ as defined in Recommendation G.213.

of lower standard of impedance regularity. If the condition mentioned in paragraph A.e of this Recommendation is fulfilled, internal cable irregularities may then be up to 10 dB worse than for the 4.4-mm pair (see Recommendation G.342).

3.6 Other modern carrier systems

Even though the systems described in the present sub-section are modern, particularly because the audio-frequency band effectively transmitted for each telephone channel is from 300 to 3400 Hz, the general recommendations of Section 2 above cannot be applied to them entirely, having regard to certain peculiarities of their make-up. For this reason the following special arrangements have been made.

RECOMMENDATION G.361 (former Recommendation G.351)

SYSTEMS PROVIDING THREE CARRIER TELEPHONE CIRCUITS ON A PAIR OF OPEN-WIRE LINES

A. STANDARDIZED SYSTEM

The particular system described below provides three good-quality telephone circuits in the frequency band above the existing audio circuit. This system can be arranged below the frequency band shown in Scheme I of Figure 1 (Recommendation G.311) for a 12-circuit system.

The arrangement of line frequencies in this system has been so specified that when such a system crosses a frontier (perhaps in a completely uninhabited area) it is not necessary to use modulators and demodulators.

Besides the audio circuit, it is moreover possible, with this arrangement of line frequencies, to provide either one carrier telephone circuit together with one two-way, normal programme circuit type A or B [1].

This system can also include a certain number of telegraph channels without change to the transmitted frequency band of the carrier circuits. The bandwidth of the audio circuit, however, is in this case reduced.

The specification below has been designed for the above particular case.

a) *Frequency band transmitted*

The carrier frequency spacing should be 4 kHz.

The lower band transmitted to line, for one direction of transmission, should be between 4 and 16 kHz, and the upper band, used for the other direction of transmission, should be either 18 to 30 kHz or 19 to 31 kHz, so as to allow the use of staggered carrier frequencies,

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[1] See Recommendations J.21 and J.31.

if it is later decided to use a second similar system on the same pole route (see paragraph j) below and Figure 1).

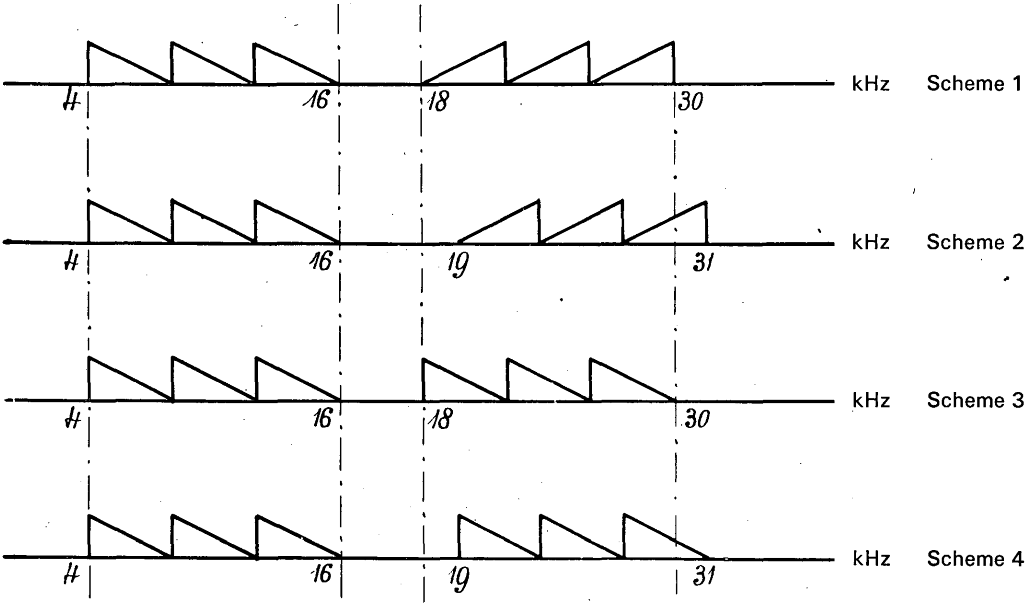

FIGURE 1. — **Frequency spectra for four systems, each providing three carrier telephone circuits which can be set up one after another on the same pole route**

b) *Relative power level*

The relative power level at the output of the terminal equipments and intermediate repeaters, on each channel and for the frequency of this channel which corresponds to the audio-frequency 800 Hz is not greater than + 17 dB or + 2 Np.

c) *Pilots*

The pilots are normally 16.110 kHz for the lower line-frequency band and 31.110 kHz for the upper band. The relative frequency accuracy recommended for them is 2.5×10^{-5}. This recommendation applies to all the four frequency spectra shown below. The absolute power level of the line pilots should be —15 dB (—1.73 Np) at a point of zero relative level.

The upper pilot of 31.110 kHz is suitable for most administrations. Normally it may be expected to give a rather better regulation performance than a pilot of lower frequency.

In other cases it may be unsuitable for the following reasons:

1. The regulation may be affected when the open-wire pair is already equipped with a number of filters designed to separate 12-circuit systems from old-type 3-circuit systems.

2. When a single modulation stage is used for the low-frequency telephone channels of the standardized system, it is convenient for interband telegraph channels (see part B of this present recommendation) to be located above, rather than below, the frequency band occupied by the telephone channels in the high-frequency direction of transmission.

The C.C.I.T.T. accordingly recommends that an alternative pilot frequency of 17.800 kHz be used when it is agreed between the administrations concerned that the normal pilot frequency of 31.110 kHz is unsuitable either for the reasons given above or to meet other circumstances peculiar to the route.

d) *Variation (with frequency) of the overall loss at the output of the transmit terminal equipment*

See paragraph A e) of Recommendation G.232.[1]

e) *Non-linearity distortion of all the terminal equipments*

See paragraph A f) of Recommendation G.232.[1]

f) *Crosstalk in terminal equipments*

See paragraph A g) of Recommendation G.232.[1]

g) *Impedance (as seen from the switchboard-jack)*
See paragraph A h) of Recommendation G.232.[1]

h) *Stability of carrier generators*

So that the effect of the modulations and demodulations never gives rise to a difference greater than 2 Hz between the audio-frequency input and the audio-frequency output at the far end (where there is no intermediate demodulation and modulation), the stability of the carrier frequency generators should be such that the frequency is always correct to within 2.5×10^{-5}.

i) *Carrier leak sent to line*

At a zero relative level point, the absolute power level of the carrier leak should not be greater than:

−17 dBm or −2.0 Np for one channel and for each direction of transmission;

−14 dBm or −1.7 Np for all channels of the system taken together and for each direction of transmission.

j) *Several systems working on the same route*

The C.C.I.T.T. recommends the four arrangements of frequencies shown in the diagrams of Figure 1. No order of preference has been decided and in each particular case the administrations concerned will choose the most appropriate scheme(s).

Note. — Also, by agreement between administrations or private operating agencies concerned, the lower frequency band transmitted to line schemes 2 and 4 may be inverted.

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[1] *Note by the C.C.I.T.T. Secretariat:* This recommendation was not revised by the Plenary Assembly of Geneva, 1964. The references are to Recommendation G.232 in the *Red Book*, Volume III, and a study should be made to determine whether the clauses of Recommendation G.232 of the present volume are applicable or not.

B. SYSTEMS USING COMMON REPEATERS FOR TELEPHONY AND INTERBAND TELEGRAPHY

For international traffic, it is necessary to provide for an open-wire system which uses common line repeaters for telephone and interband telegraph channels.

a) *Line-frequency arrangement for telephony*

The arrangement of line frequencies so far as the telephone channels are concerned would be as shown in part A of this present Recommendation.

b) *Line-frequency arrangements for telegraphy*

1. It is recommended that the system should provide four telegraph channels, the nominal frequencies to be used being as follows:

   1.1 *Low-frequency direction of transmission*

   3.22 — 3.34 — 3.46 and 3.58 kKz

   1.2 *High-frequency direction of transmission*

   α) telephone channels occupying the frequency band 18-30 kHz:

   30.42 — 30.54 — 30.66 and 30.78 kHz

   β) telephone channels occupying the frequency band 19-31 kHz:

   18.22 — 18.34 — 18.46 and 18.58 kHz.

2. When in-band signalling (as distinct from out-band signalling at the edge of the 4-kHz band) is employed, it becomes possible to provide two additional telegraph channels having the following nominal frequencies:

   2.1 *Low-frequency direction of transmission*

   3.70 and 3.82 kHz

   2.2 *High-frequency direction of transmission*

   α) telephone channels occupying the frequency band 18-30 kHz

   30.18 and 30.30 kHz

   β) telephone channels occupying the frequency band 19-31 kHz:

   18.70 and 18.82 kHz

3. Where, as a result of agreement between the administrations concerned, the system has an upper pilot of 17.800 kHz (see para. A.c. of the present Recommendation), the following frequencies may be used as alternatives to those specified in paras. 1.2 β and 2.2 β above. This alternative arrangement permits, in certain types of systems, a more economical modulation process:

31.42 — 31.54 — 31.66 and 31.78 kHz instead of 18.22 — 18.34 — 18.46 and 18.58 kHz
also 31.18 and 31.30 kHz instead of 18.70 and 18.82 kHz

c) *Power transmitted to line*

The C.C.I.T.T. has not thought it desirable to standardize absolutely the power transmitted to the line as this may be dependent upon the conditions on the open-wire route. Neither was it thought necessary to differentiate between amplitude- and frequency-modulated telegraph channels. Under favourable conditions a typical value for the power on each telegraph channel would be −20 dB or −2.35 Np referred to one milliwatt at a point of zero relative level.

C. OTHER SYSTEMS

In some cases, it is necessary to operate across a frontier on an open-wire pair, without using demodulators and modulators at the frontier, using a system providing three good-quality telephone circuits (effective frequency bandwidth of each circuit—300 to 3400 Hz), and having below about 6 kHz a frequency band which can be used for other purposes. In such cases the arrangement of line frequencies should be the subject of bilateral agreement between the administrations concerned. Paragraphs b), d), e), f), g), h) and i) of part A of the present Recommendation are applicable to all such systems.

The carrier frequency spacing could be 4 kHz, as in all other recommendations of the C.C.I.T.T. for modern carrier systems. This solution would permit the use on each telephone channel of out-band signalling recognized by the C.C.I.T.T. (*White Book*, Volume VI, Recommendation Q.21). As a variant, a system could be used, having a carrier frequency spacing of less than 4 kHz, but still providing an effectively transmitted bandwidth of 300-3400 Hz in each telephone channel. Such a system would facilitate the provision, if required, of up to six telegraph channels using the same line repeaters as the telephone channels.

Establishment of a model questionnaire concerning preliminary information which should be obtained relating to existing open-wire lines by administrations or private operating agencies wishing to set up multichannel carrier telephone systems

The C.C.I.T.T. *unanimously recommends*

that the following questionnaire should be used:

1. Which communication channels should be set up on carrier systems?

2. Which lines are available for carrier working?

a) length of these lines,

b) gauge, nature of wire, distance between wires,

c) existing cable sections (location, type and length of these cables),

d) existing transpositions,

e) amongst available lines, are there two or more identical circuits which could be interchangeable, to which reserve circuits could be allocated?

3. What are suitable points for installation of the repeaters? Where are audio-frequency repeaters already located on the lines to be equipped for carrier working?

4. What are the locations of radio-transmitting stations liable to interfere with the carrier channels? What power and frequency are used by these transmitters?

5. Are the new carrier circuits to be connected to other lines permanently or temporarily?

6. Certain lines and offices having been selected as a result of the answers to the above questions, administrations or private operating agencies should obtain the following information:

What are the results of impedance and attenuation measurements made on each of the proposed line sections throughout the frequency band to be used?

3.7 International telephone carrier systems using submarine cable

RECOMMENDATION G.371 (Former Recommendation G.361 Geneva, 1964; amended at Mar del Plata, 1968)

CARRIER SYSTEMS FOR SUBMARINE CABLE

This Recommendation relates to systems not longer than 2500 km.

a) *Interconnection with overland systems*

There is a basic difference between overland and submarine systems with regard to interconnection conditions. In the first case, we are concerned with the connection, at a point close to a frontier, of two systems operated by different administrations and designed by different manufacturers, sometimes according to different principles, although they respect the same C.C.I.T.T. Recommendations. In the second, we usually have one system, purchased, installed and operated jointly, and built by one manufacturer; terminal equipments including special equipment which are studied in relation to line equipment (remote feeding, equalization, location of faults, etc.) and which cannot be dissociated therefrom. It is this system as a whole which is interconnected with the overland networks of the two countries it connects; instead of one frontier point, there are two. This being so, the interconnection point is defined as the output and the input of the special equipments which ensure the passage between the frequency allocation used in the submarine cable system and a line-transmitted frequency allocation for an overland system (or part of such an allocation plan), so as to enable group, supergroup, or mastergroup translating equipment (depending on the capacity of the system) which conforms with C.C.I.T.T. Recommendations to be used on the other side of these interconnection points (see Figure 1).

The C.C.I.T.T. recommends the application at these points of the relative levels specified in Recommendation G.213 at points T and T′ for overland systems of corresponding capacity (see paragraph b) for further details).

These points must be considered to be the T and T′ input and output points of a line link, as they are defined in Recommendation G.213. Hence, all C.C.I.T.T. Recommendations (especially Recommendation G.243) relating to interconnection of systems and to the through (or direct through) connection of groups, supergroups, etc., apply as from these points.

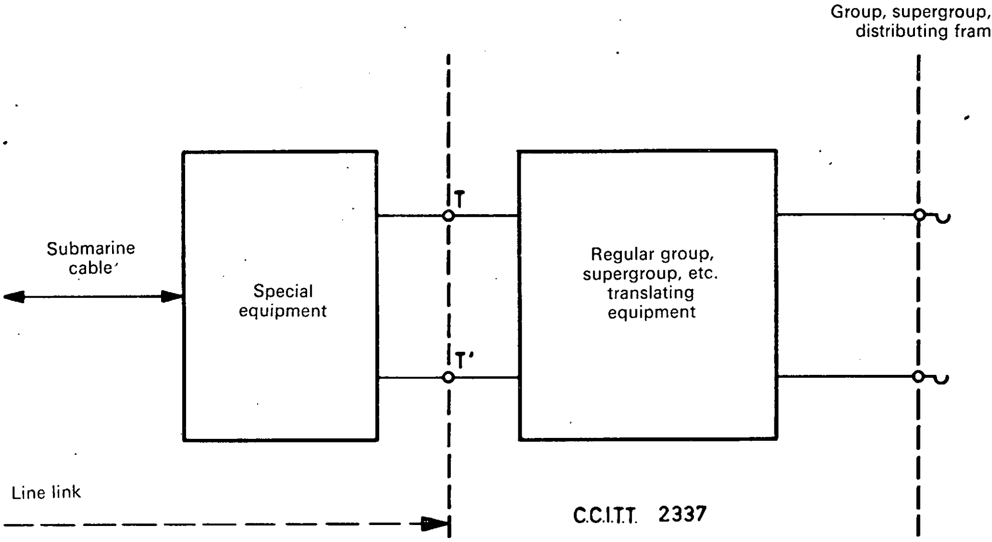

FIGURE 1

Recommendations concerning groups, supergroups, etc. — To avoid disturbing the operation of overland systems to which the submarine cable systems may be interconnected, as indicated above, the C.C.I.T.T. proposes to recommend that submarine cable systems should not use any pilot inside the band of each supergroup [1] and that, as far as economically possible, the repeater monitoring (supervisory) signals and remote signalling frequencies should be located outside the band of each supergroup, and preferably outside the band occupied by all the supergroups transmitted in either direction.

Note 1. — The repeater supervisory signals and remote signalling frequencies are not normally transmitted permanently.

Note 2. — For testing on a system taken out of service the above restriction on the frequencies of repeater monitoring signals need not apply.

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[1] Or of each group, in the case of a system having a capacity of less than 60 channels.

b) *Frequency plans*

It was not considered necessary to standardize the line-frequency band, which in each case is subject to agreement between the two administrations concerned.It is recommended, however, that the circuits be assembled in one of the basic groups specified by the C.C.I.T.T. and, where necessary, in the basic supergroup. To obtain a capacity of more than 8 groups, systems should be limited to those providing 2, 5 or 8 supergroups, on the understanding that recommendations will be made later for systems of greater capacity; this point is being studied.

It is recommended that at the input and output of the special terminal equipment, at the interconnection points defined in paragraph a), the groups and the supergroups as the case may be assembled in one of the frequency allocations (or part of such an allocation plan) already recommended by the C.C.I.T.T. for inter-connection between radio-relay links and systems on metallic lines; these allocations are given in Table 1 of Recommendation G.423. If the capacity of the system concerned does not correspond to one of those mentioned in this table, the capacity immediately above should of course be taken.

c) *General transmission conditions*

The systems should satisfy all recommendations in Sections 1 and 2 of Part I of this Volume, including: noise (objective 3 pW/km in these systems), crosstalk, attenuation distortion, error on the reconstituted frequency, variation of loss with time. However, for noise calculations it is necessary to specify a conventional load other than that at present recommended by the C.C.I.T.T. (Recommendation G.223); this point is under study.

Note. — Two load values per 4-kHz band have been proposed: both may be retained provisionally since hey correspond to two typical modes of operation:

−11 dBm0, which makes allowance for the increased load due to the use of equipments providing 16 channels per group and to the presence of call concentrators;

−13 dBm0, calculated on the assumption of 2 v.f. telegraph systems per group.

d) *Cables*

This question is being studied. Supplement 11 to this volume contains documentation on the cable-laying vessels used in various countries.

SECTION 4

GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES

The following table shows the types of system to which the various recommendations in the present section apply (the numbers of the corresponding C.C.I.R. recommendations, Oslo, 1966, are shown in brackets).

Subject of recommendation	Multiplex radio-relay systems using			Communication-satellite system [4]
	frequency division		time division [3]	
	line-of-sight [1]	tropospheric scatter [2]		
Use of radio links	G.411 (335-1)	G.411 (335-1)	G.411 (335-1)	
Terminal equipment	G.412	G.412	G.412	
Interconnection at audio-frequencies	G.422 (268)	G.422 (268)	G.422 (297)	
In-band interconnection (levels, pilots, frequency distribution in band, etc.)	G.423 (380-1, 381-1)	G.423 (380-1, 381-1)		
Hypothetical reference circuits	G.431 (391, 392)	G.433 (396-1)	G.432 (300)	G.434 (352)
Circuit noise	G.441 (393-1, 395-1), G.442	G.444 (397-1)	G.443 (394)	G.445 (353-1)

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[1] Or near line-of-sight.

[2] For the capacities (number of telephone circuits) concerned.

[3] Recommendations applicable only to the characteristics between aûdio-frequency terminals

[4] In the present section, use of these systems for telephony only is considered.

4.1 General recommendations

RECOMMENDATION G.411

USE OF RADIO-RELAY SYSTEMS FOR INTERNATIONAL TELEPHONE CIRCUITS

The C.C.I.T.T.

unanimously recommends [1]

that, between fixed points, telephone communications should be effected wherever possible, by means of metallic conductors or radio-relay links using frequencies above 30 MHz to make the allocation of radio-frequencies less difficult and, where this can be realized, the objective should be to attain the transmission performance recommended by the C.C.I.T.T. for international telephone circuits on metallic conductors.

RECOMMENDATION G.412

TERMINAL EQUIPMENTS OF RADIO-RELAY SYSTEMS FORMING PART OF A GENERAL TELECOMMUNICATION NETWORK

The C.C.I.T.T.,

considering

that in Europe, and also in other parts of the world, there is a vast international telecommunication network which (as well as national networks) has been established in conformity with the recommendations of the C.C.I.T.T., particularly as far as the frequency spectrum of the telephone channels in the frequency band up to 4 MHz is concerned, and also as regards the essential technical characteristics of the terminal equipments of all the carrier systems;

considering, further,

that the increasing introduction of demand working and semi-automatic telephone service will lead, in the near future, to an appreciable increase in the number of long-distance national and international circuits,

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[1] This Recommendation is the same as an extract from C.C.I.R. Recommendation 335-1 (Volume III). All the other C.C.I.R. Recommendations mentioned in this Section are contained in the "C.C.I.R. Documents of the XIth Plenary Assembly (Oslo, 1966)—Volume IV".

and that consequently, during the next few years, it will be necessary to install multichannel telephone systems on radio links and to integrate these links with the general telecommunication network;

and considering finally

that interconnection of the systems should be made easy and that the task of the telephone administrations which will have to use and maintain these systems should not be unnecessarily complicated,

unanimously recommends

that, when technically possible and economically desirable,

1. systems on radio-relay links should be arranged in such a way that at points of interconnection with the general telephone network, the telephone circuits appear assembled in accordance with the rules already recommended by the C.C.I.T.T. for cable systems (this rule is covered by Recommendations G.421 and G.423);
2. in all cases channel-modulating equipment should meet the basic specification clauses given in Recommendation G.232 above.

4.2 Interconnection of radio-relay links with carrier systems on metallic lines

RECOMMENDATION G.421

METHODS OF INTERCONNECTION

In studying the interconnection of radio-relay systems, either with one another or with systems on metallic lines, distinction should be made between the following cases:

a) *Interconnection at audio-frequencies*

This is the normal method, at the present stage of technical development, whenever a radio-relay system using time-division multiplex is involved. Operational requirements may be such that it is also necessary in the case of frequency-division multiplex and of systems on metallic lines. These two cases are dealt with in Recommendation G.422.

b) *Interconnection by through-group connection*

With present technical development only radio-relay links having frequency-division multiplex can provide telephone channels assembled in groups, supergroups, mastergroups, and in some cases, supermastergroups or in 15-supergroup assemblies.

Interconnection between a radio-relay system using frequency-division multiplex and a system on metallic lines can be carried out by through-connection of groups, supergroups, etc. This is possible because, according to the provisions of Recommendation G.423, the baseband of such a radio-relay system corresponds to that of a certain number of groups, supergroups or mastergroups transmitted to line in coaxial cable systems. These groups, etc., can be obtained from the relevant basic frequency band by means of translating equipment already standardized for cable systems in accordance with C.C.I.T.T. recommendations.

Through-connection should then be carried out in accordance with the C.C.I.T.T. recommendations made in Recommendation G.242, via the basic frequency range for groups (12 to 60 kHz or 60 to 108 kHz), for supergroups (312-552 kHz) etc. (see Recommendation G.211 and Figure 1, in particular).

c) *Interconnection in the baseband*

The baseband of frequency-division multiplex radio-relay links is the same as the frequency band of carrier systems on metallic lines, and interconnection in this band is possible in the conditions specified in Recommendation G.423.

Direct through-connection may also be made in this baseband, between metallic-line systems and radio-relay links, in accordance with the general provisions of Recommendation G.242, paragraph g.

For time-division multiplex radio-relay links, the baseband is defined by the C.C.I.R. as "the series of modulated pulses before it is applied to the carrier frequency". Interconnection in the baseband of time-division radio-relay links with metallic-line systems has not yet been studied.

d) *Interconnection at intermediate frequencies* and

e) *Interconnection at radio frequencies*

These are cases arising only in the interconnection of two radio-relay systems and are the concern of the C.C.I.R.

C.C.I.R. Recommendation 304 shows the recommended basis for choosing the type of multiplexing for a radio-relay system, in order to facilitate interconnection.

RECOMMENDATION G.422

INTERCONNECTION AT AUDIO-FREQUENCIES

a) *Radio-relay links with frequency-division multiplex*

C.C.I.R. Recommendation 268 states that, as far as is practicable, frequency-division multiplex radio-relay systems forming part of an international circuit should conform with the relevant C.C.I.T.T. recommendations for modern types of telephone circuit in the following respects:

1. the method of making international connections at audio-frequencies;
2. the characteristics of the frequency-division multiplex terminal equipment;
3. the method of signalling over international circuits.

b) *Radio-relay links with time-division multiplex*

C.C.I.R. Recommendation 297 states that, as far as is practicable, time-division multiplex radio-relay systems forming part of an international circuit should conform to the relevant C.C.I.T.T. recommendations for modern types of telephone circuit in the following respects:

1. the method of making international connections at audio-frequencies;
2. the method of signalling over international circuits.

Note. — Since the C.C.I.T.T. recommendations mentioned in 2 envisage the use of well-defined audio signalling frequencies sent over the speech path, no signal repetition problems should arise.

When different signalling methods are used on a cable system and a radio-relay system, equipment will be necessary at the interconnection point to convert the two types of signalling to a common type, preferably d.c. signalling.

RECOMMENDATION G.423 (amended at Geneva, 1964)[1]

INTERCONNECTION AT THE BASEBAND FREQUENCIES OF FREQUENCY-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS[2]

a) *General principles*

The C.C.I.R. issued Recommendations 380-1 and 381-1 so that, so far as possible, radio-relay links using frequency-division multiplex should have characteristics which allow direct interconnection at baseband frequencies with systems of the same capacity on metallic lines having the same line frequencies.

Direct interconnection is advantageous, for example, in the following cases:

1. at a junction between a system on metallic lines and a radio-relay system of the same capacity, when it is not required to extract groups of telephone channels;

2. at a junction point between a radio-relay system and a short cable extension (see paragraph c) below). A cable extension is regarded as "short" if it does not require its own line-regulating system.

The pre-emphasis characteristics at the output of cable system repeaters have not been fully standardized by the C.C.I.T.T. Moreover, line transmission in a repeater section of a system has various special features, due for example, to the presence of various pilots and to the power feeding of the repeaters. Further, points *R* and *T* defined in G.213 may be very near to each other, or they may be linked by several kilometres of cable.

For these reasons, it is unnecessary to provide that for the direct interconnection of a radio-relay link with either a carrier or coaxial cable telephone system, the input and output levels of the relay link shall be such as correspond exactly to the normal levels at the input and output of a repeater in the cable system. It is preferable to make the interconnection at a point in the telephone equipment where the level is independent of the

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[1] Brought up to date by the Secretariat after the Plenary Assembly of Mar del Plata, 1968.

[2] Similarly to the corresponding C.C.I.R. recommendations, this Recommendation applies to line-of-sight and near line-of-sight radio-relay systems, and also to tropospheric scatter systems of the capacities concerned.

TABLE 1

Frequency arrangements within the baseband of radio-relay links, which are recommended in the case of interconnection with systems on metallic lines

Capacity of radio-relay system (maximum number of telephone channels)	Recommended alternative arrangements of telephone channels	Diagram in figure	Limits of band occupied by telephone channels (kHz)	Pilots or frequencies which may be transmitted [1] (kHz)		Total bandwidth [2] (kHz)
				below (4)	above (4)	
1	2	3	4	5		6
24	2 G[3] 2 G[4]	2-a (G.322) 1 (G.327)	12-108 6-108 or 12-120	— —	— —	12-108 6-108 or 12-120
60	SG 1	2-c (G.322)	12-252	—	—	12-252
	SG 1	4 (G.322)	60-300	—	—	60-300
120	SG 1 and 2	4 (G.322)	12-552	—	—	12-552
	SG 1 and 2	4 (G.322)	60-552	—	—	60-552
300	5 SG	1-a (G.341)	60-1300	—	1364	60-1364
	1 MG[5]	1-b (G.341)	64-1296	60	1364	
600	10 SG	1	60-2540	—	2604	60-2792
	2 MG[5]	2	64-2660	—	2792	
900	3 MG or 1 SMG[6]	4	316-4188	300, 308	4287	60-4287
960	16 SG	5	60-4028	—	4092	
1260[7]	21 SG 21 SG 4 MG	Diagr. 1 Diagr. 2 Diagr. 3 [8]	60-5636 60-5564 316-5564	— — 308	5680 5608 5608	60-5680
1800	15 SG+3 MG	6	312-8204	300, 308	8248	300-8248
	15 SG + 15 SG[9]	7	312-8120			
	6MGor2SMG	8	316-8204			
2700	15 SG+6 MG	9	312-12388	300, 308	12435	300-12435
	15 SG + 15 SG + 15 SG[9]	10	312-12336			
	9MGor3SMG	11	316-12388			

G = group
SG = supergroup

MG = mastergroup
SMG = supermastergroup

frequency. Consequently, interconnection with multiplex telephone equipment in the baseband of a radio-relay link (which in accordance with C.C.I.R. Recommendation 381-1 is always considered to be at one end of the line-regulating section on a radio-relay link) should always be effected in a main repeater station [1]. Interconnection with another system whether cable or radio-relay link will be effected in this station between points T and T' defined in Recommendation G.213.

b) *Baseband frequency limits, impedance and relative power levels*

C.C.I.R. Recommendation 380-1, reproduced below, includes a table which shows preferred values given by the C.C.I.R. for the following:

— baseband frequency limits;

— nominal baseband impedance;

— input and output relative power levels at the radio equipment input and output points are R' and R;

together with an annex on definitions which corresponds to C.C.I.T.T. Recommendation G.213.

Table 1 on the preceding page shows the baseband frequency arrangements, corresponding to the baseband frequency limits in C.C.I.R. Recommendation 380-1, recommended by the C.C.I.T.T. for radio-relay systems that may be interconnected with metallic lines. These frequency arrangements are produced by C.C.I.T.T. standardized frequency-translating equipments for cable systems.

FIGURES 1 to 11. — **Diagrams of the frequency arrangement for the radio-relay baseband, recommended for purposes of interconnection with coaxial cable systems**

Notes. — 1. All the diagrams in Figures 1 to 11 show the line pilots, the mastergroup pilots, the supermastergroup pilots and the additional measuring frequencies which *may* be in the band transmitted (see paragraph c) of this Recommendation).

2. The symbols used in these figures are shown on the inset at the end of this volume.

3. Some of the diagrams in the figures of other Recommendations also apply to radio-relay links (see Table 1 of this present Recommendation).

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[1] Described in point 18 of Recommendation G.211.

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[1] See paragraph c) of the present recommendation.

[2] This is the bandwidth occupied by the telephone channels, the associated pilots and reference frequencies, excluding the continuity pilots of the radio-relay system.

[3] For 12-channel systems either of the basic groups A (12-60 kHz) or B (60-108 kHz) recommended by the C.C.I.T.T. may be accommodated in the band 12-108 kHz.

[4] In these variants, there are certain restrictions on the use of noise measurement channels or continuous pilot channels recommended by the C.C.I.R. (see Note 6 to C.C.I.R. Recommendation 380-1, reproduced below).

[5] This frequency arrangement is obtained from the basic mastergroup by modulating with multiples of the supergroup carriers.

[6] The special case of 600 channels comprising 2 mastergroups in the band 316-2868 kHz (Figure 3) is regarded as a partially equipped 960-channel system.

[7] According to C.C.I.R. Recommendation 380-1, other limits of the band occupied by telephone channels may be used by agreement between the administrations concerned.

[8] Figure 1 of Recommendation G.344.

[9] For the use of 15-supergroup assemblies, see Recommendation G.211.

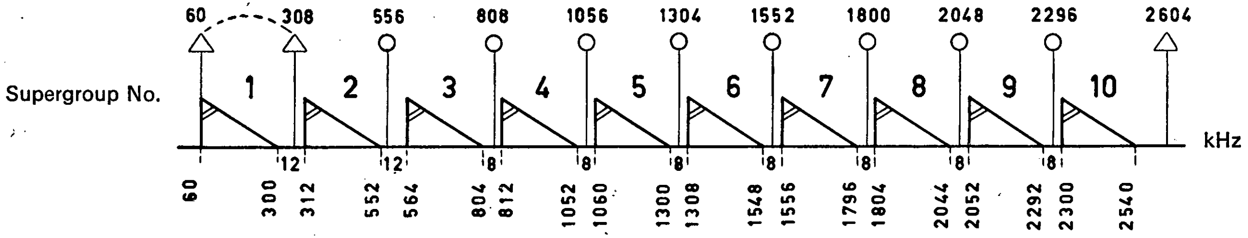

FIGURE 1

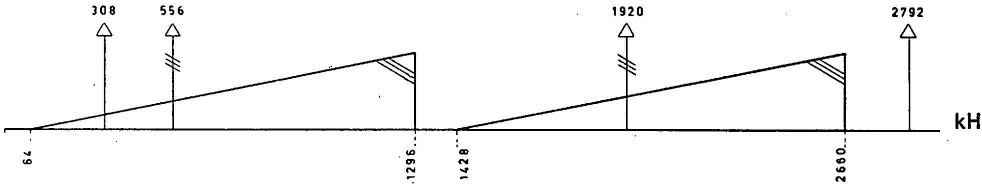

FIGURE 2

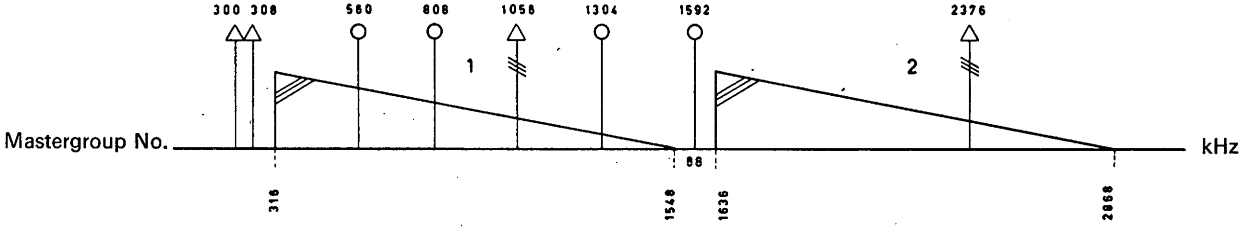

FIGURE 3

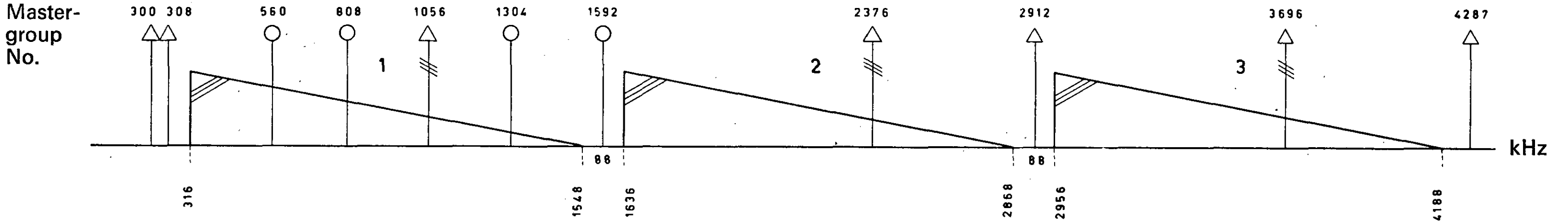

FIGURE 4

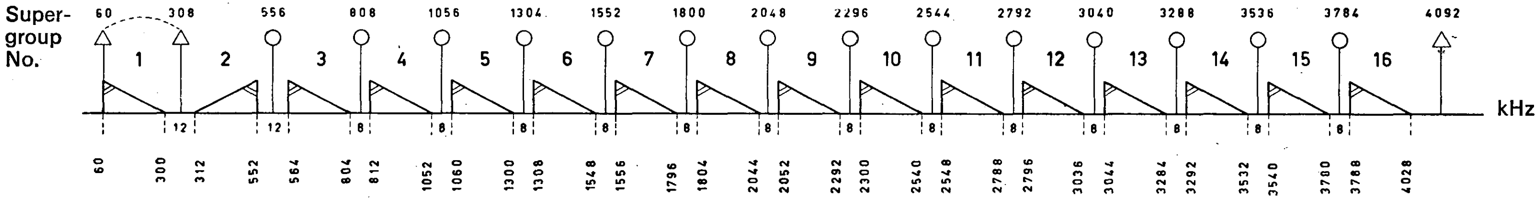

FIGURE 5

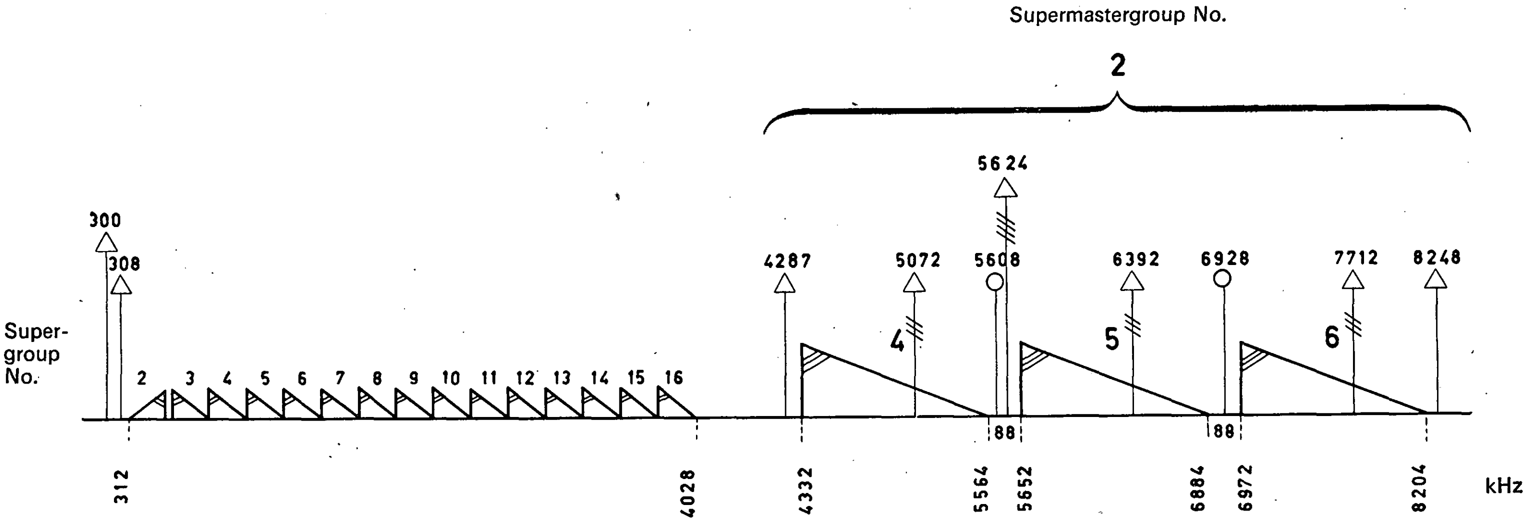

Figure 6

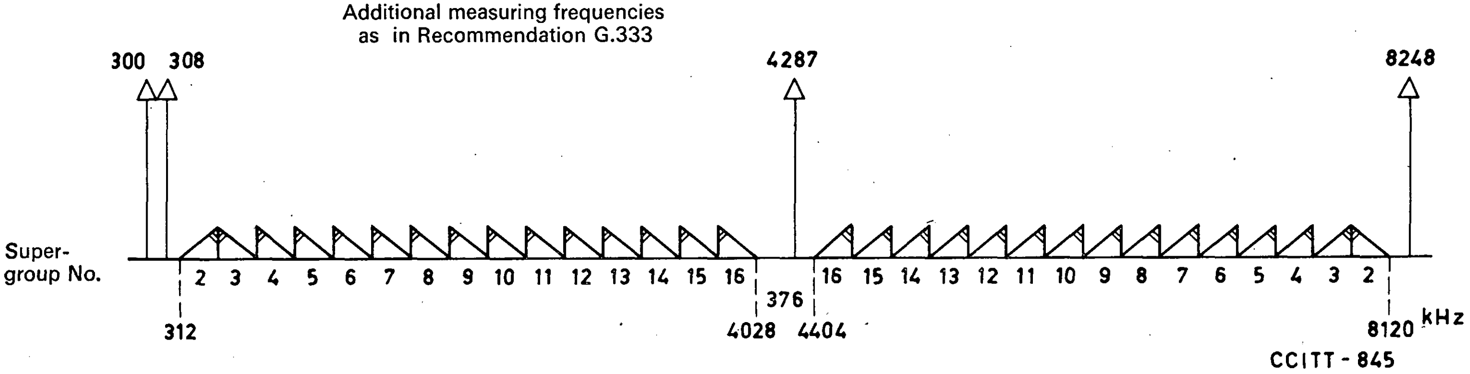

Figure 7

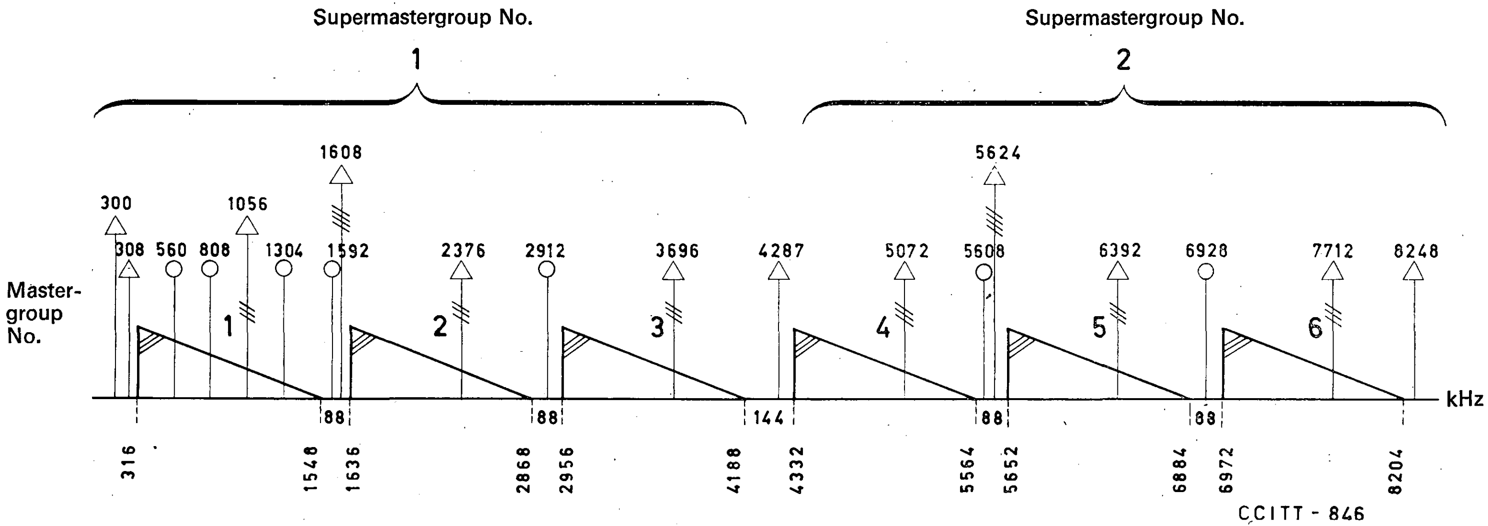

FIGURE 8

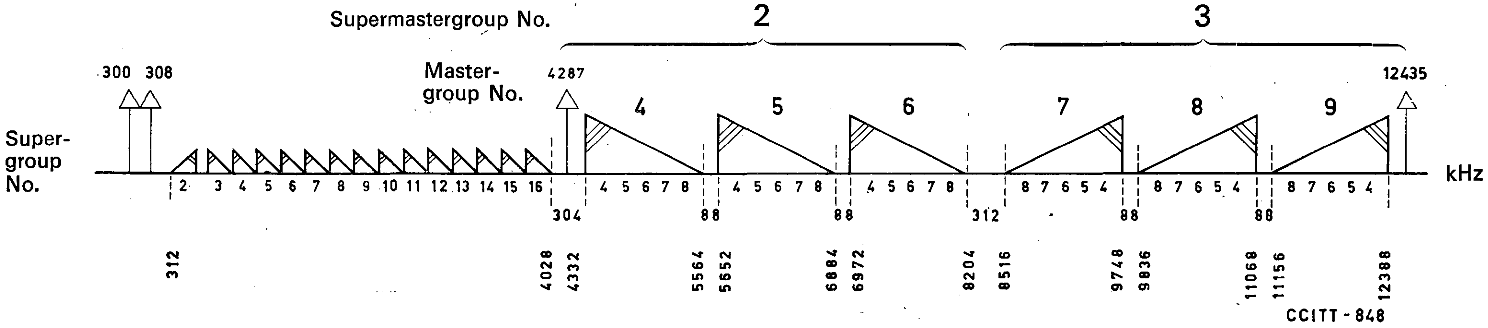

FIGURE 9

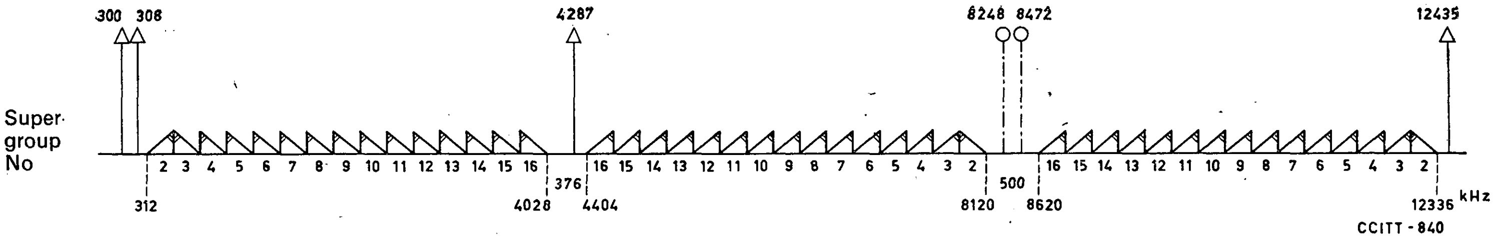

FIGURE 10[1]

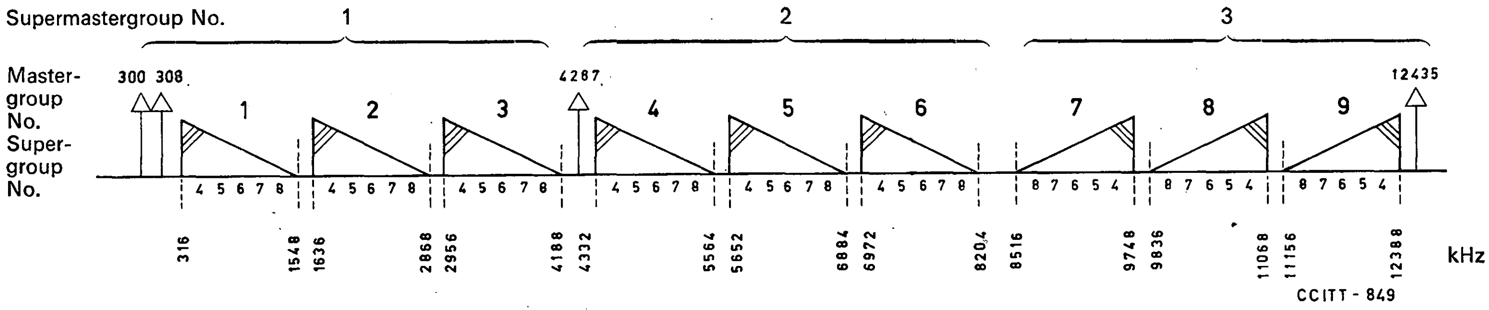

FIGURE 11

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[1] For pilots and additional measuring frequencies transmitted in the frequency band of telephone channels, see Recommendation G.332.

c) *Regulated-line sections—Line-regulating and other pilots*

In C.C.I.R. Recommendation 381-1, reproduced below, the following pilots are recommended for the regulation of radio-relay links:

1. a continuity pilot outside the "total bandwidth" shown in Table 1 in b) above;

2. a line-regulating pilot with a frequency of 308 kHz (or 60 kHz, depending on the radio-link capacity), and a level of −10 dBm0;

3. when required, an upper line-regulating pilot of frequency and level in accordance with C.C.I.T.T. recommendations for the relevant cable systems.

Pilot-blocking at an interconnection point. — The C.C.I.T.T. makes the following general recommendations to the C.C.I.R.: in all cases, the level of the continuity pilot of a radio-relay system should be reduced so that it is not greater than −50 dBm0 at an interconnection point with a system on a metallic line.

This interconnection point normally occurs at the limits of two regulated-line sections, one of them being on a metallic line and the other on a radio-relay system. This being so, at the interconnection point the following conditions should be observed:

1. the level of any line-regulating pilot on the metallic line should be reduced so that it is not greater than −50 dBm0, unless otherwise agreed by the administrations concerned;

2. the absolute power level of any regulating pilot of the radio-relay link should be reduced so that it is below −50 dBm0[1];

3. any other pilot or additional measuring frequency of the metallic line system that is within the "total bandwidth" defined in Table 1 will be freely transmitted over the radio-relay system.

A radio-relay system may be extended by short cable sections that form part of the same regulated-line section; there may then be overall transmission of the pilot on that regulated-line section.

d) *Limits for residues of signals outside the baseband*

The C.C.I.T.T. makes the following recommendations to the C.C.I.R. for residues of signals outside the baseband frequency limits:

1. In the absence of any special agreement between administrations, the level of any pilot or supervisory signal transmitted outside the baseband of a radio-relay system at a frequency not specified by the C.C.I.R. should be reduced, within the radio equipment, to −50 dBm0 at point *R*.

Similarly, in the absence of special agreements between administrations, the levels of all pilots or supervisory signals sent over the cable system outside the baseband of the radio-relay link should be reduced, within the equipment of the cable system, to −50 dBm0 at point *T*.

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[1] In the case of low-capacity systems (up to 120 channels) a line-regulating pilot of 60 kHz with a level of −10 dBm0 may be used; in this case the suppression level should conform with the provisions of the C.C.I.T.T. (Recommendation G.243 and Recommendation G.322, paragraph A d); the level of the line-regulating pilot established by the C.C.I.T.T. for lines differs according to whether it concerns coaxial cables or symmetric pairs (−10 dBm0 for coaxial cables and −15 dBm0 for symmetric pair systems).

2. If a radio-relay system service channel, adjacent to a telephone channel in the baseband, uses the levels, frequency allocation and signalling levels corresponding to those which would be recommended by the C.C.I.T.T. for an ordinary telephone channel in the same position in the frequency spectrum, the channel filters are sufficient to avoid the risk of crosstalk interference.

3. If the condition referred to in paragraph 2 is not met, an additional filter may be necessary and must be provided in the radio equipment.

4. The frequencies mentioned in paragraphs 1 and 2 must be sufficiently distant from the baseband to ensure that the filters (or other appropriate devices) required to eliminate them do not cause attenuation distortion in the passband to exceed the recommended values.

5. To avoid overloading the cable system, the level of any signal transmitted beyond point R outside the baseband must be kept down to —20 dBm0. Moreover, the level of the total power of the residues of such signals (including noise and intermodulation products) must be kept down to —17 dBm0.

e) *Other requirements intended to ensure satisfactory transmission performance*

1. *Return loss* — This characteristic is of great importance for carrier cable systems, which comprise a number of fairly regularly spaced repeaters. It is felt that, in the case of radio-relay systems, the cable sections linking the radio equipment to the multiplex equipment are generally fairly short and of unequal lengths, so that there is little fear of systematic undulation of the "frequency-attenuation" characteristic.

That being so, it is recommended that at interconnection points T and T' the return loss, in relation to the nominal impedance, should be at least 20 dB (2.3 Np) throughout the frequency band occupied by the telephone channels. The main purpose of this recommendation is to facilitate measurements and maintenance, and to ensure some protection against the random reflections which occur at various points between the equipment and the cable sections; it takes into account the value of 24 dB for the return loss at R and R' recommended by the C.C.I.R. (Recommendation 380-1, clause 3).

Note. — The attention of the C.C.I.R. is drawn to the fact that, if the cables joining the radio equipment to the multiplex equipment in the intermediate stations are long enough (for example 1 to 2 km) and not equipped with amplifiers, systematic reflection effects may occur. These special cases must be studied in accordance with the principles established by the C.C.I.T.T.; they do not seem to justify a general recommendation.

2. *Attenuation/frequency distortion* — According to C.C.I.T.T. Recommendation M.45, paragraphs 2.b and 2.c (*White Book*, Volume IV), the levels measured at the frontier on a high-frequency cable line section must not deviate, at any frequency, by more than ± 2 dB from the nominal values, whatever the pre-emphasis characteristic used. At point T, for a cable system, one can expect to find variations of the same order in relation to a flat characteristic.

No value is fixed for radio-relay links in paragraph 1.2.a of the same recommendation. The C.C.I.R., in its Recommendation 380-1 (Note 7), has recommended the same tolerance of ± 2 dB at the points R and R'.

3. *Variation of loss with time* — The C.C.I.T.T. is studying the results that can be obtained on cable line-regulating sections, taking into account Recommendations M.19 and M.53 and Recommendation G.333. When this study is completed, it will be possible to point out to the C.C.I.R. that a similar recommendation would be desirable for radio-relay links.

C.C.I.R. RECOMMENDATION 380-1 *

RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION MULTIPLEX

Interconnection at baseband frequencies

(Question 1/IX)

The C.C.I.R., (1956 — 1963 — 1966)

CONSIDERING

a) that frequency-division multiplex radio-relay systems may form part of an international circuit;

b) that international connections between such systems, among themselves and with other radio-relay or line systems, may at times have to be made at baseband frequencies;

c) that definitions for the points *R* and *R′* of interconnection at baseband frequencies are given in the Annex to this Recommendation and Fig. 1;

d) that the levels of the points *T* and *T′*, which are the responsibility of C.C.I.T.T., Doc. 175, Geneva, 1963, should be known to system designers;

UNANIMOUSLY RECOMMENDS

1. that the important baseband characteristics for a frequency-division multiplex radio-relay system forming part of an international circuit are:

1.1 maximum number of telephone channels;

1.2 limits of band occupied by telephone channels;

1.3 frequency limits of the baseband, including pilots or frequencies which might be transmitted to line;

1.4 relative input and output power levels, at the points of interconnection *R* and *R′*;

1.5 nominal impedance of the baseband circuits at the point of interconnection;

2. that, as far as practicable, these characteristics should conform to the preferred values given in Table I**;

3. the return loss at the points of interconnection should be $\geq$ 24 dB.

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* This Recommendation applies to line-of-sight and near line-of-sight radio-relay systems, and also to trans-horizon radio-relay systems of the capacities concerned.

** It is recognized that in certain cases and regions it may be desirable to use baseband characteristics other than those given above, by agreement between the Administrations concerned.

TABLE 1

1	2	3	4	5	6	7	8
Maximum number of telephone traffic channels (Note 5)	Limits of band occupied by telephone channel (kHz)	Frequency limits of baseband (kHz) (Note 4)	Nominal impedence at baseband (Ω)	Relative power level per channel (dBr) (Notes 1, 2)			
				Radio equipment output *R* (Note 7)	Main repeater station		Radio equipment input *R'* (Note 7)
					T	*T'*	
24	12-108 (Notes 3, 6)	12-108 (Notes 3, 6)	150 bal.	−15	−23	−36	−45
60	12-252 60-300	12-252 60-300	150 bal. 75 unbal.	−15	−23	−36	−45
120	12-552 60-552	12-552 60-552	150 bal. 75 unbal.	−15	−23	−36	−45
300	60-1300 64-1296	60-1364	75 unbal.	−18	−23	−36	−42
600	60-2540 64-2660	60-2792	75 unbal.	−20[1]	−23 −33	−36 −33	−45[1]
960	60-4028 316-4188	60-4287	75 unbal.	−20[1]	−23 −33	−36 −33	−45[1]
1260[2]	60-5636 60-5564 316-5564	60-5680	75 unbal.	−28	−33	−33	−37
1800	312-8204 316-8204 312-8120	300-8248	75 unbal.	−28	−33	−33	−37
2700	312-12 388 316-12 388 312-12 336	300-12 435	75 unbal.	−28	−33	−33	−37

---

[1] Alternative levels $R = -23$ dBr and $R' = -42$ dBr can be used when the associated line transmission equipment is wholly of a type for which the C.C.I.T.T. recommends baseband interconnection levels $T = -33$ dBr and $T' = -33$ dBr (Main repeater station equipped with transistors).

[2] Other limits of band occupied by telephone channels may be used by agreement between the Administrations concerned.

Note 1. — The particular preferred values of the relative power level given in the Table are agreed with the C.C.I.T.T. These values apply to future systems.

Note 2. — The level shown is referred to a point of zero relative level in the system, in accordance with the practice of the C.C.I.T.T.

Note 3. — For 12-channel systems, either of the basic groups A (12-kHz) or B (60-108 kHz) recommended by the C.C.I.T.T. may be accommodated in the band 12-108 kHz.

Note 4. — Including pilots or frequencies which might be transmitted to line.

Note 5. — Larger capacity systems are not excluded by the Table.

Note 6. — A permissible alternative arrangement uses the frequency range 6-108 kHz. With this first alternative, it is possible to use only the noise measuring channel, situated above the baseband, according to Recommendation 293. A further permissible alternative arrangement uses the frequency range 12-120 kHz. With this second alternative, it is possible to use only a continuity pilot situated below the baseband, according to Recommendation 381-1.

Note 7. — The variation with frequency, over the range of baseband frequencies, of the equivalent loss of a homogeneous section of the hypothetical reference circuit from point R' to point R, should not exceed a provisional limit of ± 2 dB relative to the nominal value. This tolerance is similar to that accepted by the C.C.I.T.T. for cable systems (see C.C.I.T.T. Recommendation M.45).

The subject of variation with frequency should be studied further. It is also desirable to study the variation of loss as a function of time.

ANNEX

DEFINITION OF THE POINTS OF INTERNATIONAL CONNECTION AT BASEBAND FREQUENCIES

(This Annex corresponds to paragraph b) of Recommendation G.213 above)

C.C.I.R. RECOMMENDATION 381-1 *

INTERCONNECTION OF RADIO-RELAY AND LINE SYSTEMS

Line regulating and other pilots
Limits for the residues of signals outside the baseband **

The C.C.I.R., (1953 — 1959 — 1963 — 1966)

CONSIDERING

a) that it may be necessary to interconnect radio-relay and line systems when establishing international circuits;

b) that a continuity pilot may be required to establish the continuity of the transmission path between the input and output terminals of a radio-relay system, independently of the frequency-division multiplex telephony being transmitted;

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* This Recommendation applies to line-of-sight systems and near line-of-sight-systems, and also where appropriate, to trans-horizon radio-relay systems.

** Attention is drawn to the fact that, for direct through-connection between two radio-relay systems, frequencies outside the baseband may pass between the points R and R', with negligible attenuation relative to the baseband. The precautions called for to protect cable systems may, therefore, also be necessary to protect radio-relay systems. The points R and R' and the points T and T' are defined in Fig. 1 of Recommendation 380-1 (reproducing Fig. 1 of C.C.I.T.T. Recommendation G.213).

c) that in addition, a line-regulating pilot may be required to measure the level stability in the baseband of a frequency-division multiplex telephony radio-relay system;

d) that the variations of the level of the line-regulating pilot should correspond closely to the variations of the overall gain of the radio-relay system between its input and output terminals at the frequencies of the frequency-division multiplex telephony signals;

e) that pilots are also required on line systems for gain-regulating, monitoring and frequency-comparison purposes;

f) that the line pilots used for monitoring and frequency comparison may also be required to be transmitted over a radio-relay system;

g) that a pilot frequency of 308 kHz is already in use by line systems for gain-regulating and other purposes, and that there is a gap in the frequency-division multiplex signal spectrum within which the pilot is located;

h) that, in some radio-relay systems, it is permissible to place the service channels of a radio-relay system below the baseband (in certain cases, a service channel may be very near to a telephone channel in the general network);

i) that it is essential to avoid undesirable effects, such as the interaction of the gain-regulating systems and interference or crosstalk from the pilots, when radio-relay and line systems are interconnected;

j) that all signals transmitted on a radio-relay system, even if they cannot cause interference to either the telephone channels or the pilots of a cable system interconnected with that radio-relay system, must have a limited power to avoid overloading the cable system;

k) that; if such interfering signals have to be eliminated by a filter incorporated in the radio equipment, that filter, the attenuation-versus-frequency characteristic of which has a finite slope, must not cause appreciable attenuation distortion on the telephone channel thus protected;

UNANIMOUSLY RECOMMENDS

1. that the point of interconnection between a radio-relay system and a line system forming part of an international circuit shall be considered as a junction between line-regulating sections, except when the cable system constitutes a short extension of the radio system and is then a part of the same line-regulating section; if the radio-relay link constitutes a regulated-line section, the station at one end of the system would be called "the radio-link control station" and the station at the other end would be called "the radio-link sub-control station". The duties of these stations are given in the maintenance instructions in Volume IV of the C.C.I.T.T.;

2. that the continuity pilot of a multi-channel telephony radio-relay system should be located outside the band of frequencies occupied by the frequency-division multiplex signal and the preferred frequencies and levels will be as shown in Recommendation 401-1 *;

3. that the level of the continuity pilot of a radio-relay system for telephony be suppressed below -50 dBm0 at the point of connection with a line system (point *R*);

4. that, for a line-regulating pilot on a frequency-division multiplex telephony radio-relay system with a capacity of 60 channels or more, 308 kHz ± 3 Hz be the preferred frequency and the preferred pilot level be -10 dBm0. A second line-regulating pilot situated in the upper part

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* A continuity pilot within the baseband, possibly acting as the line-regulating pilot, may be used, in systems of up to 120 channels for reasons of economy, after agreement between the Administrations concerned.

of the baseband may also be used, the preferred value of frequency and level of which should be those recommended by the C.C.I.T.T. for cable systems *;

5. that the level of the line-regulating pilot of a telephony radio-relay system be suppressed below −50 dBm0 at the point of connection with a line system, in all cases where this point is a junction between line-regulating sections (point *T* or before this point);

6. that the level of any line-regulating pilot of a line system to which a radio-relay system is connected be suppressed below −50 dBm0, preferably before the input terminals of the radio-relay system (point T'), in all cases where this is the junction between line-regulating sections, except by agreement between the Administrations concerned;

7. that, when cable systems constitute short extensions of the radio system and are then part of the same line-regulating section, the same line-regulating pilots may be transmitted in the two systems;

8. that in the absence of any special agreement between Administrations, the level of any pilot or supervisory signals, transmitted outside the baseband of a radio-relay system at a frequency not specified by the C.C.I.R., should, within the radio equipment, be reduced below −50 dBm0 at point *R*;

9. that similarly, in the absence of special agreements between the Administrations concerned, the levels of all pilots or supervisory signals, transmitted over the cable system and having frequencies outside the baseband of the radio-relay link, should, within the equipment of the cable system, be reduced below −50 dBm0 at point *T* (and consequently at point R');

10. that, if a radio-relay system service channel, adjacent to a telephone channel in the baseband, uses the levels, frequency allocation and signalling levels corresponding to those which would be recommended by the C.C.I.T.T. for an ordinary telephone channel in the same position in the frequency spectrum, the channel filters are adequate to avoid the risk of crosstalk interference; if this condition is not met, an additional filter may be necessary and should be provided within the radio equipment;

11. that the frequencies mentioned in sections 8 and 10 must be sufficiently distant from the baseband to ensure that the filters (or other appropriate devices) required to eliminate them do not cause attenuation distortion in the passband to exceed the recommended values;

12. that, to avoid overloading the cable system, the level of any other signal outside the baseband range be less than −20 dBm0 at the point *R*; similarly, to avoid overloading the radio-relay system, the level of any other signal outside the baseband should be less than −20 dBm0 at the point R';

13. that, further, the level of the total power of all the signals outside the baseband range, including thermal and intermodulation noise, be less than −17 dBm0 at the points *R* and R';

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* For systems up to 120 channels a line-regulating pilot of 60 kHz with a level of −10 dBm0 may be used; in this case the suppression level should conform with the provisions of C.C.I.T.T. Recommendation G.243, Section A-a (Vol. III); thus the level of the line-regulating pilot, established by the C.C.I.T.T. for lines, differs according to whether it concerns coaxial cables or symmetrical pairs (−10 dBm0 for coaxial cables and −15 dBm0 for symmetrical pair systems).

14. that all other line pilots *within* the band of frequencies occupied by the frequency-division multiplex telephony signal be freely transmitted by the radio-relay system to which the line system is connected,

Note. — The problems raised by continuity pilots for television transmission should be the subject of a separate study.

4.3 Hypothetical reference circuits

RECOMMENDATION G.431 (modified at Geneva, 1964)

HYPOTHETICAL REFERENCE CIRCUITS FOR FREQUENCY-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS[1]

A. HYPOTHETICAL REFERENCE CIRCUIT FOR RADIO-RELAY SYSTEMS PROVIDING 12 TO 60 TELEPHONE CHANNELS

The hypothetical reference circuit defined in C.C.I.R. Recommendation 391, for frequency-division multiplex radio-relay systems with a capacity of 12 to 60 telephone channels per radio channel, has a length of 2500 km.

This circuit has for each direction of transmission:

— three pairs of channel modulators,
— six pairs of group modulators,
— six pairs of supergroup modulators,

it being understood that a "pair of modulators" comprises a modulator and a demodulator (see Figure 1).

This circuit also has six sets of radio modulators and demodulators, for each direction of transmission, so that they divide the circuit into six homogeneous sections of equal length (see Recommendation G.222).

B. HYPOTHETICAL REFERENCE CIRCUIT FOR RADIO-RELAY SYSTEMS PROVIDING MORE THAN 60 TELEPHONE CHANNELS

The hypothetical reference circuit defined in C.C.I.R. Recommendation 392, for frequency-division multiplex radio-relay systems with a capacity of more than 60 telephone channels per radio channel, has a length of 2500 km.

This circuit has for each direction of transmission:

— three pairs of channel modulators,
— six pairs of group modulators,

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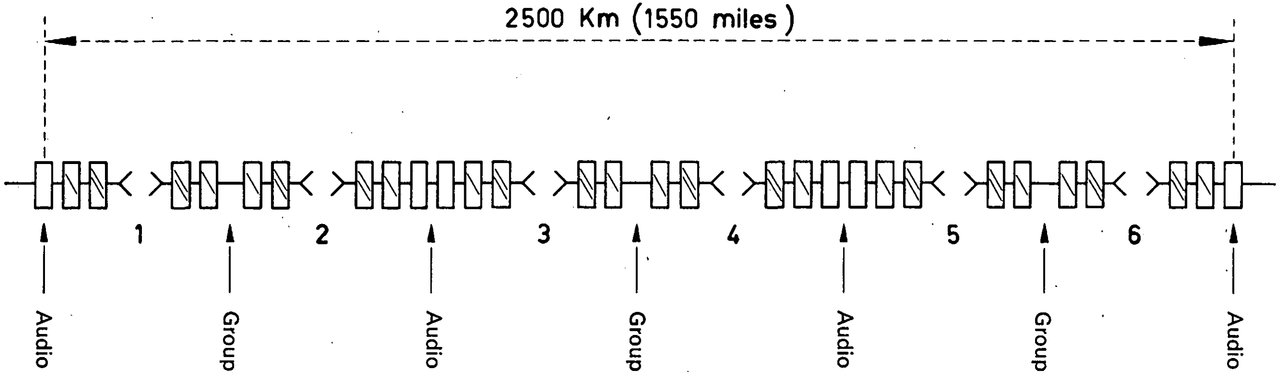
[1] This recommendation applies only to line-of-sight or near line-of-sight radio-relay systems.

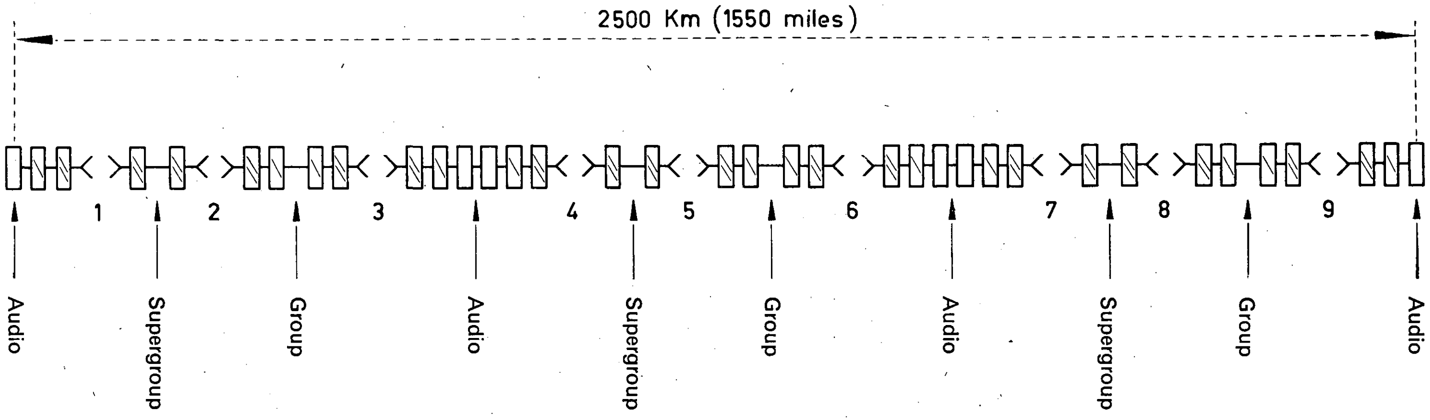


Key :

—< Radio modulator or demodulator
(baseband input or output)

(for other symbols, see the inset at the end of this volume)

FIGURE 1. — **Hypothetical reference circuit for frequency-division multiplex radio-relay systems with a capacity of 12 to 60 telephone channels per radio channel**



Key:
Radio modulator or demodulator
(baseband input or output)

(for other symbols, see the inset at the end of this volume)

FIGURE 2. — **Hypothetical reference circuit for frequency-division multiplex radio-relay systems with more than 60 telephone channels per radio channel**

— nine pairs of supergroup modulators,

it being understood that a "pair of modulators" comprises a modulator and a demodulator (see Figure 2).

This circuit also has nine sets of radio modulators and demodulators for each direction of transmission so that they divide the circuit into nine homogeneous sections of equal length (see Recommendation G.222).

RECOMMENDATION G.432

HYPOTHETICAL REFERENCE CIRCUITS ON TIME-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS [1]

The hypothetical reference circuit defined in C.C.I.R. Recommendation 300, for time-division multiplex radio-relay systems with a capacity of 60 or less telephone channels per radio channel, has a length of 2500 km.

This reference circuit consists of six sections of equal length, with voice-channel modulation and demodulation at each end of a section.

RECOMMENDATION G.433 (Geneva, 1964)

HYPOTHETICAL REFERENCE CIRCUIT FOR TROPOSPHERIC-SCATTER RADIO-RELAY SYSTEMS USING FREQUENCY-DIVISION MULTIPLEX

C.C.I.R. Recommendation 396-1 is reproduced below:

C.C.I.R. RECOMMENDATION 396-1

TRANS-HORIZON RADIO-RELAY SYSTEMS

Hypothetical reference circuit for radio-relay systems for telephony using frequency-division multiplex

(Question 7/IX)

The C.C.I.R., (1963 — 1966)

CONSIDERING

a) that trans-horizon radio-relay systems may form part of an international connection;

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[1] This Recommendation applies only to line-of-sight or near line-of-sight radio-relay systems.

b) that the characteristics of trans-horizon systems do not allow the application of existing hypothetical reference circuits for line-of-sight radio-relay systems;

c) that trans-horizon systems are generally limited to 120 telephone channels not utilizing supergroup through-connection;

d) that the specific characteristics of trans-horizon systems are usually individually optimized;

UNANIMOUSLY RECOMMENDS

1. that a hypothetical reference circuit for trans-horizon radio-relay systems should be 2500 km long;

2. that the hypothetical reference circuit for trans-horizon radio-relay systems should not be divided into homogeneous sections of fixed length because these systems, as distinct from line-of-sight systems, are usually composed of long radio sections, the length of which depends on local conditions and may vary considerably (e.g. between 100 and 400 km);

3. that, if a radio section under study is L km long, the hypothetical reference circuit should be composed of $2500/L$ sections of this type in tandem, the value $2500/L$ being taken to the nearest whole number;

4. that the hypothetical reference circuit should include:

— 3 sets of channel modulators,
— 6 sets of group modulators,
— 6 sets of supergroup modulators,

for each direction of transmission, the term "set of modulators" being taken to comprise a modulator and a demodulator.

RECOMMENDATION G.434 (Geneva, 1964)

HYPOTHETICAL REFERENCE CIRCUIT FOR COMMUNICATION-SATELLITE SYSTEMS

C.C.I.R. Recommendation 352 is reproduced below

C.C.I.R. RECOMMENDATION 352

ACTIVE COMMUNICATION-SATELLITE SYSTEMS FOR MULTIPLEX TELEPHONY AND/OR MONOCHROME TELEVISION

Hypothetical reference circuit for intercontinental systems

(Question 2/IV)

The C.C.I.R., (1963)

CONSIDERING

a) that it is desirable to establish a hypothetical reference circuit for active communication-satellite systems to afford guidance to designers of equipment and systems for use in intercontinental telephone and television networks;

b) that with various types of active satellite system, it is possible to arrange that the majority of intercontinental connections may be made with no more than one satellite link, if it is capable of spanning a great circle distance of at least 7500 km;

c) that, to span the great circle distances of up to 25 000 km, required for a global system, it will be necessary to connect two, and occasionally three links in tandem;

d) that the overall performance of each satellite link depends only to a small extent on the great circle distance between the earth stations;

e) that provision for television standards conversion in a hypothetical reference circuit is undesirable;

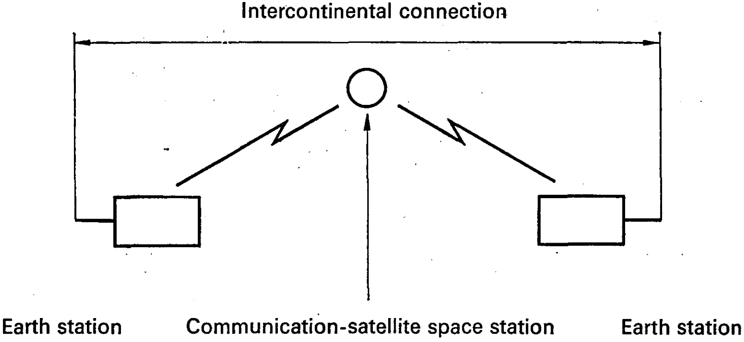

FIGURE 1. — **Basic hypothetical reference circuit**

UNANIMOUSLY RECOMMENDS

1. that a basic hypothetical reference circuit for active communication-satellite systems should consist of one earth-satellite-earth link (see Fig. 1);

2. that the performance for at least a portion of intercontinental connections should take account of the need to connect two, and sometimes, three such links in tandem;

3. that this circuit should include one pair of modulation and demodulation equipments for translation from the baseband to the radio-frequency carrier, and from the radio-frequency carrier to the baseband respectively.

4.4 Circuit noise

RECOMMENDATION G.441

PERMISSIBLE CIRCUIT NOISE ON FREQUENCY-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS[1]

a) *Design objectives for noise on hypothetical reference circuits*

In C.C.I.R. Recommendation 393-1 (reproduced below)[2] it is recommended that the noise power at a zero relative level point in any telephone channel on a 2500-kilometre hypothetical reference circuit for frequency-division multiplex radio-relay systems (see Recommendation G.431)[1] should not exceed the provisional values given below:

1.1 7500 pW mean psophometric power in any hour[3];

1.2 7500 pW one-minute-mean psophometric power for more than 20% of any month;

1.3 47 500 pW one-minute-mean psophometric power for more than 0.1% of any month;

1.4 1 000 000 pW unweighted power (with an integrating time of 5 ms) for more than 0.01% of any month.

Adding these values to the 2500 pW of psophometric power allowed for multiplexing equipment (paragraph c) of Recommendation G.222) gives the recommended objectives shown in paragraph a) 1 of Recommendation G.222 for the telephone transmission and signalling aspect. C.C.I.R. Recommendation No. 393-1 gives the conditions for applying these objectives to radio-relay systems; these conditions are in general the same as those given in paragraph b) of Recommendation G.222 and in Recommendation G.223.

The C.C.I.R. has not yet recommended any noise objectives in connection with voice-frequency telegraph transmission. C.C.I.T.T. Recommendation G.442 covers this aspect.

b) *Noise on real circuits*

See C.C.I.R. Recommendation 395-1 reproduced below.

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[1] Brought up to date by the Secretariat in the light of the C.C.I.R. (Oslo, 1966) Recommendations quoted.

[2] This Recommendation applies only to line-of-sight or near line-of-sight radio-relay systems.

[3] See note ** to Recommendation 393-1.

C.C.I.R. RECOMMENDATION 393-1

RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION MULTIPLEX

Allowable noise power in the hypothetical reference circuit

(Question 2/IX)

The C.C.I.R., (1956 — 1959 — 1963 — 1966)

CONSIDERING

a) that the hypothetical reference circuit is intended as a guide to designers and constructors of actual systems;

b) that the total noise power in a radio-relay system is dependent on the one hand upon a number of factors concerned with equipment design, and on the other hand upon the path attenuation and the variation of path attenuation with time, which are in turn dependent upon factors such as the spacing of stations and the nature of the intervening terrain;

c) that the total noise power in the hypothetical reference circuit should not be such as would appreciably affect conversation in a substantial number of telephone calls or the transmission of telephone signalling;

d) that, in the opinion of the C.C.I.R., based on evidence so far available from the C.C.I.T.T., the typical distributions of one-minute-mean noise power in any month (given in the Annex) would not seriously affect telephone conversations;

e) that, if the condition given in Notes 3 and 4 of this Recommendation were met, it is unlikely that there would be large numbers of noise surges either of long or of short duration and therefore interference to telephone signalling due to such noises could be neglected;

UNANIMOUSLY RECOMMENDS

1. that the noise power at a point of zero relative level in any telephone channel on a 2500 km hypothetical reference circuit for frequency-division multiplex radio-relay systems should not exceed the provisional values given below, which have been chosen to take account of fading:

1.1 7500 pW psophometrically weighted * mean power in any hour **;

1.2 7500 pW psophometrically weighted * one-minute mean power *** for more than 20% of any month;

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* The level of uniform-spectrum noise power in a 3.1 kHz band must be reduced by 2.5 dB to obtain the psophometrically-weighted noise power.

** This clause, which does not give any statistical distribution in time, is well suited to cable systems, but it presents difficulties when applied to radio-relay systems. For this reason, a number of Administrations have taken no account of this clause in the design of radio-relay systems so far. Accordingly, its interpretation and practical application to radio-relay systems are under study. The hours when the noise is greatest are usually those in which the fading is most severe. These hours will sometimes be different from the busy hours.

*** The one-minute mean power was chosen by C.C.I.T.T. Study Group XII which is responsible for all studies concerned with the quality of telephone transmission (C.C.I.T.T. *Red Book*, 1957, Vol. I, pp. 110 and 662).

1.3 47 500 pW psophometrically weighted* one-minute mean power for more than 0.1% of any month;

1.4 1 000 000 pW unweighted (with an integrating time of 5 ms) for more than 0.01% of any month;

2. that in a part of the hypothetical reference circuit consisting of one or more of the equal homogeneous sections defined in Recommendations 391 and 392, the mean noise power in any hour** and the one-minute mean noise power in 20% of a month be considered to be proportional to the number of homogeneous sections involved;

3. that in parts of a hypothetical reference circuit consisting of one or more of the equal homogeneous sections defined in Recommendations 391 and 392, the small percentage of a month, in which the one-minute mean power may exceed 47 500 pW and in which the noise power (with an integrating time of 5 ms) may exceed 1 000 000 pW, be regarded as proportional to the number of homogeneous sections involved;

4. that the following Notes should be regarded as part of the Recommendation:

Note 1. — Noise in the frequency-division-multiplex equipments is excluded from the above. On a 2500 km hypothetical reference circuit, the C.C.I.T.T. allows 2500 pW mean value for this noise in any hour.

Note 2. — This Recommendation relates to the hypothetical reference circuit and the indicated figures are design objectives and it is not intended that they will be quoted in specifications for equipment or used for acceptance tests. Recommendations relating to real circuits are contained in Recommendation 395-1.

Note 3. — The Recommendation relates only to "line-of-sight" radio-relay systems with adequate clearance over intervening terrain.

Note 4. — It is assumed that noise surges and clicks form power supply systems and from switching apparatus are reduced to negligible proportions and will not be taken into account when calculating the noise power.

Note 5. — For the calculation of noise in hypothetical reference circuits the characteristics preferred by the C.C.I.R., and to be found in their Recommendations, should be used where appropriate; where more than one value is recommended the designer should indicate the value chosen.

Note 6. — Designers should indicate their own assumptions regarding the lengths of repeater sections, the nominal attenuation between transmitter outputs and receiver inputs, intermodulation noise in feeders and the radio path, possible interference between the radio channels of the system under consideration, precautions taken against fading (in particular the use or not of diversity reception and protection channels) and the distribution curve of fading over short periods of time. It is preferred that the predicted distribution curve of one-minute mean noise power in any month should satisfy the values recommended in Sections 1.2 and 1.3. Designers are expected to fit their distribution curves to fall below both values. That portion of the curve relating to 50% or so of the time will then give the "non-fading" noise value upon which the design is based.

Note 7. — It is assumed that, at junctions between the homogeneous sections of a hypothetical reference circuit, the telephone channels, groups, supergroups and mastergroups are interconnected at random; and that the noise coming from the homogeneous sections of the hypothetical reference circuit is power-additive.

Note 8. — It is assumed that, during the busy hour, the multiplex signal can be represented by a uniform-spectrum signal, the mean power absolute level of which, at a point of zero relative level is equal to $(-15 + 10 \log_{10} N)$ dBm for 240 channels or more, and $(-1 + 4 \log_{10} N)$ dBm for numbers of channels between 12 and 240 (this value is provisional for systems the capacity of which is less than 60 channels), N being the total number of channels for which the radio-relay system is to be designed.

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* The level of uniform-spectrum noise power in a 3.1 kHz band must be reduced by 2.5 dB to obtain the psophometrically-weighted noise power.

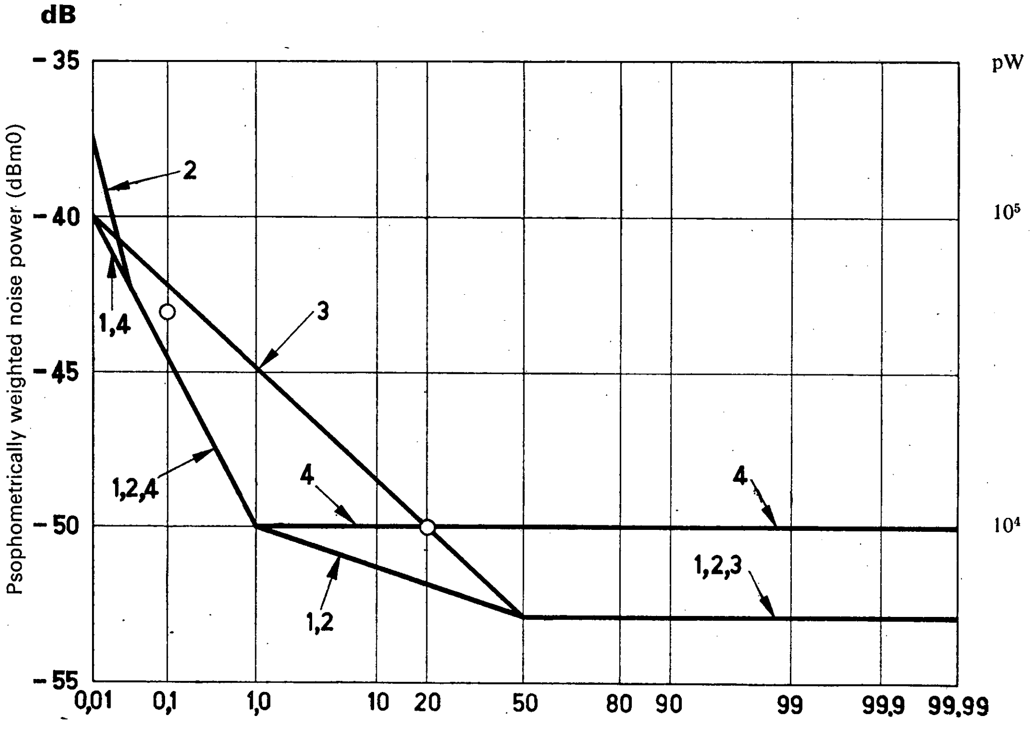
** This clause is provisional. Since, in radio-relay systems, the mean noise power in any hour varies, the subdivision of this noise objective between sections on the basis of length is inappropriate, because the worst hours of all the sections will be uncorrelated. More suitable bases for subdivision are under study.

Note 9. — The requirement indicated by Section 1.4 is related to the need to transmit signalling for telephony satisfactorily. It is also related to the need for VF telegraphy at 50 bauds over telephone channels. Whereas the requirement indicated by Section 1.4 is likely to be satisfactory when 50 bauds, frequency-modulation VF telegraph equipment is used, the extent to which the operation of 50 bauds, amplitude-modulation VF telegraphy systems will be satisfactory is still under study by the C.C.I.T.T.

Note 10. — Recommendation 357-1 fixes the maximum permissible value of interference caused by communication-satellite systems to a telephone channel of a radio-relay system. The values indicated in Recommendation 357-1 (or smaller values calculated taking account of the parameters of the radio-relay system) should, in principle, be included in the general objectives with regard to noise (see C.C.I.T.T. Recommendation G.222 in Doc. A.P.III/51 of the IIIrd Plenary Assembly). In certain cases, however, additional noise may cause the limits fixed in the general objectives to be slightly exceeded. This should not cause serious concern, provided that the provisions of C.C.I.T.T. Recommendation G.222, Section 6 are met.

ANNEX

EXAMPLES OF DISTRIBUTION CURVES FOR THE PSOPHOMETRICALLY WEIGHTED ONE-MINUTE MEAN NOISE POWER AT THE END OF THE HYPOTHETICAL REFERENCE CIRCUIT



The noise figures include 2500 pW for terminal equipments.

○ Design objectives, including terminal noise.

The numbers 1 to 4 are used to distinguish the curves.

C.C.I.R. RECOMMENDATION 395-1 *

RADIO-RELAY SYSTEMS FOR TELEPHONY USING FREQUENCY-DIVISION MULTIPLEX

Noise in the radio portion of circuits to be established over real links **

(Question 2/IX)

The C.C.I.R., (1966)

CONSIDERING

a) that provisional maximum values for the noise in hypothetical reference circuits are given in Recommendation 393-1 as a guide to designers of equipment;

b) that real circuits sometimes differ in composition from the hypothetical reference circuit (Recommendation 392) (see Fig. 1);

c) that the hypothetical reference circuit shows a single 2500 km telephone circuit and that circuits carried over real links will share many of the component baseband sections with other telephone circuits of lesser length. While the performance requirements of these shorter circuits could safely be relaxed to ease the planning of links, the longer international circuits must not be allowed to suffer the full cumulative effect of any relaxations which are permissible for the shorter circuits;

d) that, in some circumstances, a planned real link may comprise a larger number of baseband points than is envisaged in the hypothetical reference circuit;

e) that equipment, which has been designed to satisfy the design objectives (Recommendation 393-1) for the hypothetical reference circuit (Recommendation 392), cannot be expected to give the same standard of performance when used in a circuit established over real links, the actual composition of which differs from that of the hypothetical reference circuit or its homogeneous section;

f) that, therefore, it is necessary to give planning objectives for noise to guide in the planning of links forming part of international circuits;

g) that noise contributions arise from several sources; some of these contributions depend on the number of baseband equipment and others on the law of addition for intermodulation noise in a long chain of repeaters or in permanently connected group links (defined in C.C.I.T.T. Recommendation G.211), and that these contributions differ in different parts of the baseband-frequency spectrum;

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* This Recommendation applies only to line-of-sight radio-relay systems suitable for use in the international telephone network.

** The term "circuit" is understood to refer to a circuit as defined in No. 02.06 of the I.T.U. List of Essential Telecommunication Terms, Second Impression, Geneva, 1961, Part I. The calculations are performed between the points R' and R (see Recommendation 380-1) of each radio section which enters into the circuit under consideration.

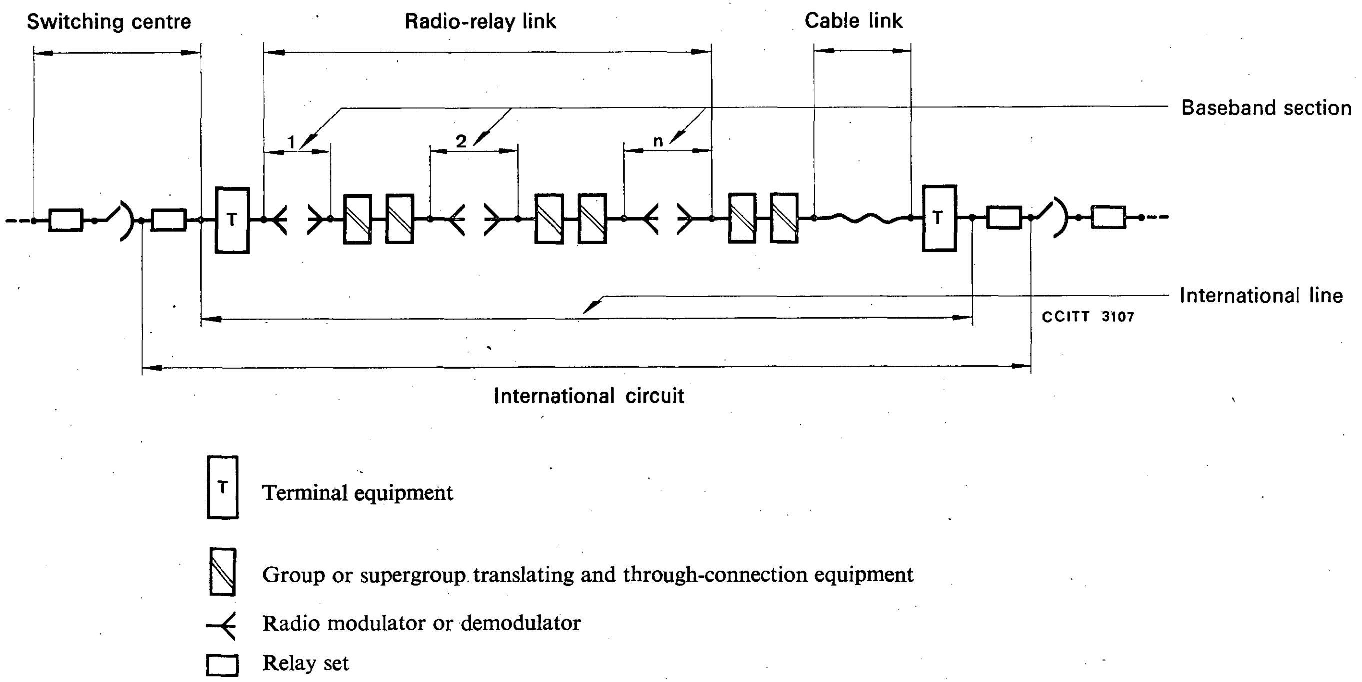

FIGURE 1. — **Constitution of an international circuit comprising real links on radio-relay and cable systems**

(The figure is intended to illustrate the terms used in this Recommendation)

UNANIMOUSLY RECOMMENDS

1. that, in circuits established over real links which do not differ appreciably from the hypothetical reference circuit, the psophometrically weighted* noise power at a point of zero relative level in the telephone channels of frequency-division multiplex radio-relay systems of length *L*, where *L* is between 280 and 2500 km, should not exceed:

1.1 3 *L* pW mean power in any hour **;

1.2 3 *L* pW one-minute mean power for more than 20% of any month;

1.3 47 500 pW one-minute mean power for more than (*L*/2500) × 0.1% of any month; it is recognised that the performance achieved for very short periods of time is very difficult to measure precisely and that, in a circuit carried over a real link it may, after installation, differ from the planning objective;

2. that circuits to be established over real links, the composition of which, for planning reasons, differs substantially from the hypothetical reference circuit, should be planned in such a way that the psophometrically weighted noise power at a point of zero relative level in a telephone channel of length *L*, where *L* is between 50 and 2500 km, carried in one or more baseband sections of frequency-division multiplex radio links, should not exceed:

2.1 for 50 km $\leqq L \leqq$ 840 km:

- 2.1.1 3 *L* pW + 200 pW mean power in any hour **,
- 2.1.2 3 *L* pW + 200 pW one-minute mean power for more than 20% of any month,
- 2.1.3 47 500 pW one-minute mean power for more than (280/2500) × 0.1% of any month when *L* is less than 280 km, or more than (*L*/2500) × 0.1% of any month when *L* is greater than 280 km;

2.2 for 840 km $< L \leqq$ 1670 km:

- 2.2.1 3 *L* pW + 400 pW mean power in any hour **,
- 2.2.2 3 *L* pW + 400 pW one-minute mean power for more than 20% of any month,
- 2.2.3 47 500 pW one-minute mean power for more than (*L*/2500) × 0.1% of any month;

2.3 for 1670 $< L \leqq$ 2500 km:

- 2.3.1 3 *L* pW + 600 pW mean power in any hour **,
- 2.3.2 3 *L* pW + 600 pW one-minute mean power for more than 20% of any month,
- 2.3.3 47 500 pW one-minute mean power for more than (*L*/2500) × 0.1% of any month;

3. that the following notes should be regarded as part of the Recommendation:

Note 1. — Noise in the frequency-division multiplex equipment is excluded. On a 2500 km hypothetical reference circuit the C.C.I.T.T. allows 2500 pW mean value for this noise in any hour.

Note 2. — It is assumed that noise surges and clicks from power-supply systems and from switching apparatus are reduced to negligible proportions and will not be taken into account when calculating the noise power.

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* The level of uniform-spectrum noise power in a 3.1 kHz band must be reduced by 2.5 dB to obtain the psophometrically weighted noise power.

** The hourly mean noise power objective and its subdivision are at present under study (see Recommendation 393-1).

Note 3. — It is permissible to assume that noise coming from individual baseband sections is power-additive, but only if the baseband spectra of adjacent baseband sections are substantially different.

Note 4. — It will be assumed that, during the busy hour, the multiplex signal can be represented by a uniform-spectrum signal, the mean power absolute level of which at a point of zero relative level, is equal to $(-15 + 10 \log_{10} N)$ dBm for 240 channels or more, and $(-1 + 4 \log_{10} N)$ dBm for numbers of channels between 12 and 240 (this value is provisional for systems the capacity of which is less than 60 channels), N being the number of channels for which the radio-relay system is designed.

RECOMMENDATION G.442 (modified at Geneva, 1964)

RADIO-RELAY SYSTEM DESIGN OBJECTIVES FOR NOISE AT THE FAR END OF A HYPOTHETICAL REFERENCE CIRCUIT WITH REFERENCE TO TELEGRAPHY TRANSMISSION

As is shown in Recommendation G.222, if the intention is to use, on radio links, voice-frequency amplitude-modulated telegraph equipment for 50 bauds conforming to Series R Recommendations of the C.C.I.T.T., then in order to obtain telegraph connections with the quality indicated in C.C.I.T.T. Recommendation F.10, the design of these radio links should include the objectives recommended for telephone transmission and signalling and, in addition, should include the objectives set out below:

On any telephone channel constituted in accordance with the hypothetical reference circuit for the type of radio link considered, the unweighted noise power, measured or calculated with a time-constant (integrating time) of 5 milliseconds and referred to a zero relative level point, should not exceed 10^6 pW during more than 10^{-5} (i.e. 0.001 %) of any month, nor more than 0.1 % of any hour.

Provided that short bursts of high level noise due to causes other than propagation have been reduced to negligible proportions, and assuming that the fine structure of the noise is the same as white noise, it is assumed that, in designing line-of-sight radio links, the objective during any month is in practice equivalent to the following objective:

The unweighted noise power on a telephone channel at a zero relative point, calculated from measurements made with an integrating time of 1 second, should not exceed 2×10^5 pW for more than 10^{-4} (i.e. for more than 0.01 %) of any month.

With regard to the objective to be met during any hour, it may happen that on certain radio links unforeseen exceptional propagation conditions may result in this objective not being met during certain most unfavourable hours. These hours, called "hours of interrupted telegraph traffic", will be those during which a noise level of 10^6 pW is exceeded for more than 36 seconds.

Every effort should be made to reduce the number of such hours to a very small fraction of the total time. Since it follows from the recommended objective for telephone signalling that the 5-millisecond unweighted noise power should not exceed 10^6 pW during more than 10^{-4} (i.e. 0.01 %) of any month, there should never be more than seven "hours of interrupted telegraph traffic" during a month.

It may then be expected that the telegraph service will be satisfactory. Nevertheless, to achieve this object, it may be necessary in certain cases to select the channels allocated to voice-frequency amplitude-modulated telegraphy for 50 bauds from among those which are the least sensitive to propagation noise.

Note 1. — Use of a measuring instrument having a 5-ms time-constant (integrating time) is recommended so as to detect, in particular, the presence of short high-level noise bursts, such as those caused by power supplies and by the equipment. Administrations should take all possible practical steps to eliminate such noise.

It is expected that on the majority of line-of-sight radio links (if not on all) it will be possible to reduce short noise bursts to negligible proportions, and that for the majority of radio links, any remaining short high-level noise bursts will be due to propagation. Noise surges having a mean power in excess of about 10^5 pW will then last from 1 to 10 seconds and will have an approximately constant level during this period. Under these conditions, for propagation measurements and preliminary design measurements for radio links, instruments having a time-constant (integrating time) of 1 second could be used.

Note 2. — The fraction 10^{-5} of a month, for a 2500-km circuit, leads to impracticably small fractions of the time for shorter circuits (for example, 10^{-6} for a 250-km circuit). It is for this reason that the practical objective refers to a greater fraction of the time (10^{-4} for 2500 km), together with a reduced power (2×10^{-5} pW), the latter measured with a time-constant (integrating time) of 1 second.

RECOMMENDATION G.443

DESIGN OBJECTIVES FOR NOISE ON THE HYPOTHETICAL REFERENCE CIRCUIT ON TIME-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS

C.C.I.R. Recommendation 394, reproduced below, recommends objectives for the telephone transmission and signalling aspect that correspond to those given in paragraph a) 1 of Recommendation G.222.

The C.C.I.R. has not yet recommended any noise objectives in connection with voice-frequency telegraph transmission.

C.C.I.R. RECOMMENDATION 394 *

RADIO-RELAY SYSTEMS FOR TELEPHONY USING TIME-DIVISION MULTIPLEX

Allowable noise power in the hypothetical reference circuit

(Question 2/IX)

The C.C.I.R., (1956 — 1959 — 1963)

CONSIDERING

a) that a hypothetical reference circuit for radio-relay systems for telephony using time-division multiplex has been defined in Recommendation 300;

b) that the total noise power in the hypothetical reference circuit should not be such as would appreciably affect conversation in a substantial number of telephone calls or the transmission of telephone signalling;

c) that the allowable noise power in hypothetical reference circuits for telephony radio-relay systems using time-division multiplex should conform to the values given for frequency-division multiplex (see Recommendation 393-1);

UNANIMOUSLY RECOMMENDS

1. that the noise power at a point of zero relative level in any telephone channel on the 2500 km hypothetical reference circuit for time-division multiplex radio-relay systems should not exceed the provisional values given below, which have been chosen to take account of fading, under conditions equivalent to those in normal service:

1.1 10 000 pW, psophometrically weighted ** mean power in any hour;

1.2 10 000 pW, psophometrically weighted ** one-minute mean power for more than 20% of any month;

1.3 50 000 pW, psophometrically weighted ** one-minute mean power for more than 0.1% of any month;

1.4 1 000 000 pW, unweighted (with an integrating time of 5 ms) for more than 0.01% of any month;

2. that the following Notes should be regarded as part of the Recommendation:

Note 1. — The Recommendation relates to the hypothetical reference circuit. The figures given are design objectives, and it is not intended that they should be quoted in specifications or used for acceptance tests.

Note 2. — The requirement indicated by Section 1.4 is related to the need to transmit signalling for telephony satisfactorily. It is also related to the need for VF telegraphy at 50 bauds over telephone channels. Whereas the requirement indicated by Section 1.4 is likely to be satisfactory when 50 baud, frequency-modulation VF telegraph equipment is used, the extent to which the operation of 50 baud, amplitude-modulation VF telegraph systems will be satisfactory is still under study by the C.C.I.T.T.

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* This Recommendation replaces Recommendation 301.

** The level of uniform-spectrum noise power in a 3.1 kHz band must be reduced by 2.5 dB to obtain the psophometrically weighted noise power.

RECOMMENDATION G.444 (Geneva, 1964)

ALLOWABLE NOISE POWER IN THE HYPOTHETICAL REFERENCE CIRCUIT FOR TROPOSPHERIC SCATTER RADIO-RELAY SYSTEMS USING FREQUENCY-DIVISION MULTIPLEX

C.C.I.R. Recommendation 397-1 is reproduced below:

C.C.I.R. Recommendation 397-1

TRANS-HORIZON RADIO-RELAY SYSTEMS

Allowable noise power in the hypothetical reference circuit for telephony transmission using frequency-division multiplex

(Question 7/IX)

The C.C.I.R., (1963 — 1966)

CONSIDERING

a) that a hypothetical reference circuit for trans-horizon radio-relay systems is established in Recommendation 396-1, as a guide to the designers of systems in use in international telecommunication networks;

b) that wherever practicable and possible, trans-horizon radio-relay systems should meet the same performance regarding noise as recommended for line-of-sight systems in Recommendation 393-1;

c) that, nevertheless, the achievement of this desirable objective would sometimes result in a very high, even prohibitive cost or a power that is impractically high, or such that is likely to result in harmful interference;

d) that this might well retard desirable extensions of the telephone network;

UNANIMOUSLY RECOMMENDS

1. that, from the point of view of performance, trans-horizon radio-relay systems be divided into two classes;

2. that, when a trans-horizon system is intended to operate between two points for which other transmission systems could be used without excessive difficulty, e.g., line-of-sight radio-relay, underground cable, etc., the hypothetical reference circuit should be established in accordance with Recommendation 396-1. The noise power at the end of this hypothetical reference circuit will be calculated by statistical combination of the noise power in each of its radio sections. The statistical distribution curve of the one-minute mean psophometric power, during the most unfavourable month, should then pass below the points defined in Recommendation 393-1, Sections 1.2 and 1.3. Besides which, the mean psophometric power during any hour should not exceed the figure laid down in Recommendation 393-1, Section 1.1;

3. that, if a trans-horizon system is to be used between points, for which other transmission systems cannot be used without excessive difficulty, and if the condition laid down in Recommendation 393-1 cannot be met without excessive difficulty, the following conditions will apply, once the statistical noise power distribution at the end of the hypothetical reference circuit has been calculated by the method set out in Section 2;

3.1 the mean psophometric power during one minute must not exceed 25 000 pW for more than 20% of any month;

3.2 the mean psophometric power during one minute must not exceed 63 000 pW for more than 0.5% of any month;

4. that for the two classes of system defined above, the unweighted noise power (with an integrating time of 5 ms) must meet Recommendation 393-1, Section 1.4, but with the percentage of the most unfavourable month changed to 0.05%, for the systems referred to in Section 3 of the present Recommendation;

5. that the conditions given in Sections 3 and 4 are provisional and should be reconsidered later.

Note 1. — All the values given above include the intermodulation noise in the radio part of the system. On the other hand, noise within the frequency-division multiplex equipment is excluded. On a hypothetical reference circuit 2500 km long, the C.C.I.T.T. authorizes a mean value of 2500 pW during any hour for this latter noise.

Note 2. — The method of statistical combination referred to in Section 2 is described in detail in the paper "Thermal noise in multi-section radio links" by B. B. Jacobsen, I.E.E. Monograph No. 262 R (1957).

Note 3. — The method of calculation of mean noise power in a telephone channel from the distribution of the received signal amplitude in each receiver is given in "Puissance moyenne de bruit dans les faisceaux hertziens transhorizon à modulation de fréquence" by L. Boithias and J. Battesti, Annales des Télécommunications (May-June, 1963).

Note 4. — Systems which comply only with the terms of Sections 3 and 4, will be excluded from the main international and intercontinental routes; consequently in a world-wide connection, a maximum of one or two circuits of medium length will be encountered which comply only with the terms of Section 4 with a percentage of 0.05%; as far as telephone signalling is concerned, this state of affairs is acceptable. Under these conditions, the transmission of voice-frequency telegraph is also satisfactory (see the reply by Joint Special Study Group C (C.C.I.T.T./C.C.I.R.) to Question 1/C, annexed to Docs. IX/240, and Doc. IX/164, 1963-1966).

RECOMMENDATION G.445 (Geneva, 1964)

NOISE OBJECTIVES FOR COMMUNICATION-SATELLITE SYSTEM DESIGN

C.C.I.R. Recommendation 353-1 is reproduced below:

C.C.I.R. RECOMMENDATION 353-1

ACTIVE COMMUNICATION-SATELLITE SYSTEMS FOR FREQUENCY-DIVISION MULTIPLEX TELEPHONY

Allowable noise power in the basic hypothetical reference circuit

(Question 2/IV)

The C.C.I.R., (1963 — 1966)

CONSIDERING

a) that the basic hypothetical reference circuit is intended as a guide to the design and construction of actual systems;

b) that the costs of establishing and maintaining communication-satellite systems are critically dependent on the overall signal-to-noise performance requirements;

c) that the total noise power in the basic hypothetical reference circuit should not be such, as would affect appreciably conversation in most telephone calls or the transmission of telephone signalling;

d) that the extent of fading cannot be determined fully until more experimental data are available, but is not expected to be appreciable in active communication-satellite systems;

e) that there may be other sources of noise of short duration;

UNANIMOUSLY RECOMMENDS

1. that the noise power, at a point of zero relative level in any telephone channel in the basic hypothetical reference circuit as defined in Recommendation 352, should not exceed the provisional values given below:

1.1 10 000 pW psophometrically-weighted mean power in any hour;

1.2 10 000 pW psophometrically-weighted one minute mean power for more than 20% of any month;

1.3 50 000 pW psophometrically-weighted one-minute mean power for more than 0.3% of any month;

1.4 1 000 000 pW unweighted (with an integrating time of 5 ms), for more than 0.03% of any month;

2. that the following Notes should be regarded as part of the Recommendation:

Note 1. — Noise in the multiplex equipment is excluded from the above.

Note 2. — It is assumed, that noise surges and clicks from power supply systems and from switching apparatus (including switching from satellite to satellite), are reduced to negligible proportions and therefore will not be taken into account when calculating the noise power.

Note 3. — In applying the basic hypothetical reference circuit and the allowable circuit noise to the design of satellite and earth station equipment for a given overall signal-to-noise performance, the system characteristics preferred by the C.C.I.R., as found in its Recommendations, should be used where appropriate; where more than one value is recommended, the designer should indicate the value chosen; in the absence of preferred values, the designer should indicate the assumptions used.

Note 4. — For frequency-division multiplex telephony, it will be assumed that, during the busy hour, the baseband signal can be represented by a uniform-spectrum signal, the mean absolute power-level of which, at a point of zero relative level, is equal to $(-15 + 10 \log_{10} N)$ dBm for 240 channels or more, and $(-1 + 4 \log_{10} N)$* dBm for numbers of channels between 12 and 240, N being the number of channels. These formulae apply only to baseband signals without pre-emphasis and using independent amplifiers or repeaters for the two directions of transmission. Further information on the conventional load, in particular in the case of a repeater which is common to both directions of transmission, is given in C.C.I.T.T. Recommendation G.223 (*Blue Book*, Vol. III, Geneva, 1964).

Note 5. — It is not yet possible to make firm recommendations regarding requirements to be met, if VF telegraphy and data transmission are required over telephone channels in a communication-satellite system.

Note 6. — The system should be designed to operate under the noise conditions specified, including noise due to interference within the limits defined in Recommendation 356-1 for line-of-sight radio-relay systems sharing the same frequency bands and noise during periods of adverse propagation conditions such as those resulting from atmospheric absorption and increased noise temperature due to rain. In certain cases, however, additional noise may cause the limits fixed in the general objectives to be slightly exceeded. This should not cause serious concern, provided that the provisions of C.C.I.T.T. Recommendation G.222, Section 6, are met.

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* It is considered that these formulae give a good approximation in calculating intermodulation noise when $N \geq 60$. For small numbers of channels, however, tests with uniform-spectrum random noise are less realistic, due to the wide difference in the nature of actual and test signals.

SECTION 5

AUDIO-FREQUENCY CIRCUITS

This section concerns audio-frequency circuits which may be used as international circuits, i.e. either four-wire cable circuits, or two-wire audio-frequency circuits on open-wire lines.

The specifications given at the end of this section also apply to national trunk circuits liable to be used for an international call.

5.1 Recommendations applying to circuits

RECOMMENDATION G.511

GENERAL CHARACTERISTICS OF AUDIO-FREQUENCY CIRCUITS

A. Frequency band effectively transmitted

The C.C.I.T.T.,

considering

that it is desirable to have satisfactory transmission quality in the international telephone service and to take advantage of the electro-acoustic progress in the design of subscribers' telephone sets,

unanimously recommends

that the use of lines and equipments which appreciably limit the band of frequencies effectively transmitted within the range 300 to 3400 Hz should be avoided for international calls.

The allowable limits for the variation (as a function of frequency) of the relative power level at the output of a frontier repeater, on a four-wire audio-frequency circuit, transmitting effectively the frequency band from 300 to 3400 Hz, are shown in Graph No. 4 (Figure 1).

B. Other characteristics

The provisions of Section 1 of Part 1 of this volume are applicable, except in respect of overall loss and stability of circuits on open-wire lines (see Recommendation G.521).

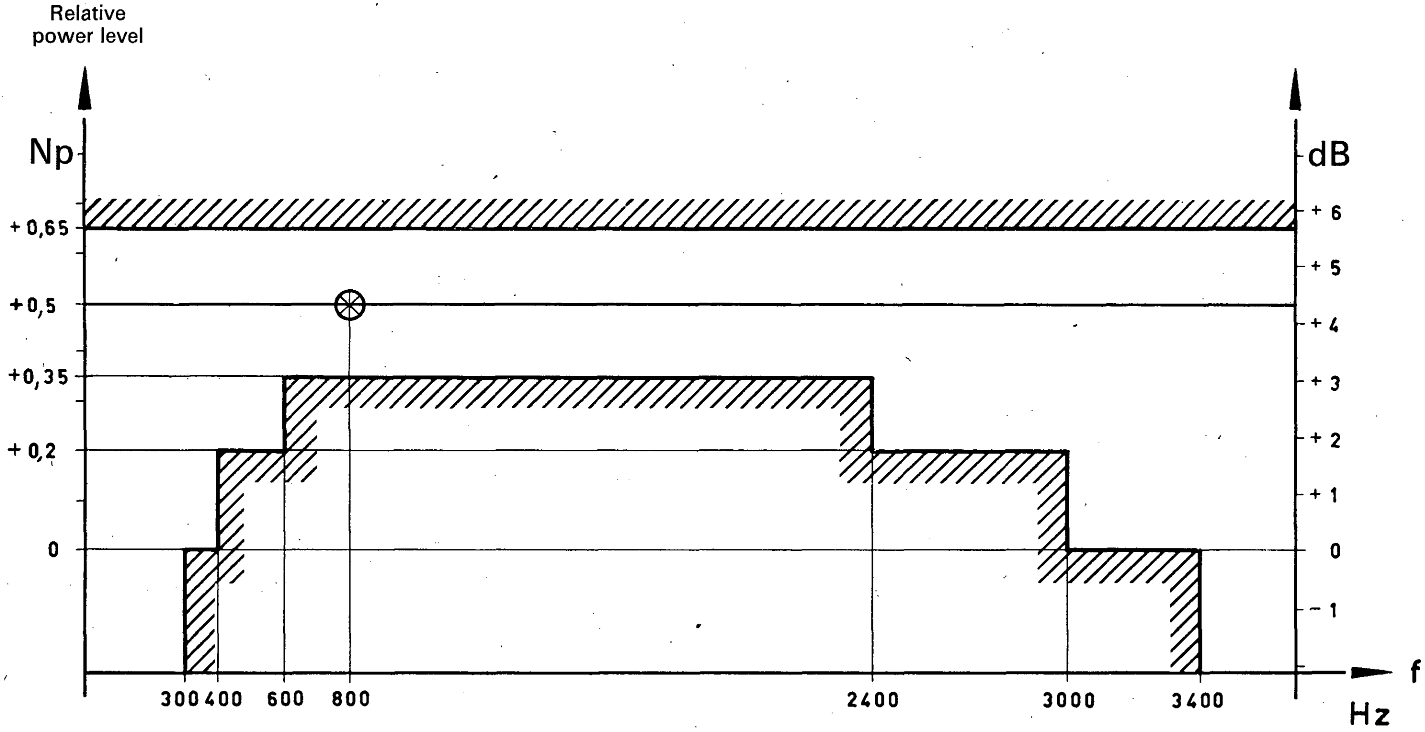

FIGURE 1. Graph No 4. — **Permissible limits for the variation with frequency of the relative power level at the output of a frontier repeater (frontier side) of a four-wire international circuit, effectively transmitting the frequency band from 300 to 3400 Hz**

RECOMMENDATION G.512

INTERCONNECTION OF INTERNATIONAL CIRCUITS

The C.C.I.T.T. *unanimously recommends*

that, for reasons of stability, international telephone circuits should never be joined together other than in complete sections, limited to two repeater stations.

5.2 Audio-frequency lines

RECOMMENDATION G.521

OPEN-WIRE LINES AND COMPOSITE LINES

A. LOADING OF OPEN-WIRE LINES

The C.C.I.T.T.,

considering

that the loading of open-wire lines

1. makes the use of these lines difficult because of variation of insulation resistance and magnetization of the coils by lightning discharges;

2. makes the use of repeaters difficult;

3. is incompatible with the use of these lines for carrier telephony;

4. makes the transmission of different audio-frequencies too variable, introduces distortion and, as a result, reduces the articulation of the conversation,

unanimously recommends

that telephone circuits on open-wire lines, fitted with repeaters, and used in international long-distance calls, should not be loaded.

B. CONSTRUCTION OF OPEN-WIRE LINES

The C.C.I.T.T.,

considering

that at present, in certain countries, the setting-up of long-distance international calls requires the use of open-wire lines;

that the best utilization of these lines would be obtained by phantom working, the use of repeaters, and then the installation of multichannel carrier telephone systems;

that, to ensure good performance from such lines, it is essential to achieve electric symmetry of the circuits and also a uniform distribution of electrical constants throughout the length of a repeater section;

that it is not possible to fix finally and for general use the geometric or mechanical configuration of the lines, the choice of these being a function not only of electrical factors, but also of economic factors varying with time and from one country to another,

unanimously recommends

that international telephone lines on open wires should satisfy the following conditions:

a) *Mechanical qualities*

1. For the construction of long-distance international telephone lines, only conductors with a diameter not less than 3 millimetres and with sufficient mechanical strength to minimize breaks should be used.

2. The strength of the pole line should be adequate to carry the highest loading arising from storms, icing and snow.

b) *Electrical qualities*

1. The conductors should be either copper or a copper alloy having a conductivity not more than 10% different trom that of high-conductivity copper, and in either case should give the same advantages and should meet the conditions enumerated below.

2. On a long-distance telephone circuit, in any one repeater section, or in any one section between one repeater station and the next, the conductors should be of the same metal, have the same diameter and their spacing should be the same, so as to provide a satisfactory uniformity.

Sections of open-wire line or of composite lines, used in the European international telephone network, should be so constructed and maintained (frequent maintenance measurements, preventive maintenance, etc.) that the regularity return loss has at least the following values:

α) in the case of lines having a single repeater in the middle of the circuit, the regularity return loss of each amplifier section should be at least equal to the circuit equivalent (without the repeater). If the repeater is not in the middle of the circuit, an increase up to about 1.7 dB or 0.2 Np is enough;

β) if two repeaters are inserted, the regularity return loss of each repeater section should be at least equal to the circuit equivalent (without repeater) increased by 3.5 dB or 0.4 Np provided the lengths of the three repeater sections are about equal. If several repeaters are inserted, the increase should be greater.

In the case of open-wire lines without any cable sections, the above figures are easily achieved if the lines are constructed in accordance with this recommendation.

In the case of composite lines consisting of open-wire sections and cable sections (usually very short, such as lead-in cable, cable for crossings of tunnels, rivers, etc.), the above figures can be met if the unavoidable cable sections are continuously or lump-loaded in accordance with the "Directives for the construction and loading of cables inserted in audio circuits on open-wire lines" in paragraph f) below, or if appropriate building-out networks are inserted at junction points between the cable sections and the open-wire sections (as suggested in the "Directives").

If the regularity return loss is kept to the value given above, the circuit can be worked at an equivalent of 8.7 dB or 1 Np with satisfactory stability (at least 2.6 dB or 0.3 N when the circuit is open at both ends)[1].

Weather conditions affect the attenuation (and hence the equivalent) of open-wire, line sections, and also their impedance (and hence the regularity return loss). However, this effect is usually not very great.

Taking a mean value of ambient temperature of + 10° C, the resistance of an open-wire line changes by ± 14% for a temperature change from + 45° C to —25° C. The resulting change in the circuit attenuation is of the same order (12% to 14%). The change is almost uniform over most of the audio-frequency band. If there are no very definite defects in the open-wire circuits, the effect of humidity on leakance is small. This is not the case, however, when the lines are not so well maintained and a difference of 20% may then be observed in extreme cases between the attenuations in wet and in dry weather.

In general, these changes in attenuation can be compensated by adjusting the repeater gain, without reduction in circuit stability, provided the different parts of the circuit are sufficiently uniform. However, on very long open-wire circuits automatic gain regulators can be usefully employed.

The modulus of the characteristic impedance of an open-wire line with a conductor diameter of 3 mm or more only changes by ± 5% for a temperature change from + 45° C to —25° C. The effect of humidity is even less if the circuit is perfectly maintained. On the other hand, in the case of a very long circuit using light gauge conductors (≦ 2.5 mm diameter) changes of impedance, especially at low frequencies, depending especially on whether the weather is wet or dry, can be sufficient to warrant a reduction in repeater gain, the arrangement or adjustment of balances not being practicable. This is another reason for not setting up long open-wire circuits on light gauge conductors.

Changes in weather conditions (temperature, relative humidity) can therefore in general be neglected, but from time to time the stability of the circuit should be checked (with the circuit open at both ends) when there are major changes in atmospheric conditions.

3. All joints on an open-wire line should be made so that they do not introduce variations in resistance.

On an open-wire line in any one repeater section, or in any section between one repeater station and the next, the difference in resistance of the two conductors of any pair should not exceed 2 ohms.

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[1] This value of stability will be reached only if the impedance of the balance coincides with the curve of the average line impedance when terminated with its characteristic impedance.

The values given for stability and equivalent are different from the general recommendations in Section 1 of Part 1 of this volume.

4. Any filters in the repeaters which are inserted in the open-wire circuits and also the loading of any short cable sections should be such that the circuits will effectively transmit the frequency band recommended for international circuits and will have a stability always greater than 2.6 dB (0.3 Np)[1] when the circuit is open at both ends (see Recommendation G.132).

5. To avoid disturbances arising from crosstalk or from main interference on telegraph circuits, long-distance international telephone circuits should have twist or transposition systems arranged so that the length of an anti-induction section between any two pairs on the route shall be less than 100 km. It may be desirable to increase the number of twists or transpositions in the case of high-frequency carrier telephony, of interference from heavy current or high-voltage mains installations, or of proximity to telegraph circuits.

6. In respect of dangers and difficulties arising from mains lines, telephone circuits should meet the conditions given in the *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines.*

7. The insulation of each wire to earth should not go below 1 megohm per kilometre, which is the value that experience in different countries has shown to be practical under normal conditions of atmospheric humidity. The use of properly made double-skirt insulators enables this value of insulation to be maintained. The value may be decreased in areas having an exceptionally humid climate.

8. The composite attenuation of a repeater section or of a section between a repeater station and an adjacent terminal exchange should not exceed 13.9 dB (1.6 Np).

On long open-wire circuits, a value of 10.4 dB (1.2 Np) is to be recommended for the composite attenuation of a repeater section, the repeaters having a gain of about 10.4 dB (1.2 Np). A distortionless building-out network should be inserted if required, whose image impedances match the characteristic impedance of the circuit concerned.

9. Open-wire circuits should be provided with break-jack test points (in accordance with paragraph c) of this present recommendation).

c) *Break-jack test points on international open-wire lines*

The C.C.I.T.T.,

considering

that fault location should be, in the main, by precision measurement, cutting the circuit being avoided so far as possible,

that connecting circuits through break-jacks at numerous exchanges increases attenuation and destroys uniformity,

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[1] This recommendation is different from the general recommendations in Recommendation G.131 above .

unanimously recommends

1. that, on international open-wire lines, the number of break-jack frames, which are frequent sources of faults, should be reduced to the minimum necessary to meet local requirements;

2. that precision measuring sets should be installed at about 200-km intervals in exchanges on the route. These exchanges will be called "main test points" and the section between two main test points will be called a "main section". Location of a fault in a main section will be achieved by measurements at the break-jack points on the two sides of the fault. Results of measurements will be compared between the two exchanges concerned;

3. that conductor resistance and insulation resistance tests should be made regularly, and at least each month, by the control stations or repeater stations on each side of frontiers and that the results of these tests should be exchanged between the services interested.

Note. — If the circuit is fitted with repeaters, the repeater stations will be main test points.
It is recommended that, to avoid the use of long leading-in cables permanently in circuit between the route and a main test point, remote testing facilities be used.

d) *Patrolling along international open-wire lines*

The C.C.I.T.T.,

considering

that it is desirable that open-wire international telephone lines should be frequently patrolled, in order to reduce faults as much as possible and to ensure rapid clearance,

unanimously recommends

that, when justified by the importance of the route, arrangements should be made for patrols along the routes as is already done in certain countries.

e) *General conditions to be fulfilled by composite lines*

The C.C.I.T.T.,

considering

that, on composite lines—i.e. open-wire lines with cable sections—it is difficult to have stable and effective operation of the repeaters;

that, at the junction of lines having different characteristics, there are always reflection losses which reduce the overall efficiency of the circuit;

that the insertion into telephone lines of sections with different characteristics, even if extremely short (through tunnels, large towns, etc.) is, in the experience of certain countries represented in the C.C.I.T.T., such as to interfere seriously with the development of long-distance telephony, because of the effect on the operation of repeaters and carrier telephone systems, and that it is therefore necessary to avoid the use of these composite lines;

that, nevertheless, special cases may make the use of these composite lines unavoidable, but that special precautions should then be taken,

unanimously recommends

1. that, whenever possible, it is desirable to avoid composite lines for long-distance international telephony;

2. that if it is impossible to avoid composite lines, efforts should be made to reduce reflection effects by using, for example, suitable continuously-loaded or coil-loaded cable, in accordance with the "Directives for the construction and loading of cables inserted in audio circuits on open-wire lines" of paragraph f) below;

3. that, for a composite line of any length, the overall loss and frequency/attenuation distortion should be as near as possible to those of a uniform line.

f) *Directives for the construction and loading of cables inserted in audio circuits on open-wire lines*

The C.C.I.T.T. *unanimously recommends*

that any cable section more than 100 metres long, which is inserted in an open-wire line, should be made to meet the following recommendations:

1. Z_1 being the impedance of a composite section between two intermediate repeaters, or between a repeater and the adjacent terminal exchange, and

Z_2 being the impedance of a perfectly uniform section of open-wire line, or of the corresponding balancing network,

the quantity $2 \dfrac{Z_1 - Z_2}{Z_1 + Z_2}$ measured at the ends of the section shall not exceed a value of 0.05 at any frequency in the range 300 to 3400 Hz.

Depending on the length and the number of the intermediate cables, this condition may be met by using continuously loaded or lightly loaded cables (see 3 below).

2. The electrical characteristics of a cable inserted in an open-wire section, namely the resistance R_1, the inductance L_1 and the capacity C_1 compared with the same characteristics R, L and C for the open-wire line, should meet the relations

$$\frac{R_1}{R} = \frac{L_1}{L} = \frac{C_1}{C},$$

leakance not being included because its effect is both small and variable.

3. The sections of cable should be either continuously-loaded cable having values of R, L and C which meet the conditions in 2 above (this method is particularly used when there are one or several short cable sections in the same circuit); or lump-loaded cable having values of R, L and C which meet the conditions in 2 above, and having a cut-off frequency such that the circuit impedance meets the conditions in 1 above. If there are several cable sections in one and the same open-wire circuit, the cut-off frequency of the various cable sections must be increased so as to meet the conditions in 1.

RECOMMENDATION G.522

AUDIO-FREQUENCY CABLES

Use of different types of loading

1. Having regard to the fact that in certain countries an extensive cable network already exists, and to the conditions which must be satisfied when laying new loaded cables, it is not practicable to standardize in detail the characteristics such as loading coil spacing, conductor, diameter, etc., of cable circuits.

The usual loading and corresponding conductor gauges offer sufficient variety to meet all practical conditions as regards spacing of repeater stations.

Nevertheless, cases may arise where it is not possible to use these types of loading; care must then be taken to ensure that the general characteristics of the international telephone circuits to be set up conform to those in Recommendation G.511.

When it is proposed to increase the gauge of the conductors, the C.C.I.T.T. points out that it is more difficult to achieve a uniform distribution of line-constants with larger conductors. Hence, when it is necessary to increase the diameter of the conductors in order to reduce the attenuation of a particularly long repeater section, it may be necessary to choose a gauge such that the attenuation of the repeater section is less than its normal value. In this way it is possible to use the circuit with lower repeater gains and thus to obtain the same stability, from the point of view of transmission, as with a more usual type of circuit.

2. To avoid reflection loss and also to ensure satisfactory operation of the repeaters, it is desirable to have uniformity of electrical characteristics throughout the repeater section. The cable pairs between adjacent repeaters in the same country should be absolutely uniform. Also, the construction of the cables should be such that the circuits are perfectly balanced and such that the electrical constants of the circuits are evenly distributed. However, for cable sections crossing a frontier between two countries it is sometimes possible to join two sections of cable made to different specifications; in fact, certain junctions of this sort, already made, are giving good results.

Consequently, although uniformity is very desirable for the repeater section of an international cable crossing a frontier, the direct connection of two sections made to different specifications may be permitted, exceptionally, in certain cases and with the reservation that, for the section thus constituted, the conditions for matching of impedances described in paragraph f) of Recommendation G.543, under “Specification for repeater sections of loaded telecommunication cables” are met.

[See: 1. Annex to Recommendation G.543 entitled: “Different methods of co-operation between two administrations or private operating agencies for the construction of a loaded cable section crossing a frontier”; 2. Recommendation G.533 dealing with “Repeaters to be used at the junction of two cables with different characteristics”.]

The uniformity of repeater sections is of particular importance for circuits with 1.3- and 1.4-millimetre conductors; but, because for these circuits the total capacity of the loading coil sections is very nearly the same for several common types of loading, there will be adequate uniformity if, in a complete repeater section, only one or the other of the two kinds of loading coil is used, keeping respectively the characteristics of the two types of loading as regards equipment for the cable sections to be connected.

5.3 Repeaters [1]

RECOMMENDATION G.531

GENERAL CHARACTERISTICS OF REPEATERS FOR FOUR-WIRE CIRCUITS

a) *Type*

Repeaters used on four-wire circuits should amplify in one direction only and without noticeably affecting the quality of transmission at any frequency which the pairs associated with the repeaters should effectively transmit, when the input power is the maximum met with in practice.

b) *Amplification*

The gain of the repeater (or of the repeater with its equalizer) should so vary with frequency as to adequately compensate for the distortion introduced by the line in the frequency band effectively transmitted (300 to 3400 Hz).

Provision should be made for a gain-regulating device which should preferably alter the gain in steps not exceeding 1 dB or 1 dNp. With very long circuits it may be necessary for the steps to be not greater than 0.5 dB or 5 cNp.

The curves representing the gain/frequency characteristics should be parallel for all values of repeater gain, throughout the band of frequencies effectively transmitted by the circuit.

The repeater should be so designed that, in the normal state of maintenance of the power supplies, variations of the voltage and current from these supplies produce variations not exceeding 0.26 dB (3 cNp) in the gain of the repeater under working conditions.

c) *Impedance*

The impedance of the repeater, excluding line transformers, measured at the input and output terminals, and at a frequency of 800 Hz, should, in principle, have the value allowed by the C.C.I.T.T. for the impedance of international circuits.

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[1] The Recommendation entitled "Valves for repeaters" (*Yellow Book*, Volume III *bis*, pages 64 and 65) has not been reproduced, as the XVIIIth Plenary Assembly of the C.C.I.F. did not think it necessary to draw up a model specification for the supply of thermionic valves nor even to draw up a list of essential clauses for such a specification.

The impedance of the repeater, excluding line transformers, should be approximately equal to that of the circuit to which this repeater is to be connected, so that the modulus of the return current coefficient

$$\left|\frac{Z - W}{Z + W}\right|$$

should be not greater than 0.4 for the input impedance of the repeater, and 0.6 for the output impedance of the repeater, Z being the impedance of the line (including the line transformer) and W the impedance of the repeater; these two limits should not be exceeded at any frequency effectively transmitted.

d) *Monitoring*

Arrangements should be provided for monitoring on circuits with an operator's telephone in either or both directions, and for talking on these circuits when necessary.

When monitoring a working repeater, the loss resulting from the connection of the monitoring instrument should not exceed 0.26 dB (3 cNp).

e) *Crosstalk*

1. *Crosstalk between repeaters.* — When repeaters are installed side by side, or one above the other, and when the power supplies are normal, the results of crosstalk measurements made between output terminals should give a signal-to-crosstalk ratio of not less than 74 dB or 8.5 Np. For those measurements, the repeaters should be set to their maximum working gain, and should be connected to impedances equal to Z, the stated impedance of the circuits concerned. Suitable measuring equipment is shown in Figure 1.

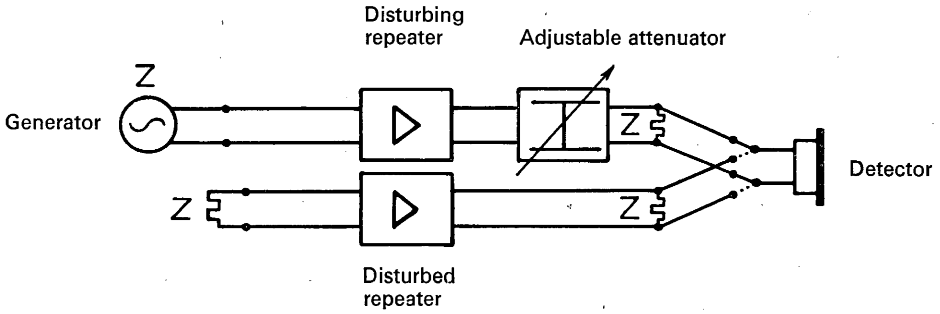


FIGURE 1

2. *Crosstalk in a station (including cabling).* — The results of crosstalk measurements made between any two four-wire repeaters, or between one two-wire repeater and one four-wire repeater, in the same repeater station and including the station wiring and line

transformers (i.e., between the incoming and outgoing cable heads) should give a signal-to-crosstalk ratio of not less than 70 dB or 8 Np. For these measurements, the repeaters should be under working conditions, set to their maximum working gain, and should have connected to their line transformer terminals impedances equal to *Z*, the stated impedance of the circuits concerned. The gain of two-wire repeaters in the direction which is not being measured should be suppressed. Suitable measuring equipment is shown in Figure 2.

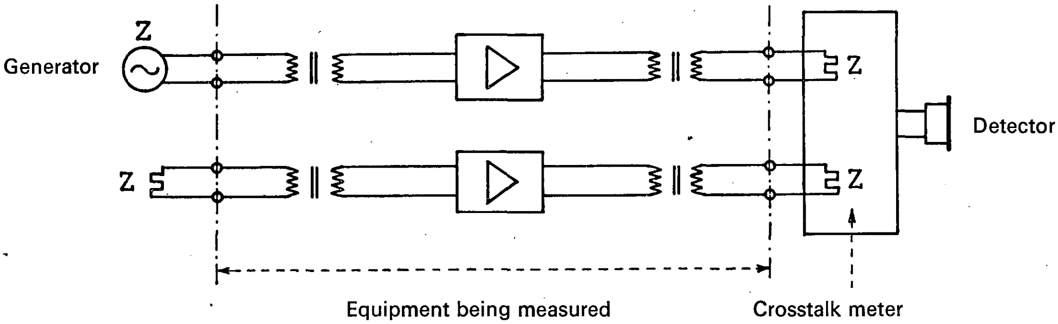


FIGURE 2

f) *Non-linear distortion*

The total harmonic ratio should not exceed 5% at a frequency of 800 Hz and for a maximum power of 50 milliwatts in the case of a four-wire circuit, the supplies to the valves of the repeaters having their normal values and the grids of the valves being always negative with respect to their cathodes; the line transformers should be excluded from this measurement and during the test the output of the repeaters should be connected to a pure 600-ohm resistance.

Further, the C.C.I.T.T. considers that it would be desirable, provisionally, to fix the maximum power measured at the output of a repeater, as follows:

Repeaters for four-wire telephone circuits in cable	50 milliwatts;
Repeaters for voice-frequency telegraphy	50 milliwatts.

This condition has been fixed on the assumption that the relative power level at the output of any repeater should never exceed + 10 dB or + 1.1 Np.

RECOMMENDATION G.532

GENERAL CHARACTERISTICS OF REPEATERS FOR TWO-WIRE CIRCUITS

a) *Type*

On two-wire circuits, on open-wire lines or in cable, only reversible repeaters having two balances which separately balance the two sides of the telephone circuit should be used. These repeaters should not sing, that is to say oscillation should not occur at maximum gain, when the "line" and "balance" terminals corresponding to one direction are closed with non-reactive resistances having a value equal to the impedance specified for the repeater, the "line" and "balance" terminals for the other direction being open or short-circuited, or vice versa. The two resistances should be directly connected to the terminals of the differential transformer.

If the repeaters include adjustable equalization, this condition should be met for all possible settings of the equalization.

b) *Amplification*

The repeaters should ensure a faithful reproduction of speech, that is, the repeater gains should be such that the circuit effectively transmits frequencies from 300 to 3400 Hz.

To achieve this result, the repeaters used can either amplify all the above frequencies to the same extent, independent equalizers being associated as necessary, or they can be designed to carry out the necessary equalization themselves.

If the repeaters provide equalization of the line characteristic, the repeater gain should change with frequency over the frequency band to be effectively transmitted. For frequencies higher than this, the gain should decrease to zero at around the cut-off frequency of the circuit. For frequencies lower than this, the gain should not exceed the values required for an exact equalization of the circuit.

Provision should be made for a gain-regulating device which should preferably alter the gain in steps not exceeding 1 dB or 1 dNp.

The curves representing the gain/frequency characteristics should be parallel for all values of repeater gain, throughout the band of frequencies effectively transmitted by the circuit.

The repeater should be so designed that, in the normal state of maintenance of the power supplies, variations of the voltage and current from these supplies produce variations not exceeding 0.26 dB (3 cNp) in the gain of the repeater under working conditions.

c) *Impedance*

The impedance of the repeater, including line transformers, should be approximately equal to that of the circuit to which this repeater is to be connected, so that the modulus of the return current coefficient

$$\left|\frac{Z-W}{Z+W}\right|$$

should be not greater than 0.2 for medium loading and 0.1 for light loading, at any frequency in the band effectively transmitted, Z being the characteristic impedance of the circuit and W the impedance of the repeater measured as follows:

the impedance of the repeater is measured under working conditions, including the two balances, but with feedback effects suppressed. For example, to measure the impedance on the "X" side of the repeater, the line on the "Y" side is replaced by its balance. The balance on the "X" side should match the line on the "X" side, which is replaced by the measuring instrument. The potentiometer for the X→Y direction stays on its normal stop, and transmission in the Y→X direction is suppressed without changing the impedance.

d) *Monitoring*

Arrangements should be provided for monitoring on circuits with an operator's telephone in either or both directions, and for talking on these circuits when necessary.

When monitoring a working repeater, the loss resulting from the connection of the monitoring instrument should not exceed 0.26 dB (3 cNp).

e) *Crosstalk*

1. *Crosstalk between repeaters.* — When repeaters are installed side by side, or one above the other, and when the power supplies are normal, the results of crosstalk measurements made between output terminals should give a crosstalk ratio of not less than 70 dB or 8 Np. For these measurements, the repeaters should be set to their maximum working gain, and should be connected to impedances equal to *Z*, the stated impedance of the international circuits concerned. Suitable measuring equipment is shown in Figure 1.

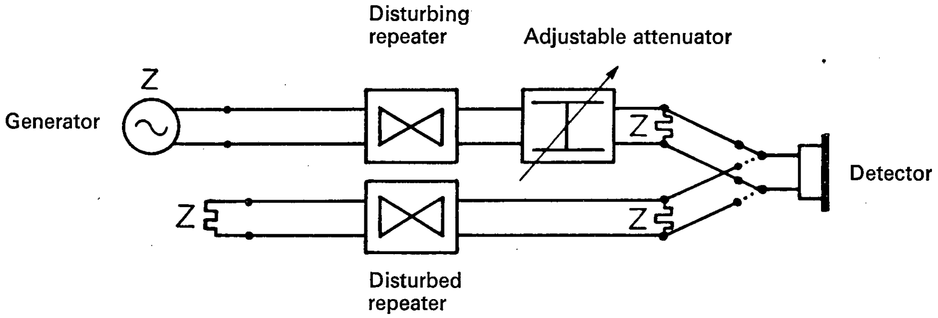


FIGURE 1

Note 1. — In making this measurement, the gain in the direction not being measured should be suppressed.

Note 2. — The line transformers and cabling connecting them to the repeater rack are not included in the tests; the measuring equipment should be so arranged that the repeaters are in their operating condition, particularly as far as symmetry is concerned.

2. *Crosstalk in a station (including cabling).* — The results of crosstalk measurements made between any two two-wire repeaters in the same repeater station, and including the station wiring and line transformers (i.e., between the incoming and outgoing cable heads) should give a signal-to-crosstalk ratio of not less than 65 dB or 7.5 Np. For these measurements, the repeaters should be, under working conditions, set to their maximum working gain, and should have connected to their line transformer terminals impedances equal to *Z*, the stated impedance of the circuits concerned. The gain of two-wire repeaters in

the direction which is not being measured should be suppressed. Measuring equipment similar to that shown in Figure 2 of Recommendation G.531, for four-wire circuits is suitable.

f) *Non-linear distortion*

The total harmonic ratio should not exceed 5% at a frequency of 800 Hz and for a maximum power equal to 20 milliwatts in the case of a two-wire circuit, the supply voltages and valve bias being normal, and the control grids being always at a negative potential to their cathodes. The line transformers should be excluded from this measurement, and during the test the output of the repeaters should be connected to a pure 600-ohm resistance.

Further, the C.C.I.T.T. considers that it would be desirable, provisionally, to fix the maximum power measured at the output of the repeater, as follows:

Repeaters for two-wire telephone circuits in cable	20 milliwatts;
Repeaters for two-wire telephone circuits on open-wire lines	20 milliwatts.

RECOMMENDATION G.533

REPEATERS TO BE USED AT THE JUNCTION OF TWO CABLES WITH DIFFERENT CHARACTERISTICS

Generally, these repeaters should fulfil the conditions given above for all four-wire repeaters.

There are several ways in which repeaters between four-wire circuits with different characteristics can be made to fulfil these conditions.

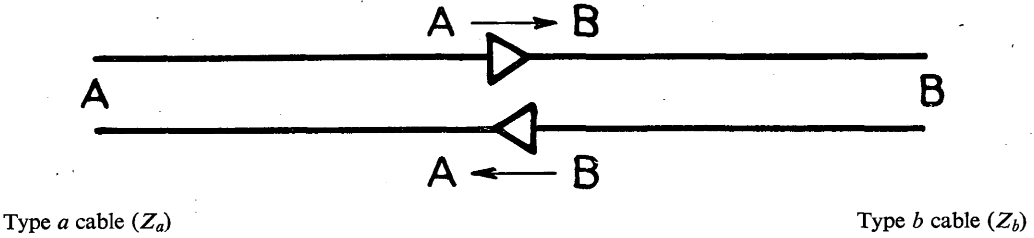


FIGURE 1

a) If the principle is adopted that the repeater should correct the attenuation of the preceding repeater section throughout the frequency band to be effectively transmitted, then, strictly speaking, repeaters should be used which correct the attenuation distortion in a different way in the two directions of transmission.

The gain/frequency characteristic of the repeater A → B (see Figure 1) should be suitable for the attenuation/frequency characteristic of type *a* cable, when on the input side it is terminated by Z_a, which is the impedance of type *a* cable, and on the output side by Z_b, which is the impedance of type *b* cable. For the repeater B → A, it is exactly opposite. When there are various types of cable in a country, the application of this principle involves the use of a relatively large number of different types of repeater which have to be specially designed for the purpose.

b) If repeater A → B is a normal repeater of the type which is used for a network constructed entirely of type *a* cable, and similarly, if repeater B → A is a normal repeater suitable for type *b* cable, the normal gain/frequency characteristic will not be obtained because, for example, the output of repeater A → B is terminated by the impedance of type *b* cable, instead of by type *a* cable, and this produces an additional attenuation.

Let:

Z_a = the impedance of type *a* cable,
Z_b = the impedance of type *b* cable,
Z_v = the impedance of the repeater;

$$K_1 = \frac{Z_a}{Z_v} \qquad\qquad K_2 = \frac{Z_b}{Z_v}$$

The additional attenuation is:

$$a = \tfrac{1}{2} \log_e \frac{K_2 (1 + K_1)^2}{K_1 (1 + K_2)^2}$$

This additional attenuation in practice is only a few hundredths of a neper and can therefore be ignored. There is thus need for a much smaller number of different types of repeater than the number indicated under a).

c) If the transmission characteristics of the existing types of cable are similar with respect to impedance and attenuation, it is not possible to have a different correction for the two directions of transmission. In this case, it is practical to establish, from different attenuation curves of the existing types of cable, an average curve to which repeaters in the two directions should be matched. Because their attenuation/frequency curves are different, it is necessary to distinguish between circuits with medium loading and circuits with light loading. It is thus possible to reduce to two the number of "junction" type repeaters to be used.

d) Another method is to use repeaters with an adjustable equalizer, which allows the most suitable gain/frequency characteristic to be used for each direction of transmission.

5.4 Specifications recommended by the C.C.I.T.T. for audio-frequency cable circuits

INTRODUCTION

The C.C.I.T.T. recommends administrations and private operating agencies to use the following specifications for the supply of audio-frequency telecommunication cables liable to be used in the international service (and also auxiliary equipment: loading coils, repeaters, etc.).

In these specifications, only the clauses relating to four-wire circuits apply to international telephone circuits on loaded cables. All the specifications apply to national trunk circuits liable to enter into an international call, these being either two-wire or four-wire circuits.

The C.C.I.T.T. considers that the efficiency of such a long-distance cable (with several repeater stations) depends to a large extent on constructional details and the general arrangement of the system.

An administration or private operating agency might prefer to place a contract with a firm for a complete system (cable and repeater) instead of having their own specialist engineers assume the responsibility which results from acceptance of the parts of the system separately. The C.C.I.T.T. proposes to recommend to such an administration or private operating agency to obtain from the contractor detailed information regarding the project and to obtain all the necessary guarantees to ensure strict adherence to the outline specification below. The administration or private operating agency should give prior information to the contractor regarding the circuits necessary and estimated traffic.

Certain administrations and private operating agencies include in their specifications for underground cables details of methods of manufacture, laying, etc. These are not included in the following specifications, because the C.C.I.T.T. considers it is better to leave the different administrations and private operating agencies free to choose their own methods for manufacture and laying of cables, with the reservation that the complete circuits should satisfy the general conditions shown in Recommendation G.511.

(See also the Annex to Recommendation G.543, headed “Different methods of co-operation between two administrations or private operating agencies for the construction of a loaded cable section crossing a frontier”.)

RECOMMENDATION G.541

SPECIFICATION OF FACTORY LENGTHS OF LOADED TELECOMMUNICATION CABLE

a) *General*

The present specification lays down the electrical conditions to be met by factory lengths of loaded, paper-insulated, air-spaced, lead-covered telephone cable, for long-distance communications.

These conditions are specified to ensure that cables will allow:

1. the use, if necessary, of phantom circuits;
2. the loading of the side circuits and if necessary of the phantom circuits;

3. the obtaining of satisfactory long-distance repeater circuits;

4. the obtaining of satisfactory long-distance programme circuits using screened circuits.

These conditions do not apply:

1. to cables with conductors having a diameter less than 0.8 mm (approximately 16 lb per mile);

2. to groups of conductors having the same gauge but with less than 20 pairs;

3. when the total number of pairs is such that the arrangement of the conductors in the cable is necessarily unsymmetrical, or such that the conductors of different gauges are placed in the same layer.

Certain essential conditions relating to raw materials are also specified in paragraph b); the following paragraphs deal with electrical characteristics.

b) *Raw materials*

Copper conductors. — Each conductor will consist of a wire of pure copper, annealed, uniformly drawn, cylindrical, and of uniform quality and resistance, without cracks or other faults, having a conductivity at least equal to that which has been specified by the International Electrotechnical Commission (Berlin, 1913)—i.e. 1/58th of an ohm per metre for standard annealed copper wire, having a cross section of one square mm at a temperature of 20° C.

To correct for temperature, the temperature coefficient specified by the same Commission will be assumed—i.e. 0.00393 per degree C for the temperature coefficient at a constant mass of standard annealed copper, at a temperature of 20° C.

The diameter of the wires should not vary by more than ± 1.5% of the nominal diameter.

Joints made during manufacture. — When it is necessary to joint conductors during manufacture, a method fulfilling the following conditions will be used:

The tensile strength of a length of conductor including a joint will be at least equal to 90% of that of a similar adjacent length having no joint.

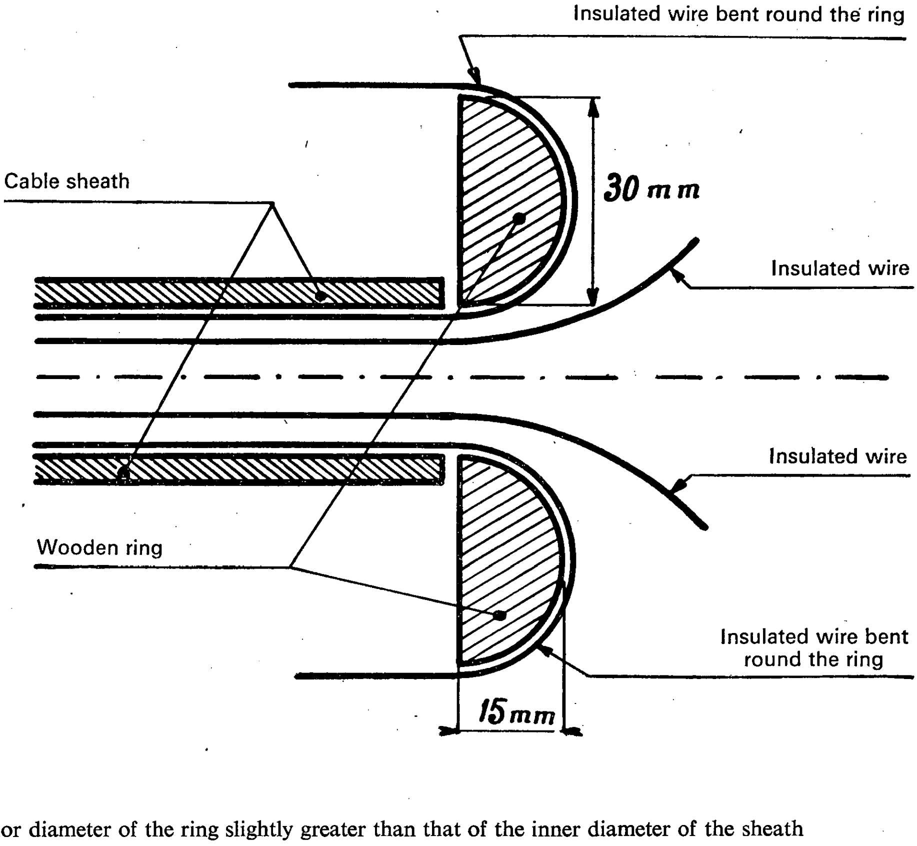
The resistance of a length of conductor not exceeding 15 centimetres in length (approximately six inches) and including a joint should not exceed by more than 5% the resistance of a similar adjacent length having no joint. Twisted joints are not to be used. A flux containing acid must not be used.

Insulating paper. — Insulating paper will be homogeneous, of uniform thickness with long fibres and as far as possible free from metallic particles; it should be practically free from resinous materials and from acid or alkaline substances, and should not contain substances which might have a harmful effect on the conductors or lead sheath.

The insulating paper on the conductors should not tear when these conductors, taken from the finished cable, are bent round a cylinder (or toroid), having a radius of curvature of 15 mm (see the explanatory sketch of Figure 1). A sample of the paper taken from the finished cable and having been exposed for two hours to an atmosphere of 65% humidity should have a tensile strength at least equal to the weight of 5 kilometres (3.1 miles) of paper of the same type and dimensions.

Materials used for the sheath and for the armouring of cables. — The conditions to be met by these materials are specified separately for each cable.

Pressure tests. — The soundness of the lead sheath should be verified by pressure tests rather than immersion tests.



Interior diameter of the ring slightly greater than that of the inner diameter of the sheath

FIGURE 1. — Explanatory sketch

c) *Resistance of the conductors*

The resistance of any conductor in a factory length, measured with direct current, should not exceed by more than 4% the value calculated for a rectilinear conductor having the nominal diameter of the conductor considered.

The average resistance for all the wires of a group of conductors of a given gauge should not exceed the nominal value defined above by more than 1%.

An allowance for lay will be made in the resistance value as follows:

Diameter (in millimetres) of the outside layer formed by conductors of the gauge considered	*Allowance for lay*
Under 30	1.0%
30 to 40	1.6%
40 to 50	2.5%
50 to 60	3.7%
60 to 70	5.0%
70 to 80	7.0%

The resistance unbalance of two conductors of a same pair taken in any length of cable, measured with direct current, should not exceed the loop resistance of this pair by more than 1%.

The resistance unbalance of the two pairs of the same phantom group, the conductors of each pair being joined in parallel, in any length of cable, measured with direct current, should not exceed by more than 2% the loop resistance of the two pairs, the conductors of each pair being joined in parallel.

d) *Dielectric strength*

If specially asked for, the cables should be constructed in such a way that the insulation of any length of cable is capable of withstanding a potential difference, specified in each particular case but not exceeding 2000 volts r.m.s., applied for at least 2 seconds between all the conductors (bunched) and the earthed sheath. The test can be made with alternating current of 50 Hz. The test voltage should not exceed by more than 10% the maximum value of a sinusoidal voltage having the same r.m.s. value.

The test can also be made with direct current (see Annex 19, *Blue Book*, Volume III, Part 4 entitled "Dielectric strength tests"). In this case, the limit for the d.c. voltage will be 1.4 times the limit for the r.m.s. a.c. voltage[1].

e) *Insulation resistance*

In a length of cable, the insulation resistance measured between a conductor and all the other conductors connected to the sheath and earth should not be less than 10 000 megohms

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[1] Paragraph 4 of Annex 19 does not recommend a formula for general application for tests on mixed dielectrics. However, for tests of telephone cables, the C.C.I.T.T. recommends the use of the factor 1.4 as representative of current commercial practice.

per kilometre (approximately 6200 megohms per mile), the potential difference used being from 100 volts to 500 volts. The reading should be made after electrification for one minute, the temperature being at least equal to 15° C (59° F).

f) *Effective capacity measured with alternating current*

The effective capacity of a pair is the capacity measured between the two conductors of this pair, all the other conductors being connected to the lead sheath; the nominal value of this capacity for each cable will be specified.

The effective capacity of the phantom circuit of a phantom group is the capacity measured between the two pairs of this phantom group, each pair being short-circuited, all the other conductors of the cable being connected to the lead sheath. By definition, the nominal capacity of the phantom circuit is equal to 1.6 times the nominal capacity of the pair (multiple twin or Dieselhorst-Martin cables).

The test will be made with alternating current at room temperature. No temperature correction will be applied. In case of dispute, the results obtained with an alternating current having a frequency of 800 Hz and at a temperature of at least 15° C (approximately 60° F) will be considered as final.

In each length of cable, the average capacity of all the pairs of the same gauge will be in accordance with the conditions imposed by the administrations and private operating agencies concerned; a tolerance will, however, be allowed on each factory length.

For programme circuits, a tolerance of effective capacity of ± 12% from the nominal value will be allowed.

In each factory length, the average of the effective capacities of the phantom circuits of each group of the same gauge will not differ by more than ± 5% from the value obtained by multiplying the average value of the capacities of the pairs of this group by 1.6.

This factor is valid for multiple twin cables. For star quad cables, this factor is higher; its value should be specially fixed in each particular case.

The effective capacity of each side circuit and of each phantom circuit will be measured on at least 10% of the factory lengths.

The "difference of capacity" of a side circuit or of a phantom circuit in any length of cable should not exceed the following values in a group of conductors of the same gauge:

Average	4.0%
Maximum	12.5% .

("Difference of capacity" means the difference between the capacity of any circuit of a group and the average capacity of all similar circuits of this group, in the same factory length. This difference is expressed as a percentage of the average value.)

Note. — For each group of side and phantom circuits in the cable, the average capacity of the different loading sections within the same repeater section should not differ by more than ± 2% from the average value of the capacity for the group of circuits considered, for the whole of the loading sections. In the case where such a degree of regularity could not be obtained directly by factory methods, if there are differences higher than the limits indicated, it is recommended that factory lengths should be so allocated within a repeater section that the capacities of the different loading sections satisfy the condition above.

g) *Leakance*

The average leakance of the side and phantom circuits will be measured on a small percentage of the factory lengths, with an alternating current having a frequency of 800 Hz.

The average leakage constant for each type of circuit and for all factory lengths tested should not exceed 25. This constant is equal to the ratio of the average conductance to the average capacity, measured with alternating current.

Its value can also be expressed by the ratio

$$\frac{G}{\omega C} = \frac{\text{leakance}}{\text{capacitance}}$$

which should not exceed 0.005.

h) *Capacity unbalances*

The capacity unbalances measured with alternating current at a frequency of about 800 Hz on cable lengths of 230 metres (approximately 750 feet) should not exceed the values shown below, each group of circuits of a same gauge being considered separately.

These values are suitable for pairs in loaded cables to be used at audio-frequencies.

Allowable limits for capacity unbalances
(in pF for lengths of 230 metres)

		Av.	*Max.*
I. *Ordinary telephone circuits*			
In all quads	side-side	40	150
	phantom-side	75	375
	side-earth	150	600
	phantom-earth *	300	1200
Capacity unbalances between circuits in the outer layer and earth	side circuit	150	600
	phantom circuit	300	1200
Between circuits situated in adjacent quads in a same layer or between a quad in the first layer and a quad in the centre	pair-pair *	40	170
	phantom-pair *	40	170
	phantom-phantom	40	170
Between four-wire "go" and "return" pairs (this does not apply to adjacent quads)			20
II. *Programme circuits*			
α) Within a screened quad (multiple twin or star quad)	side-side		150
	phantom-side		375
	side-earthed screen		600
	phantom-earthed screen *		1200
β) Screened pairs (single pair)	pair-earthed screen		600
γ) Unscreened pairs (single pair)	pair-earth		600
	pair-pair in adjacent quads		170
	pair-phantom in adjacent quads		170

The measurement of the above unbalances involves a large number of tests and it is desirable to limit them. This limiting may best be done by making tests in the cases marked with an asterisk * in the table above on only 2% of the factory lengths of an order, with a minimum of two lengths. In exceptional cases, administrations and private operating agencies concerned could request tests on a greater number of lengths; the factory lengths on which these measurements are made will be selected by administrations and private operating agencies.

If a length does not comply with the above specification for unbalance, this length will be rejected; the administrations or private operating agencies could request measurements on the other factory lengths.

In the case of cables intended to be worked four-wire, average capacity unbalances between "go" and "return" pairs will be measured on one or more factory lengths, and the average unbalance for a factory length of 230 metres should not exceed 3 pF.

In each factory length of cable, for a length other than 230 metres, the capacity unbalances, measured with alternating current for the various diameters of conductors, should not exceed the values obtained by applying the following rules:

1. Between circuits:

side-side pair-pair phantom-pair phantom-phantom	average values

multiply the values given in the above table by the square root of the ratio of the length to 230 metres.

2. Between circuits:

side-side pair-pair phantom-pair phantom-phantom	maximum values
phantom-side side-earth phantom-earth	average and maximum values

multiply the values given in the above table by the ratio of the length to 230 metres.

This rule does not apply to lengths of less than 100 metres (approximately 110 yards), to which the values for factory lengths of 100 metres, calculated by the above rules, will apply.

Note 1. — Definitions of capacity unbalances are given below.

Note 2. — When sheath capacity unbalances for pairs and phantoms in the outer layer are specified, it is not necessary to specify for these circuits limits for capacity unbalances to earth.

Definitions of unbalances

If, in a short section of telephone pair (e.g. in a factory length of cable), the electrical characteristics of this pair (between wires or between each wire and earth) are irregular, there is said to be an unbalance at this point. Thus, there can be resistance unbalances, leakage unbalances, self- or mutual-inductance unbalances, and capacity unbalances. In cable pairs, it is the capacity unbalances which are important as regards crosstalk and induced noise.

Telephone cable conductors are laid up to form quads as shown in Figure 2.

From different conductors of one or several quads, side and phantom circuits (single and double) are formed, using the arrangements shown diagrammatically in Figure 3.

The different capacity unbalances of importance in a factory length of cable are defined as follows:

The capacity unbalance of a side circuit of a quad, with respect to the other side circuit of the same quad, is the value of the capacity which, when connected between a wire of a pair and a wire of the other pair of this quad, corrects the unbalance.

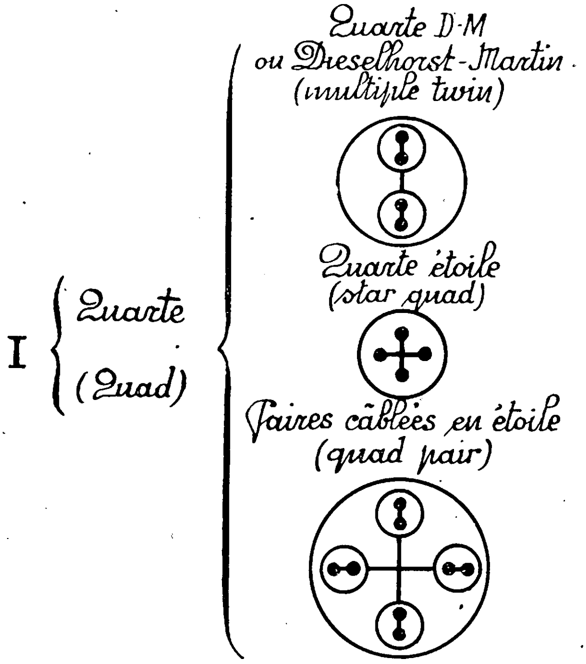

FIGURE 2

The capacity unbalance of a phantom circuit, with respect to any one of the side circuits of the same quad, is the value of the capacity which, when connected between a wire of this pair and the two short-circuited wires of the other pair of this quad, corrects the unbalance.

The capacity unbalance of a pair, with respect to a pair of a different quad, is the value of the capacity which, when connected between a wire of one pair and a wire of the other pair, corrects this unbalance.

The capacity unbalance of a phantom circuit, with respect to either of the pairs of another quad, is the value of the capacity which, when connected between one of the pairs of the phantom circuit and one of the wires of the pair in question, corrects this unbalance.

The capacity unbalance between two phantom circuits is the value of the capacity which, when connected between a pair of the first phantom circuit and a pair of the second phantom circuit, corrects this unbalance.

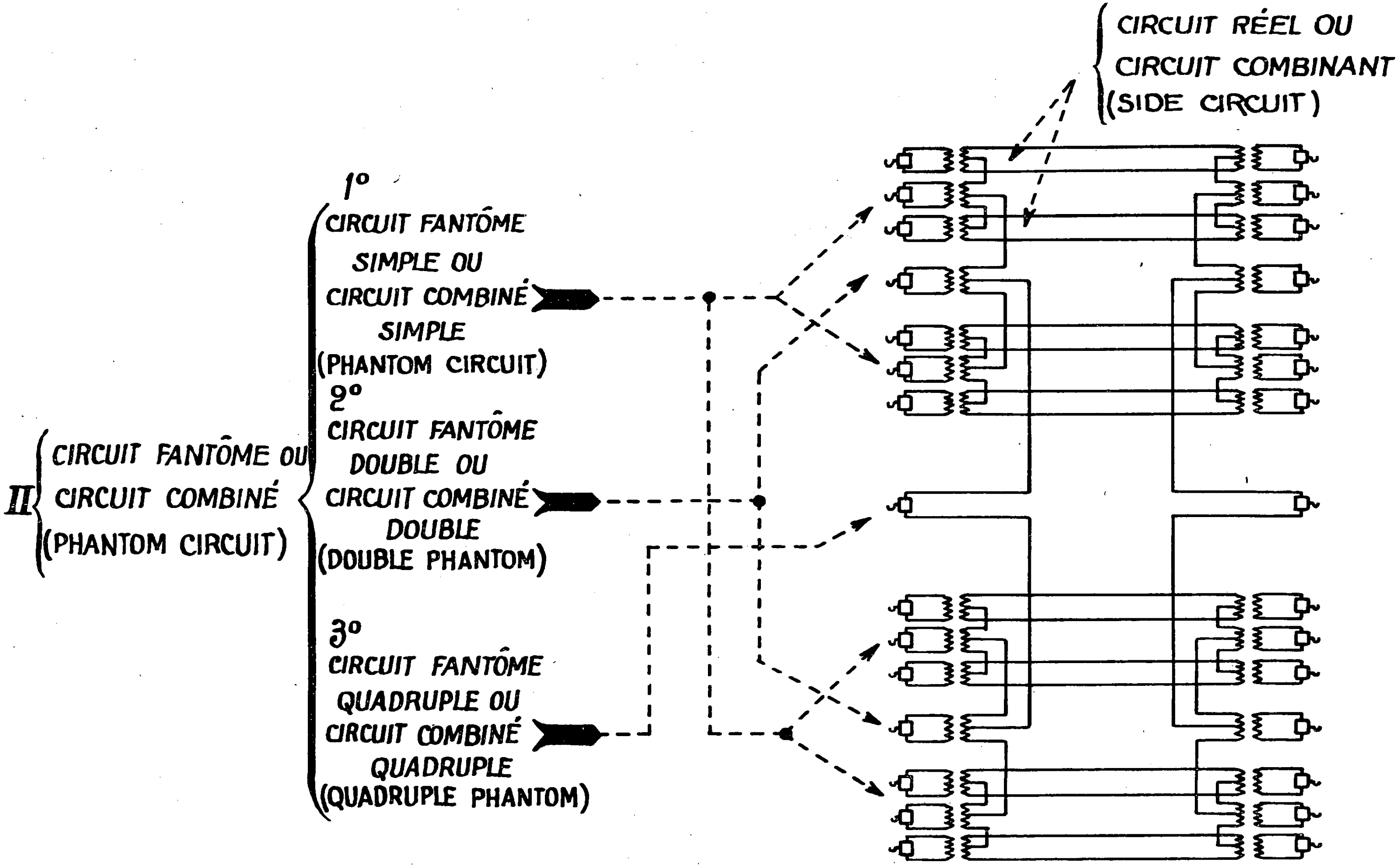
CIRCUIT RÉEL OU
CIRCUIT COMBINANT
(SIDE CIRCUIT)
II
CIRCUIT FANTÔME OU
CIRCUIT COMBINÉ
(PHANTOM CIRCUIT)
1°
CIRCUIT FANTÔME
SIMPLE OU
CIRCUIT COMBINÉ
SIMPLE
(PHANTOM CIRCUIT)
2°
CIRCUIT FANTÔME
DOUBLE OU
CIRCUIT COMBINÉ
DOUBLE
(DOUBLE PHANTOM)
3°
CIRCUIT FANTÔME
QUADRUPLE OU
CIRCUIT COMBINÉ
QUADRUPLE
(QUADRUPLE PHANTOM)

FIGURE 3

The capacity unbalance of a side circuit with respect to earth is the value of the capacity which, when connected between one of the wires of the pair and all the other conductors of the cable joined to the earthed sheath, corrects this unbalance, the two other wires of the quad being joined to the middle point of the ratio arms.

The capacity unbalance of a phantom circuit, with respect to earth, is the value of the capacity which, when connected between one of the two pairs of the phantom circuit and all the conductors of all the other quads of the cable joined to the earthed sheath, corrects this unbalance.

The sheath unbalance of a side circuit (or pair) in a quad in the outer layer is the value of the capacity which, when connected between one of the wires of the pair and the earthed sheath, corrects this unbalance, all conductors in other pairs being at the same potential as the two conductors of the circuit under test.

The sheath unbalance of a phantom circuit formed by a quad in the outer layer is the value of the capacity which, when connected between one of the pairs of the phantom circuit and the sheath, corrects this unbalance, the conductors of all quads in the cable being connected together and being at the same potential as the wires of the quad under test.

RECOMMENDATION G.542

SPECIFICATION OF LOADING COILS FOR LOADED TELECOMMUNICATION CABLES

The loading coils should be suitable for loading two side circuits and the phantom circuit. The coils used will be assembled so as to form a loading unit such that the introduction of this unit into a quad loads the two side circuits and the phantom circuit. The electrical conditions specified below apply to the side and phantom circuits of such a loading unit.

Magnetic materials used will be of the compressed powdered-iron type, or of other material having equally satisfactory characteristics.

a) *Loading pots*

The coils will be assembled in suitable protective cases (pots), which will be hermetically sealed. The cases should be watertight and be able to be buried in humid soil without deteriorating.

Suitable arrangements for easy connection of the loading units to the main cable will be provided.

b) *Magnetic stability*

The magnetic stability of the material of which the cores are made should be such that the change in the inductance of a coil is not more than ± 2% after passing through the winding corresponding to one wire of a direct current with a value from zero to two amperes. The maximum direct current should be applied for about five seconds. The measurement will be made five minutes after the current ceases to be applied. This test spoils the coils and should only be applied to samples.

c) *Inductance*

The inductance measured with a current of one milliampere, at a frequency of 1800 Hz, should be equal to the nominal value with the following tolerances:

1. For coils with an inductance not less than 22 millihenrys ± 1.5%

2. For coils with an inductance not less than 10 millihenrys and less than 22 millihenrys ± 2.0%
3. For coils with an inductance less than 10 millihenrys ± 3.0%

d) *Resistance*

The difference between the effective resistance and the direct-current resistance of the loading coils for side and phantom circuits, measured on a loading unit, should not exceed the following value, in order to avoid excessive attenuation distortion:

1. For telephone circuits used only for voice frequencies:

   125 ohms per henry.

2. For old-type programme circuits[1]:

   180 ohms per henry.

e) *Effective resistance*

The effective resistance of the loading coils for side and phantom circuits, measured as a loading unit, with a current of 1 milliampere, should not exceed the following value:

1. For telephone circuits used only to transmit audio-frequencies (ordinary telephony):

   200 ohms per henry at a frequency of 3400 Hz.

2. For old-type music circuits[1];

   300 ohms per henry at a frequency of 6400 Hz.

The additional resistance due to hysteresis h, measured at 800 Hz and expressed in ohms per milliampere per henry, should not exceed the values shown below:

1. For two-wire circuits not exceeding 200 kilometres:

$$h = 24 \sqrt{L} \text{ ohms/mA} \times \text{H.}$$

2. For two-wire circuits of 200 kilometres or more, as well as four-wire circuits used for audio-frequency transmission only:

$$h = 12 \sqrt{L} \text{ ohms/mA} \times \text{H.}$$

3. For old-type music circuits[1]:

$$h = 6 \sqrt{L} \text{ ohms/mA} \times \text{H.}$$

In these formulae, L is the inductance of the coil, expressed in henrys.

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[1] These are circuits specially set up for programme transmissions and which meet the requirements of Recommendation J.41.

f) *Crosstalk*

The crosstalk for the loading coils in cases will be measured with alternating current of 800 Hz and with a current of not less than 5 milliamperes. This test will be made under the following conditions:

The terminals of the loading coils will be closed with non-reactive resistances approximately equal to the characteristic impedance of the circuit in which these coils are to be connected.

The crosstalk attenuation between the different circuits in the same loading coil case should not be less than the values shown below:

Side-side	in the same loading unit	87 dB or 10 Np
Side-phantom	in the same loading unit	
Side-side	in different loading units	
Side-phantom	in different loading units	
Phantom-phantom	in different loading units	

g) *Dielectric strength*

A check of dielectric strength can be made using either a.c. or d.c.

A.c. tests. — The insulation between any two line windings shall be capable of withstanding a potential difference with an r.m.s. value of 500 volts. This test will be made with alternating current at a frequency not less than 50 Hz, the potential difference being applied suddenly.

Further, the insulation between any line winding and the case shall be capable of withstanding a potential difference of 2000 volts r.m.s. applied for two minutes.

The maximum value of the test voltage should never exceed by more than 10% the maximum value of a sinusoidal voltage having the same r.m.s. value.

D.c. tests. — The potential difference which the insulation shall withstand shall be 700 volts between any two line windings, and 2800 volts between any line winding and the case.

h) *Insulation resistance*

Insulation resistance measured between any winding of a loading unit and all the other line windings (in the same loading unit and in all the other loading units) and the case will not be less than 15 000 megohms. This test will be made with a potential difference not less than 100 volts and not greater than 500 volts, the temperature being not less than 15° C (approximately 60° F).

i) *Unbalance*

Capacity unbalance to earth. — The difference of capacity to earth of the loading coils of two pairs of the same quad should not exceed a value fixed provisionally at 100 pF.

Inductance unbalance. — The difference in inductance of the loading coils of the two pairs of the same quad—measured on the phantom circuit—should not, provisionally, exceed 0.25% of the inductance of the phantom circuit.

Resistance unbalance. — The difference in resistance of the loading coils of the two pairs of the same quad, measured with direct current and measured on the phantom circuit, should not, provisionally, exceed 0.20 ohm.

RECOMMENDATION G.543

SPECIFICATION FOR REPEATER SECTIONS OF LOADED TELECOMMUNICATION CABLE

a) *General*

The present specification lays down the principal electrical conditions which the repeater sections of the loaded cable should meet after laying, assuming that the cable lengths and loading coils meet the appropriate specifications.

The clauses of this specification have been revised to permit the use of phantom circuits in these cables and to obtain good-quality transmission on long-distance communication circuits with two- or four-wire repeaters.

The clauses below apply equally to four-wire and two-wire circuits, except where shown otherwise in the text.

b) *Resistance unbalance*

In any cable section between repeaters, the difference between the resistance of two conductors of any pair, measured with direct current, should not exceed three ohms for conductors having a diameter not exceeding one millimetre, and 2 ohms for larger conductors.

The difference between the resistances of the two pairs of any quad, measured with direct current, should not exceed 3 ohms for conductors having a diameter not exceeding one millimetre or 2 ohms for larger conductors.

The difference between the resistances of two pairs of any quad, the conductors of each pair being in parallel, should not exceed 4 ohms for conductors having a diameter not exceeding one millimetre, or 3 ohms for larger conductors.

c) *Dielectric strength*

If it is required to check the dielectric strength of a repeater section after laying, d.c. will be applied to the cable at a voltage equal to the r.m.s. a.c. test voltage for acceptance tests on factory lengths (see Recommendation G.541).

d) *Insulation resistance*

The insulation resistance measured at the end of the cable (excluding internal cabling) and between any conductor and all the other conductors connected to the earthed sheath should not be less than 10 000 megohms per kilometre, this insulation resistance being measured with a potential difference not less than 100 volts and not more than 500 volts, the readings being made after electrification for one minute at a temperature of 10°C (50° F).

e) *Uniformity of the average capacities of the loading sections*

For each group of side and phantom circuits of the cable, the average capacities of the different loading sections within the same repeater section should not differ by more than 2% from the average value of the measured capacity for the group of circuits considered, for all of the loading sections.

f) *Impedance balancing*

The relation between the impedance Z_{ct} of any side or phantom circuit and the impedance Z_{eq} of the corresponding balance, calculated from measurements of the average constants of the circuit, should meet the following conditions after measurement of the real and imaginary parts of the impedances Z_{ct} and Z_{eq}; the differences of these real and imaginary parts are expressed as a percentage d_r and d_i of the impedance Z_{eq} of the balance. If d_r and d_i are plotted as cartesian co-ordinates of a point, this point should, for all circuits and for any frequency in the frequency band to be transmitted effectively, be situated within a circle having a radius of 9% of Z_{eq}. Also points corresponding to 90% of the circuits and at all the preceding frequencies should be situated within a circle having a radius of 7% of Z_{eq}. The values of the regularity return loss corresponding respectively to the values above, 9% and 7% of Z_{eq}, are 27 dB or 3.1 Np and 30 dB or 3.4 Np.

g) *Crosstalk*

The values below show the maximum allowable crosstalk between any circuits in accordance with the above specifications, measured on a repeater section. These values are those which should be measured at the ends of the cable and do not include crosstalk other than that due to the cable and loading coils.

These numbers do not cover crosstalk arising from protectors, terminal transformers, repeater station cabling or equipment or from the cable terminating rack.

The crosstalk will be measured by voice tests or by using an objective method of measuring with alternating current (see the Annex to Recommendation G.134).

For these measurements the disturbing and disturbed circuits will be terminated with impedances equal respectively to the image impedances of the disturbing and disturbed circuit.

The following minimum figures are provisionally recommended for far-end and near-end crosstalk:

Near-end or far-end crosstalk between two-wire circuits in the same quad or in different quads:

61 dB or 7.0 Np.

Near-end crosstalk between four-wire circuits in quads transmitting in opposite directions:

65 dB or 7.5 Np.

Near-end or far-end crosstalk between a two-wire circuit and a four-wire circuit, or between a two-wire circuit and an *un*screened programme circuit:

1. With the two-wire circuit being the disturbing circuit,

65 dB or 7.5 Np.

2. With the two-wire circuit being the disturbed circuit:

61 dB or 7.0 Np.

Far-end crosstalk between four-wire pairs transmitting in the same direction:

65 dB or 7.5 Np.

Near-end or far-end crosstalk between an *un*screened programme circuit and a four-wire pair:

65 dB or 7.5 Np.

Near-end or far-end crosstalk between *un*screened programme circuits:

65 dB or 7.5 Np.

Near-end or far-end crosstalk between a *screened* programme circuit and any telephone pair:

1. With the telephone pair being the disturbing pair:

82 dB or 9.5 Np.

2. With the telephone pair being the disturbed pair:

65 dB or 7.5 Np.

Near-end or far-end crosstalk between *screened* programme circuits:

82 dB or 9.5 Np.

Note 1. — *Loading spacing.* — The nominal loading coil spacing in a repeater section shall be equal to the theoretical value within ± 2%. The actual loading coil spacing measured along a repeater section may differ by ± 10 metres from the nominal spacing.

Note 2. — *Cut-off frequency.* — The cut-off frequency of the different systems of loading applied to side and phantom circuits shall be determined from the following formula:

$$f_0 = \frac{1}{\pi \sqrt{LC}}$$

where

f_0 = the cut-off frequency in cycles per second;

L = the loading coil inductance in henrys;

C = the effective capacity of the cable pair between loading coils, in farads.

The above formula being intended for the rough classification of different types of loading for administrative purposes, there is little advantage in complicating this formula by making it more precise by taking into account the inductance of the cable pair between loading coils.

When greater accuracy is needed, it is necessary to determine by precise calculations the "attenuation/frequency" and "impedance/frequency" characteristics allowing for all the parameters of the cable and loading coils.

Note 3. — *Velocity of propagation.* — The nominal velocity is calculated from the formula:

$$v = \frac{s}{\sqrt{LC}}$$

v = nominal velocity in kilometres per second;
s = loading spacing in kilometres;
L and C being the constants as defined above.

Note 4. — *Characteristic impedance.* — The characteristic impedance of the side and phantom pairs is calculated from the following formula:

$$Z_c = \sqrt{\frac{L}{C}}$$

where Z_c = characteristic impedance (L and C being the constants defined above).

Note 5. — *Attenuation coefficient.* — The attenuation coefficient will be deduced from measurements made on a complete repeater section. If the repeater is not exactly in the middle of a loading section, the pair will be built out to a half-section.

ANNEX

(to Recommendation G.543)

Different methods of co-operation between two administrations or private operating agencies for the construction of a loaded cable section crossing a frontier

Given the difficulties which arise from the existence in certain countries of large networks and conditions which have necessarily to be met in the establishment of new cable projects, it is not practicable to standardize detailed characteristics of the make-up of cable circuits such as: loading coil spacing, conductor diameter, pairs, etc. (see the above recommendation).

Nevertheless, care must be taken to ensure that the general characteristics of the international telephone circuits to be set up should be as indicated above.

Where it is proposed to increase the gauge of the conductors, the C.C.I.T.T. points out that it is more difficult to achieve a uniform distribution of the line constants with heavy conductors. Thus, when it is necessary to increase the diameter of the conductors, in order to reduce the attenuation of a particularly long repeater section, it may be necessary to select a gauge such that the attenuation of the repeater section is less than its nominal value. In this way it is possible to use the circuit with lower gains and to obtain the same stability from the point of view of transmission as for a more usual type of circuit.

To ensure the satisfactory operation of the repeaters as well as to avoid reflection losses, it is desirable to have a uniform distribution of electrical constants throughout the repeater section. Cable circuits should be absolutely uniform between adjacent repeaters situated within the same country and the construction of the cables should be such that the circuits are perfectly balanced and the electrical constants of the circuits uniformly distributed.

It is mentioned in the above recommendation that, if the uniformity of the factory lengths is not sufficient to give adequate regularity in the loading sections of a repeater section, this regularity must be achieved as far as possible by a suitable allocation of factory lengths within the loading sections.

Precise rules have been given in this recommendation on the question of loading coil spacing. If, because of local conditions, the loading coil spacing is not uniform, special arrangements should be made.

For cable sections crossing a frontier, it may be necessary in certain cases to connect two cable sections not having the same specification; in fact, certain connections of the kind already carried out are giving good results.

Consequently, although uniformity is very desirable for the repeater section of an international cable crossing a frontier, the direct connection of two sections made to different specifications may be permitted, exceptionally, in certain cases and with the reservation that, for the section thus constituted, the conditions for matching of impedances described in the clause "Impedance matching" of the above recommendation (see Recommendation G.533, headed "Repeaters to be used at the junction of two cables with different characteristics") shall be respected.

The uniformity of repeater sections is of particular importance for circuits with 1.3 and 1.4 millimetre conductors; but because, for these circuits, the total capacity of the loading coil sections is very nearly the same for several common types of loading, there will be adequate uniformity if, in a complete repeater section, only one or other of the two kinds of loading coils is used, keeping the respective characteristics of the two types of loading as regards the equipment for the cable sections to be connected.

If it should happen that different types of loading are used by each of the countries concerned with a repeater section of an international loaded cable crossing a frontier, or that the methods of balancing are different (balancing by crosses or by capacitors), two cases have to be considered:

a) where two countries have adopted the same type of loading for their national network;

b) where two countries have adopted different types of loading for their national network.

In case a), the most satisfactory procedure technically and economically is to obtain the whole of the repeater section from the same contractor; it is always necessary to do this when there is less than a quarter of the length of the section in one of the countries, and this method is strongly to be recommended for all cases. An agreement could, however, be made if necessary so that the contract concluded by each country with the single supplier should be on the same technical basis.

In countries where the manufacture of the telephone networks by the national industry is considered as being of the first importance, this has the disadvantage that one of the countries has to accept that part of the cable on its territory should be of foreign origin. This disadvantage, however, seems of little importance because there are probably several cables connecting the two countries which could take it in turns to supply.

Such arrangements for the supply of cable sections are already in current practice when submarine cables are laid between two countries.

The advantages of this method are:

1. A better quality of transmission for the whole cable, because the different parts of this are more uniform;
2. A greater economy in manufacture;
3. The contractor will give to the two administrations or private operating agencies guarantees on the characteristics of the whole section.

If the two countries do not follow the above recommendations and each constructs the cable up to the frontier, it is then necessary to take special measures to ensure uniformity of construction; in particular the capacity and inductance standards used for measurements in the cable and loading coil factories must be compared and, above all, uniform spacing of the loading coils must be preserved.

When this is done, each contractor will naturally only guarantee the portion he has supplied, and the permissible variations of the electrical characteristics can give rise to a slight irregularity at the junction point. The magnitude of this irregularity will be variable and due mainly to differences in machines, to the extent of co-operation between manufacturers and to the position of the joint with respect to the ends of the repeater section.

In case b), the use of the same method of loading for the whole section must be recommended. The best solution is, as has been said above, to obtain the whole of the repeater section from the same contractor. If however, this solution is not possible on the grounds of national economy, the country with the shorter length of repeater section should adopt, exceptionally, the essential characteristics allowed in the other country for the pairs concerned: diameter of wires, capacity per kilometre, inductance of loading coils. If necessary, however, it is in order for four-wire pairs to have different gauge conductors on either side of the frontier.

Where two countries have different types of loading for their national networks, and where each country constructs its portion of the repeater to a common specification, this will cause one country to introduce in its network a portion of repeater section differing from its normal type. The resulting maintenance and construction difficulties are however not serious. The manufacturers are sufficiently masters of their technique not to find serious difficulty in making a cable having a capacity differing a little from the standardized capacity, and coils with an inductance differing from normal values. As far as maintenance is concerned, it should be noted that a minimum reserve of cable and loading coils generally permits maintenance over a period of years. Finally, it should be noted that, in the case of urgent necessity, it is possible to repair a cable with a short ength of cable of a different type and a loading coil case may be removed temporarily.

In all cases, it is desirable that in each country the last joint before the frontier should be in a manhole with easy access to allow localization of a fault to one or other of the countries.

The use of non-loaded cable sections may offer technical and economic advantages over loaded cables in certain special cases, e.g. for certain submarine cables; but non-loaded cable sections have only been used up to the present in international audio-telephony on a limited scale; in the absence of experience it is not possible to recommend at present the general use of non-loaded cables for the international telephone service. Nevertheless, in certain special cases, each of which should be specially studied (for example, when it is a question of submarine cables), it is possible to use, for international telephony, sections of non-loaded cable, providing the international circuits to be set up have general characteristics in accordance with the recommendations above.

RECOMMENDATION G.544

SPECIFICATIONS FOR TERMINAL EQUIPMENT AND INTERMEDIATE REPEATER STATIONS[1]

A. LINE TRANSFORMERS

This specification covers line transformers to be used on audio-frequency repeater circuits.

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[1] The specification for repeaters is covered by Recommendations G.531, G.532 and G.533.

General clauses

1. The transformer ratio should be such that, when the line transformer is connected to circuits for which it has been designed, the impedance measured at the ends of the office windings should be in accordance with recommendations dealing with the impedance of international and trunk circuits.

2. At audio-frequencies, a line transformer is specified in terms of its composite attenuation.

The composite attenuation of a normal line transformer (a transformer with a turns ratio less than 3), measured with a power of from 1 to 50 milliwatts, should not exceed 0.7 dB or 8 cNp for any frequency in the audio-frequency band effectively transmitted.

3. The transformers should be balanced as regards inductance, resistance and capacity, so that the crosstalk attenuation between the windings of side circuits and phantom circuits should be greater than 78 dB or 9.0 Np when these windings are terminated with balanced non-inductive resistances, representing the lines.

The arrangement of the different line transformers on the same rack should be such that the crosstalk attenuation between transformers of the different side and phantom combinations should be greater than 104 dB or 12 Np.

4. The insulation resistance between any two windings or between any winding and the case (or screen if used) should not be less than 500 megohms when measured with 100 volts direct current.

A check of dielectric strength can be made using either a.c. or d.c.

A.c. tests. — The dielectric strength between the line and office windings or between any winding and the case (or screen, if any) should be such that the windings will withstand the application of 500 volts a.c. at mains frequency.

When telephone lines and high tension electricity lines are in proximity, the dielectric strength between the two windings and between the line winding and the case (or the screen) should be such that the transformer will withstand the application of 2000 volts a.c. r.m.s. at mains frequency.

It should be able to withstand the application between the office winding and the case (or screen) of 500 volts a.c. r.m.s. at mains frequency.

D.c. tests. — The above limits become:

— 700 volts between the line and office windings,

— 700 volts between any winding and the case (or screen, if any),

— 2800 volts between the two windings and between the line winding and the case (or screen) when there is proximity between telephone lines and high-tension power lines,

— 700 volts between the office winding and the case.

5. The properties of the line transformers should not be changed appreciably for direct currents or alternating currents met with in practice.

Special clauses

6. *Transformers intended to be used in the line and balance circuits of a two-wire repeater*

In two-wire repeaters, when a transformer is included on the line side and another transformer on the balance side, these two transformers should be selected in pairs so that the impedances Z_1 and Z_2 of the windings measured at the repeater terminals at any frequency within the frequency band effectively transmitted satisfy the condition:

$$\left| \frac{Z_1 - Z_2}{Z_1 + Z_2} \right| \leq 0.02$$

under all conditions of current, temperature, etc., met with in practice.

When making the above measurements, the line and balance are replaced by resistances equal to the modulus of their nominal impedances.

7. *Transformers designed to transmit 16 to 50 Hz signalling current*

For these frequencies, a line transformer is characterized by its power ratio. To compare transformers, the power ratio is measured with the "line" side of the transformer closed with a pure resistance of 2000 ohms, and applying 45 ± 3 volts to the "office" side of the transformer. The power ratio should not be less than 55%.

In the above recommendation, it is assumed that the transformation ratio is 1 : 1. If the transformation ratio n is some other value, the resistance of 2000 ohms used to close the transformer should be replaced by a resistance equal to $\frac{2000}{n^2}$ ohms.

B. TERMINATING UNITS

1. This specification applies to four-wire terminating units incorporating a differential transformer.

2. The minimum value of the composite attenuation of the terminating unit, measured between the "input" and "output" terminals of the four-wire circuit, when they are closed with 600-ohm resistances (the "line" and "balance" terminals being also connected to 600-ohm resistances) at any frequency in the band of frequencies effectively transmitted, must be at least 61 dB or 7 Np; for the measurement, the capacitors of the termination should be short-circuited; if the capacitors are not accessible the limit of 61 dB is reduced to 52 dB or 6 Np.

However, these values need only be achieved when there is a likelihood that the terminating unit will be used in conjunction with a four-wire circuit extended by a long two-wire circuit including two-wire repeaters. For modern conditions, for terminating units connected between a four-wire circuit and a short unrepeatered two-wire extension, the acceptable value of composite attenuation, measured as indicated above, is 40 dB (4.6 Np) with the capacitors either connected or short-circuited, over the frequency range 300-3400 Hz.

3. The composite attenuation of the terminating unit in the direction from the four-wire to the two-wire side and vice versa should not exceed 4.8 dB (5.5 dNp), including the attenuation of any filter or similar device. In the case where the terminating unit and the filter are two distinct items, the limit for the attenuation of the terminating unit is reduced to 4.3 dB or 5 dNp.

4. The impedance, measured at the output of the terminating unit at the point where the circuit will be connected, should have the value recommended by the C.C.I.T.T. for the impedance of international circuits and repeaters, when the three other outlets are closed with pure resistances having the same value as the nominal impedance of the lines or repeaters with which the terminating unit will be used. It is desirable that these impedances should be as far as possible independent of frequency.

C. POWER SUPPLIES FOR REPEATERS

1. Since uninterrupted service must be ensured on international circuits, it is essential to provide power supply installations in such a way that interruptions to the normal supplies can be made good.

2. The whole power supply installation must be sufficiently free from disturbances.

If repeater stations are provided with direct current power supply installations (batteries, rectifiers) supplied by a different contractor from the one who supplies the repeaters, the administration concerned should make arrangements with the two contractors to ensure that this requirement is met.

3. The installation should be arranged so that variations in power supply voltages (heater supplies, anode supplies and grid priming supplies) do not exceed ± 2% of their nominal value. It is recommended that automatic regulation equipment be provided for this purpose.

D. AUDIO-CABLING IN REPEATER STATIONS

a) *Cabling between the cable head and the protectors, if any*, or between the cable head and the line transformers where there are no protectors.

Minimum breakdown voltage: 2000 volts (r.m.s. voltage applied for two seconds between the bunched conductors and the earthed sheath). The test will be made with 50 Hz a.c.

Insulation resistance: 600 megohm-kilometres between one conductor and all the others bunched and earthed, and connected to the metallic sheath, if any.

b) *Cabling between the protectors, if any,* or the line transformers, if not, *and the repeater racks.*

Minimum breakdown voltage: 500 volts (see the measuring conditions above). Insulation: 100 megohm-kilometres (see the measuring conditions above).

c) *Crosstalk due to cabling*

(See Recommendations G.531 and G.532.)

d) *Specifications*

(See Recommendation G.231, D.)

SECTION 6

CO-ORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY

6.1 Radiotelephone circuits

RECOMMENDATION G.611

INTERCONTINENTAL RADIOTELEPHONE SYSTEMS AND USE OF RADIO LINKS IN INTERNATIONAL TELEPHONE CIRCUITS [1, 2]

The C.C.I.T.T.,

considering

a) that radiotelephone systems connecting the various countries at the present time usually employ carrier frequencies under about 30 MHz [3];

b) that the use of such a radio link in a long-distance telephone circuit implies certain special conditions which introduce particular difficulties not encountered when purely metallic connections are used;

c) that such a radiotelephone circuit differs from a metallic circuit in the following ways:

c.1. such a radiotelephone circuit is subject to attenuation variation, with the special difficulty of fading;

c.2. such a radiotelephone circuit suffers from noise caused by atmospherics whose intensity may reach, or even exceed, a value comparable with that of the signal which it is desired to receive;

c.3. special precautions are necessary in the setting-up and maintenance of such a radiotelephone circuit so as to avoid disturbance of the radio receiver by any radio transmitter and especially by its own radio transmitter;

c.4. so as to maintain the radiotelephone link in the best conditions from a point of view of transmission performance, it is necessary to take special measures to ensure that the radio transmitter always operates so far as is possible under conditions of full loading whatever may be the nature and the attenuation of the telephone system connected to the radiotelephone circuit;

c.5. it is necessary to take measures to avoid or correct abnormal oscillation or crosstalk conditions;

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[1] See Section 1 above for the general characteristics of an intercontinental circuit comprising only land and/or submarine sections.

[2] Recommendation 335-1 of the C.C.I.R. All the C.C.I.R. Recommendations mentioned in Section 6 are contained in the "C.C.I.R. Documents of the XIth Plenary Assembly (Oslo, 1966), Volume III".

[3] Each time that the limit of 30 MHz is mentioned in the following text it should be taken to mean "about 30 MHz".

c.6. although the effectively transmitted frequency band recommended for international land-line circuits has been determined by a study of the requirements of the human ear, this band (in the case of a radiotelephone circuit operating at a frequency below 30 MHz) may be limited by the necessity to obtain the maximum number of telephone channels in this part of the radio-frequency spectrum and in order that each telephone channel shall not occupy a radio-frequency band larger than necessary;

c.7. in general, such a radiotelephone circuit is a long-distance international circuit giving telephone service between two extended networks, and this fact is of great importance from two points of view:

> c.7.1. international conversations, in general, are of great importance to subscribers and, also, they are made in languages which are not always the mother-tongue so that high-quality reception is particularly important;
>
> c.7.2. the public should not be deprived of a very useful service under the pretext that it does not always offer the quality desirable for long-distance communication;

unanimously recommends

1. *Circuits using frequencies above 30 MHz*

that, between fixed points, telephone communications should be effected wherever possible by means of metallic conductors or radio links using frequencies above 30 MHz so as to make the allocation of radio frequencies less difficult and, where this can be realized, the objective should be to attain the transmission performance recommended by the C.C.I.T.T. for international telephone circuits on metallic conductors;

2. *Circuits using frequencies below 30 MHz*

2.1 that, since it becomes necessary to economize in the use of the frequency spectrum when considering international circuits which consist mainly of single long-distance radio links operating on frequencies less than 30 MHz, it is desirable to use single-sideband transmission to the maximum extent possible, to employ a transmitted band less than 300 to 3400 Hz recommended by the C.C.I.T.T. for land-line circuits and preferably to reduce the upper frequency to 3000 Hz or below, but to not less than 2600 Hz except in special circumstances;

2.2 that, although it will be necessary to tolerate large variations in noise level on such a radiotelephone circuit, every possible effort should be made to obtain minimum disturbance to the circuit from noise and fading by the use of such techniques as full transmitter modulation, directional antennae and single-sideband operation[1];

2.3 that, during the time that such a radiotelephone circuit is connected to an extension circuit equipped with echo suppressors, the intensity of disturbing currents should not be sufficient to cause frequent operation of the echo suppressor;

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[1] The C.C.I.R. indicates in its Recommendation 339-1 that the signal-to-noise ratio at audio-frequency (for an audio bandwidth of 3 kHz, the audio signal being measured with a vu meter) should be at least equal to 33 dB in the following cases:

- — a radiotelephone circuit with double-sideband modulation providing a commercial service of good quality,
- — a radio link with single-sideband modulation with 1 or 4 telephone channels.

2.4 that such a radiotelephone circuit should be provided with a feedback suppressor (voice-operated switching device—see Recommendation G.623) so as to avoid singing or echo disturbance on the complete circuit;

2.5 that such a radiotelephone circuit should be equipped with automatic gain control so as to compensate automatically, so far as possible, for the phenomenon of fading;

2.6 that the terminal equipments of such a radiotelephone circuit should be such that it may be connected, in the same way as any other circuit, with any other type of circuit;

2.7 that, in the cases where privacy equipment is used (see Recommendation G.624), this equipment should not appreciably affect the quality of telephone transmission;

2.8 that when suitable automatic devices are not provided, the circuit should be controlled as often as necessary by an operator in order to ensure optimum adjustment of transmitter loading, received volume and the operating conditions of the feedback suppressor (see Recommendation G.621).

Note. — Although the requirements contained in section 2 of the present recommendation are much less severe than those imposed on international land-line circuits, the objective remains to attain the same standards of telephone transmission in all cases. In view of this, it is desirable that the telephone systems connected to a radiotelephone circuit should conform to C.C.I.T.T. Recommendations referring to the general conditions to be met by international circuits used for (see Section 1 of this volume) land-line telephony especially in respect of equivalent, distortion, noise, echoes and transient phenomena.

Bearing in mind the recommendations contained in sections 1 and 2 of the present recommendation, it is desirable that in each particular case administrations and private operating agencies concerned should first reach agreement on how far the standards usually employed for international land-line circuits may be attained in the case considered. If the technique of paragraph 1 of this recommendation can be used, the objective should be to obtain as far as possible the characteristics recommended by the C.C.I.T.T. for international land-line circuits. Otherwise, the administrations and private operating agencies concerned should study the best solution from the point of view of both technique and economy.

RECOMMENDATION G.612

INTERCONNECTION OF TWO RADIOTELEPHONE CIRCUITS BY MEANS OF A FOUR-WIRE LAND-LINE CIRCUIT

The C.C.I.T.T.,

considering

that in a large number of cases it has been possible to join two radiotelephone circuits by means of a four-wire land-line circuit by connecting the three circuits in tandem without introducing any modification of the normal arrangements;

that, nevertheless, in other cases, particularly because of high radio noise or of noise produced on one of the extension circuits, this method has not given satisfactory results, particularly due to false operation of echo suppressors or of feedback suppressors;

unanimously recommends

that, when the normal method of direct connection of two radiotelephone circuits and an intermediate four-wire land-line circuit does not give satisfactory results, one of the following arrangements should be used which may give considerable improvement:

a) take out of circuit the feedback suppressors at the junction points of the intermediate land-line circuit and the radio links;

b) take out of circuit the echo suppressor on the trunk land-line circuit (this procedure will be facilitated when the two halves of the echo suppressor are at the ends of the circuit);

c) readjust the sensitivity of the blocking arrangements to a value so that they discriminate between noise and speech currents assumed to be at sufficiently different levels.

Note. — New technical methods are being studied to improve the operation of circuits in tandem. Many administrations have studied the use of methods of distant control of the blocking arrangements, either by auxiliary signals at a specific frequency or by the carrier itself.

6.2 Devices associated with radiotelephone circuits

RECOMMENDATION G.621

DEVICES FOR MEASUREMENT AND REGULATION OF SPEECH VOLUME

A. INSTRUMENT ENABLING THE TECHNICAL OPERATOR AT THE JUNCTION BETWEEN THE RADIO LINK AND THE METALLIC CIRCUIT TO MEASURE THE VOLUME

The C.C.I.T.T. *unanimously recommends*

1. that the instruments which it is desirable to install at the monitoring point of the technical operator depend upon the observations of instantaneous volume required at that point;

2. that the present practice is normally to use two different instruments which may be of different types. The first indicates peaks of instantaneous power (maximum impulse indicator, peak indicator, maximum amplitude indicator); the second follows the average volume variations (volume indicator or average impulse indicator). In this manner protection is given to the radio transmitter against too frequent overload (sometimes by an automatic limiter) and also the modulation of the radio transmitter is kept to its optimum value. It may be desirable in certain cases to employ the two types of apparatus simultaneously;

3. that it is possible to use a single instrument which integrates the power on the circuit during an interval of time equal to the maximum interval during which overmodulation does no harm. The constants of such an instrument may be chosen so that it can function

either as a peak indicator or a volume indicator (or average impulse indicator) as required. It is then possible to adjust the modulation so that the pointer only exceptionally exceeds a fixed limit;

4. that even though the use of long-distance radiocommunications does not require the unification of the characteristics of these various instruments, it is nevertheless very desirable to adopt, in the future, uniform characteristics for the instruments used by the different administrations and private operating agencies so as to make comparisons possible of the readings made at the extremities of the same direction.

It is desirable to conform to the information on this subject given in Recommendation P.52 (*White Book*, Volume V).

B. VOLUME REGULATORS

The C.C.I.T.T.,

considering

that it is desirable to ensure approximately constant loading of the radio transmitter during variations of volume from the talking subscriber,

unanimously recommends

that it is desirable to insert in international radiotelephone circuits (except short-distance circuits) at the junction of the land telephone network and a radiotelephone link, a manual or automatic volume regulator.

Regulators of this type are at present used by various administrations and private operating agencies and give satisfaction under working conditions.

The Annex below defines the essential functions which should be fulfilled by a relatively simple automatic volume regulator. The limits therein, which are given as an indication, correspond to regulators in service.

It may be desired to have a more perfect regulator which, in consequence, will be more complex.

ANNEX

(to Recommendation G.621)

Conditions which should be satisfied by an automatic volume regulator at the junction of the land telephone network and a radiotelephone link

An automatic volume regulator inserted at the junction of the land network and a radiotelephone link should as far as possible satisfy the following conditions (the numerical values are given as an indication).

1. *General conditions.* — The speed of adjustment of the gain and the other characteristics of the operation of the regulator should be such that it produces no appreciable reduction, either in the transmission quality, or the naturalness of the conversation, throughout the frequency band in which the regulator should function (250 to 2750 Hz).

2. *Static characteristics.* — An automatic volume regulator may be defined sufficiently by its steady-state characteristics (or static characteristics) and by the duration of the initial and final transit times.

The static characteristic (Figure 1) should be such that the regulator ensures a mean value of regulated volume at the output; for a variation of the order of 43.4 dB (5 Np) of the input volume, the output volume should vary less than ± 2.6 dB (± 0.3 Np).

Below this range of input signal the gain of the regulator should remain constant.

3. *Transient period.* — The initial and final transient periods of the regulator may be either different (case *a*) or equal (case *b*):

Case a. — The initial transient period of the regulator should be of the order of a fraction of the duration of a logatom in order that the apparatus adjusts itself rapidly to the following speech volume immediately after a period of silence.

The final transient period of the regulator should be of the order of several logatoms in order that the variations of volume, during the transmission of several consecutive syllables, should be constant and that the naturalness of the voice be thus respected.

Furthermore, in order to avoid the false operation of feedback suppressors, it is necessary that the gain of the regulator should not rise, during silent periods, above a pre-determined value.

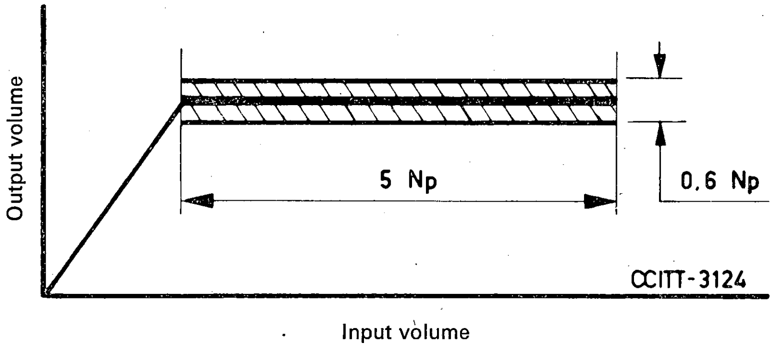

FIGURE 1. — **Static characteristic of an automatic volume regulator**

Case b. — When the initial and final transient periods of the regulator are equal, they should be of the order of the duration of several logatoms in order to respect the naturalness of the voice; but in this case, in order to avoid an overload of the radio transmitter at the start of a new speech period, it is necessary that, during silent intervals, the regulator should keep the same gain as it had when the subscriber ceased to speak.

4. *Sensitivity to noise.* — It is desirable that the regulator should be insensitive to extraneous noise. Thus, for example, the regulator might be rendered insensitive to frequencies outside the band from 600 to 2000 Hz.

It should be understood that the action of the regulating apparatus may be ineffective when noise conditions or fading are particularly unfavourable. In this case, it may be necessary to revert to manual operation.

RECOMMENDATION G.622

FADING CORRECTORS

The C.C.I.T.T.,

considering

1. that it is desirable to ensure approximately constant volume from the radio receiver connected to the land telephone network against variations in the volume of the received signal;

2. that fading of the output signal from the radio link depends considerably on the wavelength of carrier employed;

3. that the advantage of fading correctors for international radiotelephone circuits is limited for the moment to the case of short waves, to which in consequence this recommendation refers;

4. that the problem of maintaining constancy of the low-frequency output differs for the type of modulation used and that the present recommendation applies to the case of amplitude modulation, which is usually used in commercial radiotelephony;

5. that in the case of pronounced selective fading, the fading correctors considered in the present recommendation may not function satisfactorily and that other technical methods may then be necessary, notably the use of several aerials separated in space and the use of special radio receivers,

unanimously recommends

that fading correctors should have characteristics approaching the following:

1. *Steady-state regulation.* — For variations in high frequency input of about 52 dB or 6 Np, changes in volume at low frequency (i.e. audio) at the output of the receiver should not exceed ± 2.6 dB or ± 0.3 Np throughout the transmitted frequency band. This is generally obtained by variations of the potential of the valve grid of one or more controlled stages either by the rectified voltage of a single stage or by the rectified voltage of several separate stages applied separately.

2. *Time constant.* — The time constant of these instruments, for the initial transient period as well as for the final transient period should be capable of having several values between 0.1 second and 1 or 2 seconds or more.

It is desirable that the technical operator should have a switch enabling him to choose the most favourable value of the time constant at a given moment. In practice, a small number of steps (2 or 3) have been found sufficient.

3. *Attenuation distortion.* — The fading corrector should introduce only a negligible attenuation distortion at the output of the radio receiver.

RECOMMENDATION G.623

FEEDBACK SUPPRESSORS AND ECHO SUPPRESSORS

A. CLASSIFICATION AND CHARACTERISTICS OF VARIOUS TYPES OF FEEDBACK SUPPRESSORS [1]

a) *Classification*

The classification of the various types of feedback suppressors is based on the condition in which these devices place the circuits when idle, that is to say during the intervals of silence of both speakers.

Considering one end A of such a circuit AB and its two paths, transmission (E) and reception (R), it should first be noted that there is no need for the suppressors on both sides to be identical; and some circuits work perfectly well with apparatus constructed on different principles at A and B.

At one of these ends, there are the four following possible conditions during the idle periods:

1. Transmission and reception channels both open (ED and RD).
2. Transmission channel open and reception channel blocked (ED and RB).
3. Transmission channel blocked and reception channel open (EB and RD).
4. Transmission and reception channels both blocked (EB and RB).

The idle condition of the circuit may depend upon its condition prior to operation, i.e. the direction in which speech currents were last sent over the circuit; thus, during an interval of silence we have the following alternatives: caller A has just stopped talking, or he has just stopped listening (i.e. caller B has just stopped speaking). In either case, end A, in theory at least, may be in any one of the four conditions 1-4 indicated above.

We thus have 16 possible systems, which may be represented by the following 16 combinations, *in which the first figure* [2] represents the idle condition of end A when A has just stopped sending, and the second figure the idle condition of end A when A has just stopped receiving: 1-1, 1-2, 1-3, 1-4, 2-1, 2-2, 2-3, 2-4, 3-1, 3-2, 3-3, 3-4, 4-1, 4-2, 4-3, 4-4.

The four combinations 1-1, 2-2, 3-3, 4-4 correspond to systems in which the idle condition of the connection is independent of the condition prior to operation; these have been most used up to the present time.

Combination 2-3 applies to the case of a system in which the circuit when idle remains in the state in which it was placed by the last speaker.

There could also be a method of working in which the device corresponding to the inverse combination 3-2 would be of equal interest; in this case the cessation of speech by one caller prepares the link to send speech from the other. However, no system based on this principle is known.

At first sight, the ten other combinations do not appear to have any very interesting special peculiarities, and often even seem very illogical. At any rate, they have not been used as a basis for any device.

The case is otherwise for the 5 combinations 1-1, 2-2, 3-3, 4-4, 2-3, which all correspond to existing systems.

Combination 1-1 (both channels always unblocked when idle) has been used for certain minor radiotelephone connections with slight traffic (e.g. intercolonial connections).

Combination 2-2 (transmission channel open and reception blocked) includes, in particular, the principle of echo suppression called "suppressor-suppressor", in which the transmission channel is open and the reception channel attenuated during idle periods.

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[1] In C.C.I.R. Recommendation 75, it was thought unnecessary to classify feedback suppressors.

[2] Figures are used instead of letters to avoid confusion in different languages.

Classification of various types of feedback suppressors

Combination indicating the type of feedback suppressor	State of the connection when idle		Operations performed during working			Principles of operation	Examples of arrangements using these principles
	Transmit side	Receive side	Unblocking functions	1st blocking function	2nd blocking function		
1-1 (U)	D	D		RBE		Transmission and reception open (when idle) and transmission blocked (unilaterally) by the receive side	Connections of little importance and low traffic
1-1	D	D		RBE	EBR	Transmission and reception open (when idle) and blocked bilaterally	Connections of little importance and low traffic
2-2	D	B	RDR	RBE	EBR	Reception blocked (when idle) and blocked bilaterally	(Suppressor-suppressor)
3-3	B	D	EDE	RBE	EBR	Transmission blocked (when idle) and bilateral blocking	VODAS
4-4 (U)	B	B	EDERDR	RBE		Transmission and reception blocked (when idle) and blocking (unilateral) of the transmission by the reception	System considered in France
4-4	B	B	EDERDR	RBE	EBR	Transmission and reception blocked (when idle) and bilateral blocking	System used in France; American system called "positive control"
2-3	D or B	B or D	RDR or EDE	RBE	EBR	"Flip-flop" blocking	Differential control system used in Germany

Combination 3-3 (transmission channel blocked and reception channel open, during idle periods) covers one of the systems most in use, and is the principle of feedback suppressors like the (VODAS) "voice-operated device, anti-singing".

Combination 4-4 (both channels blocked during idle periods) has long been used on all the main French radiotelephone links. This also is the principle of the American systems described as having "positive control of switching-receiving equipment", such as CODAN (carrier-operated device anti-noise).

Finally the fifth combination, 2-3, has recently been used in an interesting manner in Germany (differential reaction suppressor).

The design of various types of feedback suppressors is very varied. The classification given above does not specify the design or the secondary characteristics. The C.C.I.T.T. considers that it is not necessary to give detailed nomenclature and it recommends the designation of the various types of feedback suppressors by a combination of two figures. In order to avoid confusion, the combination should be followed by the capital letter U (unilateral) when the feedback suppressor provides a unilateral blocking of the transmitting side by the receiving side.

b) *Essential characteristics of feedback suppressors of the type 3-3* (VODAS)

The essential characteristics of feedback suppressors of the type 3-3 (VODAS) which should be standardized for telephony use between fixed subscribers' stations are the following:

1. When there is no conversation the receiving channel is open and the transmitting channel is blocked.

2. When speech from the subscriber (in one country) begins, the receiving channel in the same country is first blocked, then the transmitting channel in the same country is freed and speech passes to the radio transmitter. When the speech stops, the transmitting channel is first blocked after an interval of about 120 milliseconds, and then the receiving channel is freed after only a short interval sufficient to ensure that transmitted speech radiated from the radio transmitter will not enter the receiving channel through a near-end echo path.

3. When received speech begins (following a sufficient interval of silence) the normal block on the transmitting channel is held and the normal free condition of the receiving channel allows the speech to pass to the subscriber. When received speech stops, the control over the block on the transmitting channel is removed after only a short interval, sufficient to ensure that received speech echoed from the land-line cannot actuate the transmitting channel.

4. The detectors that operate the VODAS relays are designed to discriminate against noise to mitigate false operation.

c) *Essential characteristics of feedback suppressors of the type 2-3*

The suppressor of the type 2-3 has the following characteristics:

1. In the idle condition the transmit channel is open for the subscriber who last spoke. When, for example, the subscriber in the other country spoke last the receive channel is open and the transmit channel is blocked.

2. When the subscriber who last spoke before the idle condition recommences to speak, his transmit channel remains open and the opposite channel is blocked to the speech voltages which are below (or not much above) those of the subscriber who is talking.

3. When the subscriber who was not the last speaker before the idle period starts to talk, the speech voltages unblock the new transmit channel with a sensitivity so great and a time of operation so short that the initial syllables are not appreciably cut. The opposite channel is blocked for lower (or not appreciably greater) speech voltages.

4. When the subscriber ceases to talk, the transmit channel remains open so that final syllables in a low voice are not suppressed. If the receive channel has been open, the transmit channel continues blocked for approximately 125 ms, in order that a possible echo of the last syllable shall not change the position of the suppressor in the extension circuit.

5. The suppressor operates only when the direction of conversation changes. In this manner unnecessary operation is avoided at the start and finish of the intervals of silence.

6. A subscriber might intercept by raising his voice if, at the other end of the radio link, a "flip-flop" suppressor is used.

7. If the case arises, a subscriber may overcome noise on the opposite channel (e.g. noise at the receiver) by raising his voice and thus unblocking his transmit channel.

8. The control circuits may be arranged so that they are influenced less by noise than by the voice. This selective operation may also be effected by automatic volume regulators adapted for this use.

Note. — The above classification may if required be added to if it appears that new types of feedback suppressors have been introduced into service. If so, their essential characteristics will be given at the end of this recommendation.

B. PROTECTION OF FEEDBACK SUPPRESSORS ON A RADIOTELEPHONE CIRCUIT

The C.C.I.T.T.,

considering

that for the protection against false operation by parasitic noise of feedback suppressors near the technical operator's position a measuring instrument is not always necessary, and that it is probably sufficient to have a simple peak indicator operating each time the feedback suppressor has been in action, following which the technical operator adjusts the gain;

considering nevertheless

that it may occasionally be found desirable in the case of feedback suppressors, and it will always be the case with echo suppressors on land-lines, to use measuring instruments,

unanimously recommends

that, to protect feedback suppressors on a radiotelephone circuit against false operation by noise, it is advisable to use a volume meter (volume indicator or impulse indicator whose characteristics are given in Recommendation P.52, *White Book*, Volume V), taking care that the characteristic, as a function of frequency, of this apparatus corresponds to that of the suppressor that it is intended to protect.

C. FALSE OPERATION (BY NOISE) OF FEEDBACK SUPPRESSORS OR ECHO SUPPRESSORS ON AN INTERNATIONAL TELEPHONE CONNECTION ROUTED ON RADIOTELEPHONE AND LAND-LINE CIRCUITS

In consequence of the improvement in radiotelephone circuits effected recently (particularly as regards noise), the false operation of echo suppressors or feedback suppressors connected on an international telephone circuit routed over radio and land-line sections is rare. Nevertheless, arrangements are now available to avoid false operation though feedback suppressors are no longer usual in practice on land-line circuits.

RECOMMENDATION G.624

PRINCIPLES OF THE DEVICES FOR ACHIEVING PRIVACY OF CONVERSATIONS[1]

The C.C.I.T.T.,

considering

1. that the devices referred to are intended for achieving privacy rather than secrecy of radiotelephone conversations;

2. that in the interests of maximum privacy, the details of the systems employed and of their performance should be agreed upon between the administrations or private operating agencies,

unanimously recommends

1. that the following statement in paragraphs a), b) and c), of principles and characteristics of the devices concludes the study of this subject for radio circuits operating on frequencies less than about 30 MHz;

2. that, for frequencies above about 30 MHz, the characteristics of systems to be used and their operation should be agreed upon by the administrations and private operating agencies concerned.

a) *Principles of the devices*

Two general types of systems are used for achieving "privacy" or "relative secrecy" of radiotelephone circuits operating on frequencies less than about 30 MHz as follows:
a.1. *For double-sideband systems.* — Inverter systems with or without wobbling of the carrier (i.e. rapid cyclic variation of the carrier frequency over a few hundred Hz), the speech band being inverted about a fixed frequency.

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[1] C.C.I.R. Recommendation 336-1 (with some differences in the order and numbering of paragraphs).

a.2. *For single-sideband and independent sideband systems.* — Band-splitting systems in which the speech band is subdivided into equal frequency bands, the speech components in the sub-bands being interchanged, with or without frequency inversion, and according to a pre-arranged repetitive sequence, to give "scrambled" speech. The process is reversed at the receiving terminal to re-form the speech signals. Accurate synchronization of the switching processes at the two terminals is required.

b) *Characteristics of the devices*

b.1. The band-splitting system provides superior privacy to that obtained with the inverter system, but for satisfactory operation it can tolerate less distortion such, for example, as is caused by selective fading on the radio link.

b.2. The apparatus is designed to reduce to a minimum attenuation distortion and the levels of unwanted products of modulation and of carrier signals. The extent of the permissible distortion due to the presence of the privacy devices is, in general, dependent on the type of privacy and is usually agreed between the administrations and private operating agencies concerned.

c) *Location of the devices*

To facilitate control and maintenance, and on the grounds of economy, the privacy apparatus is normally located at the point where the transmitting and receiving channels of a radiotelephone circuit are combined.

6.3 Links with mobile stations

RECOMMENDATION G.631

CONDITIONS NECESSARY FOR INTERCONNECTION OF MOBILE RADIOTELEPHONE STATIONS (FOR INSTANCE, AUTOMOBILES, AIRCRAFT AND SHIPS) AND INTERNATIONAL TELEPHONE LINES[1]

The C.C.I.T.T.,

considering

1. that the conditions concerning which international agreement is necessary appear to be few in number;

2. that these conditions, if met, would permit suitable interconnection between mobile radiotelephone stations and international telephone lines;

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[1] C.C.I.R. Recommendation 77-1.

unanimously recommends

1. that mobile radiotelephone circuits, intended for connection to international telephone systems, should terminate (on a two-wire basis, for the present at least) in such a way that they may be connected to international lines in the same manner as other land-line connections;

Note. — For information, if the termination is two-wire, it is desirable to refer to Recommendation G.123 concerning the impedance of trunk and international circuits. This recommendation states:

a) that for the impedance of two-wire circuits it is desirable to adopt the same nominal value as for the impedance of four-wire circuits;

b) that the nominal value of the impedance of four-wire trunk circuits (seen from the switchboard jack or from the selector banks) should be standardized at 600 ohms (preferred value) or 800 ohms in any one trunk exchange.

For a telephone connection to mobile radiotelephone stations terminating in four wires at the trunk exchange, reference should be made to the conditions fixed by the C.C.I.T.T. for the reflection coefficient at the junction between the four-wire repeaters and the four-wire line (Recommendation G.531)—namely, that the values of the impedance of the repeater, not including the line transformers, measured at the input and output terminals of the repeater at 800 Hz should conform to the value allowed by the C.C.I.T.T. for the impedance of international circuits.

The impedance of the repeater, excluding line transformers, will be approximately equal to that of the circuit to which the repeater is assumed to be connected such that the modulus of the return current coefficient:

$$\left| \frac{Z - W}{Z + W} \right|$$

should not be greater than 0.4 for the repeater input impedance and 0.6 for the repeater output impedance, Z being the impedance of the line (including the line transformer) and W the impedance of the repeater; these two values should not be exceeded for any frequency effectively transmitted.

2. that the mobile radiotelephone circuits should accept from and deliver to the land-line system, speech volumes conforming, as far as possible, to the C.C.I.R. and C.C.I.T.T. standards for connections to international circuits;

3. as regards the band of frequencies effectively transmitted by a telephone link having a mobile radiotelephone station, the ideal would be to have the same conditions as for international metallic circuits. (See Recommendation G.132.)

Even though the limitations on this point do not arise from terminal equipments, it should be considered that in the case of telephone connections with mobile radiotelephone stations using carrier frequencies below about 30 MHz there are limitations due, for example, to the necessity to obtain the maximum telephone channels in this part of the radio spectrum and this necessitates a restriction in the frequency band of the telephone channel; also there is the inevitable noise due to atmospherics and jamming.

The most important case in practice is that of radiotelephone stations on board ships; it is desirable that for these the frequency band transmitted should not be less than 300-2600 Hz.

The cases of mobile radiotelephone stations on motor vehicles, trains and aeroplanes should be reserved for the time being as there is little experience on the subject;

4. that noise arising from a telephone link having a mobile radio station should not be sufficient to cause false operation of echo suppressors or other apparatus on the national or international long-distance circuit forming part of the connection. As regards the false operation of echo suppressors, it should be remembered (Recommendation G.161) that the value recommended by the C.C.I.T.T. for the operating level (referred to zero relative level) of a terminal echo suppressor is −30 ± 6 dBm or −35 ± 7 dNm.

False operation of other apparatus should also be considered, particularly the calling or signalling equipment on long-distance circuits (national or international) forming part of a connection to a mobile radiotelephone station;

5. that in the case of mobile radiotelephone stations which may have to communicate with land stations in more than one country, consideration be given to the necessity for agreement as to a method of signalling for use between the land mobile stations (see C.C.I.R. Recommendation 257).

RECOMMENDATION G.632

ESSENTIAL CHARACTERISTICS OF VOICE-OPERATED DEVICES FOR SHIP STATIONS AND CARRIER-OPERATED DEVICES FOR SHORE STATIONS[1]

The C.C.I.T.T.,

considering

1. that the essential characteristics of the devices controlled by voice currents and acting on the carrier wave in radiotelephone stations on board ships and of the carrier-operated devices in receivers of coast stations are their "operate" and "release" times;

2. that the operate times of the devices should be short to minimize clipping, and their release times should be sufficiently long to enable the devices to remain operated in the intervals between words in normal speech,

unanimously recommends

a) that the operate and release times of the voice-operated carrier switching unit on the ship should be as follows:

Input level *(Note 1)*	Net operate time *(Note 2)*	Net release time *(Note 3)*
−30 dB	less than 25 ms	between 75 and 170 ms
−20 dB	less than 15 ms	between 75 and 170 ms

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[1] C.C.I.R. Recommendation 76.

b) that the operate time (Note 4) of the carrier-operated device in the coast station receiver should be as short as practicable, to allow somewhat longer operate times in the ship's apparatus and should not exceed 5 milliseconds when the carrier level at the input to the receiver is more than 1 dB above the level just necessary to operate the device. The required value of release time (Note 5) is dependent on several factors, including the time constant of the automatic gain control of the coastal radio receiver and a value between 10 and 50 milliseconds is generally suitable.

Note 1. — Input level. The level of a sinusoidal test signal of frequency corresponding to the middle of the voice-frequency range, relative to that producing 100% modulation.

Note 2. — Net operate time. The time which elapses between the instant the test signal is applied to the input to the modulator of the transmitter, and the instant when the carrier reaches 50% of its maximum amplitude.

Note 3. — Net release time. The time which elapses between the instant when the test signal is disconnected and the instant the carrier is reduced to within 5 dB of the maximum carrier suppression achieved.

Note 4. — Operate time of the carrier-operated device. The time which elapses between the sudden application of a test signal simulating the carrier wave from the ship and the instant of opening of the receiving channel (the instant when the attenuation of the receiving channel is within 5 dB of the final value of attenuation for the receiving condition).

Note 5. — Release time of the carrier-operated device. The time which elapses between the cessation of a test signal simulating the carrier wave from the ship and the instant of blocking of the receiving channel (the instant when the attenuation of the receiving channel is within 5 dB of the final value of attenuation in the blocked condition).

SECTION 7

DIGITAL TRANSMISSION SYSTEMS

RECOMMENDATION G.711 (Mar del Plata, 1968)

CHARACTERISTICS OF P.C.M. SYSTEMS

A. General

Considering that pulse-code modulation (p.c.m.) systems are already used in various countries, in particular to provide a large number of short-distance telephone circuits on certain pairs in existing cables, to minimize the number of different p.c.m. systems providing circuits which may be used in international connections,

The C.C.I.T.T. recommends that administrations concerned should make their choice among systems having characteristics conforming to those given in Section B below, until the appropriate studies undertaken by the C.C.I.T.T. are completed.

The study of the characteristics of the equipment covered in Section B and of equipments for other p.c.m. and digital systems is being carried out under Questions 1/D through 11/D.

B. Principal characteristics of p.c.m. primary block terminal equipments

The study of these characteristics is not yet complete. Further study is directed at choosing a single nominal value for each characteristic and specifying tolerances where necessary.

a) *Sampling rate for each analogue input*

The nominal value recommended is 8000 Hz.

b) *Number of quantized amplitudes*

Encoding must be based on 7 or 8 binary digits.

c) *Compression law*

Two basic laws are provisionally recommended: $A = 87.6$ and $\mu = 100$.

The definitions of these laws are as follows:

A characteristic

$$0 \leqq v \leqq V/A \quad y = \frac{Ax}{1 + \log A}$$

$$V/A \leqq v \leqq V \quad y = \frac{1 + \log (Ax)}{1 + \log A}$$

where $A = 87.6$

μ characteristic

$$y = \frac{\log (1 + \mu x)}{\log (1 + \mu)}$$

where $P = 100$

In these formulae: $x = v/V$ where v is the instantaneous input voltage;

$y = i/B$ V is the maximum input voltage for which peak limitation is absent;

i is the number of the quantization step starting from the centre of the range;

B is the number of quantization steps each side of the centre of the range.

d) *Load capacity*

The nominal values recommended are: + 2 or + 3 dBm0.

Table 1 shows the four combinations of compression laws, with their type of characteristic, and the load capacity (points b), c) and d) above) agreed to as the only combinations to be studied further by the C.C.I.T.T. for standardization purposes.

Type of law	Number of binary digits in the code	
	7	8
$A = 87.6$	Ⓦ 13 segments + 2 dBm0	Ⓧ 13 segments + 2 dBm0
$\mu = 100$	Ⓨ continuous + 3 dBm0	Ⓩ 31 segments + 3 dBm0

(The letters circled in the boxes are for ease of designation only.)

e) *Number of binary digits per time slot*

The number recommended is eight, regardless of the number of digits used for encoding (see b) above).

f) *Number of time slots per frame*

Either 24 or 32 time slots per frame must be used.

PART 2

SERIES H RECOMMENDATIONS

Lines used for the transmission of signals other than telephone signals, such as telegraph, facsimile, data, etc. signals [1]

Part 2 contains two classes of Recommendation [2]: those which define the characteristics of *transmission channels* (telephone-type, group, supergroup, etc. circuits) used only to transmit signals other than telephone signals, and those which define the characteristics of the *signals* used in such transmissions.

In this Part, "wideband" is used to qualify the transmission channels, and "wide-spectrum" the signals transmitted, so as to avoid any confusion between the transmission channels and the signals transmitted with regard to the frequency bands involved in transmission over group links, supergroup links, etc.

So far as possible, one should avoid specifying the characteristics of particular channels or signals in defining a new service and refer only to the characteristics of the channels mentioned in Section 1 of Part 2.

In fact, the Recommendations in Sections 2, 3 and 4 still include such specifications for each service. A question on the extent to which such details may be omitted is under study.

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[1] Excluding the transmission of programme and television signals, which is the subject of Series J Recommendations.

[2] This change in the plan of Part 2, decided on at Mar del Plata in 1968, has led to a change in the numbering of the Recommendations:
Recommendations H.11 to H.15 are new.
Recommendation H.21 in this volume replaces the former Recommendation H.11 (Volume III, *Blue Book*).
Recommendation H.22 replaces former Recommendations H.13, H.14 and H.15.
Recommendation H.23 replaces former Recommendation H.12.
Recommendations H.31 to H.33 reproduce former Recommendations H.21 to H.23.
Recommendations H.41 and H.42 reproduce former Recommendations H.31 and H.32.
Recommendation H.51 replaces former Recommendation H.41.
Recommendations H.52 and H.53 are new.

SECTION 1

CHARACTERISTICS OF TRANSMISSION CHANNELS USED FOR OTHER THAN TELEPHONE PURPOSES

RECOMMENDATION H.11 (Mar del Plata, 1968)

CHARACTERISTICS OF CIRCUITS IN THE SWITCHED TELEPHONE NETWORK

The characteristics of these telephone circuits, when of modern type, are in conformity with Recommendations G.151, G.152 and G.153. Audio-frequency circuits, the characteristics of which are in accordance with Recommendations G.124, G.511 and G.543, may also be found.

Some information on the characteristics of communications established in the switched telephone network are given in Supplements No. 4.1 and 4.3 in Volume IV, *White Book.*

RECOMMENDATION H.12 (Mar del Plata, 1968)

CHARACTERISTICS OF TELEPHONE-TYPE LEASED CIRCUITS

A. ORDINARY TELEPHONE-TYPE CIRCUITS

These circuits have the same characteristics as those of the switched telephone network (Recommendation H.11). However, since the circuits do not go through automatic switching equipments, the impulsive noise may be much weaker and the attenuation distortion slightly less.

B. SPECIAL QUALITY TELEPHONE-TYPE CIRCUITS

a) *Attenuation-distortion*

The limits for the transmission loss relative to that at 800 Hz for the circuit between renters' premises are given in Figure 1.

Attenuation distortion equalizers (perhaps with routing restrictions) may be needed to meet these limits.

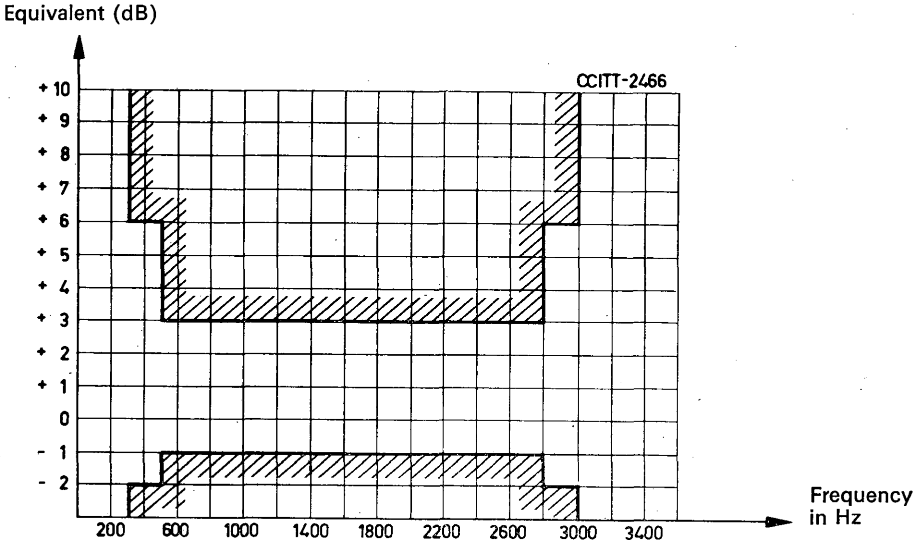

FIGURE 1. — Admissible variation of the equivalent as a function of frequency for special quality telephone-type circuits

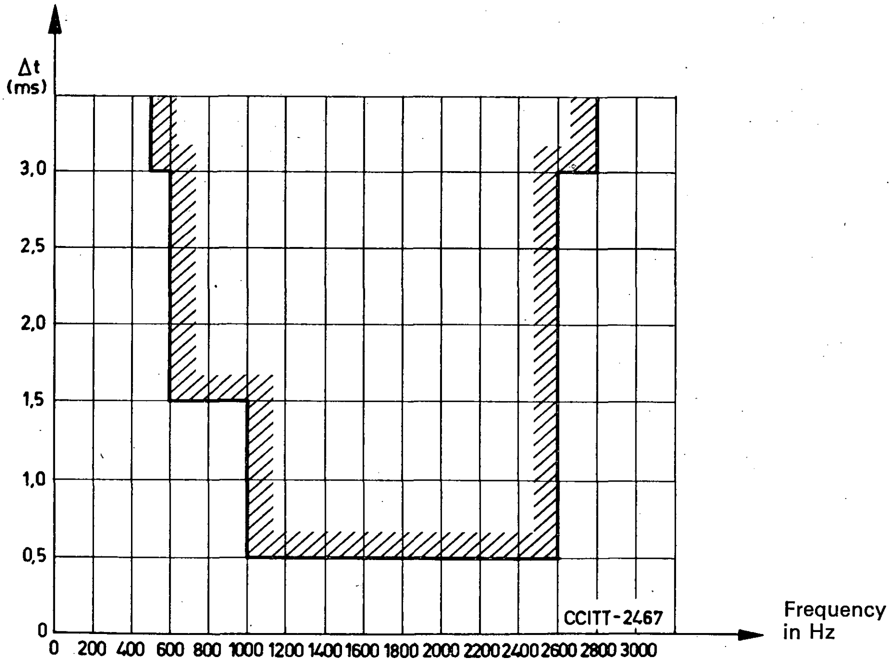

FIGURE 2. — Admissible variation of overall phase distortion with frequency for special quality telephone-type circuits

b) *Group-delay distortion*

Only some of the types of non-speech transmission require limits to be placed on group-delay distortion. It should therefore always be verified whether limits concerning group-delay distortion are necessary. When it is necessary to equalize the group-delay distortion, the limits that should apply are those given in Figure 2, in which the limiting values over the frequency band are expressed as values relative to the minimum measured group delay.

Note. — These values could be reconsidered when Question 36/XV is studied.

c) *Variation with time of the transmission loss at 800 Hz*

The variation with time of the overall transmission loss at 800 Hz should be as small as possible but should not exceed the following limits:

Short-term variations (over a period of a few seconds)	± 3 dB
Long-term variations (over long periods, including daily and seasonal variations)	± 4 dB

d) *Circuit noise*

1. *Basic noise*

The nominal level of the psophometric noise power at a renter's premises depends upon the actual constitution of the circuit, in particular upon the length of frequency-division multiplex carrier systems in the circuit. A typical mean noise power rate is 4 pW/km which for 2500 km can be expected to give rise to a psophometric noise power level of −50 dBm0p or −5.7 Nm0p. From such information an estimate of the signal/noise ratio can be made. (The absolute noise-power level measured at a renter's premises will depend on the transmission loss of the lines and apparatus connecting the renter to the carrier circuit-section.)

2. *Quantizing noise*

If any circuit-section is routed over a pulse code modulation system, the signal will be accompanied by quantizing noise giving rise to signal/quantizing noise ratios of, for example, 30 dB or 3.5 Np.

3. *Impulsive noise*

The impulsive noise requirements for non-speech transmission and the method of measurement are under study.

The apparatus for measuring impulsive noise on telephone-type circuits is specified in Recommendation H.13.

e) *Error on the reconstituted frequency*

The difference between an audio-frequency transmitted at the origin of a circuit and the frequency reconstituted at the end should not exceed 2 Hz (see Recommendation G.225 a)).

RECOMMENDATION H.13 (Mar del Plata, 1968)

CHARACTERISTICS OF AN IMPULSIVE-NOISE MEASURING INSTRUMENT FOR TELEPHONE-TYPE CIRCUITS[1]

Considering

that impulsive noise is of interest to data transmission and telegraphy and that first consideration should be given to a simple pulse counter suitable for field use,

the C.C.I.T.T. *unanimously declares the view:*

that the instrument for impulsive noise measurement should have the following characteristics:

a) It should register a count whenever the voltage applied at the input exceeds an adjustable threshold.

b) It should operate independently of the sense (or polarity) of the applied impulse.

c) The nominal input impedance should be 600 ohms within the range of 200 to 3400 Hz or a switchable high impedance giving a bridging loss not exceeding 0.1 dB. The input circuit should be balanced in relation to earth, with a degree of balance such that a pulse whose level is 60 dB higher than the threshold, applied between the mid-point of the source impedance and the earth terminal of the instrument, should not operate it.

d) The threshold should be adjustable in steps of 3 dB (with a tolerance of ± 0.5 dB) from −50 dB to 0 dB with respect to 1.1 volt, which is the peak voltage of a sine wave having a power of 1 mW in 600 ohms. The thresholds for the two polarities should be within 0.5 dB of each other.

e) After the instrument has been calibrated against a 1000-Hz sine wave signal at a level of 0 dBm and with the weighting control network in the "flat" condition, rectangular pulses of either polarity, of 50 milliseconds duration, having a peak amplitude of 1.1 volt, and with an interval between pulses in excess of the operating time of the counter (dead-time, see f)), shall be applied to the input of the instrument and shall cause the counter to operate at the correct rate. When the operating level control is set at −1 dBm, and the duration of these pulses is gradually reduced, the counter shall count at the correct rate when the pulses have a duration of 50 microseconds but shall not count when the pulses have a duration of 20 microseconds.

f) Dead-time is defined as the time after which the counter is ready to register another pulse after the start of the preceding pulse. Several values for this dead-time have been proposed. Whatever range of values may be adopted for a particular instrument, the value of 125 ± 25 milliseconds should be provided in all cases.

g) In the flat bandwidth condition, the response should be within ± 1 dB in the frequency range 275 Hz to 3250 Hz. Outside this range, the response curve should be compatible with the sensitivity requirement (clause e) above).

The instrument may provide other optional bandwidths.

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[1] This instrument can be used to check whether a circuit is suitable for data transmission or v.f. telegraphy; it can also be used to assess the disturbing effect of impulsive noise on telephone conversations (Recommendation P.55, Volume V of the *White Book*).

h) To enable the instrument to be used for other than maintenance measurements, it should be so designed that external filters may be added.

One of these filters shall have the following characteristics:

3 dB points at 600 Hz and 3000 Hz,

Characteristic from 750 Hz to 2300 Hz flat to within ± 1 dB;

Response to fall off at about 18 dB per octave:

— below 600 Hz,

— above 3000 Hz.

i) Calibration should be possible from the peaks of a 1-mW standard test tone.

j) A built-in timer, continuously adjustable from 5 to 60 minutes, should be provided. Significant testing intervals will be 5, 15, 30 and 60 minutes.

k) All the preceding clauses shall be satisfied when the ambient temperature varies between ± 10 °C and ± 40 °C.

l) The capacity of the counter shall be at least 999.

ANNEX

(to Recommendation H.13)

Use of the impulsive noise counter for data transmission

1. Levels should be expressed in dBm0, because a) the difference between the various national transmission plans is taken into account and b) the level value is related to the value of data signal level to a close degree.

Bearing in mind the following two points:

- that Recommendation V.2 demands a maximum data signal level of -10 dBm0 for a simplex transmission; and -13 dBm0 for duplex transmission;
- that there has been considerable experience of using the thresholds -18 dBm0 and -22 dBm0;

the threshold settings should be -18 dBm0 for the telephone-type circuit and 21 dBm0 for the special quality circuits mentioned in Recommendation H.12, the standard measuring instrument being adjustable to thresholds 3 dB apart.

Owing to lack of experience, no external filter should be used for present maintenance purposes.

However, the study of the use of external filters should continue; one of these filters should be the one described in point h) of Recommendation V.55; the United Kingdom Administration uses an impulse counter that also includes a filter having the following characteristics:

3 dB points at 300 Hz to 500 Hz

Response falling off at about 18 dB per octave:

— below 300 Hz,

— above 500 Hz.

At the time of measurement, the line should be terminated at both ends by impedances of 600 ohms. The modem may be used for this purpose if it complies with this impedance.

2. For counting the number of impulses, the instrument shall be used in the “flat” bandwidth condition.

On a leased circuit, the admissible limit should be 70 impulse counts per hour; but in realising that error rate measurements are conducted for periods of 15 minutes each, the recommended maintenance limit should be 18 counts in 15 minutes for leased circuits. The measurements should be made during peak hours.

3. For the general switched telephone network, there should be no recommended maintenance limits for impulse counts, but the instrument might be useful as a diagnostic aid at the discretion of the administration. This is because the impulse count results taken on any one connection vary considerably with time and even greater differences appear between various connections.

4. The correlation between the bit error rate and the number of impulsive counts thus determined has not yet been established.

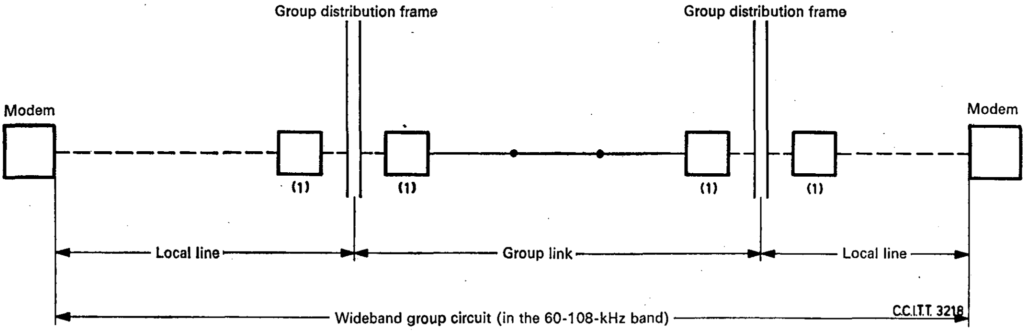
RECOMMENDATION H.14 (Mar del Plata, 1968)

CHARACTERISTICS OF WIDEBAND GROUP CIRCUITS FOR THE TRANSMISSION OF WIDE-SPECTRUM SIGNALS (DATA, FACSIMILE, ETC.)

A. GENERAL

A wideband group circuit is composed of one or more group sections in tandem, generally prolonged at each end by "local lines". These local lines connect the group distribution frames of the terminal repeater stations with the equipment for sending and receiving wide-spectrum signals (modems, etc.), which may be situated either in the station itself or at the subscriber's premises or in another place. In the latter case they are normally connected to the local telephone cable network, or sometimes a special cable line or a radio-relay link. A "wideband group circuit" includes these local lines only in the case when the signals transmitted over it occupy all or part of the 60-108-kHz frequency band. It also comprises any supplementary equipment for equalizing, filtering, etc., in the 60-108-kHz band, but not the terminal equipment (modems, etc.). Figure 1 illustrates these considerations.

The characteristics of the present recommendation apply to a wideband circuit as defined, which may be specially corrected (chiefly as regards group delay) or not.



(1) Equalizers, filters, etc. These equipments may be situated on either side of the distribution frame.

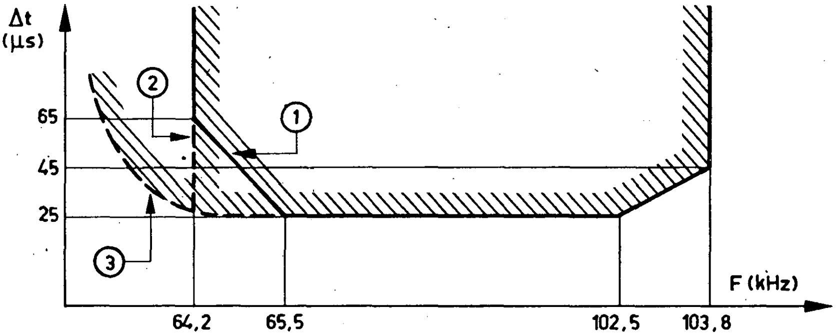
FIGURE 1. — **Component parts of a wideband group circuit**

B. PROVISIONAL CHARACTERISTICS OF CORRECTED WIDEBAND GROUP CIRCUITS

It is assumed that there are not more than two sections in tandem and not more than two through-group filters corrected with regard to group delay, the group-delay distortion of each through filter being less than 10 microseconds in the 64.2-103.8 kHz band. It is also assumed that the group and supergroup pilots at 104.08 kHz and 547.92 kHz are used and that they are blocked at the end of the link by filters with reduced group-delay distortion in the 64.2-103.8 kHz band.

a) *Group-delay distortion*

The group-delay distortion of such a circuit, between modems, is shown in Figure 2. To respect these limits, it may be necessary to avoid using groups 1 and 5.

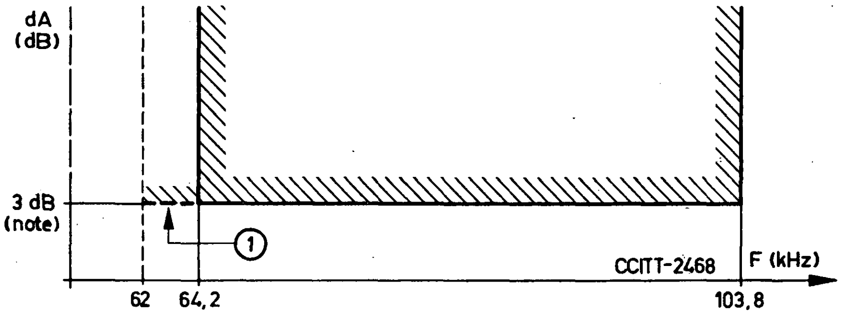


① = Circuit including one group 5 section
② = Circuit without any group 5 section
③ = Between 62 and 64.2 kHz, the characteristics may be fixed by agreement between administrations (circuit without any group 5 section).

FIGURE 2. — **Maximum group-delay distortion in a corrected wideband group circuit**

b) *Attenuation distortion*

The attenuation distortion of such circuits, between modems, is shown in Figure 3.



① = Between 62 and 64.2 kHz, the characteristics may be fixed by agreement between administrations (circuit without any group 5 section).

Note. — A lower value (for example, 1.5 dB) may be obtained in simple routings.

FIGURE 3

c) *Carrier leaks*

The leak from any carrier in the wanted band should not exceed —4.6 Nm0 (—40 dBm0). This value is provisional and may be incompatible with the pertinent value specified in Recommendation G.223 j) for a single modulation stage.

This point is the subject of a question under study.

C. PROVISIONAL CHARACTERISTICS OF NON-CORRECTED WIDEBAND GROUP CIRCUITS OF COMPLEX CONSTITUTION

(Question under study)

RECOMMENDATION H.15 (Mar del Plata, 1968)

CHARACTERISTICS OF WIDEBAND SUPERGROUP CIRCUITS FOR THE TRANSMISSION OF WIDE-SPECTRUM SIGNALS (DATA ETC.)

The characteristics of these circuits are still under study.

The following values may be indicated provisionally:

a) *Group-delay distortion*

The group-delay distortion in the 330-550-kHz band could be limited, after correction, to 5 microseconds, the distortion in each corrected through-supergroup filter being less than 3 microseconds.

b) *Carrier leaks*

The leak from any carrier in the wanted band should not exceed —4.6 Nm0 (—40 dBm0). This value is provisional and may be incompatible with the pertinent value specified in Recommendation G.223, j) for a single modulation stage.

This point is the subject of a question under study.

SECTION 2

USE OF TELEPHONE-TYPE CIRCUITS FOR VOICE-FREQUENCY TELEGRAPHY

RECOMMENDATION H.21 (Mar del Plata, 1968)[1]

COMPOSITION AND NOMENCLATURE OF INTERNATIONAL VOICE-FREQUENCY TELEGRAPH SYSTEMS

Figure 1 illustrates the composition of an international voice-frequency telegraph system and the nomenclature used.

a) *The international voice-frequency telegraph system*

This is the whole of the assembly of apparatus and lines including the terminal voice-frequency telegraph equipment. In Figure 1 the system illustrated provides 24 duplex international telegraph circuits, but other numbers of telegraph circuits can be provided.

b) *The international voice-frequency telegraph link*
(sometimes referred to as the bearer circuit)

1. Four-wire telephone-type circuits are used for voice-frequency telegraph links. The link comprises two unidirectional transmission paths, one for each direction of transmission, between the terminal voice-frequency telegraph equipments.

2. The voice-frequency telegraph link consists of an international telegraph line together with any terminal national sections connecting the international telegraph line to the voice-frequency telegraph terminal equipment and may be constituted entirely on carrier channels (on symmetric pair, coaxial pair or radio-relay systems) or on audio-frequency lines or combinations of such lines.

3. The normal links for voice-frequency telegraphy have no terminating units, signalling equipment or echo suppressors.

c) *The international voice-frequency telegraph line*

1. The international voice-frequency telegraph line may be constituted by using a channel in a carrier group or channels in tandem on a number of groups. National and international sections can be interconnected to set up an international telegraph line. See Figure 1, but note that sub-paragraph c.2) details the preferred method.
The international telegraph line could equally well be set up between, for example, only A and C or between C and D, in which case A and C, or C and D would be the terminal international centres.

2. Wherever possible an international telegraph line for a voice-frequency telegraph link should be provided on channels of a single carrier group, thereby avoiding interme-

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[1] Replaces former Recommendation H.11 (Volume III of the *Blue Book*, Geneva, 1964).

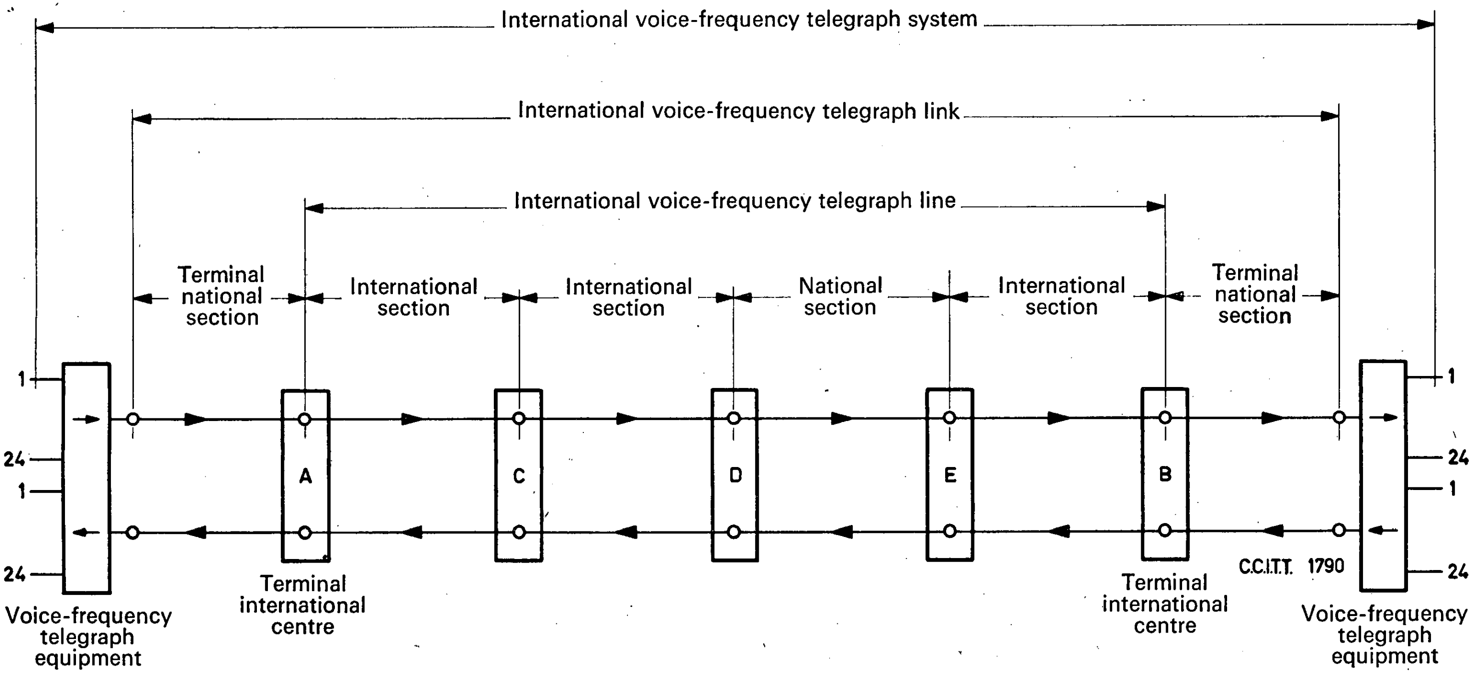

FIGURE 1. — **The components of an international voice-frequency telegraph system**

(at the intermediate centres C, D and E and at the terminal international centres A and B, the signals transmitted are at audio frequencies. At these points it is possible to make measurements.)

diate audio-frequency points. In some cases, such a group may not exist or, for special routing reasons, it may not be possible to set up the international telegraph line in the preferred way. In such cases, the international telegraph line will consist of channels in tandem on two or more groups with or without audio sections, depending on the line available and the routing requirements.

d) *Terminal national sections connected to the international telegraph line*

In many cases the voice-frequency telegraph terminal equipment is remote from the terminal international centre of the international telegraph line (Figure 1), and such cases necessitate the provision of terminal national sections in order to establish international voice-frequency telegraph links. These sections may be in short-distance local audio cables, amplified or unamplified, or may be routed in long-distance carrier groups or amplified audio plant as available.

RECOMMENDATION H.22 (Mar del Plata, 1968) [1]

TRANSMISSION REQUIREMENTS OF INTERNATIONAL VOICE-FREQUENCY TELEGRAPH LINKS (AT 50, 100 AND 200 BAUDS)

A. LINKS ROUTED ON CARRIER SYSTEMS

a) *Nominal insertion loss at 800 Hz*

The nominal insertion loss of the link at 800 Hz depends on the nominal relative power levels at the extremities of the telegraph link. These levels will be those normally used in the national network of the countries concerned so that it is not possible to recommend a particular nominal value for the insertion loss.

The nominal relative power level at the input to the link and the absolute power level of the telegraph signals at this point must be such that the limits concerning the power level per telegraph channel at a zero relative point on carrier systems are respected.

b) *Variation of insertion loss with time*

1. The mean value of the departure from nominal of the insertion loss with time should not exceed 1 dB (1.2 dNp).

2. The standard deviation of the variation of insertion loss should not exceed 1.7 dB (2 dNp).

With such values the probability of the received level falling outside the working range of the telegraph terminal equipment is very slight (see Recommendation R.31, *Blue Book*, Volume VII).

c) *Sudden variations of insertion loss and short interruptions*

Such defects of the transmission path spoil the quality of the telegraph transmission and should be reduced to the minimum possible.

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[1] Replaces former Recommendations H.13, H.14 and H.15 in Volume III of the *Blue Book* (Geneva, 1964).

d) *Insertion-loss frequency distortion*

The variation with frequency of the 600-ohm insertion loss of the link with respect to the loss at 800 Hz must not exceed the following limits:

1. *Links with 4-kHz sections throughout*

Frequency range, Hz	Insertion loss relative to that at 800 Hz	
Below 300	Not less than −2.2 dB (−2.5 dNp); otherwise unspecified	
300- 400	−2.2 to + 4.0 dB	−2.5 to + 4.5 dNp
400- 600	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
600-3000	−2.2 to + 2.2 dB	−2.5 to + 2.5 dNp
3000-3200	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
3200-3400	−2.2 to + 7.0 dB	−2.5 to + 8.0 dNp
Above 3400	Exceeding or equal to −2.2 dB (−2.5 dNp); upper limit unspecified	

These limits are shown in Graph No. 5 of Figure 1.

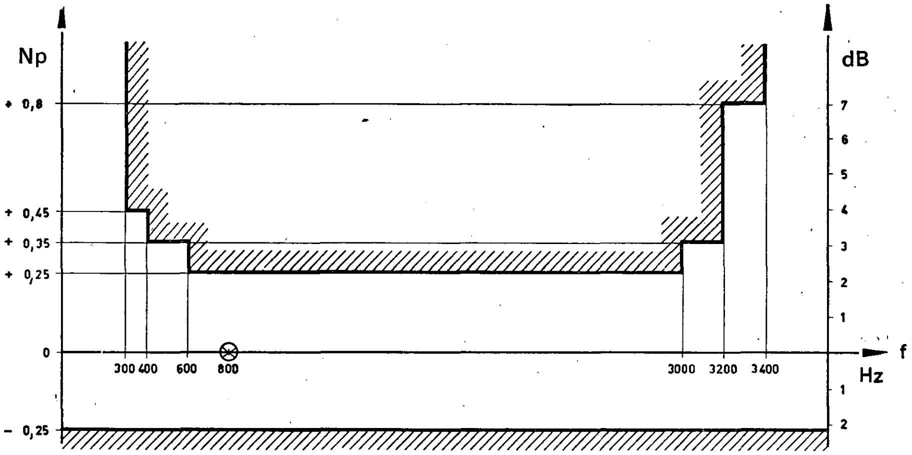

FIGURE 1. Graph No. 5. — **Variation with frequency of the overall loss relative to the value measured at 800 Hz with 4 kHz end-to-end sections**

f = frequency (Hz)

N = variation of equivalent (nepers)

Note. — The curve of variations of equivalent with frequency should lie between the hatched lines. The value at 800 Hz, according to the *Maintenance Instructions* (*White Book*, Vol. IV) is brought as near as possible to its nominal value.

2. *Links with one or more 3-kHz sections or with a mixture of 3- and 4-kHz sections* [1]

Frequency Hz	Overall loss relative to that at 800 Hz	
Below 300	Not less than −2.2 dB (−2.5 dNp); otherwise unspecified	
300- 400	−2.2 to + 4.0 dB	−2.5 to + 4.5 dNp
400- 600	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
600-2700	−2.2 to + 2.2 dB	−2.5 to + 2.5 dNp
2700-2900	−2.2 to + 3.0 dB	−2.5 to + 3.5 dNp
2900-3050	−2.2 to + 6.5 dB	−2.5 to + 7.6 dNp
Above 3050	Not less than −2.2 dB (−2.5 dNp); otherwise unspecified	

Links with one or more 3-kHz sections

Frequency range, Hz	Insertion loss relative to that at 800 Hz	
Below 300	Not less than −0.5 dB (0.6 dNp); otherwise unspecified	
300-2700	−0.5 to + 1.0 dB	−0.6 to + 1.2 dNp
2700-2900	−0.5 to + 2.5 dB	−0.6 to + 2.9 dNp
2900-3050	−0.5 to + 6.5 dB	−0.6 to + 7.6 dNp
Above 3050	Exceeding or equal to −0.5 dB (−0.6 dNp); upper limit unspecified	

Editorial note. — These are the limits of Figure 29 on page 119 of the *Blue Book*, Volume IV, from the Annex to Recommendation M.61.

This seems to be the result of some confusion, because the figure in question (which, below 300 Hz, differs in fact from the values shown) applies to a single telephone circuit or to a section of such a circuit.

Later, Study Group IV submitted the above table, which applies to a link and is taken from Recommendation M.81 (Volume IV, *White Book*), to the Plenary Assembly at Mar del Plata, 1968.

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[1] *Note by the C.C.I.T.T. Secretariat.* — The Editorial Group set up by the joint LTG Working Party at its meeting in April 1967 proposed the following limits:

e) *Noise*

1. *Uniform-spectrum random noise*

The mean psophometric noise power referred to a point of zero relative level should not exceed 80 000 pW (—41 dBm0p; —4.7 Nm0p) [1].

Note. — It was not possible to recommend a limit for the unweighted noise point level and the C.C.I.T.T. psophometer with the telephone weighting network should continue to be the instrument used for specifying and measuring random noise power levels on international telegraph links.

2. *Impulsive noise*

Impulsive noise should be measured with an instrument complying with Recommendation H.13.

The method of measurement and limits are still under study.

f) *Crosstalk*

1. The crosstalk ratio between the go and return channels of the link should be at least 43 dB (5 Np).

2. The crosstalk ratio between the link and other carrier circuits is restricted by Recommendation G.151 D to not worse than 58 dB (6.7 Np).

Crosstalk in any audio cables forming part of the terminal national sections should not normally significantly worsen the crosstalk ratio.

g) *Mean one-way propagation time*

The one-way propagation time referred to is the group delay as defined in the *List of Definitions of Essential Telecommunication Terms* (Definition No. 04-17) calculated at a frequency of about 800 Hz.

It should be noted that voice-frequency telegraph links routed over high-altitude satellite communication systems introduce mean one-way propagation times in excess of 260 ms.

h) *Group-delay distortion*

Practical experience obtained up to the present shows that it is not necessary to recommend limits for group-delay distortion for 50-baud voice-frequency telegraph links even when they are composed of several sections each provided on telephone channels of carrier systems. There is little practical experience with higher speed telegraph systems.

It may happen that under adverse conditions some telephone channels of the link are of insufficient quality to provide 24 telegraph channels. In such a case, a better combination of telephone channels must be chosen for the telegraph service.

i) *Frequency drift*

The frequency drift introduced by the link must not be greater than 2 Hz (see Recommendation G.225).

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[1] If recourse be had to synchronous operation, a higher noise level might be tolerated (such as −30 dBm0p or −3.5 Nm0p for a particular telegraph system).

j) *Interference caused by power supply sources*

When a sinusoidal measuring signal is transmitted over the link at a level of 0 dBm0 (0 dNm0) the level of the strongest unwanted side component should not exceed −45 dBm0 (or −5.2 Nm0).

k) *Variation introduced by changeover to the reserve line or section*

1. *Change in insertion loss at 800 Hz*

Bearing in mind that the insertion loss of the normal line (or section) and the reserve line (or section) are both subject to variations with time, which in general will be uncorrelated, it is not possible to assign a limit to the change of insertion loss at 800 Hz introduced by the changeover procedure.

2. *Change in the insertion loss at other frequencies relative to that introduced at 800 Hz*

The insertion-loss distortion characteristic of the link when established over the normal route should be within 2 dB or 2 dNp or less of that of the link when established over the reserve route. This limit applies over the frequency bands 300-3400 Hz or 200-3050 Hz as appropriate.

There should ordinarily be no difficulty in achieving the limit when only one portion of the link—for example, the international telegraph line or one section—has a reserve section. However, when two or more portions of the link are separately associated with reserve portions, it becomes administratively difficult to ensure that all combinations of normal and reserve portions comply with the limit. In these circumstances, the best that can be done is to ensure that the insertion-loss characteristics of corresponding normal and reserve portions are as much alike as possible. Careful attention should be paid to the impedance of normal and reserve sections at the point where they are connected to the changeover apparatus so that errors due to changing mismatch losses are minimized. A suitable target would be for all impedances concerned to have a return loss against 600 ohms, non-reactive of not less than 20 dB (23 dNp) over the appropriate band of frequencies.

3. The nominal relative power level at 800 Hz of the normal and reserve lines or sections at the changeover points for a particular direction of transmission should be the same. This level will be that normally used in the national network of the country concerned.

B. LINKS VIA AUDIO-FREQUENCY LINE PLANT

a) *Attenuation distortion*

Graph No. 6 (Figure 3) shows the variations with frequency of the difference between the relative power levels at the origin and extremity of the link relative to the measured value at 800 Hz.

The permissible tolerances for the relative power level at the output of the frontier repeater are the same as those for four-wire repeaters, if maintenance measurements are made by sending a power giving 1 milliwatt at a zero relative level point (as found from the telephone circuit level diagram) to the input of the link for voice-frequency telegraphy. These tolerances are shown on Graph No. 7 (Figure 4).

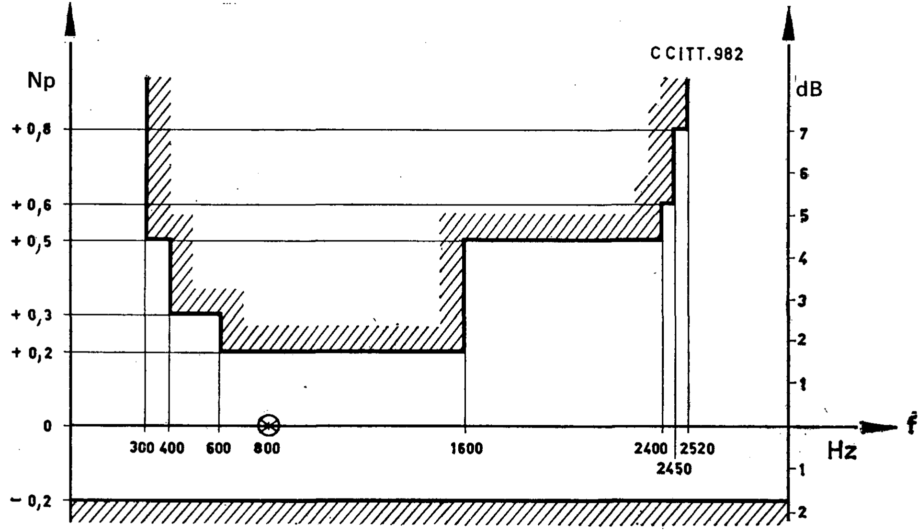

FIGURE 3. Graph No. 6. — **Limits for the variation with frequency, relative to the value at 800 Hz of the difference in relative power levels (in nepers and decibels) between the input and output of a link used for voice-frequency telegraphy (set up on a telephone circuit using the band 300-2600 Hz)**

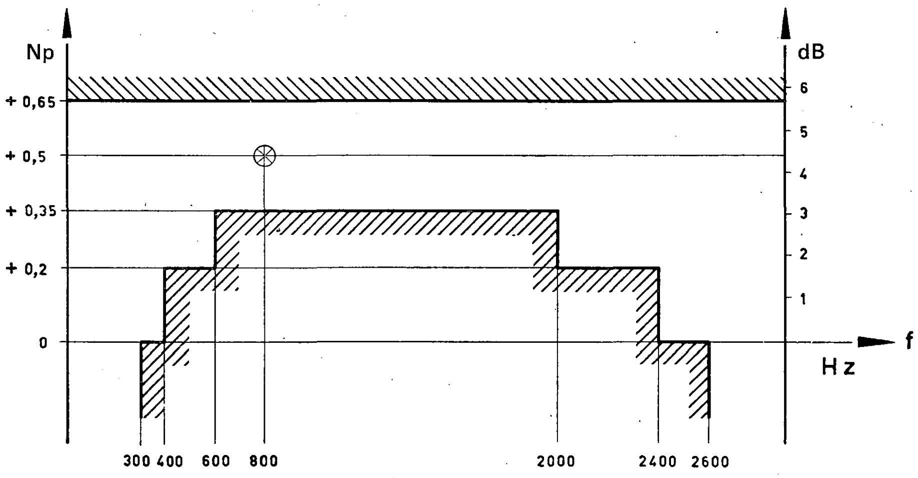

FIGURE 4. Graph No. 7. — **Maintenance limits for the absolute power level (power referred to 1 mW) (in nepers and decibels) at the output of a frontier repeater (frontier side) for an international circuit with a bandwidth of 300-2600 Hz and used for voice-frequency telegraphy (to be measured with a sent power at the origin of the voice-frequency telegraph link such as to give 1 milliwatt at a zero relative level point, deduced from the level diagram of the telephone circuit)**

It does not appear necessary to fix particular limits for the variations with frequency of the level measured at the output of the frontier repeater since these may be calculated easily from the limits allowed for the relative power level.

b) *Level variations with time*

The relative power level at the point at the receiving end where the changeover between the voice-frequency telegraph circuit and its reserve circuit takes place must be as constant as possible with time. Furthermore, any interruption in the circuit, even for a very short duration, spoils the quality of the telegraph transmission. Great care must therefore be taken when measurements are made on circuits and repeaters, when changing-over batteries, etc. To draw the attention of the staff to this matter, it is desirable for circuits used for voice-frequency telegraphy to be specially marked at the terminal stations and in the intermediate repeater stations.

c) *Freedom from modulation*

It is desirable to make special arrangements to avoid any modulation on the circuits and in the repeaters. Such modulation may in particular be caused by variation in battery voltages or by the connection of equipment for sub-audio telegraphy to the cable pairs.

RECOMMENDATION H.23 (Mar del Plata, 1968)[1]

BASIC CHARACTERISTICS OF TELEGRAPH EQUIPMENTS USED IN INTERNATIONAL VOICE-FREQUENCY TELEGRAPH SYSTEMS

A. LIMITING POWER PER CHANNEL

a) *Amplitude-modulated voice-frequency telegraph systems at 50 bauds*

Administrations will be able to provide the telegraph services with carrier telephone channels permitting the use of 24 voice-frequency telegraph channels (each capable of 50 bauds) on condition that the power of the telegraph channel signal on each channel, when a continuous marking signal is transmitted, does not exceed 9 microwatts at zero relative level points.

For 18 telegraph channels only, the power so defined may be increased to 15 microwatts per telegraph channel so that even telephone channels with a relatively high noise level can then be used.

The power per telegraph channel should never exceed 35 microwatts, however few channels there may be.

These limits are summarized in Table 1.

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[1] This Recommendation reproduces, for information, some characteristics given in Recommendations R.31-R.35 (Volume VII). It replaces former Recommendation H.12 in Volume III of the *Blue Book* (Geneva, 1964).

TABLE 1

Limiting power per telegraph channel when sending a continuous marking signal in amplitude-modulated voice-frequency telegraph systems at 50 bauds

System	Limiting power at zero relative level point per telegraph channel when sending a continuous marking signal		
	μW0	dBm0	Nm0
12 telegraph channels or less	35	−14.5	−1.6-7
18 telegraph channels	15	−18.3	−2.1
24 telegraph channels	9	−20.5	−2.3-5

b) *Frequency-shift voice-frequency telegraphy system at 50 bauds*

The mean power transmitted to line by frequency-shift voice-frequency 50-baud telegraph systems is limited to 135 microwatts (at a zero relative level point) when all channels of the system are sending, which gives the limits shown in Table 2 for the mean permissible power per telegraph channel at a zero relative level point.

TABLE 2

Normal limiting power per telegraph channel in frequency-shift, voice-frequency, 50-baud telegraph systems

System	Permissible mean power at zero relative level point per telegraph channel		
	μW0	dBm0	Nm0
12 telegraph channels or less	11.25	−19.5	−2.25
18 telegraph channels	7.5	−21.3	−2.45
24 telegraph channels	5.6	−22.5	−2.6

B. TELEGRAPH CHANNEL CARRIER FREQUENCIES

For international voice-frequency 24-channel, 50-baud, non-synchronous telegraph systems the frequency series consisting of odd multiples of 60 Hz has been adopted, the lowest frequency being 420 Hz as shown in Table 3 below. In the case of frequency-shift systems, these frequencies are the centre frequencies of the telegraph channels, the frequency of the signal sent to line being 30 Hz (or 35 Hz) above or below the centre frequency according to whether A or Z space is being sent.

TABLE 3

Telegraph channel position	Frequency (Hz)	Telegraph channel position	Frequency (Hz)
1	420	13	1860
2	540	14	1980
3	660	15	2100
4	780	16	2220
5	900	17	2340
6	1020	18	2460
7	1140	19	2580
8	1260	20	2700
9	1380	21	2820
10	1500	22	2940
11	1620	23	3060
12	1740	24	3180

In addition a pilot channel using a frequency of 300 Hz or 3300 Hz can be used. For details of the normal frequencies used in other types of telegraph system, see Recommendation R.38B, *White Book*, Volume VII.

SECTION 3

TELEPHONE CIRCUITS OR CABLES USED FOR VARIOUS TYPES OF TELEGRAPH TRANSMISSION

RECOMMENDATION H.31 (former Recommendation H.21)

PRIVATE TELEGRAPH TRANSMISSION ON A RENTED INTERNATIONAL CIRCUIT WITH ALTERNATIVE PRIVATE TELEPHONE SERVICE

1. The frequency of 1500 Hz is recommended for private telegraph transmission between subscribers permanently connected via a rented international circuit.

2. The permissible power for a continuously transmitted telegraph marking signal is 0.3 milliwatt (equivalent to an absolute power level of —5 decibels or about —0.6 neper at a zero relative level point).

It is recommended that measurements be made to ensure that this limit will not be exceeded at the time any international circuit is rented which may later be used for such telegraph transmissions.

It is the responsibility of the administrations or private operating agencies concerned to take any necessary precautions to ensure that such telegraph transmissions do not disturb their interior telephone service. These precautions may involve a limitation of the transmitted telegraph power or of the length of time telegraph transmission is used or of the type of telegraph transmissions.

3. Voice-frequency signalling units on rented telephone circuits used for private telegraph transmission between two subscribers' premises permanently connected together should be immune from operation by telegraph signals. It has been noticed that a certain type of existing signalling unit is affected by these telegraph signals, but arrangements can be made to improve such units without appreciable difficulties at the chosen frequency.

4. It appears that the maximum limit of 250 milliseconds adopted for the hand-over time for echo suppressors on international circuits[1] is not long enough to cause suppression (even partial) of teleprinter answer-back signals.

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[1] *Note by the C.C.I.T.T. Secretariat.* — This limit has been reduced to 75 ms in the present wording of Recommendation G.161 (Table 4).

RECOMMENDATION H.32 (former Recommendation H.22)

SIMULTANEOUS COMMUNICATION BY TELEPHONY AND TELEGRAPHY ON A TELEPHONE CIRCUIT

The C.C.I.T.T.,

considering

1. that the exceptional use of a leased telephone circuit for simultaneous communication by telephone and telegraph is envisaged in Recommendation D.1 (Volume II, *White Book*);

2. that the C.C.I.T.T. has indicated conditions under which the simultaneous use of telephone circuits for telephony and telegraphy is technically tolerable;

3. that standardization of the characteristics of apparatus permitting simultaneous use of a telephone circuit for telephony and telegraphy is not justified, but that it is necessary to limit the power of the signals transmitted and to avoid the use of frequencies that will interfere with any telephone signalling equipment that may remain connected to the telephone circuit;

4. that new demands for the allocation of particular frequencies for special purposes frequently arise and the number of frequencies used for any one purpose should not be unnecessarily extended,

unanimously recommends

1. that in the case of the simultaneous use of a telephone circuit for telephony and telegraphy, the telegraph signal, if continuously transmitted, should be maintained at or below a level of −13 dB (−1.5 neper) at a zero relative level point;

2. that there should not be more than three telephone circuits of this type in a group of 12 telephone circuits and that the number of circuits of this type set up on a wideband carrier system should not exceed the number of supergroups in the system;

3. that the telegraph signals transmitted must not interfere with any signalling apparatus that may remain connected to the telephone circuit;

and notes

that some administrations have permitted the use, for simultaneous telephony and telegraphy, of the frequencies 1680 Hz and 1860 Hz both for amplitude and for frequency-shift modulation.

RECOMMENDATION H.33 (former Recommendation H.23)

CO-EXISTENCE IN A SINGLE CABLE OF TELEPHONY AND DIRECT-CURRENT TELEGRAPHY

The C.C.I.T.T.,

considering

that technical processes exist by which telephone traffic and telegraph traffic can be passed through the same cable either on separate conductors or even on common conductors;

that by these processes, if the precautions described below are observed, the telephone circuits, including phantom circuits, are to all intents and purposes uninfluenced by the telegraphy as regards both their electrical properties and the flow of traffic;

that, even when the cable is subject to the influence of electric power installations (particularly a.c. railway lines), undisturbed telephone and telegraph services can be obtained by the use of devices which have been proved to be effective;

that, moreover, the simultaneous use of a long-distance cable for international telephony and telegraphy is to be recommended for economic reasons,

unanimously recommends

that it is possible to allow the co-existence in a single cable of telephony and d.c. telegraphy, provided that conditions listed below are fulfilled:

A. SIMULTANEOUS TELEGRAPHY ON SINGLE OR DOUBLE PHANTOM CIRCUITS

(*Note*. — The VIth Plenary Assembly of the C.C.I.T., Brussels, 1948, considered that the study of questions concerning sub-audio telegraphy had become pointless and should be abandoned.)

1. The e.m.f. introduced by the telegraph transmitter into the circuit containing the cable conductors must not exceed 50 volts.

2. Where a resistance of 30 ohms, substituted for the cable conductors, is placed across the terminals of this telegraph transmitter, the current flowing through this resistance must not exceed 50 milliamperes.
This limit is raised to 100 milliamperes if the cable is fitted with coils having a powdered iron core or a core of some other material with equally satisfactory characteristics.

3. At a —8.7 dB or —1.0 Np relative level point of 600-ohm impedance, the disturbing noise produced by all the telegraph apparatus on a telephone circuit must not exceed a value corresponding to a psophometric e.m.f. of 1 millivolt. To fulfil this condition, it is advisable to insert low-pass filters in the transmission path on all telegraph circuits operated by direct current. This limit may have to be lowered when the telephone circuit is already subject to considerable disturbance from an adjacent power-line.

4. The simultaneous telegraphy installations must not introduce unbalance relative to earth in the telephone circuits *(Directives concerning the protection of telecommunication lines against the adverse effects of power lines).*

5. The increase in crosstalk produced in the telephone circuits by the simultaneous telegraphy installations must not exceed a value corresponding to a decrease in near-end crosstalk attenuation of 4.34 decibels or 0.5 neper.

6. The circuits of which the single or double phantom circuits used for telegraphy are composed must not be used for programme transmission.

B. TELEGRAPHY AND TELEPHONY CO-EXISTENT ON SEPARATE CONDUCTORS

1. Telegraphy using coil-loaded conductors which may later be used for telephony:
The conditions set out above under A, 1, 2 and 3 have to be met.

2. Telegraphy using unloaded conductors:
Only the conditions set out above under A, 3 have to be met.

SECTION 4

TELEPHONE-TYPE CIRCUITS USED FOR FACSIMILE TELEGRAPHY (PHOTOTELEGRAPHY)

RECOMMENDATION H.41 (former Recommendation H.31, amended at Geneva, 1964)

PHOTOTELEGRAPH TRANSMISSIONS ON TELEPHONE-TYPE CIRCUITS

Note. — As far as carrier circuits are concerned, this recommendation applies only to systems established on the basis of 12-channel groups; systems using 16-channel groups will form the subject of a later study.

Audio-frequency telephone circuits and carrier circuits can be used for phototelegraphy.

When normal audio-frequency circuits or carrier circuits are used, amplitude-modulation offers some advantages over frequency-modulation [1] and is therefore to be preferred for phototelegraph transmissions on circuits set up from end to end on cable or line-of-sight radio-relay links [2].

However, in the case of circuits subject to sudden level variations or to noise, frequency modulation may be preferable to amplitude modulation; administrations (or recognized private operating agencies) could in this case come to an agreement to use frequency modulation for phototelegraph calls over such circuits; the provisions of Recommendation T.1 relative to the frequency-modulation characteristics (*White Book*, Volume VII) should then be applied.

For these reasons, the C.C.I.T.T. *unanimously declares the view*

that phototelegraph transmissions over telephone circuits require that the following conditions be observed, according to the way in which the circuits are used for phototelegraphy:

A. CIRCUITS PERMANENTLY USED FOR PHOTOTELEGRAPHY

It seems that these circuits are few. In any case, they should even more easily meet the characteristics given in section B below.

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[1] In particular, with the same index of co-operation and speed, frequency modulation necessitates wider frequency range than that of amplitude modulation to obtain a picture of same quality.

[2] See Recommendation T.15 (Volume VII of the *White Book*) for phototelegraph transmissions over combined radio and wire circuits.

B. CIRCUITS USED NORMALLY (AND PREFERENTIALLY) FOR PHOTOTELEGRAPHY

a) *Types of circuit to be used*

Two-wire circuits have no practical value for phototelegraphy because of feedback phenomena.

For the same reason, four-wire circuits should be extended to the phototelegraph stations on a four-wire basis at the appropriate amplifier stations, the terminating units and echo suppressors always being disconnected.

b) *Overall loss*

The same conditions apply to the overall transmission loss of four-wire circuits used for phototelegraphy as apply, in general, for telephony.

c) *Sent signal power*

The emission voltage for the phototelegraph signal corresponding to maximum amplitude should be so adjusted that the absolute power level of the signal, at the zero relative level point deduced from the hypsogram of the telephone circuit, is 0 decibel (0 neper) for amplitude-modulation facsimile transmission and —10 decibels (—1.15 neper) for frequency-modulation facsimile transmissions. In the case of amplitude modulation the level of the signal corresponding to black is usually about 30 decibels lower than that of the signal corresponding to white.

d) *Relative levels*

If phototelegraph transmissions take place simultaneously from a transmitting station to several receiving stations, arrangements shall be made at the junction point so that, on the circuits following the junction point, the same power levels are maintained as those prescribed for individual transmissions.

e) *Attenuation distortion*

When amplitude modulation is used, the attenuation distortion between phototelegraph stations should not exceed 8.7 decibels (1.0 neper). Since in the band of frequencies to be transmitted for the phototelegraph transmission the distortion admitted for the trunk telephone circuit itself should not exceed 6.6 decibels (0.75 neper), it will not in general be necessary to compensate for the distortion of the lines joining the phototelegraph stations to the amplifier stations.

In the case of frequency modulation, it suffices to use telephone circuits conforming to C.C.I.T.T. Recommendations regarding attenuation distortion (see Recommendation G.132).

f) *Variation of equivalent with time*

The overall loss should remain as constant as possible during the picture transmission. In the case of amplitude modulation, abrupt variations of even 0.2 dB (2 cNp) have an effect. It is, moreover, necessary to avoid any interruption of the circuit, however rapid. For this reason, the greatest attention should be paid to the measurements made on the amplifiers and lines and to the changing of batteries. To reduce the likelihood of disturbance, it is desirable that the terminal trunk exchanges should be excluded from the circuit when it is extended to the facsimile stations.

Special precautions should be taken to make sure that no modulation of the carrier is caused by the line or the amplifiers, even if the modulation is inaudible. Such modulation may be due, in particular, to variations in the voltage of the supply batteries, or to sub-audio telegraphy equipment.

In the case of frequency modulation, sudden changes of even 10 dB (1.15 Np) can be tolerated and telephone circuits, even when set up without special precautions, have sufficient stability.

This observation does not mean that sudden variations of level should not be avoided just as much in the case of circuits carrying frequency-modulated phototelegraphy.

g) *Phase distortion*

Phase distortion limits the range of satisfactory phototelegraph transmissions. Differences between the group delays of a telephone circuit, in the interval of the phototelegraph transmission, should not exceed

$$\Delta t \leqq \frac{1}{2f_p}$$

f_p = Maximum modulating frequency corresponding to the definition and scanning speed

(See Recommendation H.42.)

h) *Interference*

Interfering currents, whatever their nature, should not exceed the C.C.I.T.T. recommended limits for telephone circuits.

C. TELEPHONE CIRCUITS RARELY USED FOR PHOTOTELEGRAPHY

a) *Transmission characteristics*

It seems that the majority of the characteristics specified by the C.C.I.T.T. for modern telephone circuits are sufficient to permit phototelegraph transmissions on a circuit chosen at random in a group of circuits normally used for telephone working. However, it is not certain that such a circuit would have a sufficiently low phase distortion for such use, particularly channels 1 and 12 of a 12-circuit group, use of which is not advised. The influence of phase distortion is more noticeable in frequency modulation.

With amplitude modulation there is a further risk that phototelegraph transmissions will be subject to faulty modulation because the special precautions applied to circuits regularly used for phototelegraphy (see B, f above) cannot be applied to circuits taken at random.

b) *Precautions concerning signalling*

So long as automatic switching for phototelegraph circuits is not envisaged, the signal receiver can be disconnected so that no signalling disturbances can occur even when frequency modulation is used. However, if frequency modulation is used for phototelegraph transmission and if it is impracticable to disconnect the signal receiver, then it would be desirable, in the case of the one-frequency system, that a blocking signal be transmitted along with the picture signal to operate the guard circuit and render the receiver inoperative.

It is also apparent that the frequency of such a blocking signal should lie well outside the range of frequencies involved in the picture transmission and the frequency and the level of the blocking signal must depend on the characteristics of the v.f. receiver (or receivers in the case of a tandem international connection), as designed by different Administrations to meet the specification to be prescribed for international signalling.

In the case of the two-frequency international signalling system, the C.C.I.T.T. has indicated its view that no interference will take place.

RECOMMENDATION H.42 (former Recommendation H.32, amended at Geneva, 1964)

RANGE OF PHOTOTELEGRAPH TRANSMISSIONS ON A TELEPHONE-TYPE CIRCUIT

Note. — In case of carrier circuits, this recommendation applies only to systems established on the basis of 12-channel group links. Systems using 16-channel group links will be the subject of subsequent study.

1. The differences between the group delays of the various frequencies and the width of the transmission band actually usable on a circuit for telephony give rise, when phototelegraph signals are started or stopped, to transient phenomena which limit the phototelegraph transmission speed.

2. The range of phototelegraph calls of satisfactory quality, for a given transmission speed, depends especially on the constitution of the circuit, i.e. on:

- the loading and length, in the case of audio-frequency circuits;
- the number of 12-channel group links used in the case of carrier circuits,

and on the choice of the carrier frequency for amplitude-modulated phototelegraph transmission, or on the mean frequency in the case of frequency modulation.

3. Phototelegraph transmission of satisfactory quality requires that the limits of difference between the group delays in the transmitted frequency band, as shown in the graph (Figure 1), are not to be exceeded.

Note. — The spot is assumed to have the same dimensions in both directions (square or circular).

4. The C.C.I.T.T. has recommended group-delay distortion limits for international telephone circuits (see Recommendation G.133):

For these reasons, the C.C.I.T.T. *unanimously recommends*

that, as regards the effect of phase distortion on phototelegraph transmission quality, the carrier frequency (where amplitude modulation is used) or the mean frequency (when

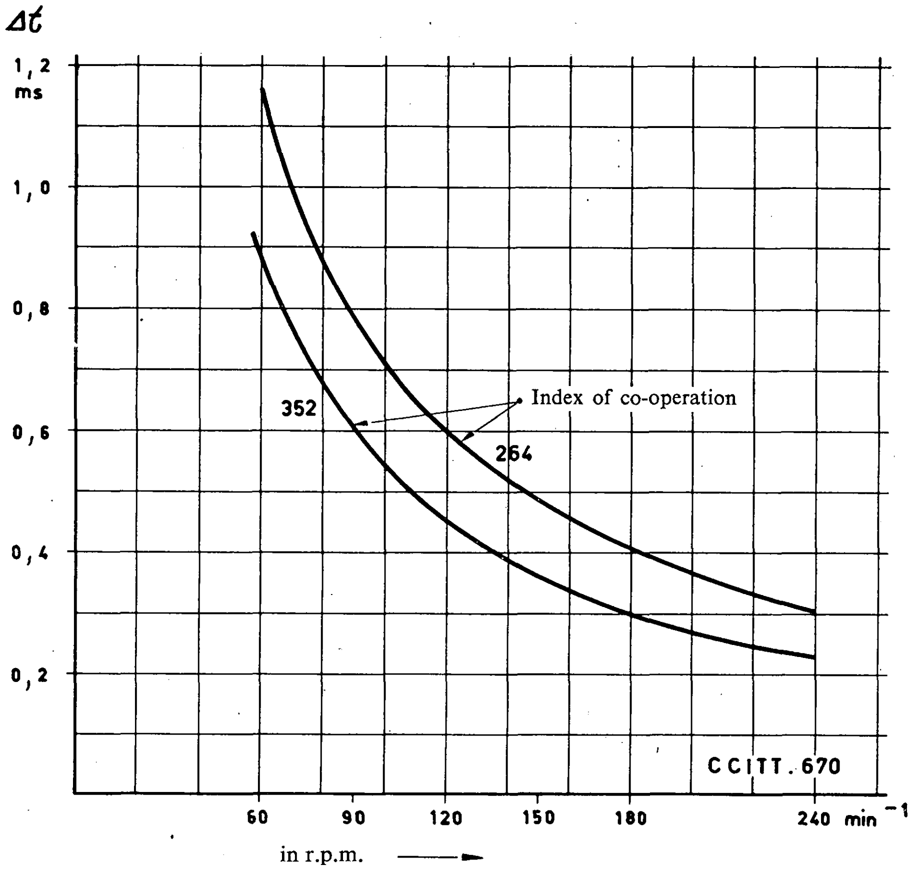


Figure 1. — **Permissible group-delay distortion in the transmitted frequency band as a function of the phototelegraph transmission speed**

frequency modulation is used) must be chosen in such a way that it is as near as possible to the frequency which has the minimum group delay on the telephone circuit.

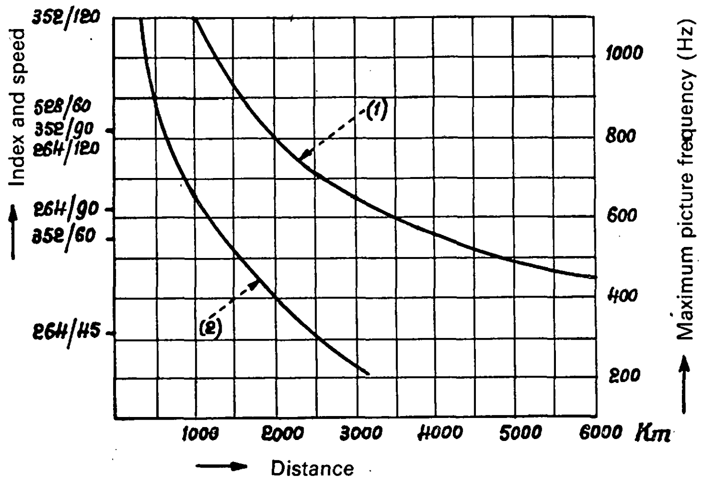
A. Circuits permanently used for phototelegraphy

1. It will generally be possible, by agreement between administrations, to choose a circuit satisfying stricter limits than those specified above from the point of view of phase distortion.

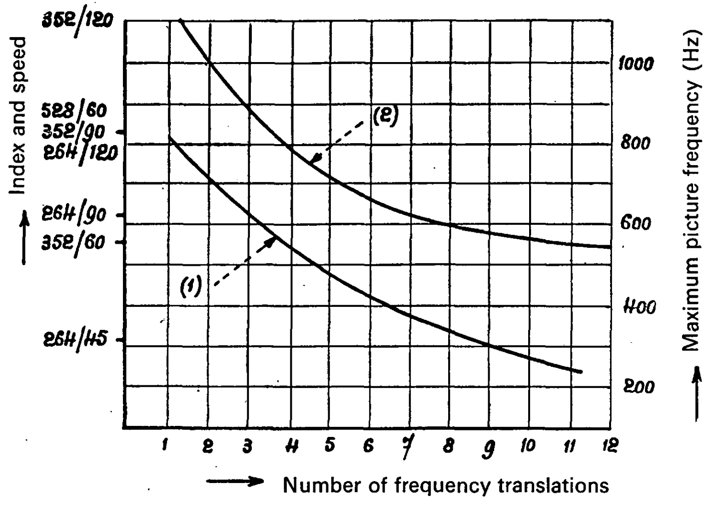
2. Moreover, it will be possible to compensate phase distortions by inserting phase equalizers and to effect phototelegraph transmissions occupying the whole nominal band of the circuit.

B. Circuits normally (or preferentially) used for phototelegraphy

1. The greater the differences between the delays in the transmission intervals, the narrower should be the bandwidth chosen (leading to a lower phototelegraph definition or transmission speed).



a) Audio circuits



b) Carrier circuits

FIGURE 2. — **Range of phototelegraph transmissions**

Curves (1) — AM carrier = 1300 Hz

Curves (2) — { FM 1900 ±400 Hz
AM carrier = 1900 Hz

2. Hence, audio-frequency circuits should in any case have only small loads.

3. Phase distortion is well within the limits indicated above, in the case of carrier circuits, if a single modern-type carrier system is considered (and considering especially the telephone channels in the middle of a 12-channel group of such a system).

4. Nevertheless, it would be unjustifiable from the financial point of view to make the aforementioned recommendation concerning phase distortion stricter simply with a view to the occasional use of only a few circuits for high-speed phototelegraph transmissions.

5. The curves of Figure 2 give information on the relative performances of amplitude- and frequency-modulated phototelegraph transmissions over audio-frequency and carrier telephone circuits.

C. TELEPHONE CIRCUITS RARELY USED FOR PHOTOTELEGRAPHY

If phototelegraph connections are set up on circuits selected at random from modern-type groups of telephone circuits (for example, by automatic switching), a circuit may be taken which has too high a degree of phase distortion, particularly if it has been set up on channel 1 or 12 of a 12-channel group, use of which is deprecated. It is impossible, in this case, to draw up general information on the range of phototelegraph transmissions; however, it will be possible to meet the conditions for a transmission of adequate quality if the phototelegraph connection comprises only one 12-channel group link and if transmission is effected in normal conditions as outlined in Recommendation T.1 (Volume VII of the *White Book*).

SECTION 5

VARIOUS TRANSMISSION CHANNELS USED FOR DATA TRANSMISSION

RECOMMENDATION H.51 (Mar del Plata, 1968)

TELEPHONE-TYPE CIRCUITS USED FOR DATA TRANSMISSION [1]

Use may be made either of circuits in the switched telephone network (see Recommendation H.11) or of leased telephone-type circuits of ordinary or special quality (see Recommendation H.12).

POWER LEVELS

The objectives in specifying data signal levels are as follows:

a) to ensure satisfactory transmission and to permit co-ordination with devices such as signalling receivers or echo suppressors, the data signal levels on international circuits should be controlled as closely as possible;

b) to ensure correct performance of multichannel carrier systems from the point of view of loading and noise, the mean power of data circuits should not differ much from the conventional value of channel loading (−15 dBm0 for each direction of transmission). This conventional value makes allowance for a reasonable proportion (under 5%) of the channels in a multichannel system being used for non-speech applications at fixed power levels at about −10 dBm0 simultaneously in both directions of transmission.

If the proportion of non-speech applications (including data) does not exceed the above figure of 5% then the mean power of −10 dBm0 simultaneously in both directions of transmission would be allowable for data transmission also.

However, assuming an appreciably higher (e.g. 10 to 20%) proportion of non-speech circuits (due to the development of data transmission) on an international carrier system, a reduction of this power by 3 dB might be reasonable. In this way the sum of the mean powers in both directions of transmission in a duplex (i.e. transmitting tones in both directions simultaneously) system would be −10 dBm0 (i.e. −13 dBm0 for each direction). The power transmitted on the channel of a simplex (i.e. transmitting in one direction only) system or on either channel of a half-duplex (i.e. transmitting in opposite directions consecutively) would be −10 dBm0 (assuming that there were no echoes);

Note. — The distribution of long-term mean power among the channels in a multichannel carrier telephone system (conventional mean value: of −15 dBm0), probably has a standard deviation in the neighbourhood of 4 dB (Annex 6, Part 4 of Volume III, *Blue Book*).

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[1] Replaces former Recommendation H.41 in Volume III of the *Blue Book* (Geneva, 1964).

c) it is probable that administrations will wish to fix specific values for the signal power level of data modulators either at the subscribers' line terminals or at the local exchanges. The relation between these values and the power levels on international circuits depends on the particular national transmission plan; in any case, a wide range of losses among the possible connections between the subscriber and the input to international circuits must be expected;

d) considerations a) to c) suggest that specification of the maximum data signal level only is not the most useful form. One alternative proposal would be to specify the nominal power at the input to the international circuit. The nominal power would be the statistically estimated mean power obtained from measurement on many data transmission circuits.

For these reasons, the C.C.I.T.T. *unanimously declares the following view :*

A. DATA TRANSMISSION OVER LEASED TELEPHONE CIRCUITS (PRIVATE WIRES) SET UP ON CARRIER SYSTEMS

1. The maximum power output of the subscriber's apparatus into the line shall not exceed 1 mW.

2. For systems transmitting tones continuously, for example frequency modulation systems, the maximum power level at the zero relative level point shall be —10 dBm0 (—1.15 Nm0). When transmission of data is discontinued for any appreciable time, the power level should preferably be reduced to —20 dBm0 (—2.3 Nm0) or lower.

3. For systems not transmitting tones continuously, for example amplitude-modulation systems, higher levels up to —6 dBm0 (—0.69 Nm0) at the zero relative level point may be used provided that the sum of the mean powers during the busy hour on both directions of transmission does not exceed 64 microwatts (corresponding to a mean level of —15 dbm0 (—1.73 Nm0) on each direction of transmission simultaneously). Further, the level of any tones above 2400 Hz should not be so high as to cause interference on adjacent channels on carrier-telephone systems.

Note 1. — In suggesting these limits, the C.C.I.T.T. has in mind that the recommended maximum level of —5 dB referred to the zero relative level point for leased circuits for alternate telephony and telegraphy may no longer be acceptable having regard to the recommendation that "to avoid overloading carrier systems, the mean power should be limited to 32 μW if systems are subject to considerable extension".

Note 2. — The proposed limit of —10 dB for continuous tone systems is in line with the existing Recommendation H.41 for frequency-modulation phototelegraph transmissions.

Note 3. — It is not possible to give any firm estimate of the proportion of international circuits which will at any time be carrying data transmission. If the proportion should reach a high level, the provisional limits now proposed would need to be reconsidered.

B. DATA TRANSMISSION OVER THE SWITCHED TELEPHONE SYSTEM

The maximum power output of the subscriber's equipment into the line shall not exceed 1 mW at any frequency.

In systems continuously transmitting tone, such as frequency or phase-modulation systems, the power level of the subscriber's equipment should be adjusted to make allowance for loss between his equipment and the point of entry to an international circuit; so that the corresponding nominal level of the signal at the international circuit input shall not exceed −10 dBm0 (−1.15 Nm0) (simplex systems) or −13 dBm0 (−1.5 Nm0) (duplex systems).

In systems not transmitting tones continuously, such as amplitude-modulation systems and multi-frequency systems, higher levels may be used, provided always that the mean power of all the signals at the international circuit input during any one hour in both directions of transmission does not exceed 64 microwatts (representing a mean level of −15 dBm0 (−1.73 Nm0) in each direction of transmission simultaneously).

Furthermore, the frequency level in carrier telephone systems which are part of a circuit should not be so high that it might cause interference in adjacent channels. Recommendation G.224 could be referred to with a view to providing adequate levels.

Note 1. — In practice, it is no easy matter to assess the loss between a subscriber's equipment and the international circuit, so that this part of the present recommendation should be taken as providing general planning guidance. As mean level at the international circuit input, the mean figure obtained from measurement or calculation (on numerous transmission data) may be adopted.

Note 2. — In switched connections the loss between subscribers' telephones may be high: 30 to 40 dB. The level of the signals received will then be very low, and these signals may suffer disturbance from the dialling pulses sent over other circuits. Hence the transmission level should be as high as possible.

If there is likely to be a heavy demand for data-transmission international connections over the switched network, some administrations might want to provide special four-wire subscribers' lines. If so, the levels to be used might be those proposed for leased circuits.

RECOMMENDATION H.52 (Mar del Plata, 1968)

TRANSMISSION OF WIDE-SPECTRUM SIGNALS (DATA, FACSIMILE, ETC.) ON WIDEBAND GROUP CIRCUITS

Circuits meeting the provisions of Recommendation H.14 should be used.

a) *Power level*

1. The mean power level of the wideband signal over the range 60-108 kHz should not exceed $-15 + 10 \log_{12} = -4$ dBm0.

2. In order to limit cross-modulation effects in wideband systems, the power level of any individual spectral component in the band 60-108 kHz should be much lower than the mean value given in 1 above.

Note. — A limit of −14 dBm0 is used by at least one administration.

3. In addition to the requirement 2 above the energy spectrum transmitted in the neighbourhood of the pilot frequencies should be limited in accordance with Recommendation G.241, f).

b) *Limitation of the energy spectrum outside the band 60-108 kHz*

The energy spectrum outside the band 60-108 kHz should be suitably limited by directives similar to those giving the values specified in Recommendation G.242, b).

RECOMMENDATION H.53 (Mar del Plata, 1968)

TRANSMISSION OF WIDE-SPECTRUM SIGNALS (DATA, ETC.) OVER WIDEBAND SUPERGROUP CIRCUITS

Circuits meeting the provisions of Recommendation H.15 should be used.

a) *Power level*

1. The mean power level of the wideband signal over the range 312-552 kHz should not exceed $-15 + 10 \log_{60} = + 3$ dBm0.

2. In order to limit cross-modulation effects in wideband systems, the power level of any individual spectral component in the band 312-552 kHz should be much lower than the mean value given in 1 above.

Note. — A limit of −14 dBm0 is used by at least one administration.

3. In addition to the requirement 2 above the energy spectrum transmitted in the neighbourhood of the pilot frequencies should be limited in accordance with Recommendation G.241, f).

b) *Limitation of the energy spectrum outside the band 312-552 kHz*

The energy spectrum outside the band 312-552 kHz should be suitably limited by directives similar to those giving the values specified in Recommendation G.242, c).

PART 3

SERIES J RECOMMENDATIONS

Programme and television transmissions

SECTION 1

GENERAL RECOMMENDATIONS CONCERNING PROGRAMME TRANSMISSIONS

RECOMMENDATION J.11

USE OF THE INTERNATIONAL TELEPHONE NETWORK FOR PROGRAMME TRANSMISSIONS

The following distinctions are made:

1. Normal programme circuits type A, transmitting a frequency band of 50 Hz to 10 000 Hz for which the characteristics are as shown in Section 2.

2. Normal programme circuits type B, which are modern circuits transmitting a frequency band of 50 Hz to 6400 Hz set up on carrier systems. When administrations consider that the provision of such circuits is of interest, the characteristics should be as shown in Section 3.

3. Old-type programme circuits, for which the characteristics are as shown in Section 4.

When the use of telephone circuits for programme transmissions is authorized under recommendations in Volume II-A, the technical conditions governing such use are as shown in Section 5.

RECOMMENDATION J.12

DEFINITIONS AND RESPONSIBILITIES FOR INTERNATIONAL PROGRAMME TRANSMISSIONS [1]

a) *Technical responsibilities during an international broadcast programme*
Definition of the constituent parts of an "international programme link"

In order to apportion responsibility during the transmission of a broadcast programme there is occasion to distinguish between (see Figure 1):

1. the broadcast authority that is the source of the programme (studio or outside broadcast point or programme switching centre) and which in the figure is at some distance from the repeater station at BRUXELLES;

2. the national circuit [2], which connects the broadcast authority to the first repeater station;

3. the "international sound-programme link" consisting in principle of a chain of national and international programme circuits, the national circuits being of the same type as if they were international circuits. In the figure this "international link" is "BRUXELLES-MESTRE", and consists of the international circuit BRUXELLES-PARIS, the national circuit PARIS-LYON, the international circuit LYON-TORINO and the national circuits TORINO-MILANO and MILANO-MESTRE;

4. the national circuit [2] which connects the last repeater station to the receiving broadcast authority;

5. the receiving broadcast authority for which the programme is intended and which in the figure is at VENEZIA, some distance from MESTRE.

The assembly of the "international sound-programme link" and the national circuits between the broadcasting organizations, constitutes the "international sound-programme connection".

The "international sound-programme link" is, in all cases, the sole responsibility of the telephone administrations.

The extreme national circuits may be the responsibility of either the telephone administration, the broadcast authority or the two together depending on the local arrangements in each particular country.

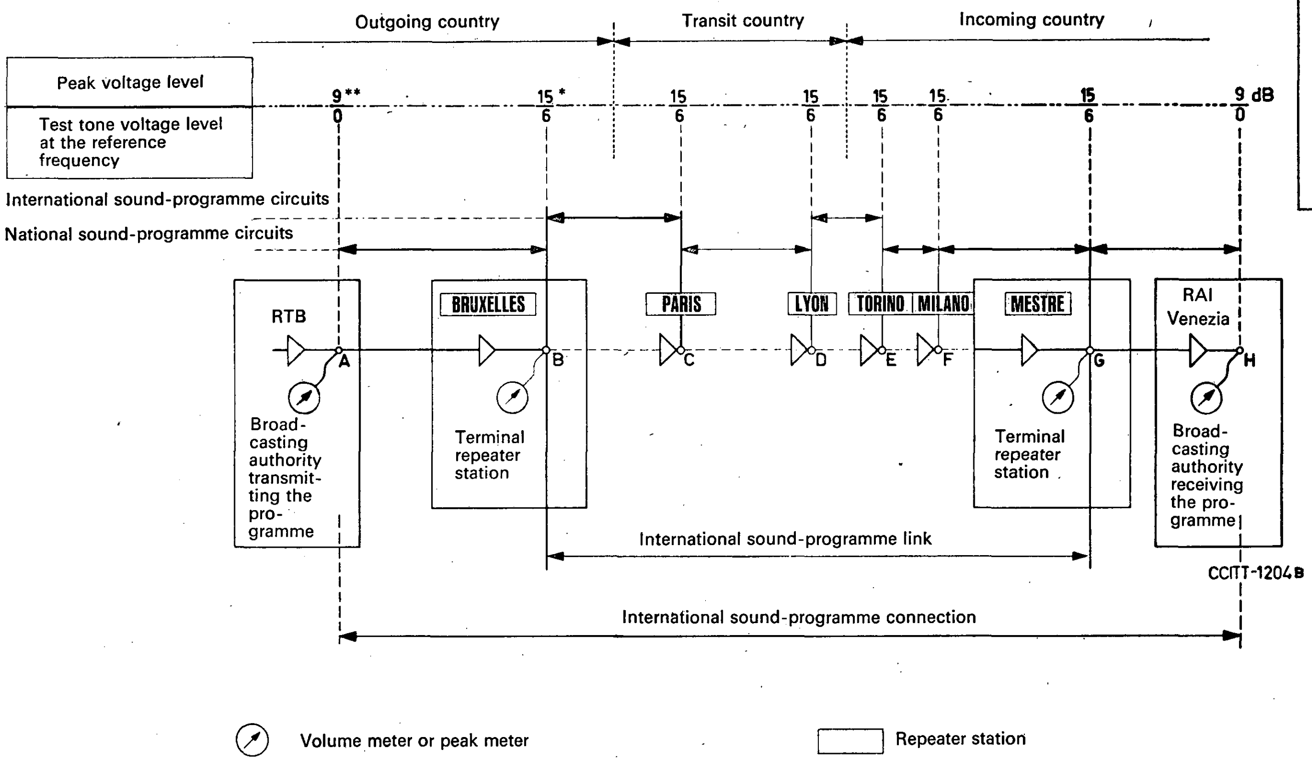
b) *Definitions of the origin and extremity of an international circuit*

The "origin" of an international circuit is considered as the output of the first amplifier and the "extremity" as the output of the last amplifier of the circuit. In the case of Figure 1, the direct circuit Bruxelles-Paris, for example, is comprised between the points B and C.

In the case of a circuit on a carrier system for programme transmissions, the origin of the circuit is the input of the modulating equipment and the extremity is the output of the demodulating equipment.

Notes by the Secretariat. — [1] The terminology and Figure 1 of this Recommendation have been brought into line with Figure 1 of Recommendation N.11 approved at Mar del Plata, 1968 (Volume IV, *White Book*). See also Recommendation N.1.

[2] "Local lines" are no longer defined in Recommendations N.1. and N.11.



The value of 9 dB shown at the ends as the peak voltage level corresponds to 3.1 V which is the maximum value of a sine wave of 2.2 V r.m.s. value

* These levels are appropriate to national sound-programme circuits in the countries concerned

** The RTB in fact adopts levels of 15/6 at this point

FIGURE .— **Diagram of an international sound-programme connection in which all the countries concerned have chosen +6.0 dBr (+7.0 dNr) as the nominal relative level at points at which circuits are interconnected**

RECOMMENDATION J.13

RELATIVE LEVELS ON AN INTERNATIONAL PROGRAMME CONNECTION

a) *Level adjustment on an international programme connection.*

The C.C.I.T.T. recommends the use of the "constant voltage" method. If, to a zero relative level point of the international programme connection is applied a zero absolute voltage level (sine wave signal of 0.775 volt r.m.s.) at one of the frequencies given in the Maintenance Instructions (Recommendation N.12, Volume IV, *White Book*), the absolute voltage level at the output of the last amplifier of each programme circuit (Points B, C, D . . . G of Figure 1 of Recommendation J.12) should be + 6 dB or + 0.7 neper (i.e. 1.55 volt r.m.s.) at 800 Hz, and should be within the given limits at other frequencies (Figure 2 of Recommendation J.21 for normal circuits type A, Figure 1 of Recommendation J.31 for normal circuits type B and Figures 1 and 2 of Recommendation J.41 for old-type circuits).

The zero relative level point is in principle the origin of the "international programme connection" (Point A in Figure 1 of Recommendation J.12). Different conventions may be agreed between telephone administrations and broadcast authorities within a country, provided that the levels on the "international programme link" are unchanged.

b) *Diagram of voltage levels on an international programme connection*

The voltage level diagram for an international programme connection, however made up, should be such that the voltage levels shown are not such as to exceed the maximum undistorted power which an amplifier can deliver to a programme link when peak voltage (i.e. + 9 dB, reference 0.775 volt) is applied to a zero relative level point on the international programme connection.

With these conditions, +6 dB (reference 0.775 volt) is the nominal voltage level at the output of the terminal amplifiers of the programme circuits making up the international programme link (Points B, C, D . . . G of Figure 1 of Recommendation J.12).

The line amplifiers of the international programme link should be capable of handling an upper voltage limit of at least + 17 dB (reference 0.775 volt), given the recommendation to use a constant voltage method for lining-up.

From the statement above that the voltage level at a zero relative level point can reach + 9 dB (reference 0.775 volt), the relative level obtained at the output of an amplifier would be $+ 17 - 9 = + 8$ dB (reference 0.775 volt). Assuming the maximum variation of this level with time to be ± 2 dB gives a nominal relative level at the output of these amplifiers of $+ 8 - 2 = + 6$ dB or + 0.7 Np (reference 0.775 volt).

If a programme circuit which is part of the international programme link is set up on a group in a carrier system, it is recommended that the programme circuit and the telephone channels should be at zero relative level at the same point on the level diagram.

It might be as well, however, if the equipment could tolerate a maximum difference of ± 3 dB between the relative levels of the programme and telephone transmissions, so that the best adjustment can be obtained, depending on any noise or intermodulation present.

For ease of interconnection, the nominal relative level at the input and output of an international circuit is also provisionally fixed at + 6 dB or + 0.7 Np, for a circuit set up on a carrier system.

Note. — This recommendation applies to a programme circuit without pre-emphasis. Different values are shown for a circuit with pre-emphasis in the Annex to Recommendation J.21.

RECOMMENDATION J.14

LINE-UP AND MONITORING OF AN INTERNATIONAL PROGRAMME CONNECTION

To meet Recommendation J.13, the line-up and monitoring of an international programme connection should ensure that, during the programme transmission, the peak voltage at a zero relative level point will not exceed 3.1 volts, which is that of a sinusoidal signal having an r.m.s. value of 2.2 volts.

The methods for achieving this condition are given in Recommendations N.10 to N.18 (*White Book*, Volume IV) and are summarized below [1].

It is assumed that the "international programme connection" is as shown in Figure 1 of Recommendation J.12. It is also assumed that the various circuits to be interconnected to constitute the "international link" are permanent circuits which are subjected to routine maintenance.

a) *Measurements to be made before the line-up period that precedes a programme transmission*

The national circuits should be so adjusted that when they are connected to the "international programme link", the voltage level diagram of the "international programme connection" shall be met [2].

For example, in Figure 1 of Recommendation J.12, the station EDINBURGH carries out the equalization and line-up of the local line from the British Broadcasting Corporation (B.B.C.).

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[1] The text has been brought up to date by the Secretariat in accordance with these Recommendations in the *White Book*, Volume IV.

[2] From the definition of the voltage level diagram of an "international programme connection" it follows that, at a given point, a sine wave having a maximum amplitude equal to the peak voltage transmitted by the studio has a nominal 600-ohm through level of + 9 decibels (+ 1.04 neper) at a zero relative level point on the "international programme link".

Principal characteristics of the various instruments used for monitoring the volume or peaks during telephone conversations or programme transmissions

Type of instrument	Rectifier characteristic (Note 4)	Time to reach 99% of final reading (milliseconds)	Integration time (milliseconds) (Note 5)	Time to return to zero (value and definition)
(1) "Speech voltmeter" British type 3 (S.V.3) identical to the speech power meter of the A.R.A.E.N.	2	230	100 (approx.)	equal to the integration time
(2) Vu meter (United States of America) (Note 1)	1.0 to 1.4	300	165 (approx.)	equal to the integration time
(3) Speech power meter of the "S.F.E.R.T. volume indicator"	2	around 400 to 650	200	equal to the integration time
(4) Peak indicator for programme transmissions used by the British Broadcasting Corporation (B.B.C. Peak Programme Meter) (Note 2)	1		10 (Note 6)	3 seconds for the pointer to fall 26 dB
(5) Maximum amplitude indicator used by the Federal German Republic (type U 21)	1	around 80	5 (approx.)	1 or 2 seconds from 100% to 10% of the reading in the steady state
(6) OIRT — Programme level meter:		for both types: less than 300 ms for meters with pointer indication and less than 150 ms for meters with light indication		for both types: 1.5 to 2 seconds from "0 dB" point at 30% of the length of the operational section of the scale
Type A sound meter			10 ± 5	
Type B sound meter			60 ± 10	

b) *Measurements to be made during the line-up period which precedes a programme transmission*

The C.C.I.T.T. recommends the use of the line-up method known as "constant voltage" [1] described above.

After the connection of the various circuits to form the "international programme link" (conforming to the voltage level diagram of these circuits) it is sufficient to verify, by means of an automatic level recorder or by measurements at individual frequencies, that the relative voltage level at the distant incoming repeater station has the correct value.

Also, but only if requested by the control station, a measurement of the psophometric noise is made at the distant incoming repeater station.

These preliminary adjustments having been made, the national circuits are connected to the "international programme link" at the International Sound Programme centres (I.S.P.C.). This is the end of the "line-up period" and the beginning of the "preparatory period" and is the instant when the complete "connection" is *placed at the disposal* of the broadcast authorities.

The latter then proceed to measure and adjust as necessary.

c) *Measurements to be made by the broadcast authorities during the "preparatory period"*

After the broadcasting authorities have taken possession of the "international programme connection", they make measurements on the complete "connection" in the band

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[1] If certain administrations or private telephone agencies have programme-circuit amplifiers which are not suitable for use for line-up by the constant-voltage method, there is no objection to using the constant electromotive force method of equalization—even though it may cause inconvenience from the point of view of maintenance—provided that administrations or private operating agencies make the necessary arrangements at frontier stations to change over from the constant electromotive force method to the constant-voltage method recommended by the C.C.I.T.T. However, new amplifiers installed for programme transmissions should be designed to provide for lining-up by the constant-voltage method.

Notes to the table

Note 1. — In France a meter similar to the one defined in line (2) of the table has been standardized.

Note 2. — In the Netherlands a meter (type N.R.U.-ON301) similar to the one defined in line (4) of the table has been standardized.

Note 3. — In Italy a programme meter with the following characteristics is in use:

Rectifier characteristic: 1 (see note 4)
Time to reach 99% of final reading: approx. 20 ms
Integration time: approx. 1.5 ms
Time to return to zero: approx. 1.5 s from 100% to 10% of the reading in the steady state.

Note 4. — The number given in the column is the index n in the formula $[V_{(\text{output})} = V_{(\text{input})}^{n}]$ applicable for each half-cycle.

Note 5. — The "integration time" was defined by the C.C.I.F. as the "minimum period during which a sinusoidal voltage should be applied to the instrument for the pointer to reach to within 0.2 neper or nearly 2 dB of the deflection which would be obtained if the voltage were applied indefinitely". A logarithmic ratio of 2 dB corresponds to a percentage of 79.5% and a ratio of 0.2 neper to a percentage of 82%.

Note 6. — The figure of 4 milliseconds that appeared in previous editions was actually the time taken to reach 80% of the final reading with a d.c. step applied to the rectifying/integrating circuit. In a new and somewhat different design of this programme meter using transistors, the performance on programme remains substantially the same as that of earlier versions and so does the response to an arbitrary, quasi-d.c. test signal, but the integration time, as here defined, is about 20% greater at the higher meter readings.

of frequencies effectively transmitted, from the point where the programme is picked up to the point where the programme is received.

The broadcasting authorities should, for their measurements, send to the origin of the "international programme connection" (point A of Figure 1 of Recommendation J.12) a sinusoidal signal, having a maximum amplitude 9 decibels or 1 neper below that of the peak voltage (i.e. of the maximum instantaneous voltage that should never be exceeded at this point in the course of a programme transmission). If necessary, it should be verified that the nominal 600-ohm through level at each repeater is + 6 decibels or + 0.7 neper, which means that there is a voltage of 0.775 volt (600-ohm through level of zero) at the zero relative level point of the "international programme connection".

It is not necessary to readjust the output levels of intermediate I.S.P.C.s since these have already been set during the line-up period.

Note. — In the final line-up, the reasons for sending a voltage to point A, 9 dB below the peak voltage, are as follows:

a) It is not desirable to subject the terminal equipments of carrier systems to overloading by transmitting continuously a test signal corresponding to the peak voltage reached only momentarily during the transmission of an actual programme.

b) Since administrations or private operating agencies make their initial and maintenance measurements with a nominal 600-ohm through level of + 6 decibels or + 0.7 neper at the repeater output, it is convenient, during the preparatory period, to be able to check whether the level measured is the same.

d) *Monitoring* [1]

At the end of the preparatory period, the transmission of the programme proper commences, which is monitored at the studio, in the repeater stations and at the transmitter. This monitoring is done with a speech level meter. One of the instruments of which the characteristics are summarized in the table below may be used.

Since there is no simple relation between the readings given by two different instruments for all types of programme transmitted, it is desirable that the broadcast authority controlling the studio and the telephone administration(s) controlling the programme circuit should use the same type of instrument so that their observations are made on a similar basis.

In general the telephone administration and the broadcast authority of a country agree to use the same type of instrument. It is desirable to reduce to a minimum the number of different types of instrument and to discourage the introduction of new types which only differ in detail from those already in service.

Point A (output of the last amplifier controlled by the broadcast authority sending the programme) should be monitored during programme transmission to see that the meter deflection of the measuring instrument is always lower than the "peak voltage" for the overall line-up, allowance being made for the peak factor of the programme involved.

It should be remembered that the amplitude range from a symphony orchestra is of the order of 60 to 70 dB, while the specification for programme circuits is based on a range of about 40 dB. Before being passed to the programme circuit, therefore, the "dynamic ratio" of the studio output needs to be compressed.

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[1] *Note by the Secretariat.* — See also Recommendation N.15 (Volume IV, *White Book*).

SECTION 2

NORMAL PROGRAMME CIRCUITS, TYPE A

For transmitting a programme that includes high-quality music, an old-type programme circuit is not suitable.

However, the wide frequency band available on modern high-velocity lines enables normal programme circuits of improved quality to be provided.

RECOMMENDATION J.21

PROVISIONAL GENERAL CHARACTERISTICS OF NORMAL PROGRAMME CIRCUITS, TYPE A

The C.C.I.T.T. has defined a 2500-kilometre "hypothetical reference circuit for programme transmissions". This circuit represents the chain of international circuit(s) and national extension circuit(s).

The make-up of the circuit is shown in Figure 1. In the case of carrier transmission, B, M, M′ and C are the only points where audio frequencies appear [1]. For example, points B and C in Figure 1 might correspond to points B and H in Figure 1 of Recommendation J.12.

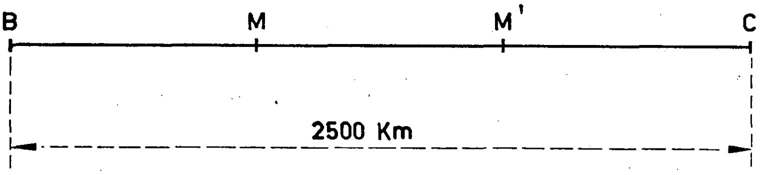

FIGURE 1. — **Hypothetical reference circuit for programme transmissions**

It has not been found necessary to give a more detailed definition of the composition of a hypothetical reference circuit for programme transmissions when routed over a carrier system, since the noise produced by the equipment can be deduced from the recommendations relative to hypothetical reference circuits for telephony.

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[1] In such a case, points M and M′ divide the hypothetical reference circuit into three carrier transmission sections: BM, MM′ and M′C.

The following recommendations apply provisionally to this hypothetical reference circuit, with the following reservations:

1. For an audio-frequency circuit, all the characteristics are valid except for intelligible crosstalk.

2. For a circuit on a carrier system, all the characteristics are valid, except for intelligible crosstalk and noise. (See the Annex to this Recommendation.)

a) *Band of frequencies effectively transmitted*

In the case of a normal type programme circuit, type A, the band of frequencies effectively transmitted by the complete link should extend from 50 to 10 000 Hz at least.

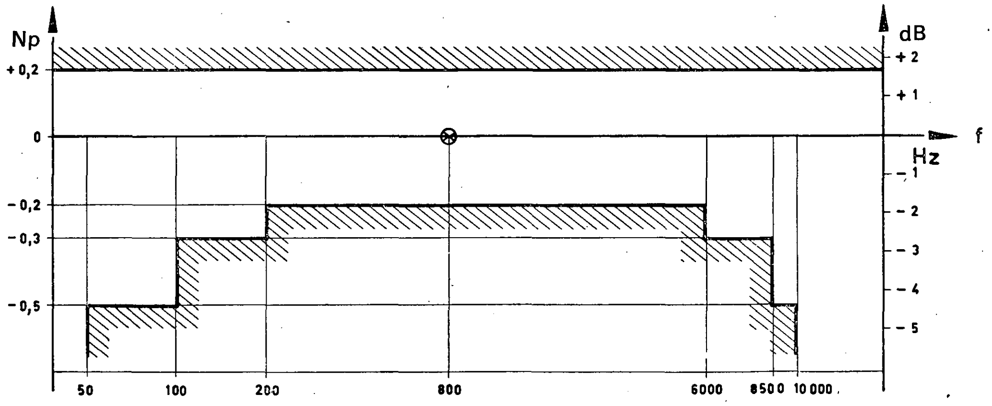
For a frequency to be considered as effectively transmitted, the equivalent at this frequency should not exceed the equivalent at 800 Hz by more than 4.3 decibels or 0.5 neper.

b) *Line levels* (see Recommendation J.13)

c) *Attenuation distortion*

Figure 2 shows the permissible limits for the variation with a frequency (relative to the value measured at 800 Hz) of the relative voltage level (referred to 0.775 volt) measured at the end of the circuit (output of the last repeater). The method of measuring this relative level is shown in Recommendation N.21 (Volume IV of the *White Book*).

When the circuit is set up on a carrier system, the curve applies to the combined three pairs of equipments for modulation from or demodulation to audio-frequencies, as included in the hypothetical reference circuit for programme transmission.



f = frequency (Hz)

Ordinates show variation of level (in nepers and decibels)

FIGURE 2. Graph No. 10. — **Variation with frequency, relative to the 800 Hz value, of the relative voltage level at the extremity (output of last amplifier) of a normal type programme circuit, type A**

d) *Phase distortion*

The index of the phase distortion (or difference between the group delay, t_f, for the frequency f considered and for the frequency corresponding to the minimum group delay) should not exceed the following values:

$t_{10\,000} - t_{\min}$ . . . . less than 8 milliseconds
$t_{100} - t_{\min}$ . . . . less than 20 milliseconds
$t_{50} - t_{\min}$ . . . . less than 80 milliseconds

e) *Noise* [1]

1. *Psophometric voltage.* — When the international circuit is terminated at the far end by a pure 600-ohm resistance, and when the input is terminated with a pure resistance equal to the modulus of the nominal impedance of the first amplifier, then, when measured with the programme-circuit psophometer [2], the psophometric voltage at the far end of the international circuit at a point where the nominal relative level is fixed at + 6 dB (+ 0.7 Np) should not be more than 6.2 millivolts for cable circuits or 15.6 millivolts for open-wire circuits.

Hence the ratio between the "maximum voltage" [3] and the psophometric voltage (circuit noise and crosstalk) is at least 710/1 (57 dB or 6.55 Np) for cable circuits, and at least 283/1 (49 dB or 5.65 Np) for open-wire circuits.

2. *Unweighted voltage.* — The voltage due to noise, measured objectively without a weighting network, at the extremity of the international circuit should not exceed 62 millivolts for cable circuits and 156 millivolts for open-wire lines. This measurement should cover the frequency band from 30 to 20 000 Hz; it is as well to make sure that there is no danger of overloading or parasitic modulation.

Note. — In fixing these values, the dynamic ratio has been taken as 40 decibels (4.6 nepers).

f) *Intelligible crosstalk.* — Provisional limits:

1. The near or far-end crosstalk ratio (for speech) between two normal type A international programme circuits or between one such circuit and all other circuits for programme relays should be at least 74 decibels or 8.5 nepers for cable circuits and at least 61 decibels or 7.0 nepers for open-wire lines.

2. The near or far-end crosstalk ratio (for speech) between a telephone circuit (disturbing circuit) and a normal type A international programme circuit (disturbed circuit) should be at least 74 decibels or 8.5 nepers for cable circuits and at least 61 decibels or 7.0 nepers for open-wire lines.

3. The near or far-end crosstalk ratio (for speech) between a normal type A international programme circuit (disturbing circuit) and a telephone circuit (disturbed circuit)

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[1] In the case of circuits on carrier systems, it is not always possible, in the absence of special precautions, to meet the limits recommended in this paragraph (see the following Annex).

[2] The psophometer should be provided with a special filter network, having the characteristics given in section B of Recommendation P.53 (*White Book*, Volume V).

[3] The "maximum voltage" at a point in a circuit is the r.m.s. voltage at this point when a sinusoidal wave of 2.2 volts r.m.s. is applied at a zero relative level point on the international circuit.

should be at least 58 decibels or 6.7 nepers for cable circuits and at least 47 decibels or 5.4 nepers for open-wire lines.

Note 1. — The C.C.I.T.T. draws the attention of administrations to the fact that, for a 1000-kilometre circuit, it is in some cases difficult to meet these limits, notably when using unscreened pairs of programme channels on carrier systems. This question is being studied by the C.C.I.T.T. (See the Annex to this Recommendation.)

Note 2. — The C.C.I.T.T. draws the attention of administrations to the fact that, because of crosstalk which may occur in terminal modulating and line equipment, special precautions may have to be taken to meet the above crosstalk limits for go and return carrier system programme circuits working simultaneously, when they occupy the same position in the line-frequency band (as is the case in the most economical arrangement). This question is being studied by the C.C.I.T.T.

g) *Change of relative level with time*

The 800-Hz relative level at the far end of the international circuit should meet the defined conditions for attenuation distortion, and also during a given programme transmission should not change from its nominal value by more than ± 2 dB or ± 2 dNp.

Also, for programme circuits on special pairs or on the phantom circuits of unloaded symmetric pairs, the 800-Hz relative level at the output of a frontier amplifier should not change from its nominal value by more than ± 1 dB or ± 1 dNp during a given programme transmission.

h) *Non-linear distortion*

The total harmonic distortion coefficient for the 2500-km hypothetical reference circuit for programme transmissions should not exceed 4% (harmonic distortion attenuation 28 dB or 3.2 Np) at any frequency within the band to be transmitted, the measurement being made with a sinusoidal signal (fundamental frequency) sent to the origin of the circuit (where the nominal relative level is + 0.6 dB) at + 4.4 volts r.m.s. (absolute voltage level [i.e. ref. 0.775 volt] equal to +15 decibels or +1.7 neper), the total harmonic distortion coefficient, k, being calculated from the formula

$$k = \sqrt{k_2^2 + k_3^2}$$

where k_2 is the 2nd order harmonic distortion coefficient and k_3 is the 3rd order harmonic distortion coefficient.

However, the following values should be considered as desirable design objectives for future developments:

3% (30 dB or 3.4 Np) at fundamental frequencies below 100 Hz,
2% (34 dB or 3.9 Np) at fundamental frequencies above 100 Hz[1].

Note. — Precautions should be taken in the measurement of harmonic distortion on circuits equipped with pre-emphasis networks. This question is being studied by the C.C.I.T.T.

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[1] The European Broadcasting Union has stated that many of its members have expressed the opinion that for a circuit of 1500 km, acceptable limits for non-linearity distortion would be 40 dB at fundamental frequencies above 100 Hz and 34 dB at fundamental frequencies of 100 Hz and below (test signal of + 9 dB at a zero relative level point).

ANNEX

(to Recommendation J.21)

(modified at Geneva, 1964, and at Mar del Plata, 1968)

Noise and crosstalk on normal programme circuits (types A and B) set up on carrier systems

a) *Precautions necessary to meet the limits on 1000-km circuits set up on cable carrier systems*

In order to meet the limits recommended by the C.C.I.T.T. for noise and intelligible crosstalk for normal programme circuits of types A and B of 1000-km length set up on carrier systems on cables, it is necessary to take special precautions.

Noise. — It is recommended that the special precautions to be taken for meeting the required limits for noise on circuits of 1000 km or less should consist of the use of pre-emphasis and de-emphasis networks. It is further recommended that the pre-emphasis attenuation curve should be that given by the following formula:

$$\text{insertion loss between nominal impedances} = 10 \log_{10} \frac{75 + \left(\frac{\omega}{3000}\right)^2}{1 + \left(\frac{\omega}{3000}\right)^2}$$

where ω is the angular frequency corresponding to frequency f.

The de-emphasis network should have a complementary curve.

The pre-emphasis curve calculated from this formula is given in the following table:

f (kHz)	Insertion loss (dB)
0	18.75
0.05	18.70
0.2	18.06
0.4	16.48
0.8	13.10
2	6.98
4	3.10
6.4	1.49
8	1.01
10	0.68
∞	0

The measured pre-emphasis and de-emphasis curves should not depart by more than ± 0.25 decibel from the theoretical curves when the measured levels at 800 Hz are made to coincide with the theoretical levels.

Note. — At present, this curve is applicable only to the pre-emphasis networks used on circuits without compandors. A study is being made of the kind of pre-emphasis networks that could be used in association with compandors.

For a programming circuit that includes pre-emphasis and de-emphasis networks, it is recommended that for reasons of overload the relative level at 800 Hz on such a circuit at a zero relative level point deduced from the level diagram of telephone circuits set up on the same 12-circuit group should lie between a maximum of −1.5 decibel and a minimum of −4.5 decibels.

The level of −1.5 decibel could be considered as normal. A further 3 decibels adjustment to permit a decrease down to −4.5 decibels should, however, be included to cover the case of exceptional overloading if operational experience shows that in fact this is necessary.

These limits apply to a normal programme circuit type A, set up on a carrier system and to a normal programme circuit type B.

Note. — Certain problems connected with the use of pre-emphasis on carrier systems have not yet been satisfactorily resolved. These are:

— the limitation of the level of testing tones, which is of concern to Study Group IV;

— the effect of pre-emphasis on the harmonic distortion requirements which the programme circuit should meet at high frequencies [1].

Intelligible crosstalk. — It should be possible to meet the required limits for intelligible crosstalk on 1000-km circuits, though it may be necessary to select suitable plant. Further study is required of the attenuation value to be met in all filters concerned in through connection. A value in accordance with the present recommended figure for intelligible crosstalk of 74 dB or 8.5 Np or somewhat higher (e.g. 80 dB or 9.2 Np) is thought desirable in those parts of the frequency band likely to be occupied by programme transmissions [2].

b) *Values obtained in practice on circuits 2500 km long set up on cable carrier systems*

Noise. — A reasonable noise limit for normal programme circuits 2500 km long set up on carrier systems with emphasis networks and used in the manner described in paragraph a) would be about −44 dBm0 or −5.1 Nm0 (referred to the zero relative level point for programme circuits) and measured with a "programme" circuit psophometer. (This is some 4 dB or 4.5 dNp worse than the limit recommended in paragraph e) of this Recommendation.)

Intelligible crosstalk. — Cable carrier systems are designed to meet the recommended limits for intelligible crosstalk between telephone circuits, namely 58.2 dB or 6.7 Np and it is not considered that any better performance can be guaranteed on these systems in respect of programme circuits without compandors unless there is some restriction of the parts of the line-frequency band occupied by the programme circuits and, in the case of balanced pair systems, selection of pairs.

Use of compandors. — Provided the compressor and the expander are of the same make, it is possible to obtain overall transmission characteristics as regards noise and crosstalk which conform to the C.C.I.T.T. recommendations for the 2500-km hypothetical reference circuit without introducing other factors that might impair transmission performance. The C.C.I.T.T. is now examining recommendations on the compressor and the expander, considered separately, in order to achieve the same result.

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[1] Measurements of harmonic distortion on programme circuits having pre-emphasis must be treated with reserve. This point is being studied by the C.C.I.T.T.

[2] See Recommendation G.242.

c) *Circuits set up over radio-relay links*

When programme circuits are set up on radio-relay links in place of telephone channels which conform to the general noise objectives (Recommendation G.222), the psophometric voltage can be expected to vary with time. The following noise values (psophometric weighting for programme transmissions) for a hypothetical reference circuit of 2500 km can be deduced from Recommendation G.222 by making certain assumptions:

TABLE 1

	One-minute mean value	
	for not more than 20% of a month	for not more than 0.1% of a month
Psophometric power (weighting for programme transmissions)	−44.5 dBm0ps	−37.5 dBm0ps

Assumptions and conventional terms

The expression dBm0ps is used to indicate noise levels in a programme circuit which are psophometrically weighted and measured in decibels relative to 1 mW at a point of zero relative level in that circuit. The C.C.I.T.T. practice is to quote noise level for programme circuits relative to peak programme or "maximum" voltage which is defined as a voltage of 2.2 V r.m.s. (across an impedance of 600 ohms) at a point of zero level, i.e. 9 dB above telephone test level, and their signal-to-noise ratio objective of 57 dB is thus equivalent to a noise level of −48 dBm0ps.

The value for not more than 20% of a month was calculated on the following assumptions:

Noise on one telephone channel (including the multiplexing equipment) according to Recommendation G.222 weighted for telephony	−50 dBm0p
Bandwidth correction	+ 5 dB
Suppression of weighting for telephony (in the case of a uniform-spectrum noise)	+ 2.5 dB
Improvement due to pre-emphasis (paragraph a) of the Annex)	− 9 dB
Effect of the relative level shifted by −1.5 dB (paragraph a) of the Annex)	+ 1.5 dB
Weighting for programme transmissions	+ 5.5 dB
Total	−44.5 dBm0ps

The value for not more than 0.1% of a month was calculated on the basis of the noise variations to be expected on a radio-relay link mainly for providing telephone circuits and conforming with Recommendation G.222.

RECOMMENDATION J.22 (modified at Geneva, 1964, and at Mar del Plata, 1968)

LINES USED FOR SETTING UP NORMAL PROGRAMME CIRCUITS, TYPE A

Normal programme circuits, type A, can be provided in wideband cables by the following method:

a) *Special pairs for sound broadcasting*

If a broadcast programme is to be distributed to a number of intermediate points along the line (if this includes carrier telephone systems), it may be necessary to use a pair of conductors with a special screen for programme transmissions; or it may happen that it is preferable to transmit the broadcast programme over the carrier system itself or on the phantom of the unloaded pairs.

It should be remembered, however, that interstice pairs in a coaxial cable are principally intended for the maintenance and supervision of the telephone carrier system routed over the coaxial pairs.

b) *Normal programme circuits routed over channels of a carrier telephone system in cable*

It is recommended to use the frequency band corresponding to three telephone channels of a carrier system to form a normal programme circuit, type A. One such assembly of three channels may be used in this manner in a 12-circuit group.

The C.C.I.T.T. has already recommended the position defined below as Position I for this assembly of three channels to provide programme transmission in basic group B.

Position I: Frequency band used: 84-96 kHz
Virtual carrier frequency: 96 kHz

The C.C.I.T.T. no longer recommends the use of Position II, defined in the old recommendation (*Red Book*, Volume III), in the international service.

The C.C.I.T.T. recommends also the following frequency arrangements in the basic group B:

Position III: Frequency band used: 84-96 kHz
Virtual carrier frequency: 95.5 kHz

This position may be adopted whether a compandor is used or not.

Supplement No. 12 of this Volume indicates the improvement in crosstalk to be expected from offset of the carrier frequency and in particular from the use of Position III.

Note. — Some administrations use a pilot inserted in the audio-frequency part of the sound-programme modulation equipment for the purpose of regulating the equivalent and supervising the link as a whole.

While, generally speaking, the provision of automatic group regulation should suffice to ensure satisfactory stability of the equivalent, a pilot like the one suggested by one of these administrations might be useful when compandors (which increase variations of the equivalent) are used, or when the switching of sound programme circuits to RF is envisaged or when frequency synchronization is required between the ends of the circuit.

With the limit that has been recommended above for the "peak voltage" transmitted by one such assembly of three channels, these assemblies (used for programme transmissions) may be placed in any basic group (or in all the basic groups) of a supergroup (or in all supergroups) of a carrier system on coaxial cable.

The C.C.I.T.T. has not limited the possible positions (in the basic supergroup) of the groups over which will be routed "normal programme circuits, type A" but it can be said that the basic groups (in a supergroup) which appear most appropriate for such circuits are groups 2, 3 and 4. These groups are subject to less attenuation distortion at the edges (produced by certain filters in the supergroup) than groups 1 and 5. The most appropriate supergroups in which to place the programme circuits are those which are transmitted on the coaxial cable with the lowest carrier frequencies, because the frequency deviation (due to instability of the frequency generators) on the channels of these groups will be proportionately lower than the deviation on channels in supergroups transmitted at a high frequency. Supergroup 2 (the basic supergroup) has the additional advantage of having one stage of modulation less than the other supergroups.

In the case of a carrier system on symmetric pairs, it may be necessary to make a special choice of the group of the system and the pairs to be used in order that the conditions concerning crosstalk for the complete programme circuit will be satisfied (see the Annex to Recommendation J.21).

c) *Use of phantom circuits on unloaded symmetric pairs equipped with carrier systems*

Recent experience has shown that the phantom circuits of symmetric pairs in cables equipped with carrier systems may allow transmission (as defined in Recommendation J.21, paragraph a)) from 50 Hz to 10 000 Hz. These circuits have the advantage that derivations at various repeater stations of the carrier system can easily be made, thus allowing the distribution of a radio programme or the picking up of a supplementary programme at various points along the line.

When such phantom circuits are used over long distances, it may be necessary to provide manual or automatic regulation to compensate for changes of attenuation with time.

d) *Use of the band of frequencies below 12 kHz*

The use of phantom circuits (see paragraph c)) naturally depends on a multiple twin or a star quad cable being available. If only a pair cable is available, a possible solution would be to place the programme transmission in the frequency band below 12 kHz, i.e. below the frequency band used for the carrier telephone channels; but this solution involves difficulties with filters or with crosstalk balancing frames, if any exist.

SECTION 3

NORMAL PROGRAMME CIRCUITS, TYPE B

RECOMMENDATION J.31

NORMAL PROGRAMME CIRCUITS, TYPE B, WORKING ON A CARRIER SYSTEM

A. LINE FREQUENCIES

The C.C.I.T.T. recommends that, when an administration wishes to provide a programme circuit transmitted on a carrier system, using a frequency band corresponding to two telephone channels, the circuit should occupy the frequency range 88 kHz to 96 kHz in basic 12-channel group B frequency band. and the virtual carrier frequency within this range should be 96 kHz [1].

B. CHARACTERISTICS FOR THE HYPOTHETICAL REFERENCE CIRCUIT

For the hypothetical reference circuit for this type of programme circuit, as defined by the C.C.I.T.T. in Recommendation J.21, the following general characteristics are recommended.

a) *Band of frequencies effectively transmitted*

The band of frequencies effectively transmitted by the complete link should extend from 50 to 6400 Hz at least.

For a frequency to be considered as effectively transmitted, the overall loss at this frequency should not be greater than the overall loss at 800 Hz by more than 4.3 dB or 0.5 Np.

b) *Line levels* (See Recommendation J.13)

c) *Attenuation distortion*

Figure 1 shows the permissible limits for the variation, as a function of frequency (relative to the value measured at 800 Hz) of the relative voltage level (referred to 0.775 volt) measured at the end of the circuit (output of the last repeater). The method of measuring this relative level is shown in Recommendation N.21 (*White Book*, Volume IV).

This curve applies to the combined three pairs of equipments for modulation from or demodulation to audio-frequencies, as included in the hypothetical reference circuit for programme transmission.

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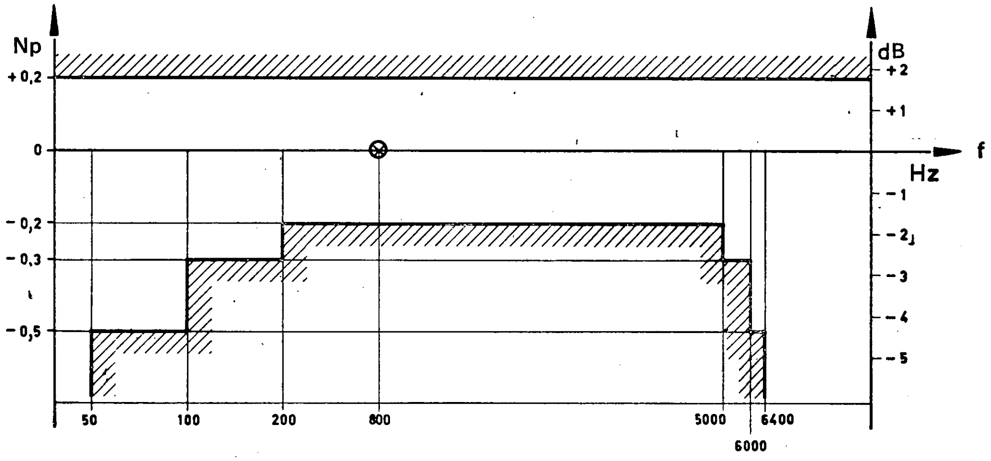
[1] For the choice of groups and supergroups used, see the information given in Recommendation J.22.



f = frequency (Hz) The ordinates show the variation of level (in nepers and decibels)

FIGURE 1. Graph No. 11. — **Variation, with frequency, of the relative voltage level at the end (output of last amplifier) of a normal programme circuit, type B. The values are shown relative to the value at 800 Hz**

d) *Phase distortion*

The index of the phase distortion (or difference between the group delay t, for the frequency f considered and for the frequency corresponding to the minimum group delay) should not exceed the values in the table below:

$t_{6400} - t_{\min}$ . . . . less than 8 milliseconds
$t_{100} - t_{\min}$ . . . . less than 20 milliseconds
$t_{50} - t_{\min}$ . . . . less than 80 milliseconds

e) *Noise*

The recommended limits are the same as for a normal programme circuit, type A, set up on 3 carrier channels (Recommendation J.21, paragraph e)); the reservations in the Annex to that recommendation also apply.

f) *Intelligible crosstalk*

The recommended limits are the same as for a normal programme circuit, type A, set up on 3 carrier channels (Recommendation J.21, paragraph f)); the reservations in the Annex to that recommendation also apply.

g) *Change of relative level with time*

The 800-Hz relative level at the far end of the international circuit should meet the defined conditions for attenuation distortion and also, during a given programme transmission, should not change from its nominal value by more than ± 2 dB or ± 2 dNp.

h) *Non-linear distortion*

The recommended values are the same as for a normal programme circuit, type A, set up on 3 carrier channels (Recommendation J.21, paragraph h)).

SECTION 4

OLD-TYPE PROGRAMME CIRCUITS

RECOMMENDATION J.41

GENERAL CHARACTERISTICS

a) *Band of frequencies effectively transmitted*

When an old-type programme circuit is used, the band of frequencies effectively transmitted by the complete link relaying the transmitted programme should be from 50 to 6400 Hz at least (the upper limit not being above 10 000 Hz).

For a frequency to be considered as effectively transmitted, the equivalent at this frequency should not exceed the equivalent at 800 Hz by more than 4.3 dB or 0.5 Np.

b) *Attenuation distortion of the international circuit*

The limits allowed for the variation with frequency of the relative level at the output of an amplifier are given on Graphs 8 and 9 of Figures 1 and 2.

The curve of the relative levels at the output of an amplifier should lie in the unshaded area. The limits of this area may be displaced by a movement of the whole upwards or downwards by an amount equal to the difference between the actual relative level at 800 Hz and 6.1 decibels or 0.7 neper (if this relative level differs from 6.1 decibels or 0.7 neper) but less than the allowable tolerance of 1.7 dB or 2 dNp for a non-frontier station or 0.9 dB or 1 dNp for a frontier station.

The relative level is equal to the absolute voltage level measured at the point considered when a voltage, constant at all frequencies, is applied to the origin of the circuit. If the output impedance of the first amplifier is not negligible compared with that of the line, then an electromotive force, constant at all frequencies, may be applied to the line by means of a generator having an internal impedance equal to the nominal output impedance of the first amplifier.

c) *Phase distortion*

The phase distortion of the international circuit (or chain of interconnected circuits) used for programme transmissions should be such that the difference between the time of propagation does not exceed the following values:

— between the group delay at 50 Hz and at 800 Hz, 70 milliseconds;

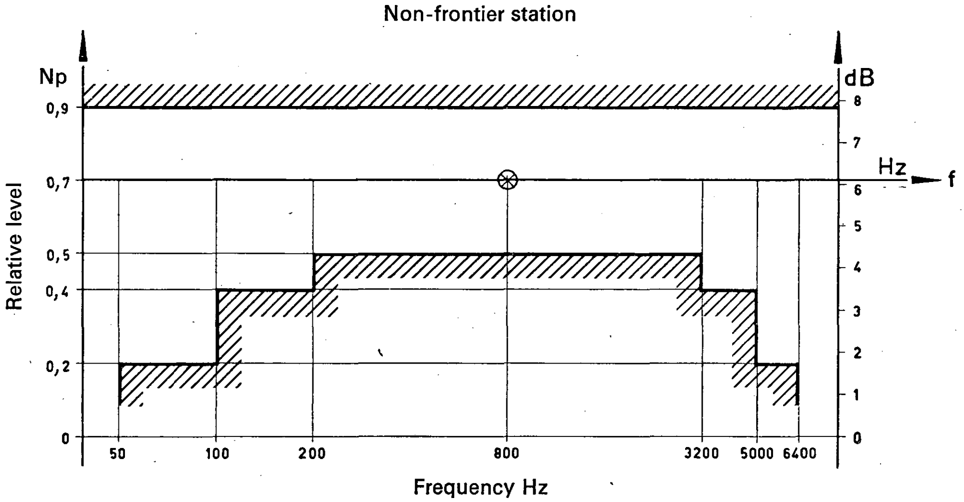


FIGURE 1. Graph No. 8 (non-frontier station). — **Permissible limits for the variation, with frequency, of the relative voltage level on an old-type programme circuit**

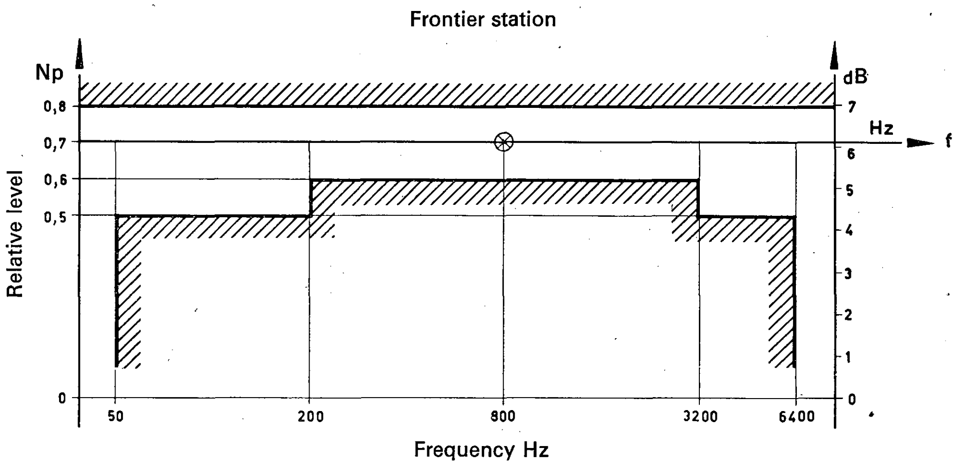


FIGURE 2. Graph No. 9 (frontier station). — **Permissible limits for the variation, with frequency, of the relative voltage level on an old-type programme circuit**

— between the group delay at 6400 Hz and at 800 Hz, 10 milliseconds.

Note. — The "group delay" referred to above is the differential coefficient of the phase shift ω, in radians of the circuit (or chain of circuits) measured at a frequency f, with respect to that frequency expressed in radians per second. This group delay is the time taken for the peak of the envelope formed by two close frequencies ω and $(\omega + d\omega)$ to pass through the circuit or chain of circuits.

d) *Noise*

1. *Psophometric voltage.* — When the international circuit is terminated at the far end by a pure 600-ohm resistance, and when the input is terminated with a pure resistance

equal to the modulus of the nominal impedance of the first amplifier, then, when measured with the programme-circuit psophometer in its high impedance condition [1], the psophometric voltage at the far end of the international circuit at a point where the nominal relative level is fixed at + 6.1 dB should not be more than 6.2 millivolts for cable circuits or 15.6 millivolts for open-wire circuits.

Hence the ratio between the "maximum voltage" [2] and the psophometric voltage (circuit noise and crosstalk) is at least 710/1 (57 dB or 6.55 Np) for cable circuits, and at least 283/1 (49 dB or 5.65 Np) for open-wire circuits.

2. *Unweighted voltage.* — The voltage due to noise measured objectively without a weighting network at the extremity of the international circuit should not exceed 62 millivolts for cable circuits and 156 millivolts for open-wire lines. This measurement should cover the frequency band from 30 to 20 000 Hz: it is useful for making sure that there is no danger of overloading or parasitic modulation.

Note. — In fixing these values the dynamic ratio has been taken as 40 dB (4.6 Np).

e) *Intelligible crosstalk.* — Provisional limits:

1. The near or far-end crosstalk ratio (for speech) between two old-type international programme circuits or between one such circuit and all other circuits for programme relays should be at least 74 decibels or 8.5 nepers for cable circuits and at least 61 decibels or 7.0 nepers for open-wire lines.

2. The near or far-end crosstalk ratio (for speech) between a telephone circuit (disturbing circuit) and an old-type international programme circuit (disturbed circuit) should be at least 74 decibels or 8.5 nepers for cable circuits and at least 61 decibels or 7.0 nepers for open-wire lines.

3. The near or far-end crosstalk ratio (for speech) between an old-type international programme circuit (disturbing circuit) and a telephone circuit (disturbed circuit) should be at least 58 decibels or 6.7 nepers for cable circuits and at least 47 decibels or 5.4 nepers for open-wire lines.

Note. — The C.C.I.T.T. draws the attention of administrations to the fact that, for a 1000-kilometre circuit, it is difficult to meet these limits when using unscreened pairs.

f) *Change of relative level with time*

The 800-Hz relative level at the far end of the international circuit should meet the defined conditions for attenuation distortion, and also, during a given programme transmission, should not change from its nominal value by more than ± 2 dB or ± 2 dNp.

Also, for programme circuits on special pairs or on the phantom circuits of unloaded symmetric pairs, the 800-Hz relative level at the output of a frontier amplifier should not

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[1] The psophometer should be equipped with a special weighting network, the characteristics of which are given in Section B of Recommendation P.53 (*White Book*, Volume V).

[2] The "maximum voltage" at a point in a circuit is the r.m.s. voltage at this point when a sinusoidal wave of 2.2 volts r.m.s. is applied at a zero relative level point of the international circuit.

change from its nominal value by more than ± 1 dB or ± 1 dNp during a given programme transmission.

g) *Non-linear distortion*

The total harmonic distortion coefficient for the 2500-km hypothetical reference circuit for programme transmissions should not exceed 4% (harmonic distortion attenuation 28 dB or 3.2 Np) at any frequency within the band to be transmitted, the measurement being made with a sinusoidal signal (fundamental frequency) sent to the origin of the circuit (where the nominal relative level is + 6.1 dB) at + 4.4 volts r.m.s. (absolute voltage level [i.e. ref. 0.775 volt] equal to + 15 decibels or + 1.7 neper), the total harmonic distortion coefficient, k, being calculated from the formula

$$k = \sqrt{k_2^2 + k_3^2}$$

where k_2 is the 2nd order harmonic distortion coefficient and k_3 is the 3rd order harmonic distortion coefficient.

However, the following values should be considered as desirable design objectives for future developments:

3% (30 dB or 3.4 Np) at fundamental frequencies below 100 Hz,
2% (34 dB or 3.9 Np) at fundamental frequencies above 100 Hz.

RECOMMENDATION J.42

LINES AND AMPLIFIERS

A. SPECIAL PAIRS FOR SOUND BROADCASTING

(See Recommendations G.541, G.542 and G.543.)

B. AMPLIFIERS

a) *Type*

The amplifier should amplify in one direction so that the band of frequencies effectively transmitted extends from at least 50 Hz to a frequency equal to 0.7 of the cut-off frequency, in the case of a loaded cable.

b) *Amplification*

The amplifier and its associated equipment should compensate as much as possible for the attenuation of the preceding repeater section. Thus, in the band of frequencies effectively transmitted, the gain should rise with frequency in such a manner that the distortion produced by the line is cancelled.

The necessary devices should be provided to adjust the gain in steps of 1 dB or 1 dNp at the most. Over the whole band of frequencies to be effectively transmitted, the gain frequency characteristics should be parallel for all positions of the gain adjustment device.

When the power supply is regularly maintained, the voltage variations at the supply terminals of the amplifier should not cause changes of gain exceeding 0.26 dB (3 cNp).

c) *Impedance*

The relation between the input and output impedance of the amplifier and the line to which it is connected should be such as to avoid detrimental reflections as much as possible. It might be an advantage to make the output impedance low in relation to the line impedance in order to reduce the harmonic distortion coefficient of the amplifier and to simplify the connection of amplifiers and lines of different impedance.

d) *Monitoring arrangements*

A monitoring facility should be provided before and after the amplifier to allow supervision of the programme. This facility should have a high impedance so as not to reduce the gain (insertion loss) by more than 0.26 dB (3 cNp).

e) *Crosstalk*

The crosstalk ratio measured under working conditions should be at least 87 dB (10 Np) between two amplifiers used for programme transmissions or between one of these amplifiers and a repeater used for ordinary telephony.

When these measurements are made the amplifiers should be terminated with impedances corresponding to those of the lines connected to them.

f) *Absence of noise*

The absolute level of disturbing noise should be at least 75 decibels or 8.65 nepers below the absolute level of the "maximum voltage", which corresponds to a psophometric voltage approximately equal to one five-thousand-six-hundredth part of the "maximum voltage".

g) *Non-linear distortion*

For an output of 5.5 volts r.m.s., the harmonic margin, with the amplifier in normal working condition and for any frequency in the band to be effectively transmitted, should be 28 dB or 3.2 Np [1].

Also, for a range of r.m.s. output voltage of 0.775 to 5.5 volts, the gain should not change by more than 0.9 dB or 1 dNp over the frequency band to be effectively transmitted.

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[1] *Note by the C.C.I.T.T. Secretariat.* — This recommendation is an earlier one than that in paragraph g) of Recommendation J.41.

SECTION 5

USE OF TELEPHONE CIRCUITS FOR PROGRAMME TRANSMISSION

(A technical recommendation will be drawn up when there is an operating recommendation specifying the conditions under which such use is permissible.)

SECTION 6

CHARACTERISTICS OF CIRCUITS FOR TELEVISION TRANSMISSIONS

RECOMMENDATION J.61 (modified at Geneva, 1964, and at Mar del Plata, 1968)

SPECIFICATIONS FOR A LONG-DISTANCE TELEVISION TRANSMISSION (System I excepted) [1]

The C.C.I.T.T.,

considering

the agreement reached by the Joint C.C.I.R./C.C.I.T.T. Committee for television transmission (C.M.T.T. on a draft recommendation concerning television transmission over long distances, common to the C.C.I.R. and the C.C.I.T.T.) at its meeting in 1968;

unanimously approves, as C.C.I.T.T. Recommendation J.61, Recommendation 421-1 as contained in C.C.I.R. Volume V (Oslo, 1966), pp. 66-86, with the following amendments:

AMENDMENT TO RECOMMENDATION 421-1

Requirements for the transmission of television signals over long distances
(System I excepted)

Annex IV of this Recommendation should be amended as follows:

a) In the last column of Table II, *add* "7" in the lines referring to the following characteristics:

power-supply hum, picture signal, field-time, line-time, overshoot and ringing, rise-time.

b) *Add* after Note 6:

"Note 7. — Further information is given in document CMTT/49, 1966-1969, O.I.R.T."

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[1] For system I, see Recommendation J.62.

RECOMMENDATION J.62 (Mar del Plata, 1968)

SPECIFICATION FOR A LONG-DISTANCE TELEVISION TRANSMISSION (SYSTEM I ONLY)[1]

The C.C.I.T.T.,

considering

the agreement reached by the Joint C.C.I.R./C.C.I.T.T. Committee for television transmission (C.M.T.T. on a draft recommendation concerning television transmission over long distances, common to the C.C.I.R. and the C.C.I.T.T.) at its meeting in 1968;

unanimously approves, as C.C.I.T.T. Recommendation J.62, Recommendation 451 as contained in C.C.I.R. Volume V (Oslo, 1966), pp. 86-105, with the following amendment:

AMENDMENT TO RECOMMENDATION 451

Requirements for the transmission of television signals over long distances (System I only)

1. *Insert* a new paragraph 4.6 after the existing paragraph 4.5 in Part 2 of the Recommendation (Volume V, p. 92) as follows:

"4.6 *Crosstalk*[2]

> Crosstalk between two circuits is measured with a specified video test-signal applied to the input of the disturbing circuit and an oscilloscope at the output of the disturbed circuit, which is otherwise quiescent. The signal-to-crosstalk ratio is defined as the ratio, expressed in decibels, of the nominal peak-to-peak amplitude of the picture luminance signal to the peak-to-peak amplitude of the picture portion of the crosstalk waveform.
>
> At present, definitive limits can be specified only for two particular cases; for other forms of crosstalk further study is required. The specifications given in the two following paragraphs are strictly applicable only when the disturbing circuit, as well as the disturbed circuit, is designed to transmit System I signals, but they may serve as a guide under comparable conditions of service with other systems.
>
> If the crosstalk is substantially undistorted, the signal-to-crosstalk ratio should not be less than 58 dB when measured with the test signal shown in Figure 1 applied to the disturbing circuit.
>
> If the crosstalk is substantially differentiated (i.e. crosstalk voltage proportional to frequency), the signal-to-crosstalk ratio should not be less than 50 dB when measured with the test signal shown in Figure 4 applied to the disturbing circuit.

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[1] For other systems see Recommendation J.61.

[2] *Note by the C.C.I.T.T. Secretariat.* — The French term "diaphotie", used in television, represents a quantity analogous to the term "diaphonie"; in English, the same term, "crosstalk", is used in both cases. In this case, the exact definition is given in the text of the Recommendation.

2. *Page 89, Table II:* below "Impulsive noise", *insert* a new line to read:

Crosstalk	4.6	Crosstalk voltage	3/2

3. *Page 89, Table II, second column: Renumber* paragraphs 4.6.1 . . . 4.9.2 to 4.7.1 . . . 4.10.2.

4. *Page 91, section 4.2, last line : Amend* "4.9.1" to read "4.10.1".

5. *Pages 92 and 93 : Renumber* paragraphs "4.6 . . . 4.9.2" to read "4.7 . . . 4.10.2".

SECTION 7

GENERAL CHARACTERISTICS OF SYSTEMS FOR TELEVISION TRANSMISSION OVER METALLIC LINES AND INTERCONNECTION WITH RADIO-RELAY LINKS

Recommendation G.331 (see Part 1) gives details of the 2.6/9.5-mm and 0.104/0.375-inch types of coaxial cable standardized by the C.C.I.T.T.

Recommendations have also been made by the C.C.I.T.T. concerning the following systems for transmitting television signals over such pairs:

— 4-MHz system, which can be used to transmit 405-line television (Recommendation J.71);

— 6-MHz system, for transmitting 625-line television (5 MHz video-frequency band) or the Belgian 819-line system (Recommendation J.72);

— 12-MHz system, which can be used to transmit telephony and television simultaneously (Recommendation J.73).

RECOMMENDATION J.71

4-MHz SYSTEM FOR TELEVISION TRANSMISSION

The 4-MHz coaxial cable system, defined in Recommendation G.337, can be used for transmitting 405-line television signals. For this it is recommended that the following conditions be met:

a) *Carrier frequency and sidebands*

It is unanimously recognized that the use of a method of transmission with a vestigial sideband is necessary for the type of television transmission considered. It is assumed that the video signal to be transmitted corresponds to an image consisting of 405 lines and that at the studio output the spectrum of the video signal has a relatively sharp cut-off at the two extremities, these being respectively 30 Hz and 3 MHz. It is also assumed that the originating broadcast authority has corrected as far as possible for aperture distortion and other distortions in the camera chain.

With a coaxial cable of the type standardized by the C.C.I.T.T. (see Recommendation G.331) and with a repeater spacing of the order of 9 kilometres (used for 4-MHz telephone carrier systems [1] on coaxial cable of this type), it is possible to transmit an upper sideband

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[1] See Recommendation G.338.

of width around 3 MHz and a vestigial lower sideband of width 500 kHz (value considered satisfactory provisionally even though there is not yet sufficient experience on this subject). If the construction of the cable has been of high quality as regards the regularity of impedance and if the equalization and phase compensation has been good, it may be assumed that the signal applied at the input will be faithfully reproduced at the output.

For television transmissions of the type considered it is recommended to employ in Europe a carrier frequency of nominal value 1056 kHz, it being understood that, during a transmission, the carrier frequency should not change by more than a few cycles per second.

In the present state of the technique, it is not yet possible to design transmitting and receiving terminal equipments independently of each other.

b) *Polarity of modulation*

The advantages or disadvantages of positive polarity (where the signal increases with the brilliance) or negative polarity have not yet been established for television transmissions on metallic lines, but, on the other hand, it is desirable not to have to use inversion apparatus at the interconnection of two circuits. Hence it is recommended that the polarity of modulation adopted at the origin of a chain for international television transmission should be conserved throughout the length of this chain.

c) *Ratio of amplitude between vision and synchronizing signal*

It is recommended that the ratio:

$$\frac{\text{amplitude of vision signal}}{\text{amplitude of synchronizing signal}}$$

in the modulated wave should equal $\frac{7}{3}$.

d) *Depth of modulation*

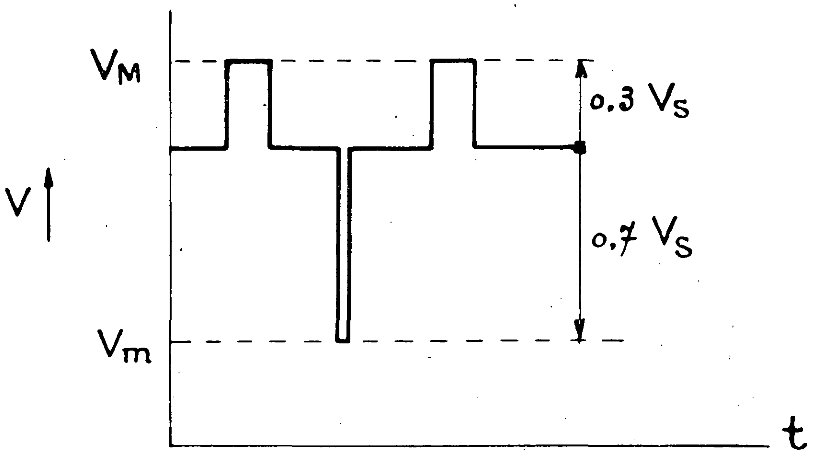
The limit allowed for the "reference modulation coefficient" defined below is provisionally fixed at 50%.

Note. — The modulation coefficient, for a given signal s, is defined as follows: V_s is the voltage (peak-to-peak) of the video signal considered. This signal amplitude modulates a carrier, the amplitude of which varies between the two limits V_M and V_m with $V_M - V_m = V_s$ when the two sidebands are retained.

By definition, the modulation coefficient τ is

$$\tau = \frac{V_s}{V_M + V_m} = \frac{V_M - V_m}{V_M + V_m}$$

It will be seen that this definition coincides with the usual definition when the signal s is sinusoidal.



t = time V = voltage

FIGURE 1

After partial suppression of the lower sideband, the amplitude ratios considered above are approximately retained and the modulation coefficient

$$\tau = \frac{V_M - V_m}{V_M + V_m}$$

remains for all intents and purposes the same.

The modulation coefficient defined above is essentially a function of the type of signal transmitted and differs according to whether the d.c. component of a video signal is retained or not.

However, there should be a limit to the highest modulation coefficient that it is possible to meet amongst all the possible types of waveform in order to limit the detection distortion which appears due to the partial suppression of the lower sideband.

The choice of this highest modulation coefficient determines the modulation coefficient for all other types of signal.

Also, the maximum amplitude of the modulated carrier that it is possible to meet should have an upper limit in order to limit the non-linear distortion. The ratio between the vision signal and the basic noise is then so much smaller that the modulation coefficient is itself small. It would appear from this that there should be a lower limit to the modulation coefficient. The choice is therefore a compromise between the two requirements.

When the complete video signal is as defined above (with for example a negative polarity of modulation) and the d.c. component has been suppressed, it is easy to determine the type of video signal corresponding to the higher coefficient of modulation. It is that which corresponds to the transmission of white spots on a dark background (Figure 1) (it might be considered that the average value of the synchronizing signal is negligible compared with V_S).

The corresponding coefficient of modulation τ_R is called "the reference coefficient of modulation".

e) *D.c. component*

It is recommended that the d.c. component of the complete video signal should be suppressed for transmission to line.

f) *Repeater input and output impedance*

The return loss between repeater input and output impedances and a pure resistance of 75 ohms should be at least 20 dB (2.3 Np) at the carrier frequency used for television; the limit permitted for such return loss may decrease progressively to 15 dB (1.73 Np) at the upper and lower edges of the band of frequencies transmitted for monochrome television.

Note 1. — This being so, at the 1056-kHz carrier frequency and at adjacent frequencies, the overall resultant value of echo in a single repeater section of normal length (sum of the three terms as defined in the Annex to Recommendation J.73) that is obtained is considerably better than the value of 70 dB or 8 Np recommended. The value of 70 dB or 8 Np is, in fact, easily achieved throughout the transmitted band in the case of the 4-MHz system, except at the lower limit of the vestigial sideband, say from 0.5 to 0.7 MHz. A lower figure is in any case acceptable here, as the energy of the signal is small at these frequencies.

Note 2. — The C.C.I.T.T. considered it unnecessary for it to specify other repeater characteristics. For the time being, the arrangements in the case of a cable crossing a frontier should be the subject of bilateral agreement between the countries concerned. (See Recommendation G.352 for the comparable case of telephony on a 2.6/9.5-mm or 0.104/0.375-in. type coaxial cable crossing a frontier.)

RECOMMENDATION J.72

6-MHz SYSTEM FOR TELEVISION TRANSMISSION

The 6-MHz coaxial cable system, defined in Recommendation G.337, is normally used for transmitting 625-line television signals (with a 5-MHz video-frequency band) or the 819-line Belgian system. It is then recommended that the following conditions be met:

a) *Characteristics at intermediate distribution points*

Interconnection between different high-frequency lines or between lines and television modulating or demodulating equipments should only be made at points corresponding to B and E in Figure 1, which might be called "television carrier-frequency interconnection points". (In the same way, points B′ and E′ are "telephony carrier-frequency interconnection points" when telephone channels have to be transmitted to line.) At such interconnection points, the line pilots are suppressed, and the gain/frequency characteristic between points B and E (or B′ and E′) is a horizontal straight line throughout the transmitted frequency band, since networks N_1 and N_2 (or N'_1 and N'_2) have compensating inverse characteristics. It is not necessary to specify the characteristics of these networks precisely, since they depend on the particular line system used for the high-frequency line, CD.

The impedance of the input and output circuits corresponding to points B and E in Figure 1 must be specified. The recommended value is 75 ohms unbalanced to earth, and the return loss against a pure 75-ohm resistance should not be less than 24 dB (2.76 Np).

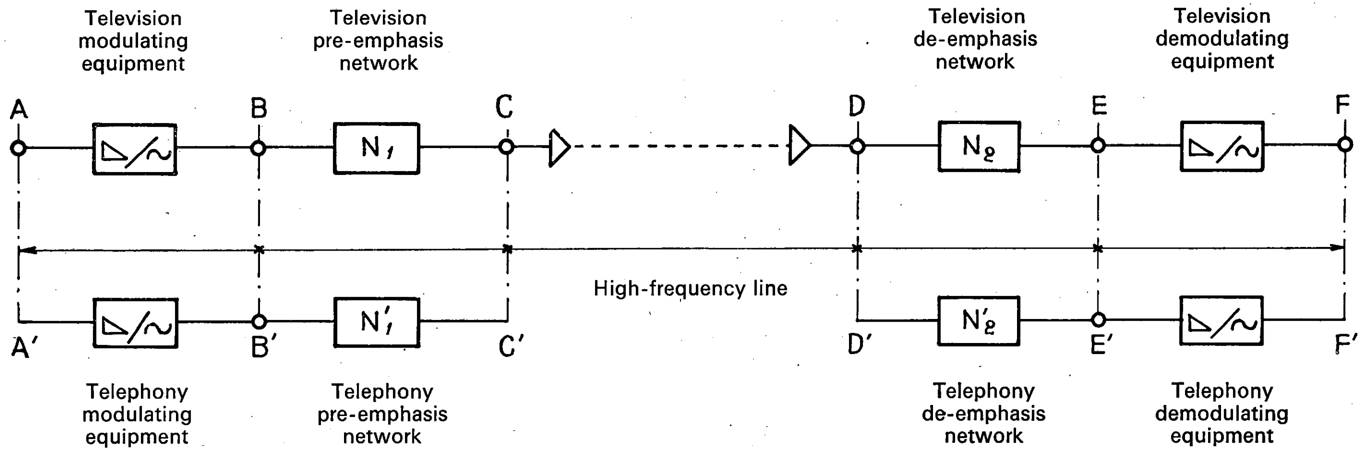


FIGURE 1. — **System of vestigial-sideband television transmission on coaxial cable**

Notes. — 1. Points A and F are video interconnection points.
Points B and E are television interconnection points at carrier frequency.
Points B′ and E′ are telephony interconnection points at carrier frequency.

2. The modulator characteristics should be defined between the points A and B.
The demodulator characteristics should be defined between the points E and F.

3. Between B E and B′ E′ the gain/frequency characteristic at the high frequency is uniform.

4. The networks N_1, N_2, etc., should be chosen to facilitate the matching to the line and to present to the modulation and demodulation equipment standard level conditions, etc.

5. If a number of high-frequency lines of different types are interconnected or if derivations are made at an intermediate point, pre-emphasis and de-emphasis networks, etc., will be necessary at junction points to enable the interconnection to be made at a point of defined level and independent of frequency.

6. For alternative telephony and television transmissions, switching should be carried out at points C and D.

When it is necessary, as an alternative, to insert pre-emphasis and de-emphasis networks, N'_1 and N'_2, the 6-MHz line, CD, can be used alternatively for television or telephony, under the conditions given in Section B of Recommendation G.337.

Note. — So that two line-systems made by different manufacturers can be interconnected at an intermediate point, such as a frontier repeater station, it is first necessary to correct for pre-emphasis (produced, for example, by network N_1 of Figure 1) by means of an inverse network (such as N_2 of Figure 1) and thus to create a point similar to E. Between B and E the line has a gain/frequency characteristic which is a horizontal straight line.

b) *Carrier frequency*

The nominal frequency of the video-signal carrier should be 1056 kHz with a tolerance of ± 5 Hz.

c) *Modulation coefficient*

Amplitude modulation should be used. The modulation coefficient should be greater than 100% (as shown in Figure 2) so that when the carrier is modulated by a signal at suppression level the amplitude of this signal should equal that of the carrier modulated by white level (assuming that the d.c. component is transmitted).

When Test Signal No. 2 (see Annex I to Recommendation J.61) is sent to the modulator input (point A in Figure 1), the nominal value of the peak voltage of the modulated carrier at the output of the modulating equipment (point B in Figure 1) and at the input to the demodulating equipment (point E in Figure 1) should be as follows (see Figure 2) :

- white level or suppression level, 0.387 volt—i.e. the peak value of a sinusoidal signal dissipating 1 mW in a 75-ohm resistance;
- synchronizing signals, 0.719 volt—i.e. the peak voltage of a sinusoidal signal dissipating 3.45 mW in a 75-ohm resistance.

d) *Shaping of the vestigial sideband*

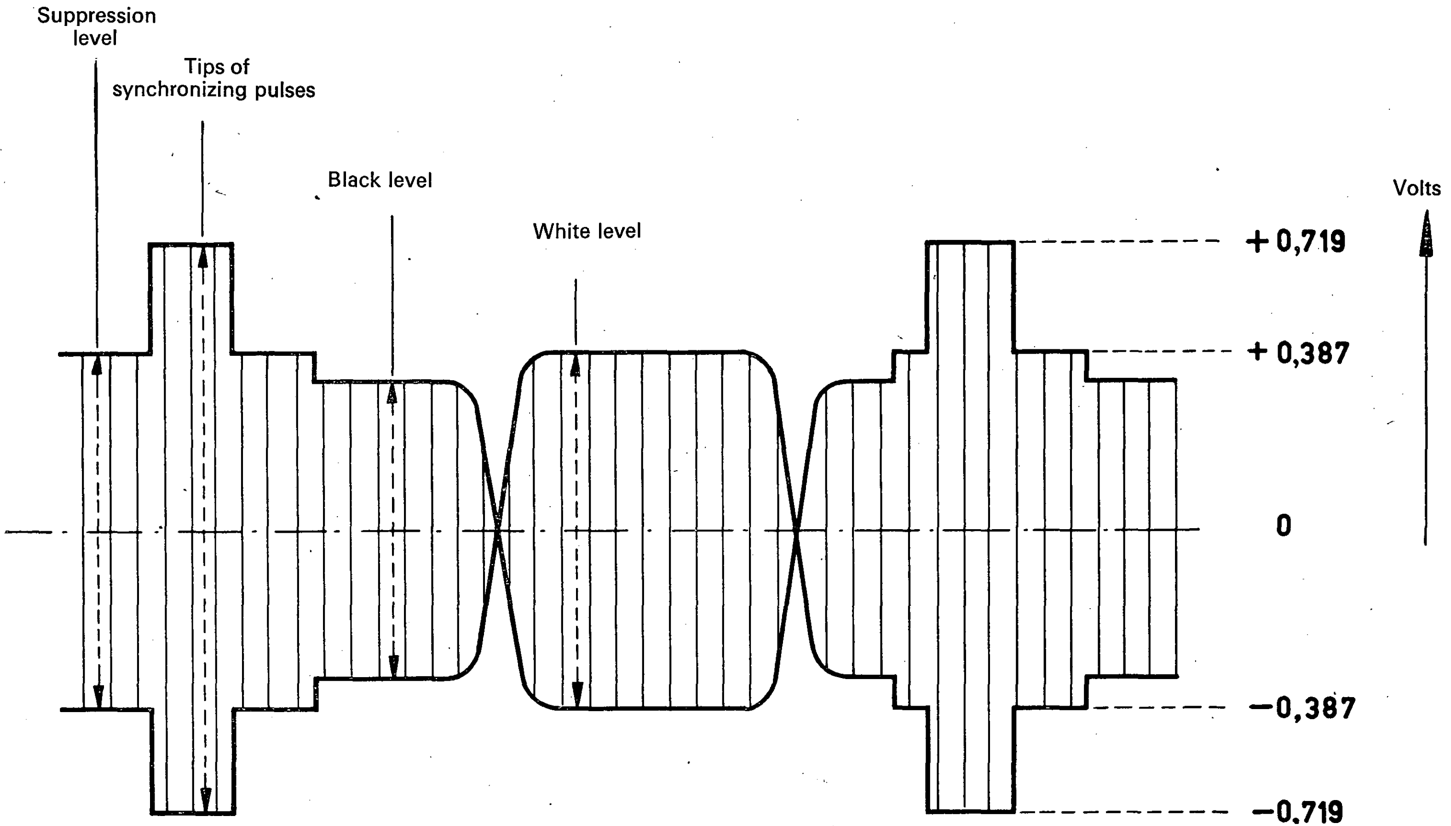
It has not appeared possible to recommend a single system, and the existing shaping filters, whose characteristics are given in the following Annex, should be used. In these systems, the modulation and demodulation equipments play equal parts in shaping the vestigial-sideband signal.

Interconnection between two different systems should be dealt with by bilateral agreement between the administrations concerned.

e) *Pilots*

Pilots should be injected at the input to the first line amplifier (after point C in Figure 1) and should be blocked after the last line amplifier (before point D in Figure 1).

To facilitate the interconnection of line systems, it is recommended that the following frequencies and levels should be standardized for the pilots in each of the two systems defined in the following Annex.



Note. — The voltages shown are the values measured:
— at the output of the modulation equipment (point B, Figure 1) in 6-MHz systems (Recommendation J.72);
— at a zero relative level point for television transmission in the 12-MHz system (Recommendation J.73).

FIGURE 2. — **Envelope of carrier modulated by test signal No. 2**

1st system. — At point B in Figure 1, the levels of the various pilots should have the following values (referred to 1 mW):

for 308 kHz: −29.7 dBm = −3.42 Np
for 4142 kHz: −22.2 dBm = −2.55 Np
for 6142 kHz: −20.3 dBm = −2.34 Np

2nd system. — At point B in Figure 1, the level of the pilots shall have the following values (referred to 1 mW) :

for 308 kHz: −39.0 dBm = −4.49 Np
for 4029.45 kHz: −39.8 dBm = −4.57 Np
for 6200 kHz: −41.7 dBm = −4.80 Np

Administrations that use different systems will reach bilateral agreement in connection with all the necessary arrangements for interconnecting their line systems at a frontier repeater station.

Whatever system is used, the C.C.I.T.T. recommends that the frequency of the line pilots should have a relative tolerance of 10^{-5}.

f) *Interference*

Paragraph 3.3 of Recommendation J.61 shows the overall target design value referred to the hypothetical reference circuit for television transmission.

It is provisionally recommended that the overall random noise should be allocated on the basis of 50% to the line and 50% to the three pairs of modulators and demodulators.

g) *Repeater input and output impedance*

The return loss between repeater input and output impedances and a pure resistance of 75 ohms should be at least 20 dB (2.3 Np) at the carrier frequency used for television.

The limit permitted for such return loss may decrease progressively to 15 dB (1.73 Np) at the upper and lower edges of the band of frequencies transmitted for monochrome television.

Note 1. — This being so, at the 1056-kHz carrier frequency and at adjacent frequencies, the overall resultant value of echo in a single repeater section of normal length (sum of the three terms as defined in the Annex to Recommendation J.73) that is obtained is considerably better than the value of 70 dB or 8 Np recommended. The value of 70 dB or 8 Np is, in fact, easily achieved throughout the transmitted band in the case of 6-MHz systems, except at the lower limit of the vestigial sideband, say from 0.5 to 0.7 MHz. A lower figure is in any case acceptable here, as the energy of the signal is small at these frequencies.

Note 2. — The C.C.I.T.T. considered it unnecessary for it to specify other repeater characteristics. For the time being, the arrangements in the case of a cable crossing a frontier should be the subject of bilateral agreement between the countries concerned. (See Recommendation G.352 for the comparable case of telephony on a 2.6/9.5-mm or 0.104/0.375-in. type coaxial cable crossing a frontier.)

ANNEX

(to Recommendation J.72)

Methods used in 6-MHz systems for shaping the television signal transmitted to line

1st system

1. The vestigial-sideband region should cover a band from approximately 500 kHz above the carrier frequency to about 500 kHz below the carrier frequency. This represents a reasonable compromise between the difficulty of designing a narrow-band filter and the difficulty of extending the frequency range of the repeaters in the low-frequency direction.

The same filter is to be used at the transmitting and receiving terminals. The loss of each filter at the carrier frequency should therefore be 3 dB relative to the filter loss at high frequencies where the transmission is single sideband. Thus, after passing through two filters, the sideband, associated with very low video frequencies will be attenuated by 6 dB, i.e. to one-half of the voltage of the single sideband by which high-frequency information is transmitted. Thus in-phase addition of the two very-low-frequency sidebands produces video information of the same amplitude as the high-frequency information.

With higher video frequencies the vestigial-sideband filters will attenuate the two sidebands unequally. If the filters are phase-equalized the two sidebands will, in the process of demodulation, add in-phase to give the video output.

The requirement, then, to obtain a video output which is independent of frequency is that the sum of the two corresponding sideband amplitudes shall be constant for all video frequencies.

There are many possible filter characteristics which will fulfil this requirement. The mathematically simplest is that producing a linear voltage/frequency characteristic as shown in Figure 3.

It is, however, not possible to realize this characteristic with practical filters. The difficulty occurs at both extremes of the vestigial-sideband region where the linear characteristic has a discontinuity. Practical filters would round off these regions and it is better to take such limitations into account in specifying the required characteristic.

A characteristic which produces the required sideband amplitudes and takes into account the limitation of practical filters is:

For one send or one receive filter

$$D\,(f) = 10 \log_{10}\ ERF\,(y)\ \text{dB}$$

where $D(f)$ is the filter loss at frequency f relative to the loss in the single-sideband region,

$$y = \frac{f - f_0}{K} \qquad \text{where } f_0 \text{ is the carrier frequency;}$$

K is a constant defining the rate of cut-off of the unwanted sideband.

The function $ERF\,(y)$ is the error function of y defined as:

$$ERF\,(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} \exp\left(-\frac{y^2}{2}\right) \mathrm{d}y$$

This function will be found tabulated in mathematical tables.

As regards the constant, K, for the definition of the rate of cut-off of the unwanted sideband, a value of $K = 215$ kHz has been proposed by the Cuban Telephone Company.

It is believed that sending and receiving vestigial-sideband terminals using rather different K values may interwork satisfactorily, provided that each terminal equipment is phase-equalized.

2. In specifying the accuracy with which such a characteristic should be met, the limits set should take into account the fact that, for a given error in the video output, a much wider tolerance can be allowed at frequencies at which the filter attenuation is high.

This is satisfied by the following expression:

$$E = \left| 10^{-\frac{D_a}{10}} - 10^{-\frac{D_f}{10}} \right|$$

E is a constant to be specified and which determines tolerances.

D_a is the actual filter discrimination (dB).

D_f is the specified filter discrimination (dB).

2nd system

The lower sideband is attenuated by the combination of transmitting modulator and receiving demodulator, in such a way that between 518 and 1594 kHz the change of amplitude with frequency is linear (see Figure 3, curve a). At the points where the voltage passes through the values 0 and 100%, there is only negligible rounding of the characteristic. The total filter attenuation required is divided equally between the sending and receiving equipments. Each component filter has an attenuation of 3 dB at the carrier frequency and of 9 dB at 400 kHz below the carrier frequency. Bearing in mind the preceding recommendation, the shape of the amplitude/frequency characteristic of a single filter is therefore that of curve b of Figure 3. The increase is proportional to the square root of the difference between the frequency considered and 518 kHz, the value being 0 and 518 kHz, 0.707 at 1056 kHz and 1.0 at 1594 kHz.

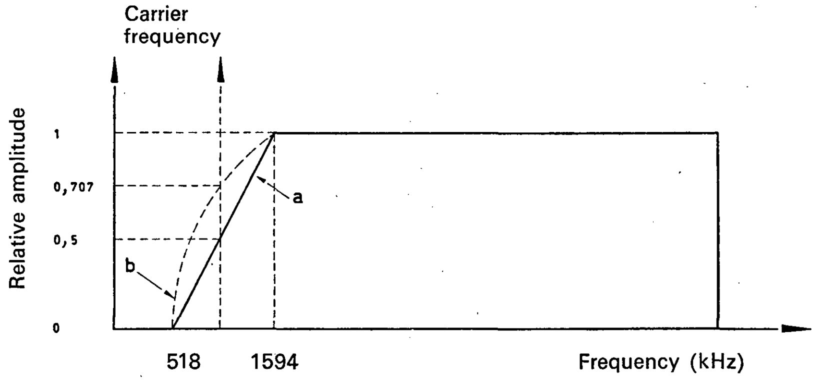


FIGURE 3. — **Partial suppression of the lower sideband**

No proposal can be made for the allowable deviation from this nominal curve but, for information, it is pointed out that the following characteristic is achieved by the Nyquist filters used by the Federal German Administration. The combined attenuation of the two filters gives a linear voltage/frequency characteristic. When this characteristic passes through 0 and 100% of the voltage, the rounding-off is insignificant. The overall attenuation of the two filters is equally divided between the sending and the receiving equipment. Each partial filter has a 3-dB attenuation at the carrier and a 9-dB attenuation at 400 kHz below the carrier. Thus the slope of the Nyquist filter characteristic is linear between the frequencies.

$$f_1 = 518 \text{ kHz and}$$
$$f_2 = 1594 \text{ kHz.}$$

RECOMMENDATION J.73 (modified in Geneva, 1964)

USE OF A 12-MHz SYSTEM FOR THE SIMULTANEOUS TRANSMISSION OF TELEPHONY AND TELEVISION

The 12-MHz coaxial pair system is defined in Recommendation G.337 and its use for telephony transmission in Recommendations G.332 and G.337.

Any 12-MHz system equipped for television transmission should be capable of transmitting the signals used in all those television systems defined by the C.C.I.R. having a video bandwidth not exceeding 5 MHz [if necessary, by means of the switching (in terminal equipments only) of certain components].

This recommendation has been drafted only for the transmission of monochrome television systems defined by the C.C.I.R. up to 1964.

a) *Carrier frequency*

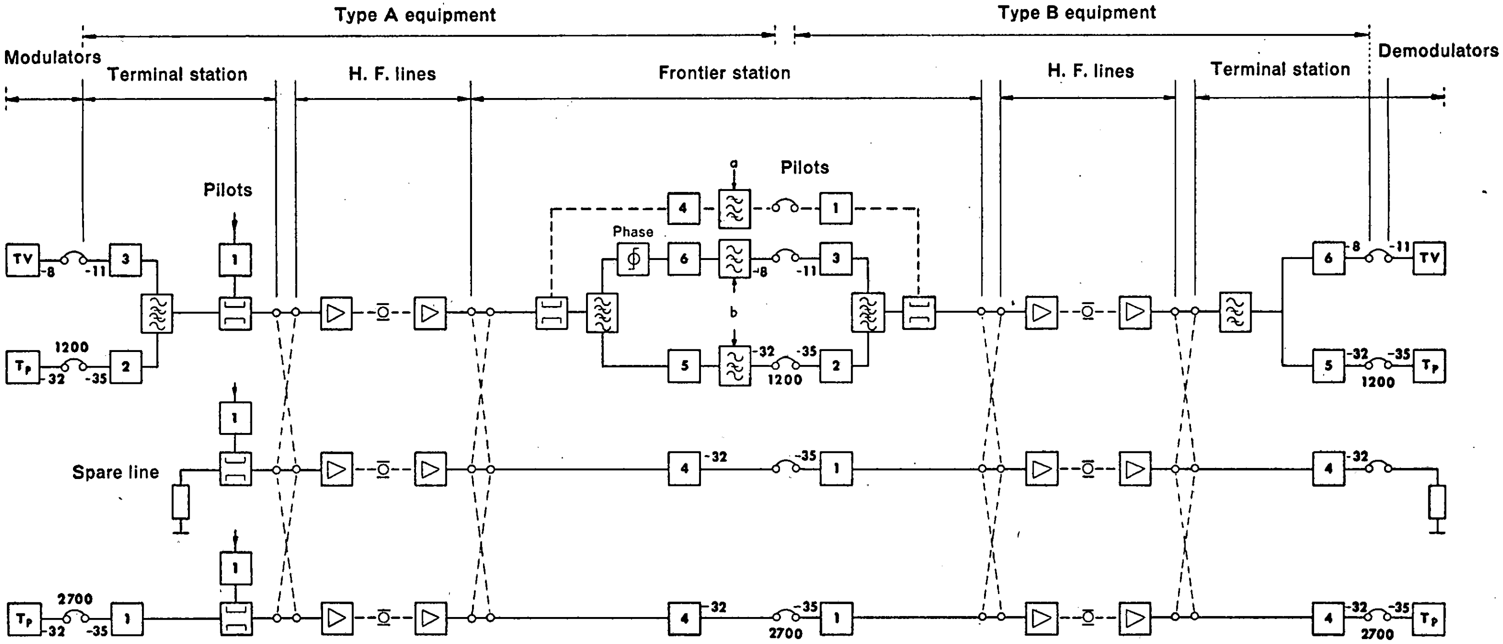
The C.C.I.T.T. recommends the use of a carrier frequency of 6799 kHz with a tolerance of ± 100 Hz for the transmission of all the television signals indicated above. The video band transmitted over the cable should be 5 MHz wide, whatever television system is to be used. The level provisionally recommended for this carrier has been defined for the interconnection points and is shown in Figures 1 and 2 (see Note 3).

b) *Modulation ratio*

Amplitude modulation has to be used. The modulation ratio has to be higher than 100% (as indicated in Figure 2, Recommendation J.72), so that, when the carrier is modulated by a signal corresponding to blanking level, its amplitude is equal to that of the carrier when it is modulated by a signal corresponding to white, assuming that the d.c. component is transmitted.

When test signal No. 2 (see Annex I to Recommendation J.61) is applied at a video junction point, the nominal peak voltage of the modulated carrier, at a point where the relative level for the television transmission is zero, should be as follows:

- — for white or blanking level, 0.387 volt (i.e. the peak voltage of a sine wave signal dissipating a power of 1 mW in a resistance of 75 ohms);
- — for the synchronizing signals, 0.719 volt (i.e. the peak voltage of a sine wave signal dissipating a power of 3.45 mW in a 75-ohm resistance).



1 4 Pre-emphasis (respectively de-emphasis) for telephony 2700 channels

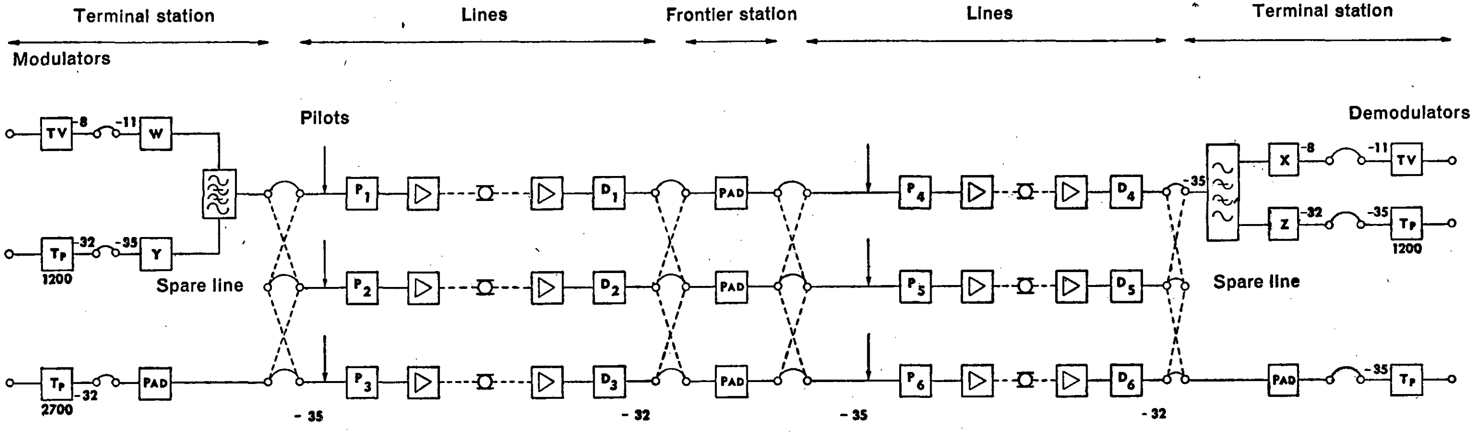
2 5 Pre-emphasis (respectively de-emphasis) for telephony 1200 channels

3 6 Pre-emphasis (respectively de-emphasis) for television

} Simultaneous transmission

a) Pilot pass-filter
b) Pilot stop-filter

FIGURE 1. — **General case of interconnection of 12-MHz lines**



Nominal relative levels on the line for each telephone channel in the "all-telephony" case

W X	Differential pre-emphasis and de-emphasis for television	common for all types of 12-MHz line
Y Z	Differential pre-emphasis and de-emphasis for telephony 1200 channels	
P1 D1	Pre-emphasis and de-emphasis for telephony, 2700 channels, particular to each design of 12-MHz line	

FIGURE 2. — **Showing use of differential emphasis networks to simplify interconnection of 12-MHz lines of different designs**

c) *Vestigial-sideband shaping*

The shaping of the vestigial-sideband signal has to be carried out entirely at the transmit point. Provisionally, the vestigial sideband should not exceed a width of 500 kHz. Figure 3 shows the frequency arrangement recommended for television transmission over the 12-MHz system.

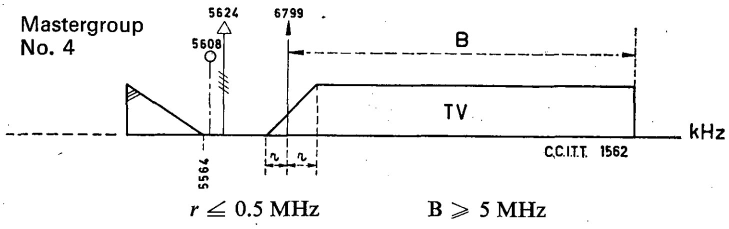


FIGURE 3. — **Frequency allocation for television transmission on a 12-MHz system**

d) *Relative power levels and interconnection at a frontier section*

It is not possible to recommend relative power levels at the output of intermediate repeaters since they are very closely linked to the inherent design of each administration's system.

When interconnection between two telephone systems is effected via a cable section that crosses a frontier, in accordance with Recommendation G.352, each administration should accept, on the receiving side, the level conditions which normally apply to the incoming system used in the other country. It may be possible to comply with this condition simply

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Notes on Figures 1 and 2

1. Interconnection of pilots, e.g. blocking and re-injecting or by-passing, should be agreed between administrations.

2. The level of the line pilots is fixed at −10 dBm0 or −1,15 Nm0, for the all-telephony case. When the line is used to transmit telephony and television simultaneously, different values of pre-emphasis may be required; although the absolute levels of the pilots will remain the same, they may no longer be at −10 dBm0.

3. The television levels shown are those of the modulated carrier, relative to that of the idealized reference signal described in paragraph b) of this recommendation. (See also Figure 2 of Recommendation J.72.)

4. The characteristics of the filters in Figure 1 (used for separating and combining the telephony and television bands so that the necessary arrangements for pre-emphasis and de-emphasis can be made) must be agreed between administrations.

Levels shown in dB in Figures 1 and 2	Corresponding values in nepers
− 8 dB	(−0.92 Np)
−11 dB	(−1.27 Np)
−32 dBr	or −3.7 Nr
−35 dBr	or −4.0 Nr

by insertion of a correcting network at the receiving end. The repeater section crossing the frontier should then be less than 4.5 km long. The details being agreed directly between the administrations concerned before the repeater stations are sited.

Where a line is to be used alternatively for "all-telephony" or for "telephony-plus-television", such a solution is not generally applicable. In this case, one of the frontier stations may act as a main station having the necessary types of pre-emphasis and de-emphasis networks to permit interconnection at flat points at the recommended levels. Figure 1 shows how this may be done in the general case and also shows how, at terminal stations, the same interconnections levels are used when connecting the line to telephony and television translating equipment.

However, if a common differential characteristic can be agreed for all types of 12-MHz line, then free interconnection of the full line-bandwidth becomes possible, both nationally (e.g. between working and spare lines) and internationally (between national systems of different designs). This method leads to the simpler interconnection arrangement of Figure 2.

In this arrangement, the circuit is always lined up for "all telephony". For telephony-plus-television, the emphasis characteristic used for the "all-telephony" case is modified by the insertion, at the terminal equipment stations only, of differential pre-emphasis and de-emphasis networks additional to those used for "all-telephony" transmission.

e) *Repeater input and output impedance*

The return loss between repeater input and output impedances and a pure resistance of 75 ohms should be at least 20 dB (2.3 Np) at the carrier frequency used for television.

The limit permitted for such return loss may decrease progressively to 15 dB (1.73 Np) at the upper and lower edges of the band of frequencies transmitted for monochrome television.

Note. — This being so, at the 6799-kHz carrier frequency and at adjacent frequencies, the overall resultant value of echo in a single repeater section of normal length (sum of the three terms as defined in the Annex to this recommendation) that is obtained is considerably better than the value of 70 dB or 8 Np recommended. The value of 70 dB or 8 Np is, in fact, easily achieved throughout the transmitted band.

f) *Interference*

Paragraph 3.3 of Recommendation J.61 indicates the overall values relative to the hypothetical reference circuit for television transmissions which are taken as objectives for design projects.

In the experience of certain administrations, the weighted psophometric power can be distributed between the terminal equipment and the line in the ratio of 1 to 4.

In particular, the Federal German Administration uses, for the 12-MHz system, the following signal/weighted noise ratio:

a) for terminal modulation equipment	70 dB
b) for terminal demodulation equipment	64 dB
c) for a line 840 km in length	58 dB

These values result in a signal-to-noise ratio of 52 dB at the end of the reference circuit.

ANNEX

(to Recommendation J.73)

Impedance matching between repeaters and coaxial pair in television transmission

Such impedance matching, for television transmission systems having repeater sections of about 9 km or 6 miles, was formerly specified by stating an overall limit, as follows (taken from pages 269 and 270 of Volume III *bis* of the C.C.I.F. *Green Book*):

"Let Z_L be the measured line impedance at frequency f seen from a repeater station (see Figure 4);

Let Z_E be the measured output impedance at frequency f of the repeater station equipment seen from the line;

Let Z_R be the measured input impedance at frequency f of the repeater station equipment seen from the line;

Let A be the total line attenuation al, at frequency f, between two adjacent repeater stations, a being the measured attenuation coefficient of the coaxial pair and l the distance between the two adjacent repeater stations concerned.

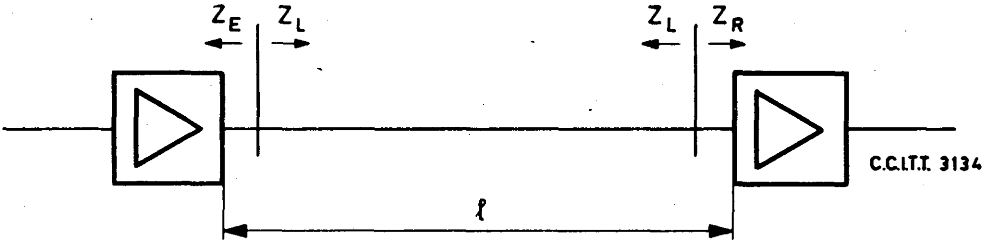

FIGURE 4. — **Repeater section of a coaxial pair**

Then the value N (in decibels or nepers) is taken to be defined by the formula

$$N = 2A + 20\log_{10}\left|\frac{Z_E + Z_L}{Z_E - Z_L}\right| + 20\log_{10}\left|\frac{Z_L + Z_R}{Z_L - Z_R}\right| \text{(decibels)}$$

or

$$N = 2A + \log_e\left|\frac{Z_E + Z_L}{Z_E - Z_L}\right| + \log_e\left|\frac{Z_L + Z_R}{Z_L - Z_R}\right| \text{(nepers)}$$

Provisionally the condition indicated below should be met.

In the case of a television transmission system, N should be of the order of 70 decibels or 8 nepers at frequencies adjacent to the virtual carrier frequency used for the line transmission. At frequencies remote from the carrier frequency, lower values of N might be acceptable."

Since then, the C.C.I.T.T. has recommended limits for return loss at the input and output of repeaters, as given in the following Recommendations:

- Recommendation J.71, paragraph g), for 4-MHz systems and Recommendation J.72, paragraph g), for 6-MHz systems, both of which systems have approximately 9-km or 6-mile repeater sections and a carrier frequency of 1056 kHz;
- Recommendation J.73, paragraph e), for the 12-MHz system, with approximately 4.5-km or 3-mile repeater sections and a carrier frequency of 6799 kHz.

These give more stringent limits than the overall limit shown above, which becomes redundant for these systems. However, if in the future the C.C.I.T.T. should define other television transmission systems having a large number of closely spaced repeaters, this overall limit may again become important; in that case it will be necessary to revise and correct the recommendation from the *Green Book* quoted above, using more precise terms to specify the impedances concerned.

RECOMMENDATION J.74

METHODS FOR MEASURING THE TRANSMISSION CHARACTERISTICS OF TRANSLATING EQUIPMENTS

a) No special measuring method is necessary for the carrier.

b) An oscilloscope can be used, for example, to measure the modulation coefficient.

c) No special method is recommended for measuring pre-emphasis.

d) An oscilloscope can be used, for example, to measure the voltages at the input to the modulating equipment and the output from the demodulating equipment.

e) The following is an example of a method which can be used to measure the random noise at the modulator output:

The input and output video terminals of the modulator are closed with 75-ohm resistances and the modulator is set to give an output carrier power of 1 milliwatt. The random noise power can then be measured with a selective measuring instrument, and the result is given relative to the video-frequency bandwidth for the television system concerned.

To measure noise produced by the demodulator, 1 milliwatt of carrier power is sent to its input, and the random noise at the output is measured at the output terminals with a selective measuring instrument.

This method can also be used to measure parasitic noise having a recurrent waveform.

Note. — Methods for measuring parasitic noise in television are being studied.

RECOMMENDATION J.75

INTERCONNECTION OF SYSTEMS FOR TELEVISION TRANSMISSION ON COAXIAL PAIRS AND ON RADIO-RELAY LINKS

A. TELEVISION TRANSMISSION ONLY

Direct video transmission over long, e.g. more than 10-mile, coaxial cables is unsatisfactory, because of the likelihood of picking-up interference and the difficulties of low-frequency equalization; it is therefore necessary to transmit the television signal as a modulated carrier transmission, usually with a vestigial sideband.

On the other hand, the television signal can be transmitted directly in the baseband of a radio-relay system as a video signal; in general it is advantageous to do so, since this minimizes distortion and enables a better signal-to-noise ratio to be obtained as compared with a modulated signal with vestigial sideband, transmitted in the baseband. This procedure is recommended by the C.C.I.R.

Interconnection between television channels on radio-relay and cable systems will therefore normally take place at video frequencies.

Levels and impedances at interconnection points should then conform to Recommendation J.61.

Exceptionally, in special cases, the video signal can be transmitted over short cables or a vestigial-sideband television signal can be transmitted on short radio-relay links, to allow direct interconnection at line frequencies (radio-relay link baseband). Special arrangements may be necessary in such cases in respect of signal level, pre-emphasis and pilots, to maintain the recommended standard of transmission performance.

B. TELEPHONY AND TELEVISION TRANSMISSION, ALTERNATIVELY OR SIMULTANEOUSLY, ON COAXIAL PAIRS OR RADIO-RELAY LINKS

a) *Interconnection between a coaxial cable system having alternative transmission of telephony and television and a radio-relay link with the same alternative transmission*

It is recommended that the following conditions should be met at the interconnection point:

1) For telephony transmission, the frequency arrangements, the relative power levels of the telephone channels and the frequency of the pilots should be as indicated in Recommendation G.423.

2) For television transmission, interconnection should generally be made at video frequencies. Levels and impedances at interconnection points should then conform to Recommendation J.61.

b) *Interconnection between a coaxial system having simultaneous telephony and television transmission and a radio-relay link with the same simultaneous transmission*

On all radio-relay links designed for such simultaneous transmission it is intended to transmit video-frequency television signals in the lower part of the baseband and telephony signals in the upper part. Since these arrangements are incompatible with those which are recommended by the C.C.I.T.T. for simultaneous telephony and television transmission on coaxial cables (Recommendation J.73), it will normally be possible to consider interconnection at video frequencies, only for the television channel and interconnection at group, supergroup or supermastergroup points for telephony.

However, by agreement between the administrations concerned, direct interconnection may be achieved in special cases on a short system (on cable or radio) by using a frequency allocation recommended for the other type of system.

RECOMMENDATION J.76 (Geneva, 1964)

LOCAL LINES FOR TELEVISION TRANSMISSIONS

The C.C.I.T.T. has not issued any recommendations concerning the characteristics of "local lines" for television transmissions as defined in paragraph 1.1.3 of Recommendation J.61.

By way of information Annexes 57 to 60 (Part 4 of Volume III, *Blue Book*) describe the arrangements made in various countries:

a) to connect the sending end of an international television connection to the sending terminal station of a long-distance international television circuit, and from the receiving terminal of such a circuit to the receiving end of the international television connection;

b) to ensure satisfactory transmission over those local circuits and equipments which are the responsibility of the telecommunications authority.

Similar information may be found in the following articles:

A. Myhrman: Video amplifying equipment for television program transmission, *Ericsson Review*, No. 2, 1963.

K. Maeda: Coaxial cable video transmission system, *Japan Telecommunication Review*, Volume 1, No. 2.

T. Horiguchi: Transistorized coaxial cable video transmission system, *Japan Telecommunication Review*, Volume 9, No. 1.

PART 4

TRANSMISSION QUESTIONS FOR STUDY IN 1968-1972

IMPORTANT NOTICE

1. Since Special Study Group D was set up by the Plenary Assembly, all questions relating to pulse code modulation (p.c.m.) have been assigned to this Study Group for the time being.

The Chairman of Special Study Group D will make arrangements with the other chairmen for effecting liaison with the other Study Groups concerned as work progresses.

2. When a question is of interest to more than one study group and no joint study group has been set up to deal with it, the mention of the other study group(s) concerned is intended for the information of the members of the study group to which the question has been assigned, to enable them to arrange for the necessary co-ordination *within their national* administrations, in accordance with a decision of the IVth Plenary Assembly.

3. At the request of the C.C.I.T.T., the C.M.T.T. is in process of studying the following seven Study Programmes:

Study Programme 4A/CMTT "Co-ordination of the transmission of sound and video signals" (C.C.I.T.T. Question D/CMTT)

Study Programme 5A/CMTT "Circuits for high-quality monophonic programme transmissions" (C.C.I.T.T. Question A/CMTT)

Study Programme 5B/CMTT "Circuits for stereophonic programme transmission" (C.C.I.T.T. Question B/CMTT)

Study Programme 5C/CMTT "Revision of C.C.I.T.T. Recommendation J.21" (C.C.I.T.T. Question C/CMTT)

Study Programme 5D/CMTT "Characteristics of signals sent over monophonic programme circuits" (C.C.I.T.T. Question E/CMTT)

Study Programme 5E/CMTT "Compandors for programme circuits" (C.C.I.T.T. Question F/CMTT)

Study Programme 5F/CMTT "Noise from the power supply" (C.C.I.T.T. Question F/CMTT)

The C.C.I.T.T. Secretariat has been instructed to bring the documentation concerning these C.M.T.T. studies to the attention of Study Group XV.

Questions on transmission systems assigned to Study Group XV

Question 1/XV — Characteristics of circuits for high-quality monophonic programme transmissions

(new question)

Considering

a) that the C.M.T.T. has a Study Programme 5A/CMTT relating to radiophonic circuits for high-quality monophonic programme transmissions; *

b) that, to reply to this Study Programme the C.M.T.T. will have to define a hypothetical reference link (similar to Figure 108, *Blue Book*, Volume III, page 353) together with the characteristics of this hypothetical link at audio-frequencies (e.g. frequency band effectively transmitted, attenuation distortion, phase distortion, weighted noise [1], intelligible crosstalk, variation of level, non-linear distortion, error on frequency reconstitution, etc.);

c) that the constitution of the hypothetical reference circuit for each transmission system and the characteristics to be satisfied between audio-frequency terminals by each hypothetical reference circuit will result from the study mentioned under considerandum b; [2]

d) that the dynamic characteristics of signals sent over monophonic programme transmission circuits and in particular the maximum and the mean power of such signals applied at a point of zero relative level are being studied in connection with the Study Programme 5D/CMTT;

the following points should be studied:

1. *Characteristics at audio-frequencies of the whole or of sections of the hypothetical reference circuit*
   - a) Frequency band effectively transmitted;
   - b) relative level of a programme link at the audio-frequency amplifier output (see points D, C... in Figure 108 of Volume III of the *Blue Book*, page 353);
   - c) matching conditions;
   - d) distribution of the general conditions specified by the C.M.T.T.;
   - e) non-linearity limits for the various sections of the hypothetical reference circuit [3];

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* See *Important Notice* preceding the list of questions, paragraph 3.

Notes for the C.M.T.T.

[1] It will presumably be necessary to see whether the characteristics curve for the filter network of the psophometer, as specified in C.C.I.T.T. Recommendation P.53 (*Red Book*, Volume V, pages 131 to 133), should also be used as a basis for the large bandwidth of the link being studied. A report on previous tests is contained in the *Red Book* (1956), Volume I, pages 134 to 152.

[2] The attention of the C.M.T.T. has already been drawn to the Figure on page 353 of Volume III of the C.C.I.T.T. *Blue Book*, which can be compared with the first figure in Recommendation J.61 (C.C.I.R. Recommendation 421, Geneva, 1963). In place of the definition of the hypothetical reference circuit in Recommendation J.21 (*Blue Book*, Volume III, page 359), the hypothetical reference circuit will probably be defined as an example of a "(long-distance) international programme line" in accordance with the Figure on page 353 of the *Blue Book*, Volume III.

[3] The C.M.T.T. should consider whether recommendations on intermodulation distortion should be given in addition to those on harmonic distortions. If so, how should the intermodulation distortion be measured?

f) what usable power reserve should the circuits have?

g) frequency and level of any reference pilot which may be allocated to the long-distance international programme line or to the international programme link.

2. *Characteristics of circuits for carrier programme transmissions in a modulated section* of the hypothetical reference circuit*

a) Frequency position in the basic group of one circuit or of two circuits set up for independent programme transmissions;

b) relative level of the programme transmission circuit in the group, compared with the relative level of telephone channels;

c) permissible variation in relative level with time;

d) frequency and level of any pilot allotted for the modulated section;

e) permissible carrier leaks in the frequency band of the programme channel and provisions required to meet this requirement [1];

f) permissible frequency error at the end of a modulated section of the programme circuit and measures required to meet this requirement;

g) provisions required to meet noise and crosstalk conditions (pre-emphasis, compandor, frequency position).

Note 1. — It would be useful to study points 2 a to g bearing in mind also the conditions to be met in order to provide either two circuits for monophonic programme transmission in the same group, or a pair of programme circuits to provide a stereophonic transmission (see Question 2/XV and Study Programme 5B/CMTT). The Study of Question 8/XV will also be taken into account.

Note 2. — The attention of Special Study Group C is drawn to points 2 b and 2 g.

Question 2/XV — Characteristics of pairs of circuits providing stereophonic programme transmissions

(new question)

Considering

that the C.M.T.T. has a Study Programme 5B/CMTT relating to the transmission of stereophonic programmes;

b) that the general characteristics of the complete transmission chain are defined in C.C.I.R. Report 293-1;

c) that a number of questions on stereophonic transmission methods have been submitted to the C.M.T.T. in Note 1 of Study Programme 5B/CMTT but that nevertheless, for technical reasons, only the use of two circuits transmitting signals A and B seems to be open to consideration in the case of cable systems;

d) that Question 1/XV has been proposed relating to the characteristics of circuits for high-quality monophonic programme transmissions;

---

* An exact definition of the "modulated section" should be drawn up once the corresponding hypothetical reference circuit has been defined.

[1] The C.M.T.T. is requested to indicate the permissible level for sine-wave interference.

e) in reply to Study Programme 5B/CMTT, recommendations will presumably have to be made for a hypothetical reference circuit and for the characteristics of the two circuits providing a stereophonic transmission;

the following question should be studied:

What additional characteristics should be defined for each circuit of a pair providing stereophonic transmissions, compared with the characteristics of a circuit for monophonic transmission studied under Question 1/XV?

The following aspects of carrier transmission should be studied:

a) Frequency position in the basic group,

b) What phase difference may be permitted at the end of a modulated section of a programme transmission circuit between the two circuits of a pair providing stereophonic transmission and how can the recommended value be maintained?

Note 1. — The phase difference limits specified by C.C.I.R. Report 293-1 imply that any frequency offset due to transmission on either circuit should be strictly the same. This limitation, moreover, implicitly sets the permissible difference in propagation time between the two circuits.

c) What difference in level is permissible at each frequency of the transmitted band of a modulated section between the two programme circuits of a pair providing stereophonic transmission and how can it be kept at the recommended level?

Note 2. — To ensure economic utilization of circuits, it should be possible for a pair of circuits set up for stereophonic transmissions to be used for two independent monophonic transmissions as well. This would mean in particular that the crosstalk conditions recommended for monophonic transmissions should also apply to circuit pairs set up for stereophonic transmissions.

Note 3. — The study of Question 8/XV will be taken into account.

Question 3/XV — Relative gain of international telephone circuits outside the band 300-3400 Hz

(continuation of Question 3/XV studied in 1964-1968)

What should the limits be for the gain relative to that at 800 Hz outside the band 300-3400 Hz for channel equipment used for international telephone circuits?

Note 1. — At the present time international telephone circuits are set up and maintained in accordance with Recommendation M.58 (*White Book*, Volume IV) in which no relative gain is permitted outside the band 300-3400 Hz. There is no problem in satisfying this recommendation with current types of frequency division multiplex channel translating equipment and exchange line signalling equipment (see Annex 1 to the Question).

Note 2. — In the future:

a) there may be other types of channel equipment (for example, p.c.m. equipments) (see Annex 2 to the Question);

b) in an automatic exchange line signalling equipment may be very different (for example when signalling system No. 6 is introduced).

These two considerations in combination may make it more difficult to achieve the limits of Recommendation M.58 outside the band.

Note 3. — This study should be made jointly by Study Groups IV, XI, XV and XVI.

ANNEX 1

(to Question 3/XV)

I. Reply by Study Group XV to Question 3/XV in 1966

According to the information gathered, all send and receive channel equipments considered can ensure at least the attenuation figures shown in the following tables. (These represent the sum of send and receive attenuation for equipments of the same design; this value should be used in the calculations of stability mentioned at the top of page 17 in Volume III of the *Blue Book*.)

Equipments which permit out-band signalling

Frequency	(Hz)	100	120	150	250	3600	3700	3800	3900
Attenuation	N dB	4.03 35	1.50 13	0.748 6.5	0.115 1	1.04 9	2.42 21	3.80 33	5.76 50

Equipments which do not permit out-band signalling

Frequency	(Hz)	50	100	150	250	3400-3600	3700	3800	3900
Attenuation	N dB	0.460 4	0.173 1.5	0 0	0 0	0 0	0.173 1.5	0.921 8	2.65 23

This information has been forwarded to Study Group XVI in connection with the study of Question 2/XVI (1964-1968). These figures relate to channel equipments only and do not allow for the effect of additional equalizers or of other equipment which may be included in telephone circuits.

The attention of Study Group XVI is drawn to the fact that these values are derived from documentation assembled to date and should on no account be regarded as recommendations for the time being. Study Group XVI should indicate whether it would like Study Group XV to try to frame a recommendation.

II. Comments by Study Group XVI in 1968

To ensure the stability of international connections, it is necessary to limit to zero the relative gain (with respect to 800 Hz) at frequencies outside the band 300-3400 Hz. Study Group XVI has drafted recommendations (see Recommendation G.122) with respect to national systems. However, the question of the international chain remains to be considered. Study Group XVI notes that Study Group IV proposes to recommend that there should be no positive value for the relative gain (with respect to 800 Hz) at any frequency outside the 300-3400 Hz band, for telephone circuits. Study Group XV is requested to study this problem from the point of view of the specification of modulating equipment.

Study Group XVI does not think that a positive relative gain is likely to appear in the exchanges with the techniques used at present and for the time being it will not refer a question to Study Group XI.

ANNEX 2

(to Question 3/XV)

Co-ordination of Questions 3/XV and 2/D (point 13)

(Contribution by the American Telephone & Telegraph Co.)

The following is a suggested note for the revised Question 3/XV:

REMARK

Further study of a recommendation for limits for the equivalent outside the 300-3400 Hz band must consider both frequency division multiplexing (f.d.m.) channel translating equipment and p.c.m. channel encoding—time division multiplexing equipment. In channel translating equipment, the loss in p.c.m. encoding multiplexing equipment to the frequencies below the 300-3400 Hz band may be significantly different from that in f.d.m. equipment. Consideration of values for loss below the band for p.c.m. terminals should be studied as a part of Question 2/D (point 13).

In f.d.m. channel translating equipment the channel band-pass filters (and any equalization of their response) have loss-frequency characteristics which result in a substantial loss at frequencies below the transmitted band (as indicated in Annex 1).

In p.c.m. primary block terminal equipment, a corresponding loss to frequencies below the band would have to be provided by introducing additional loss, for example, by voice-frequency, high-pass filtering. The cost of providing such additional loss justifies consideration of how much loss below the band is actually required, not just how much loss can conveniently be provided in channel translating equipment.

Question 4/XV — Standardization of different types of programme circuits

(new question)

(also of interest to Study Groups III and IV)

Considering

1. that the exceptional use of 16-channel terminal equipment (e.g. in submarine cable systems) (Recommendation G.235) has led to the introduction by some administrations of programme channel translating equipment, which is compatible with 3-kHz-spaced telephone channels, to provide sound programme circuits of 5, 8 and 11-kHz nominal bandwidth;

2. that, as a consequence, the number of different types of programme circuit now in use is greater than the number of types recommended by the C.C.I.T.T.;

3. that the increase in the number of types of programme circuit is regrettable;

4. that the setting-up and maintenance of these types of circuit in the international network is hindered because these types are not all recognized by the C.C.I.T.T.;

5. that the different characteristics of the various types of programme circuits leads to the setting-up of international sound-programme links of mixed constitution;

there is need to study the following question:

a) What characteristics of the new types of programme circuits (based on 3-kHz telephone channel spacing) should be recognized by the C.C.I.T.T. so that Recommendations can be made on the setting-up and maintenance of such circuits?

b) Is it desirable to set up a classification of different types of sound-programme circuits?

c) If so, what would be the most rational bandwidths of the different types of sound-programme circuits?

Note. — The following Annex summarizes the proposals put forward by an Administration to Study Groups III, IV and XV in 1968.

ANNEX

(to Question 4/XV)

Summary of proposals by the Administration of the Federal Republic of Germany [1]

1. It might be useful to envisage the introduction of a new fundamental definition of nominal bandwidths for category A and B international sound-programme circuits so as to take account in a uniform manner of the structural modifications in the technique of international sound-programme circuits in recent years. With this end in view and also with a view to the problem of sound quality, the Administration of the Federal Republic of Germany wishes to submit the following four bandwidth classes for discussion (classes 3 and 4 are important only for intercontinental links by transatlantic cable):

Proposed classes of circuit	Nominal bandwidth		Number (n) of octaves from f_1 to f_2	Geometric-mean frequency (f_{gm}) of band f_1 to f_2
	f_1 kHz	f_2 kHz		kHz
1	0.04 (0.0375)	15	8.7	0.75
2	0.05	10	7.7	0.71
3	0.075	7.5	6.7	0.75
4	0.1	5	5.7	0.71

As will be seen from the table, successive bandwidth classes differ by one complete octave, and the geometric-mean frequencies are all fairly well represented by a reference frequency of 800 Hz.

2. In association with this proposal to introduce these four bandwidth classes, the Administration of the Federal Republic of Germany further proposes the limits in the following table for

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[1] In contribution COM IV—No. 156 (period 1964-1968) will be found fuller information on the proposal by the Federal Republic of Germany.

the variation of level as a function of frequency. The values given in the table are based on the following principles governing the planning of the international sound-programme circuits network.

a) As far as possible a permanent category A sound-programme circuit which is subject to separate maintenance has only one modulation section. If two modulation sections have to be connected in series, the limit values must be maintained, an additional equalizer being provided if necessary.

b) A permanent category B sound-programme circuit which is subject to separate maintenance has a maximum of three series-connected modulation sections. Here, too, an additional equalizer may be necessary, among other things.

c) A temporary chain set up to provide a category A sound-programme circuit has at most three category A sound-programme circuit sections.

d) A temporary chain set up to provide a category B sound-programme circuit rarely contains more than one category B sound-programme circuit section and never more than two category A sound-programme circuit sections.

3. The following table shows proposed limit values for variation of level with frequency for classes 1 to 4 of sound-programme circuits (referred to the level measured at 0.8 kKz).

Limits for corresponding frequency (kHz) intervals in the various classes						
Class 1	0.04-0.075	0.075-0.15	0.15-9	9-12	12-15	
Class 2	0.05-0.1	0.1-0.2	0.2-6	6-8	8-10	
Class 3	0.075-0.15	0.15-0.3	0.3-4	4-6	6-7.5	
Class 4	0.1-0.2	0.2-0.4	0.4-3	3-4	4-5	
Category A sound-programme circuits and circuit sections [1]	+0.07 −0.15	+0.07 −0.1	±0.07	+0.07 −0.1	+0.07 −0.15	N
	+0.6 −1.3	+0.6 −0.9	±0.6	+0.6 −0.9	+0.6 −1.3	dB
Category B sound-programme circuits	+0.1 −0.2	+0.1 −0.15	±0.1	+0.1 −0.15	+0.1 −0.2	N
	+0.9 −1.7	+0.9 −1.3	±0.9	+0.9 −1.3	+0.9 −1.7	dB
Category A chain of sound-programme circuits	+0.2 −0.45	+0.2 −0.3	±0.2	+0.2 −0.3	+0.2 −0.45	N
	+1.7 −3.9	+1.7 −2.6	±1.7	+1.7 −2.6	+1.7 −3.9	dB
Category B chain of sound-programme circuits	+0.23 −0.5	+0.23 −0.35	±0.23	+0.23 −0.35	+0.23 −0.5	N
	+2.0 −4.3	+2.0 −3.0	±2.0	+2.0 −3.0	+2.0 −4.3	dB

[1] If necessary with additional equalizer.

Question 5/XV — Compandors for telephony

(continuation of Question 5/XV studied in 1964-1968)

With a view to supplementing Recommendation G.162 on the characteristics of telephony compandors and to improving it, where necessary, administrations are requested to make their views known on the following points:

a) Might the limit of −30 dmB0 specified in Recommendation G.222 for unweighted noise power hamper the working of the compressor in view of the fact that in practice high-level noise may occur at frequencies outside the transmitted band? If so, what precautions are to be advocated and what clause is proposed for Recommendation G.162?

b) Might a reduction in the attack and recovery time of the compressor and expander improve the dynamic characteristics of a group of several circuits compandorized in tandem without lowering the telephone transmission quality of the whole? If so, what new limits are proposed for Recommendation G.162?

Note. — The change in the limits for attack and recovery time, and possibly in the limits for transient response to an infinite step, must in any event be in accordance with the demands of signalling. For this reason these limits given in Recommendation G.162 are already regarded as provisional.

ANNEX 1

(to Question 5/XV)

Intermodulation and harmonics in compandors

(Note by the United Kingdom Administration)

It can be shown that:

— if a compressor and expander have completely complementary characteristics,

— if the variable loss elements in the compressor and expander are identical, and

— if the signal amplitudes and control current values in the variable loss elements, corresponding to a particular uncompressed signal level, are also identical,

then, provided the circuit between compressor and expander is distortionless, there will be no distortion products in the expander output due to the non-linearity of the variable loss device and to alternating components of the control current. It follows that the distortion products of any particular type produced in compressor and expander are equal in amplitude but opposite in phase. However, if there is any mismatch between the characteristics of the compressor and expander, and if there is any attenuation or phase distortion in the circuit, distortion components will appear at the expander output, and their amplitude will, in addition to being a function of the mismatch or circuit distortion, be proportional to the amplitude of the distortion components produced in the compressor (or expander) alone.

It is therefore of interest to investigate these distortion components. In the present theoretical study, only distortion components arising in the variable loss devices will be considered. Distortion may also occur in the amplifying stages or other parts of a compressor or expander in the same way as in other parts of the transmission system, and no cancellation of these can be relied upon even with an otherwise distortionless circuit.

In the theoretical analysis, the same assumptions regarding the characteristics of the variable loss device and the control circuit will be made as in Annex 2 below.

Two classes of distortion products may appear at the output of the variable loss device:

a) Intermodulation between signal components and alternating components of the control current. (If the variable loss device is accurately balanced, the alternating components of the control current will not themselves appear at the output.)

b) Harmonics and intermodulation products of the signal due to the non-linearity of the variable loss device. If this device is accurately balanced, only odd order components will appear.

Since the attenuation of the control circuit increases with frequency, the importance of type a is greatest when the output of the control circuit rectifier contains alternating components of low frequency. Type b, which would occur even in the absence of any alternating components in the control current, is not frequency-dependent. Neglecting higher order components, the distortion products to be examined are second-order components of type a and third-order components of type b. (In a practical compandor, there may also be second-order components of type b and some components at the frequencies of the alternating components of the control current, but the level in both cases wil depend on the degree of unbalance in the variable device.)

In a 2/1 compressor, it can be shown that the level of second-order products of type a relative to the level of the desired signal is dependent solely on the *CR* product of the control circuit. It is independent of the level of the input signal, i.e. it is the same at all points on the compression range, and is also unaffected by any changes of design which alter the signal level at the variable loss device corresponding to any particular value of control current.

The ratio of the amplitude of third-order components of type b to the amplitude of the desired signal is proportional to the square of the ratio of the signal current to the control current in the variable loss device. Since the control current is proportional to the square root of the signal current, it follows that the relative level of distortion products of this type increases with the signal level applied to any particular compressor. On the other hand, their relative level can be reduced to any desired extent by modifying the design so as to reduce the signal level at the variable loss device corresponding to a particular value of control current.

The second-order type a distortion products thus represent the irreducible minimum level of distortion, which is determined entirely by the time constant of the control circuit. It is therefore of interest to study the levels of these components.

Some examples will now be given of distortion products which appear to be of greatest interest.

Intermodulation

Probably the type of signal which it is of greatest interest to consider in the study of intermodulation is multifrequency pulsing. In one such system, two out of five frequencies spaced at intervals of 200 Hz are transmitted, the transmitted amplitudes of the two frequencies being nominally equal.

Considering such a system, the worst case, as regards intermodulation, is when the two frequencies ω_1 and ω_2 differ by 200 Hz; either one or both of the intermodulation products of frequencies $(2\,\omega_1 - \omega_2)$ and $(2\omega_2 - \omega_1)$ will then coincide with other possible signalling frequencies.

These intermodulation products can arise in two ways: 1) second-order intermodulation between components of frequencies $(\omega_1 - \omega_2)$ and $2(\omega_1 - \omega_2)$ in the control current and the signal components of frequency ω_1 or ω_2 (type a above) and 2) third-order intermodulation between the signal components of frequencies ω_1 and ω_2 in the variable loss elements (type b above). The component resulting from the first cause will depend on the control circuit time constant. If in Figure 1 a) of Annex 5 we denote the ratio of the amplitude of a component of angular frequency ω in the rectifier output to the amplitude of the same component in the variable loss device by l_ω, then at the frequencies and values of time constant which are of practical interest $l_\omega \simeq \omega CR$. It can be shown that the level of the component of frequency $(2\omega_1 - \omega_2)$ or $(2\omega_2 - \omega_1)$ in the output of the variable loss device is

$$9 + 20 \log_{10} l(\omega_2 - \omega_1) \text{ dB} \tag{7}$$

For the case under consideration $\omega_2 - \omega_1 = 2\pi \times 200$ and if, for example, CR=20 milliseconds, the level of the intermodulation component is 37 dB below one of the signal components.

Note. — This is the level for an "ideal" compressor (or expander). Practical compandors may give rather higher levels of intermodulation products than those characteristic of an "ideal" compandor having the same attack and recovery times.

The level of the component of frequency $(2\omega_2 - \omega_1)$ or $(2\omega_1 - \omega_2)$ due to the second cause depends on the ratio of signal current to the control current. If the ratio, in a variable loss element, of the d.c. control current to the peak value of the current at one of the two signal frequencies ω_1 or ω^2 is q, then the level of the distortion component at $(2\omega_1 - \omega_2)$ or $(2\omega_2 - \omega_1)$ is

$$12 + 20 \log_{10} q^2 \text{ dB} \tag{8}$$

below the level of one of the signal frequencies. Since, in a 2/1 compressor, the control current is proportional to the square root of the input signal current, it follows that the relative amplitude of the distortion component is directly proportional to the signal amplitude. Hence the distortion component given by (8) becomes of increasing importance relative to that given by (7) as the signal level is raised.

The components given by (7) and (8) differ in phase by the amount of phase shift in the control circuit at frequency $(\omega_2 - \omega_1)$. With practical values this phase shift is nearly 90° and the components are therefore in quadrature.

In order to obtain the best performance with reasonable economy in design, it seems desirable to select the working signal level at the variable loss device so that the distortion component (8) becomes comparable with component (7) only at the upper end of the level range of the compandor.

Harmonics

Harmonics of the signal frequency produced by intermodulation of type a will be significant only when the signal frequency is very low. Considering a signal of a single angular frequency ω, then if the control circuit rectifier is full wave, the control current will contain components of frequencies 2ω, $4\omega \ldots$, and intermodulation of the 2ω and 4ω components with the signal can produce a third harmonic of the signal. The level is

$$15 + 20 \log_{10} l_\omega \text{ dB} \tag{9}$$

below the signal level.

(If $CR = 20$ milliseconds and $\omega = 2\pi \times 300$, for example, this becomes 46.5 dB.)

If the control circuit rectifier is half-wave, the control current will contain a component of frequency ω, and this, intermodulating with the signal, can produce a second harmonic of the signal. The level is

$$2.1 + 20 \log_{10} l_{\omega} \text{ dB} \tag{10}$$

below the signal level.

(If $CR = 20$ milliseconds and $\omega = 2\pi \times 300$, this becomes 33.6 dB.)

The control current will also contain components of frequency 2ω and 4ω and these will produce a third harmonic of the signal. The level is

$$14.8 + 20 \log_{10} l_{\omega} \text{ dB} \tag{11}$$

below the signal level.

(With the above values of CR and ω, this becomes 46.3 dB).

In addition, and irrespective of whether full- or half-wave rectification is used, a third harmonic of type b can be produced, the level being

$$21.6 + 20 \log_{10} q^2 \text{ dB} \tag{12}$$

below the signal level.

This component is level-dependent and is in quadrature with the components given by (9) or (11).

In a practical compandor, the level of harmonics may be either somewhat higher or lower than that given by the formulae (9), (10), (11) and (12) for the reasons discussed earlier in connection with intermodulation products.

Effect of circuit delay distortion

As already mentioned, if the circuit between compressor and expander is distortionless, the intermodulation and harmonic components produced in compressor and expander are 180° out of phase and cancel one another. It is of interest to estimate the amount of phase distortion required to bring them into phase. The relative level of the affected component at the expander output will then be 6 dB higher than at the compressor output. As an example, signalling using multifrequency pulsing will be considered. We have to determine the phase distortion which will bring the $(2\omega_2 - \omega_1)$ intermodulation components into phase.

The relevant circuit parameters are merely the phase shift at frequencies ω_1, ω_2 and $(2\omega_2 - \omega_1)$. However, if we assume that the phase shift-frequency characteristic is smooth, and that over this frequency range its shape is approximately parabolic, it is possible to quote the result in terms of the difference of group delay, or the delay distortion, between the two ends of this frequency range. With these assumptions, it can be shown that the required value of delay distortion is $\frac{2}{\omega_2 - \omega_1}$, that is, the period of one cycle of the difference frequency of the two input signals. Considering the case of two adjacent signalling frequencies, this means a delay distortion of 5 milliseconds between the two ends of a 400-Hz band. Taking two signalling frequencies 400 Hz apart, the required delay distortion would be 2.5 milliseconds between the ends of a band 800 Hz wide. The latter is not necessarily a worse case, because the actual level of the intermodulation component produced in the compressor (or expander) alone, assuming that type a intermodulation is predominant, would be lower than in the former case, since the value of $\omega_2 - \omega_1$ is greater.

Delay distortions of one-third the above values will give a phase difference of the compressor and expander components of 120°, and the resultant will then be equal to either of these components alone.

In practice it may be concluded that a considerable degree of cancellation will normally occur between the compressor and expander distortion components. It is probably unreasonable to assume, for design and specification purposes, the extreme adverse case of direct addition of components. However, the degree of cancellation may be reduced, not only by circuit distortion but also by mismatch between compressor and expander, and therefore it seems reasonable to assume that the relative level of any component at the expander output may be as high as the level produced in the compressor (or expander) alone.

ANNEX 2

(to Question 5/XV)

Theoretical study by the United Kingdom Administration of the transient response of compandors

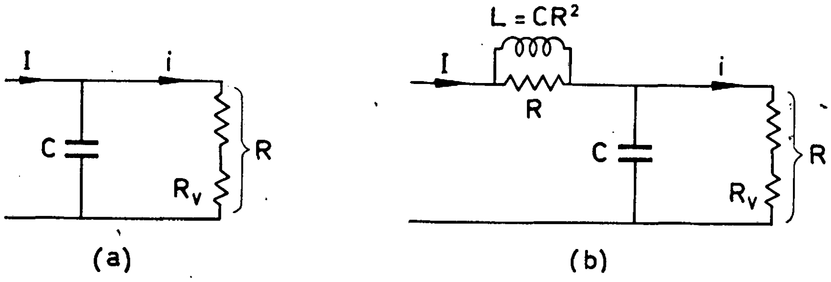
1. *Basic assumptions*

a) *Type of variable loss device*

Compandors having accurate 2/1 compression and expansion law only will be considered. It will be assumed that the compression (or expansion) is obtained by applying a control current to a variable loss device. In the case of the compressor, the variable loss device has the characteristic that the over-all gain of the compressor, expressed as a voltage ratio, is inversely proportional to the control current. Conversely, in the case of the expander, the characteristic is such that the overall gain expressed as a voltage ratio is directly proportional to the control current.

b) *Type of control circuit rectifier*

The control currents are derived by rectification of the output signal of the compressor, and of the input signal to the expander, respectively. If the gain of the expander is always to be adjusted, in a manner complementary to that of the compressor, it is essential that corresponding values of control current should be produced in the compressor and expander used on the same channel whatever the waveform of the transmitted signal. Thus, if the signal has a complex periodic waveform, the control current produced must be independent of the phase relation of the fundamental and its harmonics, since this will, in general, be disturbed by the transmission link between compressor and expander. This ideal would be achieved if a rectifier giving a d.c. output proportional to the r.m.s. value of the input were used to derive the control current. In practice, rectifiers giving an output approximately proportional to the arithmetic mean value of the signal, or to the peak value, are simpler to design. The error due to phase shift of harmonics may be considerable in the case of a peak rectifier, but will, with most waveforms, be fairly small for a mean rectifier, and this type is assumed in the present study. Figure 1 (a) shows the equivalent circuit of the control section of a compressor or expander. The signal is applied to a half-wave or full-wave linear rectifier, of high and constant internal impedance, which thus supplies to the circuit CR a current I, whose mean value is proportional to the mean value of the applied signal, and is independent of the voltage across the capacitor C. The resistance R consists of the variable loss device together with any series resistance in the circuit, and this series resistance is assumed large enough to swamp the variable loss device over the operating range, so that the value of R remains substantially constant. Figure 1 (b) shows an alternative circuit which avoids the need for a rectifier of high internal impedance. This is a constant impedance network, the impedance being a pure resistance R at all frequencies. The rectifier can thus have any value of internal impedance, provided it is constant.



R_v = Variable loss device

FIGURE 1. — **Equivalent circuit of the control section of a compressor or expander**

If the control current i contains, under steady-state conditions, an appreciable a.c. component, the effect will be to introduce harmonics in the compressor output, and also the amplitude of the fundamental may differ somewhat from the value which it would have if only the d.c. component of the control current were present. In the present study these effects will be assumed negligible, and in consequence only the mean values of I and i at any instant need be considered.

2. *Transient response of compressor*

At any instant, the voltage across the capacitor is equal to iR.

Hence

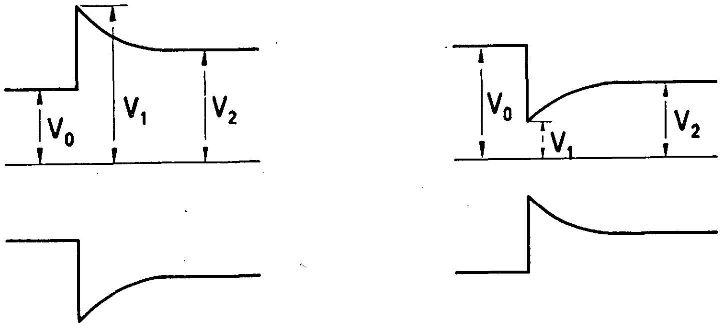
$$CR\frac{di}{dt}+i=I$$

$$=K_1V \qquad (1)$$

where V is the output voltage of the compressor and K_1 a constant. Now V is proportional to the input signal and inversely proportional to i. If the applied input signal is a single frequency having an envelope which is a voltage step, its value after the step is constant. Hence equation (1) becomes

$$CR\frac{di}{dt}+i=\frac{K_2}{i} \qquad (2)$$

where K_2 is a constant.



Attack Recovery

FIGURE 2. — **Envelope of the output of a compressor when the input signal has an envelope which is a step function**

If the value of V before the step is V_0, immediately after it is V_1 and the final steady-state value is V_2 (see Figure 2), and if the size of the input step, expressed as a voltage ratio, is S,

$$\text{then} \qquad \frac{V_1}{V_0} = S$$

$$\text{and} \qquad \frac{V_1}{V_2} = \frac{V_2}{V_0} = \sqrt{S}$$

Solving the differential equation (2), deriving from this the expression for V and determining the constants by inserting the boundary conditions, we obtain the following result:

$$\frac{V}{V_2} = \frac{1}{\sqrt{1 - (1 - \frac{1}{S})\, e^{-2t/CR}}} \tag{3}$$

From this equation we can calculate the value of t/CR at which the transient overshoot will have fallen to any desired fraction of its initial value. The result will vary with the size of step and will also be different for attack and recovery since S is greater than 1 for an upward step and less than 1 for a downward step.

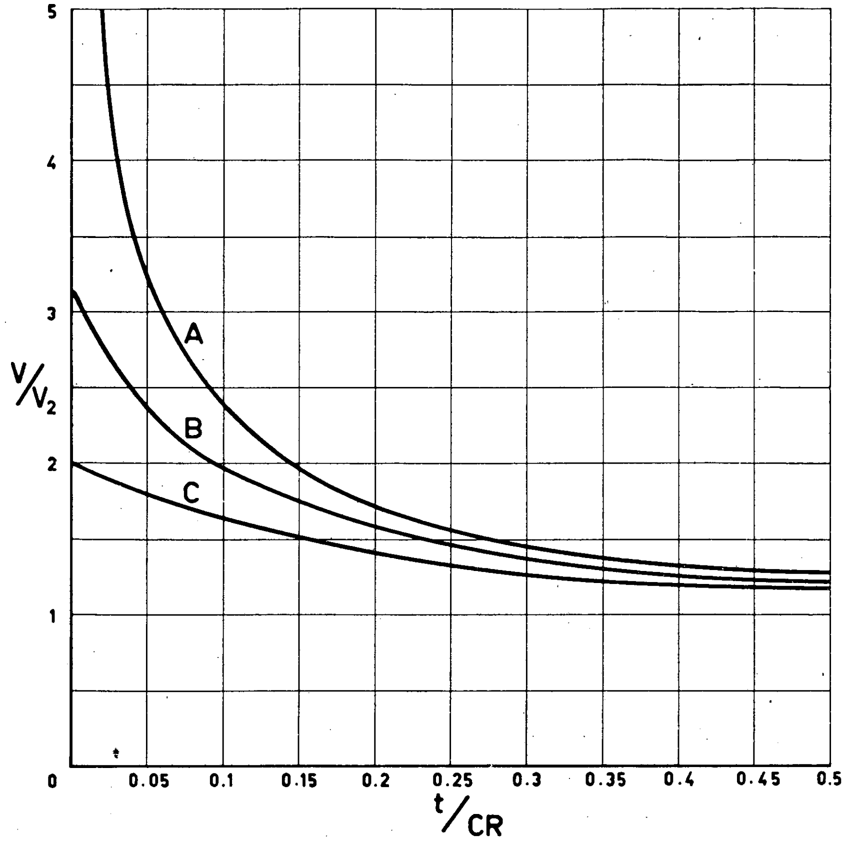
The attack time, as defined in Recommendation G.162, is the time at which V/V_2 reaches the value 1.5 for the case $S = 4$, and equation (3) gives $t = 0.149\ CR$. The recovery time is the time at which V/V_2 reaches the value 0.75 for the case $S = 0.25$, and equation (3) gives $t = 0.675\ CR$.

Curve A of Figure 3 is of interest in connection with the study of possible overloading with voice-frequency signalling. This shows the transient response to an infinite input step, i.e. to the sudden application of a signal of finite amplitude to the input of the compressor after a period with zero input. The rise to an initial peak of infinite amplitude results from the assumption of infinite dynamic range of the compressor, which therefore has infinite gain with no input. In practice, this peak will be limited by the maximum gain available in the compressor when the control current is zero, or when it is limited to the value produced by circuit noise. If the peak does in fact reach a value which overloads the compressor itself, the shape of the transient will be still further modified, since the gain will not then fall as rapidly as when overload does not occur. However, the curve gives a fair indication of the behaviour on overload of a practical compandor. For comparison, similar curves of transient response for input steps of 20 dB (curve B) and 12 dB (curve C) are also shown in Figure 3.

3. *Effect of small differences in time constants of compressor and expander*

In studying the effect of a difference between the time constants of the compressor and expander used on the same channel, it is assumed that both have an accurate 2/1 law and that in all respects other than the time constants of the control circuits they have complementary characteristics. Considering the control circuit of the expander, we have to solve the equation

$$C_e R_e \frac{di_e}{dt} + i_e = KV \tag{4}$$



A = Compressor output due to the sudden application of a finite signal after a period of zero input (i.e response to an infinite step).

B = Response to a 20-dB step.

C = Response to a 12-dB step.

FIGURE 3. — **Transient response of a compressor**

where V is the input voltage of the expander (equal to the output voltage of the compressor), C_e, R_e are the values in the expander control circuit, i_e the control current and K a constant. Considering a step function input to the compressor, we have already shown (equation (3)) that

$$V = \frac{V_2}{\sqrt{1 - (1 - \frac{1}{S})\, e^{-2t/C_cR_c}}} \qquad (5)$$

where V_2 is the final steady-state output voltage of the compressor, and C_c, R_c are the values in the compressor control circuit.

Substituting the value of V in (4), we obtain an equation which does not yield readily to general solution. However, making the following substitutions,

$$\frac{C_cR_c + C_eR_e}{2} = CR$$

and
$$\frac{C_cR_c - C_eR_e}{CR} = h$$

and if we assume that h (i.e. the difference between the CR values expressed as a fraction of the mean) is small compared with 1, it follows that ht/CR is small compared with 1 throughout the range of t/CR which is of interest, and we arrive at the following approximate solution for V', the output voltage of the expander

$$\frac{V'}{V_2'} = 1 + h \frac{me^{-t/CR}}{\sqrt{1 - m^2e^{-2t/CR}}} \left(\text{arc sin } m - \text{arc sin } me^{-t/CR} \right) \tag{6}$$

where
$$m = \sqrt{1 - \frac{1}{S}}$$

and V_2' is the final steady-state output voltage of the expander. The second term represents the overshoot or error due to the inequality of time constants. For attack, this error is positive for

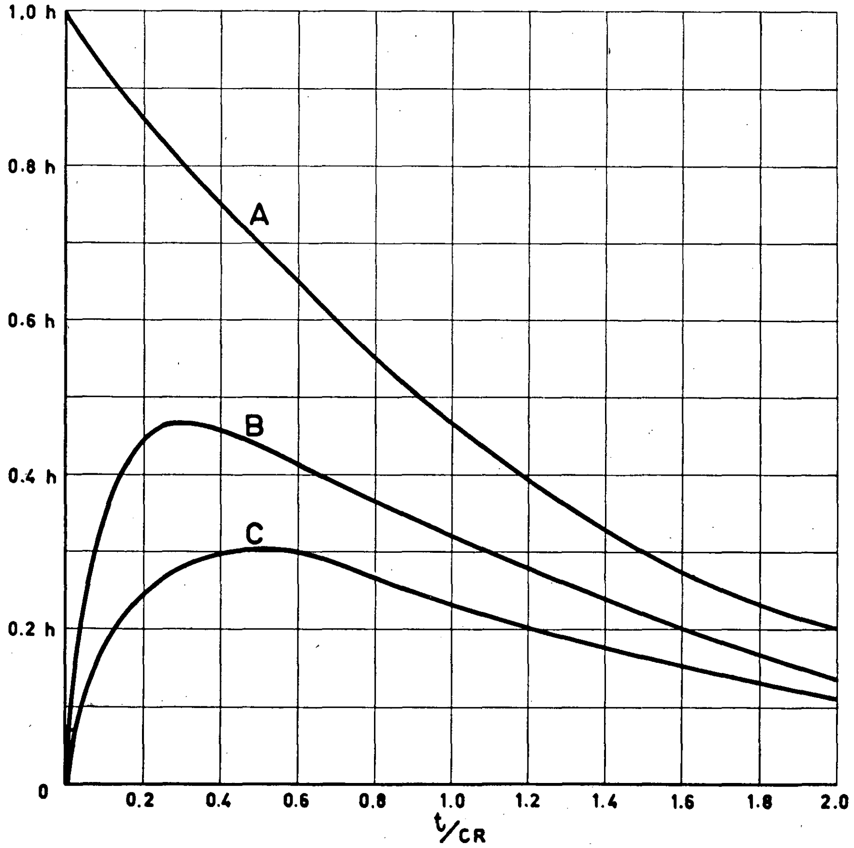
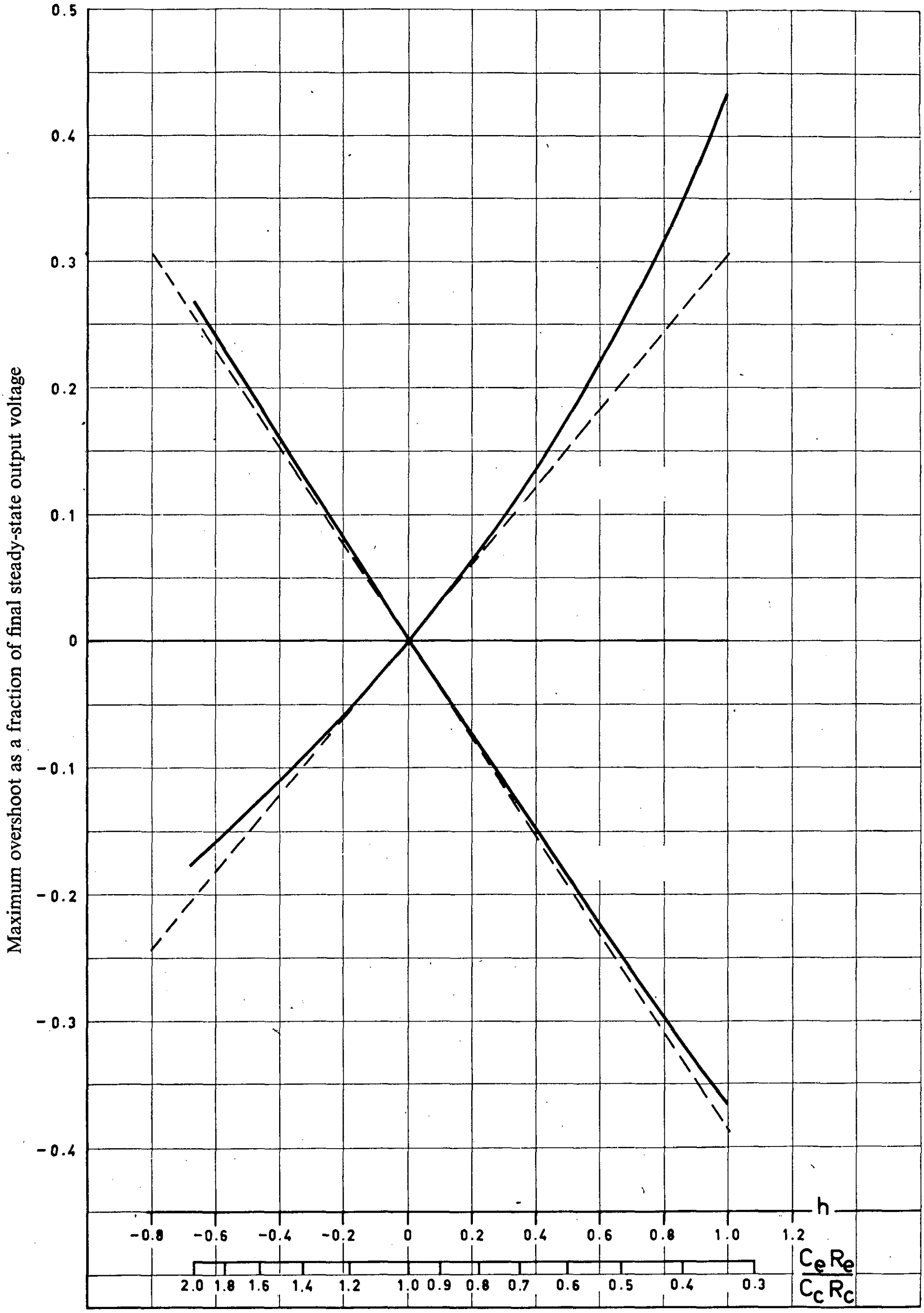


FIGURE 4. —Effect of differences in time constant of compressor and expander

Error in expander output when the input step to the compressor is:
A = infinity B = 20 dB C = 12 dB



——— curves obtained by numerical solution of differential equation

– – – straight lines corresponding to approximate solution

FIGURE 5. — **Effect of differences in time constant of compressor and expander on the maximum overshoot for a 12-dB step**

positive values of h, i.e. when the CR value for the compressor is greater than that for the expander, and is negative for negative values of h, i.e. when the CR value of the compressor is less than that for the expander.

The error term for attack is plotted, for various values of input step to the compressor, in Figure 4. As would be expected, the error at times $t = 0$ and $t = \infty$ are zero, for steps of finite size. For an infinite step, the error at $t = 0$ is equal to h. This arises from the fact that an idealized compandor with infinite dynamic range has been assumed, so that with no input the compressor has infinite gain and the expander has infinite loss. In any practical compandor this will not be the case. Provided the gains of compressor and expander remain complementary, the error at time $t = 0$ will be zero, and the peak value of the error will occur at a small positive value of t/CR and will be slightly less than h. If the gains with no input are not complementary there will be a finite error at $t = 0$, but with practical values of the time constant the time for the control currents to rise to values which cause the compressor and expander to enter the dynamic range in which they have complementary gains will be so short that this initial error is not likely to be of any practical significance.

It will be noted that, even in the extreme case of an idealized compandor and infinite input step, the maximum error, expressed as a fraction of the steady-state output, will never exceed h.

If h is not very much less than 1, no explicit solution of equations (4) and (5) is known, but a numerical solution can be obtained in any particular case. Figure 5 shows curves, calculated in this way, of the maximum overshoot for a 12-dB step.

ANNEX 3

(to Question 5/XV)

Essential characteristics of compandors for telephony

(Contribution by the Italian Administration)

1. *Effect of unweighted noise outside the telephone band on the control of the compressor*

An out-of-band noise which controls only the compressor (since it cannot control the expander as it is suppressed by the channel filter) introduces a further attenuation to which there corresponds an increase in the equivalent which can be expressed by the equation

$$\Delta E = 10 \log_{10} \left(1 + \frac{P_B}{P_S}\right)$$

where P_B is the mean noise power and P_S is the mean signal power, integrated in accordance with the time constant of the compressor.

Taking into account the time constants normally used in these equipments, the mean noise power P_B can generally be considered constant when the mean power P_S of the audio signals varies within a range of about 10 dB, depending on the sequence of syllables.

This power fluctuation, which could be called the " syllabic dynamics of the signal ", is therefore transmitted in altered form whenever the signal/noise ratio at the compressor input is less than 10 dB and therefore ΔE is a function of P_S.

The effect of out-of-band noise which enters the compressor may therefore be taken as a whole to be a fluctuation of the rate of compression on the signals involving a variation of this rate from

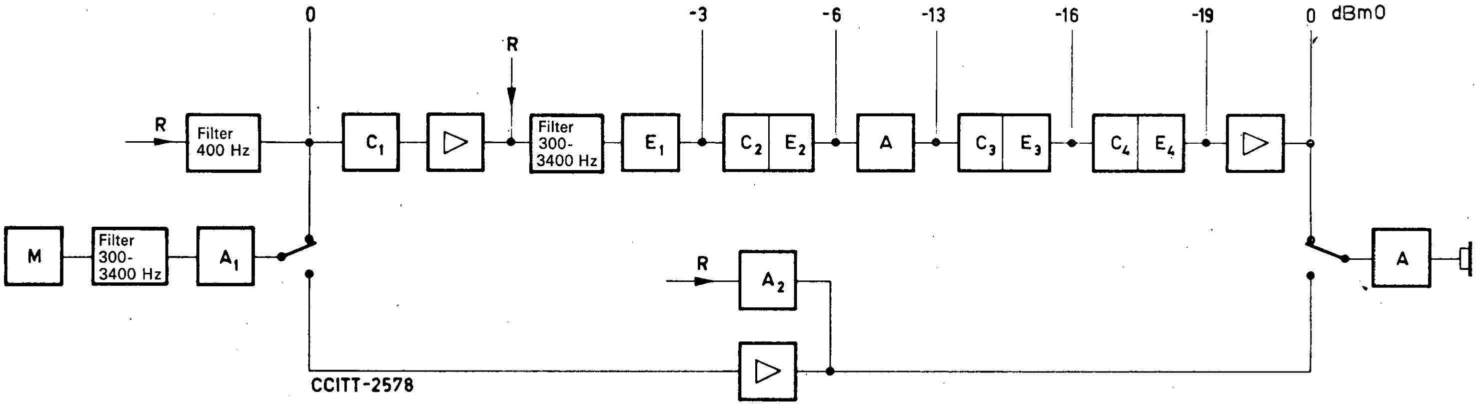


FIGURE 1. — **Diagram of the test circuit**

the normal value equal to 2, which remains when P_S/P_B ratio is very large, to 1 which occurs when $P_S \ll P_B$.

Subjective tests have been carried out, based on the isopreference method, to determine the impairment of transmission quality due to such fluctuations in the compression rate.

The experimental circuit consisting of four pairs of compandors in tandem was set up as shown in Figure 1.

The mean power level for a long signal cycle at the input of the first compressor was varied, by means of the attenuator A, from 0 dBm0 to —40 dBm0.

Two levels of the low-frequency noise (up to 100 Hz) were injected at the compressor input, i.e. —20 dBm0 and —130 dBm0.

The test results are summed up by the curve in Figure 2, which gives the variation in quality, expressed as equivalent signal/noise ratio, as a function of the signal level.

The tests were repeated, altering the time constant of the compandors ($RC = 4$ ms and $RC =$ 20 ms), to bring out any effect that might depend on this characteristic but in actual fact the results coincided in both cases.

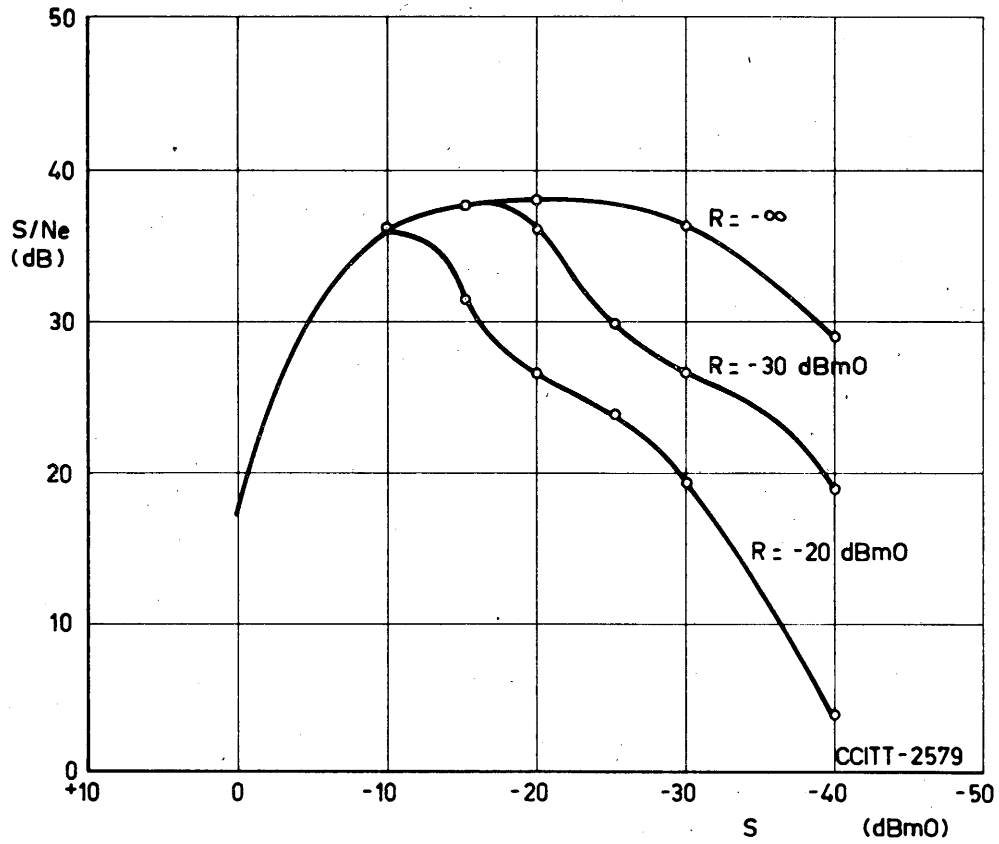


FIGURE 2. — **Results of the equivalent signal/noise ratio determined with different out-of-band noise levels at the compressor input**

2. *Effects of the time constant on transmission quality for a chain of compandors*

The circuit shown in Figure 1 and the same method of isopreference were again used for the subjective tests. Three time constants were used: $RC = 4$ ms, $RC = 10$ ms, $RC = 20$ ms.

The tests were carried out either in the complete absence of noise or with a noise of —35 dBm0p injected at the input of the first expander of the chain. In the first case a small advantage was noted for the time constant $RC = 4$ ms. In the second case no difference was found for the three time constants used.

3. *Conclusions*

The tests described are significant enough to show the desirability of continuing this study on a more thorough basis.

Question 6/XV — Programme circuits set up on group or supergroup links

(new question)
(of interest to Special Study Group C)

Considering

that the total number of programme transmission circuits needed for a sound or television programme of general interest depends primarily on

a) the nature of the programme;
b) the number of countries receiving the programme;
c) the number of commentators the broadcasting organizations wish to send to the event to be reported (different languages, or several independent organizations in the same country);

that the total number of circuits for programme transmissions required for such a programme may be more than the number of circuits normally available to the telecommunication administration concerned;

that, particularly in the case of administrations using programme circuits set up via carrier systems, the number of programme circuits requested might be more than the total number of group links between the repeater station situated nearest to the scene of the event to be reported and the exchange of higher rank on which it depends for the routing of these groups;

that circuits for programme transmissions may be of different types, such as:

1) normal type A programme circuits,
2) normal type B programme circuits,
3) "high-quality" programme circuits,
4) a combination of programme circuits of categories 1, 2 and 3;

it would be desirable to study the following question:

How many circuits for programme transmission can be set up on one or more group or supergroup links, taking into account:

— the different types of programme circuits,
— the maximum permissible load for each group or supergroup?

The following should be specified in particular:

a) What frequency positions should be adopted when it is desired to transmit two normal type A programme-transmission circuits simultaneously over the same group link?

b) Whether, in view of the possibility of correlation between the signals transmitted over each programme circuit, it is possible to observe the clauses of Recommendation J.13 in respect of each programme circuit, or whether other provisions should be adopted for such operation.

Question 7/XV — Compandors for programme transmission

(continuation of Question 7/XV studied in 1964-1968)

What essential (static and dynamic) characteristics should be recommended for compandor devices for use on programme circuits?

Note 1. — Two types of compandors can be considered for programme circuits:

- the first to be inserted at the points where the transmitted signal lies within the music frequency band (audio-frequency compandor);
- the second to be inserted after modulation and before demodulation of the music signals (high-frequency).

It seems to be confirmed that two separate specifications will be required for the two types of compandors mentioned above. These specifications should cater for three different roles, which may be performed by a single type or by different types of compandor:

- use on normal programme circuits in accordance with Recommendations J.21 and J.22;
- use on high-quality monophonic programme circuits (see Study Programme 5A of the C.M.T.T. [1]);
- use on stereophonic programme circuits (see Study Programme 5B of the C.M.T.T.).

Note 2. — As a guide for the study of this question, a list of characteristics is given below, on which the required specifications should be based in principle.

1. *Unaffected level*

In choosing this level, the effect it will have on the mean signal power at the compressor output must be considered.

2. *Compression and expansion ratios*

There is no reason why these ratios should be constant throughout the entire dynamic range of the programme to be transmitted.

3. *Range of levels in which a defined response characteristic must be observed*

4. *Compression and expansion ratio tolerances*

It might be well to consider the tolerances for the compressor and the expander separately and, in addition, the tolerances for the compressor and expander at the two opposite ends of a circuit. These tolerances should be given throughout the dynamic range considered under 3.

There is no need to consider questions of stability, since programme transmission does not involve two-wire/four-wire terminations.

5. *Nominal impedances and return loss relative to the nominal impedance, at the input and output of the compressor and expander*

6. *Operating characteristics at various frequencies and corresponding tolerances for the compressor and expander*

   a) for the transmission circuit, the control circuit being clamped;

   b) for the control circuit.

7. *Non-linear distortion and overload characteristic, considered separately for the compressor and the expander*

8. *Weighted and unweighted noise voltages at the output of the compressor and the output of the expander*

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[1] See *Important Notice* preceding the list of Questions, paragraph 3.

9. *Attack and recovery times and corresponding methods of measurements*

10. *Determination of the characteristics (e.g. frequency, level, bandwidth, etc.) of any pilot channel used to adjust the circuit loss, or possibility to enable the expander-control circuit to be locked to the compressor-control circuit*

11. *Characteristics of a pre-emphasis network if it is associated with a compandor*

The studies carried out on this same subject in the 1964-1968 period have confirmed the validity of this list, even though it might possibly be incomplete with regard to the requirements of high-quality monophonic and stereophonic circuits and it may not be a complete list of the characteristics of some types of compandors.

Note 3. — In the 1964-1968 study period, several administrations submitted values for the subjective improvement of the signal/noise ratio for compandors: these values vary between 10 and 25 dB. This difference in values is due partly to the different characteristics of compandors and partly to the different subjective test methods used, including the types of noise and programmes used. The evaluation of the improvement that can be obtained with compandors is a matter for the C.M.T.T., which has Study Programme 5E/CMTT on this subject.

Note 4. — It might be desirable for the administrations concerned to submit also contributions on the results of measurements of electrical characteristics, carried out on real programme circuits of complex constitution including, if possible, several compandor sets in tandem. In this context, Annex 7 contains a contribution from the Federal Republic of Germany relating to a widely used high-frequency compandor which was described in an annex to Question 7/XV of the 1964-1968 period, but which no longer appears in the annexes to the present question.

Note 5. — Annex 1 reproduces a summary of the provisional reply given to Question 7/XV in the 1964-1968 period.

Annexes 2, 3, 4, 5 and 6 contain contributions from various administrations concerning compandors designed for programme circuits.

Note 6. — Administrations which use compandors on programme circuits by suppressing a certain number of telephone channels with 3-kHz spacing are also requested to submit contributions on this matter. Annexes 2 and 3 constitute contributions of this type.

Note 7. — The possibility of having a pre-emphasis network and a compandor simultaneously is envisaged. In such a case, it is recommended that the compandor be placed after the pre-emphasis network.

Note 8. — The question should be studied in close liaison with Questions 1/XV, 2/XV, 6/XV and 9/XV, and with Question 5/CMTT and Study Programmes 5A/CMTT and 5B/CMTT of the C.M.T.T.

ANNEX 1

(to Question 7/XV)

Summary of the provisional reply given to Question 7/XV in the 1964-1968 period

The contributions received so far do not justify a reply substantially different from that formulated in the 1961-1964 period. It therefore seems certain that, to save time, two separate specifications should be drawn up: one for audio-frequency compandors and one for high-frequency compandors. The latter seem to be very widespread, at least in Europe.

To a certain extent the use of audio-frequency compandors should simplify switching conditions for audio-frequency programme circuits in that, on a connection consisting of several circuits connected in tandem, they would obviate the need for several compandor sets which might result in deterioration in the quality of the signals transmitted. It should be noted, moreover, that there is also a tendency to use radio-frequency switching on programme circuits (i.e. the band occupied by the programme circuit in a basic group) to counteract the deterioration in quality caused by the presence in tandem of several radio modems. Thus the use of several compandor sets in tandem is avoided, even in the case of high-frequency compandors.

The switching of programme circuits on a "high-frequency" basis is the subject of Question 8/XV.

ANNEX 2

(to Question 7/XV)

Contribution by the American Telephone and Telegraph Company to the study of Question 41 in 1957-1960

In the Bell System, programme compandors are used only on those circuits having noise magnitudes substantially larger than the design objectives. A very large percentage of long-distance programmes do not employ compandors.

Certain characteristics of, and other factors related to, programme companding systems are as follows:

1. No frequency shaping is applied to the variolosser, line amplifier, or control amplifier, at either the compressor or expander units.

2. The rate of compression and expansion for the normal rate of signal magnitudes is designed to 2/1 and 1/2 respectively.

3. Adjustments are made so that under operating conditions the improvement in signal-to-noise ratio is no greater than 25 dB on relatively narrow band circuits (200-3500 Hz) and no greater than 20 dB on wider band circuits (100-5000 Hz or 50-8000 Hz). These magnitudes of improvement in signal-to-noise ratio are for noise measured in the absence of the signal.

4. Judgement tests have indicated that the effective improvement in the signal-to-noise ratio is of the order of 5 dB less than determined from noise measurements in the absence of signal, because of the presence of substantial levels of noise during intervals when signals are being transmitted.

5. The limitation of the effective amount of improvement that can be obtained from a companding system for programme signals is due to hush-hush effect—i.e., the noticeable presence of noise in the upper frequency range at the cessation time of medium to strong signal transmissions. When this noise is unmasked by a signal, a disagreeable effect is obtained which is proportional to the rise of high-frequency noise during periods of signal transmission. This rise is in turn proportional to the amount of noise suppression produced by the expander and hence must be controlled to reduce the hush-hush effect to tolerable limits.

6. The initial signal-to-noise ratio on a circuit to which a compandor is to be applied should be 35 dB or more for the narrow band circuits and 40 dB or more for the wider band circuits (see paragraph 3 above).

7. The overall amplitude response of a compandor (compressor plus expander) should be uniform within ±1 dB over the frequency range of the particular grade of programme facility with which the compandor is associated.

8. Extensive judgement tests have indicated that the attack and release times of the companding system for programme use should be about 5 ms and 60 ms respectively.

ANNEX 3

(to Question 7/XV)

Contribution by the Telephone Association of Canada

Introduction

During the past three years, the Canadian broadcasting authorities have implemented an 8-kHz radio broadcast service on a country-wide basis. The Canadian telephone operating organizations have undertaken to provide the network facilities for this service which involve distances up to 6400 km in length.

To provide the high-quality network facilities, it has been necessary to develop an appropriate programme terminal, pre-emphasis network and programme compandor. The transmission characteristics of the 8-kHz programme compandor are dealt with in this document and are submitted below.

Programme compandor—transmission characteristics

1. *Signal-to-noise improvement*

With full loss in the expander (no signal condition) the noise level is reduced by 28 dB on an 8-kHz circuit. However, subjective tests have indicated that the improvement in signal-to-noise ratio with a signal is in the order of 5 dB less than the noise improvement measured in the absence of signal.

2. *Unaffected level*

The level which is not affected by the compressor is —6 dBm at the input to the compressor. This level corresponds to a level of +15 dBm0 on a programme circuit.

3. *Compression and expansion ratio*

The rate of compression and expansion over a dynamic range of 45 dB is specified as 2:1 and 1 : 2 respectively.

4. *Dynamic range*

The response characteristic is defined for a range of levels at the input of the compressor of —3 dBm to —48 dBm (+18 dBm0 to —27 dBm0 on a programme circuit).

5. *Tracking characteristic*

The tracking characteristic of the compandor over the dynamic range of 45 dB specified in 4 is to be within ±0.5 dB. The tracking characteristic of the compressor and expander individually over the dynamic range is ±0.2 dB.

6. *Impedance*

The compressor and expander are impedance-matched to the connecting equipment which has an impedance of 600 ohms.

7. *Frequency response*

The frequency response for the compandor at an input level to the compressor of —21 dBm (0 dBm0) has a maximum spread of 0.6 dB from 100 Hz to 8 kHz. The frequency response of the compressor and expander are complementary, and the compressor has a maximum spread of 0.4 dB from 100 Hz to 8 kHz and the expander has a maximum spread of 0.6 dB from 100 Hz to 8 kHz.

8. *Harmonic distortion*

The harmonic distortion of the compandor is less than 0.42% at peak programme level of —13 dBm (+ 8 dBm0) with the reference frequency of 400 Hz, and the distortion at the maximum level to the compressor of —3 dBm (+ 18 dBm0) is normally less than 0.75%. The distortion figures are the root sum square of the compressor and expander distortion.

The harmonic distortion of the compressor with 400 Hz at peak programme level of —13 dBm (+8 dBm0) is less than 0.3% and with the maximum input level of —3 dBm (+ 18 dBm0) is normally less than 0.4%.

The harmonic distortion of the expander with 400 Hz and peak programme level of 0 dBm is less than 0.3% and the distortion at maximum input to the expander of +5 dBm is normally less than 0.62%.

Note. — 400 Hz is the reference frequency for distortion testing and requirements are stated in terms of this frequency.

9. *Noise level*

Noise levels for the compandor units only are:

— noise level at the output of the compressor is 15 dBRN (—74 dBm) with 15-kHz flat weighting;

— noise level at the output expander is 20 dBRN (—70 dBm) with 15-kHz flat weighting.

10. *Temperature*

The ambient temperature range for the compandor is 10 °C to 50 °C.

11. *Time constants*

The time constants of the compressor and the expander using the C.C.I.T.T. definition are: *attack time :* 20 ms and *recovery time :* 75 ms.

12. *Pre-emphasis network*

Predistortion is used in the programme terminal associated with the compandor. The predistorter has a characteristic curve which attenuates the low frequencies by 18 dB more than the high frequencies. A restoral network at the receiving programme terminal has a complementary characteristic and the net effect of the predistorter and restorer is a flat response. Predistortion is normally inserted after the compressor and before modulation and the restorer is inserted after demodulation and before the expander.

Conclusions

The programme compandor described above has been in service for a number of years. Experience has shown that a most satisfactory grade of service can be given with the compandor provided the signal-to-noise ratio before the expander is equal to or better than 40 dB.

It might also be of significance to point out that programme network switching is carried out either at programme carrier frequencies or compressed audio-frequencies. This arrangement eliminates the need for tandem operation of compandors.

ANNEX 4

(to Question 7/XV)

Compandor for programme transmission

(Contribution submitted by the Netherlands Administration)

1. The following is a description of a compandor for programme transmission with the associated modulation equipment, suitable for transmission of two programme channels over a group link. These may be the A and B channels of a stereophonic programme circuit, or they may be two independent monophonic channels.

2. The compandor is of the high-frequency type—i.e. compression takes place after modulation to a position in the basic group, expansion before demodulation. The compandor being made to act on the modulated programme signal, short times of attack and recovery can be applied without excessive distortion at low audio-frequencies.

The compression curve of the compressor is shown in Figure 1. In order not to increase the average load on the line, the boosting of the lower levels is offset by a lowering of the higher levels, the unaffected level being 0 dBm0. The characteristic is curvilinear. For low absolute input levels,

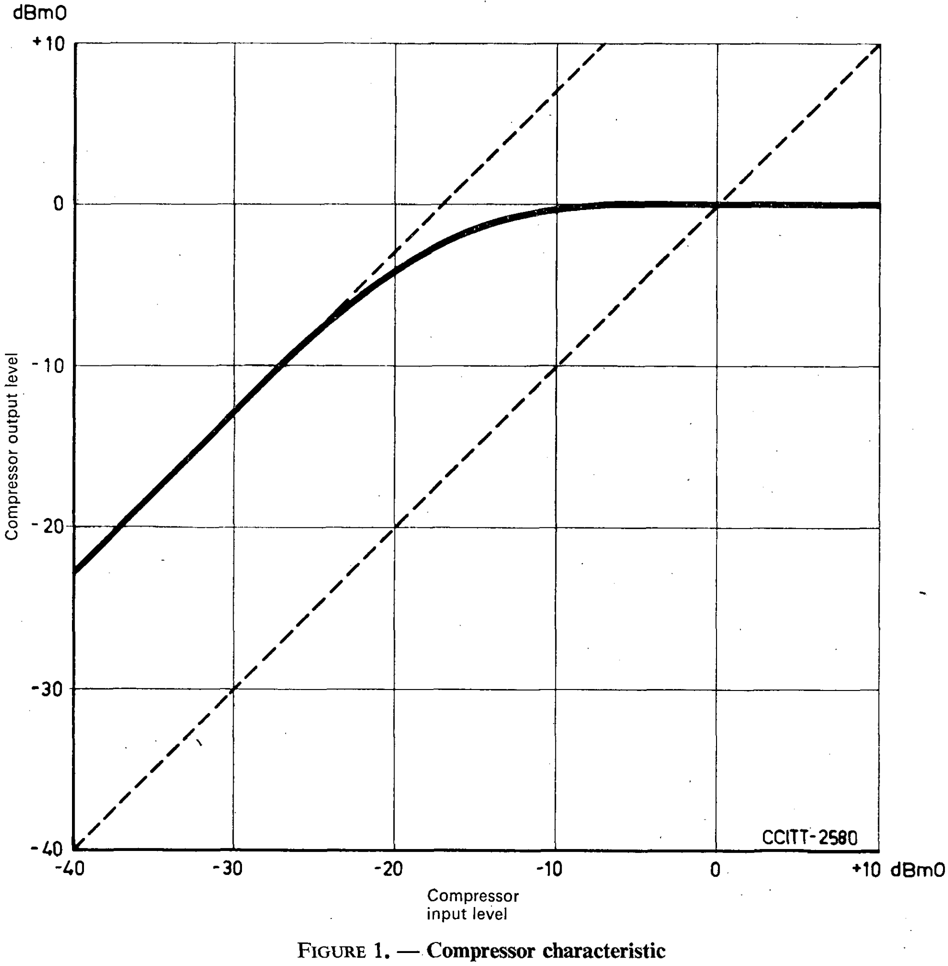


FIGURE 1. — Compressor characteristic

the compressor has a gain of 17 dB; this gain is constant up to an input level of —25 dBm0. For input levels above —10 dBm0 the degree of compression is so high that the output level becomes constant and therefore independent of the input level.

An expander which derives its information as to the required degree of expansion from the envelope of the compressed signal cannot cope with such a high degree of compression. Another disadvantage of such a type of expander is that it interprets variations of line attenuation as compressed level variations and reproduces these attenuation variations, multiplied by the expansion factor, in its output signal.

The ideal solution is therefore a compandor with a separate control channel. The system thus obtained is comparable to a level control device at the transmitting end and a reciprocal device at the receiving end, coupled together by a rigid shaft, so that the algebraic sum in dB of the two control settings is zero for any position of the shaft. This comparison with a rigid shaft obviously holds good only if the control channel transmits the control information with high fidelity and independently of variations in line attenuation.

3. The proposed programme modulation system is based on the following principles:

a) a bandwidth of 30 to 15 000 Hz is used for the programme channels;

b) two programme channels with associated control channels for compandor operation may be accommodated in one basic group;

c) these two programme channels are suited for use as A and B channels in stereophonic programme transmission;

d) each of the two programme channels may be replaced by six voice channels.

The modulation plan is shown in Figure 2. The 0.03-15-kHz band is first modulated with a 32-kHz carrier to 32.03-47 kHz (upper sideband). Modulation then takes place again, either with a 56-kHz carrier to the 88.03-103-kHz band (upper sideband) or with a 112-kHz carrier to the 65-79.97-kHz band (lower sideband).

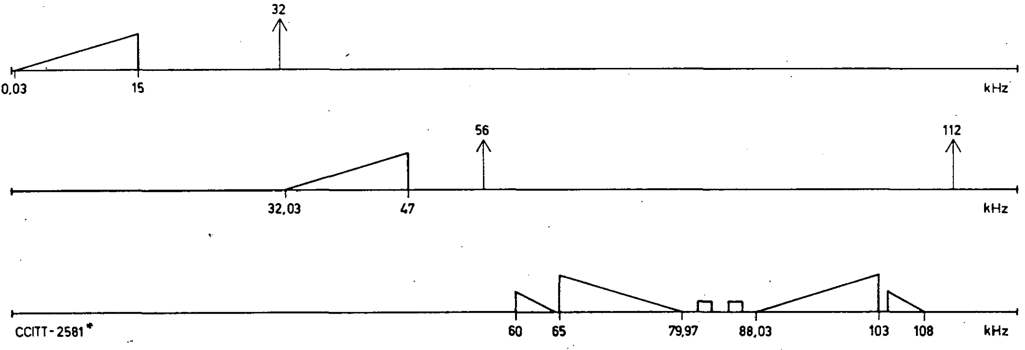


FIGURE 2. — **Modulation process**

If compandors are used, the two control channels are placed in the 80-88-kHz band.

The frequency allocation is fully compatible with existing group and supergroup pilots and with the pilots proposed in the reply to Question 14/XV in 1968.

The modulation plan chosen ensures that the control channels and the programme band sections corresponding to the lowest programme frequencies are as close together as possible in the middle of the basic group, so that group delay differences between corresponding frequencies in the two channels are minimized. This is important for stereophonic programme transmission, which has to meet stringent requirements as to phase equality of the lower frequencies in the two channels.

The two remaining voice channels on the edges of the group band can be used as service channels. The two programme channels can also be used for the transmission of two monophonic channels.

The carrier equipment may introduce a frequency shift which, in accordance with Recommendation G.225, is restricted to 2 Hz. In the case of programme transmission, however, it may be desired to restrict this frequency shift even further. With stereophonic programme transmission in fact, any frequence shift between the two channels is unacceptable. The problem has been solved by an arrangement whereby the programme modulation equipments have their own carrier supplies, the receiving end being synchronized by an 84-kHz frequency pilot.

The virtual carrier frequencies of the two programme channels are 80 kHz and 88 kHz, and thus differ from the synchronizing frequency by 4 kHz. The maximum frequency shift of 2 Hz introduced by the carrier system is now reduced by a factor of 21, thus becoming approximately 0.1 Hz. This frequency shift is exactly the same, both in absolute value and sign, for the two programme channels in the same group.

Residual phase discrepancies between the two channels can be cancelled out with a variable phasing network in one of the carriers, so that the phase requirements applicable to stereophonic programme transmission can be met.

4. The control signal of the compressor is generated by rectifying the modulated programme signal plus a constant alternating voltage. This varying direct voltage is modulated in order to be fed via the control channel to the expander at the far end. Frequency modulation is employed in the bands 81.4-82.9 kHz and 85.1-86.6 kHz respectively. The f.m. signal is converted into a direct voltage by a discriminator. The output voltage of this discriminator is compared with the control signal and the frequency of the f.m. signal is set so that these two voltages are equal.

The frequency-modulated control signal is added to the programme signal at the input of the compressor. At the output the level of the control signal is —5 dBm0 when the programme signal level is very low. When the programme signal is high, the level of the control signal will be low in consequence of the action of the compressor. This ensures that the control signal hardly affects the peak load on the transmission line.

At the input of the expander the control signal is filtered out and converted into a direct voltage by a discriminator. At the output the programme signal and the frequency-modulated control signal are rectified in the same way as in the compressor. The two direct voltages are compared and the expander is set so that they are equal. This means that the input voltages to the rectifiers in compressor and expander are identical and that the output signal of the expander is an exact reproduction of the input signal to the compressor.

REFERENCE

BEIJNINK, W.: Programme transmission on carrier telephone routes, *Philips Telecommunication Review*, Volume 27, No. 3, May 1968, pages 135-143.

ANNEX 5

(to Question 7/XV)

Compandor for programme transmission

(Contribution by the Federal Republic of Germany)

Our experience has shown that it is preferable to carry out compression and expansion at carrier frequencies, and for transmission of the signal band (widened slightly by the control operations) to occupy a frequency band that suffers the least possible linear distortion by the transmission channel because such a linear distortion in the transmission channel of the compressed signal appears as a non-linear distortion after passing through the expander. If we choose for compression and expansion a high enough frequency position, several advantages will accrue, e.g.: short attack and recovery times are usable since very low frequencies do not exist any more. A great part of the non-linear products and also the control voltage lie outside the transmitted band. Further details will be found in an article [1]. The Administration of the Federal Republic of Germany equipped programme circuits in carrier systems uniformly with the compandors therein described, whereby each carrier programme section will be improved to C.C.I.T.T. quality. In co-operation with a number of other administrations, international circuits with the same compandor are in service. Annex 7 deals with the results of measurements on a chain of such international circuits.

When turning over to the use of transistors in transmission equipment, the German Administration again endeavoured to find the most suitable compandor for carrier programme circuits.

It was found that transistorized compandors, controlled only by the programme signal, with new circuitry principles, could be made at very little cost for use in the carrier frequency position. A new compandor became constructed together with a new modulation equipment for high-quality transmission of one stereophonic or two independent monophonic programmes in one group. Because of the co-operation between the compandor and the modulation equipment, it seems necessary to describe the main lines of this new system.

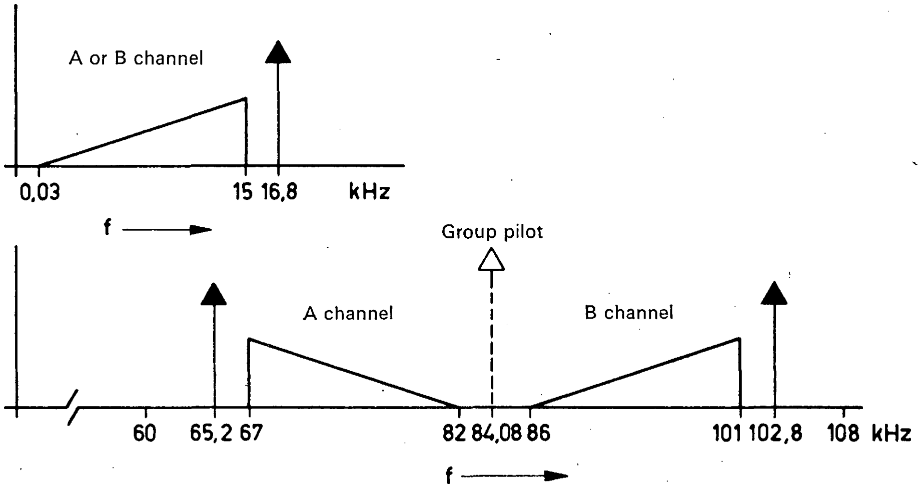


FIGURE 1. — **Line-frequency positions of the two-programme channels in the group**

Figure 1 shows the line-frequency positions of the two programme channels in the group, Figure 2 the modulation scheme. A pilot frequency of 16.8 kHz, inserted in both channels in the audio-frequency position, is used to supervise the circuit including the modulation steps and, because the expander is controlled by the programme signal and needs no pilot control, the pilot is further used to correct the level and frequency errors, introduced by the group link. Figure 5 shows the details (AGC—Automatic Gain Control, AFC—Automatic Frequency Control). Without any additional frequency pilot the received pilots are locked to the pilot, generated at the receiving site. Frequency shift between sending and receiving sites is equal to the frequency difference of the two pilot generators at both sites and is mostly below 0.01 Hz. Moreover, stereophonic transmission is possible.

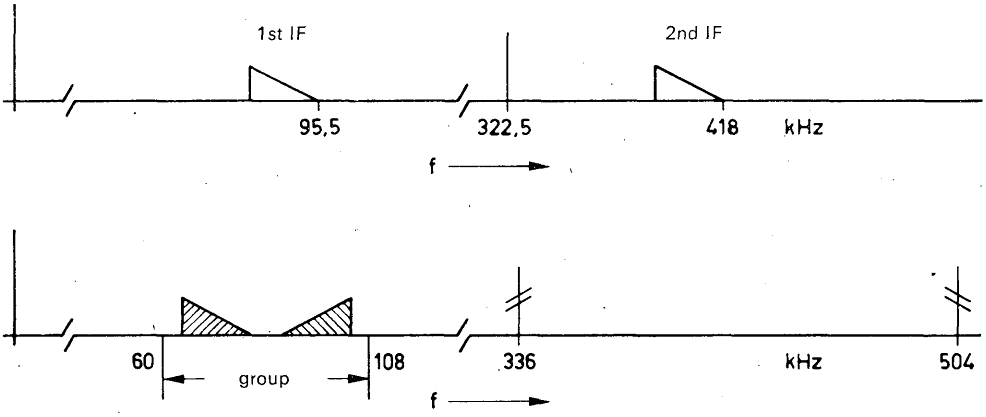


Figure 2. — **Modulation scheme for the two-channel programme system**

The first modulation step between AF and 1.IF and vice versa, shown at the top and the bottom of Figure 5, contains all modules, including the compandor, which are necessary for programme transmission. Filters with a bandwidth of 10 kHz immediately would make possible transmission in the frequency position No. III. This is, however, at the moment not envisaged. 15-kHz filters are used and via simple frequency-shifting modules any wanted line-frequency position can be reached by suitable choice of auxiliary carrier frequencies. By using high 1. and 2.IF positions the wanted frequency bands are free from unwanted modulation products of low order. All modules in the A channel are fully identical to the modules in the B channel. No equipment equalization therefore is necessary for stereophony.

By this arrangement switching in the 1.IF position, using only the frequency-shifting modules, is possible, which is economical and will be used especially in Frankfurt, where a big star switching centre with remote control for this system is planned.

The line-frequency positions are chosen symmetrically and very near to 84 kHz with a view to stereophonic transmission. At the same time, the group pilot frequencies at 84.08 (84.14) kHz and 104.08 kHz are well respected. Nevertheless, the last bandpass filter at the receiving site, which guarantees the receiving selectivity, can be relatively simple. The named group pilots, if wanted, can be used. One programme channel can be replaced by six telephone channels. Use of the places of telephone channels Nos. 1 and 12 is at the moment not envisaged, but would be possible. Carrier residues at 72 kHz and 96 kHz are suppressed by quartz stop filters at 85.5 kHz, positioned after the expander in the 1.IF position. The small gaps, produced at 10 kHz in the audio-band, are not detectable in programmes.

Our decennial experience with programme compandors indicated that the new characteristic, shown in Figure 3, is most suitable. A constant gain (17 dB) at low levels eases tolerating the reciprocity between compressor and expander in the low level region. At the same time the measurable noise suppression is equally valid in subjective tests, for which the gain at about —35 dBm0 is decisive. The point of unaffected level must be in the region of the long-time mean power, i.e. relatively low, in order that the mean loading of the carrier system is low. The point was fixed at —4.5 dBm0. At high levels the suitable characteristic passes over into a constant attenuation. By this way the compandor cannot become overloaded, because it acts like a quasi-linear attenuator up to +26 dBm0. In spite of the non-limiting characteristics the peaks of the programme signal respect the limits for the equivalent peak power in the group (+19 dBm0). This is reached by an attack time of only 1.7 ms. The decay time is 3 ms, both measured corresponding to Recommendation G.162, A.g., but using the levels —12 dBm0 and 0 dBm0.

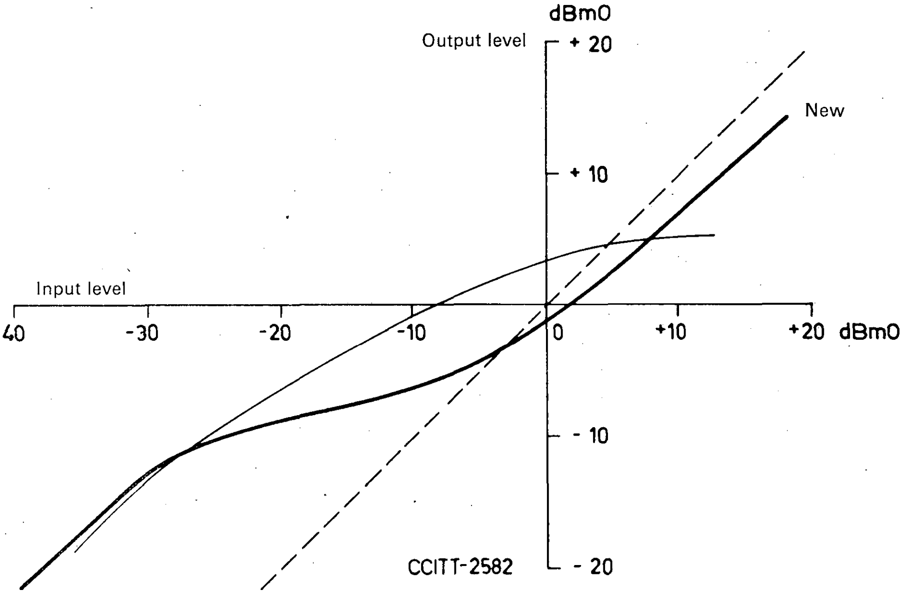


FIGURE 3. — Characteristics of old and new carrier frequency compressor

The relative simple scheme of the new module, which is of a size of 65 × 100 × 160 mm, is shown in Figure 4. The crossed or non-crossed connections, which are not in the module but in the bay, change numerator and denominator in the expression for the gain, and determine the same module to be a compressor or an expander. Nearly ideal reciprocity has been reached. Compandors in tandem can be used and stereophony is not disturbed.

Normally the compandor will be used combined with pre-de-emphasis corresponding to Recommendation J.21. This pre-emphasis, in consequence of its differentiating character, raises the programme peaks by about 5 dB. Besides, a noise suppression of about 20 dB always is sufficient if,

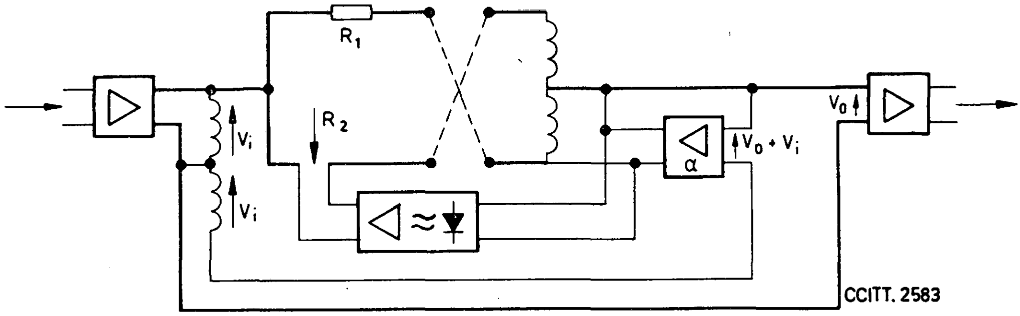


FIGURE 4. — **Scheme of the new compressor/expander**

$$V_0 = V_i \pm a\,(V_0 + V_i)\,\frac{R_1 - R_2}{R_1 + R_2} \qquad R_2\,|\,V_i + V_0\,| \approx \text{const}\,(1 - a) \ll 1;$$

$$\frac{V_0}{V_i} = \frac{R_1\,(1 \pm a) + R_2\,(1 \mp a)}{R_1\,(1 \mp a) + R_2\,(1 \pm a)} \qquad \frac{V_0}{V_i\,\text{(compr)}} = \frac{V_i}{V_0\,\text{(exp)}} \approx \frac{\text{(const)}}{|\,V_i + V_0\,|}$$

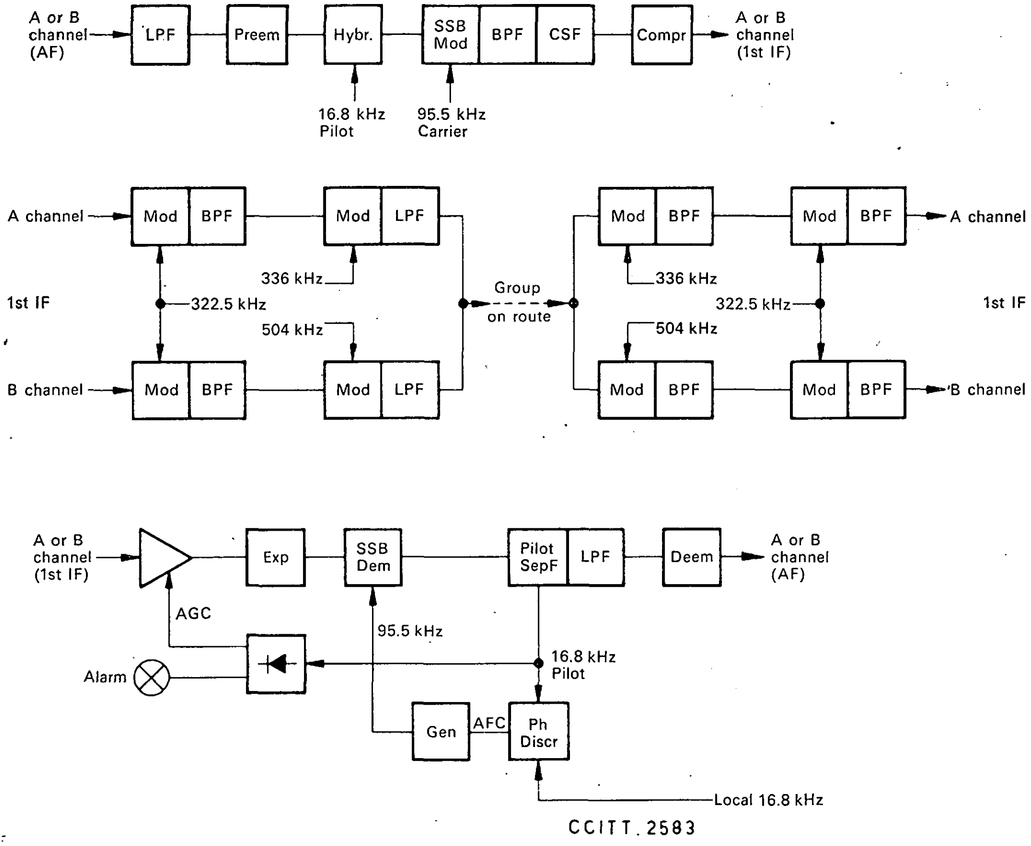


FIGURE 5. — **First modulation, auxiliary modulations and demodulation of the two-channel programme system**

with a view to sounds poor in harmonics, the noise in the treble frequency region by a de-emphasis is more suppressed than in the bass region. Therefore the relative level at 800 Hz after the pre-emphasis for combined service with compandor is set up to —6.5 dBm0 instead of the value of —1.5 dBm0, recommended in J.21. Sending the 800-Hz measuring tone with the new level of —12 dBm0 in the audio input, the group is loaded precisely by —10 dBm0 (the 0 dBm0 measuring tone at the input gives about —5.6 dBm0). The long-time mean power per programme channel (including its pilot) now is about —6 dBm0 in the group, which is similar to the loading by six telephone channels (6×32 μW or —7 dBm0). This is possible with the pilot level of —29 dBm0 before the compressor. The pilot level in the carrier system in absence of a programme is —29 dBm0+17 dB = —12 dBm0. This low value is important with a view to the peak factor, resulting from many pilots in the case of a multi-channel system. Besides, no stop filters are necessary in the compandor control path.

The following values are measured on the modulator + demodulator, containing pre-de-emphasis and compandor:

Attenuation distortion 30 Hz-15 kHz	$< \pm 0.3$ dB
Non-linear distortions, also difference tones in the treble region, up to +18 dBm0	$<$ 0.1%
Noise	—73 dBm0ps
Noise, $12 \times 10\,000$ pW being added between modulator and demodulator	—56 dBm0ps
Intelligible crosstalk between A and B channels	$>$100 dB
Level and phase differences between A channel and B channel, 30 Hz-15 kHz	$<$ 0.3 dB and $<$ 3° resp.

Field tests on different groups showed the expected results, and gave indications for the equalization, necessary for stereo service.

REFERENCE

[1] von GUTTENBERG, W. and HOCHRATH, H.: A compandor for broadcast programme links, *NTZ-Communication Journal*, 1962, No. 2, pp. 66-72.

ANNEX 6

(to Question 7/XV)

Compandors for programme transmissions

(Contribution by France)

Most international programme links consist of national or international programme circuit chains and of incoming and outgoing local lines (e.g. see Figure 108, *Blue Book*, Volume III, page 353). Some transmissions from the same source are routed in different directions and are then broadcast by several transmitters simultaneously. In this case we have a complex multiple relay network for a programme transmission, an example of which is given in the *Blue Book*, Volume II, page 149.

In either event the component programme circuits may be set up by applying either the "audio-frequency" technique (paragraphs a, c and d of Recommendation J.22, *Blue Book*, Volume III, pages 365 to 367), or the " carrier" technique in which the channels of carrier telephone systems are used (paragraph b) in Recommendation J.22).

In Annex 1 to the former Question 9/XV (*Blue Book*, Volume III, page 575), the Administration of the Federal Republic of Germany rightly points out that a programme channel set up on the hypothetical reference circuit for telephone systems shows a psophometric power 11.6 dB too high and a crosstalk attenuation 16 dB too low, thereby making it necessary to use special devices, such as compandors, pre-emphasis and de-emphasis networks, or a combination of both, to overcome these defects.

Although they are usually more difficult to measure, similar deviations are often observed on circuits using the audio-frequency technique. For practical and economical reasons, the solution adopted to improve transmission performance should be identical for both carrier and audio-frequency circuits.

Since the function of compandors is to protect programme transmissions from interference originating in the programme circuit itself, there is every advantage in providing such protection on as much of the link (whether single or multiple) as possible and to place the compandors as near as is feasible to the extremities. In practice, they should be installed at the ends of the international programme line, unless agreements between the broadcasting authority and the telephone administration of a particular country specify otherwise.

Although there is not yet enough experience in this matter, it can be assumed that too many pairs of compandors used simultaneously on the same programme link is likely to impair transmission to an unacceptable degree.

The French Administration therefore believes that so far as possible only one, or at most two, pairs of compandors should be permitted on any programme circuit. This means that the compandors must be easily installed or removed; if they are inserted at points where the transmitted signal is included in the music-frequency band, this condition presents no difficulty.

For example:

a) in the case shown in Figure 108, Volume III, page 353, of the *Blue Book*, the compressor would be installed at the repeater station in Edinburgh and the expander at the repeater station in Mestre; any compressors and expanders in London, Paris, Lyons, Turin and Milan would all be removed;

b) in the transmission network shown on page 149 in Volume II of the *Blue Book*, the compandor would be installed at the repeater station in London and an expander at each of the repeater stations in Copenhagen, Hamburg, Stockholm, Warsaw and Vienna as well as at the input of the circuits (after branching) supplying the Brussels and Berlin transmitters.

The French Postal and Telecommunication Administration therefore considers that a recommendation should be issued on the use of compandors, if necessary associated with pre-emphasis and de-emphasis systems, for programme transmissions in the music-frequency band.

The Administration considers further that the advantages of pre-emphasis and de-emphasis networks should be combined with those offered by compandors with a view to improving the signal/noise ratio, and that such networks should be used either separately or in conjunction with compandors. The point of insertion in the transmission circuit, however, should be so selected that either device may be installed or removed without difficulty when the Administrations concerned so wish.

PROPOSED CHARACTERISTICS OF COMPANDORS USED FOR PROGRAMME TRANSMISSIONS IN THE MUSIC-FREQUENCY BAND

1. *Definition and value of the unaffected level*

The unaffected level is the absolute level, at a zero relative level point on the line between the compressor and the expander, of an 800-Hz signal which remains the same whether the circuit is operated with the compressor or not.

To facilitate interconnection the relative level at the compressor input and the expander output is fixed at the same value as at the output of the amplifiers, i.e. at +0.7 Nm or at + 6 dBm, on the international programme circuit (Recommendation J.13, *Blue Book*, Volume III, page 354).

2. *Compression and expansion ratios*

a) *Definition and nominal value of the compression ratio*

The compression ratio of a compressor is defined by:

$$\alpha = \frac{n_e - n_{e0}}{n_s - n_{s0}}$$

where n_e is the input level,

n_{e0} is the input level corresponding to +0.7 Nm or 6 dBm,

n_s is the output level,

n_{s0} is the output level which corresponds to an input level of n_{e0}.

The preferred value of α is 2, although lower values are acceptable provided sufficient improvement of the noise factor is obtained. This value should not exceed 2.5 at any level of the input signal and at any temperature between +10 °C and +40 °C.

b) *Definition and nominal value of the expansion ratio*

The expansion ratio of the expander is defined by:

$$\beta = \frac{n'_s - n'_{s0}}{n'_e - n'_{s0}}.$$

where n'_e is the input level,

n'_{e0} is the input level corresponding to +0.7 Nm or +6 dBm,

n'_s is the output level,

n'_{s0} is the output level which corresponds to an input level of n'_{e0}.

The preferred value of β is 2, although lower values are acceptable provided sufficient improvement of the noise factor is obtained. This value should not exceed 2.5 at any level of the input signal and at any temperature between +10 °C and +40 °C.

3. *Variation in the composite gain of the compressor*

The output level of the compressor, measured at frequency 800 Hz for an input level of +0.7 Nm or 6 dBm, should not vary by more than ±2.5 cNp or 0.2 dB from its nominal value at any temperature between +10 °C and +40 °C or for a variation in feed voltage of ±5% from the nominal value.

4. *Variation in the composite gain of the expander*

The output level of the expander, measured at frequency 800 Hz for an input level of +0.7 Nm or 6 dBm, should not vary by more than ±5 cNp or 0.4 dB from its nominal value at any temperature between +10 °C and +40 °C or for a variation in feed voltage of ±5% from the nominal value.

5. *Tolerance for output levels of the compandor set in one transmission direction of a programme circuit*

(The compressor and expander are of the same make; the individual characteristics of the compressor and the expander are not given for the time being.)

Compressor and expander are connected in tandem. Between the compressor output and the expander input a loss (or gain) is inserted which is equal to the nominal loss (or gain) between these points on the side circuit on which they will be used. Figure 1 shows (in Nm and dBm) the permissible limits of the difference Δn_s between the output level of the expander and the input level of the compressor as a function of the level of the 800-Hz signal at the input of the

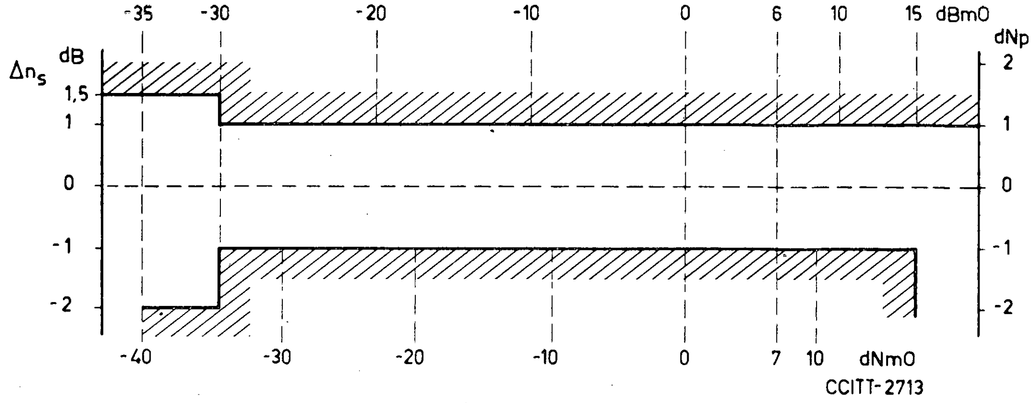


FIGURE 1. — N_e = **input level of the compressor**

compressor N_e. (Positive values indicate that the output level of the expander exceeds the input level of the compressor.)

These limits must be observed for all compressor and expander temperature combinations between +10 °C and +40 °C.

6. *Nominal impedance and return loss*

The nominal impedances of compressor and expander should be 600 ohms (pure resistance).

At any level between +1.75 and —4.0 Nm or +15 and —35 dBm at the compressor input or at the expander output, the return loss in relation to the nominal impedance at the input and output of compressor and expander should not be less than:

23 dNp. (20 dB) between 200 and 6400 Hz
12 dNp or 10 dB between 50 and 200 Hz
16 dNp or 14 dB between 6400 and 10000 Hz

7. *Operating characteristics at various frequencies*

a) *When the control circuit is clamped*

The control circuit is considered to be clamped when the control current (or voltage) obtained by rectifying the signal is replaced by a direct current (or voltage) from an outside source. This current (or voltage) must be equal to the control current (or voltage) obtained when the input signal level is 0.7 Nm or 6 dBm at 800 Hz.

For either compressor or expander, variations in net loss as a function of frequency must not exceed the limits of a scale that may be derived from the one shown in Figure 110 in Recommendation J.21, *Blue Book*, Volume III, page 360, by dividing the tolerances given by 4, the measurement being made with an input signal corresponding to the level +0.7 Nm or 6 dBm.

These limits must be observed at any temperature between +10 °C and +40 °C.

b) *When the control circuit is operating normally*

The scale mentioned above must be observed in respect of the compressor when the control circuit is operating normally. the measurement being made with a constant input level corresponding to 0.7 Nm or 6 dBm.

With regard to the expander, the scale shown in Figure 110 of Recommendation J.21 should be applied with the same measurement conditions, the tolerances being divided by 2.

8. *Non-linear distortion*

The harmonic distortion coefficient measured with a sinewave at +0.7 Nm or 6 dBm should not exceed the following limits in these frequency ranges:

50 to 100 Hz: $\leqq$ 2%
100 to 7500 Hz: $\leqq$ 0.5%
7500 to 10 000 Hz: $\leqq$ 3%

The intermodulation at levels and frequencies to be specified should also be measured.

9. *Noise voltages*

The effective value, measured at a zero relative level point, of the source of all noise voltages at input and output terminating on resistances of 600 ohms must not exceed:

at the compressor output: —40 dBm (unweighted);
at the expander output: —61 dBmp (weighted).

10. *Attack and recovery times*

To define the attack and recovery times of the compressor, it is proposed that 1.4 Np or 12 dB should be adopted as the value of the sudden variation in input level for the compressor, actual values being variations from —1.0 Nm or —8.5 dBm to +0.4 Nm or 3.5 dBm for the measurement of attack time, and from +0.4 Nm or 3.5 dBm to —1.0 Nm or —8.5 dBm for the measurement of recovery time; these levels are referred to zero relative level point. Attack time will then be defined as the interval between the instant when the sudden variation is applied and the instant when the output voltage envelope reaches a value 1.5 times its steady-state value. Recovery time will be defined as the interval between the instant when the sudden variation is applied and the instant when the output voltage envelope reaches a value 0.75 times its steady-state value.

The proposed values should be:

$\leqq$10 ms for attack
$\leqq$35 ms for recovery

A direct method should be used to measure attack and recovery times. The measurement frequency is still to be specified.

ANNEX 7

(to Question 7/XV)

Compandors for programme transmissions

(Contribution by the Federal Republic of Germany)

Measurements on international sound-programme links

On 7 September 1967, measurements were made on two international sound-programme links operated in opposite directions at the International Sound Programme Centre at Frankfurt (Main). The links consisted of the following international sound-programme circuits which were connected in tandem as shown in Figure 1.

Direction 1		*Direction 2*	
Frankfurt/M.–Zürich	R 1	Frankfurt/M.–Vienna	R 1
Zürich–Vienna	R 2	Vienna–Zürich	R 2
Vienna–Frankfurt/M.	R 1	Zürich–Frankfurt/M.	R 1

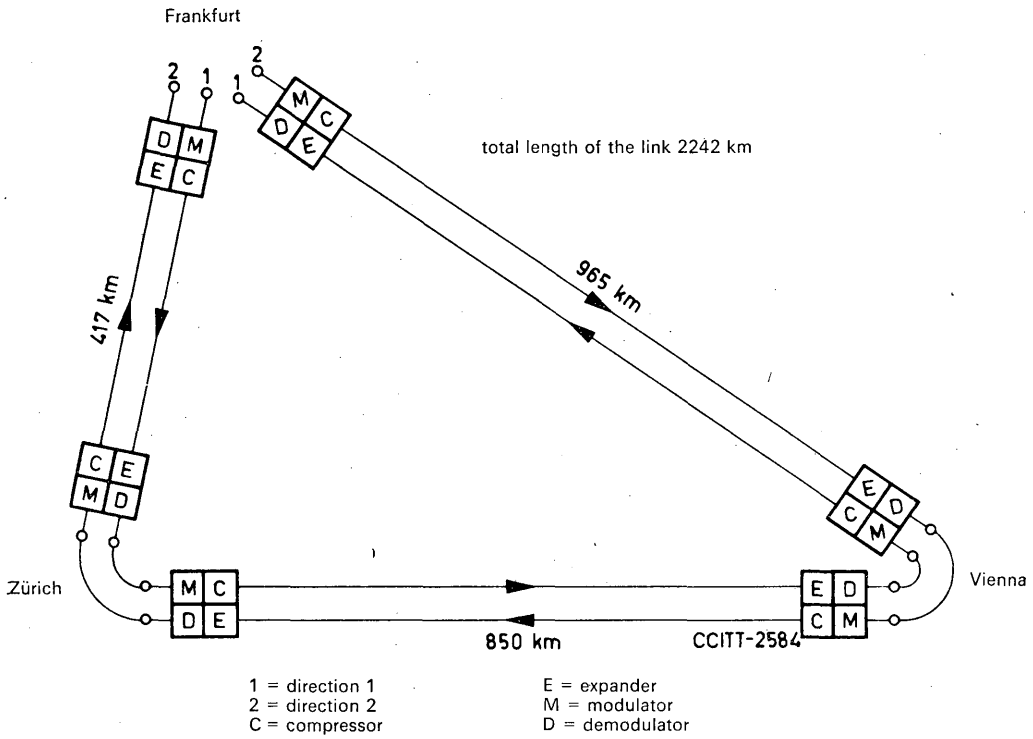


FIGURE 1. — **Loop for measurements**

Three international sound-programme circuits equipped with compandors connected in tandem

All of these international sound-programme circuits are routed over carrier systems and are equipped with compandors in carrier-frequency position according to *Blue Book*, Volume III, page 571. The required interconnections at Zürich and Vienna were made in the normal audio-frequency position. As far as composition and total length are concerned, the two links are similar to the hypothetical reference circuits consisting of three modulation sections (see *Blue Book*, Volume III, page 359, Figure 109). Essentially, these measurements were performed to find out whether a link with several compandors connected in tandem can satisfy the present performance requirements drawn up by the C.C.I.T.T. The fact that the measurements could be made on two links set up in the same way increases the conclusiveness of the results. It should be noted that the measurements concerned were not preceded by any kind of lining-up.

Results

1. *Attenuation distortion*

Figure 2 shows the output level in relation to the frequency response for both directions of transmission appertaining to the value measured at 800 Hz. The deviations found to exist in the frequency range of 50 to 10 000 Hz do not exceed ±0.9 dB (±0.1 Np).

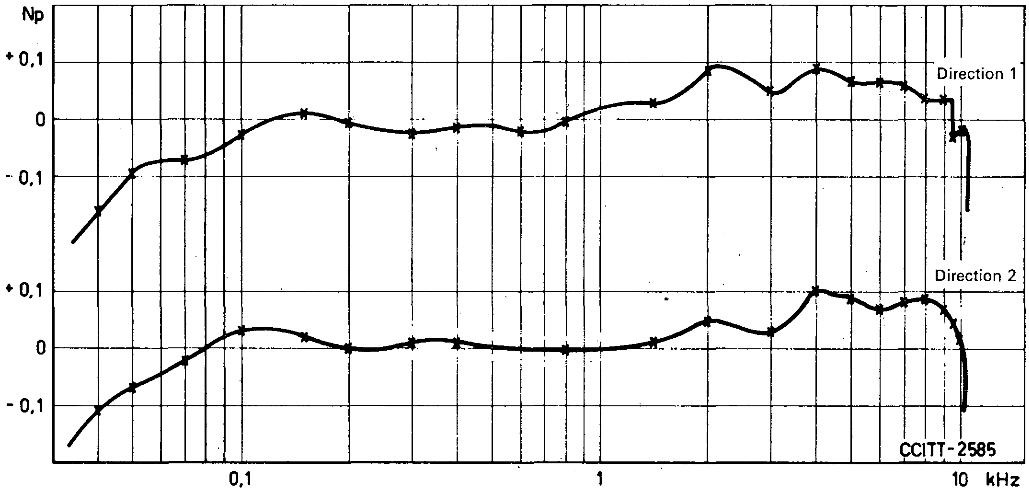


FIGURE 2. — **Output level. Variation with frequency relative to the 0.8 kHz value**

2. *Non-linear distortion*

The following values were obtained with fundamental frequencies whose transmission levels are equivalent to the maximum programme level of +9 dBm0:

Distortion coefficient	Fundamental frequency	Measured values Direction 1	Direction 2
k_2	90 Hz	0.85%	1.0% [a]
k_3	60 Hz	0.80%	0.8%
k_2	800 Hz	0.22%	0.21%
k_3	533 Hz	0.25%	0.58%
d_2	5600/7200 Hz	0.1%	0.1%
d_3	4200/6800 Hz	0.54%	1.4%

[a] These values include the hum modulation.

3. *Noise*

The following mean values of the unweighted and phosophometric noise levels were measured during the busy hour:

	Direction 1	*Direction 2*
Unweighted noise	−55 dBm0	−60 dBm0
Weighted noise	−53.5 dBm0	−55 dBm0

The weighted noise level of —48 dBm0 recommended for the reference circuit was not exceeded in both directions of transmission.

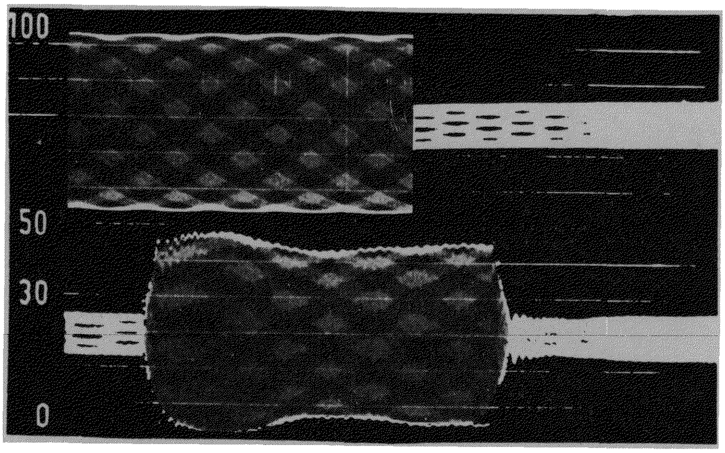
4. *Distortion of the dynamic range*

A variation of the level by 40 dB, i.e. from —31 dBm0 to +9 dBm0 at the input resulted in variations at the output of:

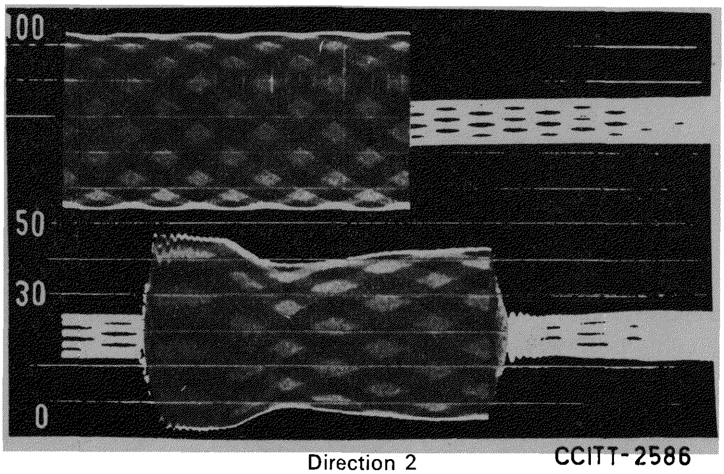
40.6 dB in direction 1 and
39.0 dB in direction 2.

5. *Dynamic behaviour*

The level of a 5-kHz tone was switched periodically between —12 dBm0 and 0 dBm0 (see *Blue Book*, Volume III, page 573). This is a very severe test, since such steep step function signals do not occur in music programmes. Each level was transmitted for 50 ms. Figure 3 shows the oscillograms of the input and output signals of both directions. The oscillograph was operated in the "chopped" position. After the signals passed through three circuits equipped with compandors, the level variations shown in the oscillogram during the first 20 to 30 ms after the sudden change in level until the steady state is reached are inaudible, because they are already over before the transient time of the human ear is over. As is well known, within its transient time the ability of the human ear to differentiate amplitude levels is more or less impaired depending on the preceding sudden change in level. Hence, the German Administration has no objection to connect three compandors in tandem.



Direction 1



Direction 2

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FIGURE 3. — **Responses to sudden level variations from —1.4 Nm0 to 0 Nm0**

6. *Summary*

The test results confirm that when connected in tandem three international sound-programme circuits routed over carrier systems and equipped with compandors satisfy the performance requirements drawn up by the C.C.I.T.T. When bearing in mind that the experience gained to date will lead to further improvements of the compandor characteristics it seems to be possible to draw up recommendations concerning the characteristics and application of compandors, which will ensure that the noise requirements are also met by international sound-programme circuits routed over carrier systems.

Question 8/XV — Interconnection of sound-programme circuits in the basic group

(new question)

Considering that some administrations are thinking of interconnecting sound-programme circuits in the frequency band which these circuits occupy in the basic group,

What procedure should be recommended to carry out this interconnection method?

The following points especially should be considered:

a) Frequency positions at the interconnection points
   1. in the case of a monophonic sound-programme transmission with a nominal bandwidth of 10 kHz or 15 kHz (Question 1/XV);
   2. in the case of a stereophonic sound-programme transmission (Question 2/XV);

b) Relative level of the sound-programme signal at the interconnection point;

c) Nominal impedance and matching conditions;

d) Through-connection of a sound-programme pilot, if any. Frequency and level of such a pilot;

e) Characteristics of through-connection filters.

Note 1. — In particular, if this method is used the insertion of several h.f. compandors in tandem and one demodulator-modulator can be avoided when sound-programme transmissions use group links in tandem.

Note 2. — Advantages will primarily be:
1. reduction of the non-linear distortion due to audio-frequency equipment;
2. reduction in modulation noise.

Question 9/XV — Improvement of the crosstalk ratio between the two directions of transmission

For the purposes of equipment specification there is a need to make a subdivision of the overall objectives for go/return crosstalk for circuits given in Recommendation G.151, section D.b. Provisional recommendations have been made in Recommendation G.232 for the combination of channel-translating equipment for use with an ordinary telephone type circuit and for a circuit liable to be included between echo suppressors. These need to be reviewed and supplemented.

a) Are any changes required in the crosstalk ratio figures provisionally specified for ordinary channel-translating equipment and the cabling between that equipment and the distribution frames in order to satisfy Recommendation G.151, section D.b.1 ?

Annexes 1 and 2 give some viewpoints on this subject.

b) With a view to future needs, Study Group XVI has indicated a need for a crosstalk ratio for a circuit between echo suppressors of 60 dB (see Annex 3). This value would also meet the requirements of circuits associated with speech concentrators. Are any changes needed to the corresponding values of crosstalk ratio for channel-translating equipment and its cabling for this case?

c) What values of crosstalk ratio can be specified for the remaining items constituting the circuit (but excluding the switching equipment) such as:

— higher stages of f.d.m. multiplex equipment, and their cabling,

— line links?

d) Can subdivisions between the channel-translating equipment and its station cabling be made for the two cases in a and b above?

Note 1. — A circuit should be considered to comprise three circuit sections, each with a pair of channel-translating equipments. For further details, see Annex 3.

Note 2. — It may be useful in replying to part c to consider the requirements of carrier programme circuits as given in Recommendation J.21.

Note 3. — The outcome of the study of Questions 22/XV and 33/XV might have a bearing on the study of this question.

ANNEX 1

(to Question 9/XV)

Go-return crosstalk

(Contribution by L M Ericsson)

a) At the meeting in Lisbon certain values for the specification of go-return crosstalk measured in the *channel-translating* stage were provisionally proposed by Study Group XV subject to subsequent review.

We have considered these values and find them inadequate to meet the objectives of Recommendation H.13, section e (*Blue Book*, Volume III). As it is now accepted that the values given therein for telegraphy should now be the general objective for all circuits set up on modern equipment (see Recommendations G. 151, section D.b.2, and M.61, section 5) the specifications for modulation stages should be established with this objective in mind.

The crosstalk contribution from higher modulation stages has yet to be fixed, but even assuming this is negligible the proposed values would be inadequate. In all the hypothetical reference circuits there are three modulations from channel to group and three corresponding demodulations. If we calculate on the basis of power addition of the various crosstalk contributions, then the values $X=50$ and $A=44$ lead to an overall go-return crosstalk ratio of 38.2 dB. The criticism may be raised that the values given were specification limits rather than design objectives, so that average values could be expected to be better. This is, however, offset by the fact that we calculated with power addition, whereas in fact the various contributions change in phase due to the different master oscillators not being synchronous, so that something very near voltage addition can occur from time to time. This could give a degradation of over 7 dB in the case considered above.

We therefore propose for the general case, without echo suppressors or call concentrators, that the minimum specification limits for both *X* and *A* be set at *53 dB*. This leaves a small but reasonable margin for contributions from other modulation stages.

The values proposed where echo suppressors or call concentrators are used are left without comment.

b) As regards *higher modulation stages*, the following points of view may be of interest for the further study of the question.

If we accept the value of 53 dB for the contribution to go-return crosstalk ratio from any channel modulation or demodulation stage, the sum of 6 contributions on a power basis yields 45.2 dB. Given the target of 43 dB for a complete hypothetical reference circuit (h.r.c.) as indicated in Recommendation H.13, section e, all higher modulation stages together may contribute 47.0 dB. The number of higher stages is 30 in the h.r.c. of Recommendation G.332, Figure 56, 36 for the h.r.c. of Recommendation G.333, Figure 67, and 42 for the new 60-MHz system h.r.c. The difference in numbers of stages only makes at most 1.5 dB difference in the result. An adequate value for this purpose alone would thus be 65 dB measured from either side. However, we need to consider here too the case of circuits with echo suppressors or call concentrators, and the value should be raised by an amount corresponding to the increase for the channel-translating stages, i.e. to *77 dB*.

As the observance of such a limit does not provide great difficulty, since both station and bay wiring normally use coaxial cable which is inherently screened, there seems no object in formulating separate specification clauses. In fact it appears quite practicable even to go somewhat further. The need for this occurs if we wish to make use of a frequency band in one direction of transmission where the opposite direction is occupied by a sound-programme channel, e.g. separate programme channels in the two directions occupying the same line-frequency allocation (see Note 2 to Recommendation J.21, section f). The crosstalk ratio objective for this case is 74 dB. We have found that there is unlikely to be any difficulty in meeting this recommendation for circuits established over most types of h.f. line provided that the following values of go-return crosstalk ratio are required by the specifications—

Group translating equipment	80 dB
All higher stages	85 dB

c) In practice it will be found that any *h.f. line* does, at least at some frequencies, contribute appreciably to the go-to-return crosstalk.

At present, in the absence of any recommendation on the subject, it would not be realistic to assume a better performance than 74 dB crosstalk ratio for a homogeneous section at the worst frequency. Due to the fact that we can assume random through-connection of traffic at the ends of a homogeneous section (Recommendation G.212), the use of the same frequency band for two different programme channels in opposite directions of transmission is usually possible without special restrictions concerning the frequency allocation. It must also be remembered that the noise level is likely to be high enough to mask the crosstalk on longer circuits—see Annex 1 to Question 22/XII studied in 1964-1968.

ANNEX 2

(to Question 9/XV)

Intra-group crosstalk coupling measured on installed channel banks (Go-to-return crosstalk ratio)

(Contribution by the American Telephone and Telegraph Company)

The results of near-end crosstalk coupling measurements (intra-group) on installed Western Electric Type A5 channel banks are as follows. All these measurements include approximately 500′ of interbay cabling about half of which is shielded. With the test set-up shown in Figure 1 A, the equal level crosstalk coupling loss between the "mod in" and the "demod out" points of the banks (the "audio in" and "audio out" points) averaged 84.6 dB. The lowest value observed was 77 dB; the highest value observed was 93.9 dB. These measurements were made at 1000 Hz. Measurements were also made at other frequencies in the audio pass-band of the channels, but no severe coupling peaks were observed.

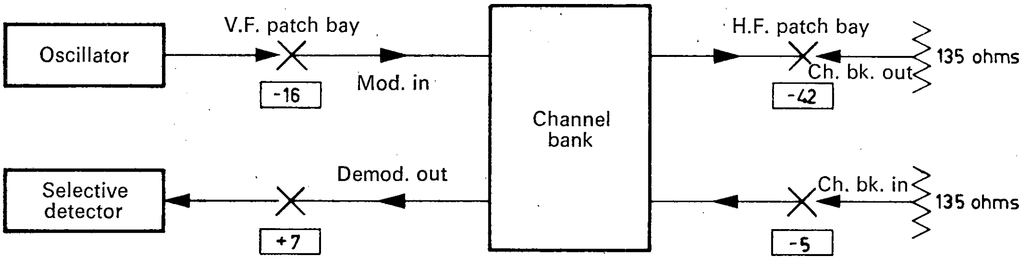

FIGURE 1A

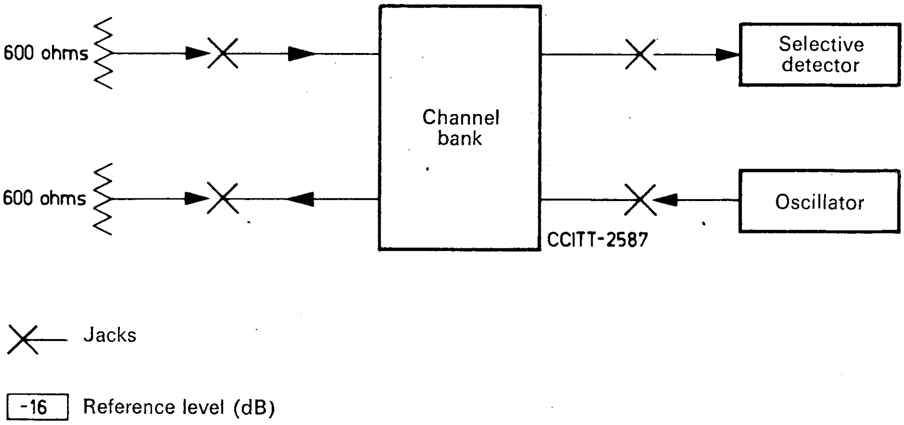

FIGURE 1B

The crosstalk coupling loss between the channels on the carrier-frequency side of the banks was also measured using the test arrangement shown in Figure 1B. The average value of coupling loss measured at the carrier frequency corresponding to the 1-kHz point of each channel was 64.9 dB. The lowest value of coupling loss observed was 46 dB; the highest value of coupling loss observed was 78 dB.

The values of coupling loss measured at this point varied considerably with frequency. Each channel was therefore also measured at the frequency giving the lowest crosstalk coupling loss. The average value of crosstalk coupling loss under these conditions was 61.3 dB. The lowest coupling loss measured was 46 dB; the highest coupling loss measured was 69.5 dB.

All these values are summarized in the following table:

Crosstalk type	Frequency	Equal level coupling loss (dB)		
		Average	Maximum	Minimum
Audio in to audio out	1 kHz	84.6	93.9	77
Channel bank in to channel bank out	Group frequency equivalent to 1 kHz	64.9	78	46
	Group frequency of minimum loss	61.3	69.5	46

ANNEX 3

(to Question 9/XV)

Comments by Study Group XVI on redraft of Recommendation G.151-D

1. Study Group XV proposes minimum values of 65 dB for the go/return crosstalk ratio at the voice-frequency terminals of a channel-translating equipment suitable for use with modern echo suppressors, and 59 dB for the corresponding ratio at the high-frequency terminals.

2. Study Group XI proposes a minimum value of 60 dB for the go/return crosstalk ratio introduced by an international telephone exchange.

3. Considering the methods used to provide long international circuits that exhibit substantial delays, the practical arrangements can have up to three pairs of channel-translating equipments, i.e. three circuit-sections. (It is believed that there are no long delay circuits more complicated than this.)

4. On such a circuit the crosstalk paths which lie between echo suppressors (and thus tend to nullify their action) are three voice-frequency paths and three high-frequency paths. Assuming the limiting ratios given in 1 above and further assuming power addition of the echo signals leads to an aggregate go/return crosstalk ratio of about 53 dB.

5. If we note that the go/return ratios quoted by Study Group XV are limiting minimum values and that it is known that there is a spread among the ratios exhibited by practical equipment the average ratios of an equipment will be higher than the limiting values. Hence the overall crosstalk ratio calculated in 4 above can reasonably be expected to be exceeded in practice.

6. Turning now to the future when perhaps connections of the maximum permitted delay are established and all intermediate echo suppressors have been switched out (or disabled) we might encounter the conditions of Figure 1 in which three circuits are connected together by two intermediate international exchanges. The middle circuit has 3-circuit sections and the other two 2-circuit sections each. Assuming the appropriate limiting figures for channel-translating equipment and for international telephone exchanges given in 1 and 2 above, and also assuming power addition gives an aggregate go/return crosstalk ratio of about 48 dB, which is somewhat lower than the 55 dB required between suppressors.

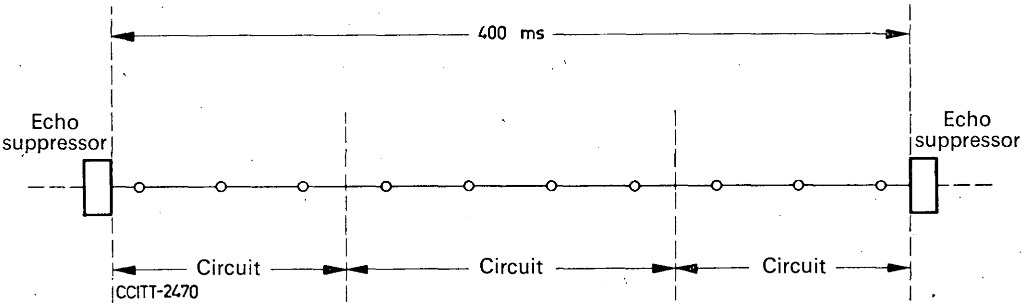

FIGURE 1

If each *circuit* and exchange were capable of achieving 60-dB crosstalk ratio the aggregate would be 53 dB which, bearing in mind the fact that all this is based on an adverse combination of limiting conditions, would be acceptable.

7. The conclusion is:

a) the limit of 55 dB for circuits is provisionally acceptable but would not be suitable in the future. A limit of 60 dB is proposed;

b) Study Group XV should be asked to reconsider the problem for the future, for example: Could the minimum values be improved by 6 dB?

Question 10/XV — Fuller specification of echo suppressors, new methods of controlling echo

(continuation of Question 10/XV studied in 1964-1968)

a) Considering: that new Recommendation G.161 (*White Book*, Volume III) provides characteristics of echo suppressors suitable for use on circuits having either short or long propagation times, and associated tone disablers, and that the Recommendation contains certain provisional and study items:

what values can be recommended for those provisional items, and what additional items are needed? (See the Annex to this question for a list of the items.)

b) Considering that new or improved means of controlling echo, including adaptive echo cancelling, may be feasible in the future and may provide better service to subscribers using circuits that involve such means:

1. what new and improved devices and methods for controlling echoes should be recommended? (Refer also to Question 6/XII, part d);

2. what characteristics of the echo path, as defined in Figure 2 of section A of Recommendation G.161 (*White Book*, Volume III) must be known to permit specification of new echo control devices?

Note. — Data on time variability and non-linearity are important for the study of adaptive echo cancellers. Study Group XVI is requested to assist by the collection of such data. Study Group XV will supply more definite information on the parameters of non-linearity and time variability which should be determined.

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ANNEX

(to Question 10/XV)

Recapitulation of the provisional recommendations and study items

1. What values should be recommended for those transmission characteristics that are given provisionally in Recommendation G.161, section B. c.1? (See Table A.)

2. What characteristics of tone disabler guard action should be recommended? (See Recommendation G.161, section C.c.)

3. What tone disabler holding band characteristics should be recommended to ensure release in the presence of maximum expected circuit noise? (See Recommendation G.161, section C.d.)

4. What specifications should be recommended for tone disabler recycle times? (See Recommendation G.161, section C.f.)

5. What test methods should be recommended for tone disablers? (See Recommendation G.161, section C.h.)

TABLE A

Tabulation of limits proposed by several organizations for transmission performance of echo suppressors

Between +10 and +40° C and permitted power supply variations	G.T. and E/COMSAT	A.T. & T.	F. R. of Germany	United Kingdom	France	S.G. XI (for switching equipment)
Insertion loss (dB) Send and receive paths, unoperated, measured at 800 (or 1000) Hz	0 ± 0.3	0 ± 0.1	0 ± 0.3	Adjustable to 0 ± 0.125	± 0.3	
Frequency characteristic Deviation from loss (dB) at 800 (or 1000) Hz	+0.3, −0.2 (300-3400 Hz)	+0.5 +1.0 −0.2 −0.5 (300-3200) (200-3400)	+0.3, −0.2 (300-3400)	±0.25 (300-4000) +0.2, −0.9 (at 200)	+0.3 −0.2	+0.5 +0.3 −0.2 −0.2 (300-400) (400-3400)
Delay distortion Envelope delay distortion (μs) between any two frequencies (Hz)	100 (500-3000)	14 30 (1000-2400) (500-3200)	100 (500-3000)	—	150	100 100 (500-3000) (may be tightened)
Impedance — Nominal	600 ohms (n.r.)	600 ohms (n.r.)	600 ohms (n.r.)	600 ohms (n.r.)	600 ohms (n.r.)	600 ohms (n.r.)
— Return loss (dB at ... Hz)	20 (300-3400 Hz)	25 (500-2500) 16 (200-500, 2500-3200)	20 (300-3400)	20 (200-4000)	20	15 (300-600) 20 (600-3400)
— Unbalance to earth (dB at ... Hz)	40 (300-3400 Hz)	56	40 (300-3400)	50	40	40 (300-600) 46 (600-3400)
Overload dB increase in loss, relative to loss for a 0 dBm0 input, for input shown (dBm0)	—	0.2 at +10	—	—	—	0.2 at +3.5
Harmonic distortion Total distortion power (dBm0) relative to 0 dBm0 800 (or 1000 Hz) sine wave input	−40	−30	−34	−35 at 0 −28 at +7	2%	
Intermodulation G.162, B.e.2 if receiving loss operates at syllabic rate		NA	−26	NA		−6 dBm0 (f_1, f_2) 40 ($2f-f$)

Between +10 and +40° C and permitted power supply variations	G.T. and E/COMSAT	A.T. & T.	F. R. of Germany	United Kingdom	France	S.G. XI (for switching equipment)
Transient response G.162, B.g. if receiving loss operates at syllabic rate		NA		NA		
Noise Mean dBm0p, any hour dBm0	−70 −40	−77 —	−70 —	−70 —	−70 —	— −50
Crosstalk Send-receive path loss (dB) (crosstalk attenuation)	70	65 for disturbance < +10 dBm0	70 (300-3400 Hz)	60 same supp. 95 between supps.	70	50 (consider 60)
Spurious outputs Zero-to-peak (dBV0) in filtered band. Not audible in normal noise of −50 dBm0p	−34 (500-3400 Hz)	—	—	Not spec.	−34	

Question 11/XV — Protection of group and supergroup pilots against wide-spectrum signals; regulators associated with these pilots

(new question)

The various group and supergroup pilots may be used when the group or supergroup link transmits wide-spectrum signals (data, facsimile, etc.) occupying the greater part of the frequency band of the link (Recommendation G.241).

It is appropriate to study simultaneously and in correlation points a, b, and c below:

a) The characteristics to be recommended for group and supergroup regulators.

In particular, their sensitivity to sustained and to transient interfering signals, such as components from the wide-spectrum data or facsimile signal which fall in the vicinity of the regulating pilot.

Remark. — The behaviour of a pilot-operated regulator in the presence of unwanted signals depends in a complicated way on the characteristics of the selection filter, the detection law and the regulator time constant; all these factors will have to be taken into account in considering the effect of unwanted signals.

b) The limitation which should be imposed on the energy spectrum of components of the wide-spectrum signal in the vicinity of the regulating pilot.

Remark. — A provisional proposal on this point appears in Recommendation G.241.f.1.

c) The group-delay characteristics to be recommended for a band-clearing filter which would ensure that the requirements of b are achieved whilst giving the least disturbance to the wide-spectrum signal.

Note. — Three cases should be studied:

1. when a group link is used for wideband transmission—interference from the wide-spectrum signal into the group regulator on the same group link;
2. when a group link is routed in the position in a supergroup occupied by a supergroup pilot—interference from the wide-spectrum signal on the group link into the supergroup regulator;
3. when a supergroup link is used for wideband transmission—interference from the wide-spectrum signal into the supergroup regulator on the same group link.

General note. — This question is closely related to Question 15/XV on the specification of regulators.

Question 12/XV — Protection of the group pilot and the supergroup pilot in certain cases of through-connection

(new question)

In certain cases of through-connection of links used for wide-spectrum signal transmission, e.g. the unrestricted through-connection of a group (G.233.g.2), “delayed transfer” (G.241.f.2), multipoint links (G.241.f.3), it may be necessary to suppress the pilot received at the end of a link to avoid interference with the pilot on a subsequent link. What group delay characteristics should be recommended for a pilot-suppression filter which would give the least disturbance to the wide-spectrum signal?

Note. — Information which may be relevant to the present study can be derived from the practices of administrations in meeting the requirements of G.233.g.2—e.g. providing a "spike" filter in the transmit and receive sides of group translating equipment and giving at least 20 dB suppression over a band about 6 Hz wide centred on the supergroup pilot. Such a filter would be provided in every group 3 position to suppress 104 + d kHz when the 412 − d kHz pilot was used, or in every group 5 position to suppress 64.08 kHz when the 547.92-kHz pilot was used.

Question 13/XV — Suppression of line-regulating pilots

(continuation of Question 13/XV studied in 1964-1968)

Considering

1. That, where line-regulated sections are connected in tandem, any line-regulating pilot must be suppressed by at least 40 dB to prevent interference with a similar line pilot in a subsequent section (Recommendation G.243, E.b);

2. That interconnected sections do not necessarily use line-regulating pilots at the same frequency,

a) can residues of line pilots suppressed by less than 40 dB be tolerated if the section immediately following does not use a line-regulating pilot of the same frequency?

b) If so, what minimum suppression of line pilots may be permitted and in what circumstances?

c) What consequential changes, if any, are necessary to the recommended methods of suppressing line-regulating pilots (Recommendation G.243, E.b)?

d) Irrespective of the outcome of the studies of points a to c, what changes might be introduced to Recommendations G.213 (C.C.I.R. Recommendation 380-1), G.243 and G.423 to eliminate inconsistencies?

Note 1. — It is probably desirable that in C.C.I.R. Recommendation 381-1, point 6, the words "input terminals of the radio-relay system (point T′)" be replaced by "input terminals of the radio equipments (point R′)."

Note 2. — It will be necessary to refer any proposed modifications to C.C.I.R. Study Group IX.

Question 14/XV — Carrier leaks in translating equipments

(new question)

What values should be recommended in a single stage of modulation in group, supergroup, mastergroup, supermastergroup or 15-supergroup translating equipment for the maximum permissible level of any carrier leak which might appear as a disturbing signal on a wideband group or supergroup circuit used for transmitting wide-spectrum signals (e.g. data or facsimile)?

Note. — Recommendation G.233,j gives a provisional value of −40 dBm0 for a single stage of modulation, but Recommendations H.14, Bc and H.15,b give the same value as the objective for a complete wideband group or supergroup circuit.

Question 15/XV — Line regulators, group regulators, etc.

(continuation of Question 15/XV studied in 1964-1968)

What recommendations should line, group, supergroup, etc. regulators meet, as regards

a) the dynamic stability of a connection;

b) protection against noise and disturbing signals?

Note 1. — Annexes 1 to 4 should be borne in mind for the study of point a. With regard to point b, see Recommendations G.232, G.233, G.241.

Note 2. — This question is related to Questions 11/XV and 26/XV.

ANNEX 1

(to Question 15/XV)

Reply given by Study Group XV in 1968 to Question 15/XV: Time constants of regulators

I. PRINCIPLES FOR THE SPECIFICATION OF REGULATORS AS REGARDS DYNAMIC STABILITY

A. *Definitions*

Many types of regulators are possible; they have been classified provisionally to facilitate the continuation of this study (see Figure 1).

Type 1

Regulator with linear relation between the pilot level at the amplifier input and the amplifier gain. This linearity is given only for a limited range of pilot level deviation. The regulator is continuously connected to the amplifier.

Type 2

Similar to type 1, with the exception that the regulator does not respond to output level variations if they do not depart from a narrow, predetermined range of values of this level.

Type 3

The steady-state relation between the pilot level at the amplifier input and the amplifier gain is given by a step function. For small pilot level deviations there is a small range, as in the case of type 2, where the regulator does not respond. The regulator is continuously connected to the amplifier. There is a memory within the control loop.

Type 4

Scanning action regulator with only one pilot receiver for controlling a number of amplifiers one after the other. Each amplifier needs a memory device to store the amplifier gain until the next cycle of the scanner. Normally, this regulator has a step function characteristic.

This classification considers only the differences in a steady-state situation and not in respect of time response. The time response of the step function regulators (types 3 and 4) is normally smoothed by time constants, e.g. thermistor, condenser, etc.

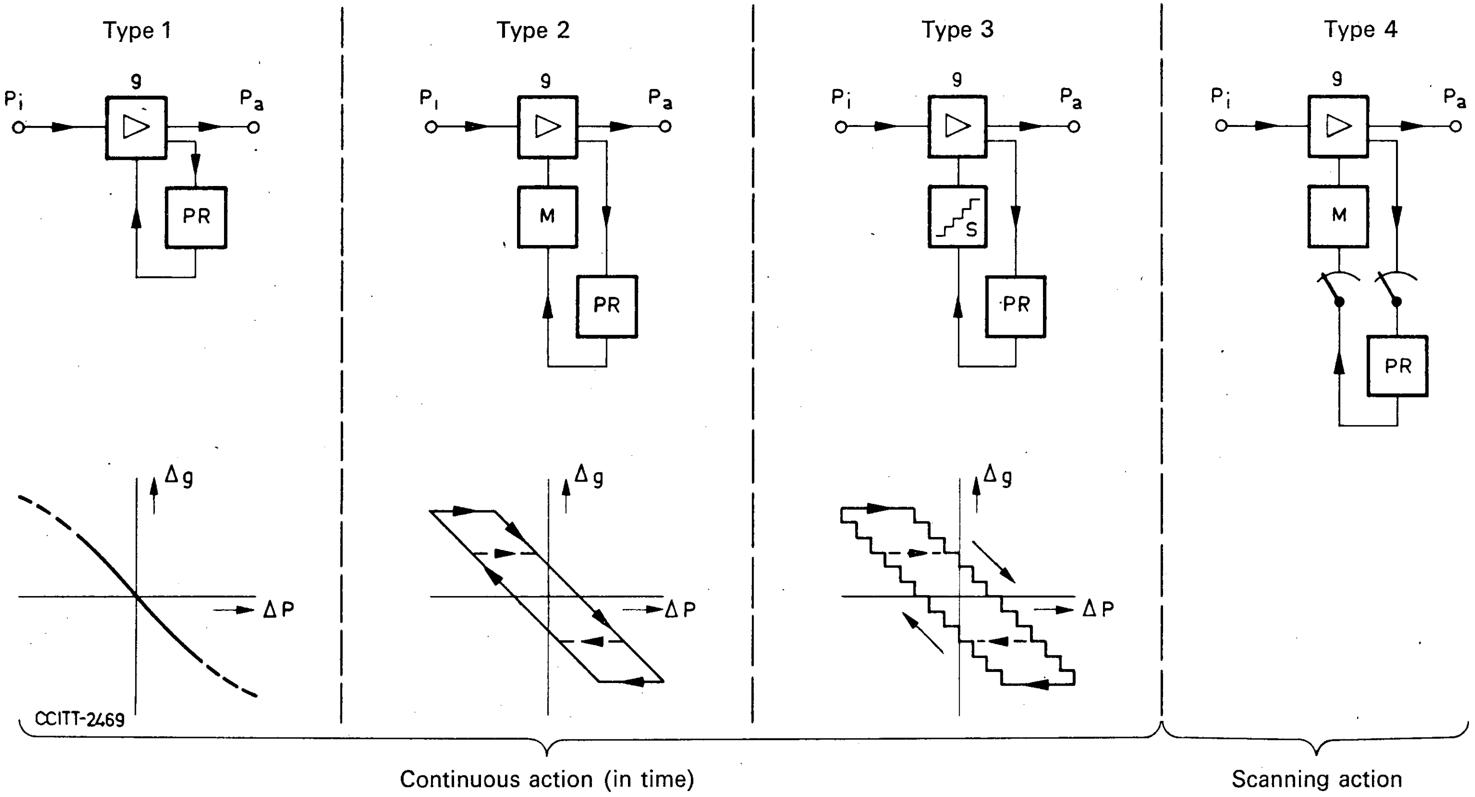


FIGURE 1. — **Definition of four regulator types**

Legend: P_i = input level, P_a = output level, g = repeater gain, M = memory, PR = pilot receiver, S = step function device incl. memory, Δ = deviation from the nominal value

B. *General objective*

The link to be considered should be the most general type of *group link*, set up over several regulated-line sections in tandem:

a) The group pilot level must not increase or diminish by more than 2 dNp at the end of the group connection when there is a sudden attenuation variation of 2 dNp before the first regulator of the first regulated-line section;

b) Response to a quasi-periodic disturbance of small amplitude (e.g. 2 cNp) should be kept within certain limits, which will have to be studied (see Annex 2).

C. *Systems with continuous-action regulators for which some assumptions are fulfilled*

1. *Assumptions*

It is assumed that the line regulators and group (supergroup, mastergroup, etc.) regulators are all of type 1.

It is assumed that a sudden variation does not occur simultaneously on several regulated-line sections.

It is assumed, further, that the envelope gains of all the regulators reach their maximum at the same frequency, so that the envelope gain of a section is in proportion to the number of regulators in tandem on the section concerned. If in fact there is a difference in the critical frequencies, this will mean that better regulation performance is actually achieved.

2. *Overall condition*

It can be shown (see, for instance, *Bell System Tech. Journal*, March 1963, pages 230-241) that the condition of B.a will be met if the envelope gain G of the most general type of group link defined above does not exceed 1 neper. This result is obtained by assuming the linearity of type 1 regulators so that the envelope gain is independent of the level deviation.

3. *Condition for the envelope gain G_{Rg} of group (supergroup, etc.) regulators*

The same condition is assumed for each regulator, regardless of its type (group, supergroup, mastergroup, etc.).

If n_g is the maximum number of such regulators on the most general type of group link,

$$G_{\mathrm{Rg}} \leqq \frac{G_g}{n_g}$$

For the purposes of this study, n_g should be taken to be 10'. It would be advisable, however, to provide a safety margin when setting the limits for G_{RL} and G_{Rg}. Study of the margin to be recommended should be continued.

D. *Systems with continuous-action regulators for which the calculation assumptions referred to in C.1 are not fulfilled*

When the envelope gains of regulators reach their maximum at different frequencies, advantage can be taken of this condition to relax the requirements in section C.

This problem must remain under study.

E. *Other types of regulators*

The case of other types of regulators requires further study. As regards type 3 regulators, see Annex 3, while for type 4 regulators see Annex 4. It is noted that the rate of regulation for this type may be slower than for regulators of the continuously-acting type.

II. Time constants

If the final reply to Question 15/XV results in a new Recommendation on the performance of regulators, it will be convenient for the text to include a cross-reference to the remarks annexed to Recommendation G.232 and to Recommendation G.241.d (pages 107 and 120 of Volume III of the *Blue Book*): these assume that the speed of group, etc. regulation shall not be too rapid. In fact, no trouble in respect of interference by telephone channels seems to have been reported for regulators whose speed of response is limited by thermal or mechanical inertia.

In actual fact, these regulators may have a control loop that has a linear and a non-linear operating region. Generally the device operates in a linear fashion for small-amplitude variations in the pilot level. For large variation in pilot amplitude the control action may be non-linear. The gain enhancement of concern is that occurring in the linear operating range because the gain enhancement in the non-linear region tends to be less and in fact tends to zero. It is appropriate to take the maximum gain variation value for the sudden attenuation variation mentioned in B.a, and in that which follows reference is intended to the maximum value measured when the device is operated in the linear region.

III. Sharing of G between line regulators and group (supergroup, etc.) regulators

If G_L is the envelope gain of the first line-regulating section,
and if G_g is the envelope gain of all the regulators of groups (supergroup, etc.) in tandem, we have:

$$G = G_L + G_g$$

Suitable values appear to be:

$$G_L \leqq 0.7 \text{ Np}$$
$$G_g \leqq 0.3 \text{ Np}$$

but this point should be studied further.

IV. Conclusion

a) *Condition for the envelope gain G_{RL} of a line regulator*

If n_L is the number of line regulators (which are assumed to be identical) of a regulated-line section equal in length to a homogeneous section of the hypothetical reference circuit applicable to the system under consideration, the condition to be laid down for the line regulators of that system is:

$$G_{RL} \leqq \frac{G_L}{n_L}; \text{ in other terms } G_{RL} \leqq \frac{0.7}{n_L} \text{ Np.}$$

Data transmission also may cause interference. Special study should be made of the regulation rate of group, supergroup, etc., regulators with the object of making section d) of Recommendation G.241 more precise and enabling Special Study Group A to investigate the limits to be adopted for the spectral power of the data signal close to a group, supergroup, etc, pilot.

ANNEX 2

(to Question 15/XV)

Contribution by Nippon Telegraph and Telephone Public Corporation

The N.T.T. has continued investigations on Question 15/XV, paying full attention to the contents of the reply given in 1966 in COM XV—No. 95, and has found that more thorough clarification of the problems which confront us is indispensable at this stage of the study. Principal results of our investigations are shown below.

1. The condition that the envelope gain of regulated group link should not exceed 1 neper has been established taking the objective for dynamic stability as shown in section I-B of Annex 1. The objective is that the group pilot level must not increase or diminish by more than 2 dNp at the end of a group link as a result of a sudden attenuation variation of 2 dNp before the first regulator of the first regulated-line section.

The relationship between the transient response objective of the regulated link and the permissible envelope gain of the link applies only when the regulators in the link are assured of linear operation (see note 1).

In practically all existing types of regulators, however, the linear operation may not be ensured for the case of an abrupt level change of 2 dNp at the input, although it may for a 2-cNp change. (It should be noted that the linear operation range for sudden level variation is smaller than for a slow level variation in most types of regulators.)

2. When a regulator has a limiter action in its control circuit, the transient response to a sudden large change tends to be more favourable than the response to a small change.

Thus the envelope gain of a regulated link, which is simply defined for a small amplitude variation only, may be permitted to have a value larger than 1 Np, in order to satisfy the transient objective for the 2 dNp sudden change.

3. The response of a regulated link to a "quasi-periodic variation in pilot level, however, should be given due attention in specifying the dynamic stability, as well as the response to an abrupt level variation. The response will be also quasi-periodic and result in an amplitude modulation of all the signals transmitted over the link.

4. "A quasi-periodic disturbance" may be produced by a disturbance from an insufficiently suppressed pilot frequency of, say, the previous regulated link, or/and by an amplitude modulation of a pilot frequency caused by harmonics of power supplies, or/and by a disturbance from unwanted frequency components which may fall in the pass-band of a pilot pick-off filter, etc.

For example, a quasi-periodic level variation of 1 cNp will occur if we assume a pilot leak suppression of 40 dB. It will result in a quasi-periodic level variation of about 3 cNp at the end of the regulated link with the 1 Np envelope gain. The frequency of the level variation will fall in the range of 0 to 1200 Hz if we assume a frequency stability of 10^{-5} for the highest frequency pilot of a 60-MHz coaxial-pair cable system.

5. A large abrupt level variation such as 2 dNp may be mainly attributable to a maintenance operation and may not occur simultaneously at several points of a regulated link. In any event the use of transistors in place of vacuum tubes means that variations due to this cause will occur less frequently.

On the other hand, quasi-periodic disturbances may be expected to occur simultaneously at several points in a regulated link, thus making the situation more harmful.

6. There are problems in a single concept of envelope gain as applied to all regulator types even when we restrict our considerations to the continuous-action types under conditions where the disturbance is of small magnitude. For example there is a type of regulator that employs a fixed regulating speed independent of level change (see Annex 26, page 495, *Blue Book*, Volume III). Another type provides a continuous gain adjustment (without any sudden gain adjustment) based on a stepwise operation in a part of its control loop.

The above consideration suggests to us the need for a more comprehensive classification of regulator types and a more precise definition of each class.

7. Various types of regulators are being used in the N.T.T.'s networks. As line regulators, linear proportional type regulators have been widely used. Supergroup regulators, however, are mechanical regulators which regulate the gain stepwisely according to scanning measurement of pilot level. For mastergroup regulators, we are going to adopt a type of regulator in which the regulation is performed on an electronic scanning basis. The regulator will employ a memory that records the pilot level in a stepwise manner. The gain, however, is regulated continuously by means of a thermistor whose heat inertia smooths the gain change.

8. The requirement for the response to quasi-periodic disturbances will become more severe if we think about the transmission of not only telephone signals but also other information signals such as sound-programme, facsimile, television type signals, etc. (See Question 37/XV.)

Conclusion

We suggest from the above considerations that investigations should be performed and a reply to the question should be compiled according to the schemes as shown below.

a) Classification of possible disturbance.

The objectives of dynamic stability of a regulated link should be separately specified, having regard to the classes of level variation.

1. Response to a sudden level variation of linear amplitude (say 2 dNp as mentioned in Annex 1).
2. Response to a quasi-periodic disturbance of small amplitude (say 2 cNp) (see note 2).

b) Classification of regulators.

Further investigations should recognize the various types of regulators and that, in general, any regulator control loop will have a non-linear region of operation.

Note 1. — For more detailed discussion, not only the maximum value of the envelope gain but full information of envelope gain vs. frequency characteristics will be required.

Note 2. — Especially for the study of the aspect a.2, due attention should be paid to the fact that the requirement varies depending on the kind of signals to be transmitted.

The recommendation may be compiled either to cover all conceivable kinds of signal transmission or for telephone signal transmission only, leaving the more general considerations as a future problem.

ANNEX 3

(to Question 15/XV)

Time constants of regulators

(Contribution by the Federal Republic of Germany)

Annex 1, section A, shows four different types of regulators all of which are used in the Deutsche Bundespost network. A level regulator of AEG-Telefunken is described below as an example of the type 3 regulator.

The level regulator operates in steps with a constant rate of regulation which is not affected by level deviations.

A. *Main parts of the level regulator*

The regulator consists essentially of the following component parts:

1. The level discriminator which responds to a level deviation exceeding the threshold by starting the timing device.
2. The timing device which determines the timing of the regulating steps in the control unit.
3. The control unit which steps the control value (control current) up or down to its instantaneous nominal value and stores it in case of a sudden pilot level failure.
4. The control element which obtains the control value from the control unit and causes the level to be adjusted.

B. *Fundamental properties of the level regulator*

1. The regulator is a three-point regulator.
2. Since with each regulating step the regulator causes the same level adjustment to be effected per timing interval, it has a constant rate of regulation which is independent of the amount of the level deviation.
3. In order that the regulator is in a steady state, the level correction for one regulating step is below the threshold of the level discriminator.
4. The timing and the time-constant of the control element are brought into line so that the level correction—which results in a regulating step—is nearly completed within the timing interval.

C. *Dynamic behaviour of a chain of regulators*

The individual regulator of the type described above adjusts a sudden variation of level without overshoot. If several regulators are inserted in tandem, overshoot will, however, be experienced irrespective of the type of regulator.

Mathematical investigations and a model test on a chain of 20 regulators of the above type revealed an excellent dynamic behaviour. This is proved by the following results:

1. The first overshoot value is the highest. In theory it amounts to 38% of the level variation to be adjusted. This applies to any number of regulators inserted in tandem. The model test showed 45%.
2. The regulation processes of the last and the first regulators are completed at the same time. Thus the chain of regulators stops operating within a very short period of time.

ANNEX 4

(to Question 15/XV)

Step-by-step regulators

(Contribution by L M Ericsson)

As has already been pointed out, the action of step-by-step regulators is considerably slower than that of continuous-action regulators: regulating times of up to an hour are mentioned. In any case it seems that we can rely on their being at least 10 times slower, and hence effects of interaction with continuous-action regulators can be neglected.

The regulation time is determined by the length of the test cycle and the size of the regulation step. Even with fairly rapid cycling, it is desirable not to have too small a step to ensure reasonably quick correction. There are two factors tending to limit the size of the step:

a) The objective for overall group regulation performance, since it is preferable to avoid having different types of regulation for intermediate and terminal stations of a group link.

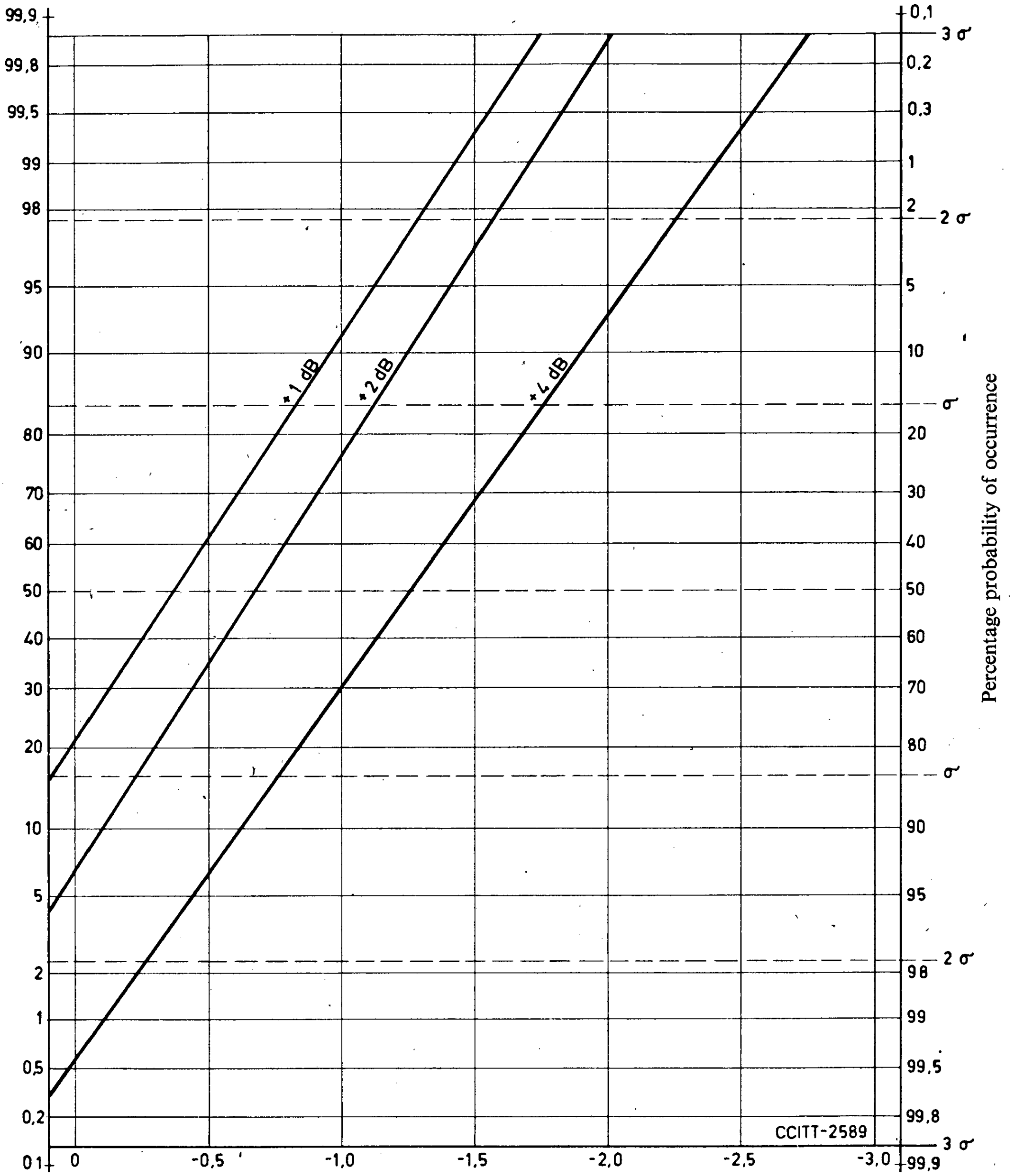
b) The possibility of the different regulators in a complex group link operating in such a sequence that the level at the end of the link exhibits overcorrection in the sense of Recommendation G.333, h, i.e. an output level error in the opposite sense temporarily exceeding in magnitude the change causing it.

As regards a, the objective has been set by Study Group IV as a standard deviation of 5 cNp apart from errors of measurement. This appears feasible with an adjustment step not exceeding about 0.5 dB. (In fact the average step size we use is 0.25 dB.)

The question thus arises whether this is acceptable from the point of view of b. It is clear that there will be a possibility of an overcorrection occurring if a 2-dB step is applied and there are eight or more regulators each making a 0.5-dB step in exactly the right sequence. Eight regulators is already quite a large number: thus between the ends of a group link in the hypothetical reference circuit of a 12-MHz system, only two demodulations to supergroup and one to group are included. Even if each intermediate and terminal point had step regulators, which is more than is required to satisfy Recommendation M.18, there would only be four altogether.

Nevertheless, it was considered of interest to examine the risk of regulation errors accumulating in more complex links. This has been done both theoretically and on a computer using a Monte-Carlo method. The length of the test cycle will in general be different at different stations and the order in which the first step is taken at the various stations will be purely random. As was expected, the result is not determinate but analogous to a random walk process, with the probability of the occurrence of large reverse level errors being very small. The amplitude of the maximum error in the opposite sense to the applied step increases with the size of the applied step, but not linearity. Some typical results are shown in Figure 1. These show the performance which can be expected at the end of a chain of 10 identical step regulators, for input steps of 1, 2 and 4 dB respectively. For a 2-dB applied step, the amplitude of the maximum reverse level errors has a 50% expectancy of exceeding about 0.7 dB, but the expectancy of exceeding 2 dB (corresponding to overcorrection) is less than 0.2%. This is considered to be acceptable.

If we were to measure with an applied step of 1 dB, it can be seen that the risk of overshoot is about 8%.



Maximum overcorrection at 10th station for suddenly applied error of value shown

FIGURE 1. — **Behaviour of step regulators in tandem**
Average size of regulation step 0.25 dB

Question 16/XV — Through group and supergroup connection equipment

(new question)

The levels and attenuation of through group and supergroup connection equipment (Recommendation G.242, b and c) are referred to 84 kHz and 412 kHz, respectively.

Since pilots at 104.080 and 547.920 kHz will be used in some cases,

a) is it necessary to relate these values not only to the level and attenuation at 84 and 92 kHz but also at 104 kHz and 548 kHz respectively?

b) if so, can one keep for the values referred to 104 and 548 kHz the same tolerances as those already recommended for values referred to 84 and 412 kHz?

Note. — Part a should first be studied by Study Group IV before Study Group XV can examine part b.

Question 17/XV — Aerial lines for carrier systems

(continuation of Question 17/XV studied in 1964-1968)
(Africa Question K.1 proposed by the Plan Sub-Committee for Africa)

Preparation of specifications of sufficient accuracy to serve as references when tenders are invited on the international market for the following transmission systems:

Overhead lines built for carrier systems (characteristics of wires, insulators, iron fittings and struts—conversion rules—permissible limits for attenuation and crosstalk—ranges and range regularity—separation between wires).

Note. — Study Group XV considers that no detailed specifications, such as those which can be drawn up for the supply of cables, are possible when overhead lines are to be put up. It would, however, be exceedingly useful if information could be assembled about the practice followed in the various countries, so that advice could be given to the administrations of the "new or developing" countries. A book on open-wire lines for carrier systems has already been drafted. In 1968 Study Group XV confirmed the mandate of Mr. Bashir (Pakistan) as rapporteur to continue the study of this question with regard to wideband systems on open-wire lines. If he sees fit, he may convene his correspondents, later on, for a meeting.

Question 18/XV — Cable systems with a small number of channels

(continuation of Question 18/XV studied in 1964-1968, replacing Africa Question K.2 and Asia Question 8 proposed by the Plan Committees)

Considering

1. that in the new or developing countries the cost of labour for the laying of cables is usually very low,

2. that in the circumstances peculiar to some of these countries, it may be cheaper, more reliable, and more convenient to lay cables rather than to erect overhead wire lines,

the following question should be studied:

a) What new or existing systems could suitably be used to obtain a few circuits, with the performance ratings recommended by the C.C.I.T.T. in the Recommendations appearing in the *White Book*, Volume III, section 1, for distances of between 200 to 500 kilometers (125 to 310 miles)?

b) What kind of cables (underground or overhead) should be advocated for use with the systems referred to above? How many pairs should they carry to produce, in all, 30 to 100 circuits, by applying such systems to a number of cable pairs?

Note 1. — The Annex describes why this question has been set for study.

Note 2. — A first system in reply to this question has been defined and forms the subject of Recommendation G.356 (*White Book*, Volume III).

ANNEX

(to Question 18/XV)

Why this question has been set for study

There have been considerable developments in plastic materials and in cable types as well as in repeater equipment. New types of cable include those using small coaxial tubes as well as symmetrical pair cables using foamed polythene insulation and plastic sheathing. Cable systems have important advantages over open-wire systems as concerns simplicity, maintenance, reliability, and stability, and it is most desirable that they should be used wherever possible in the development of networks. The only reason for the use of overhead wire systems is their economical advantage for small numbers of circuits. The use of a two-wire system on a single small coaxial tube or of a symmetrical pair cable may fulfil these requirements, especially in countries where the cost of laying cables is very low. The study and standardization of systems of the type indicated could make a great contribution to telecommunications development in these areas.

Question 19/XV — Crosstalk in programme transmissions in case of through connections of groups, etc.

(new question)

For the various types of through connection forming the subject of Recommendation G.242 (Volume III of the *White Book*), a difference of 9.2 nepers or 80 dB between the wanted and unwanted components is recommended *provisionally* in various bands which may be used by circuits for programme transmissions.

What definitive recommendations should be issued by the C.C.I.T.T. in this respect?

Question 20/XV — Over 2700 channels on 2.6/9.5-mm coaxial

(continuation of Question 20/XV studied in 1968-1972)

What is the best way of increasing the number of circuits which can transmit a 2.6/9.5-mm coaxial pair, standardized by the C.C.I.T.T., to more than 2700?

Note. — The reply to this question calls for additions to the provisions of Recommendation G.333; Annex 1 below lists various points to be studied.

ANNEX 1

(to Question 20/XV)

Points to be studied in connection with Question 20/XV

The paragraphs of this annex correspond to those of Recommendation G.333 (*White Book*, Volume III).

Introduction

To facilitate the design and development of equipment, administrations are invited to complete the information already supplied by giving information about the following parameters:

— spread of the attenuation per unit length up to 60 MHz;

— impedance irregularities of the cable and the splices with pulses of short duration, of the order of 60 ns and 10 ns. Attention is drawn to the fact that the distribution of impedance irregularities in a repeater section of the 4- or 12-MHz system may no longer be satisfactory when the repeater section is divided into 2 or 3 sections of a new system;

— attenuation distortion at certain frequencies and effect of impedance irregularities on this distortion;

— signal-to-crosstalk ratios measured up to 60 MHz, particularly on cable sections in service.

b) *Pilots, etc.*

The following point still has to be studied:

b.1) The choice of the main line-regulating *pilot* in the list of the reserved frequencies.

b.3) *Additional measuring frequencies*

The study of this point must be continued. Study Group XV noted that it might be desirable to have the following additional measuring frequencies:

below 12 MHz, as in the 12-MHz system,

12 435 (note 1)
14 408 (note 2)
17 488
22 372 (note 1)
26 948
31 344
35 748
40 920 (note 1)
46 748
51 148
55 548 kHz

Note 1. — This frequency is not needed if a pilot is placed there—see c.1.

Note 2. — This frequency has been chosen assuming a frequency allocation built up using mastergroups. Its position corresponds to that of 11 112 kHz in the 12-MHz system.

These frequencies are more or less equally spaced on a logarithmic frequency scale. Except for 12 435 kHz (line pilot in 12-MHz system) they are all chosen as multiples of 4 kHz, assuming that the level will be -10 dBm0 as hitherto. For frequency tolerance the value of 10^{-5} is proposed as in Recommendation G.333, paragraph c.3.

b.4) *Band to be reserved for monitoring and fault-tracing signals*

This point has to be studied. In principle these signals should be higher than the upper line-regulating pilot or below the pilot at 4287 kHz.

c) *Hypothetical reference circuit*

c.2) *Modulation*

The provisional recommendation should be confirmed or amended.

c.3) *Direct through-connection at line frequencies*

It was agreed that direct through-connection was envisaged not for points intermediate between the main stations as defined above, but rather at these stations themselves so that demodulation would be avoided. While this would be an advantage from the point of view of the amount of modulation equipment, it would involve more severe requirements on line equipment.

It has, however, been found possible to use restricted direct through-connection at main repeater stations with equipment designed to meet the normal noise objectives defined in connection with a hypothetical reference circuit for the 60-MHz system or coaxial pairs (see Figure 3 of Recommendation G.333) without incurring a noise penalty [1].

The necessary restrictions are as follows:

1. The frequency band containing supermastergroups 6 to 9 inclusive may be directly through-connected over a total length which must not exceed 830 km, but the adjacent frequency bands in the sections concerned must be made up of homogeneous sections which are not abnormally long.

2. It is in principle also possible to use direct through-connection for the frequency band containing supermastergroups 2 to 5 inclusive provided that the adjacent frequency bands containing supermastergroups 6-9 and 10-13 are made up of normal length homogeneous sections.

2.a) In practice it may be necessary to restrict the through-connection to supermastergroups which have a sufficiently low impedance mismatch effect (paragraph g) to permit the extension without excessive accumulation of attenuation roll effect.

3. After further study it may be found possible to allow direct through-connection of the lower and the middle supermastergroups (1 and 2 above) over a certain line length without causing undue noise effects.

c.4) *Equalization of direct through-connections*

The connection is made at a main station which will normally be the terminal point of line-regulation sections and the relative level deviations will therefore be limited. If, however, the residual level deviations in the line-regulation sections involved tend to be systematic, it may be necessary to provide supplementary equalization at the direct through-connection points.

If such systematic effects are known to occur, a supplementary equalizer can be designed in advance of establishing the direct through-connection.

There may be a need for additional measuring frequencies or even for continuously transmitted pilots for the through-connected frequency band. This point should be borne in mind.

d) and c.5) *Low-noise channels*

It seems too early to try to give any indications at this stage. Whether we can hope to look for these in the middle supermastergroups will depend on whether these can be allowed to retain their positions, or whether a completely random through-connection will be needed to achieve the noise targets for the remainder of the band. This point can be taken after completion of the studies called for above.

A study will have to be made of the precautions to be taken in designing the system to ensure that about 10% of the channels are low-noise channels as envisaged by Special Study Group C.

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[1] See Annex 2 prepared for the study of this point.

e) *Matching of repeater impedances and line impedance*

On the basis of the hypothetical reference circuit (defined in paragraph c above) it is necessary to decide how to reduce to 1 dNp the irregularities at the end of a section of such a length that the circuits as a whole risk being transmitted in line in the same frequency band along the whole of this line section. I.T.T. has submitted a contribution on the general method of calculation and its application to different systems (reproduced in a supplement of the *White Book*, Volume III). The Plenary Assembly of Mar del Plata (1968) has provisionally recommended a value of 65 dB for the magnitude *N* defined in paragraph e of Recommendation G.332, subject to further study on the principles set out in this supplement. Administrations are requested to indicate in their subsequent contributions the standard variation in the length of repeater sections that is to be expected so that the possibility can be studied of making this provisional limit less rigid.

f) *Interconnection*

f.2) *Line levels*

It would no doubt be more difficult to agree on a recommendation on line levels and pre-emphasis, but it would be interesting to compare the results of the studies undertaken in different countries.

ANNEX 2

(to Question 20/XV)

Direct through-connection of supermastergroup assemblies—Noise effects

(Nos. 6 to 9 inclusive)

Through-connection of a supermastergroup assembly involves changes in two sources of noise and these changes tend to cancel. These effects are discussed below.

1. Through-connection of a block of frequencies causes extended in-phase addition, over a longer distance, of only a part of the third-order non-linearity noise. This part of the noise may be called "self noise" and consists of that part of the non-linear noise which arises from the signal loading in the block itself.

The "self noise" for the middle third of the line-frequency band of a system without pre-emphasis contains only 1/9 of the third-order non-linearity noise falling into the band. When pre-emphasis is used the fraction is substantially smaller.

If interconnection is extended from 280 km to 840 km, the additional "self noise" will amount to 185 pW or less. With pre-emphasis the noise increase will not exceed 130 pW.

2. Direct through-connection renders certain modulation equipment unnecessary and this involves a reduction of terminal equipment noise of three times 40 to 60 pW or 120 to 180 pW.

Conclusion

The net effect on noise performance of using direct through-connection of the frequency block containing supermastergroups 6 to 9 inclusive is approximately zero for through-connection up to 840 km, but not for longer through-connections.

Restricted direct through-connection may therefore be used without a noise penalty and there is no need to modify the hypothetical reference circuit to permit such through-connection.

Question 21/XV — Over 2700 channels on new type cables

(continuation of Question 21/XV studied in 1964-1968)

What types of cable and transmission system could be standardized by the C.C.I.T.T. for the transmission of very big carrier systems (more than 2700 circuits) or for other services using a wide-frequency bandwidth?

Note 1. — The use of 2.6/9.5-mm coaxial pairs for this purpose is dealt with in Recommendation G.333 (*White Book*, Volume III).

Note 2. — Annex 1 below reproduces the reply to this question drawn up by a Working Party and approved by Study Group XV during the period 1964-1968.

ANNEX 1

(to Question 21/XV)

Reply to Question 21/XV studied in 1964-1968

Recommendation G.333 shows that it is technically feasible to use a 2.6/9.5-mm coaxial pair up to 60 MHz.

At its meeting in March 1965, the Working Party requested administrations to study the relationship between the cost of repeaters and the cost of cables. The purpose of this study was to ascertain whether a new type of coaxial pair should be recommended, in order to obtain a more economical solution than the one resulting from the reply to Question 20/XV, when a new cable route has to be constructed.

Economic studies were submitted at the meetings in October 1966 and November 1966. These reveal that the diameter of the coaxial pair shows a very flat optimum corresponding to maximum frequencies ranging from 25 to 60 MHz according to the particular contributions. This dispersion is due to the fact that the assumptions on which the calculations have been based are different, because difficult to define.

60 MHz seems to be the absolute maximum.

In particular, the repeater spacing is of the order of 1.5 km and it is to be feared that any reduction in this figure (if the upper frequency transmitted is increased) would entail certain difficulties, notably some degree of unreliability. But technical progress will probably demand ever-wider bandwidths. One solution would be to use a coaxial pair more than 9.5 mm in diameter.

At its meeting in June 1967, the Working Party examined various new contributions. Annex 2 summarizes the chief characteristics of the coaxial pairs described in the contributions, while Annex 3 gives information about a link via circular waveguides of helicoidal structure. Annex 4 contains a bibliography.

Study of this question should be pursued taking into account the following points:

1. Since the cable characteristics must be known for the purpose of designing the equipment, it would be desirable to study the diameter of a coaxial pair which could be two or even three times the present diameter of 9.5 mm.

2. The 2.6/9.5-mm coaxial pair would make it possible to set up 60-MHz systems. Before recommending the use of systems with larger capacities, one should bear in mind that there is a risk of losing 100 000 or 200 000 operational circuits all at once if very large capacity arteries are built.

Hence there is no urgent need to standardize new types of coaxial pairs. If they are standardized, attention should be confined to one or two types. Administrations making standardization studies at the national level are urgently requested to inform the C.C.I.T.T.

3. The possibility of using waveguides should also be considered. Study of this question should be pursued taking into account the possibilities of use with modulation systems (either f.d.m. or t.d.m.).

ANNEX 2

(to Question 21/XV)

Chief characteristics of the cables described in the contributions or temporary documents in 1967

1. FRANCE

These pairs have a tubular central conductor made of copper with "balloon" polythene insulation.

	Type of pair	
a) *Geometrical characteristics*	$^{7}/_{27}$ mm	$^{12}/_{46}$ mm
— Diameter of central conductor (mm)	7	12
— Diameter across insulation (mm)	24	43.5
— External conductor	Corrugated aluminium	
b) *Electrical characteristics*		
— Relative permittivity	1.16	1.16
— Effective capacitance (nF/km)	48	48
— Impedance at 1 MHz (ohms)	75	75
— Electric diameter (mm)	27	46
— Attenuation (Np/km) at:		
1 MHz	0.12	0.08
10 MHz	0.38	0.25
100 MHz	1.22	0.85
— Maximum impedance irregularity	0.22	
$\frac{\Delta Z}{2Z}$ in 0/00 with a pulse of 10 nanoseconds	5	5

2. A.E.G.-TELEFUNKEN

Construction: coaxial pairs with polythene helix and corrugated outer conductor (copper or aluminium).

	Type of pair	
Type	$^{7}/_{8}$"	1 $^{5}/_{8}$"
Characteristic impedance (ohms) ±1%	75	75
Rel. velocity of propagation, per cent	92	91.3
Capacity, pF/m approximately	48	49
Relative permittivity	1.16	1.16
Attenuation, dB km at: 30 MHz approximately	6.2	3.3
100 MHz approximately	11.5	6.3
300 MHz approximately	20.5	11.6
1000 MHz approximately	39.8	24.1
3000 MHz approximately	75.3	49.6
Diameter of inner conductor (bare) mm	5.7	10.9
Diameter over helical insulator mm	20.1	39.7
Electrically effective diameter mm	21.5	42.0
Diameter over outer conductor (gas-tight corrugated copper tubing), mm	25.4	46.5

3. France

These pairs have a tubular internal conductor made of copper, insulation consisting of a low-pressure polythene spiral or discs, and an external conductor of extruded aluminium.

	Type of pair		
	4.9/18.7	6.5/24.8	9.5/35.9
External diameter of the central conductor (mm)	4.9	6.5	9.5
Electric diameter including the insulator (mm)	18.7	24.8	35.9
Diameter including the aluminium (mm)	22.2	28.6	41.3
Relative permittivity	1.15	1.15	1.14
r.m.s. capacitance (nF/km)	48	48	48
Ratio of propagation speed to free-space speed	0.935	0.935	0.940
Characteristic impedance (ohms) at 1 MHz	75	75	75
Attenuation (Np/km) at 100 MHz	1.51	1.16	0.79
Maximum impedance irregularity $\frac{\Delta Z}{2Z}$ in 0/00 with a pulse of 10 nanoseconds	5	5	5
Maximum standing wave ratio up to 1000 MHz	1.05	1.05	1.05

ANNEX 3

(to Question 21/XV)

Chief characteristics of a waveguide used for an experimental correction, and measurement results

(Contribution by the French Administration)

The French Administration has laid a 10-km connection via waveguides in the Paris area, using the TE_{01} mode.

The guides are circular, of helicoidal structure, with an inner diameter of 50 mm. They consist of a wrapping of 0.2-mm enamelled copper wire with contiguous turns. The turns are held in position by a dielectric sheath made of glass fibre strands and a coating of epoxy resin pressure-injected between the covering and the sheath. For rigid guides, the covering consists of a steel tube and, for flexible guides, of an assembly of jointed steel plates forming a helix.

Measurements made in a straight line showed the attenuation to be:

3 dB/km at 35 GHz
2 dB/km at 70 GHz

On flexible guides, the additional attenuation due to bending is as follows:

a) *at 35 GHz*

0.03 dB/radian for a bend radius of 50 m
0.04 dB/radian for a bend radius of 30 m
0.1 dB/radian for a bend radius of 10 m

b) *at 70 GHz*

0.5 dB/radian for a bend radius of 50 m
0.75 dB/radian for a bend radius of 30 m
1.5 dB/radian for a bend radius of 10 m

Measurements carried out on a section 3 km long showed that group delay distortion was less than 1 nanosecond.

ANNEX 4

(to Question 21/XV)

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Question 22/XV — Impedances and levels at group and supergroup distribution frames

(new question)

Since, in view of the diversity of carrier systems already in service, it has not been possible to recommend international standards for the impedance and relative carrier levels at group and supergroup distribution frames (see Recommendation G.233 b), and since such standardization would facilitate the interconnection in these distribution frames of equipment of different manufacture would simplify matters for manufacturers of equipment for use in stations in different countries and would thereby lower their production costs:

a) Is it desirable to recommend preferred levels and impedances to be adopted whenever possible, particularly by countries which have not yet fixed values for their national networks? If so, what should the preferred values be?

Note. — In this study account should be taken of the fact that modern equipment uses transistors.

b) Administrations are requested to indicate, for information purposes,

1. which level and impedance values they use, and
2. they intend to use in future in these distribution frames.

Question 23/XV — Extension of former Recommendation G.335 to transistorized systems

(new question)

How should Recommendation G.335, *Blue Book*, Volume III (Recommendation G.351, *White Book*, Volume III) be brought up to date to allow for coaxial-pair systems using transistors?

Note. — The following Annex contains examples of information supplied in 1968.

ANNEX
(to Question 23/XV)

Power feeding and grounding of 0.375-inch (2.6/9.5-mm) coaxial cables

Revision of Annex 30 prepared by the American Telephone and Telegraph Company
(*Blue Book*, Volume III, pages 505-506)

System designation	Number of 4-kHz channels	Type of power feed [1]	Voltage (volts) [2]			Current	
			Centre conductor to ground	Between centre conductors	Allowed variation	mA	Allowed variation
L1	600	a.c. 60 Hz (regulated constant current) Centre conductors looped back at centre section of power span	800 r.m.s.	1600 r.m.s.	500-2500 r.m.s.	435	±2%
L3	1860	a.c. 60 Hz (regulated constant current) Centre conductors looped back at centre section of power span	2000 r.m.s.	4000 r.m.s.	0-4400 r.m.s.	1500 to 1700	±3%
L4	3600	d.c. (regulated constant current feed) Feed-through, + voltage at one end and − voltage at other end for power span	+ or −1800 d.c. nominal ("centre-point" grounded at one end of power section. Centre-points at other end floats unless voltage there is +36 above ground)	3600 d.c.	0-3600 d.c.	520	±20 mA or ±4%

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[1] Maximum distance between power feed points is 150 miles for all systems.
[2] Outer conductor of coaxial unit grounded in all cases.

Question 24/XV — Characteristics of systems for short and medium distances

(continuation of Questions 24/XV and 32/XV studied in 1968)

Considering

that there exist numbers of different systems for application in national networks over medium and very short distances;

that no recommendations concerning the underconnection of such systems at line frequencies are necessary or contemplated;

that it is important that the performance of such systems is compatible with overall limits to be established for the national parts of international connections,

What recommendations on the performance requirements of very-short-distance carrier systems (additional to those of Recommendation G.125) and medium-distance carrier systems (possible new recommendation) are necessary in the light of the transmission characteristics which may be established for the parts of a national network included in an international connection (Question 6/XVI)?

Question 25/XV — Intelligible crosstalk caused by intermodulation with the line pilot

(new question)

Considering

1. that line pilot frequencies which are an integer multiple of 4 kHz can give rise to intelligible crosstalk by way of intermodulation;

2. that on cable systems, which are designated for a noise performance in agreement with Recommendation G.222, intelligible crosstalk caused by intermodulation with the pilot signal can have an attenuation substantially lower than the values required to meet Recommendation G.151,D.a;

3. that the crosstalk requirements for telephone and programme circuits have to be met regardless of the source of crosstalk;

What measures should be taken to improve the performance regarding intelligible crosstalk caused by intermodulation with pilot signals which have a frequency of an integer multiple of 4 kHz?

Note. — The Annex below gives some information for the study of this question.

ANNEX

(to Question 25/XV)

Contribution by the Swiss Administration

The problem of intelligible crosstalk occurs in various cable systems standardized by the C.C.I.T.T., such as the 300- and 960-channel systems on coaxial cables in accordance with Recommendations G.341 and G.343.

For example, in the case of the 300-channel system (A-B) type, intermodulation with the 1364-kHz pilot causes intelligible crosstalk between supergroups 2 and 4 and vice versa. In the case of the 960-channel system (A-B) type, intermodulation with the 4092-kHz pilot causes intelligible crosstalk between supergroups 2 and 15 and vice versa.

Three particular cases have been investigated, and the results are briefly outlined below.

The study is related to a homogeneous section of the hypothetical reference circuit 280 km long. The permissible noise power is 840 pW; a third of this power (—65.5 dBm0p) is allowed for second-order intermodulation noise. It is also assumed that the shape of the pre-emphasis curve may be represented as follows:

$$y(x) = 0.0075 \exp(4.8\,x) + 0.0925$$

where y is the channel level, and x the frequency normalized with respect to the highest channel, $y(1) = 1$. This curve is similar to that in Recommendation G.344, g, for $a = 10$, $b = 2.20$.

The intermodulation noise power T_2 is given by

$$T_2(x) = t_2(x) + 2P - 10 \log N + K_2(x) \text{ dBm0p}$$

where t_2 is the distortion coefficient of the homogeneous section if it is assumed that the signal spectrum is flat; P represents the conventional load (G.222) and K_2 is a correction factor taking into account the pre-emphasis and the psophometric factor.

The most important results are given in Table 1 below:

TABLE 1

	System		
	300 channels	960 channels	10 800 channels
t_2 (dB)	$-60.3-K_2$	$-65.3-K_2$	$-75.8-K_2$
K_2 (dB)	-8.5	-15	-15
Approximate level[1] of the disturbed channel (dB)	-5 $(x \sim 0.7)$	0 $(x \sim 1)$	0 $(x \sim 1)$
Pilot level (dBm0)	-10	-10	-10
Level of the disturbing channel[1] (dB)	-10 $(x \sim 0.2)$	-10 $x \sim 0$	-10 $x \sim 0$
Crosstalk attenuation over 280 km (dB)	61	65	75

These results concern second-order intermodulation noise of 1 pW/km. If the latter is improved by S dB, the crosstalk attenuation likewise increases by S dB.

Question 26/XV — Dynamic stability of regulation

(continuation of Question 26/XV studied in 1964-1968)

How should the provision of Recommendation G.214 relating to the dynamic stability of the regulation system for cable systems be made more specific?

Note. — This question should be studied in conjunction with Question 15/XV.

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[1] Level referred to the level of the highest channel.

Question 27/XV and 4/IV — Terminology for carrier systems

(new question)

Is it necessary to amend or complete some of the definitions appearing at present on page 70 of Volume III of the *Blue Book* and which have been repeated in Recommendation G.211 of Volume III of the *White Book*, in view of the generalization of non-telephone signal transmission in networks? If so, what amendments or additions are proposed?

Note. — The chief purpose of this question is to harmonize certain terms used by Study Group XV and by Study Group IV.

Question 28/XV — Television on 1.2/4.4-mm coaxial pairs

(continuation of Questions 28/XV and 29/XV studied in 1966-1968)

a) What characteristics should be recommended for alternate telephony and black-and-white or colour television transmissions on 6-MHz systems on 1.2/4.4-mm coaxial pairs (defined in Recommendation G.344 for telephony)?

Note. — The provisions to be studied include the allocation of the overall permissible limits for random and periodic noise to:

1. a terminal modulating equipment;
2. a terminal demodulating equipment;
3. the high-frequency line;

b) Can Recommendation J.72 (drafted for transmission over 2.6/9.5-mm coaxial pairs) apply unaltered to the transmission of black-and-white television signals over 1.2/4.4-mm coaxial pairs?

Note. — Two proposals were submitted regarding the shaping of the vestigial sideband: to recommend the first system mentioned in the Remark to Recommendation J.72 (*Blue Book*, Volume III, pp. 411 and 412), or to effect this shaping entirely at the sending end as in the case of the 12-MHz system (Recommendation J.73, paragraph c, *Blue Book*, Volume III, p. 416).

Question 29/XV — Television transmission on the 60-MHz system

(new question)

Considering

that the 60-MHz coaxial pair system may be used to perform wideband services such as carrying the colour television signals defined by the C.C.I.R.;

and that it is desirable in this case to use the same repeaters as when only telephone signals are transmitted,

what complementary recommendations should be issued as regards the line (cables and repeaters) and for the terminal translating equipments?

Note 1. — The following points should be considered in particular:

a) What line-frequency allocation should be recommended for the simultaneous transmission of telephony and television?

b) Which is the better method of video-frequency translation, direct modulation or premodulation? If it is better to adopt the premodulation method, what should be the carrier-frequency?

c) What values should be recommended for modulation index and relative power level of television signal?

d) What values should be recommended for the repeater input and output impedance?

e) How could such video signals be coded in digital form so as to permit the transmission of one or more digital signals of this type on the 60-MHz analogue coaxial pair system, at the same time as frequency division multiplex telephone channels?

Note 2. — Point e) should be studied in liaison with Question 10/D.

Note 3. — The Annex below gives an example of a transmission method envisaged by one administration.

ANNEX

(to Question 29/XV)

Note by the Nippon Telegraph and Telephone Public Corporation

N.T.T. considers that the premodulation method is more economical and easier than the direct modulation method in making up the television multiplex signal to be transmitted over the 60-MHz system.

Following are the outlines of the systems now being studied by N.T.T.

a) *Line-frequency allocations*

Two allocation plans are shown in Figure 1 together with the allocation only for telephony.

One television channel (plan 1) or one television channel and 300 telephone channels (plan 2) correspond to two supermastergroups, and they are stacked up in turn from the lower part of the transmission band up to six systems in place of telephone channels.

The frequencies shown in the plans are calculated in the case of 4.3-MHz television signals, while these allocations can be used, also, for 5.5-MHz television signals.

b) *Modulation*

2. First modulation:
   1.1 Plan 1: Lower vestigial sideband of the premodulation carrier (10 560 kHz) is produced. Both the carrier frequency and d.c. component of the video signal are suppressed, not to be transmitted to line.
   1.2 Plan 2: Upper vestigial sideband of the premodulation carrier (6799 kHz) defined in Recommendation J.73 on a 12-MHz system is produced.

Transmitting the 5.5-MHz colour television signals is easier in plan 1 than in plan 2.

2. Second modulation:

The supermastergroup translating equipment can be used, also, for the second modulation of television signals without changing the carrier frequencies.

c) *Relative power level*

The relative power level of the television signal is higher than that of a telephone signal by about 13 dB.

d) *Repeater input and output impedance*

The value of N defined by Recommendation J.73 should be at least 70 dB.

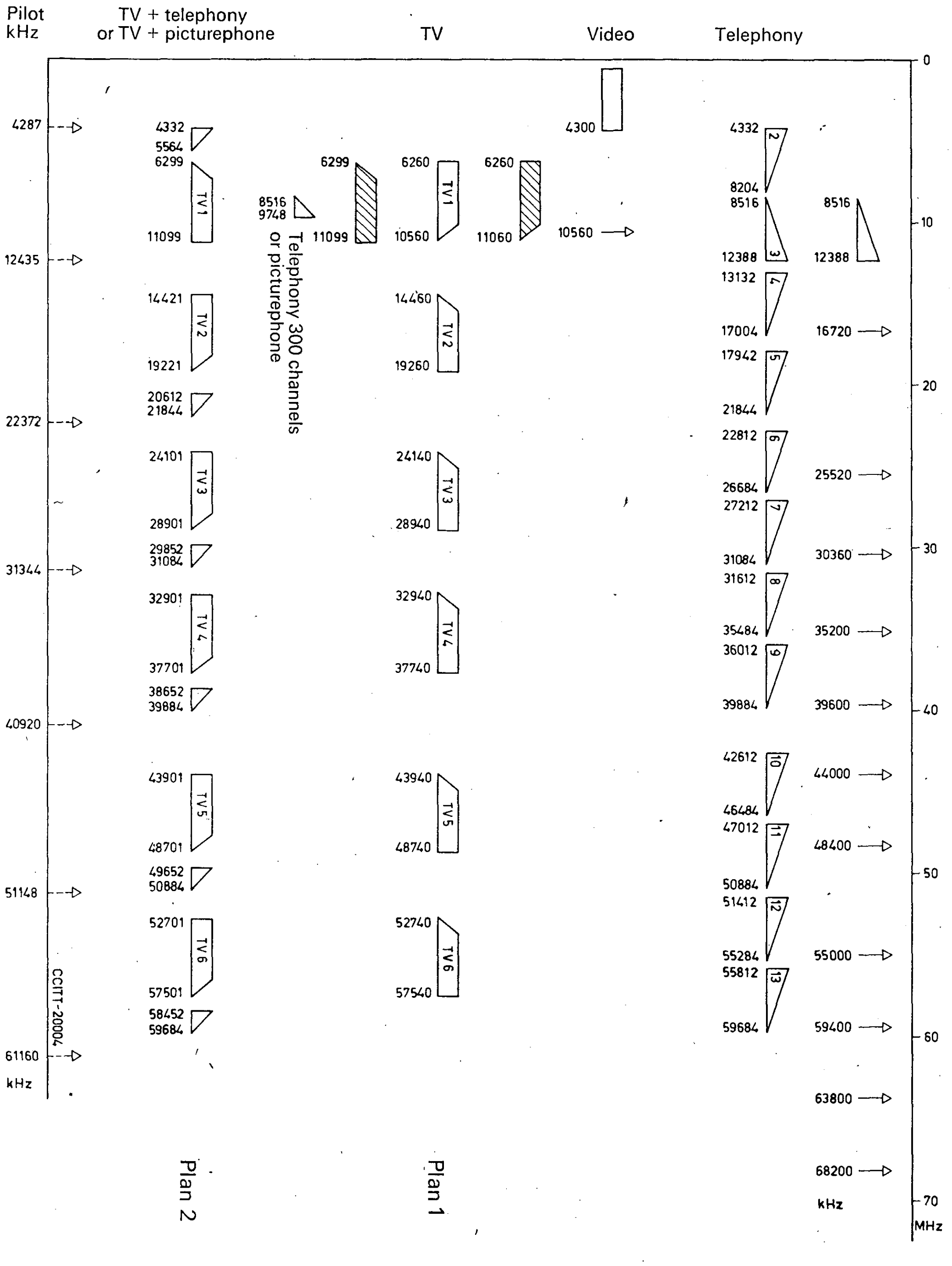

FIGURE 1. — **Allocation of line frequencies for simultaneous transmission of telephony and television on 60-MHz system**

Question 30/XV — Impedance matching in 12-MHz systems on 1.2/4.4-mm coaxial pairs

(continuation of Question 30/XV studied in 1964-1968)

According to Recommendation G.345, it would be desirable to fix a value of N equal to 63 dB throughout the transmitted frequency band, N being the magnitude defined in Recommendation G.332.e.

Is such a value feasible in the lower part of this band and, if not, what value should be recommended?

Question 31/XV — Submarine cable systems

(continuation of Question 31/XV studied in 1964-1968)

a) What types of submarine cable could be standardized by the C.C.I.T.T. for systems of different capacities not more than 2500 km long?

Note 1. — Such systems would permit the establishment of circuits made up entirely of submarine cables meeting the requirements of Recommendation G.152-A.

Note 2. — Administrations which are studying new types of submarine cable are requested so to advise the C.C.I.T.T. immediately in connection with this question, to facilitate international standardization. It is desirable, moreover, that these administrations should directly contact each other so that joint contributions to this question by several administrations may be furnished to the C.C.I.T.T.

Note 3. — Part a of this question concerns both cables which are to be laid in the normal way and the corresponding types of repair cable.

b) What capacities should be recommended for submarine cable systems providing more than eight supergroups?

Question 32/XV — Noise transmitted between interconnected systems

(of interest to Study Group IV)

(new question)

Considering

1. that large values of noise can arise in a signal band being transmitted by a chain of repeaters, due to a failure or malfunction in that chain, where the individual repeater gains are controlled by some system parameter;

2. that the noise may overload systems interconnected with the noisy system;

the following question should be studied:

What characteristics of transmission systems should be recommended to prevent noise or other interferences caused by failure or malfunction of one system from being passed on to interconnected systems?

Note. — Account should be taken of the following factors:

a) Both analogue and digital systems and combinations of both types (see Question 1/D, note e).

b) Indication or detection of failure or malfunction, e.g.:
   1) pilot failure;
   2) increase in long-term total power of transmission signal being monitored;
   3) increase in noise in a frequency band which is not used for the transmission of any signal;
   4) change in some other parameter whose value is indicative of system performance;
   5) some combination of the above four.

c) Number of channels to be monitored as a single broadband signal.

d) Action which the terminal or line equipment should take to control the amount of noise or interference passed on to the interconnected systems.

e) Provision of means of restoring the system to a normal condition after the trouble has been corrected.

f) Provision of trouble indications for use external to the transmission system.

Question 33/XV — Levels at the input and output of 12-channel terminal equipments

(new question)

Recommendation G.232 contains no specification regarding the levels of audio-frequencies at the input and output of 12-channel terminal equipment.

In the case of old equipment this lack of recommendation, together with the possibilities offered by tubes, led administrations to adopt a great variety of levels. To cover all cases manufacturers devised equipment with high receive output levels and low send input levels. This practice was carried over to the early transistor systems. It was then found, on one hand, that the resultant heat dissipation limits the miniaturization of equipment and, on the other, that the possibilities arising from the existence of high levels are put to use only in the rare cases of two-wire extension of circuit. Considering that present technique can solve this problem by other means, and considering the useless expense that systematic application of high output levels might entail:

a) Would it not be desirable to make recommendations on this subject for future equipment, which might possibly be extended to other equipment with similar input and output terminals?

b) If so, what range of values should be recommended for input and output terminals at audio-frequencies?

Note. — This question should be studied in liaison with Question 2/D.

Question 34/XV — Visual telephone service

(new question)

There is a growing interest in the possibility of operating a videophone[1] service in conjunction with existing telephone services. Administrations and other interested organ-

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[1] Videophone is used to describe a real-time picture service of less than a broadcast TV standard directly associated with telephone service; it is also referred to as picturephone or viewphone by some organizations.

izations are asked to provide information on any proposed plans or experimental work for such a service with a view to a study of the following:

a) Acceptable standards obtained by subjective measurement for a service providing:

1. head and shoulders picture;
2. picture of small meeting (say up to six people);
3. reproduction of graphics;
4. any other appropriate picture.

b) On the basis of the acceptable standards proposed in a, what characteristics should be recommended for the subscribers' videophone equipment?

Note. — These characteristics should include:

1) type of scan (horizontal or vertical);
2) number of scanning lines/frame;
3) line structure and method of interlacing (if any);
4) number of frames/second;
5) size of reproduced picture including aspect ratio;
6) picture/subject distance;
7) minimum reproduced picture brightness level;
8) minimum light level acceptable to camera;
9) synchronizing signal structure;
10) range of levels transmitted to and received from line;
11) signal spectrum.

c) What transmission standards should be recommended for international links in a videophone connection?

Note. — These should include:

1) whether transmission should be by analogue or digital methods;
2) definition of a hypothetical reference circuit;
3) transmission characteristics at the video frequencies to be recommended for the h.r.c., which should include the following:
   3.1 video channel response
      — frequency domain (amplitude/frequency and phase/frequency)
      — or time domain (echo rating, etc.)
   3.2 random noise — peak-to-peak signal/r.m.s. noise ratio
      — unweighted noise,
      — weighted noise;
   3.3 impulsive noise—number of pulses per unit time of given relative amplitude;
   3.4 single frequency interference;
   3.5 low frequency roll-off;
   3.6 power hum (peak-to-peak signal/r.m.s. noise ratio);
   3.7 worst disturber crosstalk ratio.

d) What Recommendations should be issued for switched videophone transmission in the international network?

Question 35/XV — Unification of the characteristics of telephone-type circuits used for transmission (telegraphy, facsimile, data, etc.)

(new question to be studied by the Joint Working Party LTG)

Recommendation H.12 mentions the characteristics of private telephone-type circuits of ordinary and special quality.

The Recommendations in Sections 2, 3 and 4 in Part 2 of Volume III specify circuit characteristics which sometimes are slightly different owing to the fact that in the past they were adopted by different study groups.

Is it possible to make all these characteristics uniform so that finally only one common series of values may be recommended?

Note. — The Secretariat of the C.C.I.T.T. will publish a contribution indicating the characteristics that it is advisable to try to make uniform in virtue of Questions 35/XV and 36/XV, bringing up to date the text published on pages 144 to 153 of document AP IV/62 (COM XV—No. 179 of 1964-1968).

Question 36/XV — Unification of certain characteristics of signals transmitted over telephone-type circuits

(new question to be studied by the Joint Working Party LTG)

The Recommendations in Sections 2, 3, 4 and 5 of Part 2 in Volume III mention different signal characteristics (levels, etc.).

Is it possible to introduce the maximum uniformity in these characteristics so that all services other than the telephone service respect the same standards? If so, what would these characteristics be?

Note. — See Note to Question 35/XV.

Question 37/XV — Interference at harmonics from the mains

(continuation of Question 37/XV studied in 1964-1968)

Signals transmitted by carrier systems are sometimes modulated by interfering signals from industrial-frequency power supplies.

Characterizing this interference as the level of the strongest unwanted side component observed when a sine wave is applied with a power of 1 mW at the point of zero relative level (0 dBm0) on a telephone circuit, and considering that —45 dBm0 has been recommended as the maximum admissible level of the strongest unwanted side component on a complete telephone-type circuit:

What provisions should be made in the equipment to ensure that —45 dBm0 is never exceeded?

Note 1. — The effect of the modulation process is that an input signal of frequency f Hz will produce, for example, corresponding output signals at frequencies f, $f \pm 50$, $f \pm 100$, $f \pm 150$ Hz, etc. Modulation involving subharmonics has also been observed in some countries. The effect can be aggravated when the transmission system passes through areas using different or asynchronous power-supply frequencies. One source of the trouble is inadequately-smoothed power supplies to the carrier frequency-generating equipment associated with frequency-division multiplex systems.

Note 2. — To begin study of this question, it will be assumed that the value indicated (—45 dBm0) is to be observed on an 830-km circuit corresponding to a third of the hypothetical reference circuit.

The composition of the interference from the various equipments operated on this 830-km circuit will be studied and an attempt will be made to determine a permissible maximum value for each of them.

In the light of the result of this study and in particular of the technical or economic difficulty of observing the clauses in the case of individual equipments, it will be seen whether the value —45 dBm0 can be set for longer circuits (e.g. 2500 km).

Note 3. — Annex 1 summarizes the work carried out on this subject by the Working Party on the "Use of lines for telegraphy" in 1964-1968. Annex 2 reproduces a recent contribution made by the United Kingdom.

ANNEX 1

(to Question 37/XV)

Summary of the work of the Joint Working Party LTG

During the 1964-1968 period the Joint Working Party LTG (Use of lines for telegraphy) prepared the following reply, approved by Study Group XV, to Question 37/XV:

1. With regard to the maximum admissible level of the strongest unwanted side component, when a sine wave is applied at 0 dBm0 level, a limit of —45 dBm0 (—52 dNm0) could be acceptable for circuits for FM and AM VF telegraphy, facsimile transmission, speech, telephone signalling and data transmission.

With regard to sound-programme circuits, the same limit has been accepted by the C.M.T.T. (documents CMTT/114 and CMTT/118).

2. The main causes of interference due to power sources are:

a) residual ripples at the terminals of d.c. supply which are directly transmitted to equipments through the power-fed circuits;

b) the a.c. to the dependent power-fed stations in some systems, which interferes through the power-separating filter or through the iron tapes of coaxial pairs;

c) the induction voltages in the d.c. supply line to power-fed dependent stations in some systems;

d) the amplitude and phase unwanted modulations of the various carriers due to cause a which are increased in the frequency-multiplying equipments.

3. It is very difficult to specify the performance of individual items in terms that will ensure that a derived circuit meets a specific limit, such as: —45 dBm0 or —5.2 Nm0.
The following information in contributions received during this period may be useful for the remainder of this study.

Federal Republic of Germany

As a result of its studies to subdivide this overall limit among individual sources of hum modulation, the Federal Republic of Germany proposes an admissible value of 58 dB for the degree of hum phase modulation of the highest carrier frequency produced in any carrier-generating equipment.

American Telephone and Telegraph Company

The A. T. & T. uses as an overall objective for interfering hum modulation a *ratio* of 30 dB between the desired signal and the most significant interfering f.m. hum modulation sideband. This value will provide satisfactory performance for A. T. & T. voice, voice-band data, and 150 words/minute multichannel v.f. carrier telegraph services. For the latter, a 30-dB ratio may be expected to provide between 5% and 10% overall telegraph distortion.

On the basis of this overall objective of 30 dB, an objective value of 36 dB has been allocated statistically to *each* of the several transmitting-receiving multiplex terminal pairs in a complex connection 4000 miles long.

However, transmitting-receiving pairs of vacuum tube multiplex terminal equipment (LMX-1) provide a performance of 50 dB in the highest frequency carrier channel. Modifications are being made to all of our modern transistorized terminals (LMX-Z) by adding d.c./d.c. converters to all the battery feeds to carrier supplies, to achieve at least the same ratio of 50 dB, per transmitting-receiving terminal pairs, between the desired signal and the most significant hum modulation sideband in the highest frequency carrier channel.

United Kingdom

(See Annex 2.)

ANNEX 2

(to Question 37/XV)

Contribution by the United Kingdom Administration

1. In modern frequency translating equipments modulation of the signal at 50 Hz (or harmonics of 50 Hz) originates from two sources. These are:

a) impurity of carrier supply: the presence of signals of $f_c + 50$ Hz etc. (where f_c is the carrier frequency) in the carrier supply to the modulators, and

b) inadequate power supply decoupling: the presence of 50 Hz and its harmonics in the d.c power supply to active devices due to inadequate decoupling.

2. *Purity of carrier supply*

The U.K. Administration specifies for its carrier-generating equipments that in the carrier supply feeds to modulators/demodulators the level of spurious signals such as $f_c \pm 50$ Hz shall be 53 dB or more below the level of the carrier supply signal. This ensures that at the output of any modulator such spurious signals will be at least 58 dB below the wanted sideband signal.

In the 830-km hypothetical reference circuit (h.r.c.) there are 12 stages of modulation. Since each could thus contribute a level of −58 dBm0 the total contribution from this source might be −47 dBm0.

3. *Inadequate d.c. power supply decoupling*

The U.K. Administration requirements on decoupling are such that any spurious signals will be restricted to levels not exceeding those indicated in Table 1 (column 2). The addition of the contributions due to carrier supply impurities could result in the maximum levels shown in Table 1 (column 3).

Table 1 shows also the number of the different equipment types appearing in the 830-km h.r.c.

4. The addition of the contributions from the various sources gives an overall figure for an 830-km h.r.c. of −45 dBm0.

It should be noted that these figures are for the most susceptible equipment operating under the most adverse conditions with maximum impurity of carrier signal supply and of d.c. power supply. It is considered unlikely that this combination is likely to occur in practice.

TABLE 1

(1)	(2)	(3)	(4)	(5)
Equipment	Maximum level of spurious signal per equipment (transmission + receive)		Effective number of equipments in 830-km h.r.c.	Total contribution from each type of equipment
	Due to inadequate decoupling (dBm0)	Due to all sources (dBm0)		(dBm0)
Channel translating	−50	−48.8	1	−48.8
Group translating	−60	−53.8	2	−50.8
Supergroup translating	−80	−55	3	−50
Through supergroup filter	−80	−80	1	−80
Through group filter	−80	−80	1	−80

5. It is concluded therefore that the following limits might be applied for each of the equipments (transmit+receive) indicated:

Equipment type	*Maximum level of the strongest unwanted side component (dBm0)*
Channel translating	—50
Group translating	—55
Supergroup translating	—55
Through group filters	—80
Through supergroup filters	—80

Question 38/XV — Characteristics of wideband group or supergroup circuits for the transmission of wide-spectrum signals

(new question to be studied by the Joint Working Party LTG)

Recommendations H.14 and H.15 contain some provisional characteristics of group or supergroup wideband circuits, for the transmission of wide-spectrum signals (data, etc.).

What characteristics should be specified for these circuits, and what values should be recommended for these characteristics?

Question 39/XV — Characteristics of wide-spectrum signals to be transmitted over wideband group or supergroup circuits

(new question to be studied by the Joint Working Party LTG)

Recommendations H.52 and H.53 mention provisional characteristics for such signals. These Recommendations should be confirmed or amended and supplemented.

Question 40/XV — Definition of the reliability of a system

(new question) [1]

How may the reliability of a transmission system be defined?

Note. — Study of this question should take note of the following:

a) the reliability definition should be readily applicable to all types of transmission systems (radio-relay systems, cable systems, etc.);

b) means of measuring system reliability and describing the results are required;

c) means of combining the individual reliabilities of systems operating in tandem to provide an overall reliability for the combination are required.

Question 41/XV — Reliability objectives for different services

(new question) [1]

What reliability objectives are appropriate for the different types of services—telephony, data, etc.—carried over international connections?

Question 42/XV — Reliability of transmission systems

(new question) [1]

How may reliability objectives be best achieved for transmission systems of various types—radio-relay, cable, etc.?

Note. — Study of this question should take note of the following:

a) System design factors—repeater spacing, fading margins, etc.

b) Emergency provisions—standby power arrangements, automatic line switching, provision of spare transmission lines, etc.

Question 43/XV — Reliability of system components

(new question) [1]

a) How may the reliability of system components—amplifiers, regulators, etc.—be defined and measured?

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[1] In the study of these questions, account will be taken of the general studies on the definition of reliability and on certain fundamental principles which were entrusted to the Joint Special Study Group C (Question 12/C).

b) How can these reliability figures be combined to arrive at an overall reliability for numbers of amplifiers, regulators, etc. ?

Question 44/XV — Reliability of components

(new question) [1]

a) How may the reliability of active and passive components (transistors, capacitors, resistors, etc.) be defined and measured ?

b) How can these reliability figures be combined to arrive at an overall reliability figure for devices using a number of these components such as amplifiers, regulators, etc. ?

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[1] See footnote on the preceding page.

Summary of questions assigned to Study Group XV during the period 1968-1972

Question No.	Short title	Remarks
1/XV	Characteristics of circuits for high-quality monophonic programme transmissions	
2/XV	Characteristics to be met by pairs of circuits providing stereophonic programme transmissions	
3/XV	Relative gain of international telephone circuits outside the 300-3400-Hz band	Of concern to S.G. IV, XI and XVI
4/XV	Standardization of different types of programme circuits	S.G. III and IV to be kept informed
5/XV	Compandors for telephony	
6/XV	Programme circuits set up on group or supergroup links	Of concern to Sp. S.G. C.
7/XV	Compandors for programme transmissions	
8/XV	Interconnection of sound-programme circuits in the basic group	
9/XV	Improvement of signal-to-crosstalk ratio between the two directions of transmission	
10/XV	Fuller specification of echo suppressors; new methods of controlling echo	
11/XV	Protection of the group and supergroup reference pilots against wide-spectrum signals; regulators associated with these pilots	
12/XV	Protection of group and supergroup pilots in various cases of through-connection	
13/XV	Suppression of line-regulating pilots	
14/XV	Carrier leak in modulating equipments	
15/XV	Line regulators, group regulators, etc.	
16/XV	Through group and supergroup connection equipment	To be studied first by S.G. IV
17/XV	Overhead lines for carrier systems	(Question Africa K.1) Rapporteur, Mr. Bashir
18/XV	Cable systems with a small number of channels	(Questions Africa K.2 and Asia 8)
19/XV	Crosstalk in programme transmissions in the case of through connections of groups, etc.	

Question No.	Short title	Remarks
20/XV	Over 2700 channels on 2.6/9.5-mm coaxial pairs	
21/XV	Over 2700 channels on new type cables	
22/XV	Impedance and levels at group and supergroup distribution frames	
23/XV	Extension of former Recommendation G.335 to transistorized systems	
24/XV	Characteristics of systems for short and medium distances	In conjunction with S.G. XVI (Question 6/XVI)
25/XV	Intelligible crosstalk caused by intermodulation with the line pilot	
26/XV	Dynamic stability of regulation	
27/XV	Terminology for carrier systems	In collaboration with S.G. IV (Question 4/IV)
28/XV	Television on 1.2/4.4-mm coaxial pairs	
29/XV	Television transmission on the 60-MHz systems	
30/XV	Impedance matching in 12-MHz systems on 1.2/4.4-mm coaxial pairs.	
31/XV	Submarine cable systems	
32/XV	Noise transmitted between interconnected systems	
33/XV	Levels at the input and output of 12-channel terminal equipments	
34/XV	Visual telephone service	
35/XV	Unification of the characteristics of telephone-type circuits used for telegraph, facsimile, data, etc. transmission	To be studied with Joint Working Party LTG
36/XV	Unification of certain characteristics of signals transmitted over telephone-type circuits	To be studied by Joint Working Party LTG
37/XV	Interference at harmonics from the mains	
38/XV	Characteristics of group and supergroup links for wideband signal transmission	To be studied by Joint Working Party LTG
39/XV	Characteristics of wideband signals transmitted on group or supergroup links	To be studied by Joint Working Party LTG
40/XV	Definition of the reliability of a system	[1]
41/XV	Reliability objectives for different services	[1]

Question No.	Short title	Remarks
42/XV	Reliability of transmission systems	[1]
43/XV	Reliability of system components	[1]
44/XV	Reliability of components	[1]

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[1] In the study of these questions, account will be taken of the general studies on the definition of reliability and certain fundamental principles which have been assigned to Special Joint Study Group C (Question 12/C).

Questions on telephone circuits, assigned to Study Group XVI

Question 1/XVI — Circuits of the switched network

(continuation of Question 1/XVI studied in 1964-1968)

What transmission characteristics should be recommended for the telephone-type circuits which may be part of switched connections set up in the public international network, in accordance with the C.C.I.T.T. transmission plan?

Note. — For further study of Question 1/XVI the points listed in Annex 1 should be considered in particular.

ANNEX 1

(to Question 1/XVI)

Points for study within the framework of Question 1/XVI and points studied by other Study Groups which are of interest to Study Group XVI

I. POINTS FOR STUDY BY STUDY GROUP XVI

1. *Definition of reference connections*

(review of Recommendation G.110)[1].

2. *Use of echo suppressors*

(review of Recommendation G.131, in the light of Recommendation G.161, — see also Annex 2, which is also submitted to Study Group XI).

3. *Balance return losses in national networks*

(one aspect of this study is the subject of Question 19/XII).

4. In which cases can the use of *terminating sets incorporating non-linear components* be recommended?

See Annex 3. In the study of this point, account should be taken of the results of the tests which the C.C.I.T.T. Laboratory was requested to perform, and of the study to be effected by Study Group XII under Question 19/XII.

5. *Transmission characteristics for an international automatic exchange*

(This is the study mentioned in Recommendation G.142 which will concern the new text for Recommendation Q.45 in Volume VI of the *White Book.*)

6. *Restriction on system loading,* allowance being made for the minimum sending reference equivalent (point 22).

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[1] The references to C.C.I.T.T. Recommendations apply to the texts in Volume III of the *White Book* (Mar del Plata, 1968).

Measurements of the power of signals transmitted over telephone circuits can be carried out for various reasons, for example:

- — to find out the effective load of wideband systems—this involves determining the long-term mean and the dispersion of the power *per channel*;
- — to find out the power (mean and dispersion) *per call*, for example to try to establish a relationship between this power and the reference equivalent at the transmitting end.

The first of these aims should be tackled by Joint Special Study Group C (Question 11/c) on behalf of Study Group XV; the second mainly concerns Study Group XII (Question 10/XII).

Study Group XVI should make use of the conclusions of these two other Study Groups (Special Study Group C and Study Group XII) in establishing or improving the transmission plan.

At the meeting of Study Group XVI at Mar del Plata in October 1968, Mr. Toutan called a meeting of delegates who intended to effect measurements with a view to replying to Question 11/C, in order to establish a programme and calendar for these measurements by agreement between the administrations interested. Administrations have been informed of the results of this meeting by a circular from the Director of the C.C.I.T.T.

7. *Use of laboratory assembly* representing an intercontinental connection.

This assembly was set up in the C.C.I.T.T. laboratory in accordance with the instructions issued by Study Group XII.

8. *Carrier systems for very short distances*

(re-examination of Recommendation G.125, with a view to obtaining more precise values; to be studied in conjunction with Questions 24/XV and 6/XVI).

9. *Transmission tests with signalling system No. 6*

What facilities should be afforded by signalling system No. 6 to help ensure satisfactory transmission quality on switched connections in the international network?

II. Points studied by other Study Groups which are of interest to Study Group XVI

21. *National reference equivalents*

(subject of Question 1/XII).

22. *Minimum reference equivalent* of a national sending system

(subject of Question 1/XII, part c); to be studied in conjunction with point 6 and Question 10/XII).

23. *Results of the measurement programme* to ascertain the actual transmission performance of switched *connections.*

(an analysis of the measurements carried out in 1967 is to be found in the Annex to Question 4/XVI. Other measurements will be carried out in 1968-1972 as part of the work on Question 21/IV).

24. The cumulative effect of the *go-to-return crosstalk* introduced by exchanges and circuits in a world-wide connection (covered by Question 9/XV).

25. *Intelligible crosstalk between different circuits*

(forms the subject of Question 11/XII).

26. Incorporation of *p.c.m. circuits* in the present telephone network.

(forms the subject of Question 12/D; the results of this study will be communicated to Study Group XVI).

ANNEX 2

(to Question 1/XVI)

Systematic study of conditions governing the insertion of echo suppressors and the conclusions to be drawn as regards their location

(Contribution of the Administration of the Federal Republic of Germany, May 1967, COM XI—No. 120)

1. *Introduction*

Within the framework of C.C.I.T.T. Questions 5/XI (period 1960-1964) and 2/XI (period 1964-1968) the discussions have hitherto mainly been confined to the use of echo suppressors for the *complete* international telephone connection. However, no specifications have as yet been drawn up for the control of echo suppressors when interconnecting long continental and/or intercontinental circuits each of which requires an echo suppressor in any case.

The present considerations aim at the standardization of the requirements to be met by a new signalling system with regard to the control of echo suppressors. In this connection allowance has to be made for the possibilities to be introduced by the new routing plan and in part also for the conditions existing on the national sections.

In this contribution an attempt is made to give a systematic and complete survey of the arrangement of circuits in international telephone connections, which are of interest with regard to the insertion of echo suppressors, and of the possible location of echo suppressors. Based on the above, the necessity and the possibilities of using echo suppressors are investigated. Moreover, it is tried to specify principles for a general practice in the light of the "Ideal Rules" A to D laid down in Recommendation G.131.

2. *Possible combinations of circuits*

As far as the insertion of echo suppressors is concerned, an international connection may comprise two types of circuits:

a) circuits which, when considered on their own, would not require an echo suppressor. They will normally not be equipped with echo suppressors;

b) circuits which by virtue of their transmission characteristics would require an echo suppressor.

TASI as well as satellite circuits fall into the latter group. Because of the limited delay on international connections, satellite circuits must always be identifiable. For TASI circuits, such an identification is required only if, because of the signalling system, special attention must be paid to their characteristics, otherwise they could be considered as normal circuits of this group.

For the four-wire circuits to be used in international connections, the propagation time is the essential distinguishing feature between the two groups.

The following combinations of circuits are possible in the establishment of international transit connections:

2.1 The connection consists solely of circuits which do not require echo suppressors. The overall propagation time of the four-wire chain necessitates, however, the use of an echo suppressor.

2.2 In addition to circuits requiring no echo suppressor, the connection comprises at least one circuit necessitating the use of echo suppressors. The circuits can be arranged in the following ways:

2.2.a) a circuit requiring no echo suppressor at the outgoing end;

2.2.b) a circuit requiring no echo suppressor at the incoming end;

2.2.c) circuits requiring no echo suppressors at both ends of a connection requiring echo suppressors;

2.2.d) a circuit requiring an echo suppressor at the outgoing end;

2.2.e) a circuit requiring an echo suppressor at the incoming end.

2.3 The connection comprises solely circuits requiring echo suppressors.

3. *Location of active echo suppressors*

According to the number and type of the individual circuits of an international connection active echo suppressors may be fitted at the following exchanges:

3.1 *At the outgoing end*

3.1.a) *at the outgoing international exchange.* This applies on condition that the propagation time of the preceding national sections does not exceed a permissible limit which has still to be fixed (according to contribution COM XV—No. 93, page 11, echo suppressors of recent design allow end delays up to 25 ms);

3.1.b) *at an outgoing national exchange,* provided the echo delay on the national sections preceding this exchange exceeds the permissible limit;

3.1.c) *at an international transit centre,* if available echo suppressors shall also be used for the country of origin and the echo delay on the preceding sections is short enough.

3.2 *At the incoming end*

3.2.a) *at the incoming international exchange,* provided the propagation time on the following national sections does not exceed a permissible limit;

3.2.b) *at an incoming national exchange,* if the echo delay on the national sections following the incoming international exchange exceeds the permissible limit;

3.2.c) *at an international transit centre,* if available echo suppressors shall also be used for the incoming country and the end delay is short enough.

4. *Control information for the operation of echo suppressors*

For each connection it is necessary to know which of the arrangements listed in sections 2 and 3 above applies. Dependent on the particular arrangement, the incoming and outgoing exchanges as well as the transit exchanges must obtain sufficient information enabling them to control the echo suppressors in accordance with Rules A to D or E to K of Recommendation G.131. In forming this control information a number of factors have to be considered. Moreover, it depends upon the particular arrangement, i.e. upon the type and arrangement of the circuits and the location of the echo suppressors.

The required control information is considered below according to the location of the echo suppressors.

4.1 *Outgoing international exchange*

4.1.1 The outgoing circuit does not require any echo suppressors. The decision to provide an echo suppressor can be derived from:

4.1.1.a) the country code of the incoming country;

4.1.1.b) the country code of the incoming country and, in the case of large incoming countries, the following national digits;

4.1.1.c) the information listed in 4.1.1.a or 4.1.1.b in which case the desired direction is also considered if, for instance, the direct route does not require echo suppressors, but alternate routes necessitate their insertion;

4.1.1.d) by backward information of the international route passed (identity of the international transit centre, number of transit exchanges, propagation-time properties of the chain of circuits, satellite circuits, etc.), when echo suppressors are required while setting up the connection. In this case the proposal laid down in item a) 2 of Annex 1 to Question 2/XI (*Blue Book*, Volume VI, p. 289) does not apply.

The routing in international transit centres may require the subsequent insertion of an echo suppressor at the outgoing exchange, which proves to be difficult with conventional switching equipment. However, it would also be possible to permanently fit the circuits with echo suppressors and to activate them, if required. A decision in favour of one of these possibilities must be made according to local conditions.

4.1.2 The outgoing circuit requires an echo suppressor. The outgoing exchange does not need any further information to activate the echo suppressor. However, an echo suppressor will certainly also be necessary at the incoming end (see 3.2). Corresponding information must be given by the outgoing exchange and must reach the possible points of insertion in the international part of the connection (see 3.2.a, 3.2.c).

4.1.3 If the outgoing national section is so long that an echo suppressor has already been inserted on it, the outgoing international exchange must operate in the same way as an international transit centre (see 4.2) and by means of forward information it has to indicate that an echo suppressor is required on the incoming side of the connection.

4.2 *International transit centre*

An international transit centre should never activate echo suppressors, even if the circuits switched in tandem require an echo suppressor. The control information is passed on in both directions.

There are the following exceptions to this rule:

4.2.1 The international transit centre has to insert the echo suppressor for the immediately preceding outgoing international exchange. For this purpose the transit exchange must be able to recognize clearly that the call actually originated there and was not only through-connected.

The required information can be derived from:

4.2.1.a) a special signal sent by the outgoing exchange;

4.2.1.b) a group identification, if a particular group is used only for connections of this type;

4.2.1.c) an identification of the outgoing exchange, which would then, however, be necessary for any connection between the two exchanges concerned.

The decision to provide echo suppressors could then be made with the aid of one of the criteria according to 4.1.1.a to 4.1.1.d. Information corresponding to the relevant decision must then be transmitted to the points of insertion in the international part of the connection on the incoming side (3.2.a and 3.2.c).

4.2.2 The international transit centre must insert an echo suppressor for the immediately following international exchange. Here the insertion of echo suppressors can be controlled by simultaneous evaluation of the routing information and the general decision governing the insertion of echo suppressors (echo suppressor yes/no).

4.2.3 The functions of international transit centres are described in Recommendation Q.115 of the *Blue Book*. If more than one international transit centre avails itself of the facilities specified under b)i to b)iii of the above Recommendation, it is very likely that the number of echo suppressors permissible according to Rule K of Recommendation G.131 is exceeded. In its present form Recommendation Q.115 is inconsistent with Rule K and might therefore need a revision.

When applying Rule F of Recommendation G.131 together with the routing plan, there may be another international transit exchange between an outgoing international exchange and the international transit exchange responsible for the insertion of echo suppressors. This case should be excluded, since forming part of the necessary information according to 4.2.1.a to 4.2.1.c is rendered more difficult and ultimately it follows that such international transit centres must determine the origin of each call. Hence, we started from the assumption that instead of the incoming or outgoing international exchange only the international transit centre immediately following or preceding the incoming exchange should be responsible for the insertion of echo suppressors. The same assumption has been made in contribution COM XI—No. 100 when considering the "bis" systems ("next CT").

4.3 *Incoming international exchange*

4.3.1 The last circuit of a connection does not require an echo suppressor. The incoming exchange can determine the need for the insertion of an echo suppressor:

4.3.1.a) from particular signals transmitted in the forward direction (information about the propagation time, type of circuits, etc.);

4.3.1.b) by inviting the sending of a signal indicating the origin and by evaluating it;

4.3.1.c) by inviting the sending of the route control information and by evaluating it.

4.3.2 The last circuit of a connection requires an echo suppressor. In this case, an echo suppressor must either be inserted in the circuit or it is already included in it. It has to be ascertained whether a corresponding signal must be sent in the backward direction, if an invitation to insert an echo suppressor has not already been received in the forward direction. This applies particularly when the incoming national section requires an echo suppressor which is to be inserted in the incoming international exchange.

4.3.3 If an echo suppressor is included in the following national section, the international incoming exchange must proceed like an ordinary international transit centre.

4.4 The evaluation of the propagation times on the individual circuits provides an exact and comparatively simple means to determine the need for echo suppressors. The information about the control of echo suppressors obtained as described above can be made available to all exchanges taking part in the establishment of the connection by sending relevant signals in the forward and backward directions. Similar proposals have been made in various documents.

In this connection it must be borne in mind that even a chain of circuits as specified in paragraph 2.1 may require echo suppressors. By means of the information about the propagation time it can be determined whether or not an echo suppressor is required. For instance, the following scheme may be used for this purpose:

Propagation time	Category	Decision to insert an echo suppressor
Less than 10 ms	I	No
From 10 to 25 ms	II	No
Equal to or above 25 ms [a]	III	Yes
More than 250 ms (satellite)	IV	Yes

[a] And TASI circuits if no special TASI identification is required.

Category IV does not allow the inclusion of a (further) satellite circuit. Purely terrestrial connections do not fall into this category.

The above categories can be added according to the following scheme:

I + I = II
I + II = III
II + II = III
III + ...[1] = III
III + IV = IV
IV + ...[1] = IV

It may be possible to find more appropriate times for the above propagation time categories. This method would allow the decision about the insertion of echo suppressors to be more closely adapted to practical requirements, even if a connection comprises only circuits which do not require echo suppressors.

The rule drawn up in contribution COM XI—No. 100, page 74 (item 2.1.1.1.a) does not cover this case and does not prevent connections with inadmissible echoes.

5. *Conclusions*

When applying Rules A to E of Recommendation G.131 and making allowance for the new routing plan as well as for long national sections, the following essential features are obtained for the operation of echo suppressors on international telephone connections.

During the establishment of a connection or at the latest after its completion it must be determined whether or not echo suppressors are required. This can easily be done by assessing the added propagation times of the individual sections.

The places at which echo suppressors must be inserted can be determined by an exchange of special information for the control of echo suppressors between the international exchanges of a connection and by logic decision. This results in a greater flexibility in the application of future methods for the insertion and operation of echo suppressors.

The possibility of inserting an echo suppressor as required or of activating and disabling a permanently associated echo suppressor is necessary in order to keep the number of active echo suppressors on a connection as small as possible.

ANNEX 3

(to Question 1/XVI)

Improvement in balance return loss by the use of terminating sets using non-linear elements

(Contribution by the Austrian Administration to the study of point 4)

Since 1958, the Austrian Administration has been using in its automatic long-distance network terminating sets with non-linear elements which proved very successful. Figure 1 shows a simplified drawing of the arrangement of this terminating set. The operation of the set has been described in detail in the *Red Book,* Volume V *bis,* pages 328-337.

A very high return channel loss (i.e. the composite loss measured between the incoming four-wire side and the outgoing four-wire side of the terminating set) and, consequently, a very low reflux can be achieved by using an ohmic resistance by way of balance. The measurements effected in the national network, with the two-wire end of the terminating set being terminated as in the case of actual service, gave return channel losses of 4 to 6 Np (35 to 52 dB) at a sending power level of —2 Np (—17.3 dB). The indication of the sending power level is necessary, since, as a result of the non-linear elements, the return channel loss depends on the sending power level.

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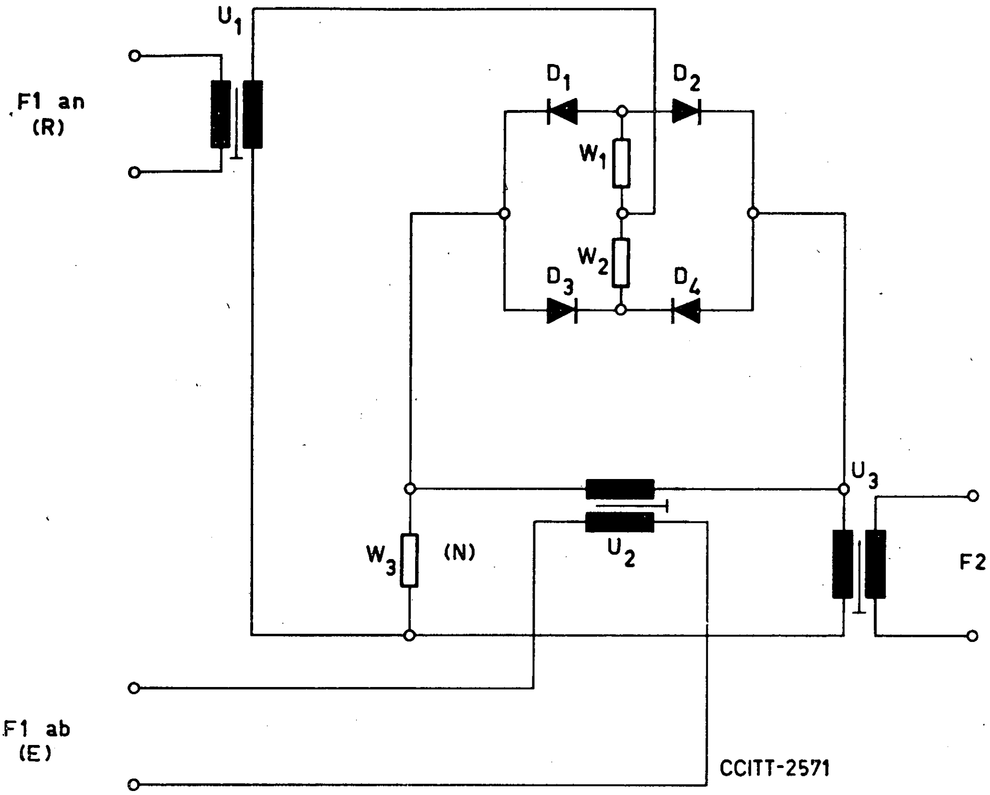
[1] All categories other than IV ; IV + IV = inadmissible route



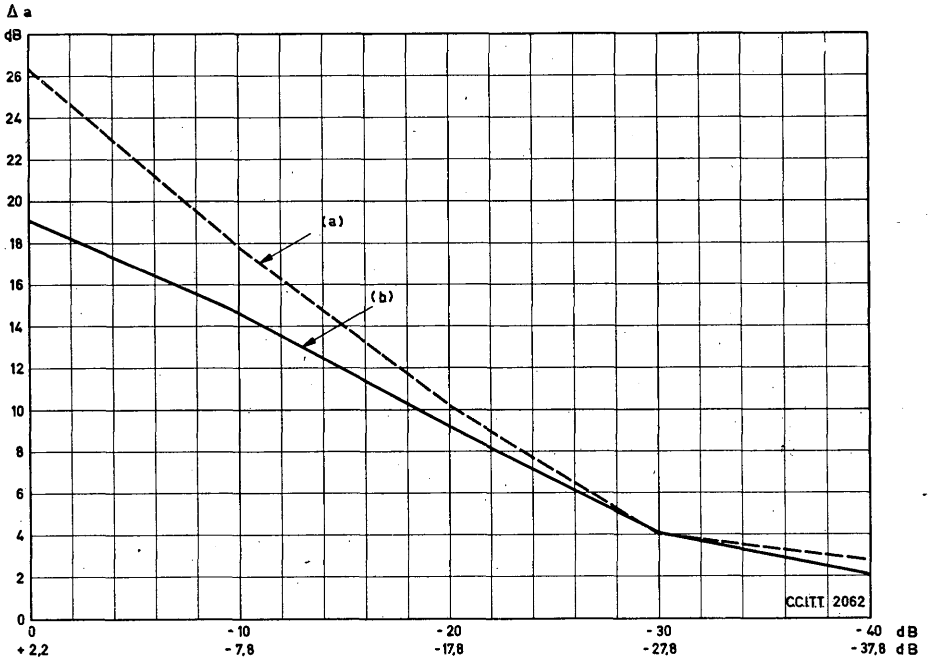
D_1, D_2, D_3, D_4 = diodes
W_1, W_2, W_3, (N) = pure resistances (W_3—balancer resistance)
U_1, U_2, U_3 = transformer
$F1$ an (R) = "four-wire input circuit" transmission path
$F1$ ab (E) = "four-wire output circuit" transmission path
$F2$ (L) = two-wire (input or output) transmission path

FIGURE 1. — **Terminating set using non-linear elements**

The C.C.I.T.T. Laboratory has carried out extensive measurements on the terminating set provided by the Austrian Administration. Within the framework of these tests, the terminating set in question has been compared with the conventional terminating sets. These comparative measurements have revealed a definite superiority of the terminating sets using non-linear elements as far as the return channel loss is concerned (see Figure 2). In making this comparison, account has been taken of the fact that the terminating set loss in the case of the Austrian terminating set amounts to 1 Np (8.7 dB). Further measurement results have been laid down in the Technical Report No. 354 of the C.C.I.T.T. Laboratory, COM XVI—No. 93 (COM XII—No. 112 of 1964-1968).

Conditioned by the non-linear elements in the terminating set, non-linearity distortions may arise when signals arrive simultaneously from both directions of transmission. It is impossible to transmit signals in both directions (duplex) without fault. This is no drawback for two-way telephone connections. Unfavourable effects are discernible, however, in data transmissions by duplex over the automatic telephone network.

The Appendix shows the electrical specifications of the Austrian terminating sets. Manufacturers must meet these specifications within the limits of tolerance indicated.



(a) Two-wire terminals of terminating set open circuited

(b) Two-wire terminals of terminating set connected to a local system (measured values for eight typical systems)

FIGURE 2. — **Average increase of insertion loss of return channel R/E in comparison with that for a conventional terminating set as a function of voltage level applied at the receiving terminals of terminating set for different terminations of the two-wire terminals of terminating set**

$\Delta a = (a' - 2g) - a$
a' = insertion loss of return channel R/E of a terminating set with non-linear elements
a = insertion loss of return channel R/E of a conventional terminating set
g = the difference between the insertion loss of a terminating set with non-linear elements and a conventional terminating set ($g = 5.7$ dB)

APPENDIX (to Annex 3)

Electrical specification of terminating sets using non-linear elements

Terminating set loss (a_G)

The terminating set loss for the two directions of transmission on the "$F1$ an $- F2$" side and the "$F2$ $-$ $F1$ ab" side (see Figure 1) for frequency 800 Hz is:

$$a_G = 1.0 \pm 0.05 \text{ Np } (8.7 \pm 0.43 \text{ dB})$$

In the 300-3400 Hz transmission band, the attenuation distortion, referred to a value measured at 800 Hz, should be:

$$\Delta a_G \leqq \pm 0.06 \text{ Np } (\pm 0.52 \text{ dB})$$

The losses are valid for a universal termination of the terminating set at 600 (real) ohms and for an output power level of 0 to -2 Np (0 to -17.4 dB).

Matching

The input and output impedances of the terminating set (on the "*F*2, *F*1 an and *F*1 ab" side) in the transmission band 300-3400 Hz should be 600 (real) ohms if possible. The following deviations are admitted:

TABLE 1

Side measured	Admissible deviation relative to 600 (real) ohms		Termination of 600 (real) ohms on the side
	Reflection coefficient $\lvert p \rvert = \left\lvert \frac{W - 600}{W + 600} \right\rvert$	Balance return loss $a_F = \ln \frac{1}{\lvert p \rvert}$ in Np ($a_F = 20 \log_{10} \frac{1}{\lvert p \rvert}$ in dB)	
*F*1 an	≦ 0.10	≧ 2.3 (20.0)	*F*1 ab, *F*2
*F*1 ab	≦ 0.10	≧ 2.3 (20.0)	*F* 1 an, *F*2
*F*2	≦ 0.10	≧ 2.3 (20.0)	*F*1 an, *F*2 ab
	≦ 0.15 only at 300 Hz	≧ 1.8 (15.6) only at 300 Hz	

Return channel loss (a_{GU})

The composite loss measured between the two transmission channels on the "*F*1 an" side and the "*F*2 ab" side is the return channel loss (a_{GU}). In the 300-3400 Hz transmission band, the respective values should not be less than the following minimum values.

TABLE 2

Termination *F*2 side	Sending power level in Np (dB)	Return channel loss in Np (dB)
600 Ω ± 1%	+ 1 to 0 (+ 8.7 to 0)	≧ 6.0 (52.1)
VI 1 to VI 3 disconnected	−2 (−17.4)	≧ 5.0 (43.4)
Open	+ 1 to 0 (+ 8.7 to 0)	≧ 3.5 (30.4)
VI 1 to VI 3 disconnected	−2 (−17.4)	≧ 2.8 (24.3)

Harmonic distortion coefficient (*K*)

In the direction of transmission "*F*1 an — *F*2", the harmonic distortion coefficient should be $K \leqq 2.0\%$ in the 300-3400 Hz frequency range, assuming a transmitting power level of +1 Np to −2 Np (+8.7 to −17.4 dB). For the direction "*F*2 — *F*1 ab" this value should not exceed 2.5%.

Variations with temperature

In the temperature range +10° to +30° C, the above-mentioned specifications should be respected. Only the harmonic distortion coefficient may rise, in both directions of transmission, to a maximum of 3% when the ambient temperature exceeds +25 °C.

Question 2/XVI — Characteristics of leased circuits

(new question)

What transmission characteristics should be recommended for leased international telephone-type circuits?

Consideration should be given to the following points:

1. preparation of a transmission plan for private telephony (which could apply the principles already adopted for public switched telephony, but which alternatively might be based on a thoroughly four-wire network);
2. point-to-point circuits;
3. multipoint circuits;
4. switched circuits;
5. a transmission reference point;
6. circuits used alternatively for other services, such as data and facsimile;
7. circuits used for several services simultaneously;
8. interconnection of private and public networks;
9. transmission characteristics imposed by telephone signalling systems (e.g. signalling for fully automatic or for manual operation).

Note. — Account should be taken of Recommendations M.101 to M.113 (*White Book*, Volume IV).

Question 3/XVI — Circuits on communication-satellite systems

(continuation of Question 3/XVI studied in 1964-1968)

(to be studied in conjunction with Question 6/XII)

What transmission recommendations should be made to enable satellite communication circuits to be successfully employed in the existing and future world telephone network?

Note. — The Annex below contains the reply given by Study Group XVI to this question in 1968.

ANNEX

(to Question 3/XVI)

Reply by Study Group XVI to Question 3/XVI in 1968

Only high-altitude satellite communication systems have been studied so far and all that follows is applicable only to such systems.

Study Group XVI reaffirms, with certain modifications, the principles set forth in its previous reply (COM XVI—No. 37, 1964-1968, page 7), namely:

Integration of high-altitude satellite circuits into the world-wide routing and transmission plan must take account of the long propagation time of such circuits. The rules for implementing the hierarchical routing plan recommended by the C.C.I.T.T.[1] have been reviewed to take account of this characteristic as well as the flexibility characteristics offered by satellite circuits.

The Study Group believes the routing plan should ensure that international connections do not infringe on the recommended limit of the mean one-way propagation times given in revised Recommendation P.14 a, b and c (G.114-A, a, b and c). Connections involving the use of two high-altitude satellite circuits in tandem should be avoided, except in exceptional circumstances, e.g. when the only alternative is an h.f. radio circuit connection of traditional type. Furthermore, it is noted that in revised Recommendation P.14.b, the limit of 400 ms restricts the total length of terrestrial circuits which would be suitable for connections including one high-altitude satellite circuit.

The Study Group notes with satisfaction that, in addition to the general routing rules [2] Study Groups XI and XIII have made provision by signalling and switching logic for calls in course of establishment to be so treated that it is impossible to set up a call involving more than one high-altitude satellite link except under the most exceptional circumstances.

Study Group XVI also notes with satisfaction that Study Groups XI and XIII will consider the potential impact in future switching systems of demand assignment and multipoint routing techniques. (See COM XI—No. 156, 1964-1968).

The implications of the above characteristics for the hierarchical routing plan are not completely evident at this time. The suitability of satellite systems for providing large numbers of direct, high-usage links (pointed out by Study Group XIII) may produce less reliance on final routes. It is clear, however, that final routes should use terrestrial links except in the most exceptional circumstances.

In principle, in connections in which a satellite link is employed in accordance with the foregoing rules, there need be no limitation on the position of a satellite link in a connection, providing only one such link is used (very exceptional cases excluded).

Question 4/XVI — Attenuation distortion in an international connection

(continuation of points 5 and 7 of Question 1/XVI studied in 1964-1968)

a) What should the objectives for the attenuation distortion in an international connection be, bearing in mind the provisions of Recommendation G.132?

b) What part of the total can be allocated to the objective for the international chain of circuits?

c) Is this objective compatible with Recommendation G.151-A (M.58) concerning the attenuation distortion for an international circuit?

d) What measures are desirable to ensure that the objectives are met?

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[1] Recommendation E.15 (C.C.I.T.T. *Blue Book*, Geneva 1964, Volume II) or Q.13 (C.C.I.T.T. *Blue Book*, Volume VI).

[2] These rules are contained in the amended version of Recommendation Q.13, approved by the 1968 Plenary Assembly (C.C.I.T.T. *White Book*, Volume VI).

Note 1. — Both directions of transmission are to be considered.

Note 2. — The small probability of encountering seven circuits in the international chain must be considered.

Note 3. — The results of sample measurements carried out during the period 1964-1968 are given in an annex.

ANNEX

(to Question 4/XVI)

Analysis of the results of the subscriber-to-subscriber tests carried out in Europe during April-June 1967

by Mr. S. MUNDAY (United Kingdom), Rapporteur

The information has been re-analysed in accordance with the wishes of Study Groups IV and XVI and replaces pages 17-37 of document COM IV—184, COM XII—119, COM XVI—96, COM SpA—188 and COM SpC—64 (period 1964-1968).

1. Over the period April-June 1967, measurements of transmission loss, attenuation distortion and noise power level were made on over 1200 telephone connections established within Europe. The measuring points were at the subscriber's location so that these results can provide an objective measure of what is offered to subscribers.

2. The number of connections established between various pairs of administrations for these tests were as follows:

Belgium – France	38
Belgium – United Kingdom	48
Denmark – United Kingdom	40
Fed. Rep. of Germany – France	116
– Italy	72
– Netherlands	180
– Switzerland	144
– United Kingdom	142
France – Italy	10
– Netherlands	24
– Sweden	16
– United Kingdom	92
Italy – Sweden	6
– United Kingdom	36
Netherlands – United Kingdom	190
Sweden – United Kingdom	132
Switzerland – United Kingdom	80

3. For this analysis, connections have been arranged in categories based on the complexity of the connection. Each connection is described by the number of two-wire and four-wire switching points. Thus category 3/1 signifies a connection with 3 two-wire and 1 four-wire switching points. In this example, since there is a total of *four* exchanges, there are *five* circuits involved, made up of three public circuits and two subscriber's local lines. (In most cases the subscriber's local line

was very short, the subscriber's location being in the same building as the local exchange.)

All calls were set up in the same way as they are by ordinary subscribers. However, it has not been possible in every case to distinguish between manual exchanges and automatic exchanges or between demand and reverted calls and no attempt has been made to include this in the analysis.

4. On each connection the subscribers' instruments were replaced by measuring equipment and the following quantities measured:

a) The insertion loss between 600 ohms at 200, 300, 400, 800, 1000, 1600, 2800, 3000, 3100, and 3400 Hz or as many of these frequencies as possible.

b) The weighted and unweighted noise power level in 600 ohms at the subscriber's location. (On some connections 800-ohm measuring equipment was used at each end. However, tests have shown that the results are not significantly different compared to measurements made with 600-ohm equipment at each end.)

5. *Number of samples in each category*

Number of two-wire switching points	Number of four-wire switching points	Total number of switching points	Number in sample tested
2	2	4	125
2	3	5	22
2	4	6	2
			149
3	1	4	275
3	2	5	169
3	3	6	65
3	4	7	19
			528
4	0	4	50
4	1	5	152
4	2	6	154
4	3	7	40
4	4	8	8
			404
5	0	5	39
5	1	6	71
5	2	7	
5	3	8	
5	4	9	3
			168
6	0	6	12
6	1	7	17
6	2	8	6
6	3	9	1
			36
7	0	7	1
7	1	8	2
			3

6. *Grouping of categories*

The categories listed in section 5 have been grouped together in two ways for this analysis:

a) Those categories with the same number of two-wire switching points, giving a set of results for connections routed through 2, 3, 4, 5 or 6 two-wire switched exchanges.

b) Those categories with the same *total* number of exchanges regardless of whether they are two-wire or four-wire, giving a set of results for connections routed through a total of 4, 5, 6, 7 or 8 exchanges.

7. The following information for each group of categories (with a sample large enough in most cases to support the analysis) has been derived:

- the distribution of insertion loss at 800 Hz (no distinction between directions of transmission);
- the distribution of the magnitude of the difference between the insertion loss at 800 Hz of the two directions of transmission;
- the distribution of weighted and unweighted noise power levels;
- the distribution of the ratio of the measured signal level at 800 Hz (with 1 milliwatt applied at the distant end) to the weighted and unweighted noise power levels;
- the distribution of the insertion loss distortion relative to the loss at 800 Hz for each measuring frequency.

Additionally, for the complete range of connections measured, the distribution of the weighted noise power per unit length is given in pWp/km. (In many cases it was necessary to estimate the length of the connection since the precise routing was not obtained at the time the tests were made.)

8. Tables 1-5 and Figures 1-11 refer to the analysis based on the number of two-wire switching centres in each connection.

Tables 6-10 and Figures 12-22 refer to the analysis based on the total number of exchanges in each connection.

Figure 23 shows the distribution of the weighted noise power per unit length in pWp/km.

Note 1 referring to Tables 1-10 following an asterisk indicates the proportion of connections on which measurements could not be made at the indicated frequency owing to the received signal's being lower than the noise level.

TABLE 1

Characteristics of international connections routed through 2 two-wire and from 1 to 4 four-wire switching centres

(Sample size 151 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	0.1	0.0	−90	−66	81	57
5% were better than	6.4	0.3	−85	−60	70	49
25% were better than	10.8	1.3	−76	−54	63	41
50% were better than	13.5	2.9	−73	−46	59	31
75% were better than	15.8	5.8	−68	−38	54	23
95% were better than	20.0	9.5	−61	−30	47	13
None were worse than	38.5	16.0	−49	−24	33	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−4.0	−6.4	−5.5	−3.5	−5.0	−3.8	−5.0	−3.8
5% were less than	3.5	0.3	−1.2	−1.4	−0.6	0.0	0.6	2.0
25% were less than	6.0	1.8	−0.6	−0.5	1.0	1.2	2.0	5.0
50% were less than	8.0	2.8	−0.3	0.0	1.7	2.0	3.2	7.0
75% were less than	9.8	3.9	0.0	0.6	3.2	3.2	4.8	9.3
95% were less than	13.3	5.6	0.6	2.0	6.0	5.5	8.0	15.8
Upper limit	28.0	8.5	4.5	8.1	19.2	24.0	31.9	36 5

TABLE 2

Characteristics of international connections routed through 3 two-wire and from 1 to 4 four-wire switching centres

(Sample size 530 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	3.8	0.0	−90	−73	77	56
5% were better than	9.2	0.2	−83	−63	68	47
25% were better than	13.6	1.2	−76	−56	60	40
50% were better than	16.1	2.6	−73	−50	56	34
75% were better than	18.8	4.6	−69	−42	52	25
95% were better than	23.7	9.4	−61	−33	43	15
None were worse than	37.4	21.3	−48	−21	23	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−3.0	−6.3	−4.8	−6.6	−8.5	−10.8	−6.5	−4.0
5% were less than	1.0	−1.0	−1.0	−0.9	1.0	2.1	2.4	4.7
25% were less than	3.8	0.6	−0.4	0.2	3.1	4.9	4.9	8.5
50% were less than	6.4	2.2	0.0	1.3	5.1	7.2	7.5	11.6
75% were less than	9.8	4.0	0.5	2.6	7.6	10.1	10.3	16.1
95% were less than	15.0	6.9	1.2	4.4	11.5	17.2	17.5	27.4
Upper limit	*	29.6	4.8	8.6	28.2	*	*	*

* Note 1

TABLE 3

Characteristics of international connections routed through 4 two-wire and from 0 to 3 four-wire switching centres

(Sample size 404 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	2.0	0.0	−90	−83	76	62
5% were better than	10.0	0.3	−83	−64	65	45
25% were better than	15.4	1.3	−76	−56	58	38
50% were better than	19.0	3.0	−73	−50	54	31
75% were better than	21.9	5.5	−69	−44	49	24
95% were better than	27.6	11.2	−60	−34	39	13
None were worse than	42.6	22.5	−47	−23	17	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−2.9	−4.3	−4.6	−5.6	−5.8	−1.1	−4.3	1.0
5% were less than	1.7	−0.3	−1.5	−1.0	−1.2	4.0	3.5	6.2
25% were less than	4.8	1.3	−0.5	0.0	4.0	7.2	6.7	11.6
50% were less than	8.2	3.0	0.0	1.3	7.1	10.4	10.1	16.3
75% were less than	11.6	4.9	0.5	3.2	10.4	14.5	14.4	23.4
95% were less than	16.1	8.0	1.5	5.5	16.8	*	*	*
Upper limit	*	17.5	6.0	12.5	*	*	*	*

* Note 1

TABLE 4

Characteristics of international connections routed through 5 two-wire and from 0 to 4 four-wire switching centres

(Sample size 168 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	6.0	0.0	−88	−75	72	56
5% were better than	11.5	0.2	−80	−63	61	44
25% were better than	16.5	1.5	−76	−57	57	37
50% were better than	20.5	3.4	−74	−52	53	31
75% were better than	23.6	5.8	−70	−46	49	24
95% were better than	28.8	11.5	−63	−34	39	15
None were worse than	40.1	19.1	−50	−25	25	4

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	1.0	−0.8	−4.6	−6.6	−0.5	−2.0	0.2	3.7
5% were less than	4.0	0.6	−1.4	−1.2	2.0	5.0	5.2	10.7
25% were less than	7.7	2.9	−0.6	0.5	5.8	9.1	9.4	17.0
50% were less than	11.1	5.0	0.0	2.2	9.3	13.0	14.0	23.6
75% were less than	14.3	6.7	0.6	4.0	13.0	17.0	18.5	30.0
95% were less than	20.1	9.3	2.0	7.3	19.1	*	*	*
Upper limit	*	13.5	3.5	12.5	29.2	*	*	*

* Note 1

TABLE 5

Characteristics of international connections routed through 6 two-wire and from 0 to 3 four-wire switching centres

(Sample size 39 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	13.0	0.1	−86	−72	67	48
5% were better than	15.0	0.1	−80	−65	58	41
25% were better than	19.5	1.7	−76	−57	53	35
50% were better than	24.2	3.7	−74	−53	49	28
75% were better than	26.9	7.0	−70	−44	46	20
95% were better than	34.0	9.8	−64	−37	36	9
None were worse than	37.1	12.8	−62	−25	29	6

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	3.0	−1.0	−2.6	−3.2	−3.0	−2.1	−0.2	5.5
5% were less than	6.0	2.0	−2.0	−1.6	0.0	3.6	3.6	9.4
25% were less than	9.2	4.6	−0.8	0.0	6.3	8.7	11.8	20.2
50% were less than	13.6	6.8	−0.1	2.0	9.9	12.5	15.2	28.5
75% were less than	16.7	8.1	0.5	3.6	13.4	17.3	29.4	*
95% were less than	24.5	11.9	1.4	5.5	19.6	*	*	*
Upper limit	*	*	3.5	7.5	28.8	*	*	*

* Note 1

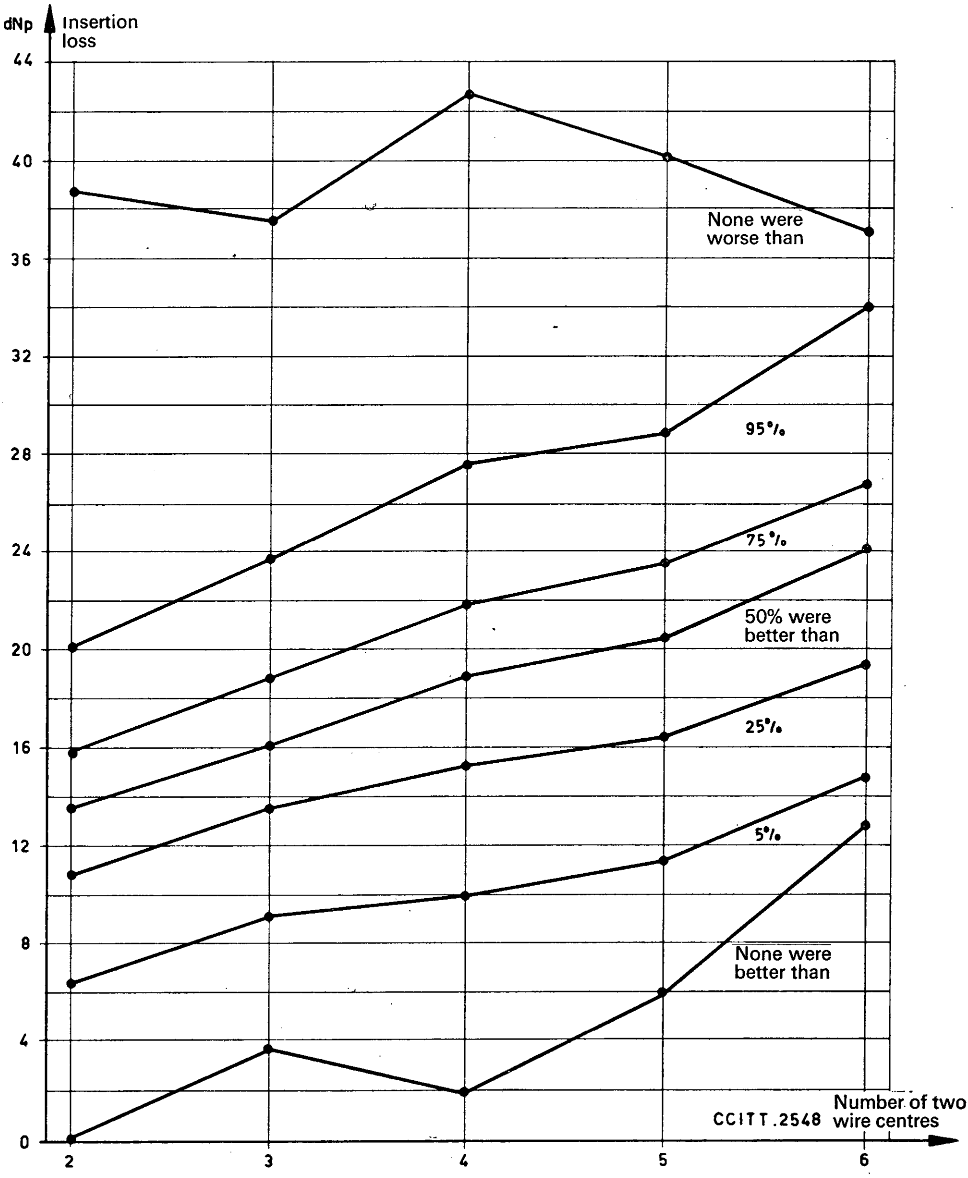


FIGURE 1. — **Distribution of insertion loss at 800 Hz as a function of the number of two-wire switching centres**

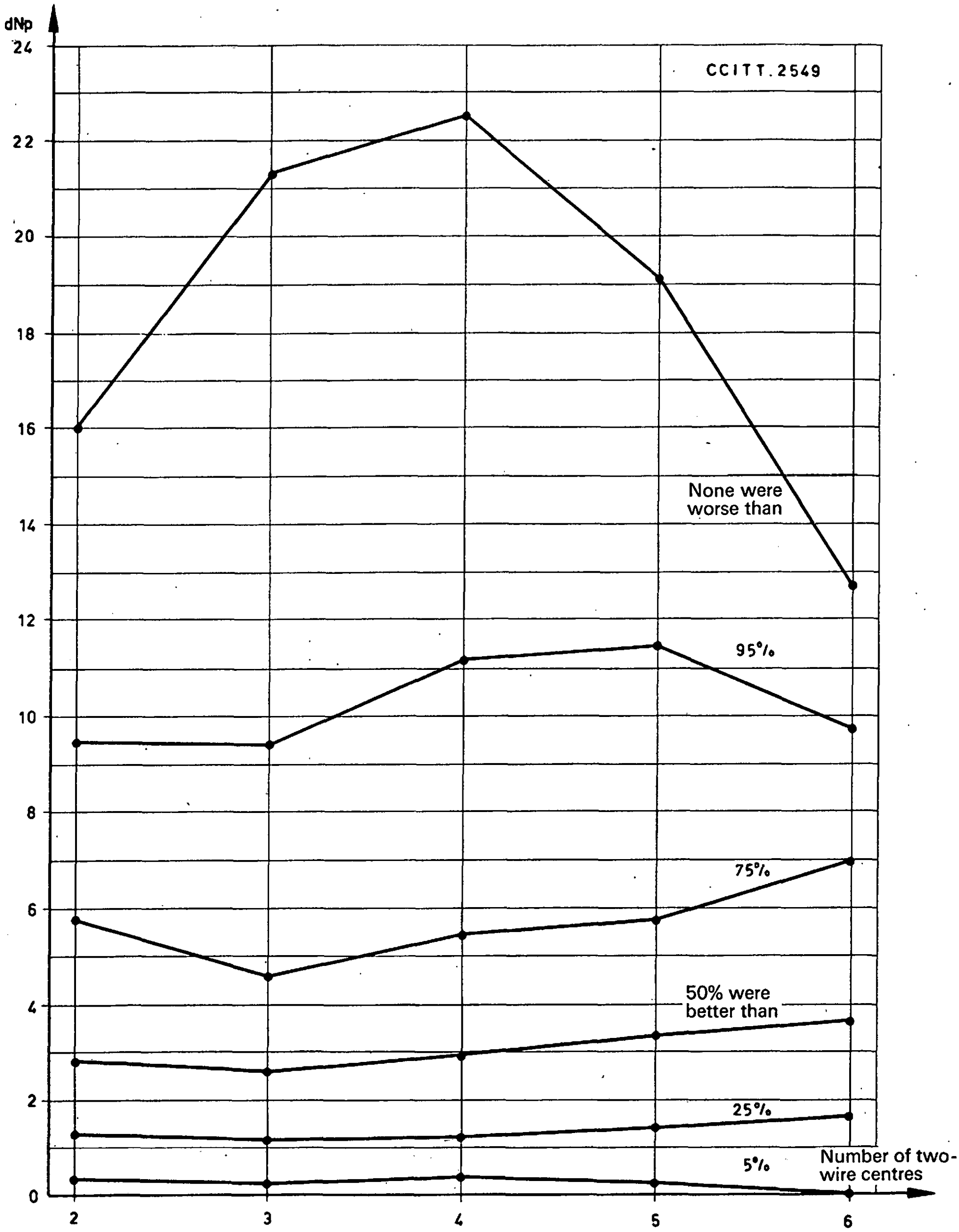


FIGURE 2. — Distribution of the magnitude of the difference in loss between transmission directions at 800 Hz as a function of the number of two-wire switching centres

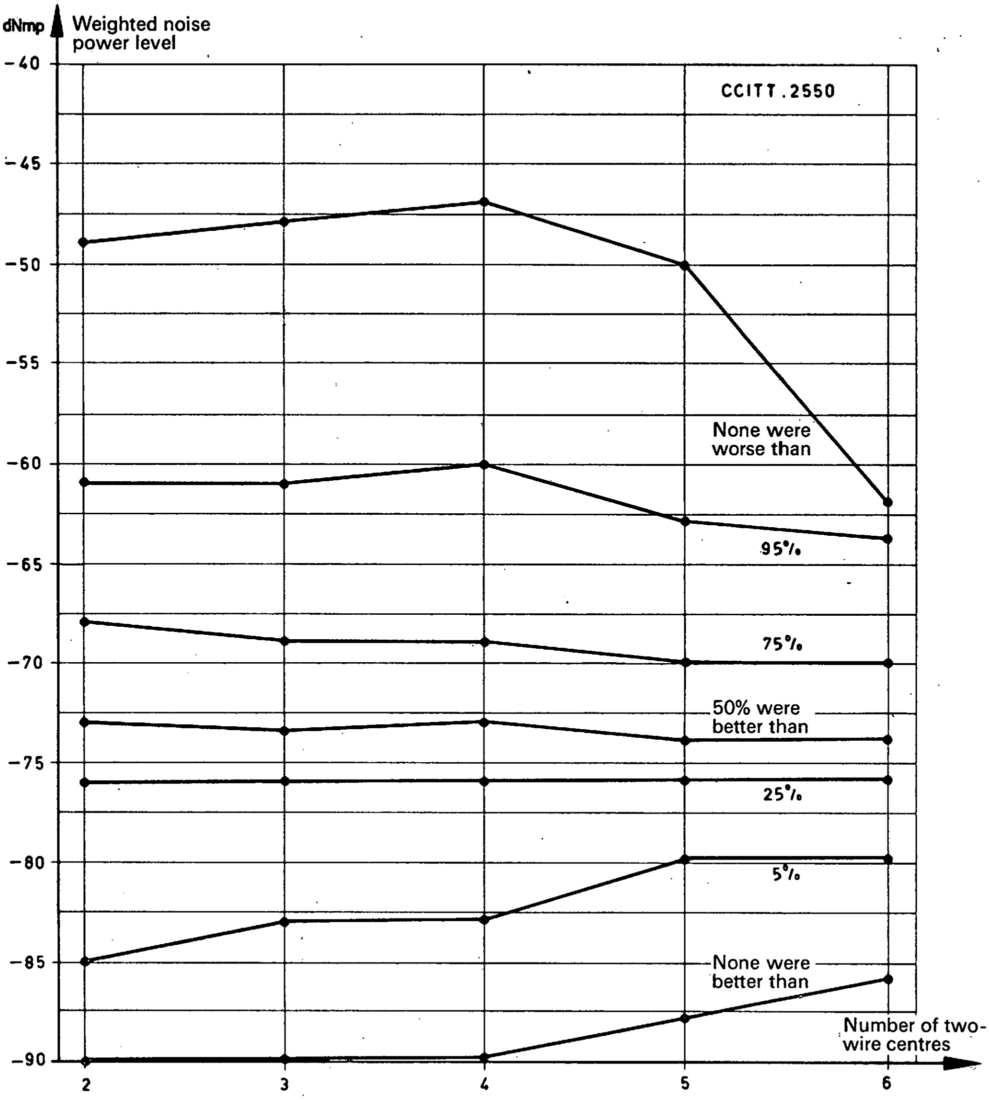


FIGURE 3. — Distribution of weighted noise power level as a function of the number of two-wire switching centres

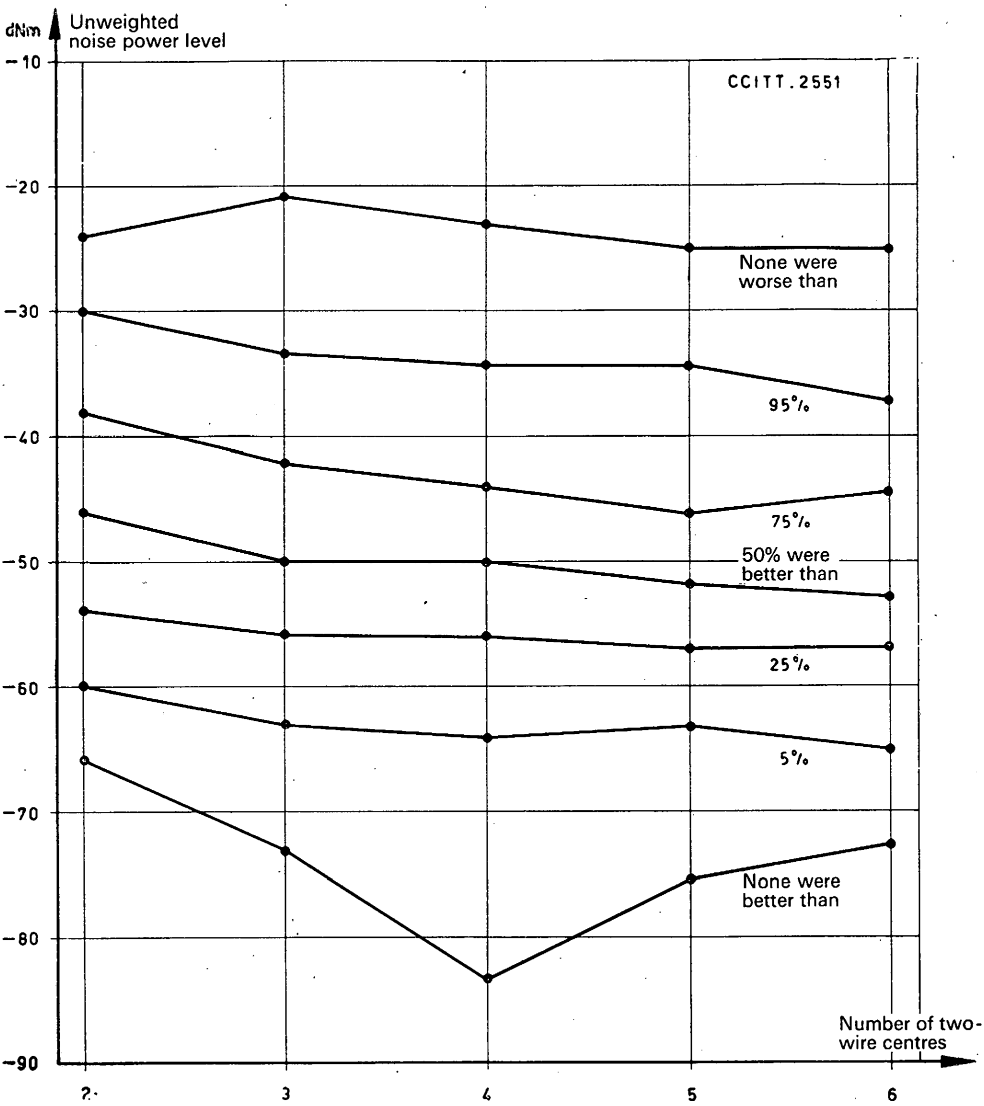


FIGURE 4. — Distribution of unweighted noise power level as a function of the number of two-wire switching centres

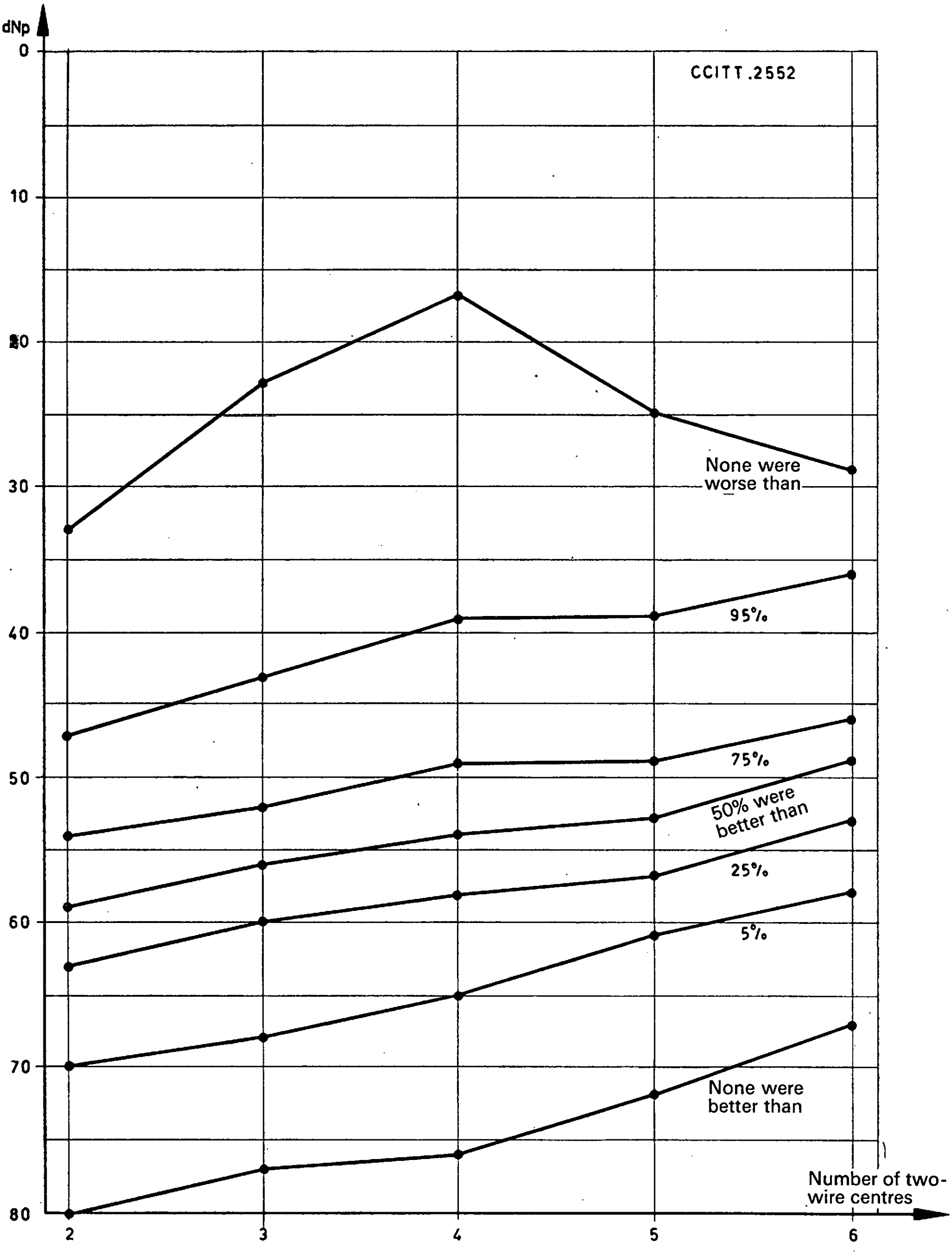


FIGURE 5. — **Distribution of the ratio measured signal level at 800 Hz to weighted noise power as a function of the number of two-wire switching centres**

(The sending level was 0 dNm)

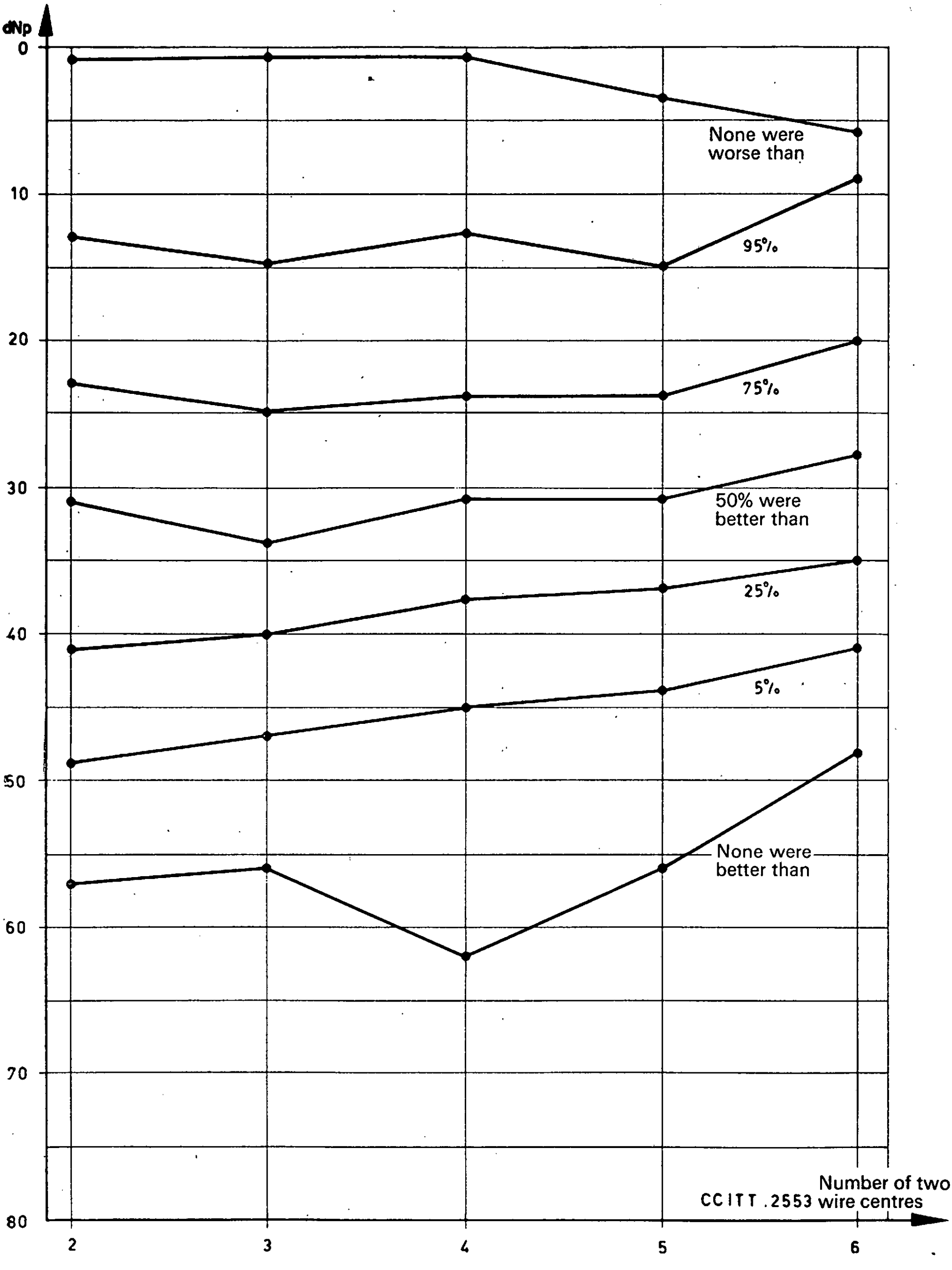


FIGURE 6. — **Distribution of the ratio measured signal level at 800 Hz to unweighted noise power as a function of the number of two-wire switching centres**

(The sending level was 0 dNm)

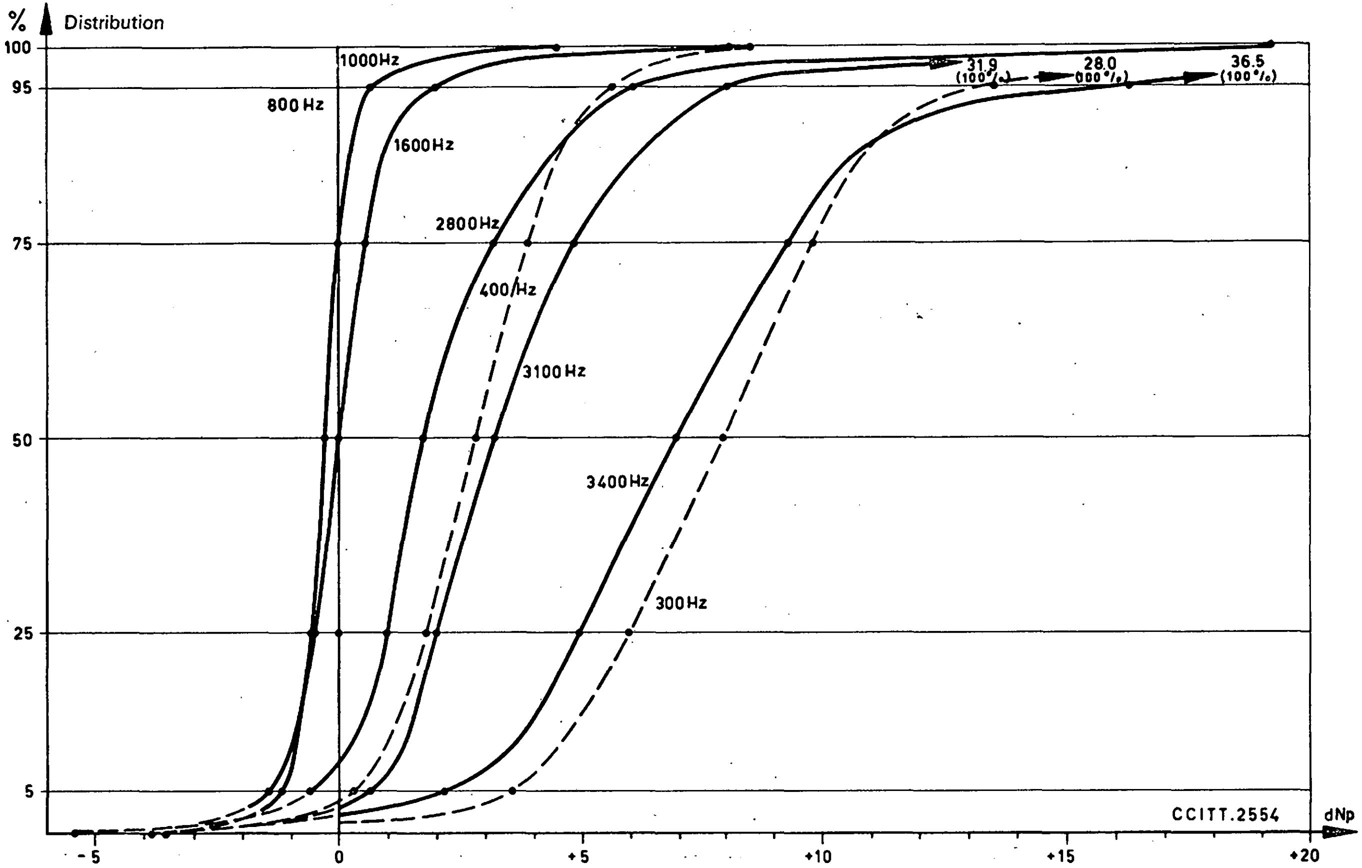


FIGURE 7. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through 2 two-wire and from 2 to 4 four-wire switching centres

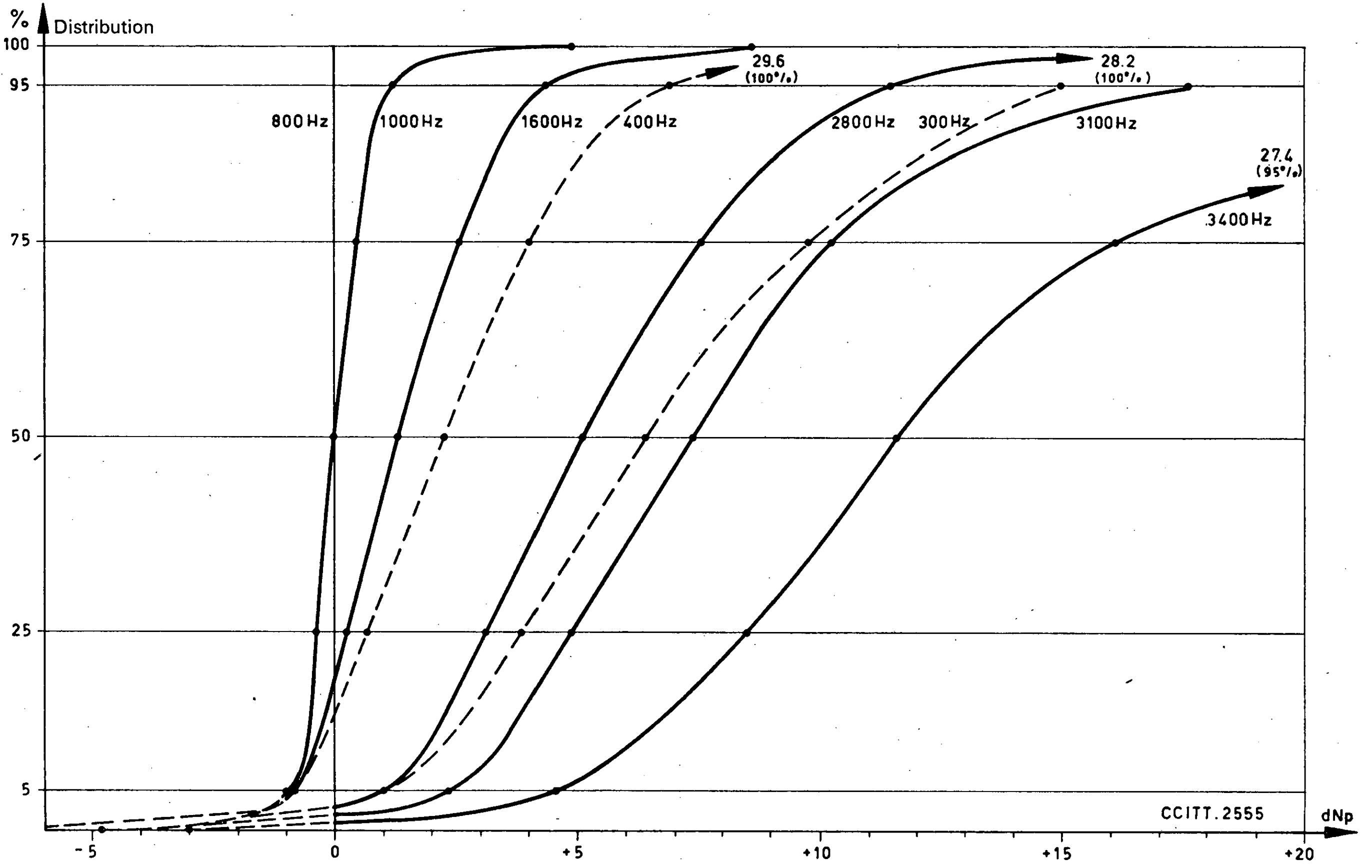


FIGURE 8. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through 3 two-wire and from 1 to 4 four-wire switching centres

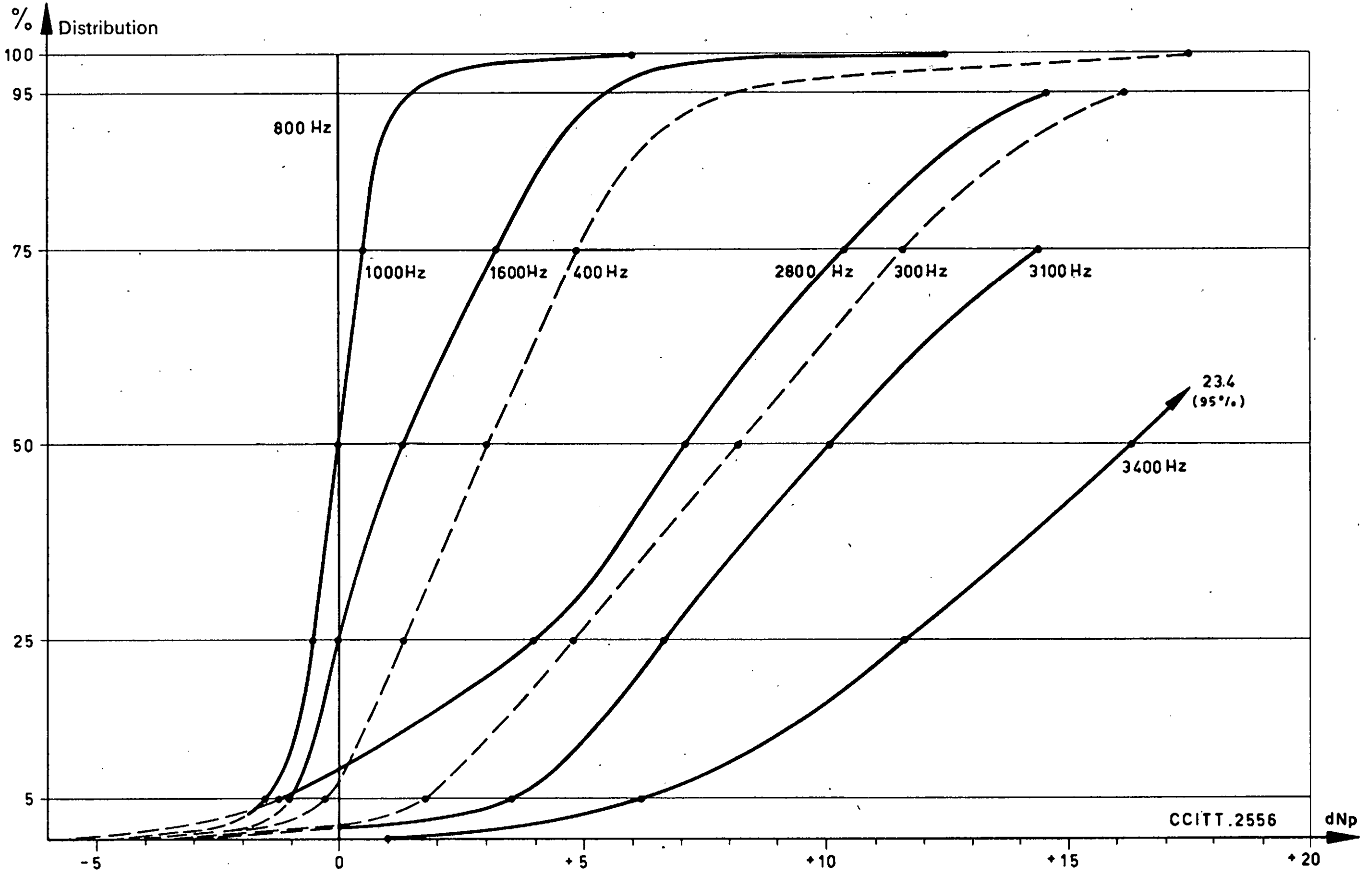


FIGURE 9. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through 4 two-wire and from 0 to 4 four-wire switching centres

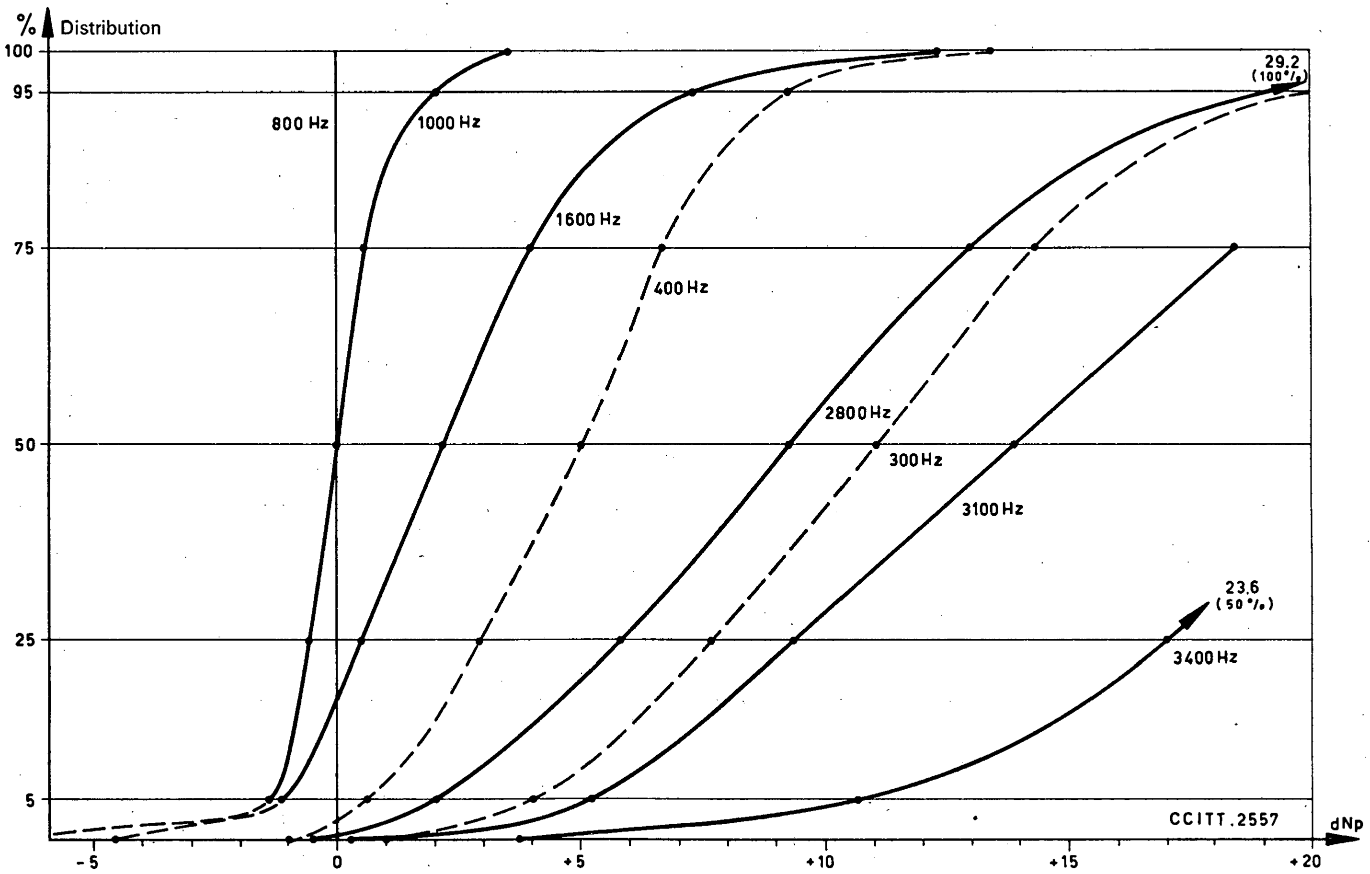


FIGURE 10. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through 5 two-wire and from 0 to 4 four-wire switching centres

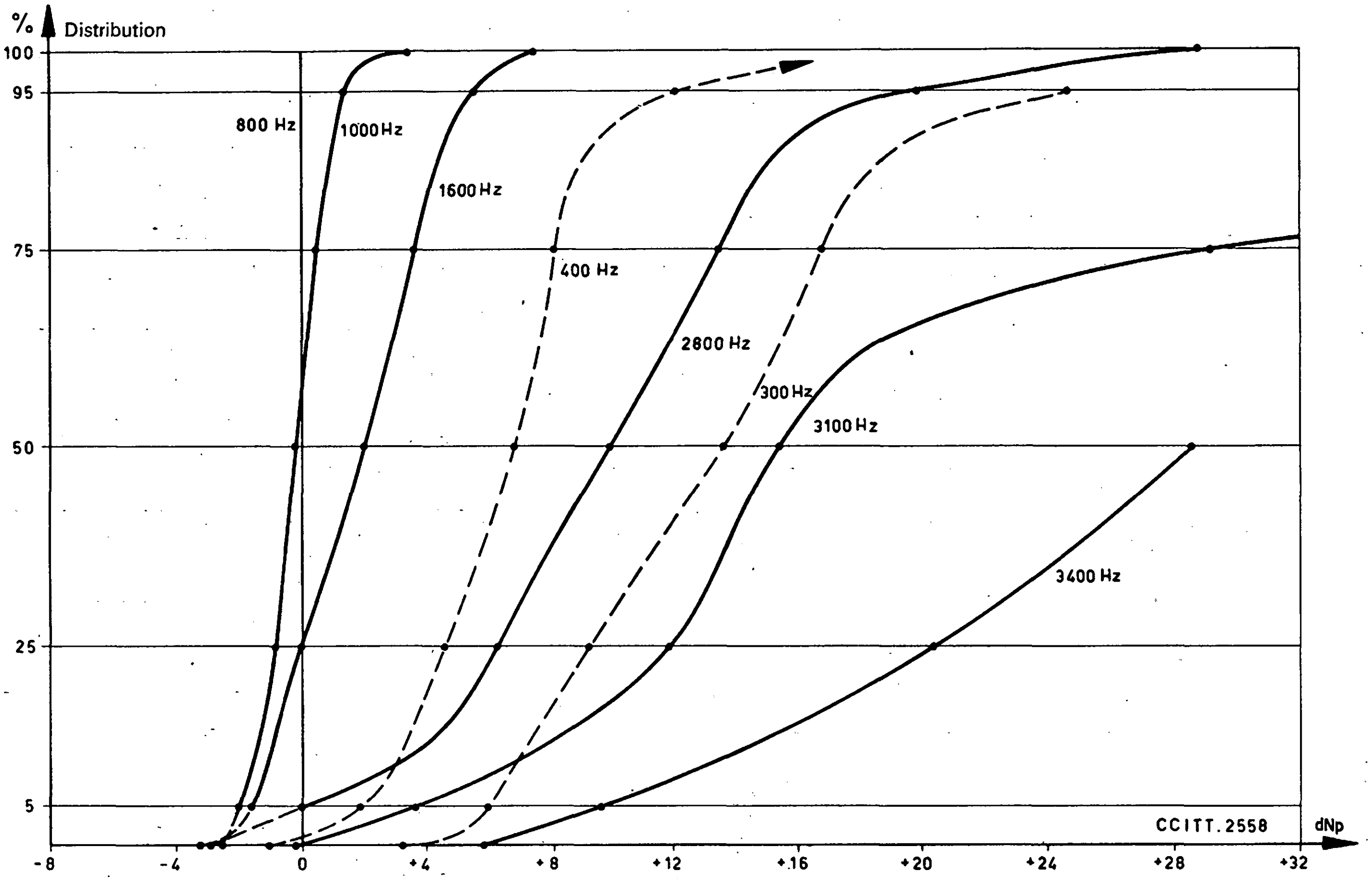


FIGURE 11. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through 6 two-wire and from 0 to 4 four-wire switching centres

TABLE 6

Characteristics of international connections routed through a total of 4 exchanges
(Sample size 450 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	0.1	0.0	−90	−73	80	57
5% were better than	8.5	0.2	−83	−60	69	47
25% were better than	13.1	0.9	−77	−54	61	38
50% were better than	15.5	2.1	−74	−48	58	32
75% were better than	18.0	4.0	−69	−40	53	23
95% were better than	21.2	8.5	−62	−30	46	13
None were worse than	38.5	16.0	−49	−21	33	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−4.0	−6.4	−5.5	−4.6	−6.0	−3.8	−5.0	−3.8
5% were less than	0.5	1.1	−0.9	−0.9	0.5	1.0	1.5	3.4
25% were less than	2.8	0.2	−0.3	0.1	2.3	3.5	3.6	6.6
50% were less than	4.8	1.4	0.1	1.2	4.5	6.2	6.2	9.5
75% were less than	7.5	2.9	0.5	2.9	7.2	9.5	9.2	13.0
95% were less than	11.8	5.3	1.4	4.6	11.0	13.7	13.4	20.4
Upper limit	28.0	14.5	4.5	10.8	21.9	*	39.8	*

* Note 1

TABLE 7

Characteristics of international connections routed through a total of 5 exchanges
(Sample size 382 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	2.0	0.0	−90	−83	76	62
5% were better than	9.1	0.4	−83	−65	66	47
25% were better than	14.0	1.4	−76	−57	59	41
50% were better than	17.4	3.1	−72	−51	55	34
75% were better than	21.0	5.3	−69	−44	51	26
95% were better than	27.0	9.5	−63	−36	42	16
None were worse than	40.1	22.5	−47	−25	27	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−1.0	−5.5	−5.3	−6.6	−8.5	−10.8	−6.5	−4.0
5% were less than	2.5	0.1	−1.3	−1.0	0.6	2.1	2.4	5.5
25% were less than	5.4	1.6	−0.5	0.1	3.3	5.9	5.5	10.5
50% were less than	7.8	3.0	0.0	1.2	6.0	9.4	9.0	15.0
75% were less than	10.5	4.5	0.3	2.9	9.5	13.5	13.7	20.6
95% were less than	15.5	7.0	1.5	6.2	15.7	19.5	21.4	31.7
Upper limit	*	29.6	6.0	12.0	*	*	*	*

* Note 1

TABLE 8

Characteristics of international connections routed through a total of 6 exchanges
(Sample size 304 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	2.0	0.0	−90	−69	76	57
5% were better than	9.7	0.3	−81	−64	65	46
25% were better than	15.2	1.6	−76	−56	58	38
50% were better than	18.5	3.7	−73	−51	53	32
75% were better than	22.2	5.9	−69	−44	49	24
95% were better than	28.0	11.4	−61	−34	40	13
None were worse than	38.0	22.5	−47	−23	23	1

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	−2.0	−4.3	−3.5	−6.6	−5.8	−2.0	−4.3	1.0
5% were less than	4.0	0.4	−1.2	−1.2	0.9	2.2	2.5	6.0
25% were less than	7.5	2.5	−0.6	0.0	3.5	6.5	6.3	12.0
50% were less than	10.0	4.1	−0.1	0.9	6.7	10.0	10.0	18.0
75% were less than	12.5	5.8	0.3	2.4	10.0	14.1	14.6	26.5
95% were less than	17.3	8.7	1.2	5.0	15.2	*	*	*
Upper limit	*	22.6	3.7	12.5	29.9	*	*	*

* Note 1

TABLE 9

Characteristics of international connections routed through a total of 7 exchanges
(Sample size 124 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	5.8	0.0	−88	−75	69	56
5% were better than	10.4	0.3	−79	−64	61	46
25% were better than	16.1	1.6	−75	−57	56	38
50% were better than	19.8	3.6	−72	−53	52	31
75% were better than	23.8	6.4	−68	−46	47	25
95% were better than	27.9	11.8	−60	−38	38	14
None were worse than	37.0	17.9	−52	−25	25	7

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	1.0	−1.2	−2.9	−4.6	−0.2	1.0	1.5	4.0
5% were less than	6.9	1.0	−1.7	−1.4	1.5	3.9	4.7	9.1
25% were less than	10.0	3.7	−0.8	−0.2	5.0	8.3	9.0	17.0
50% were less than	12.7	5.4	−0.3	0.9	8.3	11.9	13.1	24.5
75% were less than	15.4	6.9	0.3	3.2	13.2	24.2	23.9	*
95% were less than	20.2	9.7	1.7	5.5	27.6	*	*	*
Upper limit	*	*	3.5	11.5	*	*	*	*

* Note 1

TABLE 10

Characteristics of international connections routed through a total of 8 exchanges
(Sample size 24 connections)

Distribution of measurements	Loss at 800 Hz (dNp)	Magnitude of difference in loss between transmission directions at 800 Hz (dNp)	Noise power level		Ratio (in dNp) measured signal level at 800 Hz to	
			weighted (dNmp)	un-weighted (dNm)	a) weighted noise power	b) unweighted noise power
None were better than	8.6	0.0	−80	−67	67	48
5% were better than	10.6	0.2	−79	−63	59	43
25% were better than	18.4	3.1	−74	−56	51	34
50% were better than	22.0	5.0	−71	−50	47	25
75% were better than	26.0	7.9	−67	−42	44	19
95% were better than	30.6	16.0	−60	−37	30	13
None were worse than	42.6	17.3	−53	−29	17	9

Distribution of distortions (algebraic)	Distortions in dNp relative to the loss at 800 Hz (sign — indicates relative gain)							
	300	400	1000	1600	2800	3000	3100	3400
Lower limit	5.5	−0.3	−2.3	−3.2	−3.0	−2.1	−0.2	5.4
5% were less than	8.1	0.9	−2.1	−3.1	−2.9	−2.0	0.0	5.5
25% were less than	13.0	4.5	−0.9	−0.2	4.4	6.3	7.5	16.5
50% were less than	15.0	6.7	−0.5	0.5	6.7	9.4	12.6	29.2
75% were less than	17.0	8.2	0.0	2.5	11.5	22.1	*	*
95% were less than	27.2	11.0	2.1	5.8	20.5	*	*	*
Upper limit	*	12.7	2.5	7.7	25.3	*	*	*

* Note 1

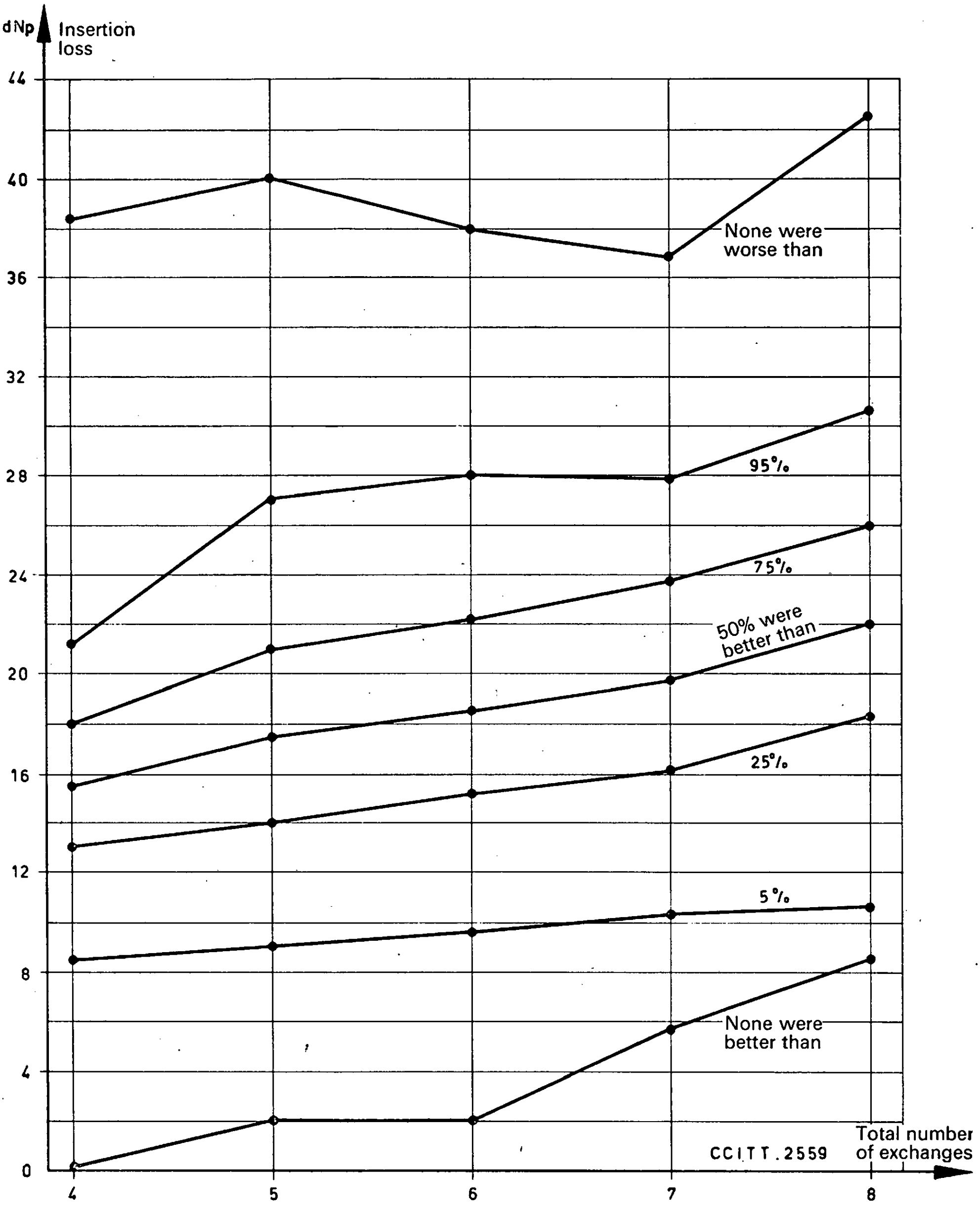


FIGURE 12. — Distribution of insertion loss at 800 Hz as a function of the total number of exchanges

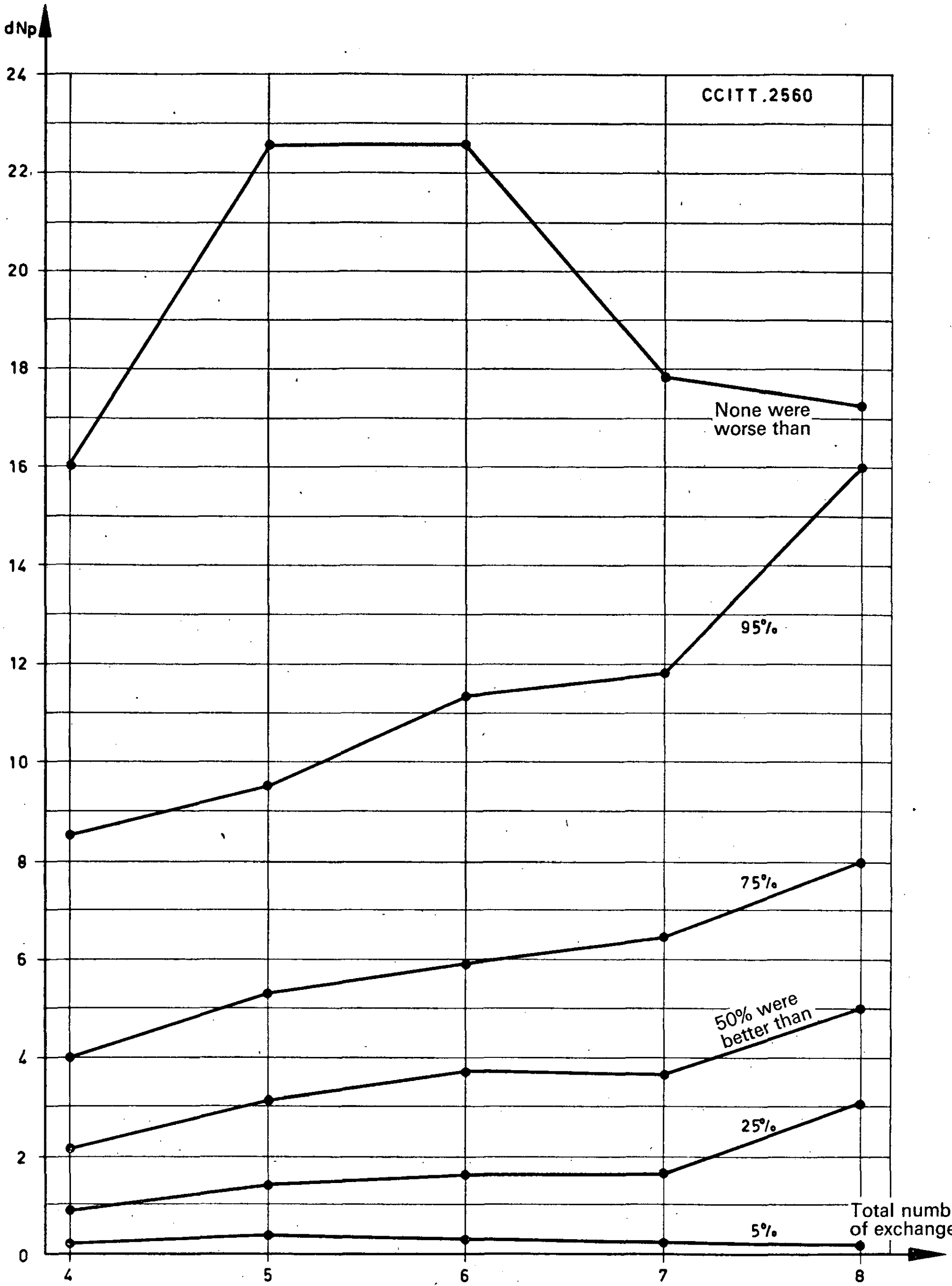


FIGURE 13. — Distribution of the magnitude of the difference in loss between transmission directions at 800 Hz as a function of the total number of exchanges

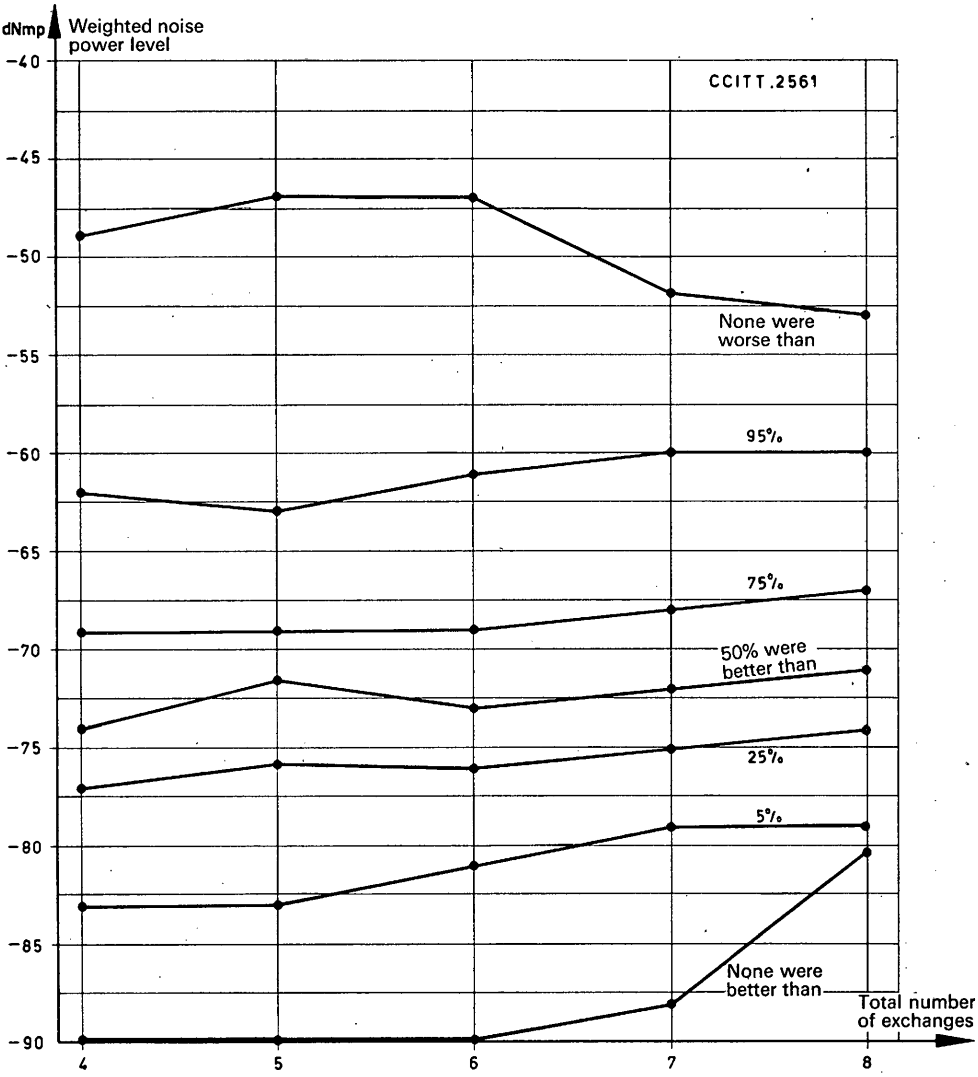


FIGURE 14. — Distribution of weighted noise power level as a function of the total number of exchanges

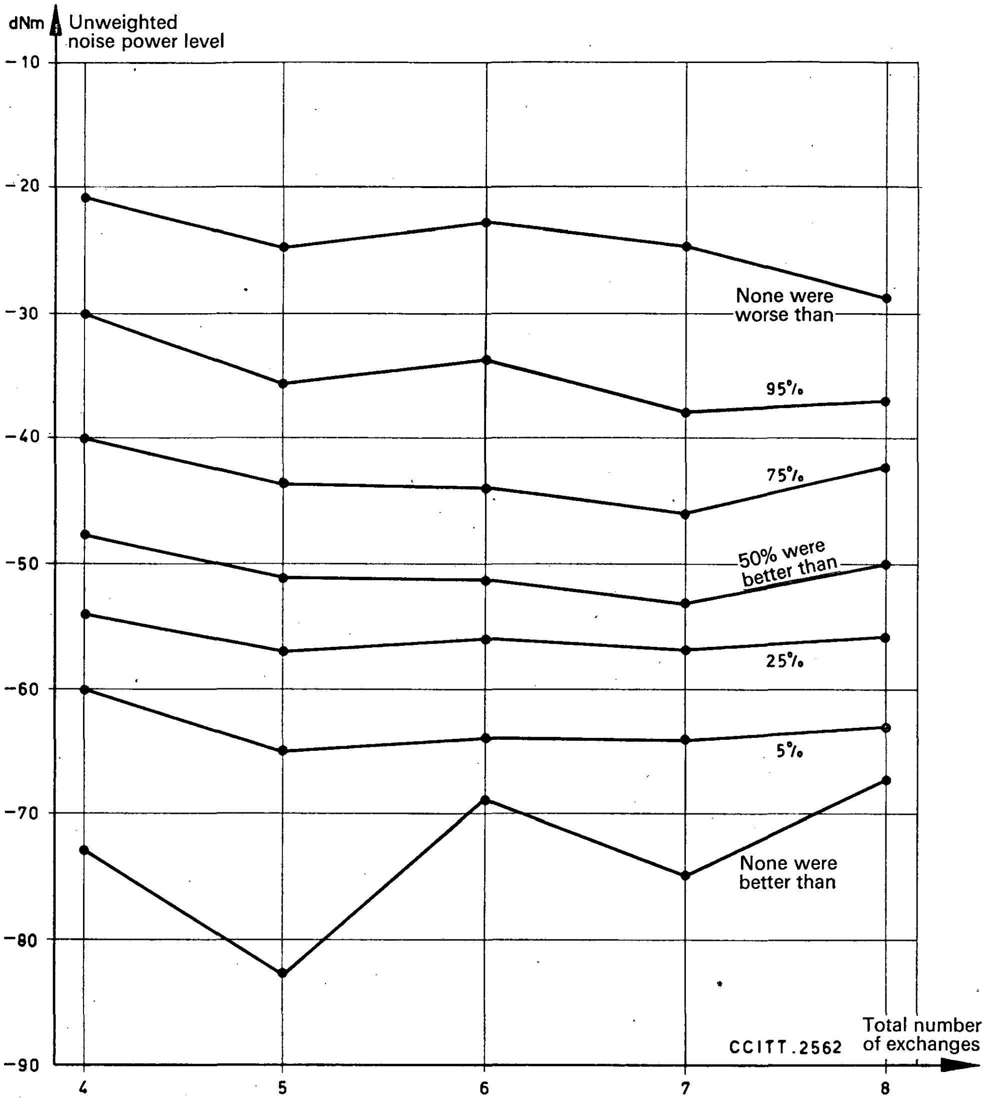


FIGURE 15. — Distribution of unweighted noise power level as a function of the total number of exchanges

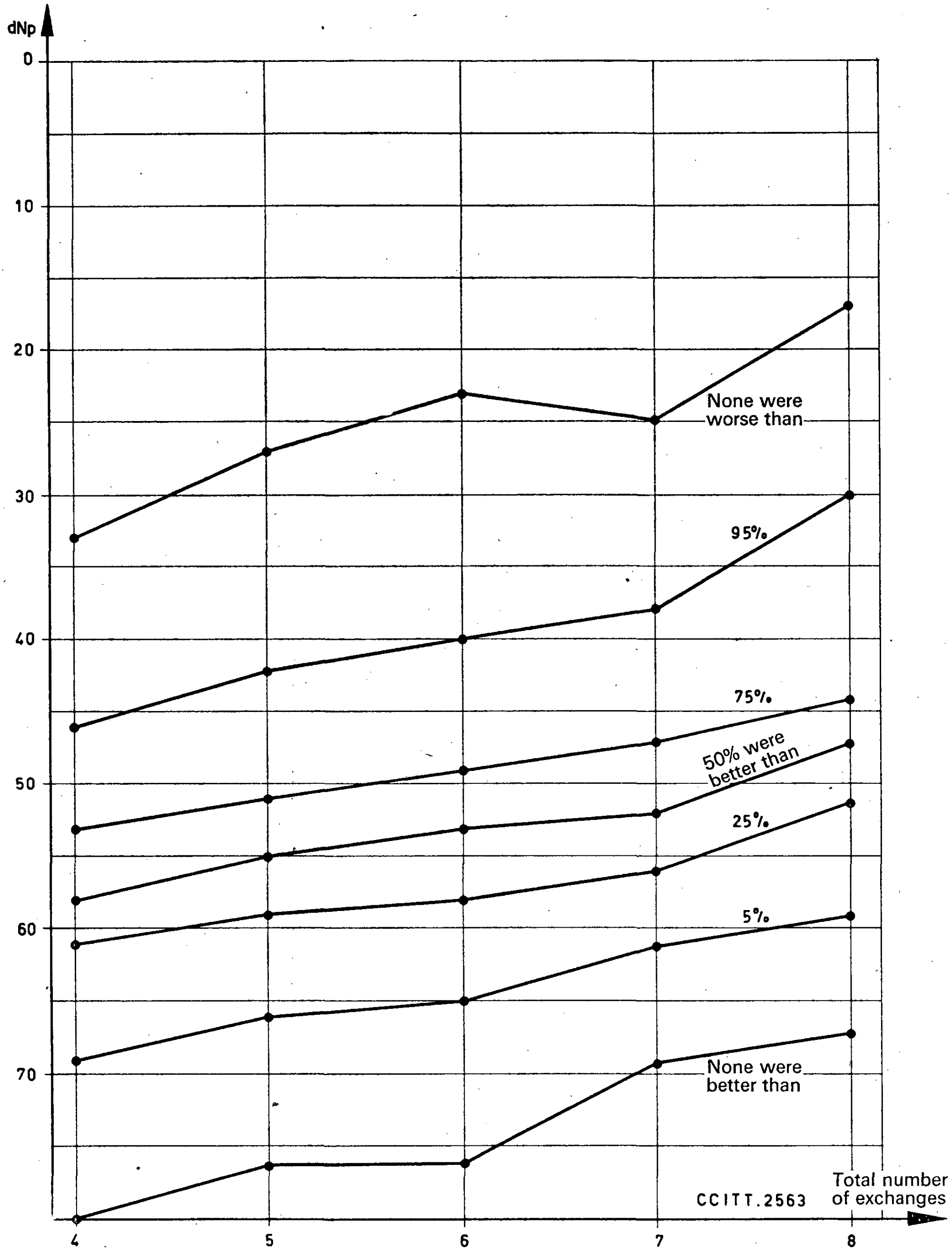


FIGURE 16. — **Distribution of the ratio measured signal level at 800 Hz to the weighted noise power, as a function of the total number of exchanges**

(Sending level was 0 dNm)

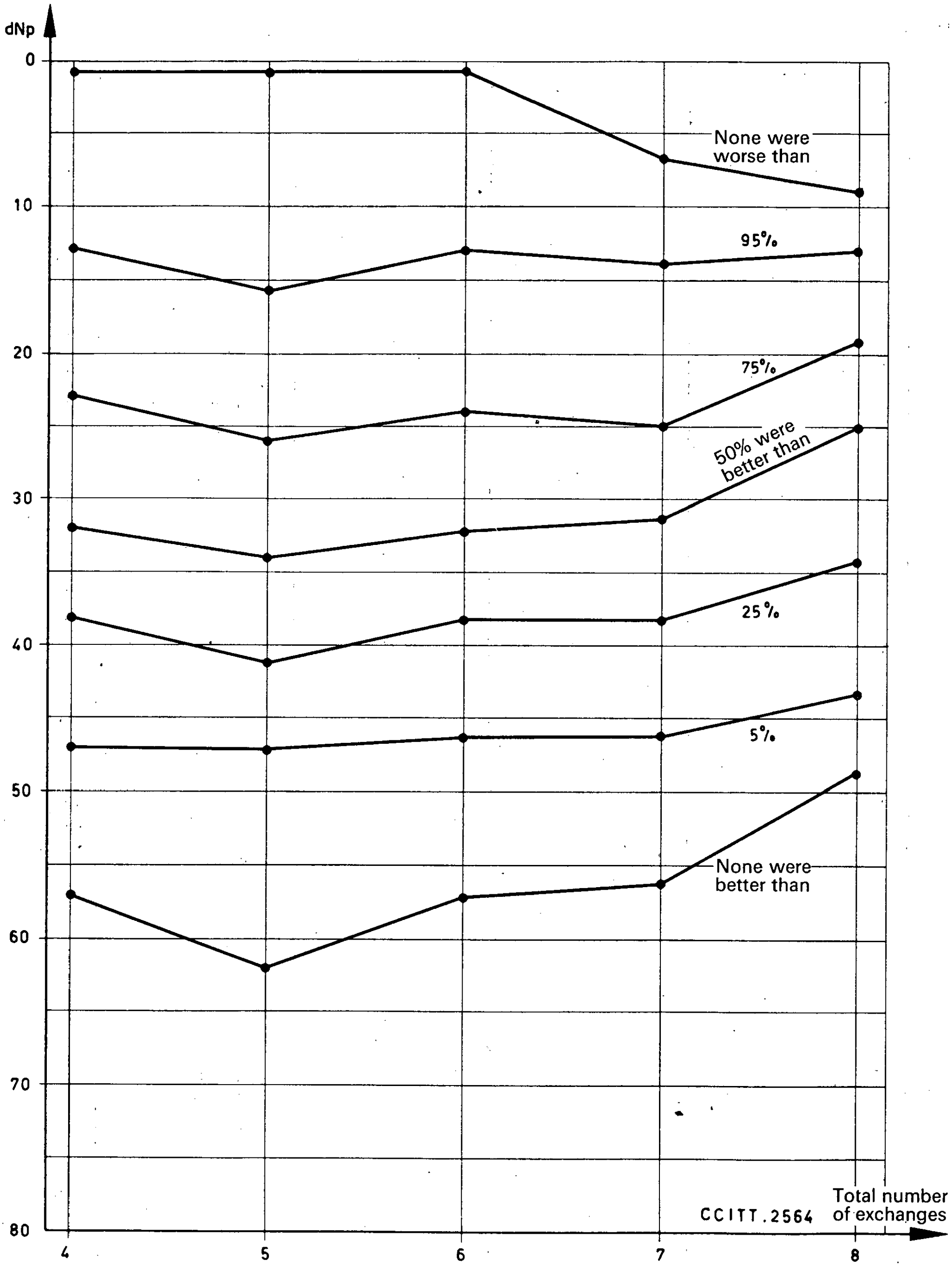


FIGURE 17. — **Distribution of the ratio measured signal level at 800 Hz to unweighted noise power, as a function of the total number of exchanges**

(Sending level was 0 dNm)

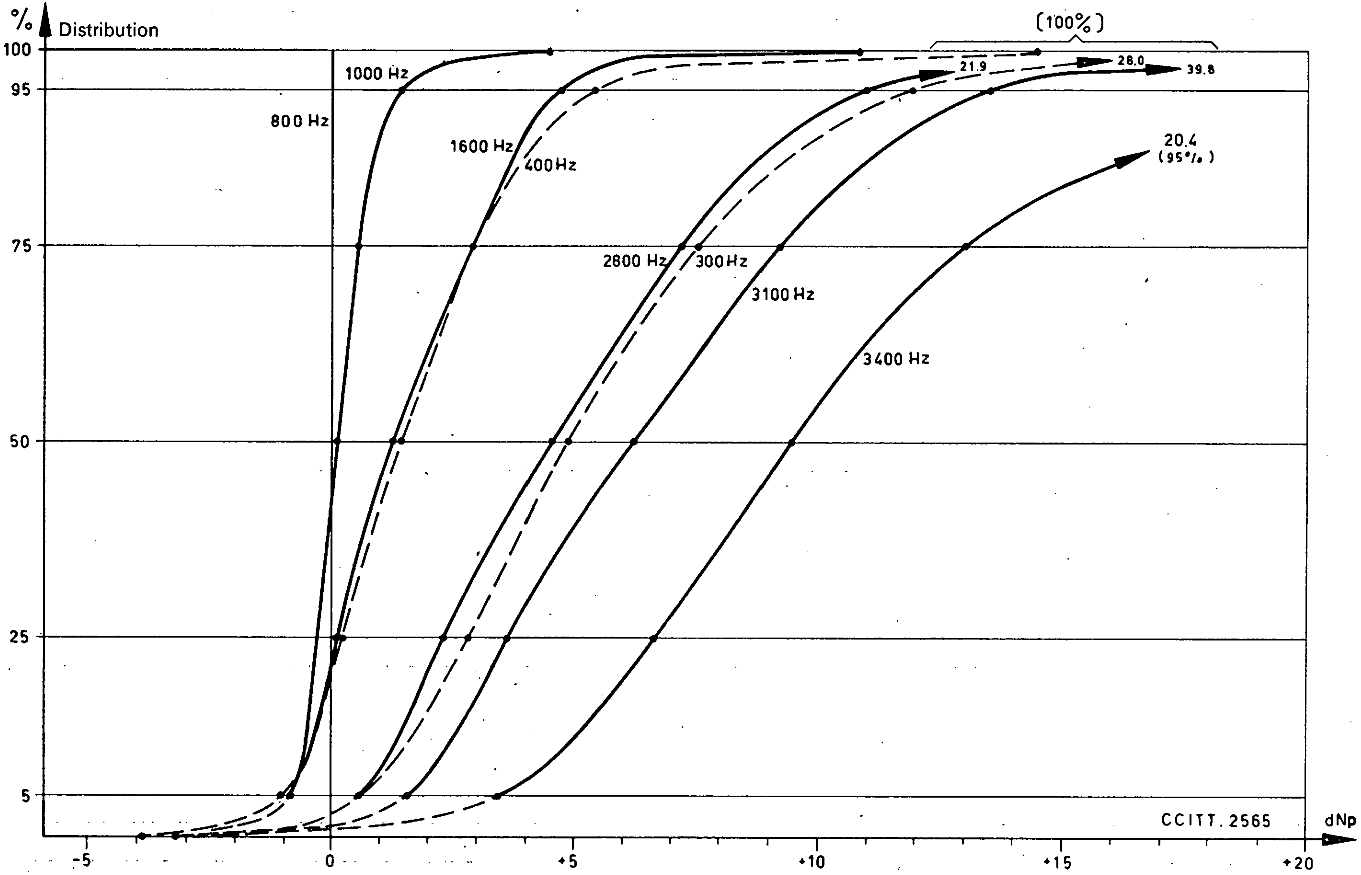


FIGURE 18. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through a total of 4 exchanges

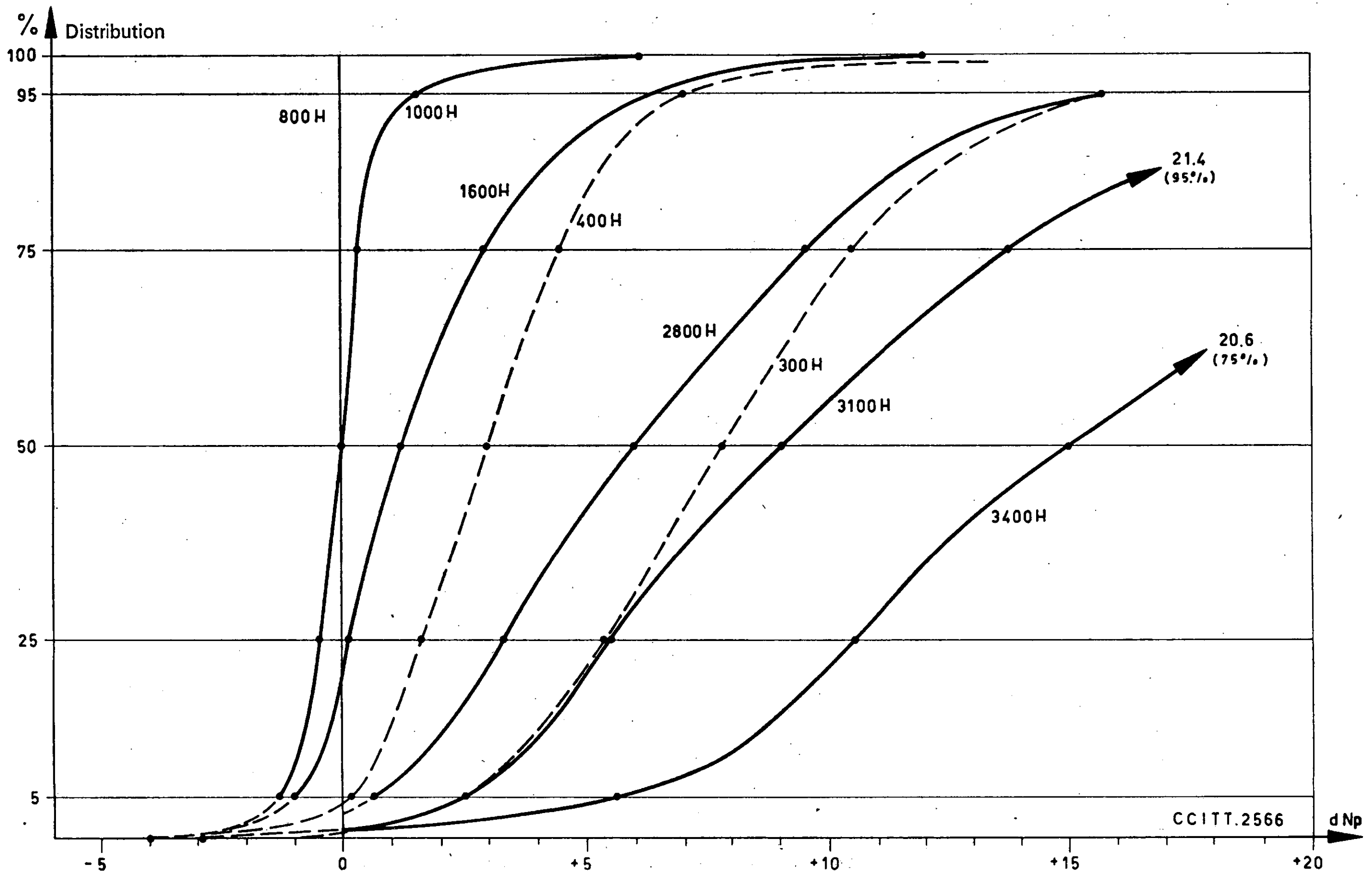


FIGURE 19. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through a total of 5 exchanges

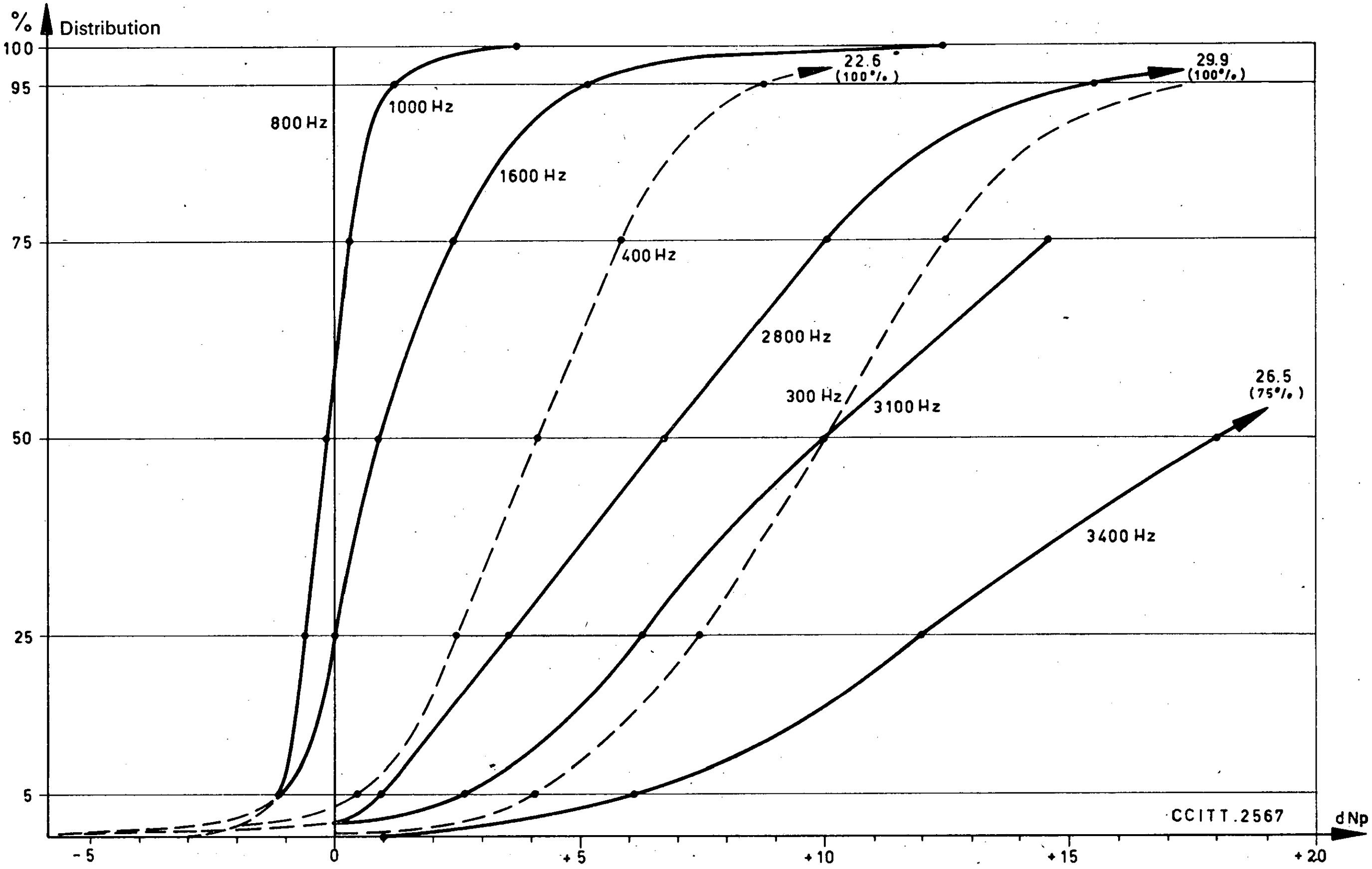


FIGURE 20. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through a total of 6 exchanges

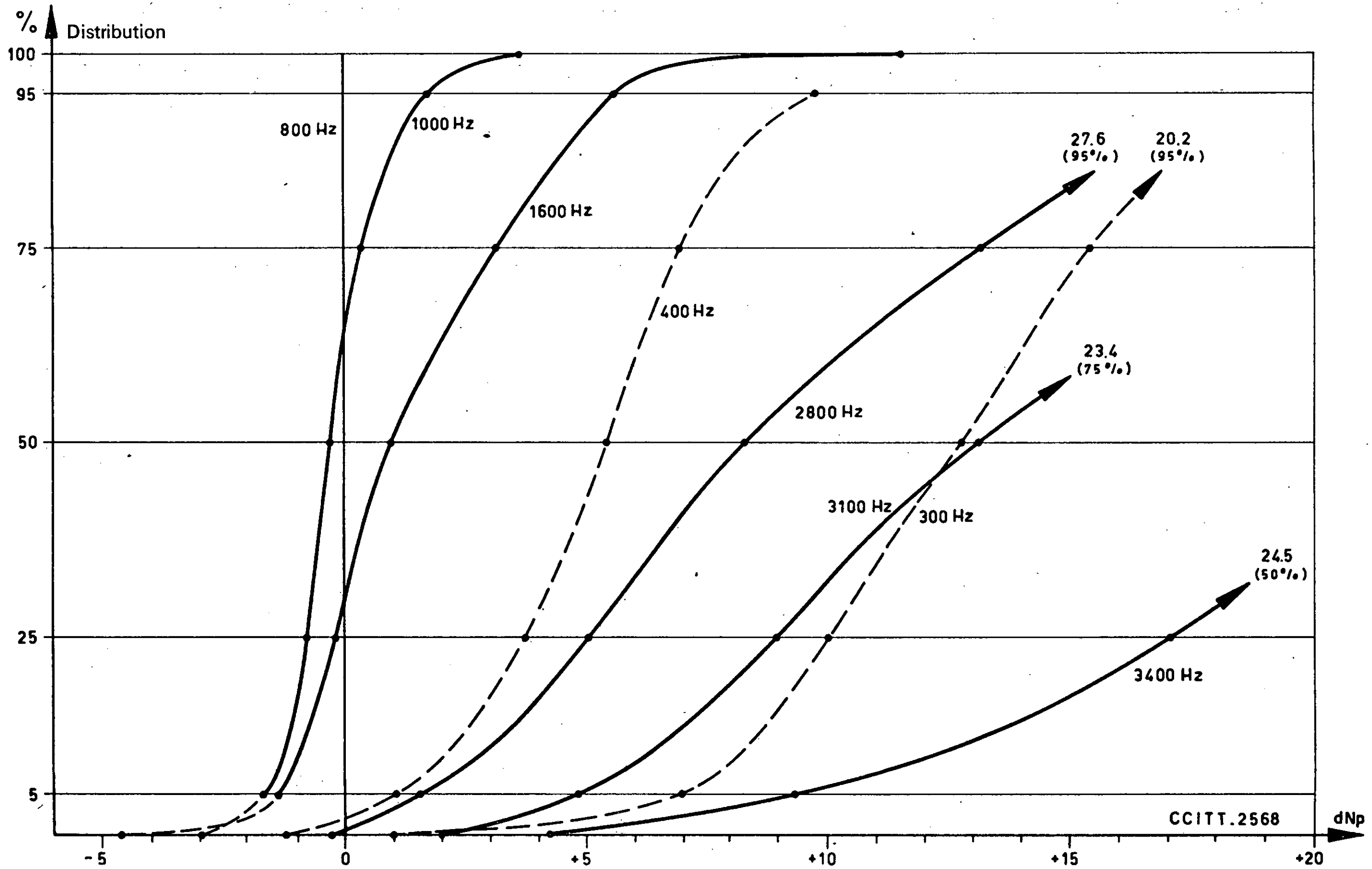


FIGURE 21. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through a total of 7 exchanges

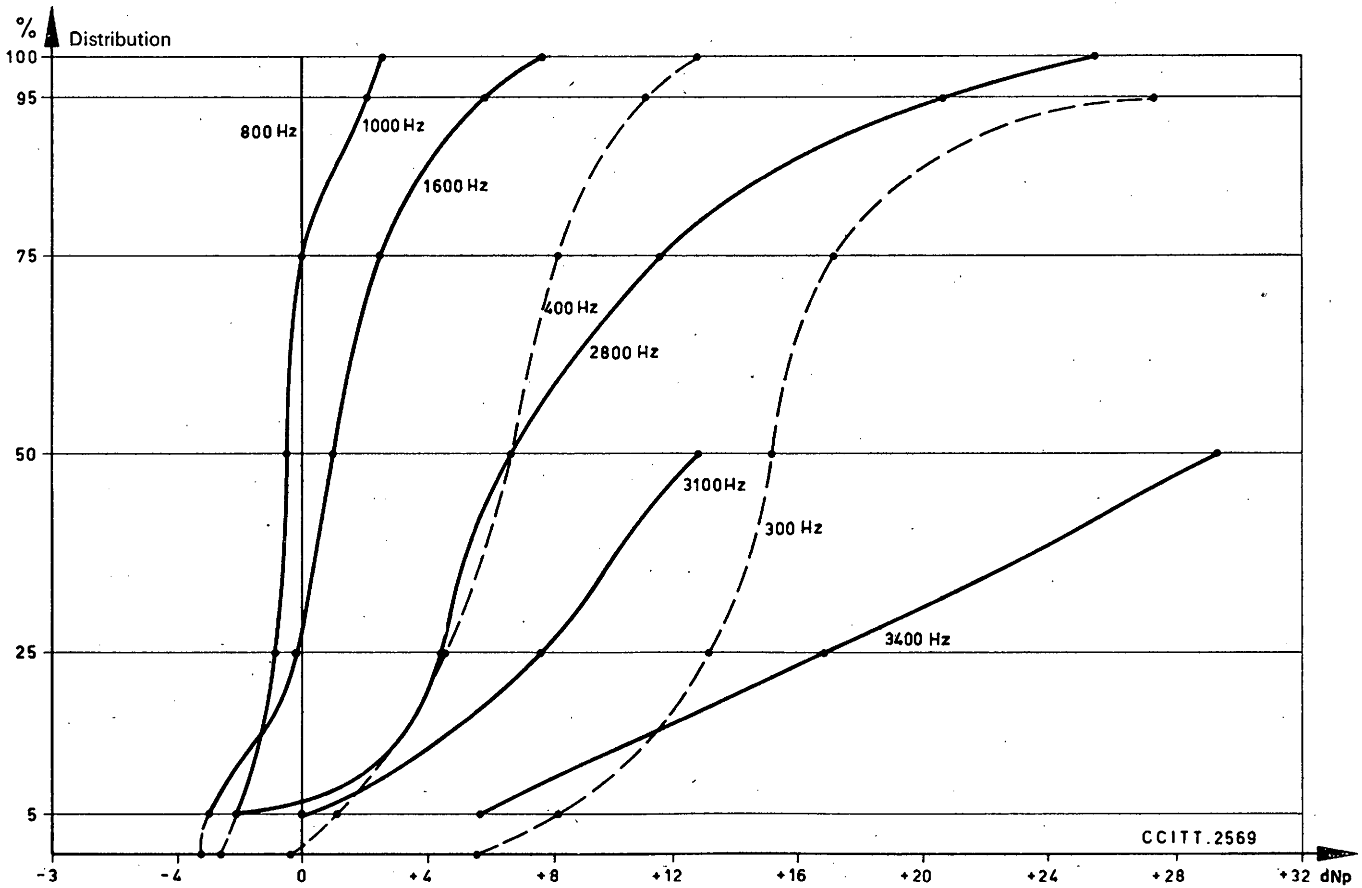


FIGURE 22. — Distribution of insertion loss distortion relative to 800 Hz for connections routed through a total of 8 exchanges

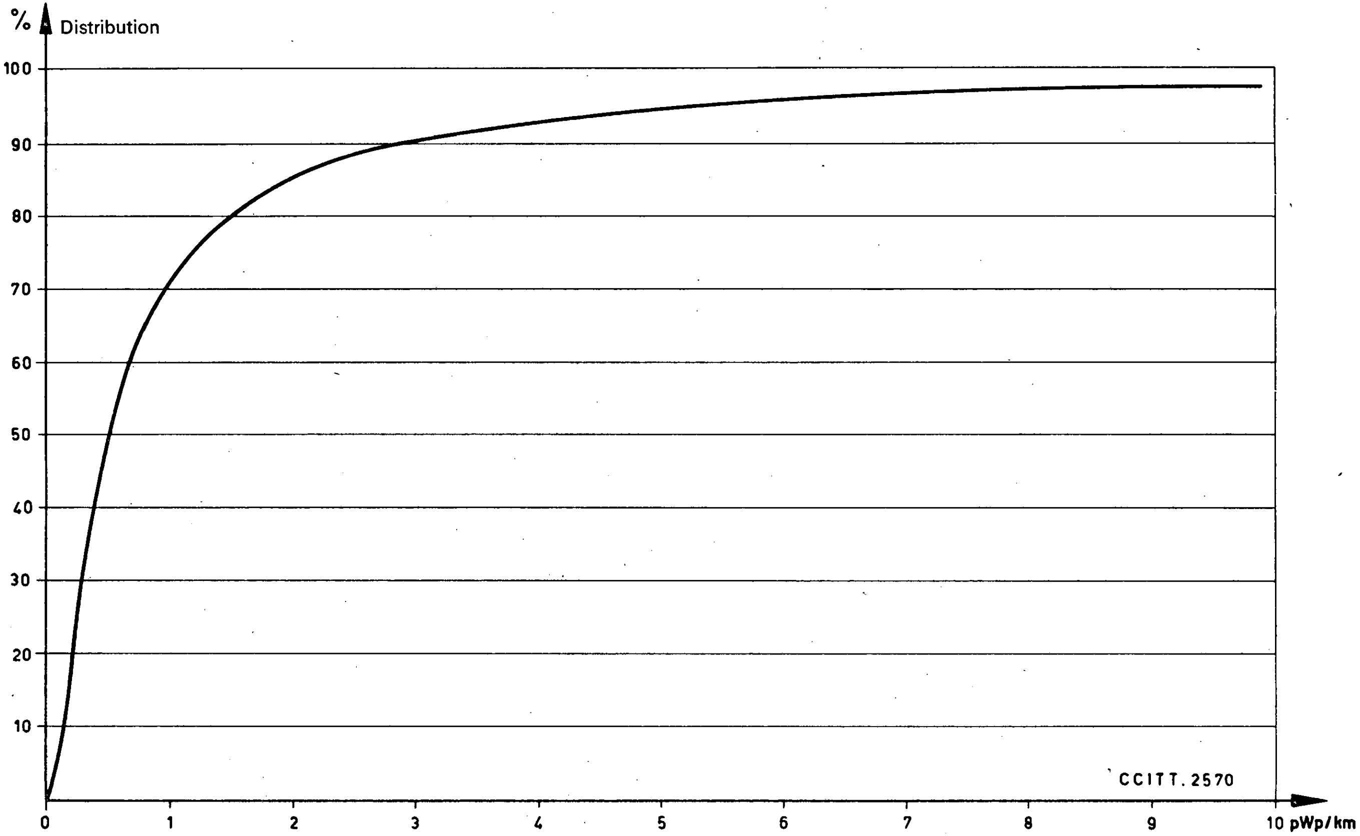


FIGURE 23. — **Cumulative distribution of the psophometric noise power per unit length in pWp/km**
(Sample size: 1292 connections)

Question 5/XVI — Difference in losses between the two directions of transmission

(new question)

Considering that

1. on the one hand, it may be desirable for telephony to have equality between the nominal values of reference equivalent for the two directions of transmission of a connection;

2. on the other hand, for non-telephony users it may be desirable to have equality between the nominal values of transmission loss between subscribers' stations for the two directions of transmission;

3. these desiderata may lead to conflicting requirements in a national transmission plan,

is it desirable to recommend any restrictions on the difference in nominal losses on the paths *a-t* and *t-b* in Figure 9 of *Blue Book*, Volume III, page 17?

Note 1. — The reply by Study Group XII to Question 3/XII will make it possible to frame considerandum 1 in more specific terms.

Note 2. — Annexes 1 and 2 discuss certain problems relating to this question.

ANNEX 1

(to Question 5/XVI)

The transmission plan recognizes that administrations are free to allocate the transmission losses in national systems as they wish and accordingly the only constraints imposed by the recommendations are those concerning reference equivalents and stability. This circumstance gives rise to the possibility of international connections having asymmetric nominal losses.

As an example of how this can arise, consider two administrations, one of which can guarantee a balance return loss of 3dB and the other a balance return loss of 6 dB. These two countries may choose to arrange the losses in their national networks as indicated in Figures 1 and 2 respectively. The diagrams are drawn in terms of virtual switching points and (practical) 3.5-dB loss termination units. The 10-dB value from the receive virtual switching point to the send virtual switching point is the target value for the path *a-t-b* referred to in Recommendation G.122-A.c), *White Book*, Volume III.

It should perhaps be emphasized that the country with 6-dB balance return loss is not obliged to put all the extra gain available in the receive path as shown in Figure 2; other arrangements are possible of course. However, the system shown does comply with the plan and hence could, if desired, be adopted.

It is easy to see that a connection between these two countries would have asymmetric nominal losses between national two-wire points (see Figure 3).

The amplifier shown in Figures 2 and 3 need not exist; the same effect could be obtained by switching out a pad and choosing suitable levels at the actual switching point. However, since the diagram is drawn in terms of virtual switching points and symmetrical 3.5-dB terminating sets, an amplifier symbol is needed.

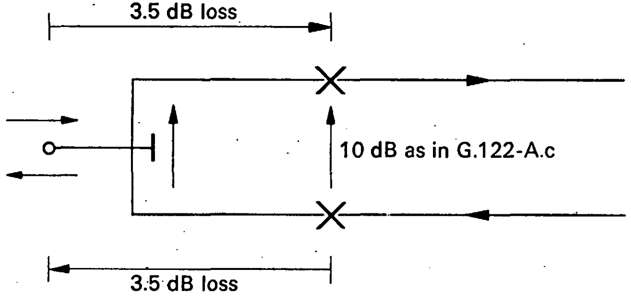


FIGURE 1. — Country with 3-dB balance return loss

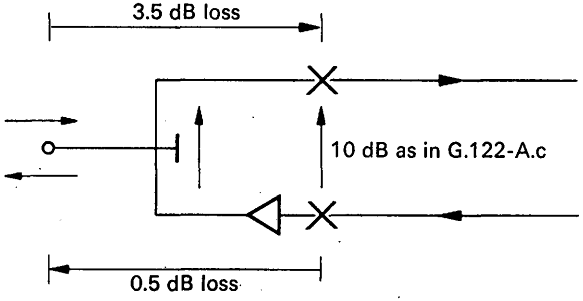


FIGURE 2. — Country with 6-dB balance return loss

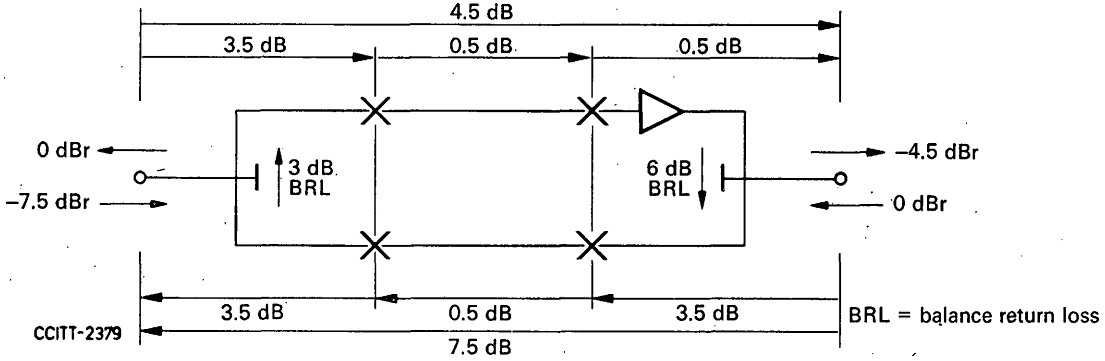


FIGURE 3. — A connection between the two countries

The Annex to Question 4/XVI contains information on the attenuation difference that may exist between the two directions of transmission. These differences were measured on connections of the type illustrated in Figure 4.

It should be noted that the values in the Annex to Question 4/XVI are *measured* differences and thus include not only systematic differences due to differences in planning methods but also random effects due to variations of transmission loss with time (and among circuits) of the chain of circuits.

Such variations mask the effect of the systematic differences.

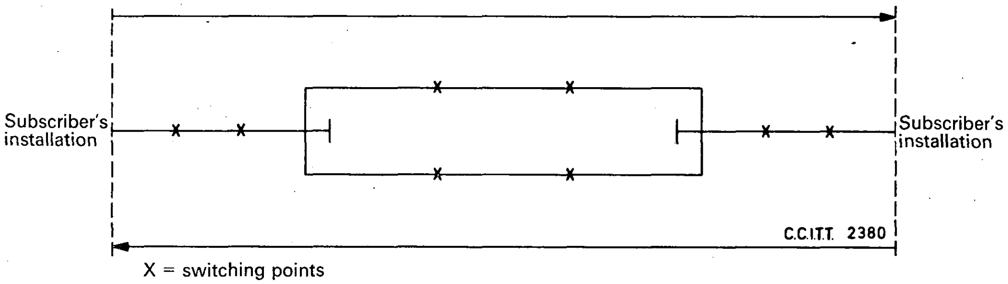


FIGURE 4

ANNEX 2

(to Question 5/XVI)

How unequal losses may occur

(Contribution from the Australian Administration and N. V. Philips' Telecommunicatie Industrie)

1. *Introduction*

This annex shows how

- the choice of a point of relative level in the two-wire network
- the application of Recommendation G.122-A and
- economic considerations

can each result in unequal two-wire-to-two-wire losses in the two directions of transmission of an international connection.

The inequalities of transmission loss described are those due to the application of planning rules, of which they are an unintentional by-product or the intentional result.

In addition, inequalities of transmission loss in the two directions can occur due to uncorrelated variations of transmission loss with time in various parts of the connection; these inequalities are not described in this annex.

2. *Effect of choice of relative level point in two-wire chain*

The design and performance of transmission systems is dependent on the signal levels presented at their inputs. It is necessary, therefore, to assign a conventional relative level to each switching point in a national chain, so that transmission equipments interconnected at each point will be properly loaded.

At four-wire switchpoints the choice of a nominal relative level may be made independently of the relative level of the international system and of the actual speech levels outgoing from the national network. This is because each of these switchpoints is in a channel-chain comprising (effectively) amplifiers and attenuators, and their nominal relative level may be adjusted merely by moving the points electrically upstream or downstream.

There is less flexibility in the assignment of the relative level at the primary centre PC or the local exchange LE in Figure 1, both of which are assumed here to have two-wire switches.

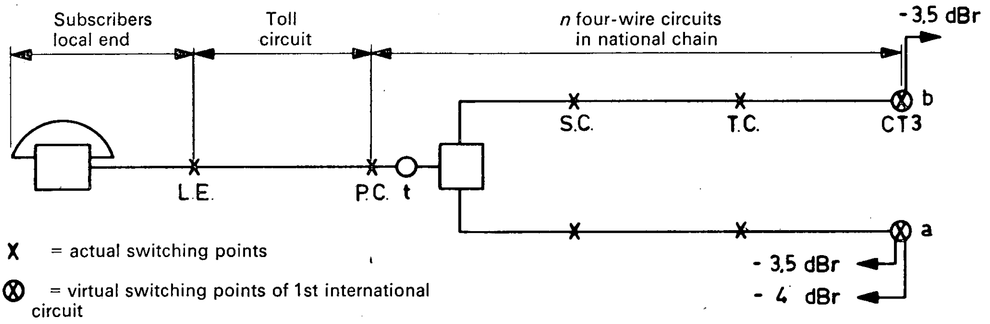


FIGURE 1. — **National chain**

Maximum signal levels (which define the overload characteristics of transmission systems) will be those passing from left to right in Figure 1 and their nominal relative level will be a function of the distribution of sending reference equivalents to the left of the point: the lower the reference equivalents, the higher the nominal relative level.

Minimum signal levels (which influence the signal-to-noise ratio of channels routed over transmission systems) will be those passing from right to left and originating in distant national or international subscribers' stations.

Having assessed the present or planned maximum and minimum signal levels present at the LE and PC in Figure 1, an administration may assign a nominal relative level to each of these points.

As a result of these studies, different administrations can, quite properly, arrive at different conventional relative levels for the PC and hence, the point t (which may be coincident).

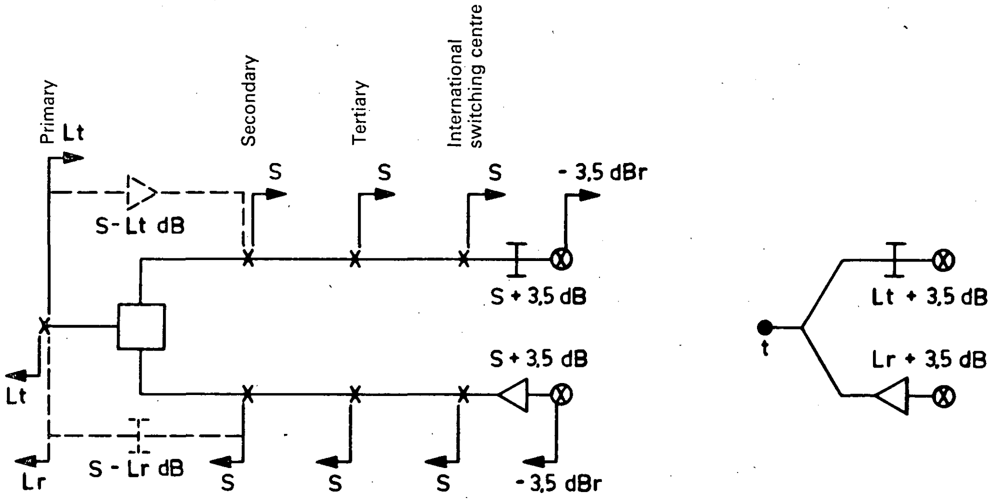
Figure 2 shows for a national chain the nominal relative levels at the two-wire point (sending: L_t dBr, receiving: L_r dBr) and the nominal relative levels at the actual switching points (S dBr). In this example, it is assumed for simplicity that the net contribution of each four-wire circuit is 0 dB; real circuit losses would add equally to each direction of transmission and can therefore be ignored in this discussion. The effective loss of the national chain between the two-wire primary centre and the first international circuit is a function of the relative levels L, as shown in Figure 2 b.

The asymmetry of the transmission loss of the national chain, or "differential gain" Δ, amounts to:

$$\Delta = L_t + L_r + 7 \text{ dB} \tag{1}$$

An international connection between two countries A and B, applying in their national networks differential gains of Δ_a and Δ_b dB respectively, will have asymmetric transmission, amounting to:

$$\delta = \Delta_a - \Delta_b \text{ dB} \tag{2}$$



Note: indicates send relative level of circuit in direction of arrow

FIGURE 2. — **Nominal relative levels in national chain**

Sometimes planning rules are applied, aiming at relative levels at the two-wire point to be equal for sending and receiving ($L_t = L_r = L$ dBr). This practice results in a differential gain (1) of:

$$\Delta = 2L + 7 \text{ dB} \tag{3}$$

An international connection between countries A and B, applying such rules, and having two-wire relative levels of L_a and L_b respectively, will have asymmetric transmission, amounting to $\delta = 2 \mid L_a - L_b \mid$ dB.

An example of this situation is given in Figure 3, which shows an international connection between country A ($L_a = -3$ dBr, $S = +1$ dBr) and country B ($L_b = -2$ dBr, $S = -2$ dBr), resulting in an asymmetric transmission of $\delta = 2$ dB.

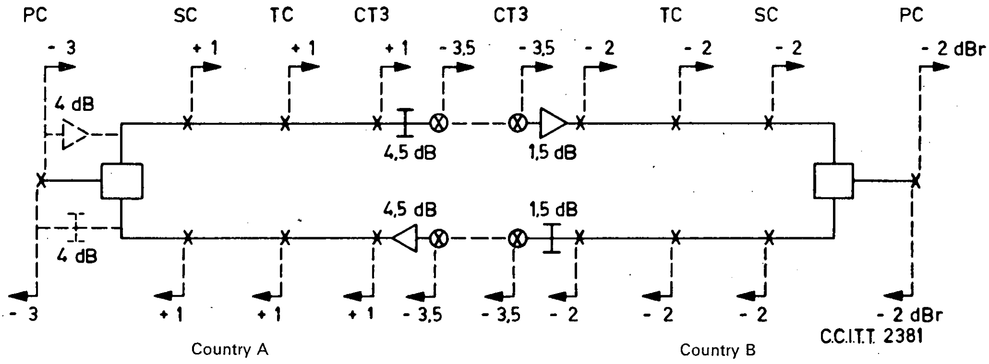


FIGURE 3. — **International connection with unequal losses due to the choice of different relative levels at the two-wire point**

3. *Effect of Recommendation G.122-A*

This Recommendation requires the path *a-t-b* (Figure 1) in the national part of an international connection to have a minimum loss of $(6 + n)$ dB over the band 0 to 4 kHz. When, for example, there are 3 four-wire circuits in the national chain, the loss of the path *a-t-b* should have a minimum value of 9 dB.

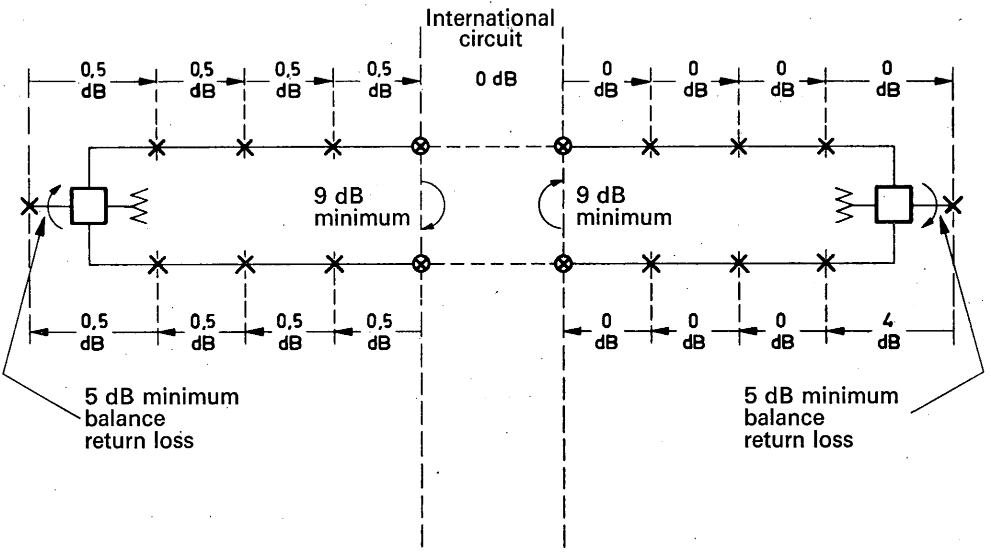
This loss comprises the balance return loss at the terminating set plus the losses from *a* to *t* and *t* to *b*.

Country A with 3 four-wire circuits and a minimum balance return loss of 5 dB may choose to allot the remainder of loss allowed by Recommendation G.122-A (4 dB) equally in the two directions of transmission. One way of doing this is shown in Figure 4 a.

Country B with the same number of four-wire circuits and the same minimum balance return loss may choose an unequal distribution of the allowable loss between the two directions, as shown in Figure 4 b). Each alternative complies with Recommendation G.122-A.

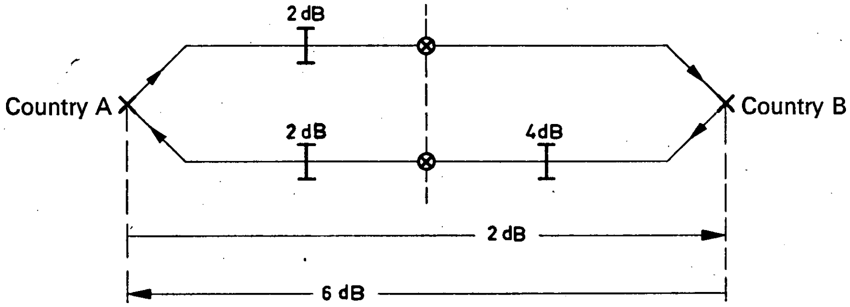
When country A is connected to country B via an international circuit of zero loss, the equivalent circuit is shown in Figure 4 c): there is a 4-dB difference between the two directions of transmission.

(It is assumed that each country would still comply with the requirements of Recommendation G.111 concerning national sending and receiving reference equivalents.)



a) Equal distribution of loss (country A)

b) Unequal distribution of loss (country B)



c) Equivalent circuit to a) + b)

FIGURE 4. — **Different interpretations of Recommendation G.122-A result in unequal losses in international connection**

4. *Effect of economics*

In a country of average size, Recommendation G.111 recommends that in at least 97% of actual international calls, the national sending and receiving reference equivalents do not exceed 20.8 dB and 12.2 dB, referred to the virtual switching points of the first international circuits.

Chapter V, paragraph 3.2 of the C.C.I.T.T.'s *National Telephone Networks for the Automatic Service* reads: "The most economical distribution of loss is to allow as much as possible to the primary area."

Administrations may regard the reference equivalents of Recommendation G.111 as practical planning maxima for national networks; if this is done, the condition for maximizing the loss in the primary area is a function of the losses a to t and t to b, as shown below.

In the national chain (Figure 5) the only section which must have the same reference equivalent in each direction is the toll circuit between the local exchange and primary centre, assuming that this is two-wire switched at each end. The following conditions then apply:

$$\begin{cases} T + C + B = 20.8 \text{ dB} \\ R + C + A = 12.2 \text{ dB} \end{cases}$$

in which A, B, C, T, R, are permitted maximum values.

$$\text{Then } T - R + B - A = 8.6 \text{ dB}$$

In practice, $T - R$ will be fixed by the telephone instruments and local network planning rules in a given country, then

$$B - A = 8.6 - (T - R) \text{ dB.}$$

If $T - R$ in a given administration happens to be 8.6 dB, then $B = A$ and there is no inequality of loss. In practice, however, a typical value of T might be 12 dB and the corresponding value of R might be 0 dB.

Then maximum economy in the primary area is obtained when:

$$B - A = 8.6 - (12 - 0)$$

$$= - 3.4 \text{ dB}$$

$$\text{or } B = A - 3.4 \text{ dB.}$$

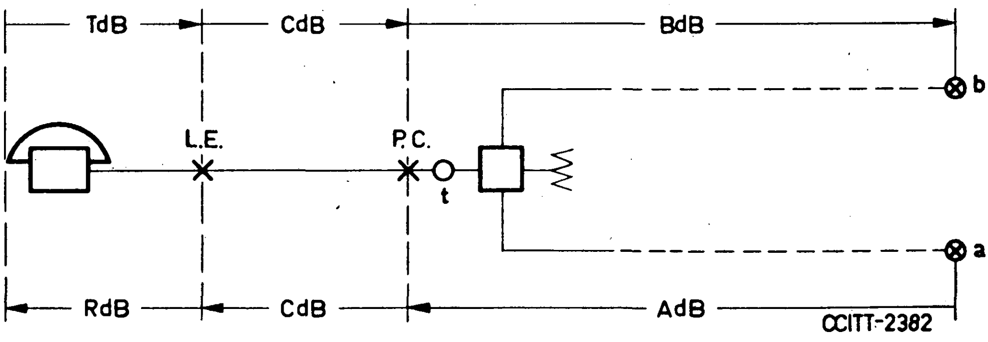


FIGURE 5. — **Basis for application of Recommendation G.111**

This yields an asymmetry of 3.4 dB in the national four-wire network; it follows that if $T - R$ is δ_1 dB in one national network and δ_2 in another national network, the difference in loss in opposite directions when the two networks are connected together will be $(\delta_1 - \delta_2)$ dB.

(The actual values of A and B, and therefore C, would depend on the balance return loss achievable; Recommendation G.122-A would apply. The relative level at the point t would also have to be considered.)

It may be observed, however, that the overall reference equivalent from subscriber A to subscriber B will, at least for limiting subscribers' lines, be equal to the reference equivalent from subscriber B to subscriber A.

The desirability of this equality is the subject of Question 3/XII.

Question 6/XVI — Characteristics of national systems

(continuation of points 5 and 7 of Question 1/XVI studied in 1964-1968)

Which general characteristics of national systems should form the subject of C.C.I.T.T. Recommendations to ensure that international connections are of suitable quality?

Note 1. — Sub-section 1.2 of part 1 of Volume III already contains several recommendations on this matter:

Recommendation G.121 lays down the limit sending and receiving reference equivalents of a complete national system (from and including the subscriber's set to the virtual switching points of an international circuit);

Recommendation G.122 specifies the conditions to be respected to ensure the stability of international connections and to limit the echo;

Recommendations G.123 and G.125 contain some recommendations relating to noise; the reply to Question 9/C of Special Study Group C will enable them to be completed.

Recommendations could also be envisaged for the " national chain " (the whole of the transmission circuits and switching equipments, between its virtual switching points in the international exchange and the terminals of the subscriber's set—in other words for the national system excluding the subscriber's set). These recommendations would apply to:

- attenuation distortion and group delay distortion as a function of frequency;
- linear crosstalk;
- and possibly to other characteristics.

Such recommendations—which should not of course be incompatible with existing recommendations relating to circuits or equipment, could be applied to a high proportion (say 95% or more) of international connections.

Note 2. — The results of measurements carried out in 1967 on national systems are given in the Supplements to Volume III of the *White Book*; further measurements will be carried out in 1968-1972, as mentioned in the Supplements to Volume IV of the *White Book*.

Question 7/XVI — Revision of the manual on Automatic Networks

(new question)

Revision of Chapter V of part A of the manual on *National Telephone Networks for the Automatic Service.*

Among the points which might usefully be studied in the course of this revision are:

a) Definition of a point of zero relative level on international and national circuits;

b) Possible effect of these definitions on the sending and receiving reference equivalents of the national system;

c) Examples of a loss distribution plan for national trunk circuits when the balance return loss is known;

d) Precautions against the effects of the high sensitivity of modern telephone sets;

e) Calculation of the reference equivalent in the passive part of the network in accordance with Annex 2 to Recommendation G.121, *White Book*, Volume III.

f) Co-ordination with the texts concerning the design and construction of local networks given in the manual on *Local Telephone Networks*.

Summary of questions assigned to Study Group XVI

Question No.	Short title	Remarks
1/XVI	Circuits of the switched network	This question will be studied under the points indicated below.
2/XVI	Characteristics of leased circuits	-
3/XVI	Circuits on communication-satellite systems	To be studied in conjunction with Question 6/XII
4/XVI	Attenuation distortion in an international connection	
5/XVI	Difference in losses between the two directions of transmission	Related to Question 3/XII
6/XVI	Characteristics of national systems	Related to Question 9/C
7/XVI	Revision of manual on Automatic Networks	

Details of points to be studied under Question 1/XVI

Question 1/XVI Point	Short title	Other references
1	Definition of reference connections	
2	Use of echo suppressors	
3	Balance return losses in national networks	Question 19/XII
4	Improvement in terminal balance return loss with non-linear devices	Question 19/XII
5	Transmission characteristics for an international automatic exchange	
6	Restriction on system loading	Questions 10/XII, 11/C
7	Laboratory assembly representing a connection	S.G. XII *
8	Carrier systems for very short distances	Question 24/XV
9	Transmission tests with signalling system No. 6	

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* This problem is being examined by Study Group XII, but there is no Question on the subject.

"Noise" questions assigned to Joint Special Study Group C in 1968-1972

GENERAL NOTES

1. Since Special Study Group D was set up by the Plenary Assembly, all questions relating to pulse code modulation (p.c.m.) have been assigned to this Study Group for the time being.

The Chairman of Special Study Group D will make arrangements with the other Chairmen for effecting liaison with the other Study Groups concerned as work progresses.

2. When a question is of interest to more than one Study Group and no joint study group has been set up to deal with it, the mention of the other Study Group(s) concerned is intended for the information of the members of the Study Group to which the question has been assigned, to enable them to arrange for the necessary co-ordination *within their national* administrations, in accordance with a decision of the IVth Plenary Assembly.

3. Special Study Group C is a joint study group and it is a normal part of its work to obtain the co-operation of any C.C.I.T.T. or C.C.I.R. study groups that may be interested in any of its questions.

Question 1/C — Signal/noise ratio and telegraph operation on radio-relay links using tropospheric scatter

(continuation of Question 1/C studied in 1964-1968)

Information should be collected on the statistical distribution, as a function of time, of the signal-to-noise ratio, under actual service conditions, of telephone circuits set up on radio links using propagation by tropospheric scatter.

Note 1. — Annex 1 to this question contains guidance on the way information regarding the statistical distribution should be obtained.

Note 2. — Annex 2 to this question gives useful guidance for studies of the behaviour of various recommended telegraph systems on tropospheric scatter links: these studies form a preliminary to a future study of additional clauses concerning telegraph transmission as referred to in Note 4 of C.C.I.R. Recommendation 397-1.

ANNEX 1

(to Question 1/C)

Information to be collected for the study of Question 1/C

a) *Noise recordings*

Administrations are invited to make recordings on magnetic tape of the noise in telephone channels on tropospheric scatter links. The recordings should consist of samples having a duration of about one to three minutes, corresponding with the duration of a telephone call. If possible, the samples should be representative of the different propagation conditions which are encountered on the link. The recordings should include a single frequency for the purpose of establishing the correct level. It is proposed that the recordings should be sent to the C.C.I.T.T. Secretariat as soon as possible. It is intended that the recordings should be available for any administration that wishes to study the effect of noise on telephone speech. It would be possible for recordings taken on single sections of a tropospheric scatter link to be combined to represent the noise at the end of a 2500-km circuit. Administrations are asked to supply full information regarding the radio path and the radio equipment, including the type of modulation and the type of diversity reception.

b) *Noise measurements*

Administrations are also invited to send to the C.C.I.T.T. Secretariat, as soon as possible, the results of measurements of noise power in telephone channels on trophospheric scatter links. The results could be in the form of distribution curves over one month, measured with a time constant (integrating time) of one minute or one second. Information on the variation of hourly median values and on the variations within each hour would also be useful. Administrations are requested to give full information on the radio path, and on the type of modulation and of diversity reception.

c) *Other information required*

1. Hypothetical curves showing the expected shape of the distribution of hourly mean noise power (measured at a zero relative level point), over a month, for a 2500-km circuit.
2. Hypothetical curves showing the expected distribution of noise power, over a month, measured with an instrument of time constant of 1 minute, for a 2500-km circuit.

The curves indicated under 1 and 2 in conjunction with the recordings under a could be used by Study Group XII to give an opinion on the service which would be provided.

ANNEX 2
(to Question 1/C)

Report by C.C.I.T.T. Study Group IX (June 1964, amended in 1966 further to a proposal by Joint Special Study Group C)

The experience to date in telegraph transmission over radio-relay systems using tropospheric-scatter propagation seems to show that satisfactory transmission is generally obtainable only if an appropriate diversity system is employed on the radio-relay system; additional clauses cannot yet be suggested.

The noise encountered on scatter radio-relay systems is by its very nature much more troublesome for telegraph transmission than a noise of the same mean power level encountered on a line-of-sight radio-relay system. This may be ascertained from published information for the case of a circuit which is subject to Rayleigh fading. To achieve a standard performance similar to that of line-of-sight radio-relay systems, one must determine the effects of fading and diversity upon events having a probability of the order of $1/10^5$. From the work referred to above, it may be deduced that with no diversity the additional S/N penalty amounts to 36.5 dB, with dual diversity 14 dB and quadruple diversity 4.3 dB.

Experience to date seems to show that satisfactory telegraph transmission (as far as C.C.I.T.T. Recommendation F.10 is concerned, i.e., with at most three errors in 100 000 telegraph signals) is obtainable only if an appropriate diversity method is used on the radio-relay system. This even holds good of scatter radio-relay systems complying with Recommendation 393 of the C.C.I.R., if they are to be used to give international telegraph circuits of some 2500 km in length. For scatter systems used when there are no other media available (mentioned in paragraph 3 of C.C.I.R. Recommendation 397-1) another point to be taken into account is that noise peaks may be five times more frequent for circuits of equal length in practice.

Moreover, the standardization of 50 bauds/240 Hz/v.f. telegraphy in Recommendation R.37 constitutes a new factor and the use of these new systems should be studied.

Question 2/C — Noise limits for telegraphy and data transmission on a telephone circuit of more than 2500 km

(continuation of Question 2/C studied in 1964-1968)

C.C.I.T.T. Recommendations G.143 and G.153 give the permissible limits for mean circuit noise and its variation with time at the end of a telephone-type circuit of more than 2500 km. C.C.I.R. Recommendation 353-1 gives the same limits for short periods of time with regard to circuits set up via communication satellites.

Are these limits tolerable for telegraphy and data transmission, taking into account:

a) the standardization of v.f. telegraph systems at 50 bauds/240 Hz and at 100 and 200 bauds;

b) data transmissions at bit rates of more than 1200 bits/second;

c) the effect of impulsive noise as measured with an instrument that complies with new Recommendation H.13, *White Book*, Volume III?

Question 3/C — Low-noise channels for very long circuits

(continuation of Question 3/C studied in 1964-1968)

Should new or additional recommendations be drawn up for the design of overland cable, radio-relay systems or short-distance submarine cable systems, so as to permit the selection of low-noise channels which are suitable for very long circuits in accordance with C.C.I.T.T. Recommendations G.152 and G.153, since the conventional assumptions of G.223, e.g. nominal mean power, may not apply as they stand to such circuits and may need to be freshly determined?

Note 1. — Account should be taken of the following factors:

a) Proportion of channels in a system which are to be selected as high quality;

b) Proportion of channels in a system which are to carry voice-frequency telegraphy, data signals and other signals with a long-term mean power higher than that assumed for telephony, as given in Recommendations V.2 and T.11, for instance [1];

c) Use of call concentrators or other factors affecting the average activity [1];

d) Use of 16-channel terminal equipment (from the points of view of loading [1], freedom from carrier peaks at 4-kHz multiples);

e) Measurements of speech power on world-wide circuits [1];

f) Possible increase in the capacity of long-distance transmission systems using submarine cables and communication-satellites;

g) Use of compandors.

Note 2. — The results of this study will be communicated to Study Group XV and to the C.C.I.R. Study Groups IV and IX.

ANNEX 1

(to Question 3/C)

Low-noise channels for very long circuits

(Reply by Special Study Group C to Question 3/C, February-March 1968)

General

Special Study Group C considers that the mean hourly noise performance of low-noise channels for very long telephone circuits should not be worse than 1.5 pW/km (exclusive of frequency-division modulating equipment). With regard to frequency-division modulating equipment, it is assumed that its contribution would not exceed the values given in Recommendation G.143, A.b. The resulting circuits would then be of 2 pW/km (or better) quality, which would be in keeping with Recommendations G.123, G.143 and G.153.

The methods considered for providing low-noise channels include derivation from:

1. Existing large-capacity cable and radio-relay systems designed in accordance with Recommendation G.222, by a) selection of channels or by b) adaptation.

2. Other large-capacity cable and radio-relay systems designed to meet new and more stringent objectives than those of Recommendation G.222.

1. *Existing large-capacity systems for Recommendation G.222*

a) *Selection of channels*

In general, traffic and other practical considerations indicate that channel selection would be considered worth while only if at least 10% of a system can be made available as low-noise channels.

Radio-relay systems — In the light of the limited documentation available up till now, the indications are that the above requirement would not be met in general, but that certain systems might be capable of doing so.

Cable systems — Channel selection is likely to provide 10% or in some cases even more of 1 pW/km channels and 30% or more of 1.5 pW/km channels without detriment to system margin.

b) *Adaptation*

This entails removing channels from service, removing or modifying pre-emphasis characteristics to increase the effective sending level of low-noise channels.

---

[1] All these points are to be studied in conjunction with Question 11/C.

Radio-relay systems — In the case of existing radio-relay systems, theoretical studies and limited tests suggest that, by removing the pre-emphasis characteristics, it should be possible to obtain results as indicated in the table below:

TABLE

Number of low-noise channels provided by system adaptation
(Reduction of load to 65% and removal of pre-emphasis)

System channel capacity		Number of low-noise channels		Number of standard channels
Nominal	65%	1 pW/km	1.5 pW/km	1.5 pW/km-3 pW/km
1800	approx. 1200	approx. 240	approx. 400	approx. 800
1200	» 800	» 180	» 300	» 500
960	» 600	» 150	» 240	» 360
600	» 360	» 140	» 220	» 120
480	» 300	» 120	» 200	» 100
N	» $0.65N$	» $5.5\sqrt{N}$	» $9\sqrt{N}$	—

In certain cases where the pre-emphasis characteristics and the deviation are replaced by the values corresponding to a system which has a lower channel capacity it appears that, at least in some instances, it is possible to obtain as many as 55% of all channels having 1 pW/km performance. In other cases where only the pre-emphasis is changed, about 50% of all channels would provide 1.5 pW/km performance and a still smaller percentage would give 1 pW/km on all channels.

Cable systems — In the case of cable systems, the adaptation considered consists of reducing the input signal bandwidth and of modifying the pre-emphasis to fit the reduced maximum line frequency (pilot frequencies remain at the original frequencies). The sending level is then adjusted to obtain minimum noise.

Theoretical considerations (see Annex 2) indicate that more than 67 to 74% of the normal channel capacity could be made available for a threefold reduction in the original noise power. The lower figure applies when the section loss at the maximum frequency in the original system is 30 dB, the upper for 40 dB section loss. If a twofold improvement should be considered adequate the yield would be 78 to 82%, other factors being unchanged. The yield is noticeably higher in this case. In actual practice, the yield is likely to be higher in both cases.

2. *Other large-capacity systems designed to meet more stringent noise objectives than those of Recommendation G.222*

This method forms the subject of Question 10/C.

ANNEX 2

(to Question 3/C)

Estimation, on basis of repeater capability considerations, of yield of low-noise channels from cable systems designed for 3 pW/km line noise performance

(Contribution by the International Telephone and Telegraph Corporation)

"Repeater capability"—System requirement

Repeater capability (A) is defined as follows:

$$A = S + 10 \log_{10} R^2 N \text{ dB}$$

In this formula

R = number of repeater sections in the 278-km homogeneous section

N = normal channel capacity

S = repeater section loss at normal maximum frequency and is proportioned to $\sqrt{N}$

If the number of channels is restricted to the N_1 lowest channels the repeater capability requirement is reduced by ΔA dB.

$$A - \Delta A = S\sqrt{\frac{N_1}{N}} + 10 \log_{10} R^2 N_1$$

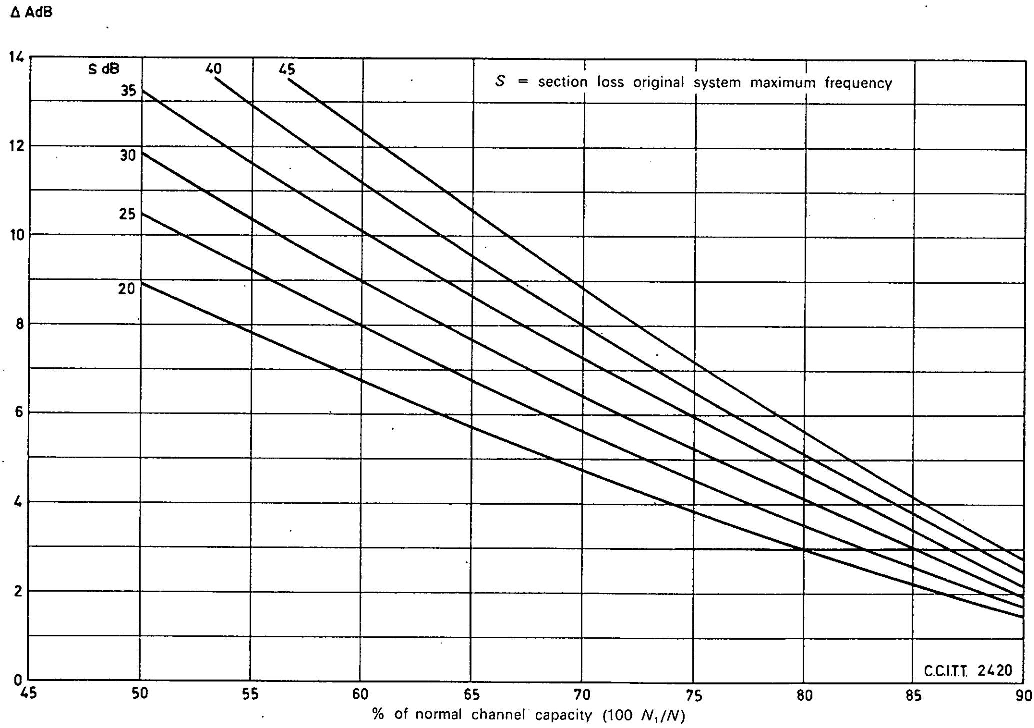

FIGURE 1. — **Reduction in channel capacity/reduction ΔA in repeater capability**

(Repeater spacing fixed)

By subtracting this formula from that for A it is found that:

$$\Delta A = S\left(1 - \sqrt{\frac{N_1}{N}}\right) + 10 \log_{10} \frac{N}{N_1} \text{ dB.}$$

Figure 1 shows ΔA as a function of $\frac{N_1}{N}$ for various values of S dB.

Repeater capability—noise performance

The repeater for the normal system is assumed to lead to a certain noise performance. It is required to improve the noise performance by X dB by reducing the number of channels, redesigning pre-emphasis and readjusting the send levels.

The repeater A factor depends on the acceptable send level, which is determined by non-linear distortion, and also on the acceptable receive level, which is determined by thermal noise (maximum line frequency).

If now the noise per km is reduced by X dB, the send level must be reduced by $\frac{X}{2}$ dB, assuming third-order non-linear noise to be dominating, and the receive level must be increased by X dB so that the section loss must be reduced by $\frac{3X}{2}$ dB.

It then follows that the repeater capability factor will be reduced by $\frac{3X}{2}$ dB. For a threefold reduction in noise

$$\Delta\ A = 15 \log_{10} 3.$$

By using this value for ΔA in Figure 1, the fraction N_1/N can be read for specified S values.

Question 4/C — Hourly mean noise for radio-relay links

(continuation of Question 4/C studied in 1964-1968)

a) How should the clause relating to the mean psophometric power during any hour (paragraph a.1.1 of Recommendation G.222) be interpreted and applied in practice in the case of radio-relay links?

b) Is it desirable to have a new rule, in addition to or in place of that given in G.222b, paragraph 4, for the subdivision of the hourly mean noise among the homogeneous sections?

Question 5/C — Artificial load for systems providing less than 60 carrier channels

(continuation of Question 5/C studied in 1964-1968)

In simulating the telephone multiplex signal when making measurements of intermodulation noise on carrier systems, of which the capacity is less than 60 channels, set up on cable or radio-relay links, what type of artificial load is to be recommended that would represent as nearly as possible normal operating conditions during the busy period?

Note. — Particular attention will be paid to the following points:

1. Several administrations consider that the simplest and most practical method for tests outside actual operating conditions of systems having 12-60 telephone channel capacity consists in applying a

white-noise signal, defined in Recommendation G.223 as the conventional load used for calculations. The level indicated in that Recommendation may be used provisionally, but the possibility that a slightly higher level would give a more realistic representation for the small-capacity systems with which this question is concerned should be considered (see Annex 1).

2. It has also been proposed that, for maintenance purposes in small-capacity systems, the conventional telephone signal defined in Recommendation G.227 should be applied to one or two channels and that the disturbance produced in another channel in the system be measured. As an example, such a method is described in Annex 2.

3. Administrations are asked to study whether it is necessary to define a signal simulating the telephone multiplex signal in systems providing less than 12 telephone channels (e.g. 3 to 6 channels).

4. Administrations are asked to provide information, on the normal percentage utilization of small-capacity systems by telephone channels, voice-frequency telegraph bearer circuits, data transmission and sound-programme circuits. This study is to be conducted in conjunction with the reconsideration of the conventional load (see Question 11/C).

5. It is pointed out that detailed C.C.I.T.T. recommendations on the characteristics of intermediate repeaters in symmetric-pair systems already exist.

6. C.C.I.T.T. Study Group IV was informed that, in the opinion of Joint Special Study Group C, the method of measuring non-linearity distortion described in Supplement No. 5 (*Blue Book*, Volume IV, p. 266) is not appropriate to check whether a system satisfies the prescribed noise objectives.

ANNEX 1

(to Question 5/C)

Contribution of France

Carrier system design depends upon calculations which use a number of assumptions and conventions, particularly as regards the conventional load representing the multiplex signal (see Recommendation G.223, paragraph 2). For measurement purposes, it would seem advisable to use a signal for simulating the multiplex signal which has the same characteristics as the one used for the calculation in order to facilitate comparison between the results of the calculation and the measurement results. It is well known that for a small number of channels a uniform-spectrum random noise is a poor representation of the real signal. Nevertheless, in the absence of any proposal for a signal which is easy to produce and which represents better the real signal, it is considered permissible, for the sake of simplicity, to adopt for both calculation and measurement a uniform-spectrum random noise, in which the absolute level of conventional mean power has in any case been set deliberately high.

ANNEX 2

(to Question 5/C)

Artificial load for systems providing less than 60 carrier channels

(contribution by BUDAVOX (Budapest Telecommunication Company, Hungary)

1. *General*

In the case of 12 channels or less the rule given by Recommendation G.222, to determine the artificial load for measuring the intermodulation noise, does not seem acceptable. Therefore, as we suppose, a special kind of artificial load signal must be used in order to ensure a perfect simulation of the real speech signal for the test of low channel equipments.

A short description of a realized speech-simulating generator is given below, designed and proposed for measurements of 3, 6, 8 and 12 channel-carrier telephone systems as well as for tests to be carried out in laboratories checking and comparing other kinds of equivalent load signal sources.

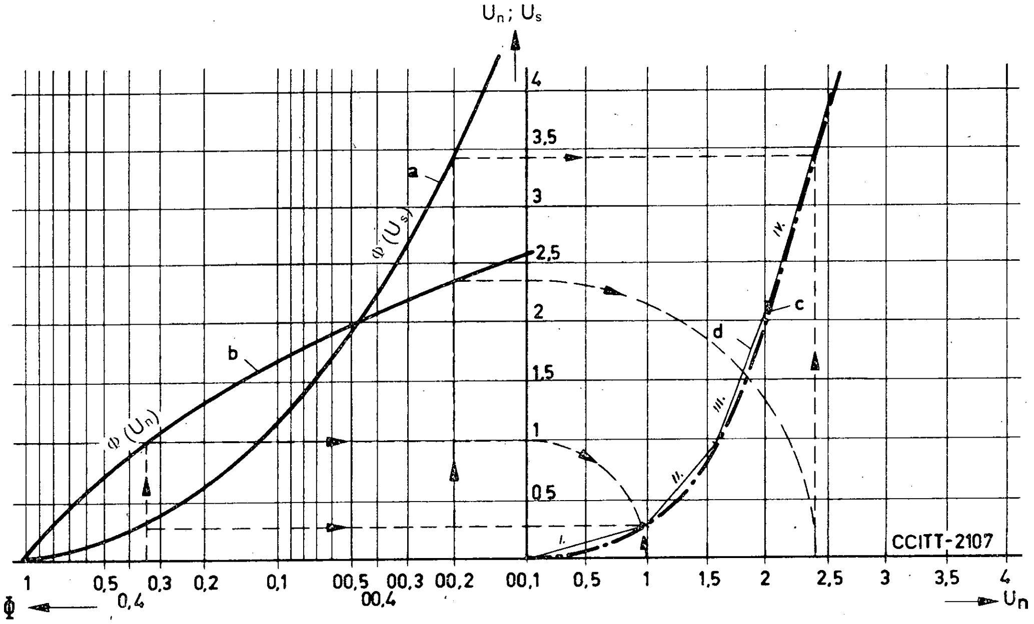

FIGURE 1

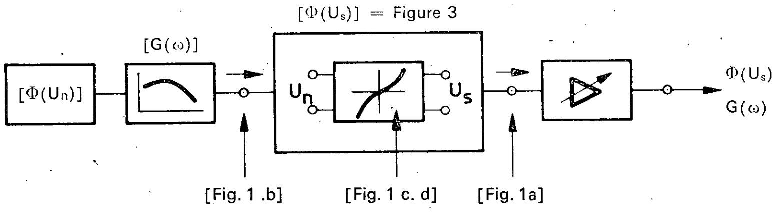

FIGURE 2

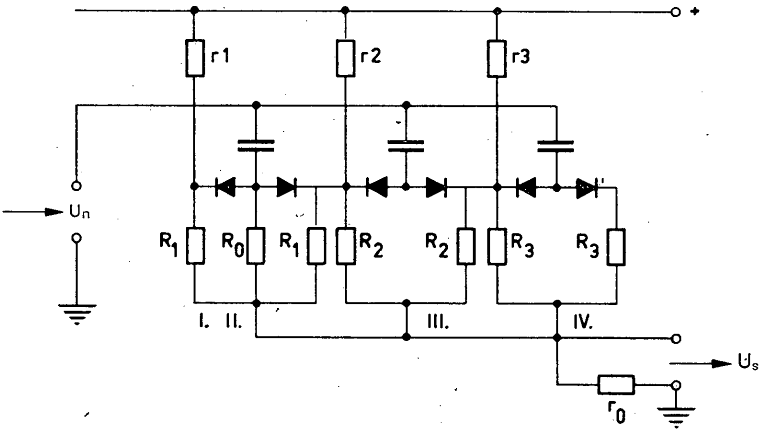

FIGURE 3

2. *Conditions*

The statistical properties of the speech signal, as a stationary and stochastic process, used to be characterized by the following two functions:

1. $\Phi\ (U_s)$: probability function of the instantaneous amplitude values in relation to r.m.s. value (see curve a on Figure 1 which has a non-Gaussian distribution as proved by Holbrook and Dixon);

2. 2. $G(\omega)$: power density function (spectrum) which is given by Recommendation G.227.

The artificial signal sources used before were all in conformity only with condition 2 above—i.e. white noise generators with normal probability distribution of the instantaneous amplitudes, $\Phi\ (U_n)$, see curve b on Figure 1.

The differences between these two curves are especially large at higher voltage peaks which are four to five times more frequent in speech than in the normal white noise, and which have then a more decisive influence on the intermodulation phenomena. It is therefore necessary to adopt a generator which simulates the speech signal from both statistical standpoints 1 and 2 above. A speech-simulating generator (Figure 2) has been designed and proved on these conditions (Figure 3).

3. *Speech-simulating generator*

On Figure 2, a normal white noise source is marked by $[\Phi\ (U_n)]$ the output signal of which is led through a weighing *RC*-network resulting in the signal due to condition 2 in point 1, and curve b on Figure 1. The next stage is a non-linear network $[\Phi\ (U_s)]$ which transforms the normal distribution into one which corresponds to condition 1 in point 1, and is represented by curve a on Figure 1. The output amplifier gives then the wanted speech simulation according to functions $\Phi\ (U_s)$ and $G(\omega)$.

The dynamic transforming characteristic of the said non-linear network was determined by graphical way, shown on the right-hand part of Figure 1, the result of which process is a curve c and a function $U_s = f(U_n)$.

The technical realization of this characteristic was accomplished by a practically good approaching of curve c by a curve d composed of linear line sections I, II, III and IV. These four linear sub-ranges of the non-linear network were realized by means of adequately designed combinations of resistors and biased diodes, as shown on Figure 3.

It must be noted that also the power density of the input signal might be slightly modified by this dynamic transformation, but this effect had been taken into account (and thus pre-equalized) at the design of the $[G(\omega)]$ network.

The final output signal of the above generator proved—as thoroughly analysed—to be very similar to that of the actual speech signal of a telephone channel.

Question 6/C — Integrating instruments for noise measurements

(continuation of Question 6/C studied in 1964-1968)
(documentary question)

Administrations are asked to furnish information, for subsequent incorporation in the supplements to Volume III, on the characteristics of instruments used or proposed for studying the noise performance of circuits and systems, in terms of integration times of one minute (psophometrically weighted) and 5 ms (unweighted) and for measuring the mean hourly power to check whether the general noise objectives (Recommendation G.222) are satisfied.

Note. — The information already assembled in the study of this question in 1964-1968 is contained in Annexes 1 and 2.

ANNEX 1

(to Question 6/C)

Equipment designed in the United Kingdom for the measurement of noise in a telephone channel

1. *Introduction*

The United Kingdom has carried out three series of measurements, extending over the last 10 years, of the noise power in the telephone channels of multichannel telephony line-of-sight, radio-relay links. The measurements lasted for about 12 months in each case and were conducted on links having capacities of 240, 600 and 960 telephone channels. The results of the measurements on the 600-telephone channel link are published in reference [1].

During each series of measurements the following information was recorded:

1. the mean power of the noise during each successive minute;
2. the number of times in each successive period of 10 minutes that the noise power, measured with an integrating time of 5 ms, exceeded 10^5 pW and 10^6 pW;
3. the aggregate time during each period of 10 minutes for which the above values of noise power were exceeded.

On the 600-telephone channel link, information was also recorded of the mean power of noise over an integrating time of one second.

2. *Measuring equipment*

The measuring equipment referred to was built some years ago and is now obsolete. Furthermore, facilities for the direct measurement of mean noise during an hour were not provided. New equipment has now been designed and built which takes advantage of the experience gained and employs circuit techniques and components not previously available. The new equipment will measure and record the following information on a telephone channel:

1. the mean power of the noise during each successive minute;
2. the mean power of the noise during each successive hour.

One of the objectives of the design is to reduce to a minimum time spent on the analysis of recorded information.

2.1 *Descriptions of measuring equipment*

2.1.1 *General*

The equipment is transportable and is contained in two cases. It is mains-operated, transistorized and designed for continuous operation.

A block diagram of the measurement equipment is shown in Figure 1.

The signal source to the equipment is a d.c. analogue of the instantaneous noise power derived from a true r.m.s. measuring instrument. The equipment is preceded by a white noise receiver when measurements are made in the baseband of multichannel telephone systems.

2.1.2 *One-minute channel*

The incoming signal from the true r.m.s. voltmeter is fed via a d.c. amplifier to an operational amplifier type integrator and then to a precise high stability d.c. log converter. The output from the

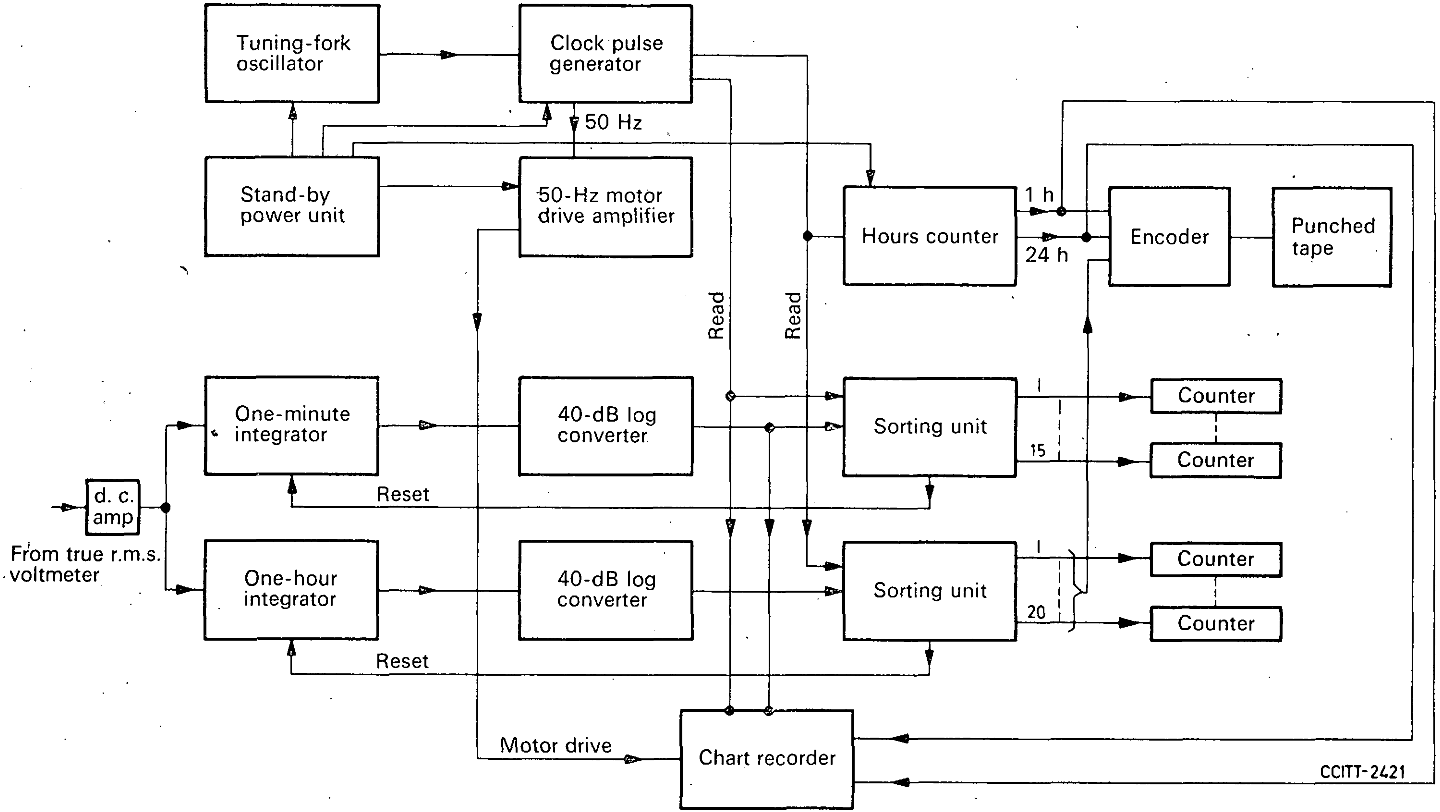

FIGURE 1. — **One-minute and one-hour noise-measuring equipment**

log converter is fed to a sorting unit which selects one of 15 output channels according to the level of the input signal. At the completion of the one-minute integrating time an impulse is generated which causes the electromagnetic counter associated with the selected channel to step on by one unit. The noise level is thus quantized to 15 levels in 15 steps of 2 dB covering a dynamic range of 30 dB. After the counter has operated, a reset pulse is derived which restores the integrators to zero. The one-minute mean noise is also recorded on a chart recorder of the type which employs pressure-sensitive paper.

To ensure accurate timing the motor of the chart recorder is operated from a 50-Hz amplifier which is controlled by the clock.

2.1.3 *One-hour channel*

This is basically the same as the one-minute channel except that the information is recorded in 20 steps of 1 dB, thus giving a dynamic range of 20 dB. To permit a more detailed analysis to be made, in addition to storage counters, facilities are provided to enable the information contained in the counters to be punched onto paper tape which can then be processed by a computer.

2.1.4 *Clock and control*

The clock is controlled by a tuning-fork oscillator, which produces impulses at intervals of one minute, one hour, 12 hours and 24 hours. These impulses are used for the various timing activities of the equipment and to provide event markers for the punched tape and chart recorder. So that the clock can be related to real time, the time of day in hours can be displayed in binary form on a set of lamps. A facility is also provided which enables the clock to be stepped on by one hour at a time.

3. *Five millisecond measurements*

New equipment for this measurement has also been designed and is being built separately. It will operate from the same signal as the equipment described above.

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[3] TURNER, D.: Equipment for the measurement of some characteristics of the noise in telephony and television channels; *The Post Office Electrical Engineers' Journal*, Volume 55, Part 4, pp. 231 to 236.

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ANNEX 2

(to Question 6/C)

Integrating measuring equipment used by the Administration of the Federal Republic of Germany for noise measurements

1. *Introduction*

In Question 6/C administrations are requested to describe the characteristics of the instruments they use for measuring noise power in systems, with different integration times (between 1 hour and 5 ms), as described in various recommendations of the C.C.I.T.T.

An example of this equipment is the automatic measuring set K 1003 described below, with which in-service supervision of the noise power in multichannel telephone systems can be ensured in accordance with C.C.I.T.T. Recommendation G.222 and C.C.I.R. Recommendations 393-1 and 395-1.

The device is generally connected to the v.f. output of non-busy channels of cable or radio-relay links. In the case of radio-relay links continuous supervision of the noise power at the h.f. output of a test channel can also be effected outside the baseband, in accordance with C.C.I.R. Recommendation 398-1. It is for this purpose, viz. supervision of radio-relay systems in the upper outband channel, that the device is being initially employed by the Federal German Administration.

The following quantities can be measured and the results can then be printed by teleprinter or recorded on perforated tape:

a) The mean psophometric power during any hour (one-hour mean value) (clause a.1.1 of Recommendation G.222). Exceeding of a selected limit of the one-hour mean value. Limit range between 100 and 100 000 pW0p. Cases of exceeding a second selected limit of the one-hour mean value can be printed out for further information.

b) A continuous sequence of one-minute mean values of the noise power in the range of 100 to 100 000 pW0p. Exceeding of a selected limit of the one-minute mean value, e.g. 47 500 pW0p (clauses a.1.2 and a.1.3 of Recommendation G.222).

c) The number of times a selected limit of the unweighted noise power has been exceeded during one minute, as measured with an integration time of 5 ms; limit e.g. 10^6 pW0 (5 ms value) (clause a.1.4 of Recommendation G.222).

d) The length of time in each minute during which a selected limit of the system load (volume), e.g. the conventional load in the busy hour, has been exceeded. The limit-value range can be adapted to all multichannel systems.

e) Date and time of day.

2. *Principle*

Figure 1 is a simplified block diagram of the noise-integrating measuring set. The output of the measuring channel of the system under test is applied to the input of a branching network 1. The output signal of one output of this hybrid is applied to a pre-amplifier 2 covering a wide dynamic range. A square-law unit 3 follows, the corresponding output signal being proportional to the noise power. An analogue-digital converter 4, which simultaneously acts as an integrator, converts this signal into the mean values of the noise power during each minute. The computer 5 processes and stores the output values of the analogue-digital converter and makes them available for output to the page-printer 6. In addition, the computer calculates after each minute the one-hour mean value from the one-minute mean values of the past 60 minutes.

The output signal of the second output of the branching network 1 is applied to another pre-amplifier 7. A square-law unit 8 (which is identical in design with the square-law unit 3) once more establishes an output voltage that is proportional to the noise power. It feeds an integrator 9 which sums up the total noise power during an integration interval of 5 ms. The comparator 10 finds out whether or not the limit selected has been exceeded during the 5 ms interval. The dead time for resetting the integrator is 50 µs and can thus be neglected with respect to the integration time. The four-digit counter 11 shows the number of such excess conditions and is interrogated every minute by the computer 5. The latter stores the information to keep it ready for output to the page-printer 6.

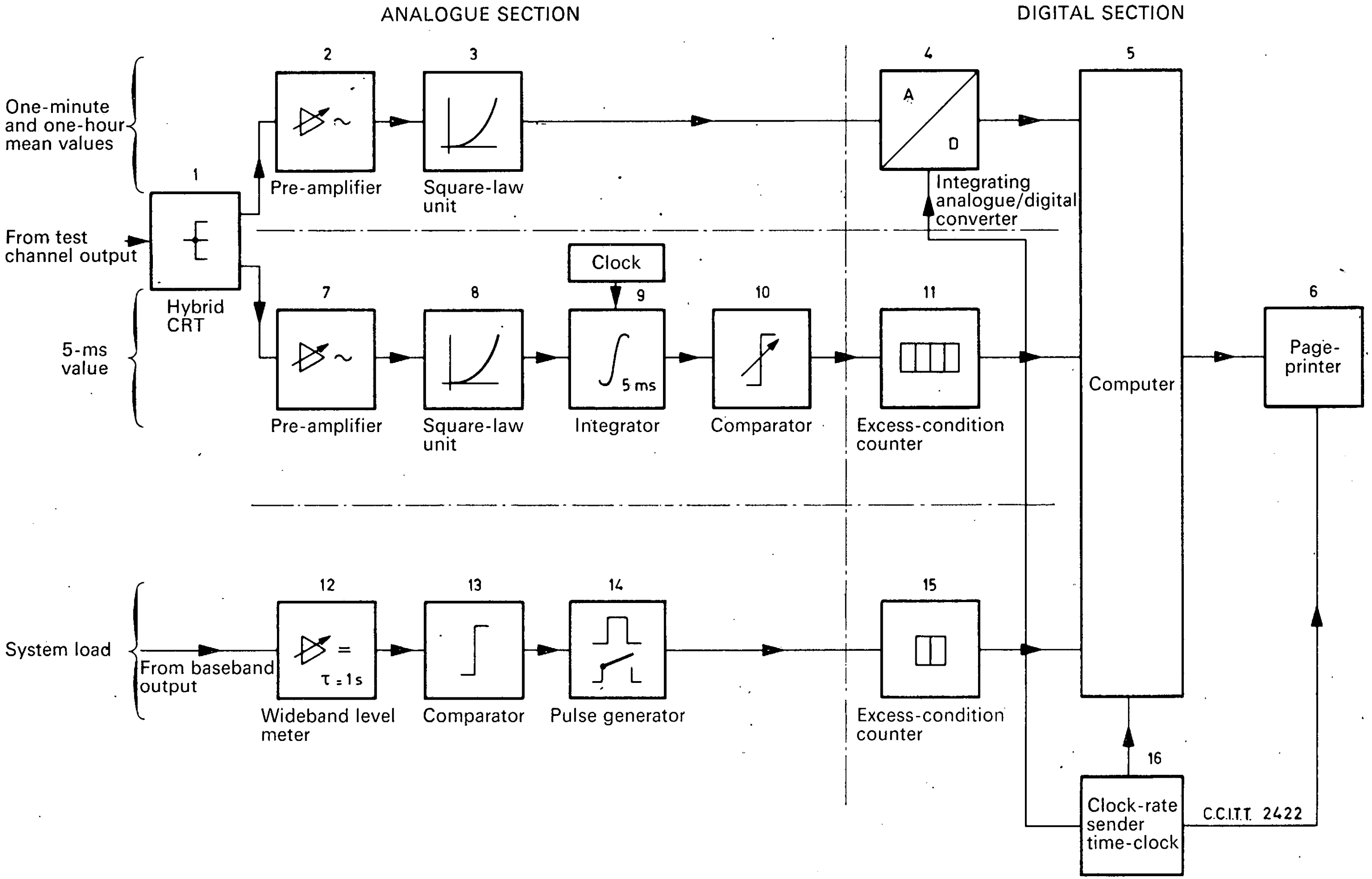


FIGURE 1. — **Block diagram of the noise-integration-measuring set-up**

The signal at the baseband output of the system is applied to a wideband amplifier 12. Via an *RC* network with a time constant of 1 second its d.c. output voltage is applied to a comparator 13 and compared with a reference voltage. For the time during which the limit has been exceeded the pulse generator 14 is turned on and feeds a pulse to the two-digit counter 15 every second. The number of these pulses is interrogated at one-minute intervals by the computer, stored and made available for the output.

The clock 16 feeds minute-rate signals to the analogue-digital converter 4 and the computer 5 and also furnishes signals to the page-printer 6 for printing the date and time of day.

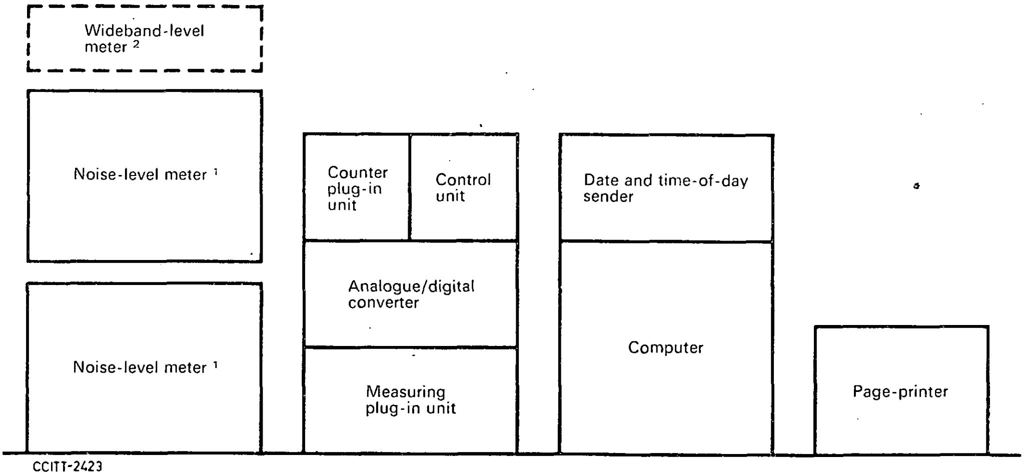
3. *Layout and mode of functioning of the system*

Figure 2 is a schematic diagram of the measuring assembly. This consists mainly of two noise-level meters (for measurements in the outband channel) or two psophometers (for measurements on non-busy inband channels in the v.f. position) and two cabinets containing the data-processing system, as well as a page-printer for the input and output of data.

The noise-level meter can be used simultaneously as a selective pre-amplifier (2, 7 in Figure 1) and as a wideband-level meter with d.c. output (12 in Figure 1).

The psophometer serves either for preamplification and psophometric weighting (2 in Figure 1) or for linear pre-amplification with a low time-constant (7 in Figure 1). In the case of measurements on non-busy voice channels the wideband-level meter in the noise-level meter (12 in Figure 1) or another suitable wideband amplifier with d.c. output must be used, if simultaneous supervision of the system load is desired.

The data-processing system comprises an analogue section and a digital section and consists of an operator's section (keyboard) for programme selection, a measuring plug-in unit (3, 8, 9, 10, 13, 14 in Figure 1) with square-law units etc., an analogue-digital converter (4 in Figure 1), a counter plug-in unit (11, 15 in Figure 1), a computer for integration and limit-value processing and a sender of date and clock time (16 in Figure 1).



[1] or psophometer
[2] only required when psophometers are used

FIGURE 2 — **Schematic presentation of the noise-integration-measuring set-up**

The square-law units 3 and 8 contained in the analogue section consist of a linear rectifier followed by a diode network with square-law characteristic. This characteristic has been realized over four decades of the noise power (50 pW to 500 000 pW). This provides a high overload margin even for extreme peaks of the noise power. The analogue-digital converter has the form of an integrating digital voltmeter (voltage-frequency converter) which is interrogated by the clock-time sender at the one-minute rate. The number of pulses this voltmeter has applied to the computer during one minute is proportional to the integral of the noise power during this minute. The measurement result is converted into pico-watts in the computer, stored and put out to the page-printer. The one-hour mean value is established in the computer by summing up 60 successive one-minute mean values and calculating the mean value. The one-hour mean value is thus determined anew every minute from the last 60 one-minute mean values. The computer furthermore determines whether certain freely selectable limits of the one-minute and one-hour mean values have been exceeded during the minute that has just elapsed. The fact that the limit has been exceeded is used with the measurement programmes Nos. 1, 3, 4 described under item 4 as a criterion for initiating print-out on the page-printer, while another programme (No. 2) effects a print-out every minute.

As mentioned in paragraph 2, apart from the noise power, it is also possible to measure the baseband load and print out the duration of the periods during which certain selected limits had been exceeded. This facilitates the judgement of the noise values.

4. *Measurement programmes, input and output of the data, measurement results*

The user of the system has a choice of four measurement programmes. Figure 3 shows the heads of the records of programmes 1 to 4 and the putting-in of the limit values. The texts of the record formats are stored in the computer for automatic printing. All that is needed is to read the figures of the limit values for the one-minute and one-hour mean values into the system with the keyboard of the page-printer; even this is necessary only when, in the case of a new measurement series, they are to be changed as compared with the preceding series. The setting of the limit value in the "5-ms channel" is done by selecting the measuring range of the pre-amplifier (7 in Figure 1).

Input of limit values (pico-watts)

1 (low limit hourly mean):	3475
2 (high limit hourly mean):	4170
3 (one-minute mean):	47500

Programme 2 serves for continuous registration of the one-minute mean values, the excess conditions of the limit value of the one-minute mean values, and the system load. In the case of programmes 1, 3 and 4 the measurement values are printed out by the page-printer only when a one-minute or one-hour limit value is exceeded. This considerably reduces the data volume.

The one-hour mean value can be checked to see whether it exceeds any of two different limits (limits 1 and 2); when the second limit is also exceeded, the print-out of the page-printer is red. The date and time of day are shown on every print-out.

Additional text can be written-in at any point in the record by means of the page-printer keyboard or a perforated tape. A perforator is also provided which can be run in parallel to the page-printer. The resultant perforated tape can, for instance, be further processed in a data system for statistical purposes.

Programme 1

Date	Time	Minute mean (pW)	Hourly mean (pW)	Exceedings of			
				Minute 3 47500	Hour 1 03475	Hour 2 04170	Volume

Programme 2

Date	Time	Minute mean (pW)	Exceedings of	
			Minute 3 47500	Volume

Programme 3

Date	Time	Exceedings of	
		5 ms value	Volume

Programme 4

Link from town A to town B, 5 hops, diversity, length 1390 km

Date	Time	Minute mean (pW)	Hourly mean (pW)	Number of times value exceeded					
				Minute 3 47500	Hour 1 03475	Hour 2 04170	Vol.	5 ms value	
022	1425	03780	03780	0	1	0	00	0000	1
022	1426	01056	03734	0	1	0	00	0000	2
022	1427	00366	03677	0	1	0	00	0000	3
022	1428	00156	03617	0	1	0	00	0000	4
022	1429	00030	03554	0	1	0	00	0000	5
022	1430	00042	03492	0	1	0	00	0000	6
(Since no excess conditions of limit values have appeared during 4 minutes, no measured values are printed out)									
022	1435	07572	03507	0	1	0	00	0000	11
022	1436	02508	03486	0	1	0	00	0000	12
022	1437	10662	03600	0	1	0	00	0000	13
022	1438	14250	03775	0	1	0	00	0000	14
022	1439	17833	04009	0	1	0	00	0000	15
022	1440	18024	04246	0	1	1	00	0000	16
022	1441	00318	04189	0	1	1	00	0000	17
022	1442	00330	04131	0	1	0	00	0000	18
022	1443	50130	04904	1	1	1	00	0000	19
022	1444	00966	04857	0	1	1	00	0000	20
022	1445	00720	04806	0	1	1	00	0000	21

Number of exceedings: Minute 3 0001 — Hour 2 0005

FIGURE 3. — **Record heads and example of printed-out measurement values**

Date	Time	Minute mean (pW)	Hourly mean (pW)	Exceedings of				
				Minute 3	Hour 1	Hour 2	Volume	5 ms value
005	1010	01128	00628	1	0	0	00	0000
005	1023	01230	00679	1	0	0	00	0000
005	1027	09306	00866	1	0	0	00	0000
005	1102	01764	00913	1	0	0	00	0000
005	1407	01230	00661	1	0	0	00	0000
005	1504	01614	00664	1	0	0	00	0000
005	1506	01140	00671	1	0	0	00	0000
005	1757	02040	00595	1	0	0	00	0000
006	0946	01296	00859	1	0	0	00	0000
006	0947	01338	00867	1	0	0	00	0000
006	0948	01440	00877	1	0	0	00	0000
006	0949	01446	00886	1	0	0	00	0000
006	0950	01368	00894	1	0	0	00	0000
006	0951	01266	00901	1	0	0	00	0000
006	0952	01182	00905	1	0	0	00	0000
006	1059	01134	00892	1	0	0	00	0000
006	1140	01110	00812	1	0	0	00	0000
006	1141	01758	00825	1	0	0	00	0000
006	1142	01230	00832	1	0	0	00	0000
006	1143	01674	00846	1	0	0	00	0000
006	1456	01848	00663	1	0	0	00	0000
006	1516	04974	00784	1	0	0	00	0000
006	1518	01872	00806	1	0	0	00	0000
006	1520	01320	00822	1	0	0	00	0000
006	1542	01314	00836	1	0	0	00	0000
006	1935	02616	00706	1	0	0	00	0000
006	1936	01356	00718	1	0	0	00	0000
006	1945	01116	00764	1	0	0	00	0000
006	1952	01104	00800	1	0	0	00	0000
006	1953	01878	00821	1	0	0	00	0000
006	1957	01452	00846	1	0	0	00	0000
006	2001	01104	00867	1	0	0	00	0000
006	2002	01200	00876	1	0	0	00	0000
007	1403	01140	00721	1	0	0	00	0000
007	1406	01332	00745	1	0	0	00	0000
007	1407	01200	00754	1	0	0	00	0000
007	1600	01326	00716	1	0	0	00	0000
007	1604	01548	00744	1	0	0	00	0000
007	1605	01230	00752	1	0	0	00	0000
007	1607	01368	00769	1	0	0	00	0000
007	1608	01128	00778	1	0	0	00	0000
007	1609	01176	00785	1	0	0	00	0000
007	1610	01152	00793	1	0	0	00	0000
007	1611	01110	00801	1	0	0	00	0000
007	1613	01122	00814	1	0	0	00	0000
007	1757	01308	00745	1	0	0	00	0000
007	1758	01692	00761	1	0	0	00	0000
007	1759	01836	00779	1	0	0	00	0000
007	1800	02028	00800	1	0	0	00	0000
007	1801	02088	00822	1	0	0	00	0000
007	1802	02082	00844	1	0	0	00	0000
007	1803	01566	00859	1	0	0	00	0000
007	1804	02082	00882	1	0	0	00	0000
007	1805	02442	00912	1	0	0	00	0000
007	1806	02274	00938	1	0	0	00	0000
007	1807	02028	00961	1	0	0	00	0000
007	1808	01704	00978	1	0	0	00	0000
007	1809	01344	00990	1	0	0	00	0000
007	1810	01134	00997	1	0	0	00	0000
007	1811	01464	01010	1	1	0	00	0000
007	1812	01116	01017	1	1	0	00	0000

Number of exceedings: Minute 3 0234 — Hour 2 0081

FIGURE 4. — **Section of a measuring series on a f.d.m. radio-relay link under service conditions (367 km long)**

Figure 3 shows a fictitious measurement record according to programme 4 with limit values and a few measured values entered. Figure 4 shows part of a measurement record according to programme 4 registered on a 4-GHz radio-relay link modulation section of 367 km in length between 2 and 7 February 1968.

At the beginning of every page of the record and on completion of the measurement the sum of all preceding excess conditions of limit values is printed out. The first 60 minutes are automatically numbered at the right-hand edge of the record, since the one-minute mean value averaged over an hour can become a reasonable mean value only when the first hour has elapsed.

5. *Comparison with another measurement method*

To check the results obtained with the measuring equipment described above the following measuring arrangement was set up for registration of the one-hour and one-minute mean values; it uses suitably designed *RC* networks for integration.

The output voltage of a psophometer which is proportional to the noise voltage in the test channel is squared in a rectifier circuit. The resultant output voltage is proportional to the instantaneous value of the noise power. It is applied to an *RC* network with suitably chosen time constant —e.g. corresponding to an integration time of 1 hour or 1 minute. The voltage across the capacitor which is proportional to the one-hour and one-minute mean values, respectively, of the noise power is measured with a voltmeter of very high input impedance ($> 10^{12}\,\Omega$), which operates on the compensation principle, and is converted into a d.c. voltage. This d.c. voltage is registered with an ink recorder.

The results simultaneously obtained with the two methods on the same route largely agreed.

Question 7/C — Characteristics of an impulsive-noise-measuring instrument for wideband data transmission

(in co-operation with C.C.I.T.T. Study Groups IV and Special A)
(new question)

What characteristics should be recommended for an instrument to measure impulsive noise on a wideband data transmission circuit:

a) in the case of circuits occupying a group or supergroup frequency band,

b) in the case of other wideband circuits?

Note. — The Annex below describes an instrument used by A. T. & T. Co. Administrations are invited to submit similar contributions for the study of this question.

ANNEX
(to Question 7/C)

Characteristics of an impulsive-noise-measuring instrument for data transmission
(Contribution by the American Telephone and Telegraph Company)

Introduction

Recommendation H. 13 (*White Book*, Volume III) gives the characteristics for a simple pulse counter suitable for field use. This instrument has a response over the frequency range 275 Hz to 3250 Hz and is intended for voiceband applications. For several years the 6A impulse counter which has characteristics similar to those given in this Recommendation has been used by A. T.& T. Co. in the maintenance of the telephone network. Supplement No. 37 to Volume VIII of the *White Book* (contribution COM Sp.C—No. 54 of 1964-1968) summarizes A. T. & T. Co. experience in the interpretation of impulsive noise measurements and outlines general voiceband measurement procedures and techniques for circuits and offices.

During the last few years a need has also developed for a portable instrument for field use which can be employed to determine impulsive noise characteristics of data circuits which are wider than 4 kHz. To meet this need, a wideband instrument has been developed based on principles similar to those of the voiceband 6A impulse counter. This wideband instrument is called the 6G wideband noise-measuring set and, like the 6A, it counts the number of impulse noise occurrences exceeding a preset threshold during a timed interval. It also measures the background noise power. Plug-in filters are used to provide for tests on the various wideband data services. The remainder of this contribution provides a summary of the characteristics of the instrument and a brief circuit description.

Characteristics of 6G wideband noise-measuring set

Purpose — The instrument is designed to register a count whenever the voltage at the input exceeds an adjustable threshold. This operation is independent of the polarity of the input pulse.

It also provides a meter for measuring the background noise power.

Both metallic and longitudinal noise can be measured.

Bandwidth — The instrument provides a maximum bandwidth from 4 kHz to 560 kHz. Other bandwidths within this range may be selected by means of plug-in filters. A plug-in filter is available for 10-50 kHz and others are being considered.

Input impedance — a) 75 ohms unbalanced;

b) 135 ohms balanced.

The balance is greater than 70 dB at 25 kHz and greater than 42 dB at 560 kHz.

c) 10 000 ohms longitudinal and 1000 ohms between tip and ring, at 135-ohm inputs, for longitudinal noise measurements.

Threshold — The threshold is adjustable in 1-dB steps from −60 to +20 dB with respect to the peak of sine wave having a power of 0 dBm in the selected input impedance (metallic noise).

The sensitivity for the r.m.s. noise meter is −90 to +10 dBm (metallic noise).

The sensitivity for longitudinal impulse and continuous noise is reduced by 30 dB.

Accuracy — The measurement accuracy for impulse and continuous noise measurements near the calibrating frequency (25 kHz) is ±0.5 dB. This accuracy applies for ambient temperatures from 0° to 50 °C and for battery voltages from 6.4 to 10 volts.

Counting rate — The mechanical register provided in the instrument permits a maximum counting rate of six counts per second. For applications requiring a higher counting rate, the output of the standard trigger circuit is available for connection to an external electronic counter. This arrangement provides a maximum counting rate of 5000 pulses per second.

Timer — The built-in timer is continuously adjustable from 5 to 60 minutes.

Circuit description of the 6G wideband noise-measuring set

The 6G wideband noise-measuring set provides input jacks for a 75-ohm unbalanced coaxial input and two 135-ohm balanced inputs. These jacks are connected by switch to an attenuator which establishes the threshold level above which impulses will be counted. This is followed by a buffer amplifier which provides a high impedance so that the termination on the attenuator may be independent of active circuit variations. The output of the buffer stage provides the proper driving point impedance for a plug-in weighting network.

The signal is then amplified by approximately 60 dB. The output of this main amplifier block is separately fed to an impulse-counting circuit and a background-noise-metering circuit.

In the impulse-counting circuit, in order to provide operation independent of impulse polarity, the signal is first full-wave rectified. This signal is then fed to the standard trigger circuit which has a fixed threshold level. Once this level has been exceeded, a narrow pulse, fixed in both amplitude and duration (i.e. a "standard pulse"), is generated. This standard pulse is used to fire a trigger circuit whose output is designed to operate a register relay that counts the noise impulses.

It has been found necessary to include the standard trigger circuit because of the characteristics of the message register's trigger drive circuit. This latter circuit's counting rate is dependent upon the size of the triggering signal. Interposing a standard trigger circuit keeps the maximum counting rate uniform from unit to unit independently of the active circuits used or mechanical variations in the message register. The output of the standard trigger circuit is also made available for fast counting by means of an electrical counter.

The background-noise-metering circuit provides means for measuring the r.m.s. background noise within the band determined by the weighting network.

A calibration oscillator is provided which is used to adjust and standardize the gain of the main amplifier so that the threshold level of the triggering circuit is known. This oscillator is also used to calibrate the background-noise meter circuit.

A timer actuated switch is incorporated in the power supply leads. Once this switch is opened, the active portions of the circuit are disabled preventing the counting of further signals. The register, however, retains the final count.

Question 8/C — Noise measurements using a signal having a uniform spectrum

(continuation of Question 36/XV studied in 1961-1964)

a) Is it practicable to recommend a technique for evaluation of circuit noise in systems not envisaged in C.C.I.T.T. Recommendation G.228 (*White Book*, Vol. III) or in C.C.I.R. Recommendation 399-1 using uniform spectrum random noise signal load simulation and capable of providing the accuracy required by these Recommendations?

b) If so, what should be the characteristics of the corresponding equipment and what measuring procedures should be recommended?

Note 1. — The specific applications referred to in Annexes 1 and 2 should be considered.

ANNEX 1

(to Question 8/C)

Noise measurements on satellite systems

Special Study Group C has given preliminary consideration to the problem of white-noise testing for communication-satellite systems, and the following proposals, which were presented to the meeting, are submitted to the appropriate study groups for detailed examination. Special Study Group C was unable to make recommendations at this stage, for the following reasons:

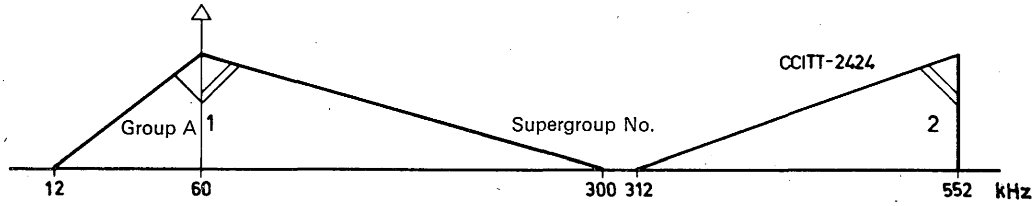
1. baseband configurations have yet to be approved by C.C.I.T.T. Study Group XV and C.C.I.R Study Group IV;

2. interconnection arrangements have similarly to be approved.

The proposed baseband capacities, frequency limits and measuring channels are set out in the following table:

Number of telephone channels	Frequency limits of band occupied (kHz)	Frequency of measuring channels (kHz)
24	12-108	16, 98
60	12-252	16, 240
132	12-552	16, 240, 534

The baseband arrangements for 24 and 60 telephone channels are already recommended for radio-relay systems (see C.C.I.T.T. Recommendation G.423 and C.C.I.R. Recommendation 380-1). In the case of 132 telephone channels, the proposed arrangement is as follows:



The proposed filter characteristics follow the pattern already recommended in C.C.I.R. Recommendation 399-1 and are given in Tables A and B below in a similar form to Tables II and III respectively of that recommendation.

TABLE A

System capacity (channels)	Limits of the band occupied by telephone channels (kHz)	Effective cut-off frequencies of band-limiting filters (kHz)		Frequencies of available measuring channels (kHz)
		High-pass	Low-pass	
24	12—108	12±0.5	108±1	16 98
60	12—252	12±0.5	252±2	16 240
132	12—552	12±0.5	552±4	16 240 534

TABLE B

Centre frequency f_c (kHz)	Bandwidth (kHz) in relation to f_c over which the discrimination should be at least:			Bandwidth (kHz) in relation to f_c outside of which the discrimination should not exceed:	
	70 dB	55 dB	30 dB	3 dB	0.5 dB
16	±1.5	±2.1	±2.7	±5	—
98	±1.5	±1.8	±2.1	±4	—
240	±1.5	±1.8	±2.2	±5	—

ANNEX 2

(to Question 8/C)

Noise-measuring channels for 60-MHz systems

During the meeting of Special Study Group C in February-March 1968, a working party exchanged views on what should be done to complete Recommendation G.228 with regard to 60-MHz systems. It came to the following preliminary conclusions:

1. A set of five measuring channels might be sufficient for the line transmitted band 4 to 60 MHz. The centre frequencies could be: 5340 kHz, 11 700 kHz, 26 948 kHz, 35 748 kHz, 55 548 kHz.

The lower two frequencies are already standardized for the 12-MHz system. The other frequencies are chosen so that we have about one channel per octave and they are situated in the middle of gaps between supermastergroups. Whilst this is of no importance for noise measurements using a uniform-spectrum signal, it leaves open the possibility of making supervisory measurements when the system is in actual service. However, it should be checked whether any carrier leaks would mask the noise in the gaps and make in-service measurements useless. The gaps at 22 MHz and 41 MHz are avoided because there are line pilots and because, in the case of line derivation of blocks of supermastergroups, the line derivation filters would block the measuring channels when used for in-service supervision. The measuring channel at 35 748 kHz would be the top channel in a 40-MHz system. Instead of the frequency 55 548 kHz perhaps the frequency 51 148 kHz might be preferable if it were found that the noise performance is more critical near this frequency.

2. Details of the filter characteristics must be studied in accordance with the principles set out in C.C.I.R. Recommendation 399-1 and C.C.I.T.T. Recommendation G.228 (amended, *White Book*, Volume III). It might be rather difficult to realize the new band elimination filters at such high frequencies.

Question 9/C — Limits on the noise due to the national system

(continuation of part b of Question 9/C studied in 1964-1968)

In view of the difficulty of assessing the effect on transmission of the noise introduced by the various national circuits forming part of an international telephone connection:

Is it desirable to allocate a fixed amount of noise to the national part of an international connection in the same spirit, perhaps, as the reference equivalents are allocated, which may be shared among the components of the national network at the discretion of the administrations concerned? If so, what proposals can be made for this allocation?

Note 1. — This question will also be of interest to Study Groups XII, XV and XVI (Question 6/XVI).

Note 2. — The annex to Recommendation G.123 (amended, *White Book*, Volume III) gives information on a method which can be used for the study of this question.

Question 10/C — Hypothetical reference circuits for very long systems

(new question)

The C.C.I.T.T. recognizes that in a large part of the world there is a need for systems capable of providing routes longer than 2500 km, on which *all* channels have a noise performance (excluding frequency-division modulation noise) of 1.5 pW/km (or better). The structure of these routes, for example the distance between modulation (dropping) points, differs substantially from that of the 2500-km hypothetical reference circuits now recommended for cable and radio-relay systems. To meet the need for systems of such length and performance, the following points should be studied:

a) should new hypothetical reference circuits be defined?
and alternatively

b) what changes should be made to existing 2500-km hypothetical reference circuits?

Note 1. — By way of an example, the Annex below briefly describes the 6400-km hypothetical reference circuit currently used by the American Telephone and Telegraph Company and the Telephone Association of Canada. Other hypothetical reference circuits could be contemplated, e.g. circuits of a length which would be a multiple of 2500 km.

Note 2. — This question should first be studied by Special Study Group C, which could seek the views of the competent C.C.I.T.T. and C.C.I.R. Study Groups.

ANNEX

(to Question 10/C)

Hypothetical reference circuit for long-haul, broadband radio-relay and cable systems for telephony

(Contribution by the American Telephone and Telegraph Company and the Telephone Association of Canada)

The following briefly outlines the salient features of the hypothetical reference circuit used in the U.S.A. and Canada as a guide for the design of long-haul broadband radio-relay and cable systems.

1. The hypothetical reference circuit is based on an overall length of 6400 km consisting of 16 sections, each having a length of 400 km.

2. At the ends of each section, it is possible to derive telephone channels on a voice-frequency (or audio) basis.

3. The current objective for psophometrically weighted noise in telephone channels is approximately 1.6 pW/km, inclusive of multiplex equipments, at the zero relative level point of the system channels.

4. The hypothetical reference circuit is used as a guide for the design of systems capable of providing telephone channels for national and international circuits as well as for the provision of extensions to intercontinental facilities.

It is submitted that the features of the hypothetical reference circuit outlined above could serve as a basis for a new C.C.I.T.T. hypothetical reference circuit for the derivation of the necessary high-quality facilities for intercontinental circuits as well as for the provision of improved circuits for national or regional use.

Question 11/C — Conventional load of carrier systems

(new question)

Paragraph 1 of Recommendation G.223 (amended, *White Book*, Volume III) specifies a conventional value (—15 dBm0) for the power level of signal transmitted (in one direction) over a telephone channel. Note 2 to this paragraph contains comments on the choice of this value.

It is desirable to reconsider separately each of the parameters used to fix this value, especially the following:

- — statistical data on speech power during the busy hour, and activity factor of a telephone circuit during the busy hour;
- — number of channels used for purposes other than telephony (programme transmission, telegraphy, facsimile, data transmission, etc.) and power of the signals sent over these channels, etc.

The attention of administrations is drawn to the fact that the load due to non-telephone services seems to be becoming excessively large compared with the load due to telephony; it might be desirable to study a reduction of the levels of signals used for these non-telephone services.

Note. — A supplement to Volume III, *White Book*, contains some information collected in 1968 with regard to the power of speech currents. The results of new measurements should be presented in the same form (see the tables of Annex 1) with all the necessary explanations for a correct interpretation of these results (source of the results, measurement or calculation; measuring method or calculation method, etc.).

Annexes 1, 2 and 3 contain information for the study of this question.

ANNEX 1

(to Question 11/C)

Conventional load for carrier systems

1. Measurements of the levels of power produced by speech signals transmitted over telephone circuits are currently being made to obtain information for a number of applications. The information required varies and the measurements are made differently according to the purpose for which the information is required. It would be advantageous if additional information were provided, with the results obtained by any method to enable them to be related on a common basis, or bases, of comparison. The basis recommended here is the mean power per channel, in a multichannel system averaged over the busy period.[1]

2. Three methods of speech power measurements which are used by various administrations are described briefly below:

a) *Measurement of speech power level during a conversation*

This measurement expresses, in dBm, the level of the mean power of a talker while "active" during the period of a conversation. The state of "activity" is usually determined by the measuring device, and this must be taken into account when determining the unidirectional conversational activity factor, τ_C, given by

$$\tau_C = \frac{D_A}{D_C} = \frac{\text{duration of "active" speech during the conversation}}{\text{duration of conversation } ^2}$$

The results of a series of speech power level measurements on a unidirectional telephone channel used successively by different talkers, or of a series of measurements on different unidirectional channels of a multiplex system, yield a distribution of speech power levels which is commonly found to be Gaussian, defined by the mean $\bar{y}$ dBm0, and standard deviation, σ dB.

A similar series of measurements to determine the unidirectional conversational activity factors also yields a distribution, of which it is usual to take the mean value $\bar{\tau}_C$, where:

$$\bar{\tau}_C = \frac{\Sigma D_A}{\Sigma D_C} = \frac{\text{total duration of active speech during all conversations measured}}{\text{total duration of all conversations measured}}$$

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[1] When designing systems having only modest numbers of channels it will be necessary to take account also of fluctuations about this mean value (see reference).

[2] The duration of conversation D_C is the time from commencement to completion of conversation between the two *subscribers*, e.g. periods of speech by P.B.X. operators are excluded.

b) *Measurement of mean power within a given time*

This measurement expresses the mean power of all signals occurring within a defined interval of time on a given telephone channel. The time interval may be chosen to include only active speech time, subscriber-conversation time or channel-busy time, and different activity factors would apply for each according to the definition used. An appropriate activity factor, τ_R, may be obtained for each reading interval using the relation:

$$\tau_R = \frac{\text{duration of active signal during measuring period}}{\text{duration of measuring period}}$$

The measurement results may be given in terms of the levels, in dBm, of the power values (μW) observed, and the standard deviation (dB) of those levels. The mean value $\bar{\tau}_R$ of the associated activity factor is also required.

c) *Measurement of the mean power of a multiplex system, averaged over a given total time*

This measurement expresses, in dBm, the level of the mean power of all signals in a particular multiplex system, averaged over a time interval determined by the measuring equipment. If the time interval for each reading is not very long, and the number of channels in the system is small, the readings will be appreciably dispersed and appropriate corrections will be necessary to obtain the long-term mean power in μW. (This can usually be done by applying a correction based on assuming the power to be log normally distributed.)

3. The measurement described in 2.c is usually conducted during a number of busy periods, and gives directly, after division by N, the required quantity—mean power (μW) per telephone channel—for the N channel system measured. For a large value of N, this quantity is the same as that for which a value of 32 microwatts at a zero level point is quoted in Recommendation G.223, provided that only normal speech channels are employed in the system. If telegraph or data channels, TASI channels, bidirectional amplifiers, pre-emphasis or peak-amplitude limiting arrangements, etc. are employed, corrections should be applied to the total mean power to obtain the required quantity. Alternatively, the special features of the system measured should be given. An example of the presentation of such results is given in Table 1 (the figures shown are by way of example and not based on any measured results).

TABLE 1

Total power measured directly in a group or supergroup, etc. P	Number of non-telephone channels in operation A	Number of telephone channels in operation B	Calculated power for non-telephone channels P_B	Total mean power per channel $\frac{P}{A+B}$	Mean power per telephone channel $\frac{P-P_B}{A}$
2600 μW0 (Note 1)	70 (Note 2)	10 (Note 2)	912 μW0 (Note 3)	32.5 μW0	24.1 μW0

Note 1. — Mean value of power distributed over the busy period.

Note 2. — Telephony channels with 3-kHz carrier spacing.

Note 3. — Telegraph bearer channels, 3-kHz carrier spacing; each telegraph bearer channel produces a load at a nominal level of −10.4 dBm0.

4. The measurement described in 2.a produces results which, after further treatment, can lead to an estimate of the mean power (μW) of speech per telephone channel in a system containing a large number of channels. The treatment depends upon further information, and also upon certain assumptions which can be expressed by means of mathematical and statistical formulae (see reference). An approximation of the mean speech power per telephone channel, valid for systems having a very large number of channels, is given by adding, to the mean value of the speech power level distribution, the quantity 0.155 (standard deviation)^2 and subtracting an allowance for the overall value of activity factors. The overall activity factor $\bar{\tau}$, in this instance, is $\frac{D_A}{D}$, the ratio of the total duration of active speech, as defined by the measuring equipment, to the total duration of the busy period. Since $\bar{\tau}_C$, the conversational activity factor, is known, $\bar{\tau}$ is given by:

$$\bar{\tau} = \bar{\tau}_C \times \bar{\tau}_A$$

where $\bar{\tau}_A$ is the circuit utilization factor, given, in this instance, by

$$\bar{\tau}_A = \frac{\Sigma D_C}{D} = \frac{\text{total duration of conversation during the busy period}}{\text{duration of busy period}}$$

$\bar{\tau}_A$ is therefore the proportion of the time for which the circuit is available for subscribers' conversation; this is approximately the proportion of revenue earning time of the circuit, and will be less than the time for which the circuit is marked as "busy".

The speech power level distribution[1] is defined by the mean, $\bar{y}$ dBm0, and the standard deviation σ dB. The level of the long-term mean speech power per telephone channel [2] is given by:

$$\bar{y} + 0.115\,\sigma^2 + 10\log_{10}(\bar{\tau}_C \times \bar{\tau}_A)\text{ dBm0.}$$

To derive the mean power per telephone channel due to all signals, it is necessary to add the equivalent mean powers due to operators' speech and to signalling. An example of the presentation of such results is shown in Table 2.

5. Treatment of the results obtained by the measurements described in 2.b requires a similar procedure to that described in 4 to obtain an estimate of the mean power per telephone channel. The mean value of the overall activity factor, $\bar{\tau}$, will be dependent upon the measuring equipment used, the time interval chosen for the measurements, and the proportion of such time intervals present during the busy period. If the measuring equipment, and time interval chosen, are such

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[1] The speech power level distribution is usually derived from speech volume measurements. Measurements of the speech volume (referred to a zero level point) of one of the participants are averaged for the duration of a conversation, and the value (V, dB) for the conversation recorded in the units of the volumeter. If $\bar{V}$ is the mean of the distribution of values of V, then

$$\bar{y} = \bar{V} - a$$

where a is a correcting factor appropriate to the type of volumeter used, e.g. $a = 1.4$ dB for a vu meter, $a = 6$ dB for B.P.O. speech voltmeters types 3 and 4A, $a = -2.2$ dB for a B.P.O. speech voltmeter type 5B.

[2] The formula gives the level of the long-term mean speech power for any number of channels, but if this number is less than, say, 250, some allowance is usually needed, when estimating the necessary load capacity of a system, to cater for fluctuations exceeding this level (see reference).

TABLE 2

Distribution of speech power levels		Conversational activity factor	Circuit utilization factor	Long-term mean per channel during the busy period	Total power per telephone channel
median	standard deviation	$\bar{\tau}_C$	$\bar{\tau}_A$		
−16.0 dBm0 (Note 4)	5.8 dB (Note 4)	0.43 (Note 4)	0.62 (Note 4)	−17.9 dBm0	28.2 μW0 (Note 5)

Note 4. — Speech power level distribution and $\bar{\tau}_C$ obtained using B.P.O. speech voltmeter 5B for which $a = -2.2$ dB; $\bar{\tau}_A$ obtained from circuit observation statistics. Long-term mean power per channel is given by:

$$-16 + 0.115\,(5.8)^2 + 10 \log_{10} (0.43 \times 0.62) = -17.9 \text{ dBm0}$$

which corresponds to 16.2 μW0.

Note 5. — An addition of 2 μW0 (an assumption based on current, but yet incomplete, measurements) has been made for operators' speech power, and a further addition of 10 μW0 (Recommendation G.223) has been made for signalling power to obtain the total mean power per telephone channel.

that the power due to all signals present is measured, the result of the treatment will give directly the mean power per telephone channel. Otherwise, an addition will be necessary, as indicated in 4, to obtain the required value.

An example of the presentation of such results is shown in Table 3. The figures shown are for example only and are not based on measured results.

TABLE 3

Distribution of values of readings		Activity factor during reading period	Utilization factor of chosen measurement period during busy period	Long-term mean per channel during the busy period	Mean power per telephone channel
median	standard deviation	$\bar{\tau}_R$	$\bar{\tau}_A$		
−15.0 dBm0 (Note 6)	6.0 dB (Note 6)	0.50 (Note 7)	0.60 (Note 8)	−16.2 dBm0 (Note 9)	24.0 μW0 (Note 9)

Note 6. — Measurements on inland route, 60 4-kHz telephone channels. Readings are of mean total power during period circuit marked "busy", and include all signals having power level greater than −40 dBm0 during an integrating period of 30 ms. Hangover time of 300 ms is also included.

Note 7. — Activity factor $\bar{\tau}_R$ measured with same instrument as used for power level readings (see section 2.b).

Note 8. — Utilization factor $\bar{\tau}_A$ obtained from record of circuits marked "busy" during busy period.

Note 9. — Mean power per telephone channel obtained from:

$$-15 + 0.115\,(6.0)^2 + 10 \log_{10} (0.50 \times 0.60) = -16.2 \text{ dBm0}$$

which corresponds to 24.0 μW0.

TABLE 4

Distribution of "active" power during the measurements		Activity factor during the measurement	Circuit utilization factor during the busy hour	Level of mean power per channel during the busy hour	Total mean power measured directly in a group or supergroup etc. P	Number of telephone channels in operation A	Number of non-telephone channels in operation B	Calculated total mean power for non-telephone channels P_B	Mean power per channel (telephone and others) $\frac{P}{A+B}$	Mean power per telephone channel $\frac{P-P_B}{A}$
median	standard deviation									
1 —	—	—	—	—	2600 μW0 (Note 1)	70	10	913 μW0 (Note 3)	32.5 μW0	24.1 μW0
2 −16.0 dBm0	5.8 dB	0.43	0.62	−17.9 dBm0	—	—	—	—	—	28.2 μW0 (Note 5)
← – – – – – – – – – – – – (Note 4) – – – – – – – – – – – →										
3 −15.0 dBm0 (Note 6)	6.0 dB	0.50 (Note 7)	0.60 (Note 8)	−16.2 dBm0 (Note 9)	—	—	—	—	—	24.0 μW0 (Note 9)

Notes 1 to 9, as shown in Tables 1 to 3

6. It is considered that, in spite of the different treatments of the measured results and the different additional information required, a standard form of presentation of results, suitable for all methods of measurement, should be used. A specimen of this form of presentation is shown in Table 4, the figures being those used as examples in Tables 1-3.

REFERENCE

RICHARDS, D. L.: Statistical properties of speech signals, *Proc. IEE*, 1964, *111*, pp. 941-949.

ANNEX 2

(to Question 11/C)

Extracts from the comments by Study Group XV on its reply to Question 36/XV (1964-1968)

Recommendations exist on the permissible levels for the transmission of v.f. telegraphy, data and phototelegraphy. Information has been requested from the C.M.T.T. on the real load produced by programme transmissions.

Special Joint Study Group C must bear these recommendations in mind in determining the conventional load, unless it intends to change the levels recommended.

Provision must also be made for wideband data transmission for which the permissible level will have to be determined.

Finally, it is necessary to anticipate the number of circuits that will be assigned to uses other than telephony in future transmission systems rather than to impose unrealistic restrictions (such as in Note 1 to point 1 of old Recommendation G.223 in the *Blue Book*, Volume III, page 80). Administrations are therefore asked to give their estimates of the numbers of circuits which will be assigned to the various services planned for future telecommunication systems. These estimates should cover a long enough period to include the time required for planning the systems plus their operational lifetime, e.g. 20 or 25 years in all.

In the course of this study, Special Joint Study Group C will be able to consider the possibility of defining the conventional load irrespective of the purpose of the system, in accordance with the following proposal.

It appears that the proportion of non-telephony exploitation of transmission systems (v.f. telegraph, data, sound-programme transmission, facsimile, picturephone, etc.) is tending to increase, so that its effect on system loading can no longer be regarded as negligible.

Rather than impose restrictions on the proportion of non-telephone circuits and their distribution over the transmitted band of frequencies, or to modify existing recommendations so as only to take account of the present situation, it would seem desirable to aim at a more permanent solution. The ideal way of achieving this would be to place all users on the same footing, not necessarily that now accepted for telephony, with the same rights and privileges as regards the loading produced by their signals, but also with the duty of ensuring that the agreed value is not exceeded. If this could be achieved, no restrictions as to the proportion of non-speech circuits need then be placed on the use of transmission systems: amongst other things this would take account of the needs of those countries where the telephone and non-telephone services are operated by separate organizations, which could nevertheless both use systems meeting C.C.I.T.T. recommendations.

ANNEX 3

(to Question 11/C)

Contribution from Chile Telephone Co. to Question 36/XV (1964-1968)

Maximum number of v.f. telegraph bearer circuits

1. The conventional value of —15 dBm0 recommended by the C.C.I.T.T. for the loading of a single telephone channel during the busy hour assumes that only a few of the channels of a wideband system, about 1½%, are used for v.f. telegraphy. We have examined the case where a much higher proportion of the channels are so used with a view to assessing the likely effects on the overall performance of wideband systems, particularly as regards operating margins and noise.

2. *System loading*

25% of the channels of a system were assumed to be used for purposes other than telephony, 17% for telegraphy applying a load of —8 dBm0 and 8% for data applying a load of —5 dBm0. Allowing —15 dBm0 for the remaining channels, the mean power per channel becomes —11.2 dBm0. The effect of this increased loading on 2700-channel, 960-channel and 300-channel coaxial pair systems of known performance can now be estimated.

For this purpose a uniform distribution, over all channels of the system, of those assigned for non-speech purposes is assumed.

3. *Overload capacity*

For the systems considered, margins between line amplifier overload points and the equivalent r.m.s. sine wave power for the numbers of channels of the systems, each at —15 dBm0, and allowing for pre-emphasis were typically 6 to 8 dB. With the postulated loading these margins would be reduced by 4 dB and become unreasonably small to cater for the effects of equalization and alignment errors.

4. *Noise performance*

For each of the systems considered the calculated line noise for —15 dBm0 channel loading was well within the C.C.I.T.T. limit of 3 pW/km. Most channels of all the systems had line noise of less than 1 pW/km and only in certain parts of the frequency bands was this figure exceeded.

However, these calculated figures exclude the effects of line-level errors, etc. If the average loading per channel is increased by 4 dB, the intermodulation noise is increased by 8 dB for second-order and 12 dB for third-order. The noise power in channels located in the worst affected bands would increase under these conditions to 5 or 6 pW/km and even to 7 pW/km in the case of one system.

In each case a better noise performance would have been obtained under these loading conditions by reducing the repeater line output levels to restore the original proportions of thermal to intermodulation noise.

5. *Pre-emphasis effects*

The foregoing assumed a uniform distribution of telegraph and data channels over the whole band. If a large number of these channels have been concentrated at the higher frequencies, the results would be worse than those indicated because of the effects of pre-emphasis. Conversely, were the telegraph and data channels to be concentrated at the low-frequency end, the results could be more favourable.

6. *Conclusions*

For wideband systems designed to C.C.I.T.T. conventional values of loading, even when reasonably generous, operating margins have been allowed, and allocation of channels for telegraphy and data purposes on the scale postulated would have serious effects as regards margins against overload and general noise performance. These effects could be mitigated to some extent, by readjustment of the system levels.

Question 12/C — Definitions and general studies relating to reliability

(The text of this question will be published later.)

Summary of questions assigned to Special Study Group C (Joint C.C.I.T.T./C.C.I.R.) for the period 1968-1972

Question No.	Short title	Remarks
1/C	Signal/noise ratio and telegraph operation on radio-relay links using tropospheric scatter	
2/C	Noise limits for telegraphy and data transmission for a telephone circuit of more than 2500 km	
3/C	Low-noise channels for very long circuits	
4/C	Hourly-mean noise for radio-relay links	
5/C	Artificial load for systems providing less than 60 carrier channels	
6/C	Integrating instruments for noise measurements	
7/C	Characteristics of an impulsive-noise-measuring instrument for wideband data transmission	
8/C	Noise measurements using a signal having a uniform spectrum	
9/C	Limits on the noise due to the national system	To be studied in conjunction with Question 6/XVI
10/C	Hypothetical reference circuits for very long systems	
11/C	Conventional load of carrier systems	
12/C	Definitions and general studies relating to reliability	

QUESTIONS ON PULSE CODE MODULATION (p.c.m.) ASSIGNED TO SPECIAL STUDY GROUP D IN 1968-1972

GENERAL

Since the IVth Plenary Assembly of the C.C.I.T.T. (Mar del Plata, 1968) set up Special Study Group D, all questions relating to pulse code modulation (p.c.m.) have been assigned to this Study Group for the time being (except for Question 21/XII, which has been allocated to Study Group XII in the specific framework of its work).

In particular, the problems forming the subject of the following questions will first be examined by Special Study Group D:

- Question 31/IX—Time division of a p.c.m. system for telegraphy and data transmission (in the framework of Question 1/D);
- point AB of Question 1/A—Use of digital transmission (or p.c.m.) (in the framework of Question 11/D);
- Question 1/A, point AJ, paragraph 3, relating to future integrated networks for data transmission (in the framework of Question 11/D).

It is for each administration to ensure co-ordination at the national level between experts in the various fields concerned, so that its contributions to the questions examined by Special Study Group D will reflect the opinion of the administration as a whole.

Subsequently, the Chairman of Special Study Group D will contact the other Chairmen to make arrangements for liaison with the other Study Groups concerned as the work progresses.

Question 1/D — Planning of digital systems

(new question)

On what general philosophy should the design and introduction of digital transmission systems be based? For example, what special provisions should be made to facilitate the introduction of integrated digital networks?

Remark : Account must be taken of the following factors:

a) The need for a progression from the existing environment, with mixed analogue and digital transmission systems and space-division switching equipments (with or without central processors) to a possible future integrated all-digital network.

The transition will be carried out gradually as time-division digital switching exchanges spread through the telephone switching network. These exchanges may be introduced initially at different points in the network.

It is essential that the characteristics of p.c.m. transmission systems recommended at the present time shall permit an integrated digital network to be set up in the future without undue difficulty.

In present circumstances, and during the transition period which will certainly last for a considerable time, satisfactory transmission performance should be ensured for connections involving analogue circuits and circuits set up on digital systems with space-division or time-division switching. (See Question 12/D.)

b) The formulation in line with a) of a hypothetical reference circuit, as a basis of design for each category of digital transmission system envisaged, and of a hypothetical reference connection, as a basis for the apportionment of impairments, tolerances, errors, etc., for each of the different services, telephony, data, etc., for which the digital network will be used.

c) The need to transmit a variety of services, including telephony, telegraph, data, television, facsimile, sound programmes in point-to-point form or from one to several other points, or in switched form under the conditions of a).

d) The consequences of the existence of systems with either 24 or 32 time slots and different fundamental characteristics.

e) The ability to include useful information on the status of, and control information for, the digital transmission network in the design of digital signal formats for those digital transmission systems so as to aid in the operation and maintenance of the network.

f) Economic comparison of these systems with analogue systems.

g) Study of this general question should facilitate co-ordination of the study of Questions 2/D to 12/D. See also Annex 3 to new Question 7/D.

ANNEX 1

(to Question 1/D)

Note by the Belgian Administration

In view of the fact:

1. that the various questions, regardless of the sector to which they refer (transmission, switching, signalling), will have to be dealt with in the light of the requirements for different types of message (telephony, telex, data transmission, etc.);

2. that the recommendations which will be issued by each of the working parties may have implications for the further work of the other working parties,

the Belgian Administration considers that there must be close co-ordination between the different specialized working parties.

Such co-ordination should, by the thorough study of all present and future implications, promote the rapid standardization of the characteristics of p.c.m. systems and the formulation of recommendations for each question, though good care should be taken to ensure that over-hasty standardization will not prejudice the development of integrated systems in the future.

The Belgian Administration further considers that everything should be done, in the framework of the study of this question, to ensure the progressive integration of all the services envisaged in the best possible technical and economic conditions.

ANNEX 2

(to Question 1/D)

Consideration on the general organization of digital networks; international digital links

(Contribution by the French Administration)

1. GENERAL

Originally devised to meet the need for cheap systems for point-to-point transmissions, pulse code modulation is now envisaged as a means of establishing large networks, culminating in an integrated network in which switching and transmission will be effected by pulse code modulation (p.c.m.).

The primary multiplex having been defined, the organization of the transmission network should be such that any primary multiplex may be routed without restriction throughout the network.

The organization should be so conceived that the system will be flexible, reliable and economical. Initially the p.c.m. links will be employed mainly for telephone circuits using channel by channel coding, but the organization ought to preserve the ability to utilize the network to route any information (f.d.m. blocks, industrial television, data, narrow-band television, sound-programme channels, etc).

The problems posed are chiefly:

- the synchronization of the digital network in the wide sense, i.e., the design of a procedure which will permit the co-existence in the same time multiplex of several primary multiplexes located in different places;
- the definition of the higher orders of multiplex.

2. SYNCHRONIZATION OF THE DIGITAL TRANSMISSION NETWORK

2.a *Asynchronous networks*

The principle of a completely asynchronous system has been described in *the Bell System Technical Journal* (November 1965) and the *I.E.E.E. Transactions on Communication Technology* (October 1966). This system has the advantage of extreme decentralization, i.e., the units which ensure the transfer of a multiplex from one means of transmission to another are proper to the transferred multiplex, or to the two means of transmission concerned. In these conditions any failure has an effect on a limited number of multiplexes. Another advantage of the system is its ability to admit any digital train whatever the information content, as long as the digit rate is within about 10^{-5} of the nominal digit rate for the multiplex T_1, T_2, T_3, or T_4.

On the debit side one can cite the relative complexity, and in particular the fact that in the equipments of transfer a dejitterizer must be included in order to ensure the regularity of the pulse stuffing operated at the time of transfer.

Another inconvenience of the system is the impossibility of operating synchronized sub-networks in the network. The systematic frequency separation between the different orders of multiplex means that a synchronized sub-network would not be able to accept a multiplex coming from the rest of the network. The whole network ought therefore to be equipped with a pulse stuffing system. However, regional networks, which are complex and short, are precisely those for which synchronization does not pose any problems of reliability, and in which significant economic benefit may result from not using pulse stuffing. Furthermore, it is probable that digital networks will initially begin in such regional networks.

2.b *Synchronized networks*

Two methods have been proposed for reliably synchronizing large meshed networks.

2.b.1 *Networks synchronized by mutual clock synchronization*—This class includes all the methods in which the synchronizing information is transmitted by modulation of the transmission time phase (see *B.S.T.J.*, December 1966). These methods require a relatively small amount of equipment but have several drawbacks.

1) The operating frequency is determined more by the phase changes (modulus $2k\pi$) introduced by the line or the system dividers than by the free operating frequency of the phase-slaved oscillators. Even if precautions are taken to minimize this effect (which is essential to ensure synchroniza-

tion, whatever the variation in line propagation time), the frequency range is thereby reduced, but is still large compared with the stability of a good oscillator that has been compensated for temperature effects. The use of a few extremely stable clocks with narrow ranges places the system in the category of a master clock network.

2) While the synchronization may be regarded as proof against the more common types of fault (failure of a unit or breaks in transmission)—although it is by no means easy to demonstrate this in general—it is harder to ensure that it is proof against more unusual faults (break in the phase-slaving of a clock).

3) Last and most important, the synchronizing equipment is complex. If a network of some size were to use this system, an abnormal situation could pose serious diagnostic problems for the operating staff.

2.b.2 *Network synchronization using a designated master clock*—This is an old idea (U.S. Patent 2.986.723). In such a system the stations are numbered to constitute a hierarchy. A digital information channel is associated with each transmission medium. In each station the base is synchronized by the timing of one of the transmission media. The timing for this purpose is chosen after examining the messages received on all the digital channels associated with the incoming multiplexes. Messages on digital channels include the characteristic figure of the transmitting station. A station transmits its characteristic figure on all outgoing lines if it is not synchronized to any other station, or retransmits the message associated with the chosen timing if it is synchronized. The timing is determined by selecting the incoming message having the smallest characteristic number, and if there are several incoming lines with this smallest number, then the first one in an agreed order is chosen.

There are several advantages in a system of this type compared with a mutual-synchronization system.

— The synchronization mechanism is easy to control because the network does not have to carry any feedback information, and the bulk of the operations are logical ones.

— The synchronization reliability is complete as regards breaks in transmission or total failure of a station. The system can also be made very resistant to the spread of asynchronization due to complex faults. For such a fault to put another station out of synchronism, the transmitting station would have to associate a correct message with an incorrect frequency.

— The fact that the normal operating frequency is extremely accurate permits, under persistent fault conditions, the temporary utilization of an emergency position whereby the station which is out of synchronism is made to work on its own frequency, relying on the (short-term) stability of its time base to achieve acceptable operation.

The usual objection to solutions of this type is their complexity. It may be noted that the non-logic part of the equipment (phase-slaved oscillators, phase control selection switches) is of the same order of complexity as the corresponding parts in the system based on mutual synchronization. The logic part of the equipment (for message reception, error detection and choice of timing) is estimated to consist of some 50 integrated logic blocks per multiplex in each station.

Lastly, these equipments will be required only in stations of the meshed part of the network, the stars or branches derived from the meshed network being synchronized by the meshed network acting as a master clock.

From the dynamic point of view, a break in transmission or a fault in the reference equipment will result in a period of some dozen milliseconds of asynchronous operation which should not introduce serious dephasing in view of the stability of the time base.

2.b.3 *Consequences of fluctuations in the propagation time*—Synchronization does not settle the problem of fluctuations in the propagation time of the transmission media. In fact, the various multiplexes in the network are homochronous. It will therefore be necessary to use a buffer store when transferring multiplex between different transmission media. These buffer stores need not have a large capacity as their role is not to absorb all the fluctuation in the propagation time, but simply to space out losses of digits. Any jump in the buffer store causes a loss of framing of the multiplexes exchanged. If the buffer store capacity is too small to absorb all the fluctuation, there will be a certain number of framing losses; this number will be small because the fluctuations in propagation time are either very small (radio-relay links) or very slow (cables). Furthermore, framing losses will occur at known intervals determined by the characteristics of the buffer store. Framing recovery for all orders of the multiplex must therefore be arranged, so that recovery from the losses introduced by the store jumps will be more rapid than normal recovery. This is obtained simply by beginning to scan positions for the synchronizing bit pattern a few positions earlier than the expected position.

Under emergency asynchronous conditions, this framing loss will occur periodically. For instance, assuming a store capacity of 1 bit per primary multiplex and a stability of 10^{-8} of the clock in the emergency position (periodic resetting of the clock frequency as long as the synchronization is working correctly preserves the short-term stability of the clock) the framing loss will occur about once per minute.

2.c *Conclusion—Influence of future integrated networks*

The integrated networks will inevitably pose a problem of synchronization. If the network is homochronous from the start the integrated network will simply use the same equipments in the t.d.m. automatic switching equipment as those used for the transmission systems.

The introduction of automatic switching equipment in an asynchronous digital network necessitates very little equipment to make the automatic switching equipment homochronous, together with the terminal equipments which are connected to them. In effect, the asynchronous network being non-code-conscious for the multiplex timing frequencies that it carries, the time bases of the terminal equipments connected to the t.d.m. automatic switching equipment will be controlled simply by the timing received originally from that equipment. The asynchronous operation of this equipment (by means of very stable clocks) is adequate for the synchronizing equipment to be simplified to the detriment of the reliability of the synchronism, provided that any failure in the synchronizing equipment causes the time basis of the equipment to pass to a very stable oscillator (without interruption).

Therefore the prospect of a future integrated network does not offer any decisive arguments one way or the other in favour of asynchronous or synchronous networks.

The synchronization methods which rely on the mutual synchronization of clocks involve disadvantages mainly from the point of view of supervision in use (refer to paragraph 2.b.1) which make the use of a designated master clock preferable, even if a little more equipment is necessary, to achieve this solution.

In a synchronized network using the designated master clock arrangement, the synchronizing equipments are as complex as those which in an asynchronous network indicate the pulse stuffing. The equipments associated with each multiplex are more simple in a synchronized network (buffer) than those used in an asynchronous network. Lastly, the equipments which select the control timing need not be associated with all the transmission means in all the stations, only those constituting the meshed structure of the network must be provided with digital channels which give the origin of their timing (see paragraph 2.b.2), the others (which are the branches that derived from the meshed network) being simply controlled by the meshed network timing. With the asynchronous solution, on the contrary, all transmission means likely to carry multiplex signals originating in the meshed network should operate at a slightly higher bit rate which excludes all possibility of simplifying the general case, even those multiplexes which are not routed over the meshed network. Furthermore, all the intermediate multiplex levels ought to be provided with pulse stuffing facilities. The synchronized solution is therefore more economical.

For these reasons, the French Administration advocates synchronization of the digital network using the designated master clock method.

3. DEFINITION OF THE HIGHER-ORDER MULTIPLEX

3.a *Framing of the higher-order multiplex*

3.a.1 A higher-order multiplex is constituted by a number of lower-order multiplexes interleaved on a bit-by-bit basis, or a time-slot basis. It is therefore necessary to provide this higher-order multiplex with frame synchronization to permit recognition of the various lower-order multiplexes. The following methods can be envisaged:

1) The lower-order multiplexes are interleaved on a bit-by-bit basis after aligning the frame phases by means of stores. The same bits permit therefore both the recognition of the framing for both the lower- and higher-order multiplexes.

2) The lower-order multiplexes are interleaved on a time-slot basis after aligning their frame phases.

3) The lower-order multiplexes are interleaved on a bit-by-bit basis, one or several of them being marked in a characteristic manner so as to permit the various components of the higher-order multiplex to be distinguished.

4) The n lower-order multiplexes are interleaved bit-by-bit. A supplementary bit is inserted for each kn bit so as to permit the recognition of the n multiplexes that have been interleaved. The frequency of one such higher-order multiplex is related to the lower-order multiplexes by the ratio $n\left(1 + \frac{1}{kn}\right)$.

3.a.2 *Conclusion*—In a national network the constitution of the higher-order multiplex will be based on lower-order multiplexes located in different places, and it is imperative that the higher-order multiplex equipment be simple. This excludes solutions 1, 2 and 3.

A higher-order multiplex like that of solution 2 is economically obtained in the case of point-to-point connections when a high-speed coder is used. This type of higher-order multiplex will therefore be strictly reserved to this case.

Solution 4 is the only one which permits the economical establishment of higher-order multiplexes.

3.b *The strict hierarchic concept of a higher-order multiplex*

According to this concept there are secondary, tertiary, quaternary multiplexes etc., which are established from n primary multiplexes, p secondary multiplexes, etc. each multiplex being provided with framing that permits the separation of the lower-order multiplexes which it contains. This concept has some advantages:

— if the equipments which permit the transfer of a multiplex from one transmission system to another are complex, it is desirable to group together in a single group all the multiplexes which have to pass over a common system in the network;

— it is possible to route the secondary, tertiary etc. multiplexes as autonomous units irrespective of the content or structure of the information they contain;

— in important stations it is preferable for reasons of simplicity to transfer telephone channels using units adapted to the traffic.

The disadvantages of the strictly hierarchic concept are:

— the need to extract the framings in cascade when returning to the lower-order level;

— the need to provide, in the asynchronous case (paragraph 2.a), a multiplex having pulse stuffing arrangements at each multiplex level;

— since the framing of secondary, tertiary etc. multiplexes can be effected simply only by the insertion of a bit (see paragraphs 3.a.1 and 3.a.2), it results that even though they may be produced starting from primary multiplexes, the secondary and tertiary multiplexes are at frequencies which are not whole multiples of the primary multiplex frequency.

In the case of the synchronized network, it will result in slight complication of the equipments providing synchronization.

3.c *Semi-hierarchic concept of the higher-order multiplex*

In a synchronized network, it is possible to realize higher-order multiplexes in a less strictly hierarchial manner without loss of the advantages cited in paragraph 3.b.

According to this concept, all the higher-order multiplexes are constituted by a number n of primary multiplexes interleaved bit-by-bit, an additional bit being inserted to distinguish the n primary multiplexes. The possible values of n are normalized:

$$n = 2^p \times 3^q$$

p being any whole number and $q = 0$ or $q = 1$.

This organization offers the following advantages:

— since the equipment which permits the transfer of the primary multiplex from one higher-order multiplex to another is simply a buffer store of small capacity, there are no economic drawbacks in making the transfer at the primary multiplex level.

— the multiplexers and demultiplexers which form or split up the higher-order multiplexes can be provided with access at levels corresponding to a frequency equal to 2^r times the frequency of the primary multiplex. Interconnection at these levels (by the use of a buffer store) therefore permits the transfer between a higher-order multiplex A and a higher-order multiplex B by digital trains of which the frequency is 2^r times that of the primary multiplex.

In order that this type of interconnection may be acceptable even if the transferred train is constituted by the interleaving of some primary multiplexes, it is necessary, in the frame of the multiplex B, to keep to the order occupied by the transferred bits in the frame of multiplex A. This result is obtained by using a store of 2^{r+1} bits, the writing and the reading into the store being controlled by the frame synchronization of the multiplexes A and B. In the case of fluctuations in the propagation time, or of emergency asynchronous operation, the reading operates with jumps of 2^r bits.

In fact this operation consists in effecting in this store the interconnection at the primary multiplex level. In practice very little extra equipment is needed.

Such an organization permits therefore the transfer by means of suitable stores of digit trains at a frequency 2^r times the frequency of the primary multiplex, whatever the nature of the information contained in the digit train.

Framing of the higher-order multiplex is done by the insertion of a bit. The use of a uniform rate of insertion whatever the capacity of the higher-order multiplex gives frequencies which are simply related to one another, e.g. the insertion of one synchronizing bit for every 48 bits of information permits the constitution of a multiplex consisting of $2^p\,3^q$ primary multiplexes (with $q = 0$ or $q = 1$) of which frequencies are related to the primary multiplex by $2^p\,3^q \left(1 + \frac{1}{48}\right)$.

The semi-hierarchic organization of the higher-order multiplexes therefore keeps the advantages of the hierarchical organization without the disadvantages listed in paragraph 3.b.

A compromise between the hierarchic and semi-hierarchic concepts consists in adopting two strictly hierarchical levels (primary multiplex and secondary multiplex) and in constituting the higher-order multiplexes by interleaving a sufficient number of secondary multiplexes. Such a compromise keeps the advantages cited in paragraph 3.c.

3.d Given the advantages cited in paragraph 3.c, the French Administration advocates:

— the constitution of a secondary multiplex from three primary multiplexes interleaved on a bit-by-bit basis, with a framing bit inserted for every 24 information bits.

The frequency of such a secondary multiplex is:

$$6144 \left(1 + \frac{1}{24}\right) = 6400 \text{ kbits/s}$$

The number of three primary multiplexes is proposed principally in order to find a repetition frequency that is common to the secondary multiplexes formed from primary multiplexes having 24 time-slots and 32 time-slots. Furthermore, this repetition frequency corresponds approximately to the bit rate needed for the transmission of a coded supergroup;

— the constitution of the higher-order multiplex by interleaving n secondary multiplexes on a bit-by-bit basis,

$$\text{with } n = 2, 3, 4, 6, 8, 12, 16, 24, 48, \ldots$$

The framing is effected by inserting one bit for every 48 bits of information.

Among the inserted bits only every other bit will serve for framing, the others being reserved to make up the digital channels necessary for the synchronization of the network 2.b.2.

Only multiplexes of an order higher than two will be provided with these digital channels.

4. INTERNATIONAL P.C.M. LINKS

4.a *General*

The international p.c.m. transfers will develop in several ways:

— between neighbouring countries by links which might be numerous and of moderate capacity;

— between distant continents by communication-satellite.

Particular attention should be paid to links of the first type, as these links could be short, and any simplification of the interconnection equipments will lead to significant economy.

Interconnection raises two important problems:

— the digit trains exchanged ought to have at least the same nominal bit frequency.

— synchronization (in the general sense) of the national networks concerned must permit the exchange of multiplexes.

4.b *Bit frequency of the higher-order multiplexes*

4.b.1 *Interconnections between countries using a primary multiplex at 2048 kbits/s*—It is desirable that this agreement be extended to the higher-order multiplexes, and that these countries adopt an identical method for the constitution of the higher-order multiplexes from the primary multiplex.

4.b.2 *Interconnections between countries having basic multiplexes with repetition rates of 2048 and 1536 kbits/s*—A common frequency can be found only at the secondary multiplex level, on condition

— that the secondary multiplexes are constituted from three primary multiplexes at 2048 kbits/s and four primary multiplexes at 1536 kbits/s in the corresponding countries;

— that the framing of the secondary multiplex is effected by the same procedure in both countries (by an insertion in a common ratio, see paragraph 3.a). The framing of the secondary multiplex proposed in paragraph 3.d also permits the framing of a secondary multiplex provided by interleaving four primary multiplexes at 1537 kbits/s.

If such compatibility is obtained, transfers can take place at the secondary multiplex level, either by bilateral agreements in one of the national systems or the other, or by a special secondary multiplex with 96 time-slots (i.e. 6144 kbits/s) equipped with an insertion in the ratio $\frac{1}{24}$ to be brought to the normal frequency of the normal secondary multiplexes. Such a secondary multiplex is more convenient for subsequent reconversion into one or other of the national systems, but the national systems have to be matched at transmission except where a rapid coder can process the 96 channels directly.

The signalling on the secondary multiplex should be entered in a number of time-slots specially set aside, so as to facilitate possible reconversion into the national systems.

4.b.3 *Interconnections between countries with primary multiplexes having repetition rates of 2048 and 1544 kbits/s*—The repetition frequency of the secondary multiplex (T2) corresponding to four basic multiplexes at 1544 kbits/s is 6312 kbits/s. Bits must be inserted in the ratio $\frac{7}{256}$ to bring the 96 time-slot, 6144 kbits/s secondary multiplex to this frequency.

4.b.4 *International secondary multiplex*—Paragraphs 4.b.3 and 4.b.4 show that a secondary multiplex with 96 time-slots (repetition frequency of 6144 kbits/s) of which a certain number of time-slots are used for framing and signalling, can serve as the basis for an international system. Each country can bring the repetition frequency of this multiplex by the insertion of bits in an appropriate ratio to the frequency of its national secondary multiplex, or to a repetition frequency which is admissible as a national secondary multiplex.

In certain cases code conversion may be necessary to take account of different compression laws.

4.c *Synchronization of international connections*

The routing in a national network of secondary multiplexes originating in other countries raises the question of synchronization:

— If the international connection is derived from asynchronous networks only, or from networks synchronized one to the other, there is no problem.

— Transfer from a synchronized network to an asynchronous network does not raise any problem either.

— Transfer from an asynchronous network to a synchronous network requires that the terminal equipment situated in the asynchronous network, and the synchronous network, operate at frequencies sufficiently accurate for a buffer store capable of holding one frame, and situated at the input of the synchronous network not to give rise to excessive losses of information.

— Transfer from one synchronized network to another synchronized network (the two networks not being synchronized one with the other) also requires high accuracy of the frequency of the two networks in order to limit the losses of information in a buffer store.

The accuracy required of these frequencies will depend chiefly on the resistance of information other than telephony coded channel by channel (data, narrowband television) to losses of information in the buffer stores (for a type of information of which the frame does not consist of a number of bits which is an exact submultiple of 768, each jump in the buffer store will lead to a loss of framing).

4.d *Conclusion*

The French Administration proposes the use, for international connections, of a secondary multiplex with 96 time-slots, one or more time-slots being used for framing and signalling.

A maximum value for the permissible frequency difference between the read-in and read-out of a buffer store of 768 bits must be defined as a function of the sensitivity to losses of information provided by this secondary multiplex.

ANNEX 3

(to Question 1/D)

Design considerations affecting maintenance of digital transmission systems

(Contribution by the American Telephone & Telegraph Company)

1. *Introduction*

In practical digital transmission systems, the actual information capacity available to the user is somewhat less than the theoretical information capacity of the transmission link. The unavailable capacity is devoted to coding restrictions to ensure d.c. balance, provide bandwidth reduction and some minimum timing energy (particularly important when the user is allowed unrestricted digital input), and allow isolated error detection; and also to provide functions such as multiplex and terminal framing, pulse stuffing, and stuffing control signals. With a relatively small amount of additional design effort, these uses may be extended to include fault isolation and terminal alerting, thus providing more complete maintenance information on the state of the digital network at both maintenance and terminal locations.

This study does not attempt to provide a maintenance plan or even a maintenance philosophy, but only to discuss the impact of maintenance on design. However, it should be emphasized that a comprehensive digital network maintenance philosophy and plan is needed to realize the full benefits and capabilities of digital transmission techniques.

To discuss design considerations affecting maintenance in more detail, we may divide a digital transmission network into digital links, digital multiplexes, and digital terminals.

2. *Digital links*

The most commonly used method of error detection on digital links is one which monitors the received digital pulse stream for violations of the coding restrictions imposed at the transmitter. There are many simple transmission coding schemes for which there is essentially a one-for-one correspondence between randomly occurring digital errors and code restriction violations for error rates in the range of interest. If violation monitors are placed periodically along the transmission link rather than just at the receiving terminal, it is possible not only to detect excessive digital error rates, but also to locate with some degree of precision the faulty digital link section. Violation monitors may be arranged to activate maintenance alarms when a set error threshold is exceeded over a set length of time.

One major difficulty with this arrangement is that a faulty digital link section will initiate maintenance alarms at every successive violation monitor. This may be avoided by devising a violation monitor which removes each violation after detection (assuming the transmission coding scheme permits effective removal), thereby preventing redetection at subsequent monitors. This prevents propagation of maintenance alarms, thus isolating and identifying the faulty section. (It should be noted that removing the violation does not necessarily remove the error, but may in fact cause one or more additional errors in other digits. However, a two- or even three-fold increase in error rate is not a serious drawback when compared with the advantages of automatic fault detection and isolation.)

Violation removal may not be effective for very high error rates, and is certainly not effective for a complete loss of the transmitted signal. In either of these events, the violation monitor and remover should be designed to substitute for the failed signal a new transmitted signal with characteristics which will inhibit maintenance alarms at subsequent monitors, thus achieving the desired fault isolation.

To summarize, the foregoing paragraphs have pointed out the desirability of employing a digital transmission code which permits detection of digital-error-caused code violations and from which the violations may be effectively removed, and of designing a violation monitor and remover capable of automatic fault detection and isolation.

3. *Digital multiplexes*

Digital multiplexes introduce two new aspects to design considerations affecting maintenance of a digital network. The first is that transmission code violations are obliterated when the signal passes through a multiplex, both because the signal is normally converted from the transmission code into a form more suitable for the multiplexing or demultiplexing process, and because consecutive digit time-slots on one side of a multiplex are usually not consecutive on the other side. Therefore, comprehensive fault isolation requires that a transmission code violation monitor be placed at each multiplex or demultiplex input. It is not necessary that these monitors remove violations, since the multiplex will do that, but that they simply detect the violations before they are obliterated in the multiplexing or demultiplexing process.

The second new aspect is that malfunctions in a multiplex or demultiplex are frequently undetectable by transmission code violation monitoring. Multiplexes and demultiplexes are always used in pairs, but the inability of a demultiplex to process an incoming signal successfully is ambiguous from a network maintenance standpoint, since it could indicate incorrect operation of either the demultiplex or the preceding multiplex, or failure of some section of the digital link between them. Comprehensive maintenance requires unambiguous fault isolation, which in turn requires monitoring of the performance of multiplexes and demultiplexes as separate units, perhaps using some form of output-input comparison. (Since the input and output of a multiplex are not of the same form, and hence not directly comparable, the design of the maintenance monitor may include some form of demultiplexing or the equivalent.)

To carry out automatic fault isolation as well as automatic fault detection at multiplexes and demultiplexes, maintenance circuitry should be designed to substitute at the output(s) of a failed multiplex or demultiplex a maintenance alarm inhibit signal such as that mentioned in section 2 to prevent alarm propagation at subsequent transmission code violation monitors.

4. *Digital terminals*

In the context used here, digital terminals are the input and output ports of a digital transmission network, and include digital/analogue converters, digital/digital converters, and transmission/switching interfaces.

When a digital link or multiplex fails, all digital terminals carrying the affected service should take some action. The action will vary with the type of terminal and type of service, but the most common action is to prevent switching machines from attempting to route traffic over the affected transmission paths. In order to take action, the terminal must be alerted to the fact that a failure has occurred, in spite of the maintenance alarm inhibition function noted previously. This may be accomplished by giving the digital signal some new characteristic not normally present (which places added restrictions on acceptable user signals) or by removing some characteristic which *is* normally present. Thus the signal emanating from the violation monitor and remover (or other source in the case of multiplex failure) should be such that *maintenance* alarms are inhibited at all subsequent violation monitors but that *service* alarms are registered at all affected digital terminals.

One characteristic normally present which could readily be removed to transmit service alarms is the framing signal. Therefore the required characteristics of the signal emanating from the violation monitor and remover, or the multiplex maintenance circuit, are that it satisfy all the transmission coding restrictions and that it contain no terminal or multiplex framing signals. A signal with these characteristics will successfully inhibit maintenance alarms but transmit service alarm information.

Removal of framing signals to transmit service alarms introduces two small problems. The first is that all legitimate transmission formats must contain framing signals. This is normally the case for time division multiplexed signals, but it does require that a special "maintenance framing signal" be inserted in those formats which do not contain multiplex framing (e.g., when a single signal such as a videotelephone or television signal occupies the entire transmission link capacity). Furthermore, for full service flexibility the framing signal should be independent of service or user signal characteristics.

The second problem involves switching/transmission interfaces. Under certain conditions, idle circuits can result in no input signal to a digital link. Under these circumstances both maintenance *and* service alarms must be inhibited, and therefore it is necessary to provide input signals to all idle digital links which satisfy all the transmission coding restrictions (including sufficient timing energy) *and* which contain the required framing signals.

When service alarms are registered at the receiving terminals, it is also necessary that the terminals at the originating ends of the affected service paths be notified of the failure so that they may take appropriate action. Therefore, the receiving terminals should provide an alerting signal to the transmitting terminals over a data link. If the data link uses all or part of the opposite direction of transmission of the failed transmission link, the terminating-to-originating alerting signal should be readily distinguishable from the failure-to-terminating alerting signal. One method to accomplish the distinction is to have the terminating-to-originating signal only modify the framing pattern rather than remove it.

One other aspect of digital terminal maintenance which deserves mention can be summed up by stating that the comments on multiplex maintenance in section 3 apply also to digital terminals. In particular, every effort should be made to monitor the performance of transmitting and receiving terminals as separate units rather than as a pair.

ANNEX 4

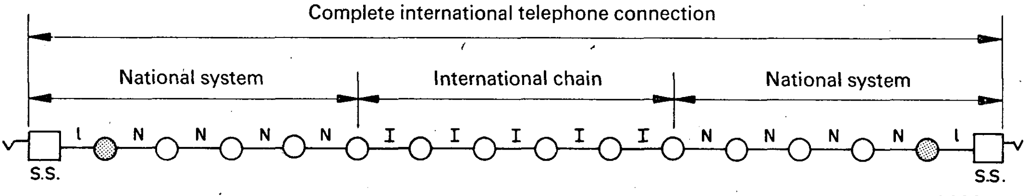
(to Question 1/D)

Representative maximum national and international connections using p.c.m. transmission links with analogue switching

(Contribution by the American Telephone & Telegraph Company)

1. *Introduction*

This contribution presents some thoughts concerning the make-up of a hypothetical worldwide reference connection of p.c.m. links. We define a link as a two-way digital transmission line terminated at each end with digital-to-analogue converters to convert the digital signal to analogue (voice frequency) form for switching purposes. The present C.C.I.T.T. reference connection [1] is given in Figure 1. It consists of five (or exceptionally six) international circuits connected at each end to four national circuits. This reference was originally postulated for analogue links. Whether it can continue to be used to model digital links or mixtures of analogue and digital links is the question to be examined in more detail below.



S.S. = Subscriber's set
l = Subscriber's loop
N = National links
I = International links

● = Local exchange
○ = Switching points

FIGURE 1. — **A representative maximum international connection**

2. *Evolution of p.c.m. networks*

2.1 *Probable trends*

Many countries have begun to install p.c.m. systems in their local networks. At the present time the U.S.A. has a large number of p.c.m. systems (T2 digital lines interconnecting D1 banks) in

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[1] C.C.I.T.T. *Blue Book*, 1965, Volume III, page 3.

metropolitan networks. At first, p.c.m. systems in the U.S.A. were used only in local connections or as end links in toll connections. However, the use of p.c.m. systems as transmission links has become increasingly attractive both economically and operationally, and therefore, following a few relatively minor changes in the D1 bank to improve performance, p.c.m. systems are beginning to be used in lower hierarchy applications in the U.S.A. toll transmission network. This trend will be accelerated with the introduction of the D2 toll grade channel bank and the T2 intermediate speed (6.3 megabits/second on symmetric pairs) digital line over the next few years. With the introduction of the high-speed T4 coaxial digital line in the early 1970s, p.c.m. transmission links will begin to appear at all levels of the transmission network hierarchy within the U.S.A. and Canada.

The evolution of p.c.m. networks in other countries will probably follow a similar trend, with p.c.m. links first appearing in local networks and the long haul toll p.c.m. links coming in later as the demand to interconnect local p.c.m. network "islands" arises. International p.c.m. links using terrestrial facilities will probably begin to appear about the same time as long haul national p.c.m. links. P.c.m. transmission over satellites will stimulate the growth of both national and international p.c.m. transmission links, and will also permit intercontinental p.c.m. transmission links to be established readily.

2.2 *Switching of p.c.m. links*

At present, all p.c.m. links are switched together by means of analogue switches. At every switchpoint the composite digital signal must be demultiplexed to the lowest standard line speed and decoded to the corresponding number of v.f. analogue signals in a p.c.m. channel bank. These v.f. analogue signals are routed through an analogue switch and, if the next link in the connection is also digital, to another p.c.m. channel bank for re-encoding. Each such decoding/re-encoding process encountered introduces additional quantizing noise which adds to quantizing noise of the original encoding on a power basis. This additive quantizing noise could be eliminated at switch points between digital links by introducing digital switching to avoid the digital-to-analogue-to-digital conversions. The most desirable form of digital switching would be that which would allow interchange of individual voice channel encoded signals among the digital links converging on a switching node without additional quantizing impairment.

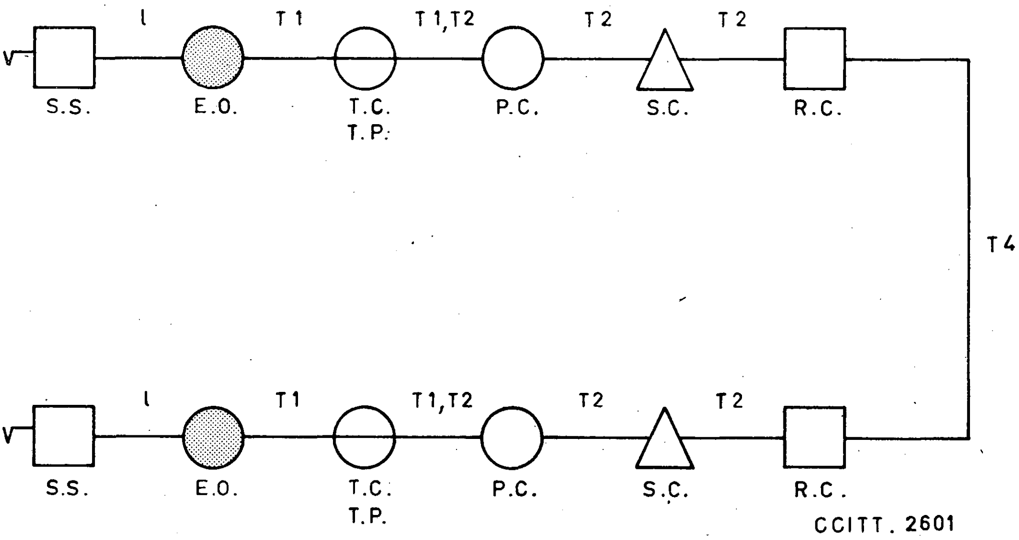
2.3 *Non-switched interconnections of p.c.m. links*

At points where switching is not required, interconnections between p.c.m. links should whenever possible be accomplished digitally. Of course as p.c.m. transmission networks are being established, there will often be instances when digital interconnections are not possible along a given route where p.c.m. transmission systems have not yet been installed. Each of these analogue interconnections adds an additional coder-decoder pair, and hence has the same effect as an analogue switch in terms of additive quantizing impairment.

3. *National and international hypothetical reference connections*

3.1 *A recommended national hypothetical reference connection*

Figure 2 shows a toll connection made up of the maximum number of tandem links permissible in the U.S.A. toll network. Between subscribers there are a total of 11 links including two subscriber lines, two local trunks connecting to the toll network, and seven toll trunks. In actual practice there are many high-usage trunks connecting non-adjacent switching offices in the hierarchy. These



S.S. = Subscriber's set	*l* = Subscriber's loop (assumed analogue)
	C.C.I.T.T. terminology
E.O. = End office	Local exchange
T.C. = Toll switching center T. P. = Toll switching point	Primary centre
P.C. = Primary switching center	Secondary centre
S. C. = Sectional switching center	Tertiary centre
R.C. = Regional switching center	Quaternary centre

FIGURE 2. — **The maximum national United States toll connection using all-p.c.m. links**

high-usage trunks allow most connections to be completed over only a few links, and only when all high-usage trunks which would result in a shorter (in terms of number of links in tandem) connection are unavailable is a maximum connection such as the one shown in Figure 2 actually used. Studies of actual connections have shown that about 67 % of all toll connections are completed over only one toll trunk (a total of five links) and that about 4 % of all toll connections require four or more toll trunks (eight or more links). The number of toll connections actually using the maximum 11 links is a fraction of one percent of the total.

At the present time in the U.S.A., p.c.m. links may be used to interconnect end offices with toll offices, toll offices with primary centres [1], and both toll offices and primary centres with others of the same rank. P.c.m. links are also used to connect P.B.X.s to end offices. Thus the maximum number of p.c.m. links which may be connected in tandem is 5 between ordinary subscribers, or 7 between P.B.X.s. (This assumes no analogue interconnections of p.c.m. links except at switching points.) As long-haul p.c.m. systems are introduced into the toll network we shall reach a time in the mid-to-late 1970s when a maximum of 11 p.c.m. links in a connection will be possible. (If during the growth of the nation-wide digital network temporary gaps appear which require analogue inter-

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[1] *Note by the Secretariat.* — Secondary centres in C.C.I.T.T. terminology (see Figure 2).

connections at other than switching points, the maximum of 11 could be exceeded under unusual circumstances). We do not envisage a separate switching hierarchy for p.c.m. links in the U.S.A. Furthermore, p.c.m. links will supplement but not replace analogue links. Therefore, p.c.m. links will in the foreseeable future be switchable to either analogue links or other p.c.m. links, and the probability of a given number of p.c.m. links in tandem will be less than the probability of the same number of links of unspecified type.

From a transmission performance standpoint, what is important is not the number of p.c.m. links in a connection, but the number of encoder-decoder pairs. These numbers will normally be the same unless time-division digital switching is used to interconnect p.c.m. links. Thus we must examine the potential effect of time-division digital switching on the emerging digital network. The system strategy which has been and is being used in the U.S.A. is to develop p.c.m. transmission systems which are competitive with analogue systems both economically and operationally, where both types of transmission links are constrained to work with existing analogue switches. Therefore p.c.m. transmission links can exist in an environment which does not contain digital switches, but the reverse is not true; that is, digital switches specifically intended to provide encoded channel interchange between p.c.m. transmission links require that a substantial p.c.m. transmission network be in existence at the time the switches are introduced. Even when digital switches become available, at the present rate of growth of the U.S.A. toll switching network (the present annual rate of additions of new toll switching machines is about 1 % of the total *number* of toll switching machines in the toll network) it will be some years before the presence of time-division digital switches has a substantial effect on the distribution of tandem p.c.m. coder-decoder pairs in toll connections.

Therefore, recognizing the preceding discussions on the probabilities of various numbers of p.c.m. links in tandem and the potential effects of digital switching, the A. T. & T. Co. recommends a national hypothetical reference connection containing eight p.c.m. coder-decoder pairs in tandem for the purpose of the study of this question.

3.2 *A recommended international hypothetical reference connection*

Referring again to Figure 1, we consider first the national portion of an international connection. A maximum connection of five national links in tandem could occur in the U.S.A. where the subscriber is located in a region served by a regional centre other than the regional centre at which the gateway (international switching centre) for a particular international connection is located. Assuming as before the possible use of p.c.m. links at all levels of the toll hierarchy by the mid-1970s, this could result in a maximum of five p.c.m. transmission links in tandem in the national portion of the connection if the call originated at a local subscriber, or six if at a P.B.X. However, with the assumed extension throughout the U.S.A. of direct dialling capability for international calls, it is likely that special trunk groups will be established bypassing the normal switching hierarchy, and therefore the likelihood of more than four p.c.m. links in tandem will be very small.

The effect of satellite circuits on the number of international links in a connection must be considered. Although transmission via satellites will undoubtedly reduce the *average* number of links in the international portion of the connection, restrictions on multiple satellite links due to excessive delay, coupled with the desirability of voice channel switching at some satellite ground stations to increase channel usage efficiency could result in no decrease in the maximum number of international links. With the introduction of p.c.m. terrestrial links between countries and between international switching centres and satellite ground stations, as well as p.c.m. transmission over satellite circuits, there will develop the potential for p.c.m. transmission over all links of an international connection.

Therefore, using the connection shown in Figure 1, we could eventually expect a maximum of 13 p.c.m. transmission links in an international connection between ordinary subscribers, or 14 or even 15 between P.B.X.s. Recognizing again the discussions of section 3.1 on the probabilities of various numbers of p.c.m. links in tandem (especially considering combinations with analogue links) and the potential effects of time-division digital switching, the A. T. & T. Co. recommends an international hypothetical reference connection containing 10 p.c.m. coder-decoder pairs in tandem for the purpose of the study of this question.

4. *Summary*

Recognizing the previously recommended hypothetical reference connections, the ways in which p.c.m. transmission networks, both national and international, are likely to evolve, the desirability of extensive interconnectibility between analogue and digital transmission networks, and the potential influence of digital switching and p.c.m. transmission over satellite circuits, the A. T. & T. Co. recommends the following:

a national hypothetical reference connection containing eight p.c.m. coder-decoder pairs, and

an international hypothetical reference connection containing 10 p.c.m. coder-decoder pairs.

Question 2/D — Basic p.c.m. multiplex terminal equipments

(new question)

What characteristics are to be recommended for the basic telephony p.c.m. multiplex terminal equipments (primary block terminal equipments), bearing in mind the desirability of recommending a single set of characteristics?

Note 1 : The following parameters will need to be specified, including tolerances where necessary:

1. Sampling rate.
2. Number of quantized amplitudes.
3. Load capacity.
4. Compression law.
5. Number of binary digits per time-slot and type of code representing each quantized sample.
6. Number of time-slots per frame.
7. Number of frames per multiframe.
8. Number of analogue inputs.
9. Allocation and significance of signalling binary digits within the frame and within the multiframe, if any (see Question 3/D).
10. Frame structure, including synchronization information (see Question 5/D).
11. Interface specification at the analogue input and output points (impedance, levels, etc.) and at signalling input and output points (see Question 7/D).

12. Interface specification for the digital signal at the output of the terminal equipment (see Question 7/D).

13. Overall transmission characteristics (attenuation/frequency and group delay/frequency) of each p.c.m. channel.

14. Tolerances and variations in the nominal over-all loss or gain of each p.c.m. channel. This will depend on terminal equipment only. It may depend not only on changes due to temperature, supply voltage, ageing, etc., but may also be a function of signal level, due to quantization in finite steps and also to imperfect tracking of coder and decoder.

15. Noise appearing in the analogue path. Noise can arise in terminal equipment in the following ways:

    15.1 Quantization distortion. The theoretical quantization distortion is defined by the number of quantized amplitudes, compression law, sampling rate, load capacity (items 1 to 4). In a practical system the quantization distortion may be modified by any causes which render the quantization steps in the coder and decoder not precisely complementary.

    15.2 Idle channel noise, due to thermal noise, coder and decoder jitter, or enhancement of low level noise (in particular at power supply frequency and its harmonics) present with the analogue input signal.

    15.3 Crosstalk between channels in terminal equipments, either in the digital or analogue portions.

    15.4 Spurious frequencies appearing at the analogue input and analogue output due to the sampling process and to finite attenuation of the low-pass filters at the analogue input and output.

16. *Non-linear distortion*

    16.1 Variation of attenuation with signal level, particularly at low signal levels, can have a marked effect upon the quality of transmission of speech when a number of p.c.m. circuits are connected in tandem at audio frequency.

    16.2 In addition, the non-linearity inherent in the quantizing process will result in intermodulation products.

    16.3 Therefore it is desirable to define limits of variation of equivalent with respect to signal level and limits of the relative levels of intermodulation products, because it may be required to transmit multi-frequency signals.

17. Return loss characteristics against nominal impedance at analogue input and output.

18. Performance characteristics of signalling channel(s) if separate from the analogue speech input.

19. Accuracy of frequency standard controlling pulse repetition rate.

20. Minimum duration of periods of

    a) interrupted

    b) mutilated transmission

before the system attempts to reframe. Maximum time to regain frame alignment. (It may be desirable to express this as a function of the duration of the period of interrupted or mutilated transmission which caused the system to attempt to reframe.)

Note 2. — The different values given in Recommendation G.711 for the nominal values of the characteristics in items 1 to 6 of Note 1 need to be reconsidered. Further study should be directed at choosing one nominal value for each characteristic.

Note 3. — The use of such signals for transmission of non-telephony signals (date, facsimile, m.f. signalling, etc.) must be considered. Particular attention is drawn to items 13, 15 and 16 in Note 1 as well as to Annex 6 below.

Note 4. — This question should be studied in conjunction with Question 1/D. Account should be taken of the annexes hereto and Annex 3 to Question 3/D. For the study of items 10 and 20, note should be taken of Annex 1 to new Question 5/D.

Note 5. — Three systems exist or are being studied which correspond to the following primary blocks:

— primary block A, containing 24 time-slots, assembled in a 193-digit frame, and providing 24 telephone channels;

— primary block B, containing 24 time-slots, assembled in a 192-digit frame, and providing 24 telephone channels;

— primary block C, containing 32 time-slots, assembled in a 256-digit frame, and providing 30 telephone channels.

Note 6. — Some aspects of the choice of parameters in items 1 to 6, including compatibility of multiplexes with different encoding laws, are being dealt with under Question 21/XII.

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ANNEX 1

(to Question 2/D)

Some observations on bunched frame synchronization

(Contribution by G. T. & E.—*Societá Generale di Telefonia ed Elettronica*)

Some results are reported here of calculations of the time required for frame recovery, when a bunched framing character of 8 or 7 bits is adopted. These calculations have been carried out with the aim of checking whether a 7-bit character is acceptable without seriously impairing the reframing performance of the system, with respect to the use of an 8-bit character. The bit which becomes so available could then be used for some service purpose.

Reduction of the synchronizing pattern from 8 to 7 bits makes framing recovery worse, in an absolute sense, because recovery time is lengthened, but such an effect seems acceptable in practice, as shown in Tables 1 and 2.

Table 1 shows the probability of framing recovery at the end of the 1st, 2nd, etc. frame after the start of framing search for 7-bit and 8-bit synchronizing patterns, as an effect of pattern simulation and in accordance with the following hypotheses:

a) the instants of the search start are distributed with constant probability along the first frame;

b) the bit assignment along every frame is random (but for sync. pattern), with equal probability of 0s and 1s;

c) error rate is zero.

Point c is reasonable, as the results are fairly approximated at least up to the error rate of 0.5×10^{-2}.

Point b is somewhat pessimistic, as a suitable choice of synchronizing pattern can avoid simulations in most search operations which affect idle channel time-slots even partially. If one assumes that every channel has 0.5 probability of being idle, it can be estimated that simulation occurs only in the 40% of search operations along the frame.

Table 2 was calculated, for the 8-bit and 7-bit cases, in accordance with this second hypothesis.

Summing up, framing recovery is anticipated within 0.5 ms in 99% of the cases, and the difference between the 8-bit and 7-bit cases does not seem to be serious, considering also that an additional time (even longer than 1 ms) may be required equally in both cases for recovering the multiframe synchronization.

TABLE 1

Probability of framing recovery for random search start and for possible simulation everywhere along the frame

Probability of synchronization recovery by the end of	8-bit synchronization character	7-bit synchronization character
1st frame	0.633	0.433
2nd frame	0.896	0.728
3rd frame	0.976	0.889
4th frame	0.995	0.961
5th frame	0.999	0.988
6th frame	0.9999	0.996

TABLE 2

Probability of framing recovery for random search start and for simulation probability of 40°/₀ along the frame

Probability of synchronization recovery by the end of	8-bit synchronization character	7-bit synchronization character
1st frame	0.824	0.689
2nd frame	0.978	0.927
3rd frame	0.997	0.986
4th frame	0.999	0.997
5th frame	0.9999	0.999

ANNEX 2

(to Question 2/D)

Multiplexing asynchronous systems with bunched synchronizing

(Contribution by N.V. Philips' Telecommunicatie Industrie)

1. *Introduction*

In the well-known pulse-stuffing method (*B.S.T.J.* volume 44, 1965, pp. 1843–1885) asynchronous inputs are applied to a higher level multiplex. The high-level multiplex adds stuffing pulses and deletes them at the demultiplexing point. An alternative approach is to first modify the input signals to produce a new common clock speed and then use a synchronous multiplex. In this case the modifications used to produce the speed adjustment are signalled to the far end of the low-level multiplex rather than to the far end of the high-level multiplex.

A method of performing this speed adjustment is described in the following paragraphs.

Having adjusted the low level systems to a common speed they can be multiplexed together very simply. In the case of the 32/30-channel systems described a simple method of multiplexing a number of systems together is to use word interleaving of the *n* systems and use the framing signal time-slot of one of these (suitably modified to differentiate it from the other systems) as the framing signal of the higher multiplex.

The following advantages can be achieved:

— fast multiframe resynchronization;

— no need for extra data bits in a multiplex scheme;
— differences in speeds may be positive or negative;
— larger incoming jitter tolerable.

2. *Description of the synchronizing method*

To describe the proposed synchronizing method it is felt useful to choose an example.

Let the system be a 32/30-channel system with bunched synchronizing in separate time-slot and with sub-multiplex signalling based on four E/M leads per speech channel in another separate time-slot.

In this case a multiframe of 15 frames would be sufficient. However, to gain a degree of freedom a multiframe of 16 frames is preferred. The signalling slot of the last frame does not carry signalling information and can therefore be used for other purposes.

The synchronization channel of the system carries a suitable pattern of 8 bits in each even-numbered frame for synchronizing purposes. The relevant time-slots of the odd-numbered frames of the multiframe contain a sequence number which labels each pair of frames. In the example chosen there are 8 such pairs, so 3 bits have to be reserved for this purpose (pair numbers 1–8 inclusive).

The remaining 5 bits of the synchronizing channel of all odd-numbered frames are available to carry special information in order to take care of speed differences between clocks. The synchronizing channel carries in this way its own data information and there is no need for extra data bits as is the case with pulse-stuffing techniques in other multiplex schemes.

Each pair sequence number relates directly to a set of signalling sub-channels, e.g.:

pair seq. number 1 relates to signalling sub-channels 1, 2, 3, 4
pair seq. number 7 relates to signalling sub-channels 25, 26, 27, 28
pair seq. number 8 relates to signalling sub-channels 29, 30, —, —

A complete illustration is given in Figure 1a.

As soon as a system is resynchronized (recognition of the patterns S in the even-numbered frames) the next odd-numbered frame will immediately give information about the signalling sub-channels to be found in the signalling time-slot (due to the pair sequence number) and therefore complete multiframe phasing.

The method of compensating for speed errors is to lengthen or shorten the last frame of a multiframe by one time-slot.

Shortening is possible because the signalling time-slot is not used in this frame. Hence channel 1 can start one time-slot early or one time-slot late as required and thus compensate for the incoming clock being either fast or slow.

This is indicated in Figures 1b and 1c.

The 5 unused bits in the synchronizing channel (labelled D in Figure 1) are used to signal in advance when this change is required. In the example described 8 such 5-bit words are available to send this information but in practice 2 or 3 of these would give sufficient redundancy to guard against errors.

One big advantage of being able to handle either positive or negative speed differences is that the nominal bit rates of different levels of the multiplex will be very simple multiples of one another, thus simplifying the production of timing pulse supplies in a large station.

Furthermore, the described synchronizing method to achieve a simple word interleaved multiplex scheme will allow a larger incoming jitter when compared with pulse-stuffing techniques for bit interleaved multiplex schemes.

3. *Notes*

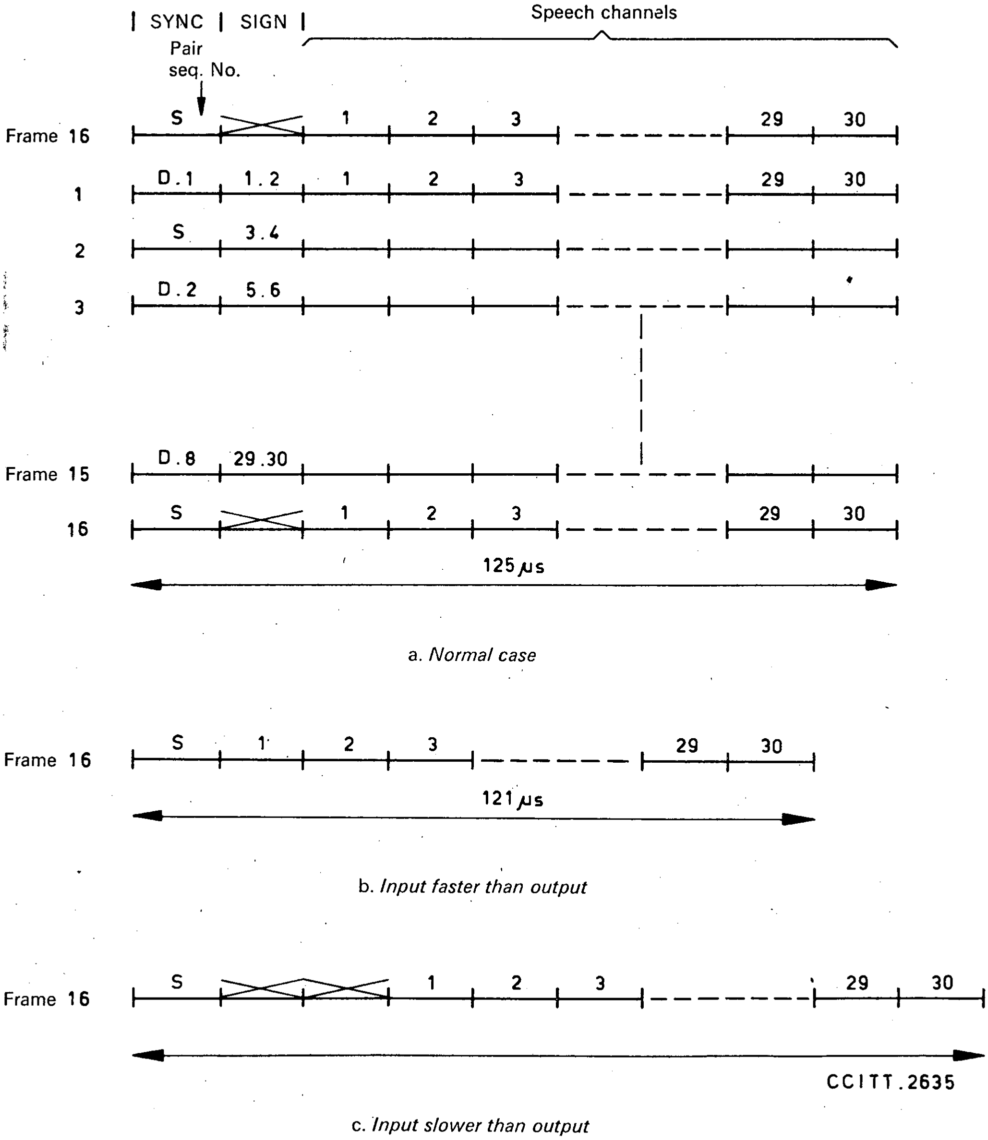
a) The method described is not necessarily restricted to the example chosen. A sub-multiplexed signalling based on two E/M leads per speech channel, for example, requires a multiframe of 8 frames and the pair sequence numbering will then be from 1–4 inclusive.

Pair sequence number 4 then relates to signalling sub-channels 25, 26, 27, 28 in frame 7
and 29, 30, —, — in frame 8.

The available shift in frame 8 is now restricted to half a time-slot but this does not affect the principle.

b) The same principle may also be applied to systems with 32/31 or 24/23 channel systems provided that the one channel is used for bunched synchronizing signals.

c) Although the above has been written in terms of shifting by a complete time-slot, exactly the same principle can be used by shifting one or any other number of bits, if required.



S = synchronization pattern

D = data bits

FIGURE 1. — **Illustration of frame formats**

ANNEX 3

(to Question 2/D)

Tabulation of p.c.m. system characteristics

TABLE 1

Fundamental characteristics of p.c.m. systems [1]

Administration or organization	United Kingdom	France	Federal Republic of Germany	Belgium	Japan N.T.T.	Poland
Sampling rate	8000	8000	8000	8000	8000	8000
Load capacity [2] dBm	+2	+2	+2	+2	+3	+3
Number of quantized amplitudes	128	128	128	256	128	128
Encoding characteristics	Log $A = 87.6$	Log $A = 87.6$	Log $A = 87.6$	Log $A = 87.6$	Log $\mu = 100$	[3]
Degree of approximation	13 seg. slope ratio 2	seg. slope ratio power of 2	13 seg. slope ratio 2	13 seg. slope ratio 2	Cont.	[3]
Compandor advantage, dB	24.1	24.1	24.1	24.1	26.8	[3]

Administration or organization	Italy	Sweden	Finland (OY NOKIA AB)	Spain (C.T.N.E.)
Sampling rate	8000	8000	8000	8000
Load capacity [2] dBm	+2	+2	+2	+2
Number of quantized amplitudes	256	256	128	256
Encoding characteristics	Log $A = 87.6$	Log $A = 87.6$	Log $A = 87.6$	Log $A = 87.6$
Degree of approximation	13 seg. slope ratio 2	13 seg. slope ratio 2	13 seg. slope ratio 2	13 seg. slope ratio 2
Compandor advantage, dB	24.1	24.1	24.1	24.1

For the notes, see the following page.

TABLE 1 (concl.)

Fundamental characteristics of p.c.m. systems [1]

Administration or organization	Netherlands		Switzerland	U.S.A.		
	Philips	P.T.T.		A.T.T. D 1	A.T.T. D 2	Lenkurt 91 A
Sampling rate	8000	8000	8000	8000	8000	8000
Load capacity [2] dBm	+3	+2	+2	+3	+3	+3
Number of quantized amplitudes	128	256	243	127	255 [4]	127
Encoding characteristics	Log $A = 87.6$	Log $A = 87.6$	Log	Log $\mu = 100$	Log $\mu = 100$	Log $\mu = 100$
Degree of approximation	13 seg. slope ratio 2	13 seg. slope ratio 2	7 seg.	Cont.	31 seg.[5]	Cont.
Compandor or advantage, dB	24.1	24.1	19	Approx. 26.7	[5]Approx. 26.7	Approx. 26.7

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[1] It is not easy to give the status of each system since the situation is continually changing; some are actually in service, others are being studied by laboratory or field trials, whilst others are just under consideration (see Table 3).

[2] The load capacity referred to in this table is the theoretical value and is defined as the quantity T_{max} (see definition).

[3] Not yet decided.

[4] Actually 8 digits less 1/6 used in time division.

[5] Last three digits linearized.

Note. — The definitions of encoding characteristics denoted by A, μ, are follows :

A characteristic

$$0 \leqq v \leqq V/A \quad y = \frac{Ax}{1 + \log A}$$

$$V/A \leqq v \leqq V \quad y = \frac{1 + \log (Ax)}{1 + \log A}$$

μ characteristic

$$y = \frac{\log (1 + \mu x)}{\log (1 + \mu)}$$

In these formulae: $x = v/V$ where v is the instantaneous input voltage
$y = i/B$ V is the maximum input voltage for which peak limitation is absent
i is the number of the quantization step starting from the centre of the range
B is the number of quantization step each side of the centre of the range

Table 2

Design characteristics of p.c.m. systems[1]

Administration or organization	United Kingdom	France	Federal Republic of Germany	Belgium	Japan N.T.T.	Poland
Sampling rate	8000	8000	8000	8000	8000	8000
Time-slots/frame	24	32	32	32	24	24[2] (25)
Channels/frame	24	31	30 or 31	30	24	24
Digits/time-slot. Code at digital interface	8 Sym B	7 Sym B	8 Sym B	8 Sym B	8 B	8 B
Gross binary digit rate kbit/s	1536	1792	2048	2048	1544	1536[2] (1600)
Framing method	D	G	G in-slot 32	G in-slot 32	out frame	D[2] (G)
Signalling method	1st in-slot	out-slot t.d.m.	1st in-slot	G (8 bits of slot No. 16)	1st in-slot	1st in-slot
Frames/multi-frame	4	8	4		1	

Administration or organisation	Italy	Sweden	Finland (OY NOKIA AB)	Spain (CTNE)
Sampling rate	8000	8000	8000	8000
Time-slots/frame	32	32	24[3]	32
Channels/frame	30	30	24[3]	30
Digits/time-slot. Code at digital interface	8 Sym B	8 Sym B	8 Sym B	8 Sym B
Gross binary digit rate kbit/s	2048	2048	1544[3]	2048
Framing method	G	G	out frame[3]	G
Signalling method	bunched	G	8th in-slot[2]	out-slot
Frames/multi-frame	8	16	1	

TABLE 2 (concl.)

Design characteristics of p.c.m. systems [1]

Administration or organization	Netherlands		Switzerland	U.S.A.		
	Philips	P.T.T.		A.T.T. D 1	A.T.T. D 2	Lenkurt 91 A
Sampling rate	8000	8000	8000	8000	8000	8000
Time-slots/frame	24	96 (128)	32	24	24	24
Channels/frame	24	90 (120)	30	24	24	24
Digits/time-slot. Code at digital interface	8 Sym B	8 Sym B	10 T	8 B	8 Sym B without alternate digit inversion	8 B
Gross binary digit rate kbit/s	1536	6144 (8192)	2560	1544	1544	1544
Framing method	Bipolar violation	G	G	out frame	out frame	out frame
Signalling method	8th in-slot	out-slot	out-slot	8th in-slot	8th in-slot	8th in-slot
Frames multi-frame	8	4	16	1	6/12	1

Legend:

Framing methods: D = distributed; G = bunched.
Codes: B = straight binary; Sym B = symmetrical binary; T = binary coded ternary.

[1] It is not easy to give the status of each system since the situation is continually changing; some are actually in service, others are being studied by laboratory or field trials, whilst others are just under consideration.

[2] In these cases changes have been made to assist with standardization; the original values are shown in brackets.

[3] The 32-time-slot system is being at present considered with its implied influence on this parameter.

TABLE 3

P.c.m. status

	United Kingdom	F. R. of Germany	Japan (N.T.T.)	Italy[1]	Sweden (LME)	Finland (OY NOKIA AB)	Spain (CTNE)	Netherlands		Switzer-land	U.S.A.		
								(Philips)	PTT		ATT D1	ATT D2	Lenkurt 91A
P.C.M. STATUS	1. SPEC. 2. SYS. DEV. (1968) 16 000 1968	1. SPEC. STUDY 2. EXPL.	SYS. DEV. (1965) 17 000-1967 25 000-1968	1. SPEC. 2. SYS. DEV. (1964) 2400-1967 2400-1968	EXPL.	SYS. DEV. (1969)	SPEC. STUDY	SYS. DEV. (1969)	EXPL.	SYS. DEV. (1969) 200-1969	SYS. DEV. (1962) 130 000-1968	SYS. DEV. (1969)	SYS. DEV. (Jan. 1968) 7000-1968

P.c.m. status definitions

SPEC.	— specification established by Administration
SPEC. STUDY	— specification being studied by Administration
SYS. DEV.	— system developed or being developed
(date)	Date—first production system carrying commercial service (rate, 2-way, ch/yr-yr)
EXPL.	— system being studied or in exploratory development

[1] The above figures do not refer to the export market.

ANNEX 4

(to Question 2/D)

Extract from the report of the Sub-Working Party on fundamental characteristics of p.c.m. terminals

(Geneva meeting, March 1968)

Encoding characteristic

The encoding characteristic may be taken to include the number of quantized amplitudes, the compression law, and the overload level.

A number of organizations expressed their preference for encoding based on 7 or 8 binary digits for each sample. The preferences were based on consideration of a number of factors, including future prospects of integrated p.c.m. networks, the place of p.c.m. links in connections, and the need for compatibility between encoding characteristics (see Appendices 1, 2 and 3). Study of this point is continuing. The actual information capacity of the channel may be somewhat less than theoretical, because occasionally one binary digit may be pre-empted for signalling, because certain code values are not used so as to reduce the chance for strings of zeros in the t.d.m. digital signal, or for other reasons.

The 13-segment A law with +2 dBm0 is preferred by the European Administrations and is used in a number of countries. The μ law with +3 dBm0 load capacity is preferred by and used in Japan and in the North American network. The 31-segment μ law is preferred by A. T. & T. for use in international connections and is in final development by A. T. & T.

Under Question 21/XII, Study Group XII is making an evaluation of the several encoding characteristics for speech transmission. To clarify the range of study asked of Study Group XII, the Sub-Working Party and Study Group XV indicated a reduced number of coding characteristics and specific proposals for hypothetical reference connections.

Further evaluation is necessary covering the effect of the fundamental encoding characteristics and of important p.c.m. terminal performance characteristics on the transmission of data and telegraph signals in the voice band. Annex 5 discusses some of the factors which should be considered. Study is also needed of characteristics which relate to direct introduction into the digital stream generated in the primary p.c.m. group coding-multiplexing terminal.

It was agreed that in principle the encoding characteristics should be optimized for speech transmission. However, interested organizations should be advised of the possible effects which these and other important performance characteristics will have on transmission of data and telegraph signals.

APPENDIX 1 (to Annex 4)

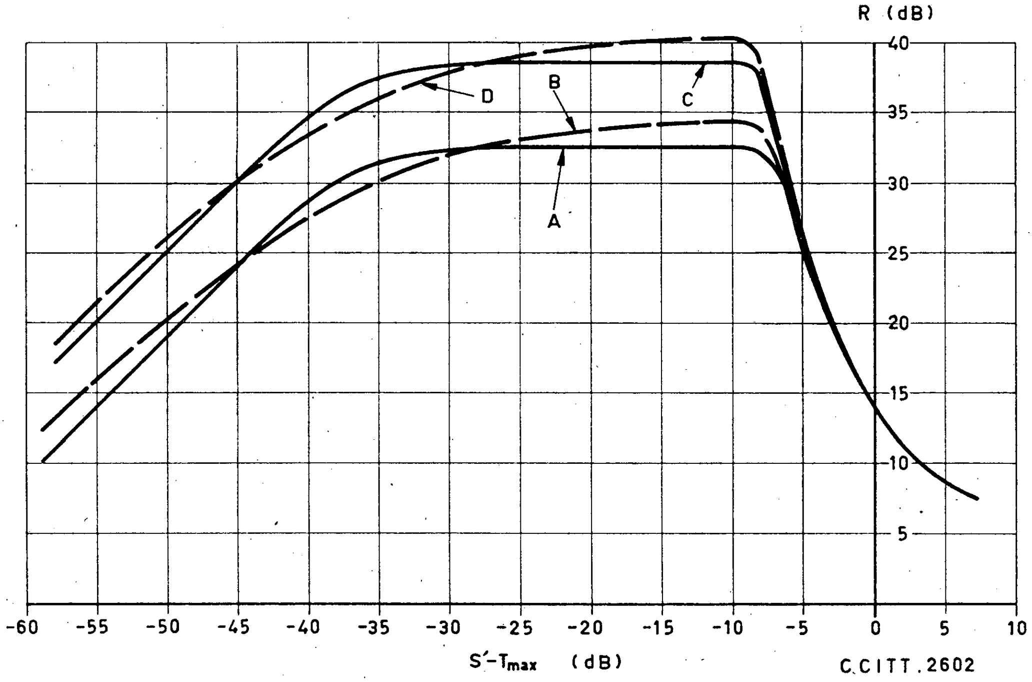
Compatibility of p.c.m. encoders and decoders

(Contribution by the United Kingdom Administration)

1. *Introduction*

For a given type of p.c.m. system, the characteristics of the encoder and decoder are very closely matched. The signal-to distortion ratio, *R* dB, produced by such a matched system is, neglecting transmission errors, determined by the compression characteristic used and the accuracy of the encoder and decoder[1]. It is important that the quantized amplitudes, w_i, at the decoder output be proportional to the mid-point amplitudes of the corresponding encoder subranges, i.e. $w_i = (v_i + v_{i-1})/2$. In a practical system the quantized amplitudes may depart slightly from their intended values due to inaccuracies in the decoder. However, measurements on a practical system[1] show that a system performance fairly closely approaching the predicted theoretical performance can be achieved.

The transmission of signals by digital methods is increasing, and, with the introduction of digital switching in electronic exchanges, it will be desirable that an encoder should be able to work with any decoder and give a satisfactory performance. In general an encoder using one compression characteristic will be incompatible with a decoder using a different one, i.e. a considerable increase in non-linear distortion will result. However, by recoding the groups of digits emitted from the encoder, it is possible to produce a much better system performance than that without recoding.



A: A = 87.6, 13-segment, 7-digit
B: μ = 100, smooth, 7-digit
C: A = 87.6, 13-segment, 8-digit
D: μ = 100, 31-segment, 8-digit

FIGURE 1a. — *R*-values for matched systems

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[1] The value of R is also affected by the character of the input signal; it will be assumed here that this has a Gaussian probability density function.

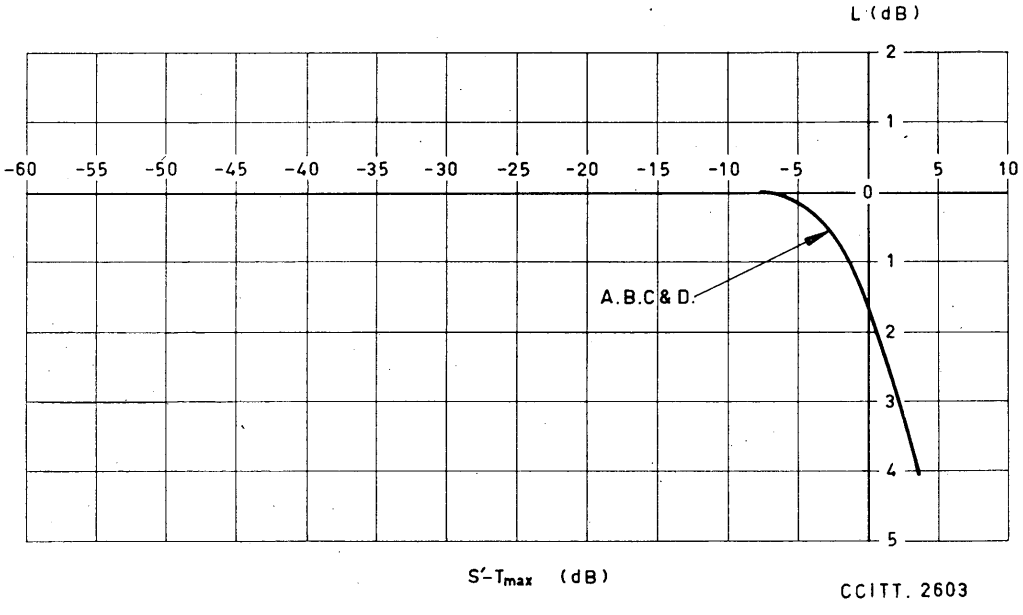
Two combinations are examined in some detail. *Combination 1:* an $A = 87.6$, 13 segments, 7-digit encoder working to a $\mu = 100$, 7-digit decoder; and *combination 2:* a $\mu = 100$, 7 digits, encoder working to an $A = 87.6$, 13 segments, 7-digit decoder. Some results from other combinations of systems are included.

2. *General*

It has been assumed that the sampling rate is 8000 per s. and that the digital signal applied to the decoder is identical with that emitted by the encoder. The spectrum of the quantizing distortion products is assumed to be uniform over the band 0–4 kHz but the signal transmitted occupies only the range 300–3400 Hz; the R and Q curves therefore have been adjusted to refer to a system bandwidth of 3.1 kHz. T_{max} is taken to be the same for each system [1]. A Gaussian test signal has been used for the calculations.

3. *Matched systems*

The magnitude of quantizing distortion is indicated by the R-curves in Figure 1a; the effect on the loss vs. input level characteristic (L-curves) is shown in Figure 1b. The estimated subjective effect of these characteristics is represented by the Q-curves shown in Figure 1c. The relationship between Q and subjective performance is discussed elsewhere.



A: $A = 87.6$, 13-segment, 7-digit
B: $\mu = 100$, smooth, 7-digit
C: $A = 87.6$, 13-segment, 8-digit
D: $\mu = 100$, 31-segment, 8-digit

FIGURE 1b. — L-values for matched systems

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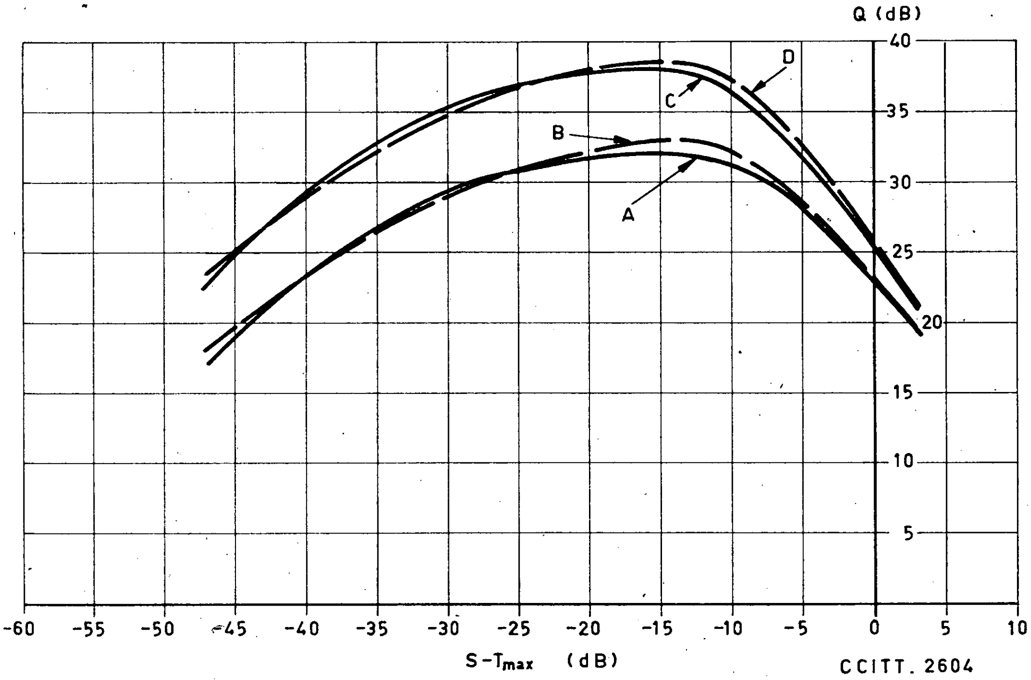
[1] Where T_{max} is different for encoder and decoder, effective idle-channel noise will be governed by the decoder, see section 5 below.



A: A = 87.6, 13-segment, 7-digit
B: μ = 100, smooth, 7-digit
C: A = 87.6, 13-segment, 8-digit
D: μ = 100, 31-segment, 8-digit

FIGURE 1c. — **Q-values for matched systems**

4. *Mismatched systems*

Figures 2a, b and c give the R, L and Q curves respectively for combinations 1 and 2. It will be seen that the performances of combinations 1 and 2 are very nearly identical but that both arrangements have introduced a considerable degradation of performance from that obtained with the systems matched.

It can be seen by comparing Figures 1c and 2c, that Q has been reduced from the value applicable to the matched system by some 6 to 7 dB over the middle range of input speech volumes. The range of speech volume for which Q is greater than 22 dB has been reduced from 40 dB to 20 dB. The performance of combinations 1 and 2 is such that they could not be tolerated except under exceptional conditions. The error in the quantized amplitudes from combination 1 is shown as a function of the desired quantized amplitudes, w_i, in Figure 3. The error amplitude has been normalized with respect to the step size h_i of the 13-segment encoder and it will be seen that a peak error of 730% is reached with a mean of approximately 250%.

The mismatch condition can be considerably improved if the quantized amplitudes intended to be represented by the transmitted codes can be substituted by quantized amplitudes selected from those available at the decoder output, choosing those more closely matched to the desired quantized amplitudes. This involves rejection altogether of some available amplitudes and the use of others more than once. However, for many practical companding laws, the process of selection is relatively systematic. (Strong similarities must be present to cater economically for similar ranges of speech

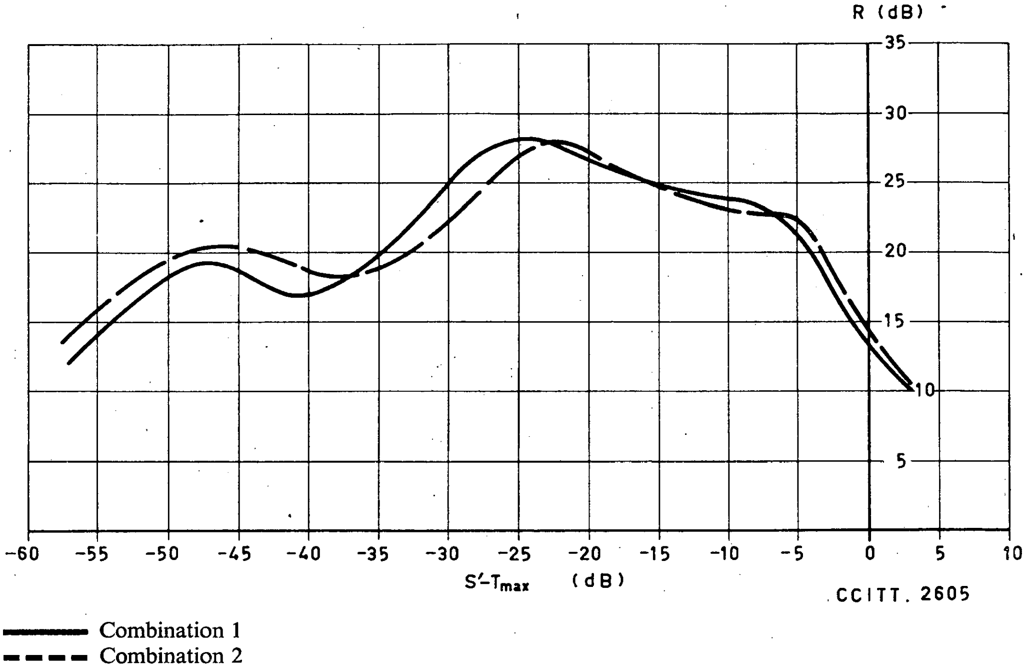


FIGURE 2a. — *R*-values for combinations 1 and 2

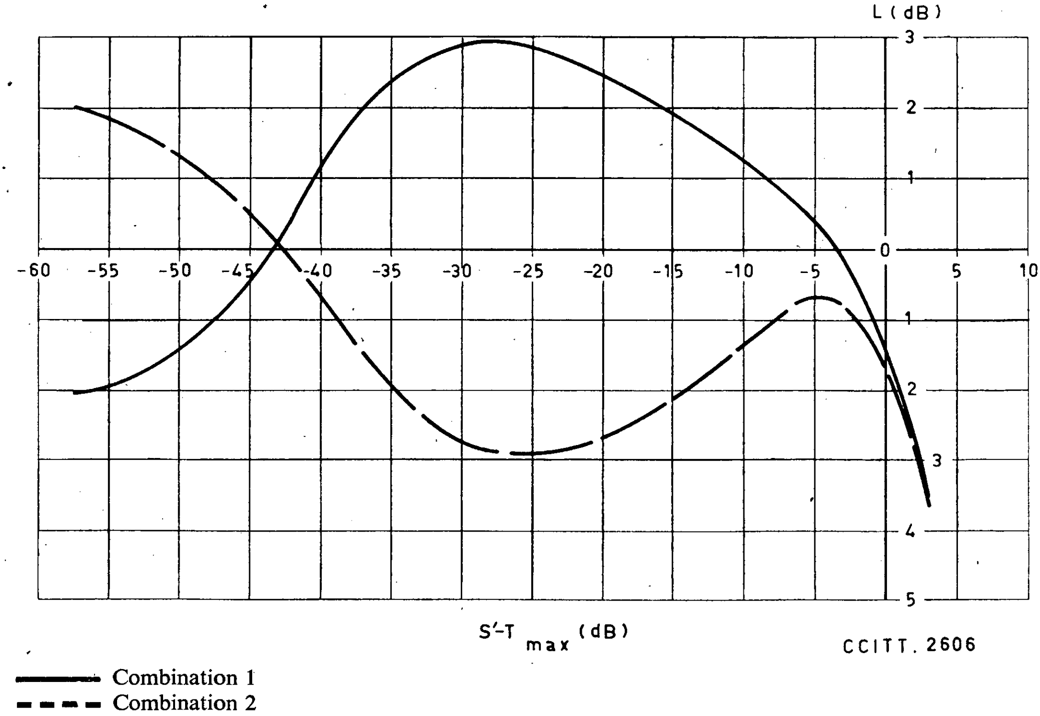


FIGURE 2b. — *L*-values for combinations 1 and 2

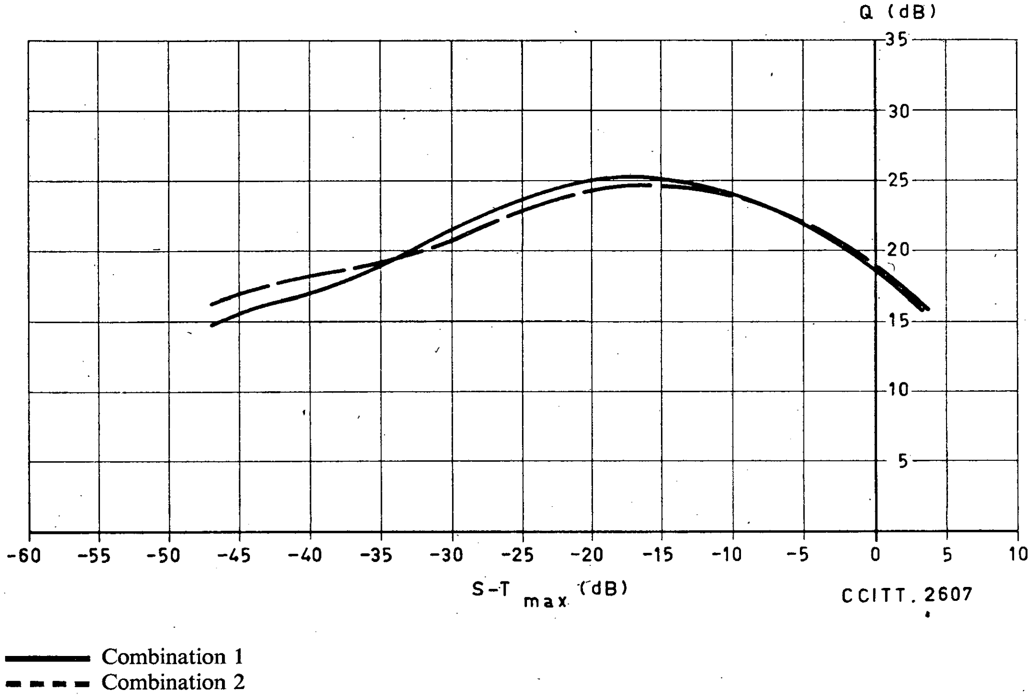


FIGURE 2c. — *Q*-values for combinations 1 and 2

volumes.) It is therefore possible to perform the selection process by recoding the groups of digits according to a relatively simple set of rules. Table 1 indicates, for positive amplitudes only, the rules required for recoding the two mismatch conditions of combinations 1 and 2, shown as the number to be added to or subtracted from the group of digits transmitted from the encoder[1]. Identical rules apply for negative amplitudes, since only the sign digit is changed.

It will be seen that, for the top five amplitudes, no change is required and, for the bottom 12 amplitudes, only a few minor changes of one digit are necessary—in practice these might even be neglected. For the remainder of the amplitude range simple addition or subtraction of the numbers one to four is required. However, the points at which the changes must be made in the numbers do not follow a simple rule, and in some cases, all of the last six digits of the group have to be recognized, before addition or subtraction can commence.

The groups of digits emitted from the encoder are transmitted to line in serial form. The circuitry involved in recoding is simplified if the digital signal is staticized before recoding takes place. A block

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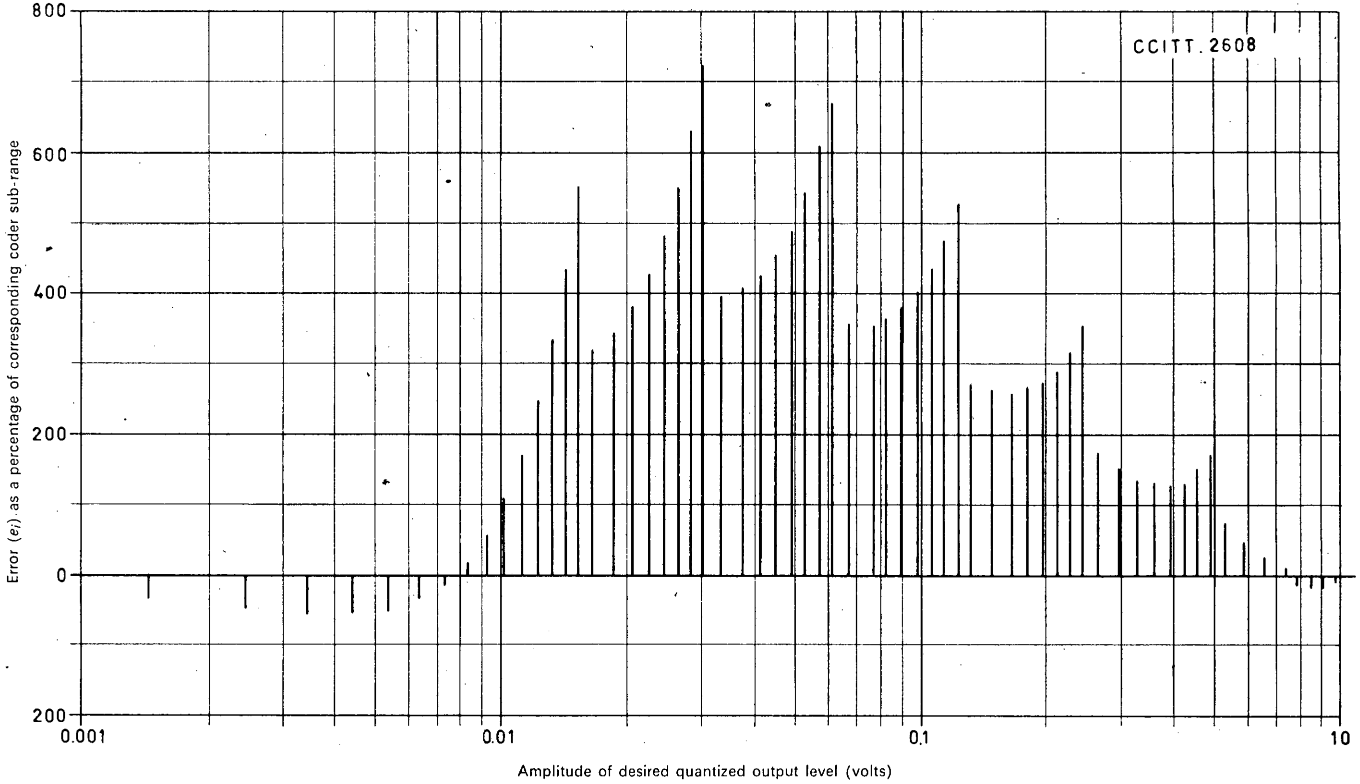
[1] For simplicity of explanation, a symmetrical binary line code is assumed.



$$e_i = \frac{w'_i - w_i}{h_i} \times 100\,\%$$

FIGURE 3. — **Mismatch error in quantized amplitudes for combination 1**

TABLE 1

Recoding rules for combinations 1 and 2

Quantized amplitude (positive range only)	Transmitted group of digits last 6 of 7-digit group	Number to be added to obtain best match		Quantized amplitude (positive range only)	Transmitted group of digits last 6 of 7-digit group	Number to be added to obtain best match	
		μ to A direction	A to μ direction			μ to A direction	A to μ direction
$i = 1$	000000	0	0	$i = 33$	100000	+4	−4
2	000001	0	0	34	100001	+4	−4
3	000010	0	0	35	100010	+4	−4
4	000011	0	+1	36	100011	+4	−4
5	000100	−1	+1	37	100100	+4	−4
6	000101	−1	+1	38	100101	+4	−4
7	000110	0	0	39	100110	+3	−4
8	000111	0	0	40	100111	+3	−4
9	001000	0	0	41	101000	+3	−4
10	001001	0	0	42	101001	+3	−4
11	001010	+1	0	43	101010	+3	−3
12	001011	+1	−1	44	101011	+3	−3
13	001100	+2	−1	45	101100	+3	−3
14	001101	+2	−1	46	101101	+3	−3
15	001110	+3	−2	47	101110	+3	−3
16	001111	+3	−2	48	101111	+2	−3
17	010000	+3	−3	49	110000	+2	−3
18	010001	+3	−3	50	110001	+2	−3
19	010010	+3	−3	51	110010	+2	−2
20	010011	+4	−3	52	110011	+1	−2
21	010100	+4	−3	53	110100	+1	−1
22	010101	+4	−3	54	110101	+1	−1
23	010110	+4	−4	55	110110	+1	−1
24	010111	+4	−4	56	110111	+1	−1
25	011000	+4	−4	57	111000	+1	−1
26	011001	+4	−4	58	111001	+1	−1
27	011010	+4	−4	59	111010	0	−1
28	011011	+4	−4	60	111011	0	0
29	011100	+4	−4	61	111100	0	0
30	011101	+4	−4	62	111101	0	0
31	011110	+4	−4	63	111110	0	0
32	011111	+4	−4	64	111111	0	0

schematic diagram of the logic requirements to recode from parallel form to parallel form is shown in Figure 4 for combination 2, the requirements for combination 1 being rather similar. Figures 5a, b and c illustrate the R, L and Q curves obtained after recoding in this way, and show the considerable improvement achieved. In Figure 6 the revised percentage error in w_i obtained as a result of the recoding process is shown.

To achieve the improvement shown in Figures 5 and 6, the code recognition portion of the recoding logic circuits must on occasions recognize groups containing six digits. The circuitry may

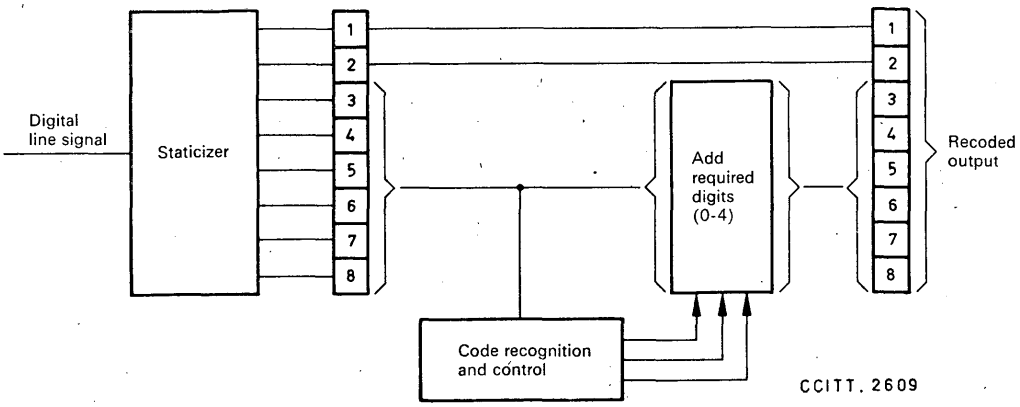


FIGURE 4. — **Recoding requirements for combination 2**

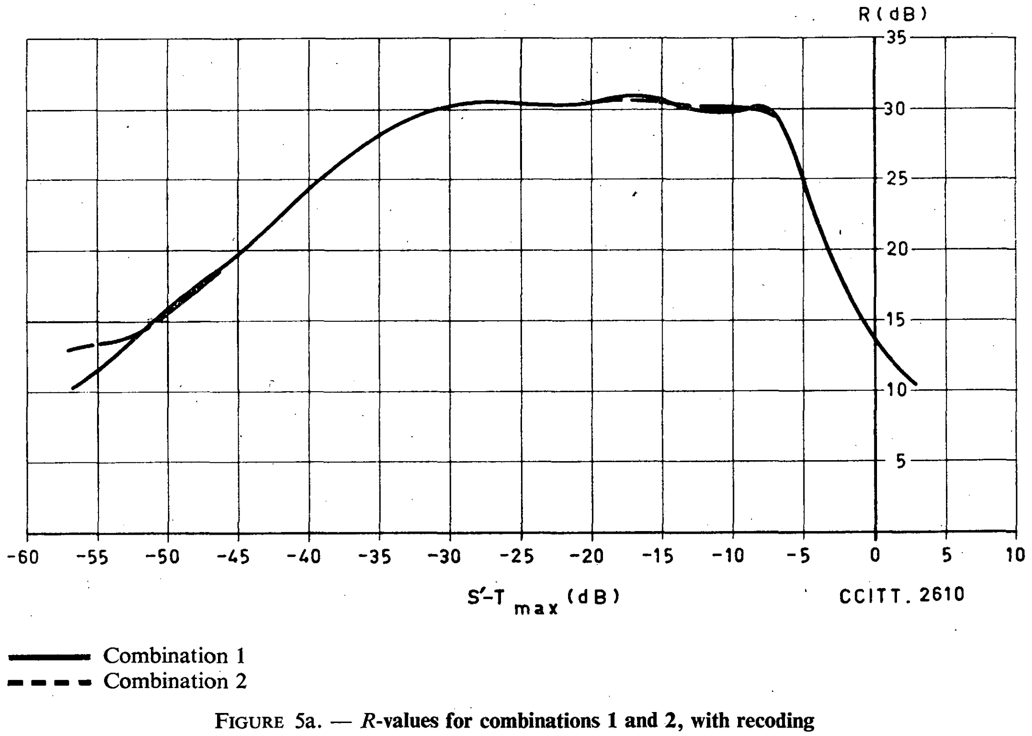


FIGURE 5a. — ***R*-values for combinations 1 and 2, with recoding**

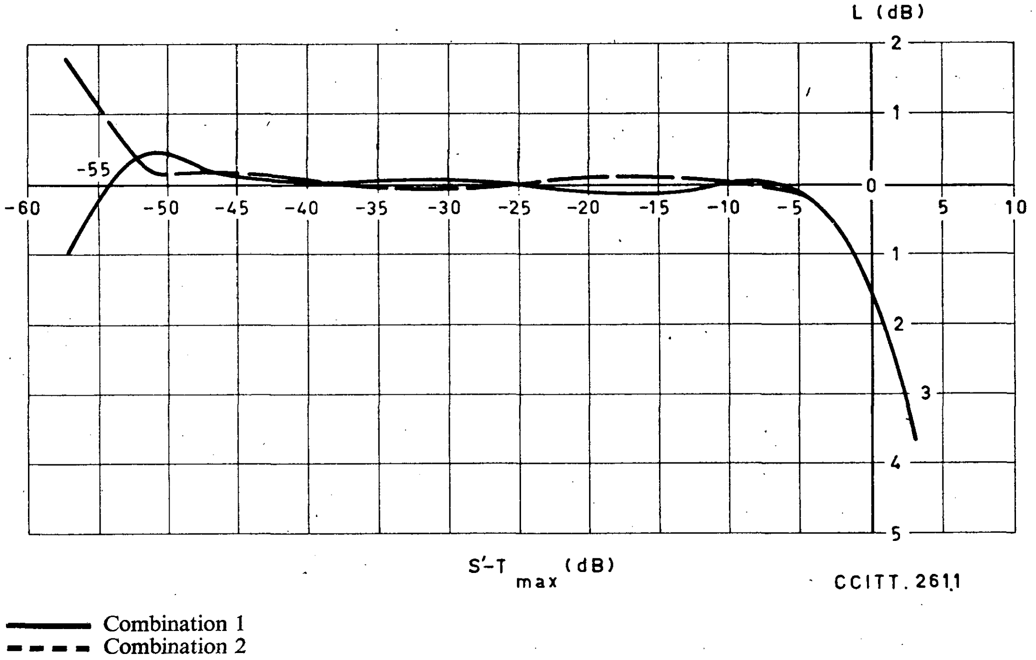


FIGURE 5b. — *L*-values for combinations 1 and 2, with recoding

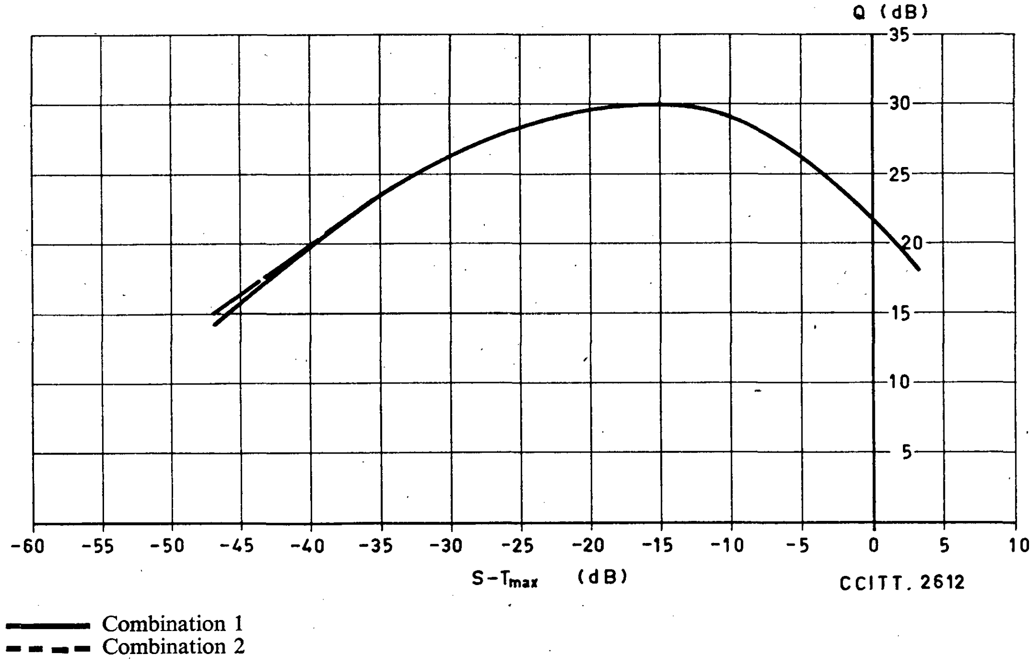
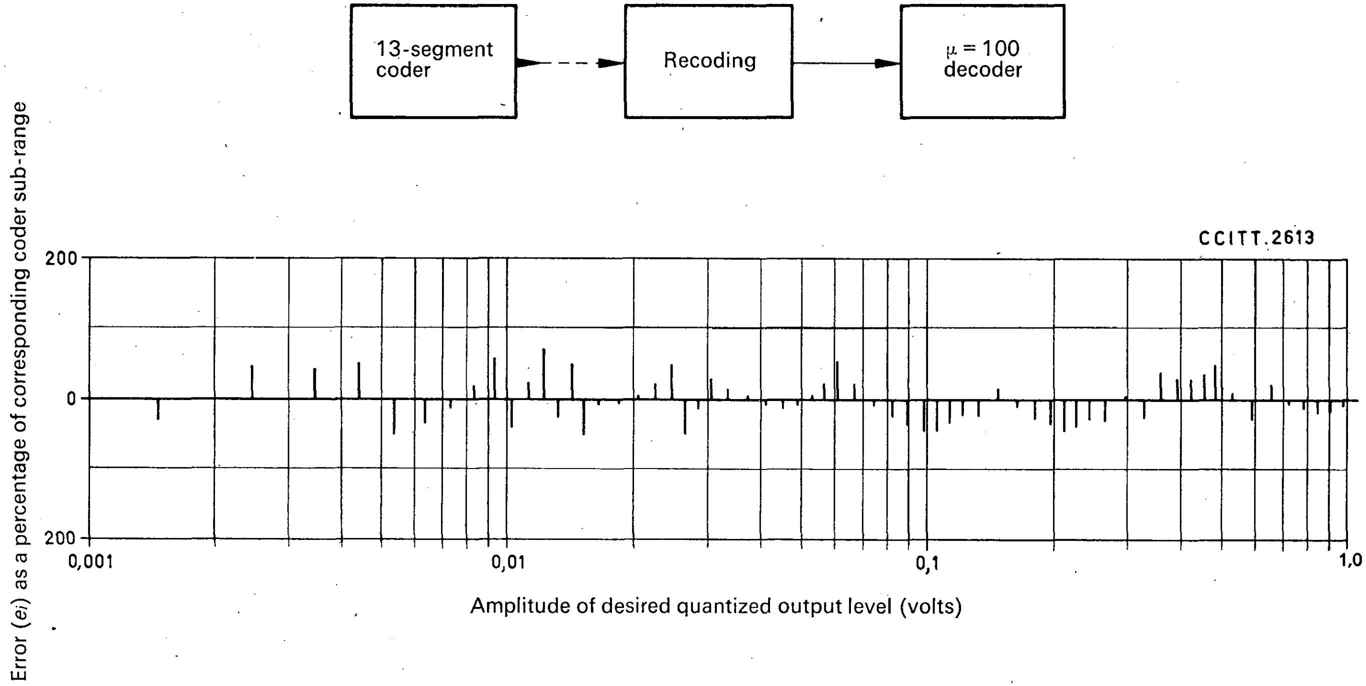
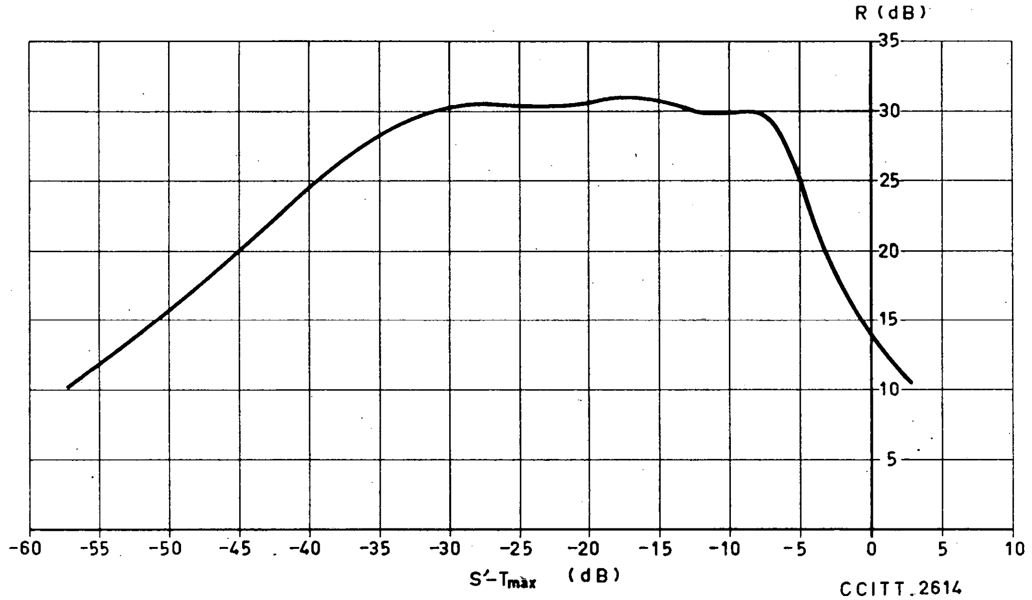


FIGURE 5c. — *Q*-values for combinations 1 and 2, with recoding



$$e_i = \frac{w'_i - w_i}{h_i} \times 100\%$$

FIGURE 6. — **Mismatch error in quantized amplitudes for combination 1 with recoding**



No effect on R-values

FIGURE 7a. — **Effect on R-values of differences in T_{max} for combination 1, with recoding**

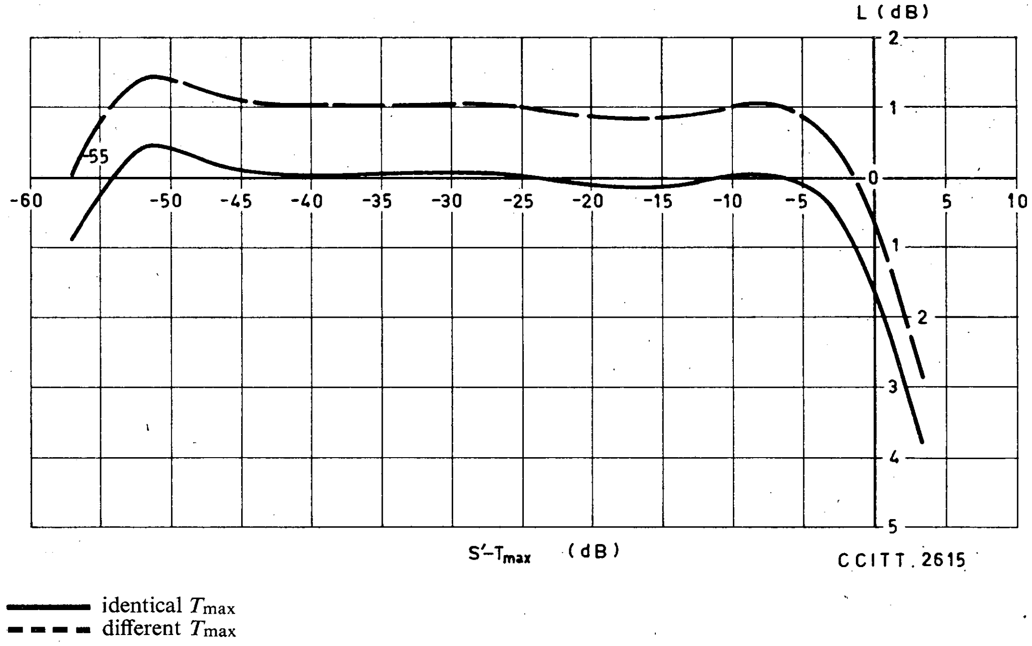


FIGURE 7b. — **Effect on L-values of differences in T_{max} for combination 1 with recoding**

be simplified by recognizing fewer digits at the sacrifice of some of this improvement. The effects of such simplification have not yet been studied.

5. *The effect of differences in* $T_{\max}$

Differences in $T_{\max}$ between encoder and decoder have little effect on the R curves for most of the input range but modify the L curves by an amount corresponding to the difference between the two values of $T_{\max}$. Figures 7a and b illustrate the R and L curves for combination 1 (with recoding) obtained by including and neglecting the differences in $T_{\max}$ ($T_{\max}$ is +2 dBm for the $A = 87.6$, 13-segment law and is +3 dBm for the $\mu = 100$ law). To relate theoretical R and L curves to those measured on a practical mismatch system $T_{\max}$ is taken as the value of $T_{\max}$ associated with the encoder.

6. *Other mismatched combinations*

R, L and Q curves are attached for the following mismatched combinations:

Figure 8a, b, c: encoder; $A = 87.6$, 13 segments, 7 digits.
decoder; $A = 87.6$, 13 segments, 8 digits.
Figure 9a, b, c: encoder; $A = 87.6$, 13 segments, 7 digits.
decoder; $\mu = 100$, 31 segments, 8 digits.
Figure 10a, b, c: encoder; $A = 87.6$, 13 segments, 7 digits.
decoder; $\mu = 100$, 31 segments, 8 digits, with recoding.
Figure 11a, b, c: encoder; $A = 87.6$, 13 segments, 8 digits.
decoder; $\mu = 100$, 31 segments, 8 digits, with and without recoding.

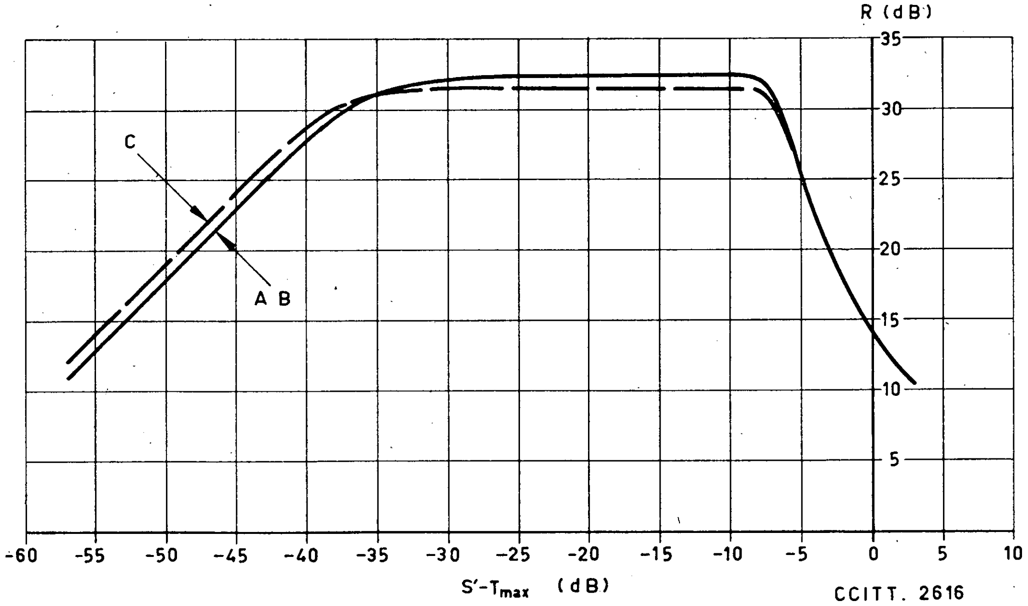


FIGURE 8a. — **R-values for $A = 87.6$, 13-segment, 7-digit encoder; $A = 87.6$, 13-segment, 8-digit decoder**

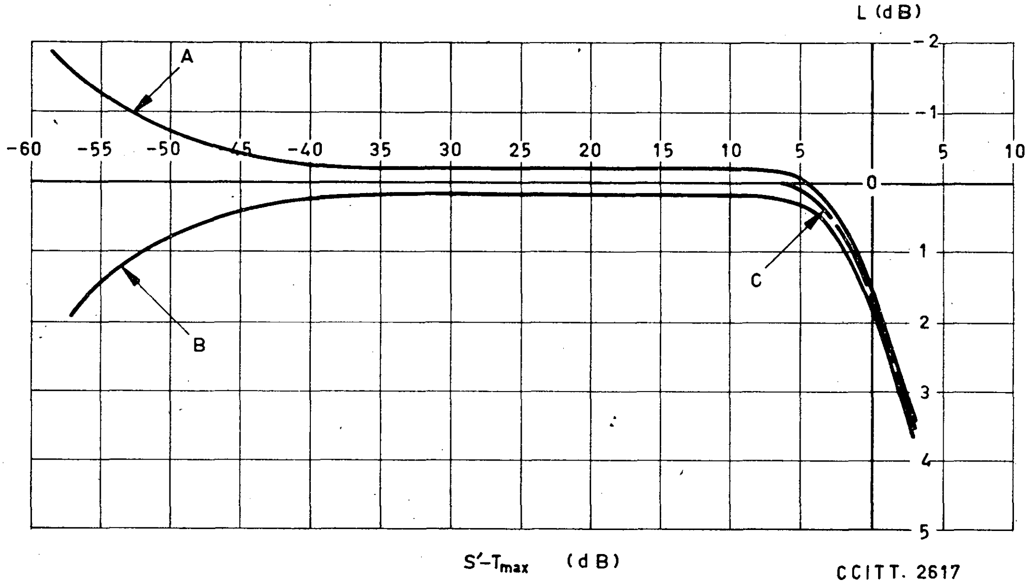
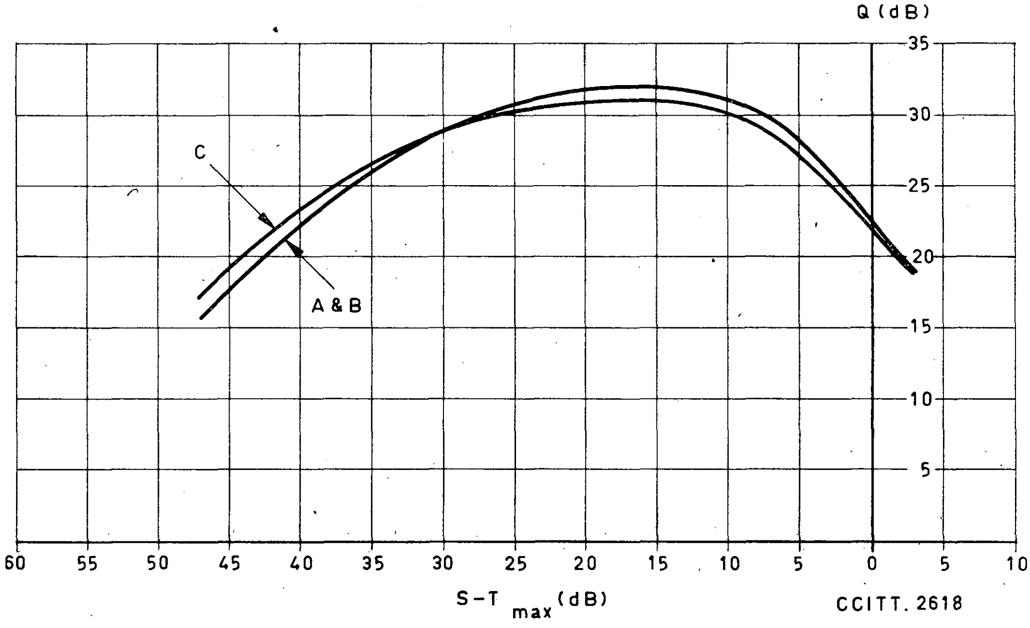
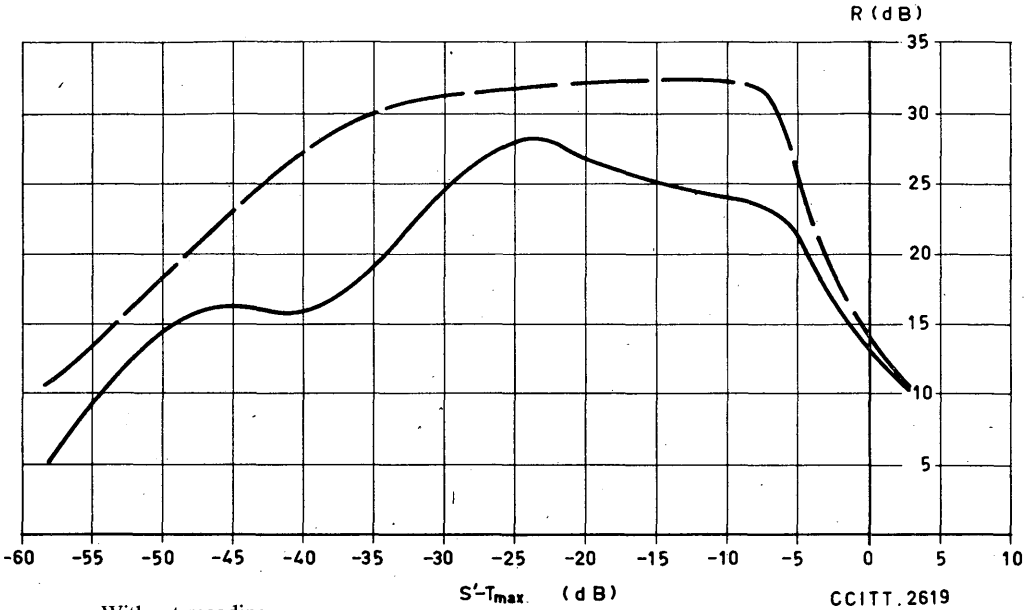


FIGURE 8b. — *L*-values for *A* = 87.6, 13-segment, 7-digit encoder: *A* = 87.6, 13-segment, 8-digit decoder



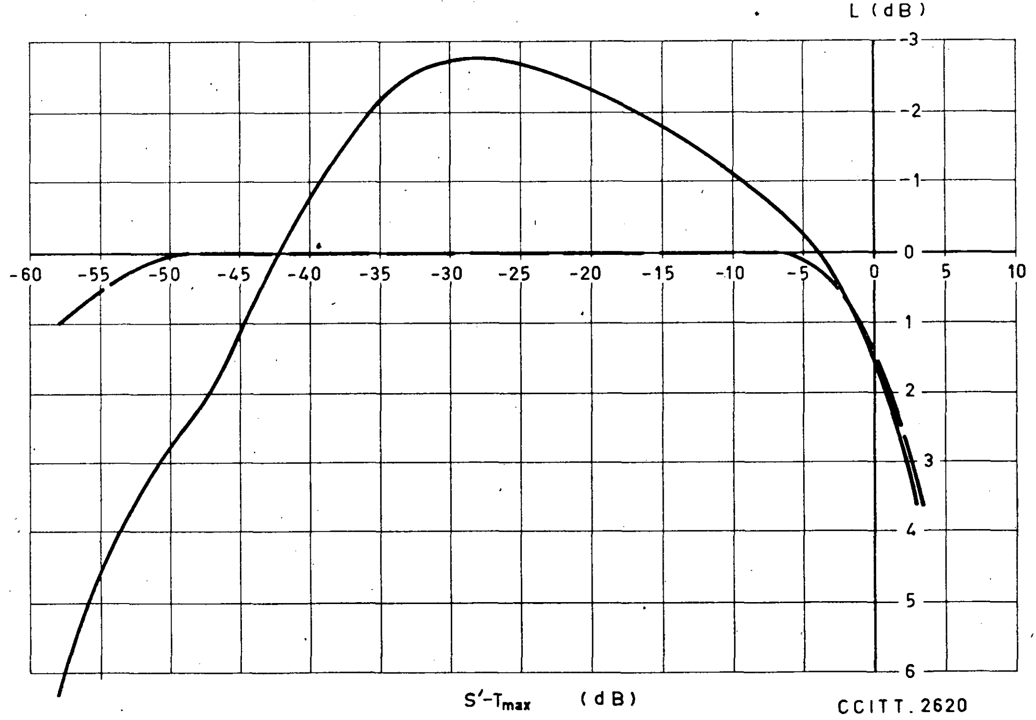
A = System A: add digital '1' to form 8-digit code at decoder
B = System B: add digital '0' to form 8-digit code at decoder
C = System C: add digital '1' to positive value codes and digital '0' to negative value codes to form 8-digit code at decoder

FIGURE 8c. — *Q*-values for *A* = 87.6, 13-segment, 7-digit encoder: *A* = 87.6, 13-segment, 8-digit decoder

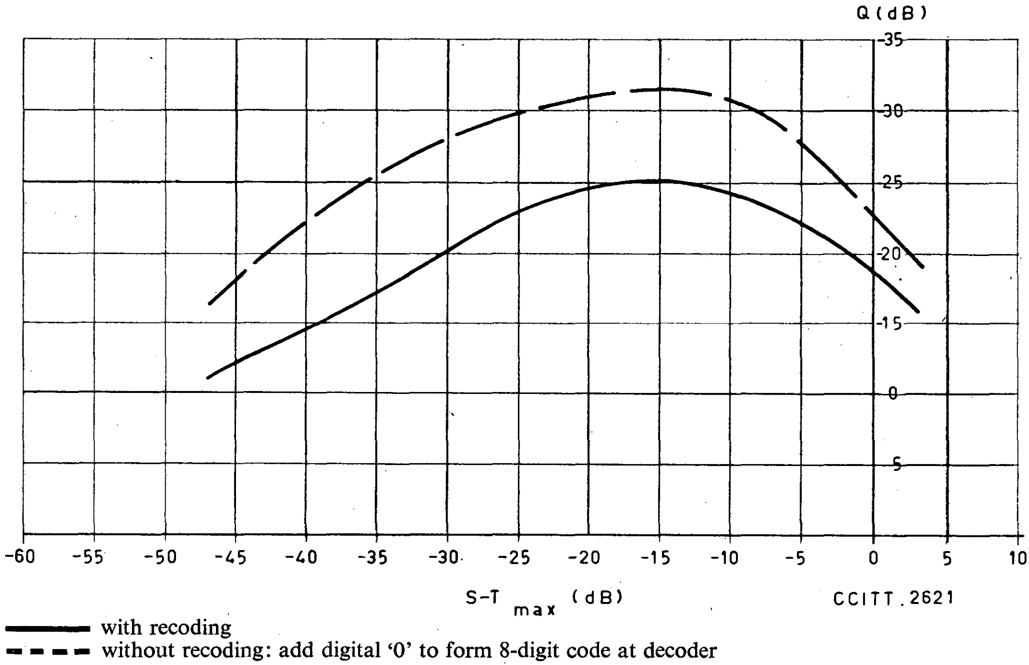


▬▬▬ Without recoding
▬ ▬ ▬ ▬ With recoding
Without recoding: add digital '0' to form 8-digit code at decoder

FIGURES 9a and 10a. — R-values for A = 87.6, 13-segment, 7-digit encoder: μ = 100, 31-segment, 8-digit decoder, with and without recoding



FIGURES 9b and 10b. — L-values for A = 87.6, 13-segment, 7-digit encoder; μ = 100, 31-segment, 8-digit decoder, with and without recoding



FIGURES 9c and 10c. — *Q*-values for $A = 87.6$, 13-segment, 7-digit encoder; $\mu = 100$, 31-segment, 8-digit decoder, with and without recoding

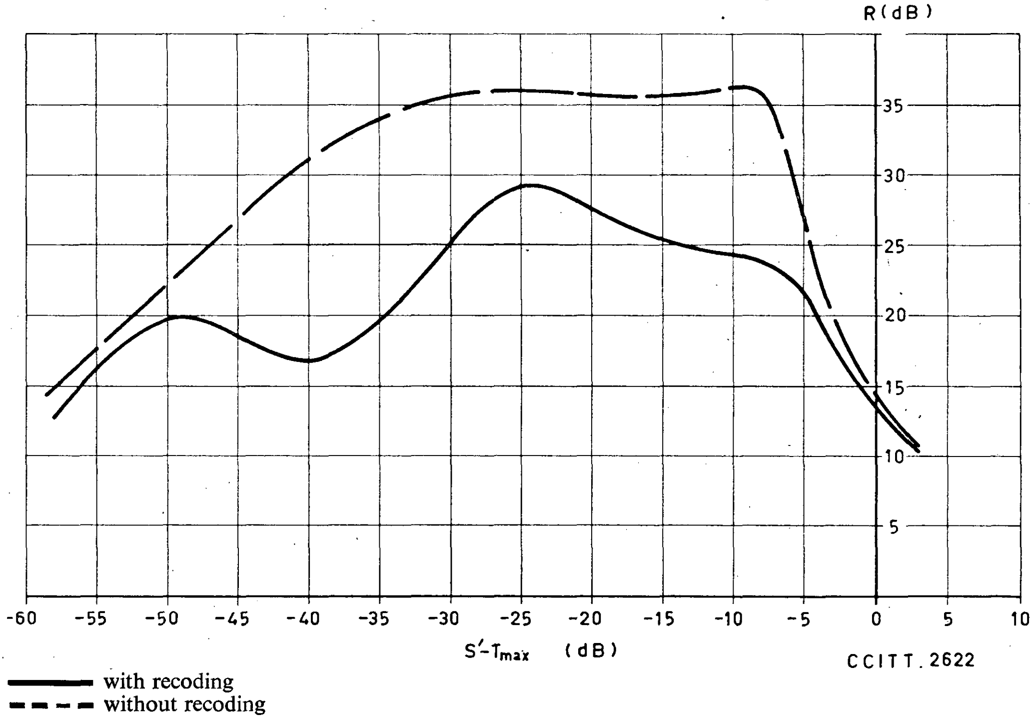


FIGURE 11a. — *R*-values for $A = 87.6$, 13-segment, 8-digit encoder; $\mu = 100$, 31-segment, 8-digit decoder, with and without recoding

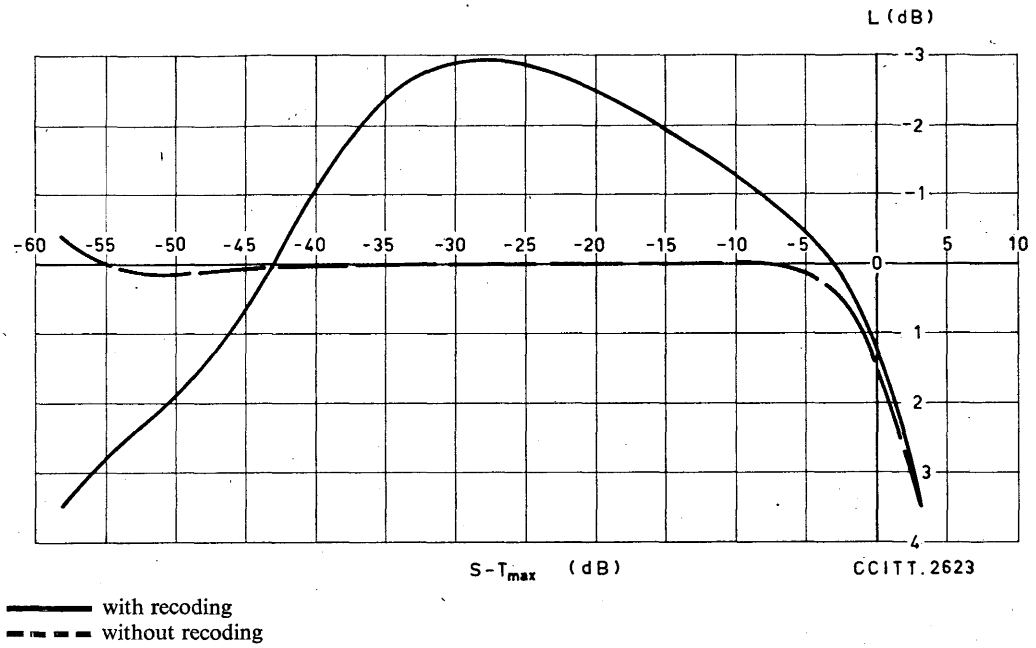


FIGURE 11b. — *L*-values for $A = 87.6$, 13-segment, 8-digit encoder; $\mu = 100$, 31-segment, 8-digit decoder, with and without recoding

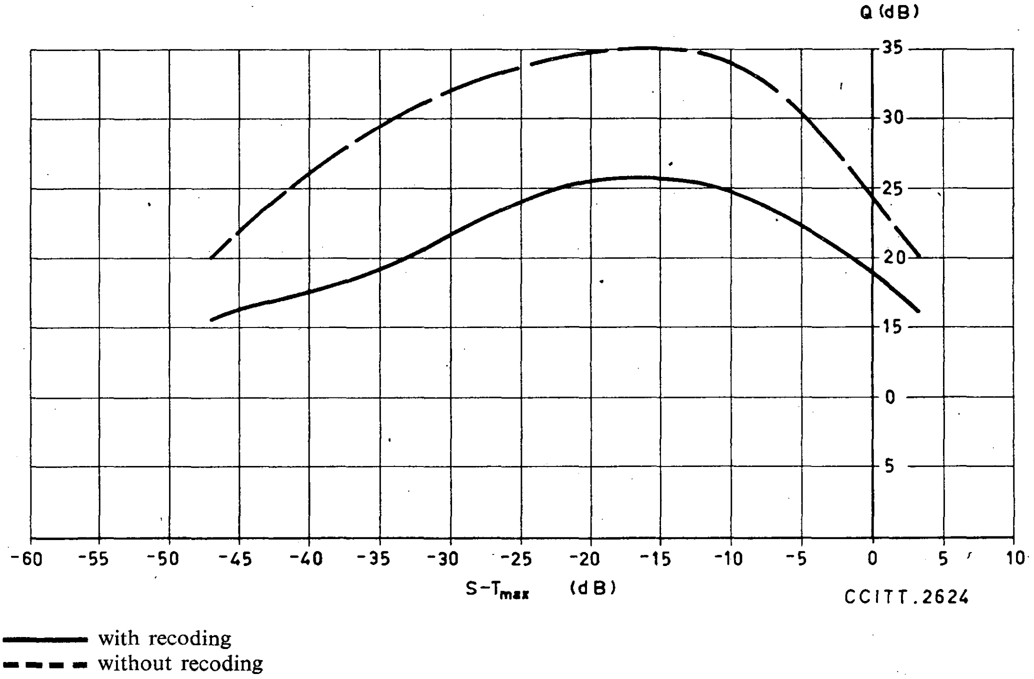


FIGURE 11c. — *Q*-values for $A=87.6$, 13-segment, 8-digit encoder: $\mu = 100$, 31-segment, 8-digit decoder, with and without recoding

7. *Conclusions*

To approach the theoretically attainable performance, an encoder using a particular compression characteristic should only be used with a decoder which is matched to the same compression characteristic. If for some other reason there is need to staticize the digital groups, it is possible, by relatively simple recoding rules, to achieve a reasonably satisfactory performance with incompatible compression characteristics, a sacrifice of only a few dB in signal-to-quantizing distortion ratio being involved.

APPENDIX 2 (to Annex 4)

Signal-to-distortion ratio for dissimilar p.c.m. coder and decoder connected via code translation

(Contribution by the American Telephone & Telegraph Company)

1. *Introduction*

This contribution is an addendum to COM XV—No. 150 (1964–1968), Annex 5, which considered the signal-to-distortion (*S*/*D*) ratio that results when a coder and decoder with dissimilar companding characteristics are connected via code translation. The code translation procedure is discussed in another recent A. T. & T. Co. contribution.

Two cases of the *S*/*D* ratio are presented for the digital interconnection of a hypothesized eight-digit United Kingdom General Post Office (G.P.O.) channel bank with the proposed eight-digit D2-channel bank. The G.P.O.-channel bank with a +2-dBm0 overload is digitally interconnected to a D2 bank with a +5-dBm0 overload. The G.P.O. bank is also digitally interconnected to a D2 bank with a +3-dBm0 overload, the new overload value now being incorporated in the D2-channel bank.

2. *Conclusion*

Digital interconnection of dissimilar banks by code translation can be achieved with only slight degradation of *S*/*D* ratio relative to the *S*/*D* ratio of the bank with lower *S*/*D* ratio.

3. S/D *ratio for D2 and G.P.O. banks*

The *S*/*D* ratio for a D2-channel bank is shown in Figure 1. The *S*/*D* ratio which is plotted relative to full load or overload is the distortion in 4 kHz with flat weighting. The *S*/*D* ratio for the eight-digit G.P.O. channel bank with a +2-dBm0 overload is shown in Figure 2. The decision levels for the eight-digit G.P.O. bank were established by doubling the number of decision levels in the seven-digit G.P.O. bank. The decision levels used in the *S*/*D* calculation for the seven-digit G.P.O. bank as given in Appendix 2 of our recent contribution.

The *S*/*D* ratio for the D2 bank with a +5-dBm0 overload transmitting to the G.P.O. bank is shown in Figure 3. Figure 4 shows the *S*/*D* ratio for the opposite direction of transmission. The *S*/*D* ratio for the D2 bank with a +3-dBm0 overload transmitting to the G.P.O. bank is shown in Figure 5. The *S*/*D* ratio for the opposite direction of transmission is shown in Figure 6.

4. *Observations*

These observations are noted:

4.1 As in the results presented in COM XV—No. 150, Annex 5, there is no significant difference in *S*/*D*, for a given input level, between the two directions of transmission.

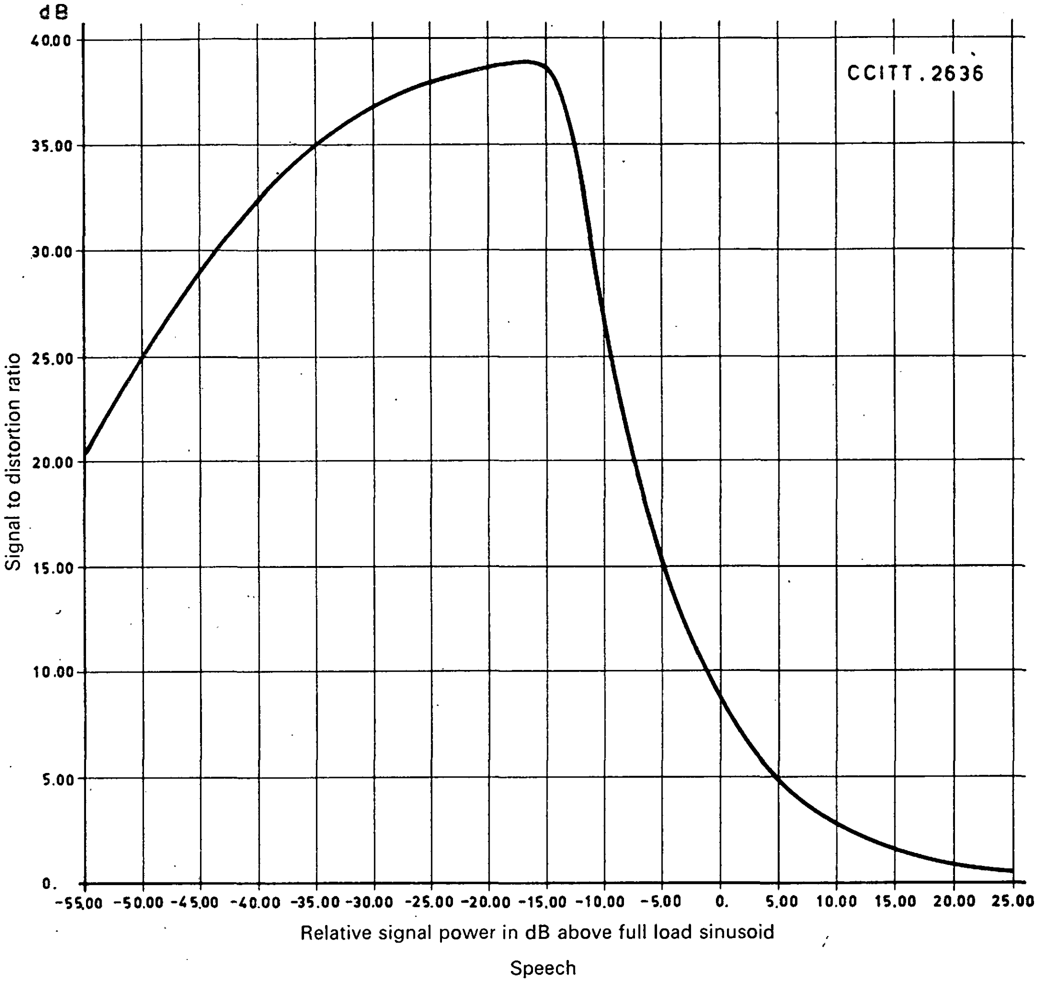


FIGURE 1. — **D2 bank + 5 dbm0 in overload (Distortion in 4 kHz)**

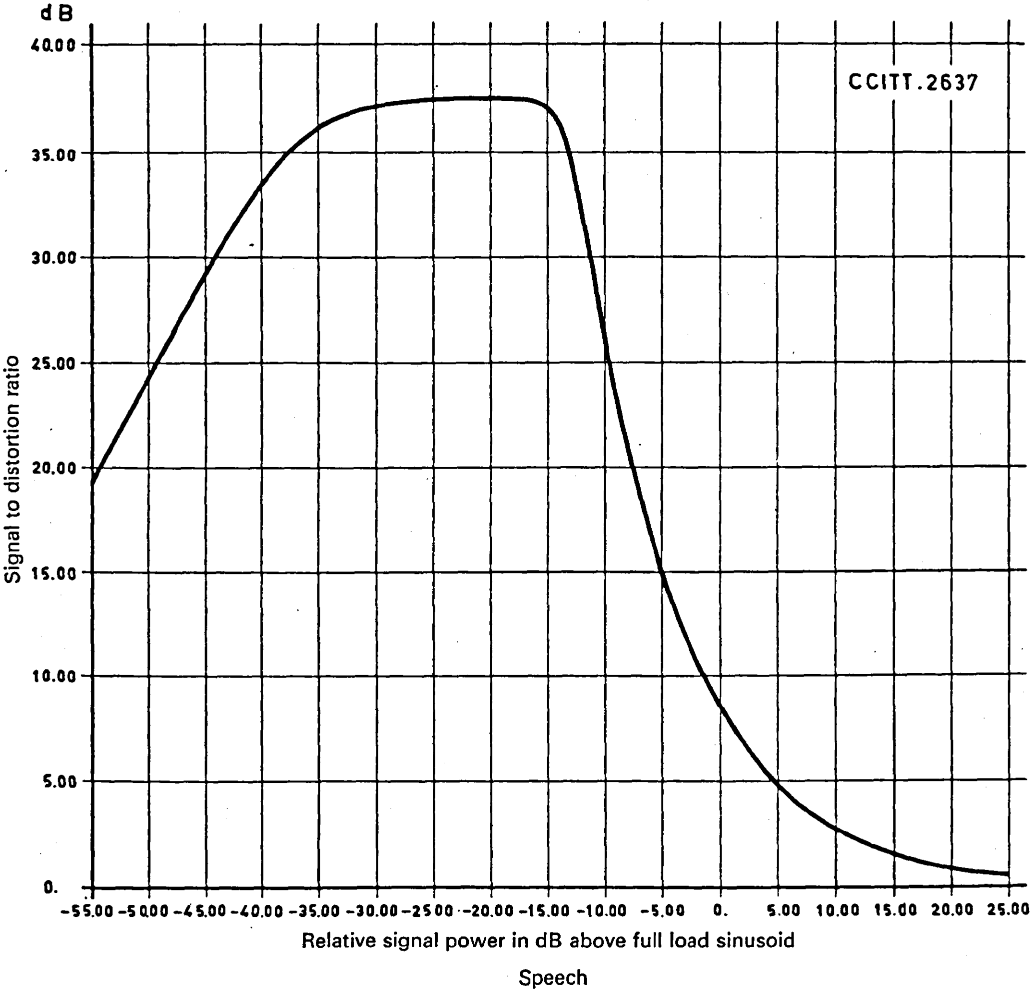


FIGURE 2. — G.P.O. bank + 2 dBm0 overload

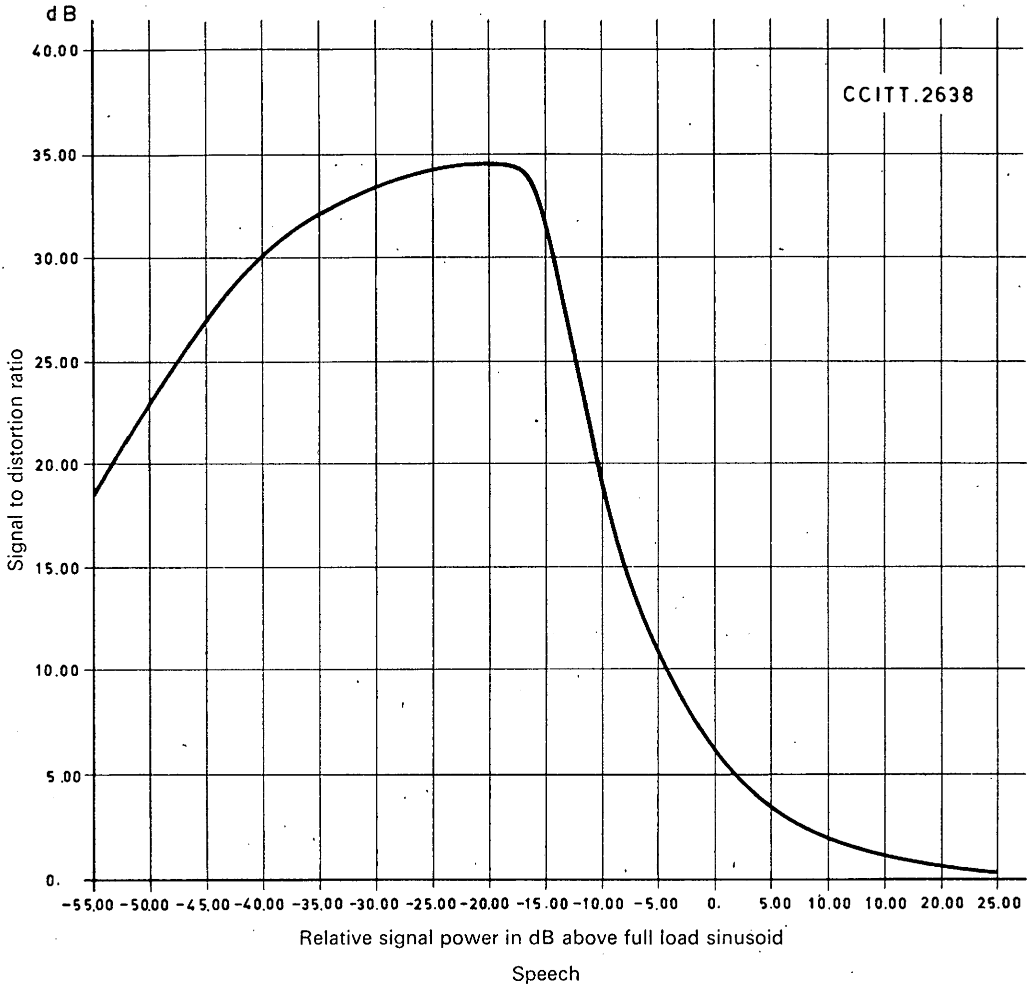


FIGURE 3. — **D2 transmitting to G.P.O. + 5 dBm0 overload**

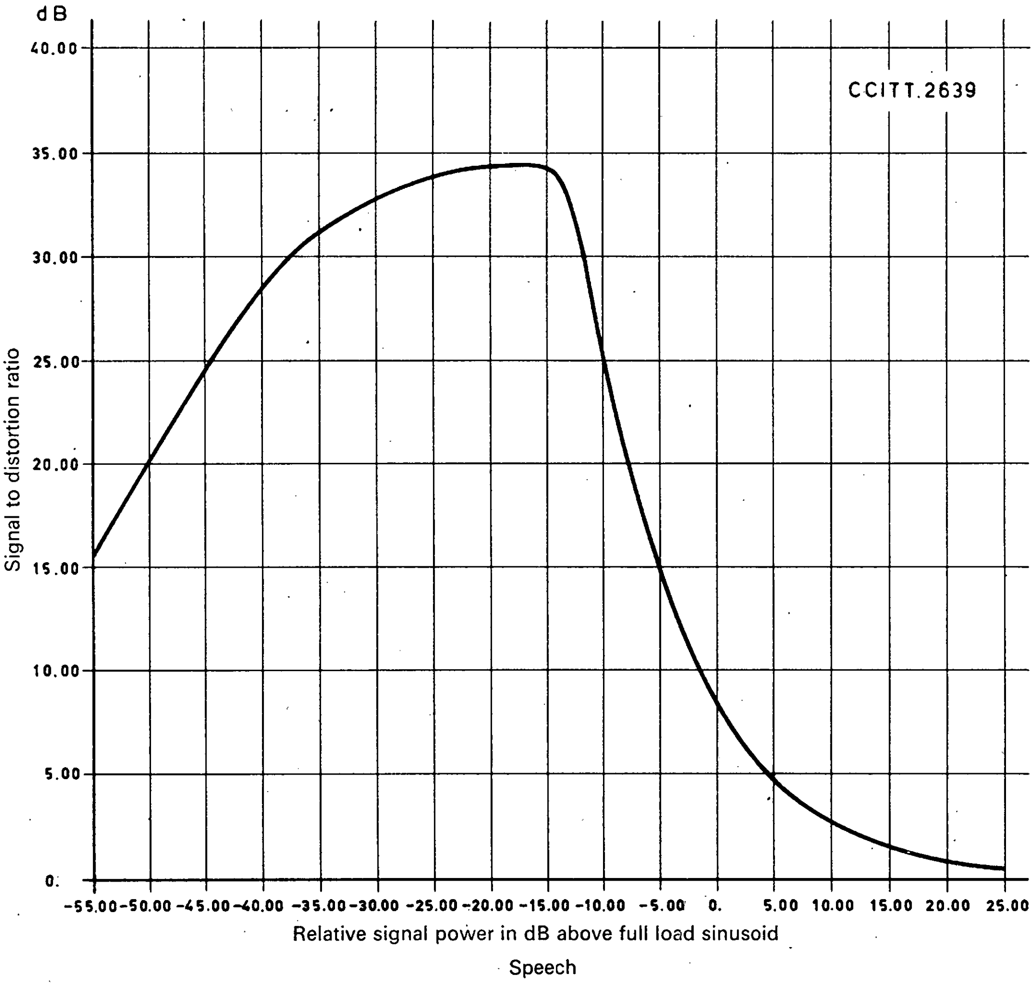


FIGURE 4. — G.P.O. transmitting to D2 + 2 dBm0 overload

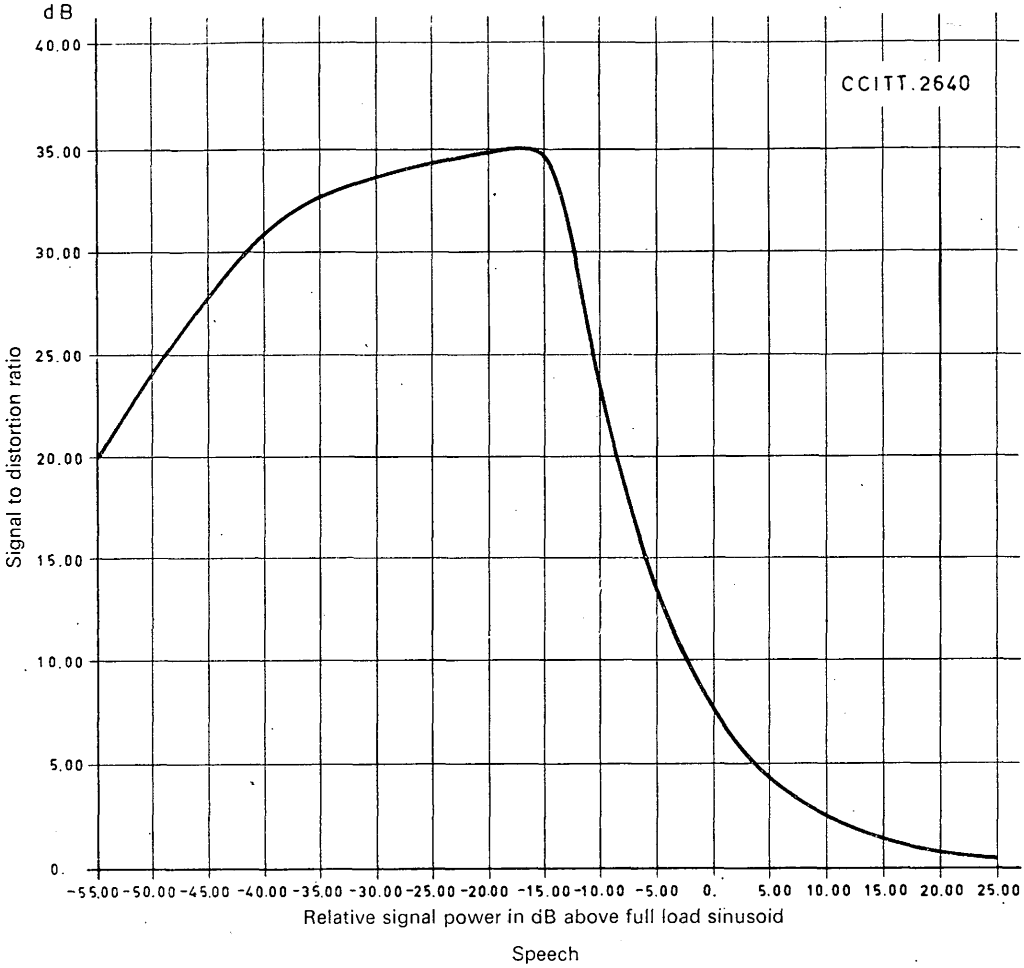


FIGURE 5. — **D2 transmitting to G.P.O. +·3 dBm0 overload**

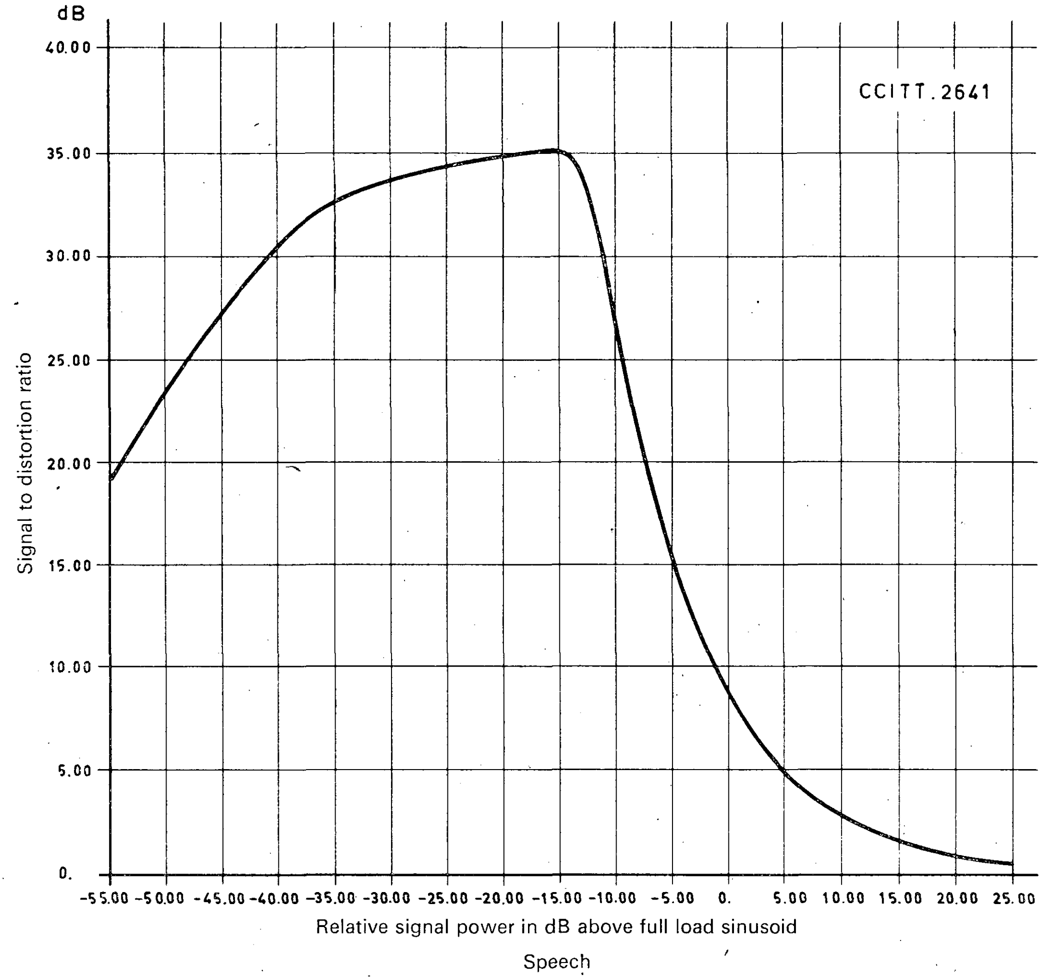


FIGURE 6. — **G.P.O. transmitting to D2 + 3 dBm0 overload**

4.2 From Figure 3 of our recent contribution and from Figure 3 of this contribution, it is noted that the digital interconnection of the two eight-digit banks produces a 3-dB improvement in S/D over the connection of the eight- and seven-digit bank (the seven-digit G.P.O. bank followed the companding law of the eight G.P.O. digit bank). This improvement is only realized over the range of inputs where overload distortion does not control the signal-to-distortion ratio.

4.3 There is a 1 to 2-dB improvement in S/D ratio for the digital interconnection in the case of the D2 bank at a +3-dBm0 overload and the G.P.O. bank as compared with the case of the D2 bank at a +5-dBm0 overload and the G.P.O. bank. As demonstrated in Figures 3–6, the improvement is for signal levels below −30 dBm0.

APPENDIX 3 (to Annex 4)

Compatibility of p.c.m. coders and decoders using different companding laws

(Contribution by the Italian Administration)

The Italian Administration submitted to the meeting of the p.c.m. Working Party in March 1968, a report by M. Décina and L. Giacomelli on a study carried out at the "Fondazione Ugo Bordoni" into the "Compatibility of p.c.m. coders and decoders using different companding laws". This report was published in the March-April issue of *Note Recensioni e Notizie*, volume XVII, No. 2, 1968.

The conclusions of this report are reproduced below.

Conclusions

The signal-to-noise ratio and the loss have been calculated for a connection, whether direct or through an optimum digital converter, between coders and decoders using different companding laws. The results show in the case of a direct connection marked deterioration of the S/N ratio (5-15 dB) compared with the case of matched codecs and notable variations (up to 8 dB) in the attenuation Γ of the useful component of the quantized signal. In the case of a connection through a digital converter, there is a clear improvement of performance. In fact the S/N degradation does not exceed 2-4 dB and the Γ variations are negligible for a vast range of the speech volumes.

Furthermore, an analysis has been made of the compatibility between coders and decoders using the companding law with $A = 87.6$ and 13 segments, whether digital or analogue, and a different number of digits (7 or 8), distinguishing the two cases of codecs with and without "centre-clipping".

It has been shown, firstly, that in the case of codecs with centre-clipping and digital compression, the companding law cannot be exactly identical to the law $A = 87.6$ and 13 segments, specified in a document of the C.C.I.T.T. Furthermore, the connection between 7-digit coders and 8-digit decoders with centre-clipping and analogue or digital companding, does not appear to cause appreciable degradation in performance, compared with the case of the 7-digit codec. In the case of connection between 8-digit coders and 7-digit decoders with centre-clipping there is, instead, a deterioration in performance as compared with the 7-digit codec. In particular, if the code is symmetrical binary, there is, in the first place, an increase of the quantity $T_{\min}$ by about 3.5 dB and, furthermore, appreciable deterioration of the S/N ratio for the low speech volumes.

In the case of codecs without centre-clipping, the connection between 8-digit coders and 7-digit decoders, whether with digital or analogue companding, does not cause any deterioration in performance as compared with the 7-digit codec. On the other hand, the connection between 7-digit coders and 8-digit decoders causes, in any case, a slight deterioration in performance as compared with the 7-digit codec; In fact, the maximum deterioration of the S/N ratio may be expected to be less than 1 dB.

ANNEX 5

(to Question 2/D)

Evaluation of transmission of data and telegraph signals in primary p.c.m. group terminals

This Annex, including contributions from France, Federal Republic of Germany, Netherlands, A. T. & T., United Kingdom and N. T. T., contains discussions of various characteristics of p.c.m. systems which are known to have significant effects on data and telegraph transmission. The characteristics discussed include non-linearity distortion, group delay distortion, digital errors, and tracking error (net loss deviation as a function of channel load).

Non-linearity distortion and group delay distortion

The p.c.m. Working Party suggests that the study of the impact of p.c.m. systems on data transmission be directed so as to ascertain the effects of:

- channel filter distortion and especially of group delay distortion;
- non-linearity distortion, including quantizing distortion.

Therefore, data experiments over p.c.m. systems should comprise:

- an experiment over a number of p.c.m. channels in tandem, with conventional equipment;
- an experiment over an equivalent number of transmitting and receiving filter pairs with the addition of white noise to produce the same impairment of the data signal as in the previous experiment (either in terms of error rate or in reduction of the opening in the eye diagram);
- the same experiment over direct connection.

It should be noted that data systems in which a backward channel is operated simultaneously with the forward channel may present particularly difficult problems when operating under extreme conditions. These occur, for example, when the level difference between the channels is large and the return loss of the terminating set is low.

The three experiments proposed above should provide guidance about the causes and extent of the impairments suffered by data signals when transmitted over a p.c.m. bearer circuit. They will also permit administrations to determine whether standard types of p.c.m. systems, as they stand, or with appropriate auxiliary equipment, will provide an acceptable data service.

It should be noted that group delay distortion in p.c.m. systems is usually less severe than in f.d.m. systems. Figures 1 and 2 represent typical group delay distortion measured on p.c.m. systems by N. T. T. and the U. K. respectively.

The effect of digital errors on voice-band data transmission

Digital errors in a p.c.m. system can cause errors in data transmitted over the system. There is a multiplicative effect which affects the resulting errors in voice-band data channels on p.c.m. systems which can be explained as follows:

If voice-band data are transmitted at a rate b bauds over a p.c.m. system with sampling rate 8000 Hz, there will be $\frac{8000}{b} = S$ samples per baud. If each sample is then encoded in, for instance, 7 binary digits, there will be $7\ S = r$ binary digits per data signal element in the line signal. If we assume that an error in any of the r binary digits representing a data signal element will result in an error in that data signal element, and if we further assume that the line error rate and distribution are such that the probability of two or more digital errors in the same data signal element is extremely small, then a line error rate of 1 error in x binary digits will result in a data error rate of 1 error in $\frac{x}{r}$ data signal elements, or r errors in x data signal elements. Hence, under the assumption made, the multiplication factor is r, the number of binary digits representing each data signal element.

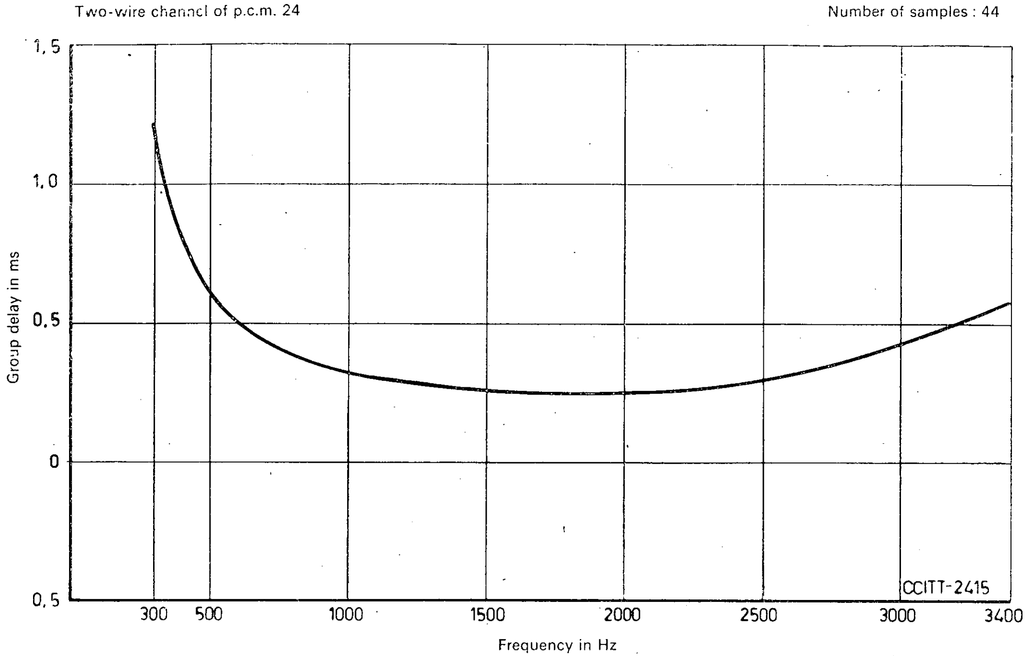
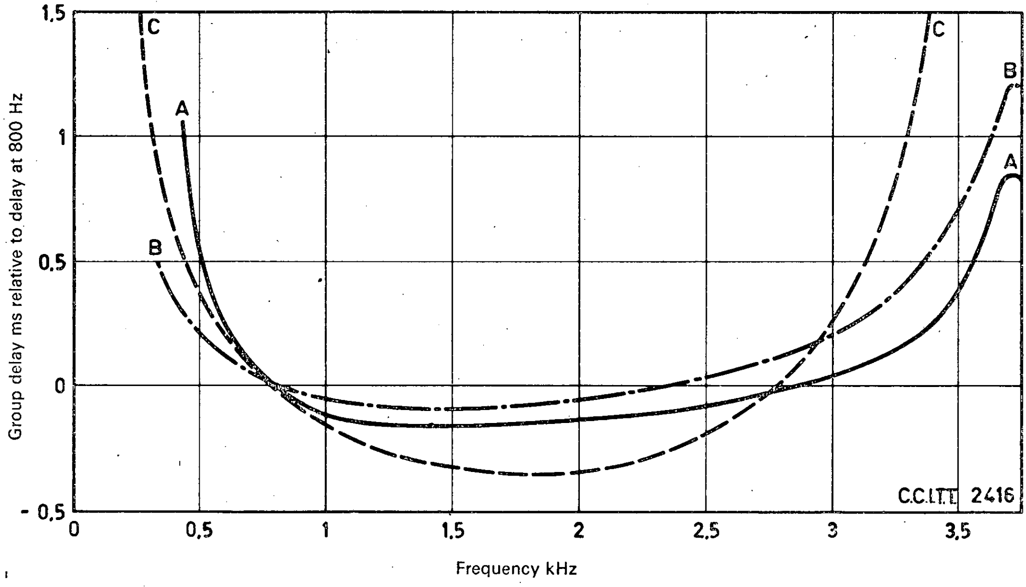


FIGURE 1. — Group delay characteristic measured by the N.T.T.



A = P.C.M. two-wire — two-wire 0 dBm} Test signal
B = P.C.M. four-wire — four-wire −5 dBm} level
C = F.D.M. four-wire — typical channel

FIGURE 2. — Group delay characteristic of a p.c.m. channel (measured in the United Kingdom)

In actual practice, the binary digits near the centre of the data signal element interval are far more likely to cause data signal element errors than those near the edges. Preliminary data from the A. T. & T. on 2400-baud transmission over the T1 line using D1 channel banks (about 23 digits per data signal element) indicate that the multiplication factor varies with signal level and activity on other channels between about 5 and 15. Assuming an average value of 10, it then follows that to achieve an error rate of less than 1 error in 10^5 data signal elements on 2400-baud voice-band data channels without error correction, the line error rate can be no worse than 1 error in 10^6 binary digits.

As an indication of what magnitude of line error rate might be expected, the A. T. & T. has submitted the cumulative line error rate distribution measured on a sample of 1133 T1 lines shown in Figure 3.

The effect of tracking errors on voice-band data transmission

A technique which has been used effectively to transmit high-speed data over voice channels is to reduce the modulation rate by converting the binary data signal to a multi-level signal and transmit this multi-level signal over the channel using vestigial sideband techniques.

The A. T. & T. has found that this transmission technique becomes quite sensitive to small tracking errors (net loss deviations as a function of channel load), particularly at the input levels well below full load, as the data signalling rate, and hence the number of levels, increases. At a data signalling rate of about 5000 binary digits/second, tracking errors of tenths of dBs or less are significant. This becomes particularly important if the tracking errors are systematic and add directly for links in tandem.

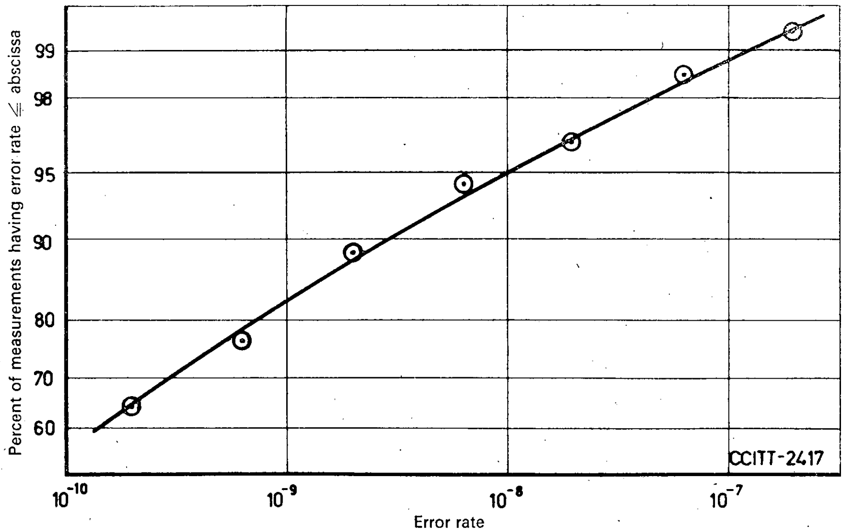


FIGURE 3. — T1 p.c.m. system error rate performance distribution (A.T.T.)

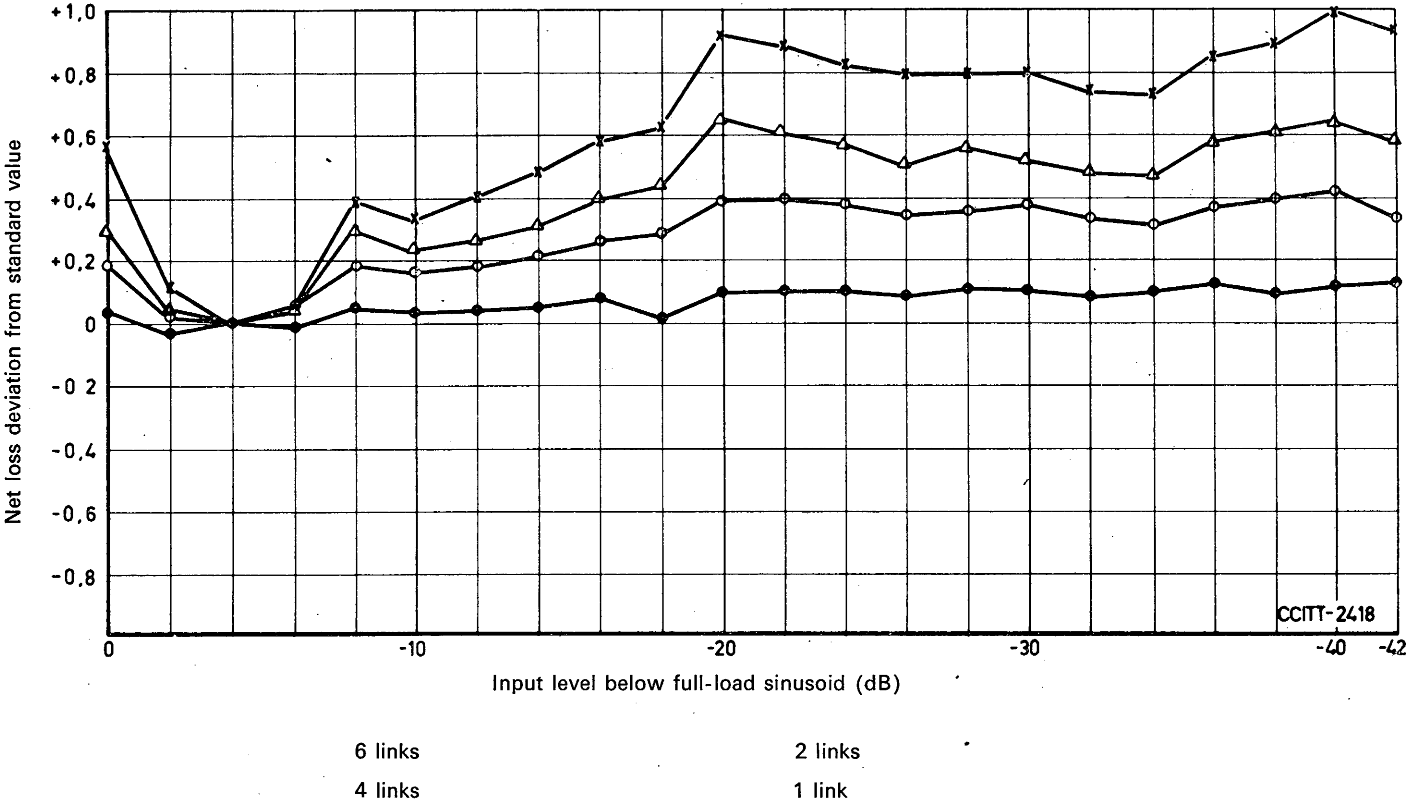


FIGURE 4. — **Attenuation-load characteristics (N.T.T.)**

As an indication of what magnitude of tracking errors might be expected, Figure 4, showing typical tracking performance on a small sample of p.c.m. links, has been contributed by the N. T. T.

Contribution by the F. R. of Germany and the Netherlands concerning v.f. telegraphy via p.c.m.

When using multichannel v.f. telegraph systems via p.c.m. systems with 7-bit encoding, it appears that the telegraph distortion due to quantizing distortion becomes dominant over other causes of telegraph distortion. For 1-1 telegraph signals and C.C.I.T.T. text, measurements, made both in the Federal Republic of Germany and in the Netherlands have indicated that the increase in distortion is about 1 to 2%, compared to the distortion in v.f. telegraph systems via f.d.m. systems.

However, if 2-2 telegraph signals were transmitted, more severe distortion was measured in v.f. telegraph systems via p.c.m. in the Netherlands. Irregular distortion of the order of 8% via one p.c.m. system was noticed. Probably this effect is due to the fact that in this case more distortion products fall into the pass-band of the telegraph-filter.

ANNEX 6

(to Question 2/D)

Proposals for the audio-audio performance characteristics of a trunk junction provided by means of a p.c.m. system

1. *Introduction*

The United Kingdom and Italian Administrations formulated proposals for the audio-audio performance of a trunk junction which is routed via a p.c.m. system and can form part of an international connection.

This Annex contains the proposals amended after discussions between the delegates of these Administrations and those of other administrations during the February 1966 meeting of the Working Party on p.c.m. systems.

2. *Reference connection*

The proposed characteristics have been determined in relation to the hypothetical reference connections given in Figure 1. It is assumed that:

a) the chain of four-wire-switched circuits shown in Figure 1a are all routed over f.d.m. systems;

b) the performance of a trunk junction excludes the line signalling relay sets.

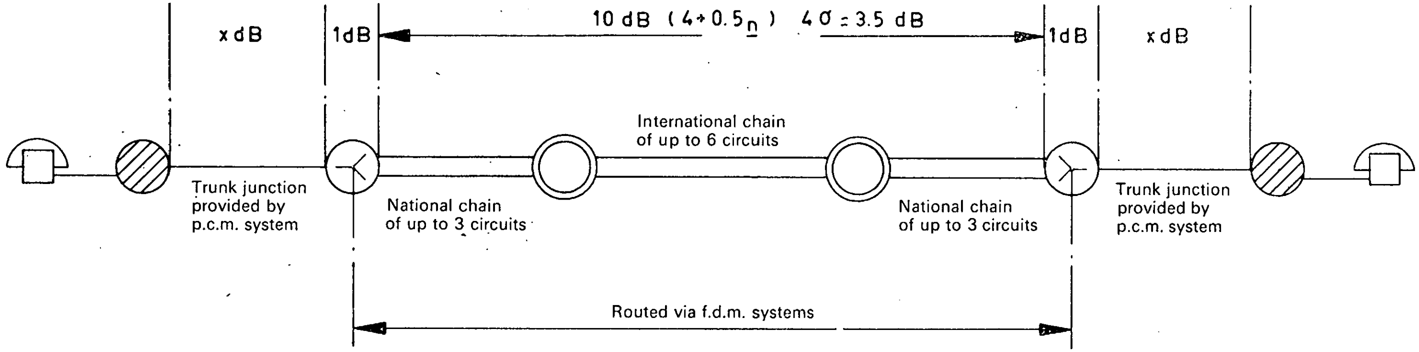
3. *Point of zero relative level*

In this Annex the two-wire switching point is taken as the point of zero relative level.

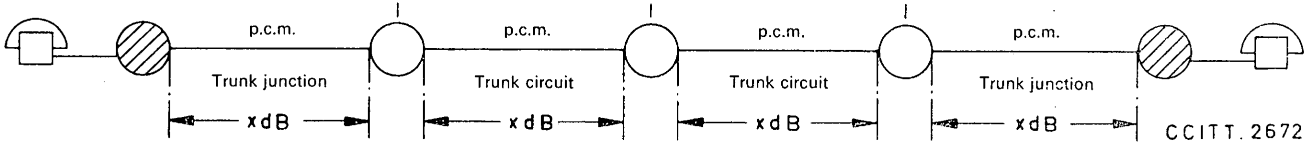
4. *Performance characteristics*

a) *Insertion loss/frequency distortion* (two-wire to two-wire)

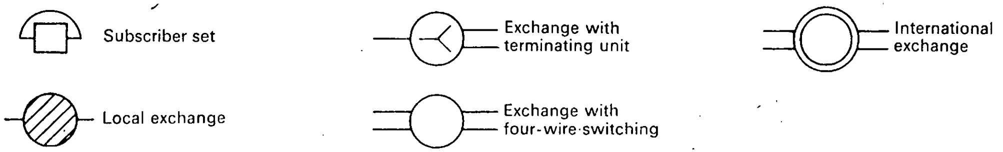
The definition of this characteristic would require making assumptions concerning network planning and transmission quality that are outside the direct concern of the Working Party. The characteristic is, therefore, not here defined but the following points may be noted:



a) Reference connection for determination of performance of a trunk junction suitable for international calls



b) The same trunk junctions participating in a national reference connection of four p.c.m. circuits



Note : The value of the overall equivalent (xdB) of the trunk junctions has been taken as being either 2 or 3 dB

FIGURE 1. — **Hypothetical reference connections for study purposes**

1. The specification of the low-frequency response should take account of the need to provide some suppression of power-frequency interference. The degree of suppression required will depend on the level of interference to be expected. It may be appropriate to assume that limited suppression is normally provided and that in circumstances where above-average levels of power-frequency interference exist, then a somewhat worse low-frequency response may result from the need to provide a relatively high degree of suppression.

2. The four-wire to four-wire performance of the channel over which the trunk junction is routed might be required to have a performance similar to that indicated in Recommendation G.232, Graph No. 2B. It would seem not necessary to refer to an average performance of a number of channels as is done in Recommendation G.232 for f.d.m. systems.

b) *Load capacity*

A value chosen in the range 0 to +3 dBm and defined as the maximum level at a point of zero relative level of the input sinusoid such that an increase of 2 dB beyond this level results in an increase of 1 dB in the output level at the fundamental frequency. The limit is to be met at all frequencies in the 300-3400 Hz band.

c) *Lower limit of the necessary dynamic range* (< —61 dBm0)

This is defined as the minimum level of the applied sinusoidal test signal that is continuously transmitted by the channel. The measuring procedures and the proposed limit are still under study.

d) *Idle channel noise*

The maximum noise in the 300-3400 Hz band should not exceed —63 dBm0p (2.5 dB of psophometric weighting is assumed).

e) *Quantization distortion*

The minimum ratio of measured signal power to quantization-distortion power resulting from the application of sinusoidal test signals in the 300-3400 Hz band and over the level range down to —45 dBm0 should be defined. It is recognized that the values given in appendices 1 and 2 are of the right order of magnitude. However, further study is necessary to determine both the preferred values and the relationship between the figures obtained using the different methods of measurement defined in the two appendices respectively.

f) *Intermodulation distortion*

Further study is needed on this point. A minimum value of 20 dB appears appropriate at this time.

g) *Channel input filter discrimination above 4 kHz*

The discrimination of the input filter in the band 4.6 to 20 kHz should be specified. Further study is required but a minimum value of 20 dB appears appropriate at this time. This recognizes that intelligible crosstalk could occur when an f.d.m. channel is connected to the p.c.m. channel.

h) *Channel output filter discrimination*

The discrimination of the output filter above 4 kHz should be specified. Further study is required but a value of 20 dB over the frequency range 4 to 8 kHz and 30 dB above 8 kHz appears appropriate at this time. This recognizes that intelligible crosstalk could occur when the p.c.m. channel is connected to an f.d.m. channel.

j) *Crosstalk between circuits*

With any test signal in the level range 0 to —20 dBm0 and the 300-3400 Hz frequency band, the crosstalk level should not exceed —60 dBm0. Consideration should be given to reducing crosstalk below this value but it must be recognized that, with some combinations of load capacity and companding advantage this may not be possible.

k) *Variation of overall equivalent as a function of transmitted level*

Figure 2 defines the permissible departures from nominal overall equivalent as a function of test-signal level.

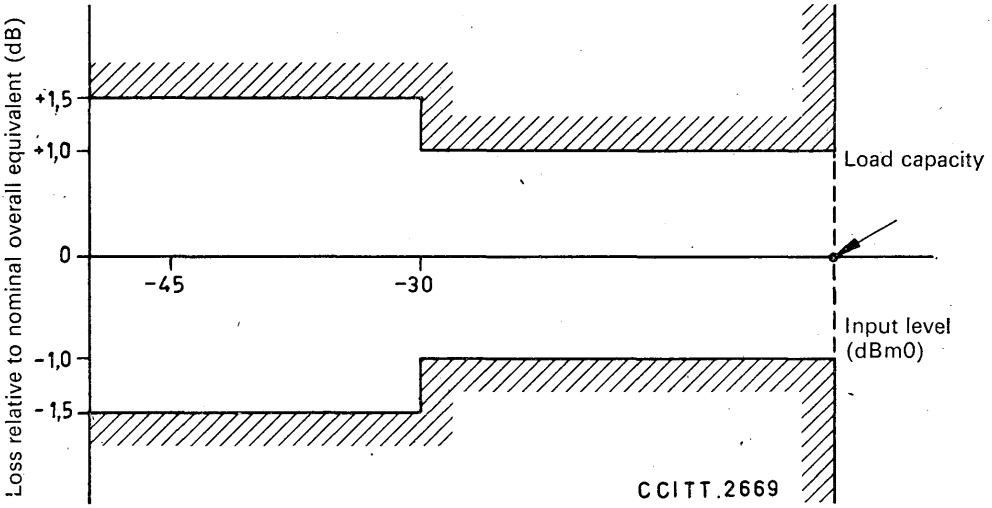


FIGURE 2. — **Variation of overall equivalent as a function of input level**

APPENDIX 1 (to Annex 6)

Values of the signal-to-noise ratio (S/N)

(Extract from a contribution by the Italian Administration)

(S/N) 26 dB $+ \ 3$ dBm0 $\geqq S > - \ 7$ dBm0
(S/N) 28 dB $- \ 7$ dBm0 $\geqq S > -27$ dBm0
(S/N) 26 dB -27 dBm0 $\geqq S > -32$ dBm0

Deviations from the above limits may be admitted, provided that each time they extend below the mask for a variation field of the test signal level no greater than 1 dB.

Definition: S/N is the ratio, expressed in dB, between the r.m.s. value of the sinusoidal test signal and the psophometric value of noise, both measured at the output leads of the equipment.

Verification must be carried out by the following procedure:

At the input, the sinusoidal signal is sent at any level from +3 dBm0 down to —32 dBm0; the signal level and the noise level are measured at reception.

This verification must be repeated with three frequencies within the bands 400-500 Hz, 1000-1100 Hz, 2500-2600 Hz respectively.

The noise measurements must be effected by means of a psophometer, after suppression of the test signal by a band-stop filter having an attenuation in the rejection band of at least 50 dB and a nominal attenuation 100 Hz beyond the limit frequencies of the above-mentioned band no higher than 3 dB with an accepted fluctuation no higher than 1 dB.

Before effecting the measurements, the equivalent attenuation due to these filters in the 300 Hz-3400 Hz band must be determined by means of a white-noise generator.

In calculating the S/N ratio, the equivalent attenuation of the filter should be considered.

APPENDIX 2 (to Annex 6)

Quantization distortion

(Extract from the contribution by the United Kingdom Administration)

The ratio of measured signal power to quantization distortion power at the two-wire output of a trunk junction should not be less than 25 dB for a test signal whose level is anywhere in the range −4 to −37 dBm0.

1. The test signal should be one having a Gaussian distribution of amplitudes and with a uniform spectrum limited in frequency to the band 450-550 Hz.

2. The measured signal power should comprise the output power at the two-wire switching point of the trunk junction within the low-frequency band up to 3400 Hz.

3. The quantization distortion power should comprise that part of the measured signal lying in the band 850-3400 Hz per second.

The above should apply in the presence of the maximum expected longitudinal voltage due to power system interference.

Question 3/D — Signalling for p.c.m. systems

(new question)

a) What general characteristics are to be recommended for the signalling channel on an international circuit set up on a p.c.m. system having a signalling capability allocated to a channel? Use of a bit per channel or of a special 8-digit time-slot must be considered.

b) What general characteristics are to be recommended for a common, data-signalling, type of signalling channel derived from a digital transmission system but not associated to a) with a particular channel or group of channels?

c) What application is foreseen of the signalling facilities envisaged in a) and b) above to switching systems in the existing environment, to possible future t.d.m. exchanges and possible future integrated digital network?

Note. — This Question should be studied in liaison with Question 2/D. Note should also be taken of the section on signalling in Annex 2 of Question 4/D.

ANNEX 1

(to Question 3/D)

Note from the Belgian Administration

The Belgian Administration suggests that the statement of this question implies study of the following point:

> What arrangements should be made in p.c.m. systems to permit the transfer of signals used in existing or recommended signalling systems?

It should be noted that the use of bits in one or more time-slots does not necessarily correspond to signalling systems on each channel or on a separate channel.

In addition, the following point has been raised in connection with studies by Special Study Group A.

> What arrangements should be made in p.c.m. systems to permit the establishment of signalling for such systems, bearing in mind the characteristics of the processing machines and the requirements of certain types of information (e.g. high-speed data transmission)?

ANNEX 2

(to Question 3/D)

Signalling system for integrated networks

(Contribution by the French Administration)

The present contribution describes the principles of the signalling system used in the digital integrated network studied by the French Administration (described in Annex 2 to Question 1/D).

1. *Basic principles of the system*

This is a separate signalling system of the same type as system No. 6 which Study Group XI of the C.C.I.T.T. studied in 1964-1968 for the international network.

Signalling between two exchanges is centralized and transmitted over a special circuit devoted to signalling (common channel, designated " semaphore channel " in what follows) in the form of individual messages.

However, channel-allocated signalling is also used on certain terminal routings of the network, for example, on links between a local exchange and remote subscriber line concentrators.

Signalling is of the " associated " type, i.e. the semaphore channel follows the same route as the speech circuits it relates to. The transit points on the speech circuit are also transfer points for the signalling.

However, the possibility of " quasi-associated " signalling is also reserved. With this method, the semaphore channel between two exchanges can also be used to route signalling messages relating to another link. This facility is to enable the signalling system to be used in the interim period of the development of the integrated network during which audio-frequency routes exist.

2. *Constitution of the signalling channel*

The signalling channel of a 32-channel p.c.m. system is derived from the eighth bit of each time-slot.

In each 125 microseconds frame there are thus 32 signalling bits available.

A superframe of eight successive frames is defined so that in each 1 ms superframe 256 bits are transmitted, thus providing a 256-kbit/s signalling channel.

3. *Different types of signalling*

3.1 *Via a semaphore channel*

Signalling is transmitted in the form of different messages of well-defined form, and with a well-defined position within the 256 bits of the superframe. Messages may be of two types:

- Switching messages, with a prefix denoting the time-slot or circuit concerned and an information-bearing part.
- Management messages, which ensure the co-ordination of two channel terminations, and the correct development of signal phases.

3.2 *Channel allocated signalling*

Signalling relating to a t.d.m. channel is transmitted by means of the eighth bit of each channel, occupying well-defined positions in the superframe.

4. *Error control*

The line transmission of pulses introduces errors which affect the two types of signalling in different ways, and against which precautions can be taken in the following manner:

4.1 *Semaphore channel signalling*

Each message includes bits reserved for an error detection code transmission. If an error is detected, a repetition of the message is generally asked for. For certain messages, however (e.g. service messages), repetition can be avoided if the redundancy is sufficient to allow for correction of most of the errors.

4.2 *Channel allocated signalling*

Protection against errors is obtained by the systematic repetition of the bit mentioned above, taking the majority situation as the real situation.

5. *Exchange of signals between switching centres*

Signalling includes switching messages and management messages transmitted on the semaphore channel in the following manner:

- the switching messages, consisting of 64 bits at the most, are transmitted during the first two frames of the superframe.
- the management messages, consisting of 192 bits at the most, are transmitted during the last six frames of the superframe.

5.1 *Switching messages*

These are for the transmission of, on the one hand, all the information which is intended to replace all existing telephone signalling (transmission of the called subscriber number, off-hook condition, etc.) and on the other hand, new information (indication of congestion at an exchange for example) or of a different nature (quasi-associated signalling message).

5.1.1 *Message structure* — The messages comprise 64 bits numbered from 1 to 64, which are used as follows:

. . . 32 bits composing a unit signal consisting of an indication of the type (3 bits), an indication of the t.d.m. channel, or of the circuit concerned, with the indication of the associated or quasi-associated structure (9 bits), an indication of function (4 bits) and the information content (16 bits).

(The type-indicating unit signals (3 bits) fall into the following categories:

— seizing or clearing signals (setting-up or clearing down of the signalling chain).

— signals necessary for switching (information about the progress of connection).

— service signals (acknowledgement of receipt).

— signals foreign to the speech channel (quasi-associated signalling).

... an index, which may be necessary if the volume of the traffic means that several successive messages must be considered before there is confirmation of good reception: for signals including a t.d.m. channel address the latter can serve as index.

... redundant bits intended to protect the unit signal bits and possibly the index.

... a return service message (possibly indexed) indicating that the message in the backward direction has been received, or in case of incorrect reception, a request for repetition. For this message a sufficient redundancy is given so that it shall be recognizable even if it contains an error.

5.1.2. *Procedure* — If the message has been received, an acknowledgement is sent back when the message reception equipment becomes available, that is to say, when a new message can be sent.

If an error is detected at the receiving end, a request for repetition is sent back during the superframe which begins immediately after receipt of the incorrect message. This request causes repetition of the message from the starting-point. A unit signal is not repeated more than twice.

5.2 *Management messages*

Management messages are exchanged between information processing centres and switching centres, or between information processing centres.

5.2.1 *Message structure* — The messages comprise 192 bits composed as follows:

— 173 information bits;

— 11 bits reserved for management of the link (service messages);

— 8 redundant bits according to an error detection code.

5.2.2 *Types of messages* — Management messages can be classified in four categories:

1) *Operational messages*

These include all messages related to telephone operation in the network under normal working conditions:

— centralized metering of call charges;

— bringing into the service of subscriber lines and circuits;

— observation of subscriber and traffic;

— special services offered to subscribers (indication of charge, wake-up service, transfers, abridged numbering);

— equipment testing and search for incorrect calls.

2) *Relief messages*

When faults occur in certain devices (translators or metering units) in the switching centre, the information processing centre can take their place and thus ensure continuation of service.

3) *Alarm and maintenance messages*

As soon as equipment in a switching centre detects a fault either in its own operation or in the exchange of information with other equipment it alerts the information processing centre. The latter can intervene by isolating the equipment presumed to be at fault, and set detection programmes in action to locate the fault.

It can also set in action a preventive maintenance programme.

4) *Service messages*

Messages acknowledging receipt, requests for repetition, withdrawal from service or return to service, etc.

5.2.3 *Procedure* — The messages are repeated until an acknowledgement of receipt is received back. If acknowledgement is not received within a set time, the transmitting equipment decides that the connection is faulty, advises the receiving equipment and cuts off.

No new message can be transmitted until acknowledgement of receipt has been received.

Information processing centres check the validity of messages received. If a message transmitted without error is of poor quality, the information processing centre orders the originating equipment to be taken out of service.

6. *Signalling exchanged between switching centres and satellite exchanges*

Satellite exchanges are distant concentrators. Both types of signalling, channel-allocated and common channel (semaphore) signalling, are used jointly:

- — channel-allocated signalling is used to transmit certain condition parameters (subscriber line loop) or control parameters (ringing);
- — common channel (semaphore) signalling is used to transmit messages produced by internal equipment in switching centres as well as acknowledgement of receipt, or requests for repetition.

Since orders transmitted from the centre towards the satellite exchange are not the same as condition tests transmitted from the satellite exchange to the centre, there is a particular arrangement of superframe for each direction of transmission.

6.1 *Centre to satellite exchange signalling*

Messages used in common channel (semaphore) signalling, which include not more than 64 bits, are transmitted during the first two frames of the superframe.

The control signals of the channel-allocated type are of four kinds, and are transmitted in frames 3 to 6:

- — 3rd frame: ringing control signals;
- — 4th frame: battery inversion control signals;
- — 5th frame: battery re-inversion signals;
- — 6th frame: metering equipment control signals.

6.2 *Satellite exchange to centre signalling*

The messages are transmitted in the same manner as in the other direction during the first two frames of the superframe.

The signals indicating the condition of the subscriber line, whether looped or disconnected, are transmitted channel by channel during the 3rd frame.

6.3 *Procedure*

For signalling of the channel-allocated type, the different parameters are sent one frame in eight, so that the signalling rate is 1 kbit/s. Protection is provided by the fact that this signalling rate is very clearly superior to the frequency of change of situation in the parameters considered.

The procedure of exchange of signalling by common channel is identical with that of links between switching centres described in the preceding section.

ANNEX 3

(to Question 3/D)

Signalling on a 32-time-slot p.c.m. multiplex

(Contribution by the Belgian Administration)

1. *Introduction*

To provide signalling facilities, the Belgian Administration advocates using the 8 bits bunched in a time-slot. A channel-allocated signalling system providing 15 signalling conditions is described. This system relates to a p.c.m. multiplex with 32 time-slots in which slot No. 0 is set aside for bunched synchronization and slot No. 16 for bunched signalling.

Subsequently, the 8 bits of time-slot No. 16 should provide a common signalling channel (semaphore channel) of 64 000 bits/s.

Although most of this Annex is devoted to channel-allocated signalling, the Belgian Administration considers that common-channel signalling will be the most rational operating method in the fairly near future.

2. *Channel-allocated signalling*

2.1 *Use of channel-allocated signalling*

Apart from the signalling system No. 6 that the C.C.I.T.T. has under study, all recommended signalling systems are " channel-allocated ".

In the period preceding the integration of p.c.m. transmission with p.c.m. switching, it will be useful to have channel-allocated p.c.m. signalling systems available.

2.2 *Comparison between a channel-allocated signalling system using 8 bits bunched within a time-slot and a channel-allocated signalling system using one bit per time-slot*

A signalling system that makes use of one signalling bit per time-slot on a p.c.m. multiplex with 32 time-slots and providing 31 speech channels offers a signalling capacity of $31 \times 8000 = 248\,000$ bits/s.

This signalling capacity is clearly excessive.

A signalling system using 8 bits bunched within a time-slot, thus providing 30 speech channels, has a signalling capacity of $8 \times 8000 = 64\,000$ bits/s, which is ample.

By adopting this second method, the 8th bit in every speech time-slot becomes available for speech encoding; the transmission quality can thus be improved.

The Belgian Administration is of the opinion that this improvement in quality is essential to permit the tandem connection of a great number of coder-decoders (transition stage using analogue switching). Furthermore, the improved quality will make it possible to cope better with future requirements involving the transmission of analogue signals other than speech signals.

Thus, besides an increase in the sampling rate (see 2.4 below), programme transmissions will need a higher number of bits to define the amplitude of a sample.

This higher number of bits could be obtained by using two adjacent time-slots. In that case, the 8th bit used for signalling would impair the free use of the 2×8 bits and introduce complications in the circuitry (the 8th bit used for signalling can be compared to the group and supergroup pilot frequencies of f.d.m. systems which are an obstacle to wide-band data transmissions).

In a p.c.m. switching centre, surrounded by switching centres using channel-allocated signalling (intermediate stage of the integration), the extraction of the signalling bits bunched in a time-slot seems to be easier than the extraction of distributed signalling bits; the subsequent changeover to common-channel signalling will be simpler, as the common channel will be using the same bunched bits.

The Belgian Administration has taken note of the advantages that certain administrations have found in a channel-allocated signalling system using distributed bits. It seems however that these advantages are mainly dependent on the characteristics of national networks. At the interface between the national and international networks, a conversion of signals will be necessary and, without much extra cost, this conversion will allow the changeover from distributed signalling to a signalling system using the bunched bits of a time-slot.

In view of the foregoing, the Belgian Administration advocates, *for international links*, a signalling system that uses the 8 bunched bits of a time-slot.

2.3 *Choice of the signalling time-slot*

In order to obtain a doubled sampling rate, time-slot $n+16$ must be associated with time-slot n.

Time-slot No. 16 thus corresponds to time-slot No. 0, which already provides the bunched frame synchronizing signal.

By choosing time-slot No. 16 for signalling, 15 channels with a doubled sampling rate can be obtained, whereas with any other time-slot only 14 such channels can be obtained.

2.4 *Channel-allocated signalling systems using 4 signalling bits per speech channel providing 15 signalling conditions*

2.4.1 *Description of the system*

For 30 speech channels, $4 \times 30 = 120$ signalling bits must be provided. As 8 bits per frame are available, a multiframe of 16 frames will provide $16 \times 8 = 128$ bits. In every multiframe, 8 bits are therefore left over.

The allocation of the signalling bits to the 30 speech channels is indicated in the table below.

The frames comprise 32 time-slots numbered 0 to 31; time-slot No. 0 contains the framing signal. Signalling makes use of the 8 bunched bits of time-slot No. 16.

There are 30 speech channels; as with the numbering of the time-slots they are numbered from 1 to 31, channel 16 being absent.

The four signalling bits allocated to a speech channel are designated a, b, c, d.

Frame No.	Bits of slots No. 16							
	1	2	3	4	5	6	7	8
0	0	0	0	0	X	X	X	X
1	1a	1b	1c	1d	17a	17b	17c	17d
2	2a	2b	2c	2d	18a	18b	18c	18d
3	3a	3b	3c	3d	19a	19b	19c	19d
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
13	13a	13b	13c	13d	29a	29b	29c	29d
14	14a	14b	14c	14d	30a	30b	30c	30d
15	15a	15b	15c	15d	31a	31b	31c	31d

The character 0000 formed by bits 1 to 4 of time-slot No. 16 in frame No. 0 provides the framing character for the multiframe. Bits 5 to 8, marked X in the table, are left over.

The 16 signalling conditions provided by the bits a, b, c, d, are reduced to 15 by the exclusion of the character a = b = c = d = 0, in order to avoid any confusion with the multiframe framing character.

Should only four signalling conditions be required, only the bits a, b, will be allocated to each speech channel.

2.4.2 *Comments*

The choice of a 16-frame (2 ms) multiframe is perfectly compatible with the distortions recommended by the C.C.I.T.T. for channel-allocated signalling systems.

By excluding the signalling character 0000, the multiframe framing character is made unambiguous.

The fact that time-slot No. 16 used for signalling includes its own framing character facilitates physical separation of the signalling equipment of the multiplex equipment proper. Moreover, this procedure will facilitate the assembly of signalling time-slots in a signalling multiplex for remote control.

3. *Common-channel signalling*

3.1 *Use of common-channel signalling*

Common-channel signalling will be used in an integrated p.c.m. network. This type of signalling can also be used between (space-division or time-division) exchanges with common processors.

Finally, on large capacity (e.g. intercontinental) p.c.m. links, common-channel signalling could be attractive; in particular, this type of signalling could provide a large number of signalling conditions.

The considerations contained in paragraph 2.2 are also applicable to common-channel signalling.

For the common signalling channel, it is proposed to make use of the 8 bits in time-slot No. 16, which would give a capacity of 64 000 bits/s.

Question 4/D — Digital switching systems

(new question)

What characteristics should be studied to facilitate the introduction of digital switching systems which would form part of an integrated digital network that might be used in international connections?

Note. — This question should be studied in liaison with Question 1/D.

ANNEX 1

(to Question 4/D)

Note from the Belgian Administration

The Belgian Administration suggests that study of this question relates to Question 11/D and implies study of the following point:

> What arrangements should be made in exchanges controlled by processing machines to permit the introduction of t.d.m.-type signalling and the establishment of integrated

digital networks, bearing in mind in particular the requirements of certain types of information (e.g. data transmission)?

ANNEX 2

(to Question 4/D)

Report of the Sub-Working Party on Integrated Systems

The objectives of the Sub-Working Party on Integrated Systems, which met on 11-12 March 1968, were the following:

1. To collect information on systems at present under study by various administrations and other organizations.

2. To study on the basis of this information, the possible repercussions of the use of p.c.m. systems in integrated networks on the parameters of those systems.

The following agenda proposed by the Chairman was adopted:

1. Fundamental characteristics of an integrated digital time division switching system:

1.1 Survey of integrated systems in field trial or under study for the different administrations and other organizations:

— switching system structure,
— synchronization,
— switching office,
— signalling.

1.2 Characteristics of the international circuit as part of an integrated digital switching system:

— synchronization,
— signalling.

2. Specific requirements of p.c.m. terminals and lines working as part of an integrated digital switching system.

2.1 Special facilities needed for the use of p.c.m. terminal equipments in an integrated digital switching system:

— additional switching functions,
— remote control.

2.2 Specific requirements:

— of p.c.m. terminals
— of p.c.m. lines

for their utilization in an integrated digital switching system.

1. *Basic characteristics of an integrated system*

1.1 *Collection of information on systems under study*

Mr. Pouliquen of the French Administration recapitulated the main features of the integrated system at present being established and described in two contributions submitted to the Working Party (reproduced in Annex 2 to Question 3/D and in Annex 3 below).

Mr. J. P. Runyon of the Bell Telephone Laboratories gave a brief description of the characteristics of the system under study at the Laboratories. A paper containing a more detailed description of the system will be presented by Mr. Brilliant to the I.E.E.E. International Conference on Communication, to be held in Philadelphia in June 1968.

Mr. K. Habara of the Nippon Telegraph and Telephone Public Corporation drew attention to contribution COM XV—No. 144 (1964-1968) which deals with work being done in Japan.

Mr. W. T. Duerdoth of the United Kingdom G.P.O. described the United Kingdom system, which had been dealt with in papers presented to the International Symposium on Electronic Switching, Paris, 1966, and to the 4th and 5th Teletraffic Congresses.

Mr. W. T. Jones of the International Telephone and Telegraph Corporation described one of several switching systems being studied at the I.T.T. Laboratory. Three articles had been written on this subject:

G. C. Hartley and J. H. Dejean: Potentialities of an integrated digital network; *Electrical Communication*, Volume 43, No. 3, 1967.

A. Chatelon: P.c.m. telephone exchange switches digital data like a computer; *Electronics*, October 1966.

J. Le Corre: Organization of a p.c.m. automatic switching office (in French); International Symposium on Electronic Switching, Paris, 1966.

Mr. A. Bachmann of the Swiss Administration spoke about the work being carried out in Switzerland and said that a paper on the Swiss system had been presented to the International Symposium on Electronic Switching, Paris, 1966. Another paper on this system was presented to the I.E.E.E. International Conference on Communication, Minneapolis, 1967.

A tabulation of the information reviewed by the several delegates is given in the appendix.

Switching on a per channel basis seems to be a feature common to all the systems presented.

Synchronization — The Sub-Working Party is of the opinion that it is too early to decide that a national network can be synchronized and the corresponding decision for an international network must come later. Some delegates think that a synchronous network should be designed so that it can continue to operate as an asynchronous network on failure of synchronism.

At this stage the question of the requirements for the accuracy and stability of the clocks used in an asynchronous network was raised by some delegates who suggested that similar requirements would arise in a synchronous network to cater for asynchronous operation in event of failure of synchronization. For this purpose, the Sub-Working Party would welcome the definition of a hypothetical reference connection involving a number of digital switching centres.

Some delegates stressed that, in addition to the frame synchronization signal, it would be useful to provide a signal conveying information for synchronization of the clocks. This information might be transmitted via any suitable path.

The Sub-Working Party concluded that the structure of a digital switch would not impose any particular restriction on the method used to transmit the control information for synchronization of the network.

Signalling — The Sub-Working Party thinks that a signalling system of the data transmission type would be the preferred solution for international p.c.m. links between time division switching centres. This is because the interest in this type of signalling is reflected in system No. 6 in course of definition by the C.C.I.T.T. and because the t.d. switching centre will probably be controlled by electronic processor and will therefore be best suited to use this type of signalling.

Furthermore, it is very likely that system No. 6 will also be used in future analogue switching centres and consequently the use of a data transmission type signalling system in a digital network will facilitate interconnections between analogue and digital switching centres.

The Sub-Working Party thinks also that signalling information will be transmitted in digital form in the t.d. systems and in order to leave open all future possibilities, some delegates feel that the signalling channel of the t.d. switching system should be much faster than that of signalling system No. 6, even if this high speed may seem unnecessary today.

When signalling is transmitted via a data channel a certain number of administrations think that the signalling channel of the p.c.m. system should not differ from other data channels. The signalling channel could be a single time-slot without specifying if this time-slot should systematically be part of each primary multiplex frame or of each secondary multiplex frame. It is noted that a bunched signalling arrangement could facilitate changeover to a traffic telephone channel, to allow for the transmission of the signalling information in the event of a failure of the dedicated signalling channel.

Other administrations think that the signalling transmission capacity on one time-slot may be unnecessarily high for some data links of the No. 6 system signalling network and would prefer using other arrangements in these cases, for example using a single binary digit in each primary multiplex frame, or the use of this single binary digit in every fourth frame only.

Under fully integrated network conditions it may be expected that facilities will exist for sub-multiplexing the data information capacity of a single time-slot for general data transmission and telegraphy purposes. It would then be possible to assign data channels of appropriate speed for use as data links in the system No. 6 signalling network.

Another possibility has also been investigated, namely, the use of a single binary digit per channel to provide a signalling path; this assumes that it is not required for the transmission of information. Because of the present uncertainty as to whether 7- or 8-binary digit coding will be used for the speech information, the Sub-Working Party thinks that it is less desirable to form a signalling path, on international p.c.m. links, by using a binary digit within the time-slot. Such a solution would make modifications necessary in the event of all 8 binary digits being used for speech transmission.

1.2 *Design parameters of international p.c.m. circuits*

As well as questions concerning synchronizing and signalling, the Sub-Working Party has examined certain system design parameters of an international p.c.m. link.

The utilization of p.c.m. links in an international integrated network does not seem to have any direct repercussions on these parameters, but this examination has shown the great importance of defining the level in the multiplex hierarchy at which international interconnections may be made.

Furthermore, it is recognized that, as far as integrated systems are concerned, there is a new situation concerning the association of transmission lines with the switching equipments in that the circuits are presented within a certain characteristic frame structure. Thus it appears extremely important to define precisely the interfaces between the transmission system and the digital switch. A proposition on this matter should be established by the Sub-Working Party.

Concerning the structure of the frame, it is noted that a character interleaved structure was the preferred solution for the basic multiplex. In all the digital switching systems under study by the members of the Sub-Working Party the switching was made on a slot-by-slot basis. The frame structure is therefore well adapted to a type of switching which permits transmission at every switching operation of all the binary digits of the same character.

It has been noted furthermore that this type of switch would be adapted also to other types of information than the telephone signal, if all the binary digits corresponding to these informations could be contained in an integral number of time slots.

2. *Specific requirements on p.c.m. terminal equipments and lines working as part of an integrated digital switching system*

The Sub-Working Party was not able to examine in detail item 2 of its agenda and limited itself to reviewing certain conditions required for the p.c.m. terminal equipments arising from their use in an integrated network.

Appendix (to Annex 2)

Table of characteristics of integrated systems under study

Appendix (to Annex 2)

Table of characteristics of integrated systems under study

Administration or other organization	States of development	Field of application	Characteristics of switching offices						Characteristics of modulation	Synchronization	Signalling	Range of size of switching office	Notes
			Concentration	Switching				Control					
				Structure	Mode of transfer	Switching control	Speech delay						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
United Kingdom	Feasibility model completed and now being installed for live traffic trial	Central tandem exchange	None	Switch-store switch with aligners at periphery	Serial at 24 time-slot rate	Ferrite cores or glass delay lines	Glass delay lines and diode-capacitor storage	Registers and supervisories in unit form. End marking for path selection	Standard 24-channel system of the United Kingdom Administration	Exchange includes a central clock from which the remote terminals are locked, synchronous start	Signals from the terminal step-by-step exchange conveyed by the first binary digit of each channel but restricted to alternative multi-frames	Suitable for 10 to 600 incoming 24 time-slot systems	
N.T. and T. (Japan)	Feasibility model completed and now being used as a small P.B.X. in laboratory, connected with national network for a year	Local and tandem exchanges	Space division (metallic contact) remotely controlled through p.c.m. links	Switch-store switch with aligners at periphery	Serial at 24 time-slot rate	Ferrite cores	Diode capacitor	Stored programme control including some wired logic (general-purpose computer with 65 kbits memory)	Standard N.T.T. 24-channel system	a. Master-slave (central office ⟷ remote office) b. b. 1 homochronous b. 2 asynchronous (central office ⟷ central office)* * 4 pseudo central offices are installed	Signals from the concentrator (subscribers) conveyed by the first binary digit of each channel	≦ 1500 Erlangs (both-way) (96 highway pairs)	1. A model of speech path alternative that can handle 4500 Erlangs has also been installed at the same time. 2. Five papers in *Review of Electrical Communication Laboratory* March or April 1968 and I.E.E.E. Trans. Com. Feb. 1968 3. Delegates of S.G. XI, Tokyo meeting inspected
I.T.T. 1	Large-scale experimental model	Tandem and toll	—	Space with time switch in centre	Parallel 96 time-slot highways	" scratch pad " stores		Stored programme	Adaptable. At present arranged for U.K. multiplex	Synchronous and asynchronous interfaces both available	Compatible with various types	Up to 6000 E.	

Continued overleaf

APPENDIX to Annex 2 *(cont.)*

APPENDIX to Annex 2 *(cont.)*

Administration or other organization	States of development	Field of application	Characteristics of switching offices						Characteristics of modulation	Synchronization	Signalling	Range of size of switching office	Notes
			Concentration	Switching				Control					
				Structure	Mode of transfer	Switching control	Speech delay						
1	2	3	4	5	6	7	8	9	10	11	12	13	14
I.T.T. 2	Study	Local exchange	Yes	Space and time switching	Parallel	Not settled		Stored programme		Synchronous on concentrator links; asynchronous to higher order exchanges	Common channel	Not yet determined	
France	Being developed	Terminal areas and local transit	Time-division by groups of 500 subscribers	Store-switch store without blocking	Parallel	Static or circulating	Static	Cabled or stored programme. Specialized units	See Tables I and II of Annex 8 below, except: digits/time-slot: 8-digit rate: 2048	Asynchronous network; can be synchronized	Common channel on a time-slot, + channel by channel for concentrators	128 groups of 32 time-slots	*Commutation et Electronique*, No. 20, January 1968
Bell Telephone Laboratories	Study	Toll, primary and higher level of Bell System network	Nil	Store-switch store	Serial 32 time-slots per frame	Circulating	Circulating	Electronic processor with stored programme	See Tables I and II of Annex 8 Format D2	Asynchronous network at the beginning of service; can be synchronized later on	Channel by channel in the beginning. Common channel on the 193rd binary digit in the future	1024 T1 systems (each one with 24 time-slots)	Will be described in a document submitted by M. B. Brilliant to the I.E.E.E. International Conference on Communication, Philadelphia, June 1968
Switzerland	Study, small-scale model	Terminal and transit areas	Time-division groups including up to 500 telephone subscribers or data subscribers	Store and switch (random access) without blocking	Parallel	Static	Static	Cabled and electronic processor with stored programme	See Tables I and II of Annex 8	Asynchronous network	Common channel on a time-slot	Combination of switching units of: 16 systems, each with 32 time-slots	

It first noted that there would be considerable interest in the definition of an interface between the transmission line equipments and the p.c.m. equipments. These interfaces would be applicable as well in the case where the p.c.m. equipments form part of transmission equipments, as in the case when they form part of t.d. switching exchanges.

In particular it was noted that the p.c.m. equipments of the t.d. switching exchanges would probably not include an adequate device which would prevent, for instance, long sequences of zeros.

At this interface an unrestricted binary code might be defined. However, the need to ensure adequate density of timing information would then have to be met by the line terminal equipment.

The need for facilities to bridge an operator across a call and to provide for a conference call were noted. A digitally linearizable encoding law in the p.c.m. terminal equipment is therefore desirable.

The Sub-Working Party noted the desirability of having an input in p.c.m. terminals giving the possibility to synchronize the local clock of these terminal equipments from a central source if required, e.g. a terminal situated within a digital exchange could then be synchronized from the exchange clock.

ANNEX 3

(to Question 4/D)

An integrated telecommunication network

(Contribution by the French Administration)

The system studied by the French Administration, the basic principles of which are outlined below, is designed to form an integrated telecommunication network.

Digital techniques are therefore used both to transmit and to switch information.

They are also used as a basis for information processing, which is another important element of the system.

Their purpose is to render the network universal, i.e. suitable for all types of information.

1. *General network organization*

The network structure, shown schematically in Figure 1, is built up from basic units formed by a group of switching centres around an information processing centre which exercises permanent check over them.

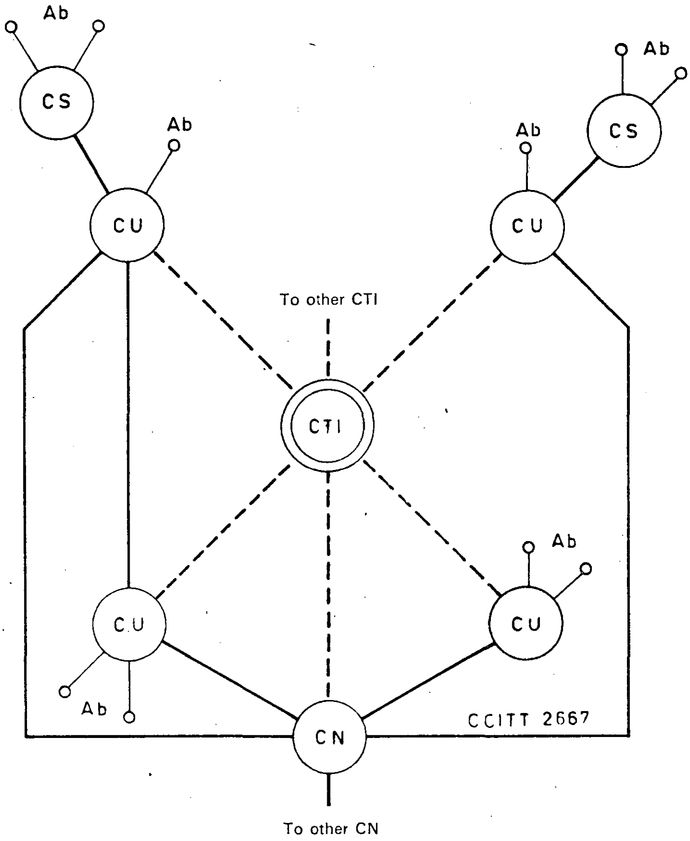
The switching centres are connected by high-speed digital links which transmit information relating to several connections by time division.

Some of these links are also used to exchange information between the switching centres and the information processing centre.

In areas of high-telephone density, where the switching centres have large capacities, a single switching centre may have its own information processing centre.

The switching centres themselves perform all the routine operations for automatic telephony (setting-up and clearing-down of calls, charging) without the help of the information processing centre, which is responsible only for operational control (management, monitoring, maintenance).

Their basic structure, which is indicated in Figure 2, rests on a division into functional elements composed essentially of switching units and control units.



Legend:

Ab	=	Subscriber station	CN	=	Nodal exchange	────	a.f. transmission
CS	=	Satellite exchange	CTI	=	Information processing centre	━━━━	p.c.m. transmission
CU	=	Local exchange				▬ ▬ ▬	Digital transmission

FIGURE 1. — **General structure of an integrated t.d.m. switched network**

The switching units comprise:

1. *Selection units*, which are the input stages, linked individually to the connection network by two multichannel lines.

A distinction may be made between the following four principal types:

a) those serving telephone subscriber lines (500 at the most). The chief functions of this type of selection unit are:

— analogue-digital conversion of telephone signals (p.c.m.),

— concentration of the traffic of 500 subscriber lines onto the two 32-channel lines,

— exploration and monitoring of the subscriber lines,

— feeding of calling lines and exchange of signalling with the subscriber stations.

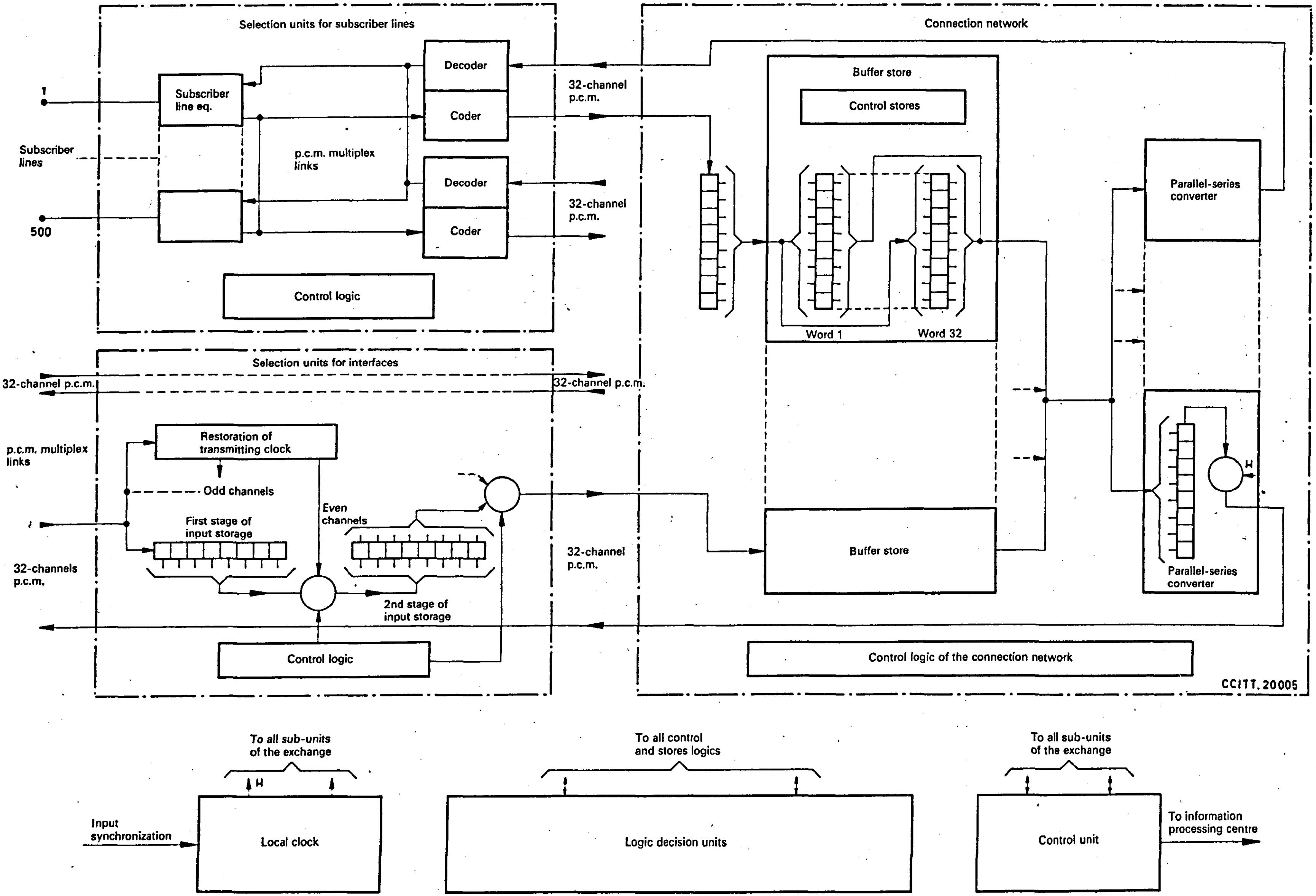


FIGURE 2. — Switching centre

b) those serving digital subscriber lines (data transmission). The chief functions are sampling or, as the case may be, synchronizing the digital signals and multiplexing them to the two multichannel lines. Like the ones mentioned above, they also explore and monitor subscriber lines and exchange signalling with subscriber terminal stations.

c) those to which the links with other switching centres are connected. Their essential function is to ensure clock changing.

d) those to which a.f. links with the normal telephone network are connected.

Note. — The subscriber line selection units may be installed at a distance from the exchange. They are then known as satellite exchanges.

2. *A connection network* without blocking of which the essential function is to ensure the interconnection of all the t.d.m. channels of the incoming and outgoing lines.

The control units comprise:

1) *The logic decision units* which control all the switching operations of the exchange by means of a programme of operation which is recorded in the storage to a certain extent;

2) *The control unit* connected with the information processing centre;

3) The *clock and general time base* which ensure synchronization of the various elements of the exchange.

2. *Modulation*

2.1 *Telephone signal*

The system makes use of pulse code modulation (p.c.m.).

The basic modulation characteristics are as follows:

1) sampling frequency: 8 kHz;

2) load capacity: + 2 dbm0;

3) number of quantizing steps: $2^7 = 128$;

4) compression law: logarithmic, $A = 87.6$, approached by 13 linear segments, the slopes of which are in the ratio two;

5) symmetric binary code.

2.2 *Analogue type signals*

For signals of this type, broadcast programmes for example, the sampling frequency is chosen from multiples of 8 kHz.

In addition, the bits resulting from the analogue-digital conversion are grouped so as to be transmitted in a whole number of time-slots.

2.3 *Digital-type signals*

1) *Medium and high-speed signals*—These may be processed in two ways:

- either by sampling at a frequency that is a multiple of 8 kHz, which is chosen all the higher if the speed of the digital signals is itself greater and the permissible distortion lower. This method does not require synchronization between these signals and the network clock.
- or by slaving them to the network clock and transmitting them direct.

In both cases the bits are grouped for transmission in a whole number of time-slots.

2) *Low-speed signals*—These may be transmitted by sampling at a frequency that is a submultiple of 8 kHz. On some p.c.m. links, one or more time-slots may be set aside specially for the transmission

of this type of information, each time-slot being used for the transmission of several calls of the same type thanks to a new time division.

3) *Transmission*

After modulation the signals are grouped on the multichannel lines in a basic primary multiplex. The frame (125 microseconds) of this primary multiplex comprises 32 time-slots, each of which is composed of 8 bits.

The corresponding pulse rate is 2048 bits per second.

31 time-slots are used for the traffic and they can route 31 telephone channels.

The 32nd time-slot is set aside for synchronization purposes.

In each time-slot, seven bits are used to transmit the modulation, the 8th being reserved to transmit the signalling.

Multiplexes of a higher order, obtained by multiplexing several primary multiplexes, can be transmitted on some transmission lines of the network.

4. *Synchronization*

The network is of the asynchronous type. Each switching centre has its own clock and incoming information is adjusted to local time.

However, it is possible to synchronize all or part of the network by slaving the various clocks to a pilot frequency.

4.1 *Clock changing in switching centres*

This is done in the selection units. The bits of each time-slot sent over an incoming line are recorded in series as and when they arrive in a first input storage stage under the control of the clock of the transmitting exchange restored locally from the synchronization bits.

There are two input storage elements assigned to each incoming line, one for the even time-slots and the other for the odd time-slots. In this way, the bits remain recorded in these storage elements throughout the time-slot following their arrival.

They are then transferred in parallel to a second stage of the input store, at one instant or another of this time-slot, chosen so as not to coincide with the instant of transfer to the store of the connection network, which is determined by the local clock of the exchange.

The bits can then be transferred and read in the buffer stores of the connection network without the risk of coincidence between the writing and reading instants.

This procedure naturally introduces transmission errors; for example, bits transmitted during a time-slot are not retransmitted or, on the contrary, are retransmitted twice consecutively, depending on the direction of the difference between clocks shift, with a periodicity which is in direct proportion to the size of this difference.

For telephone modulation, these errors do not matter provided that the different clocks of the network keep within certain limits (for example that they do not differ by more than 10^{-5}).

For medium- and high-speed data transmissions these errors may likewise be of no consequence if the precaution is taken of changing the transfer time-slot between the two element stages of the input store only when there is a particular frame during which the data transmission signal carries no information. This particular frame must naturally be repeated with a certain periodicity (for instance, that of the superframe mentioned below in paragraph 6).

4.2 *Multiplexings — demultiplexings in the transmission network*

Unlike with automatic switching equipment, where clock changing introduces errors, the information transmitted by non-synchronous sources can be multiplexed without loss of information.

This operation can be effected by adopting, for the high order-multiplexes (compound multiplexes grouping several primary multiplexes), a frequency that is slightly higher than a whole multiple of the primary multiplex frequency. Bits are inserted to adjust the phase, their position being indicated via a special channel. A method of this type was described in the *Bell System Technical Journal* of November 1965.

Other solutions, consisting in synchronizing the network, may likewise be applied.

This problem is studied in a separate special contribution.

5. *Switching*

Switching is effected without alignment of the timings. The network connecting the automatic switching equipments is constituted by the buffer stores in which the bits transmitted by the incoming lines are recorded throughout the duration of a frame of 125 microseconds. They can therefore be read and transmitted on the outgoing lines during any of the frame time-slots.

6. *Signalling*

Signalling between the exchanges is transmitted over a special channel, known as the semaphore channel, in the form of individual messages. However, channel-allocated signalling is likewise used on some terminal links of the network, for example, on links between local exchanges and satellite exchanges.

The signalling channel of the p.c.m. links with 32 time-slots is constituted by the 8th bits of each time-slot.

In each 125-microsecond frame, 32 bits are thus available for signalling.

A superframe of eight successive frames is defined, so that each superframe of 1 millisecond allows the transmission of 256 bits, which provides a signalling channel of 256 kbits/s.

Further information on the signalling system is given in Annex 2 to Question 3/D.

ANNEX 4

(to Question 4/D)

Some remarks on composing a p.c.m. integrated network

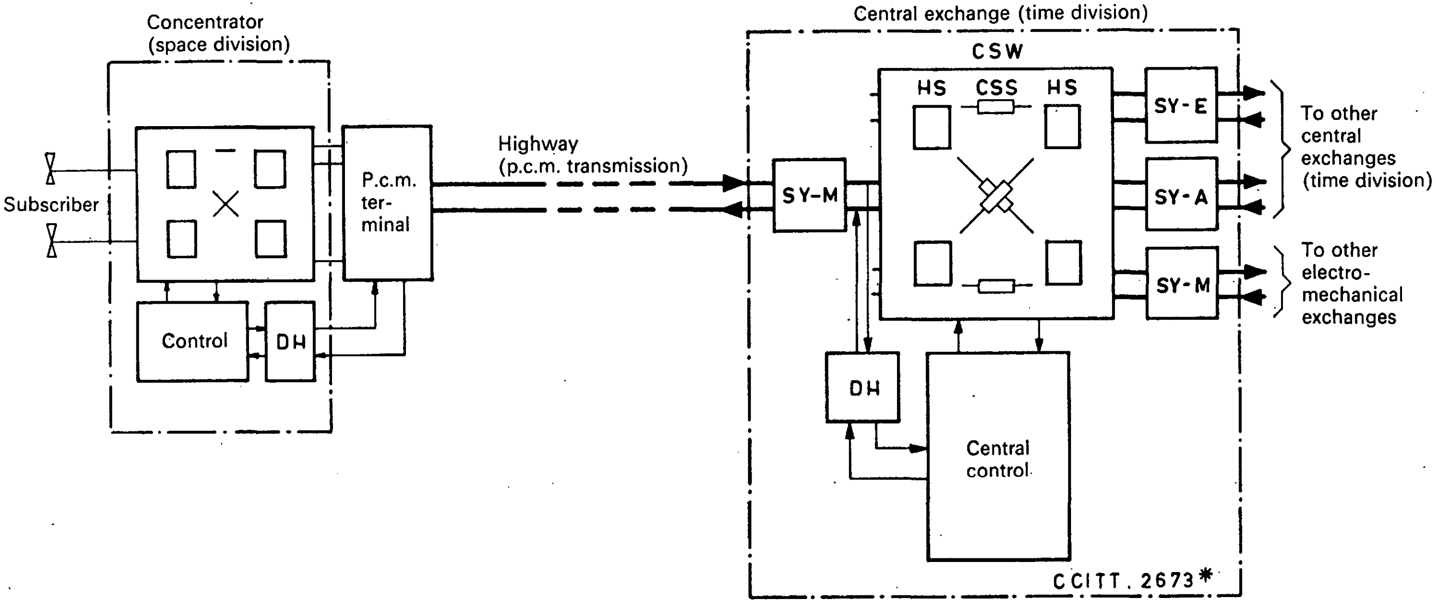
(Contribution by the Nippon Telegraph and Telephone Public Corporation)

1. *Introduction*

There are many factors of p.c.m. transmission systems which should be taken into consideration from the viewpoint of an integrated switching and transmission system. N.T.T. has studied these factors on an experimental p.c.m. integrated switching and transmission system. This Annex contains some remarks concerning the basic characteristics.

2. *Experimental system*

The basic configuration of the system is illustrated in Figure 1. The system is planned to integrate telephone exchanges and transmission links on the basis of a 24-channel p.c.m. system. The multiplex structure of p.c.m. signals is shown in Figure 2. A frame is made up of 193 digits and the 193rd digit is used for frame synchronization. The dialling and on/off hook information are carried by the first digit (signalling digit) in each time-slot.



DH = Data-handler for remote control
SY = Synchronization equipment
- E for equational timing
- A for asynchronous timing
- M for master-slave timing

FIGURE 1. — **Configuration of experimental p.c.m. integrated system**

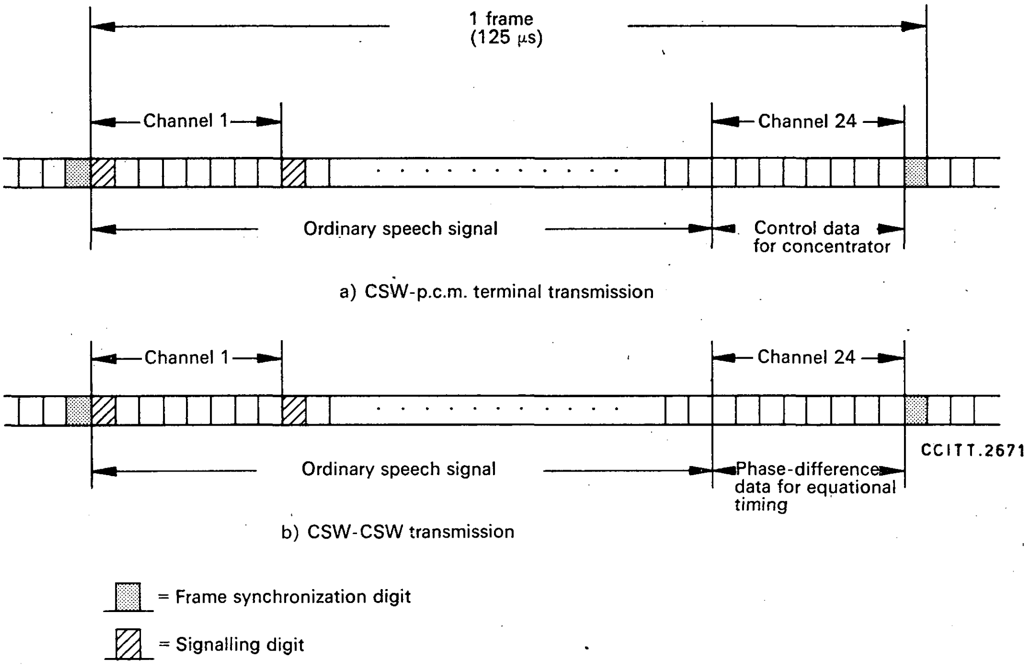


FIGURE 2. — **P.c.m. signal multiplex structure**

The central exchange consists of a t.d.m. central switching unit (CSW), synchronization equipments, a central control and data-handlers (DH). The central exchange is connected to other central exchanges and concentrators by existing p.c.m. transmission lines. Conventional electromechanical exchanges can be connected to the central exchange through p.c.m. terminals.

At the CSW, the received 8 digits of a channel on a highway are transferred to an idle channel on a designated highway through highway switches (HS) and channel shift switches (CSS). The signalling digits are picked out at the CSW and sent to the central control.

Concentrators located around the central exchange consist of space-division switches with metallic contacts and their control, and are connected to the central exchange through p.c.m. transmission lines. The concentrators are remotely controlled from the central control of the central exchange by means of data-handlers (DH). Control data are transmitted in the 24th channel of a p.c.m. transmission line.

The clock of the p.c.m. terminals at concentrators is synchronized with that of the central exchange by a master-slave timing method. A semi-fixed delay-pad and a variable delay buffer storage are equipped in the synchronization equipment (SY-M) at the input side of the central exchange. This makes the round-trip delay time between the CSW and the p.c.m. terminal become a multiple integral number of the p.c.m. frame period.

For synchronization between more than two CSWs, two methods are examined in the system:

1. Asynchronous timing: Each central exchange is operated at its own clock frequency with a specified tolerance. Received p.c.m. signals at a central exchange are written into buffer stores of synchronization equipment (SY-A), and are read out at the clock frequency of the exchange.

2. Equational timing: Each exchange has a clock and its frequency controller (SY-E). The clock frequency is controlled so as to become a common frequency which is the average of all other clock frequencies. The phase-differences information is respectively transmitted to the other exchanges over data links set up on the 24th channel of the p.c.m. transmission systems.

3. *Considerations on the basic characteristics of p.c.m. systems*

a) Systems currently operated or developed employ a character-interleaved multiplexed structure. This structure seems to be preferable from the standpoint of ordinary p.c.m. speech.

When the digits are arranged in the character interleaved format, switch-stores with a relatively long cycle-time, e.g. a time-slot period (for example 5.2 μs). can be used for the operation of p.c.m. switch gates. Otherwise, it would be necessary for switch-stores to have a short cycle-time of at least a digit period (for example 0.65 μs).

b) In designing p.c.m. switching centres, the problem raised by the fact that the digit frame is not an integral number of time-slots, each containing the same number of digits, is not so serious so far as ordinary speech is concerned. A frame has 24 time-slots and a synchronization digit (i.e. 193 digits per frame) in our experimental system.

Considering a wider-band signal transmission, the digit frame with an integral number of time-slots would be more flexible for a bandwidth of integrals of 4 kHz.

c) A separate digit for signalling which is the digital analogue of outband signalling in f.d.m. systems is believed desirable for transmitting dialling and on/off hook information economically. Even if a conventional m.f. signalling system is tentatively applied as in-band signalling, the separate digit is useful for conveying the on/off hook information.

d) The signalling information can be carried in various ways. In-channel signalling is adopted in the experimental system. Out-channel bunched signalling might merit the concept of common-channel signalling or multi-frame signalling.

e) One signalling digit per time-slot provides a possible signalling capacity of 8000 bauds per channel. This capacity seems to be sufficient for all foreseeable future signalling requirements.

f) In addition to individual channel signalling, there might be requirements for such functions as described below.

1) Common-channel signalling: This may easily be introduced by assigning one time-slot for the signalling use. One signalling digit per time-slot is still useful, for the time being, for the reason stated in item c).

2) Data transmission for synchronization or remote control: One time-slot is used for these purposes in the experimental system.

g) In some proposed systems, one time-slot in the frame is not used for traffic, but for frame synchronization over the transmission link. In other proposed systems, on the other hand, the signalling digits of some frames are used for frame synchronization.

No relative advantage in these two synchronization methods has yet been found from experience with the system described, in which the 193rd digit in a frame is assigned for frame synchronization.

h) The multi-frame concept might provide a number of different signalling conditions on a channel. Its necessity, however, has not been justified from the switching viewpoint.

i) As regards the number of time-slots in a frame, no particular problem has been envisaged in the experimental system which uses 24 time-slots per frame.

The number of speech channels of 2^n may be suitable when the p.c.m. terminals are connected to space-division switches with a matrix size on a binary basis, for example an 8×8 matrix.

When 2^n is adopted for the number of speech channels, the capacity of some switch-stores necessary to operate channel shift switches has to be increased in order to identify the " busy-idle " condition of a speech channel. Thus, 2^n is not always preferable for the number of speech channels.

Question 5/D — Synchronization of digital networks

(new question)

a) What techniques should be considered for the synchronization of digital networks and to what extent, if any, should networks be synchronized?

b) What performance criteria should be adopted as a basis for the study of synchronization of digital networks? For example, account must be taken of the need for reliability, the drift of oscillators, phenomena accompanying the loss and recovery of synchronization, etc,. and these factors must be evaluated in terms of the services, telephone and non-telephone, which may be provided by such networks.

Note 1. — It is suggested that the organizations studying the problems of network synchronization endeavour to avoid national solutions that may be incompatible in the international connection of networks.

Note 2. — This question is to be studied in conjunction with Questions 1/D and 9/D.

Note 3. — See section on synchronization in Annex 2 to Question 4/D. Note should also be taken of Annex 2 to Question 1/D.

ANNEX 1

(to Question 5/D)

The effects of digital errors and misframes (loss of frame synchronism) on signals transmitted over p.c.m. systems

(Contribution by the American Telephone and Telegraph Company)

1. *Introduction*

One of the outstanding characteristics of a p.c.m. transmission system is the sturdiness of the digital line signal. Therefore most discussions of signal impairments in p.c.m. systems and their effects on audio-to-audio performance concentrate on impairments associated with the analogue-to-digital and digital-to-analogue conversion processes at the terminals. This contribution considers two types of impairments associated with the transmission line and transmission medium: digital errors and misframes (loss of frame synchronism).

2. *Digital errors*

Errors in pulse identification at digital regenerators manifest themselves in the reconstructed signal in various ways depending on the particular coding scheme being used, and according to whether the errors are random in nature or appear in bursts. Digital errors in signals such as speech or television where the signal is first represented as a pulse amplitude modulated train and then coded into a digital stream, can be represented as a series of impulses which add directly to the otherwise unimpaired signal. If any reasonable number of quantizing steps is used in the coding process, only errors in the most significant pulse positions will be discernible as signal degradation. For voice circuits these errors appear as audible clicks while in the television signal they occur as small, fleeting spots on monochrome and as coloured spots or changes in intensity in colour pictures. Because of the complexity of colour pictures, errors are more difficult to observe in comparison with monochrome; hence error rates about an order of magnitude more severe can be tolerated with the same subjective rating.

If delta modulation or multiple-bit differential modulation techniques are used to take advantage of the redundancy present in television or videotelephone signals, the effects of single or bunched errors may extend well beyond the point at which the errors occur and appear as streaks in the decoded picture.

As with analogue service, the effects of digital errors on data transmission depend on the method used to convert the input data stream into the line signal. In general, however, each bit of the input data stream is represented by more than one symbol on the digital line. Although not every possible singly occurring digit error in the group of symbols representing a data bit will cause an error in that data bit, the number of them that do will usually be enough to cause a given digit error rate to result in an output error rate in any data channel which is higher by as much as an order of magnitude. Even though block transmission schemes are used with the higher speed data services, these services tend to dominate in the determination of system error rate requirements if error correction is not assumed in the data terminals.

With due consideration of the effects of digital errors on the various types of signals which might be transmitted over p.c.m. systems, a digital error rate objective of 3×10^{-7} (that is, one error in about 3×10^{6} digits) or better seems appropriate. A single-value objective is stated, rather than giving objectives for each type of signal, to make the system design independent of services carried, as it should be for maximum flexibility of use. In any event, there is not enough difference between reasonable objectives for many of the services to justify stating them separately.

The error rate objective of 3×10^{-7} is an end-to-end objective. When a connection is composed of a number of digital links, the error rate objective must be allocated among them. If these links are identical in digit rate, code, and transmission media, the allocation may be performed on the basis of length (number of regenerators in tandem). If the links are dissimilar, the allocation should take into account the relative difficulty on each link of coping with the transmission impairments which can cause digital errors. These include intersymbol interference due to imperfect equalization, random or thermal noise, crosstalk, impulse noise, reflections, timing jitter, and departures from ideal regenerator performance. In any event, the allocation procedure should be such that the overall objective of 3×10^{-7} is not exceeded more than 5% of the time.

All the foregoing discussion has been concerned with objectives for isolated, randomly occurring digital errors. In general, a given number of bunched errors is less disruptive than the same number of random errors over the same time period. Therefore error rate comparisons of random errors and bunched errors should be made on the basis of subjective and objective effects on transmitted signals rather than absolute numbers of errors per unit time.

3. *Misframes, or loss of frame synchronism*

A misframe, or loss of frame synchronism, causes complete loss of useful output signal for the duration of the reframing process. A misframe may result either from digital errors in the synchronizing signal which cause the receiving terminal to initiate a reframe search procedure when in fact there has been no loss of synchronism, from a patching or switching operation (as for instance from a failed line to a spare line) which results in a loss or repetition of digits, or from a service outage. In the latter case, the reframe time is usually small compared with the outage time and may be ignored.

In hierarchical digital transmission networks, especially those using pulse stuffing techniques, misframes at the higher speed levels will usually precipitate misframes at each lower level in the hierarchy. Thus misframe rate objectives must be allocated among the various levels in the hierarchy as well as among digital links placed in tandem in an overall connection.

The allowable rate of occurrence of misframes and the duration of the reframe process are interrelated. At the lowest hierarchical level, the 24-channel p.c.m. system, misframe rate objectives are principally controlled by signalling considerations such as false disconnects, false seizures of common control equipment, and mutilated address information. In the North American toll network, interruptions longer than 140 milliseconds will generally cause false disconnects. The objective for false disconnects may be translated into a requirement for a mean time of 25 days or more between misframes that take a maximum average reframe time greater than 140 milliseconds. (The maximum average reframe time is defined as the average time to reframe when a misframe occurs in such a manner that the reframe search procedure must scan the maximum number of time-slots to reacquire synchronism.) The practical effect of a requirement this severe is to force a system designer to provide a system which eliminates the possibility of such a long loss of signal due to misframes not associated with service outages (i.e. reframe faster than 140 ms for all causes of loss of frame except service outage).

The objective for mutilated dial pulse address information resulting in lost calls or wrong numbers may be translated into a requirement for a mean time of about 1.5 hours or more between misframes that take a maximum average reframe time greater than about 3 milliseconds. This is the controlling requirement on statistical misframes (due to digital errors in the synchronizing signal) at the lowest hierarchical level.

Misframe requirements directed at controlling signalling impairments are common to all levels in a hierarchical digital network, but there are additional misframe considerations at the higher levels affecting signals such as television and videotelephone which do not appear at the lowest level. For instance, one objective which has been stated calls for a minimum mean time of 50 seconds (for commercial television, 10 seconds for videotelephone) between misframes requiring a maximum average reframe time greater than 20 microseconds. Of course if these very short misframes precipitate longer misframes at lower hierarchical levels, the previously stated signalling requirements still apply.

ANNEX 2

(to Question 5/D)

Timing jitter distortion in digital systems

(Contribution by the American Telephone and Telegraph Company)

1. *Introduction*

Timing information in a digital transmission system is normally conveyed by the signal-modulated pulse stream. This information is extracted by bandpass filters and used to re-time pulses at each regenerative repeater. Thus, distorted timing information will result in varied or jittered pulse stream phase.

Timing wave distortion and the resultant phase jitter are caused by several sources, including random noise, timing filter mistuning, and pulse stream pattern variations. Jitter from additive random noise is usually negligible compared with that from other sources. Effects of filter mistuning can usually be assumed to add randomly among repeaters. Jitter due to pattern variations, on the other hand, adds directly from repeater to repeater.

Phase jitter in a pulse stream can be reduced, and its effects minimized, provided the accumulated jitter has not been severe enough to cause digital errors. This dejitterizing is done by reconstructing a relatively distortion-free timing wave.

The following sections discuss effects of pulse stream phase jitter on the recovered signal, and give broad requirements for the jitter that can be tolerated for various types of signals. Since the requirements vary widely with the type of signal, the amount of dejitterizing provided will vary with the type of signal transmitted, and much (in some cases all) of the dejitterizing will be provided in the receiving terminal just preceding the digital-to-analogue converter.

2. *Signal distortion caused by phase jitter*

The amount of distortion caused by phase jitter will depend on the characteristics of the baseband signal, the coding process, and the jitter. Analogue signals sampled and coded for digital transmission will have reconstructed sample values displaced in time from nominal sampling instants by any jitter left on the timing wave. Signal distortion can be shown in many cases to have a power spectral density given by the product of squared frequency and the convolution of signal and jitter spectra [1]. This representation has been used to analyse jitter distortion in some analogue

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[1] See for instance W. R. Bennett: Statistics of regenerative digital transmission; *Bell System Technical Journal*, November 1958.

signals that will be coded for transmission on digital facilities. For other signals, where subjective effects cannot be predicted knowing only distortion power, subjective tests have been made to determine jitter tolerance.

Jitter effects on some of the more common and/or more susceptible signals are discussed in more detail, and tentative objectives are given in the following sections.

2.1 *F.D.M. mastergroup transmission — voice channels*

The baseband signal to be sampled and coded comprises 600 voice channels which were frequency division multiplexed (f.d.m.) using single sideband suppressed carrier techniques. The squared frequency term in the expression for jitter distortion results in the worst distortion in the top frequency channel. Distortion caused by jitter with significant frequency components greater than the channel frequency separation will be a noiselike disturbance which in the time domain is equivalent to a differentiated product of jitter and talkers from other channels. One approach in setting requirements is to treat this distortion as a form of crosstalk. As jitter frequency is reduced to less than channel frequency separation, the disturbance becomes an intra-channel distortion product. Tentative r.m.s. jitter objectives for crosstalk no worse than 9-digit uniform quantizing noise and for a signal to intra-channel distortion ratio equal to at least 40 dB are not more than about 0.2 nanosecond and 0.6 nanosecond respectively.

2.2 *NTSC colour television transmission*

Subjective tests in which viewers looked for just perceptible effects in colour bar patterns have established jitter tolerances for coded NTSC colour television signals. Tests included sinusoidal and narrowband Gaussian jitter. Results showed a fine-grain oscillatory frequency dependence; however, a smooth curve drawn through points of maximum sensitivity indicates that a value of about 0.2 nanosecond r.m.s. jitter or less is required to avoid noticeable effects in a colour bar pattern.

2.3 *Wideband facsimile transmission*

Jitter causes displacement or distortion of received transitions in facsimile transmission. Considering supergroup-band facsimile, allowing maximum deviations of 0.002 inch in received copy, sinusoidal jitter should be less than 0.7 microsecond r.m.s. and random jitter less than 0.5 microsecond.

2.4 *Voice transmission in an all-digital system*

Distortion of a voice signal which has been sampled and coded, sent over a digital system with jitter, and reconstructed, is calculated as was done for the wideband f.d.m. signal. The main difference is that the highest sampled frequency in the all-digital system is only about 4 kHz, compared with a highest sampled frequency of several megahertz for the f.d.m. signal. Thus distortion, which is proportional to squared frequency, is much less in an all-digital system with equal jitter. A second difference is that in an all-digital system the primary effect of jitter is intra-channel distortion rather than crosstalk. To maintain 40-dB or greater signal-to-noise ratio, r.m.s. jitter should be 0.9 microsecond or less.

2.5 *V.F. telegraph transmission in an all-digital system*

Random jitter deviates the frequency shift keyed carriers in a multi-telegraph-channel system, resulting in distortion of mark-space transitions in the demodulated telegraph signal. To limit jitter distortion to 10%, r.m.s. jitter should be less than 8 microseconds.

Sinusoidal jitter, which shifts frequency components of the carrier signal without blurring them, can cause inter-telegraph channel distortion when jitter frequency is near a multiple of channel separation frequency. To maintain a 40-dB signal-to-crosstalk ratio, sinusoidal jitter should be less than 1 microsecond r.m.s.

2.6 *Other services*

Timing jitter will distort other signals as well as those above. Requirements discussed in the preceding sections are thought to be the more stringent of those that could be derived.

Question 6/D — Digital multiplex hierarchy

(new question)

a) Is it necessary to have a fully-standardized p.c.m. multiplex hierarchy for international service?

If not, should a minimum number of multiplex stages be standardized, corresponding to specific assemblies of telephone channels or other forms of coded signal?

b) If so, what should the standardized multiplex stages be and what interfaces should be defined?

Note. — This question should be studied in liaison with Questions 1/D, 2/D and 10/D. See section 3 of Annex 2 to Question 1/D and Annex 3 to Question 2/D.

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ANNEX 1

(to Question 6/D)

Higher capacity systems and multiplex structure

(Contribution by the International Telephone and Telegraph Corporation)

1. In planning high-capacity systems, it is necessary to allow for all classes of message which might be conveyed by digital means. These include:

- p.c.m. telephony,
- data transmission at a variety of bit rates,
- encoded facsimile and other visual displays,

— p.c.m. music channels,
— p.c.m. television to broadcast standards,
— p.c.m. television for person-to-person usage (picturephone),
— as a transitional measure, encoded f.d.m. assemblies (group, supergroup, etc.).

Agreement on the p.c.m. multiplex structure to accommodate this range of messages should precede the standardization of high capacity systems.

2. The various types of message may be accommodated by a modular family of communication systems and apparatus comprising:

— Terminals with encoding, decoding and other functions necessary to translate a message channel or group of message channels to one of the standard bit rates.

— Multiplexing and patching apparatus for a range of standard bit rates, which will convey any digital sequence of the appropriate radix and frequency regardless of geographical origin, message content, frame structure or code.

— Transmission systems suitable for the transmission of the standard bit rates and which are again independent of the type of digital sequence.

3. In choosing the standard bit rates the telephone t.d.m. group should be taken as basic. Higher rates should be chosen to accommodate convenient multiples of these groups, together with whatever auxiliary digits (for synchronizing, digit stuffing, etc.) may be necessary.

From the point of view of telephony, the successive multiplexing factors are to some extent arbitrary. It is therefore possible to accommodate other classes of message without detriment to telephone practice.

A series of multiplexing factors and bit rates has been proposed by the American Telephone and Telegraph Co. Based on a group of 24 channels, the successive multiplexing factors are 4, 7, 2 and 3. These are dictated by the inclusion of the encoded 600-channel " mastergroup ", and

TABLE

Possible multiplex structure for digital network

Bit rate Mbits/s (approx.)	Number of p.c.m.-t.d.m. telephone channels	Other types of message accommodated
1.5	24	Four p.c.m. music channels Various data multiplexes Encoded 12-channel f.d.m.
6.2	96	P.c.m. picturephone Encoded 60-channel f.d.m.
25	384	Encoded 300-channel f.d.m.
100	1536	P.c.m. television (625-line) Encoded 900-channel f.d.m.
400	6144	

Note. — It is to be understood that the higher bit rates may accommodate an arbitrary assemblage of lower capacity messages so long as the gross bit rate is suitable.

encoded 525-line television. They do not admit encoded 300-channel mastergroups, 900 channel supermastergroups or 625-line television, which are far more common outside the North American continent.

To meet the case for Europe and elsewhere a different series might be more convenient, such as, for example, successive multiplexing factors of 4, leading to bit rates of 1.5, 6.2, 25, 100 and 400 Mbit/s. The exact figures are dependent on synchronizing and stuffing arrangements.

The table above, which is not exhaustive, shows the types of message which these rates could accommodate. The parameters for some classes of message are not yet determined in detail, but it is highly probable that they could be accommodated within the bit rates stated.

4. The facilities over which the bit rates given in the above table might be transmitted are:

1.5 and 6.2 Mbit/s:	pair or quad cable
25 Mbits/s:	4.4-mm coaxial pairs short haul microwave radio
100 Mbits/s:	4.4-mm and 9.5-mm coaxial pairs
400 Mbits/s:	9.5-mm coaxial pairs waveguide systems optical beams or fibres.

ANNEX 2

(to Question 6/D)

Digital network hierarchy

(Contribution by the American Telephone and Telegraph Company)

This annex summarizes the present status of digital network planning and implementation by the American Telephone and Telegraph Company.

The digital network structure chosen by the A. T. & T. is fundamentally hierarchical in nature, although non-hierarchical interconnections are permitted.

The hierarchical nature of the networks is indicated in Figure 1, which shows that at each hierarchical level, a number of input pulse streams of approximately the same bit rates are multiplexed to form the next higher level in the hierarchy. The input bit rates need not be exactly the same, since the multiplexes use pulse-stuffing synchronization as described in the November 1965 *Bell System Technical Journal.* Thus the bit rate at the output of a multiplex is slightly higher than the input rate times the number of inputs.

Table 1 indicates the input and output interconnections at each hierarchical level presently planned by the A. T. & T. Co. Other levels may be added when and if the need arises. Multiplexes may be developed which span more than two levels, such as a multiplex which combines 42 signals each of approximately 6.312 Mbits/s directly into a 282-Mbits/s signal. This remains within the hierarchical concept defined above.

Non-hierarchical access, which is the condition in which input signals of substantially different bit rates are multiplexed together, is planned for television signals, which will be encoded into a rate of 93 Mbits/s, and for various wideband data and programme channels at bit rates of less than 1.544 Mbits/s.

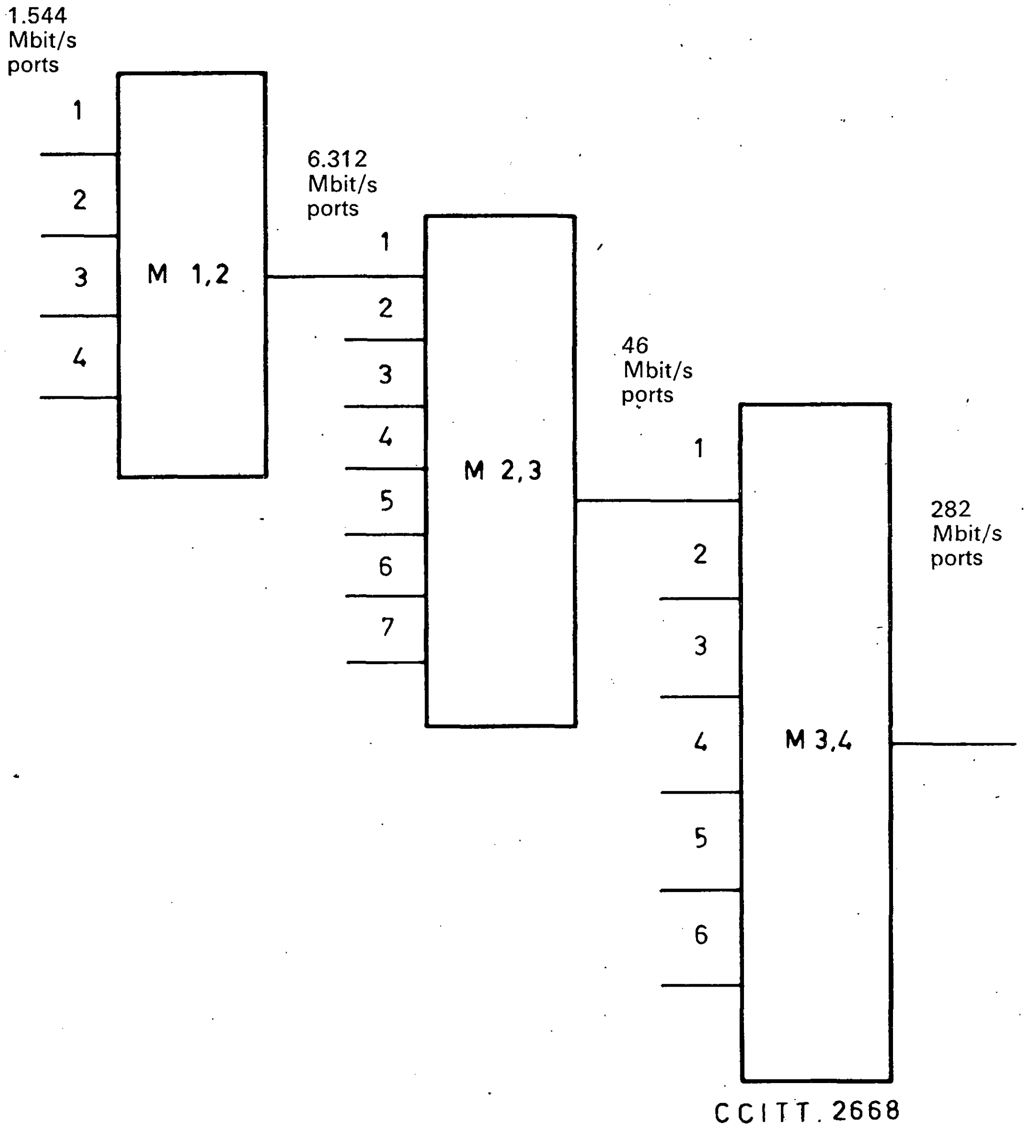

1.544 Mbit/s ports
1
2
3
4
M 1,2
6.312 Mbit/s ports
1
2
3
4
5
6
7
M 2,3
46 Mbit/s ports
1
2
3
4
5
6
M 3,4
282 Mbit/s ports
CCITT. 2668

FIGURE 1. — (A. T. & T.)

TABLE 1

Hierarchical level	Inputs (banks, codecs)	Outputs (lines)	Equivalent voice channels	
			t.d.m.	f.d.m.
1.544 Mbits/s	D1 (operational) D2 (development)	T1, symmetric pairs (operational)	24	
6.312 Mbits/s	Videotelephone codec (development)	T2, symmetric pairs (development)	96	
46 Mbits/s	600-channel master-group codec (development)[1]		672	600
282 Mbits/s		T4, 0.375″ coaxial (development)	4032	3600

[1] An NTSC-TV codec may occupy two 46-Mbits/s input ports.

ANNEX 3

(to Question 6/D)

P.c.m. multiplex system

(Contribution by the Nippon Telegraph and Telephone Public Corporation)

We adopted a 120-(24×5)-p.c.m. system as the next higher hierarchical level in Japan for the following reasons.

1. From the viewpoints of the future videophone signal transmission performance and the simplicity of its sampling devices, it seems preferable and less risky to use the 120-channel system as the next level of p.c.m. hierarchy.

2. Considering the present radio-frequency channel arrangements of microwave radio systems (C.C.I.R. Recommendations 382-1, 383-1 and 387-1), the number of channels of $120 \times n$ may be also advantageous for p.c.m. radio transmission because of band economy.

In the 120-channel p.c.m. system, a bit rate of 7.8760 Mbits/s is used for the clock, taking account of pulse stuffing and the clock frequency stability of existing 24-channel p.c.m. system, which is the first level of p.c.m. hierarchy suggested below. In addition to this, with a view to possible common use of a stable frequency source in existing carrier terminals, a multiple of 4 kHz is selected for the clock frequency.

In planning larger capacity p.c.m. systems, the transmission of various signals listed in Table 1 and the interconnection with existing f.d.m. systems, i.e. f.d.m. to p.c.m. and p.c.m. to f.d.m., should be taken into account.

As higher hierarchical levels above 120 channels, we would suggest a multiplex structure plan shown in Table 1 and Figure 1 in which a series of multiplexing factors of 5, 4, 3, 3 and 5 is introduced. Table 2 illustrates the anticipated transmission media corresponding to each hierarchical level.

TABLE 1

Levels of p.c.m. hierarchy and types of message

Bit rate (Mbits/s)	Number of p.c.m.-t.d.m. telephone channels	Other types of message
1.544	24	Music sound Various data multiplexes Encoded f.d.m. group
7.876	120	P.c.m. video phone Encoded f.d.m. (supergroup)
32 (approx.)	480	Encoded f.d.m. (master group)
100 (approx.)	1440	P.c.m. colour television Encoded f.d.m. (supermaster group)
300 (approx.)	4320	Encoded f.d.m. (2700 channels)
1500 (approx.)	21 600	Encoded f.d.m. (10 800 channels)

TABLE 2

Anticipated transmission media for each level

Bit rate (Mbits/s) (approx.)	Transmission lines
1.5	Symmetric pair cable
7.9, 16 and 32	Symmetric pair cable. Microwave radio
100	Symmetric pair cable. Coaxial pair cable. Microwave radio
300	Coaxial pair cable. Waveguide
1500	Coaxial pair cable. Waveguide. Optical beam on fibres

In this plan, the bit rate for an analogue signal such as f.d.m. block, TV signal, etc. conforms to the following relation.

$$F = 2.2 \times n \times f_B$$

where n = number of coding digits
f_B = frequency bandwidth of an analogue signal
F = bit rate

For the plan shown in Table 1 and Figure 1, the above parameters are chosen as follows:

For f.d.m. block . . . f_B = bank of group, supergroup, mastergroup and so on, $n = 10$
For TV signal . . . . $f_B = 4.5$ MHz, $n = 9$ for six-link transmission

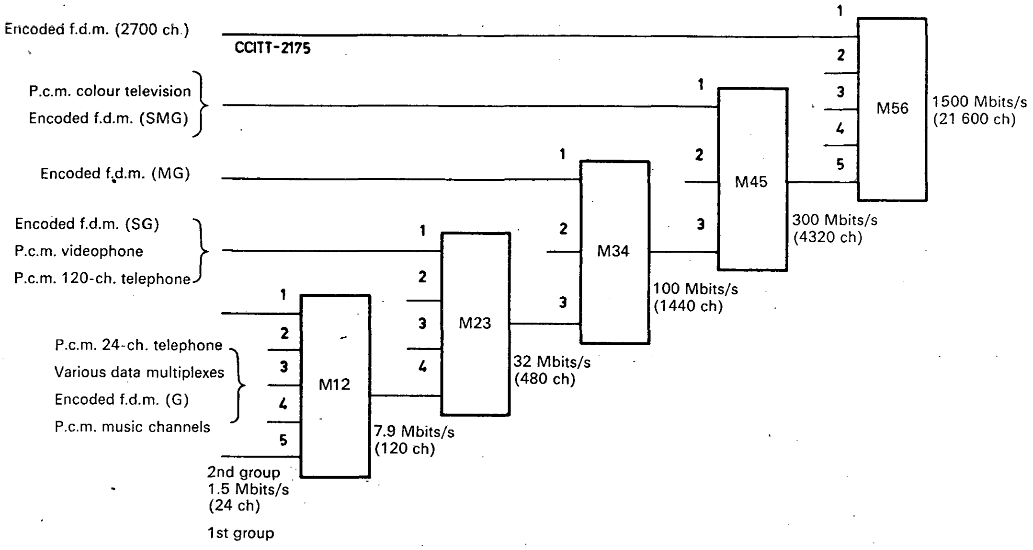


FIGURE 1. — **A multiplex structure of p.c.m. hierarchy**

ANNEX 4

(to Question 6/D)

P.c.m. multiplexers of synchronous type

(Contribution by G. T. & E. – Società generale di telefonia ed elettronica)

1. *General*

A brief description is given here of a multiplexer system fully developed by G. T. & E., which merit sattention as an example of an economical multiplexing procedure suitable for medium range networks.

The multiplexers described hereunder fit the first multiplexing order and they are built at present for the simple case of two basic groups. The design can be extended to whatever number *m* of basic groups that might be established for the first hierarchical multiplexing order.

The technique adopted is bit-by-bit multiplexing, and the recognition of the combined basic groups is accomplished by means of labels (" address bits ") held by the basic groups themselves. This procedure gives rise to no proper superframe, rather to a digital signal at a rate that is an *exact* multiple of the basic group bit rate, wherein the only existing correlations can be traced on the single basic groups, that is by cyclically selecting one bit out of *m*.

This procedure has the advantage of simplicity; in particular, generating a pulse train at a rate that is an exact multiple of the basic group rate avoids the use of a large series of frequency dividing and multiplying stages, or of phase-locked oscillators, to keep the right relations between the rates of incoming and outgoing signals.

No limit is fixed for the relative position of frame beginnings in the multiple signal.

Two mutually compatible multiplexers have been developed. Type A is to be used when the basic group-generating terminals are close together, and type B when they are not (whether one multiplexer is close to the multiplexing site or all are far from it).

An amplitude-modulation radio link for digital signals is used at present as a transmitting medium, but any other medium may be chosen. When the equipment was designed, the principle was followed that any malfunction of the equipment dealing with one basic group should not jeopardize the service on the other system parts still operating satisfactorily.

2. *Clock generation and distribution*

In order to achieve synchronous operation, with prescribed tolerances on bit rates, a single master clock must exist, and its frequency must be distributed to every part of the system. In the equipment described, the master clock operates at the multiple signal bit rate and is housed in one of the multiplexers; its frequency is transmitted to the whole system by the same information-bearing pulse trains.

Two clock signals are to be considered in each multiplexer, namely the outgoing multiple signal clock and the incoming multiple signal clock (named " demultiplexer clock ").

Each multiplexer can be preset, by a patching arrangement, in order to draw the outgoing multiple signal clock either from a master oscillator (the master clock) or from the demultiplexer clock.

One multiplexer in a given system must be preset in accordance with the former option, and the other with the latter; in this way the first equipment sends the clock frequency to the second along with the multiple signal, whereas the second multiplexer operates by means of that clock completely.

Each multiplexer replaces a periodic 1010... pattern for a missing basic group, so that the absence of a transmitted pulse stream will not prevent the clock from reaching some part of the system (a 1010... pattern does not simulate the frame synchronizing pattern, and the out-of-service condition is therefore regularly notified by the usual out-of-sync. alarm).

3. *Operation of type A multiplexer*

A type A multiplexer is used when the basic group-generating terminals are close together. The multiplexer is installed in the same bay along with them, and provides the transmitting parts of the terminals directly with properly phased clocks, which are obtained by dividing a multiple signal clock by *m*. It can therefore build the multiple signal immediately by bit-by-bit interleaving of the basic groups.

As far as receiving operations are concerned, the single terminals select the address bits and send them to the multiplexer, after the frame synchronization has been recovered. The multiplexer then checks whether demultiplexing is performed correctly or not, and takes appropriate action if required. At the start of operation there will of course be a short while of random operation, not longer than the framing recovery time in a terminal.

4. *Operation of type B multiplexer*

Type B equipment is adopted when the basic group-generating terminals are far from each other. They are also considered far from the multiplexing site, for the sake of simplicity, even if this may not be true for one of them.

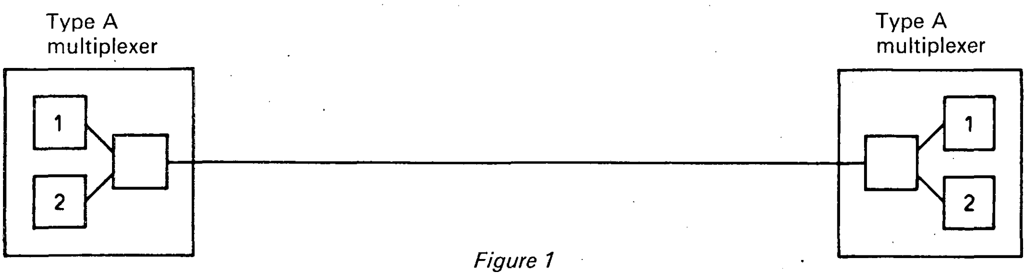


Figure 1

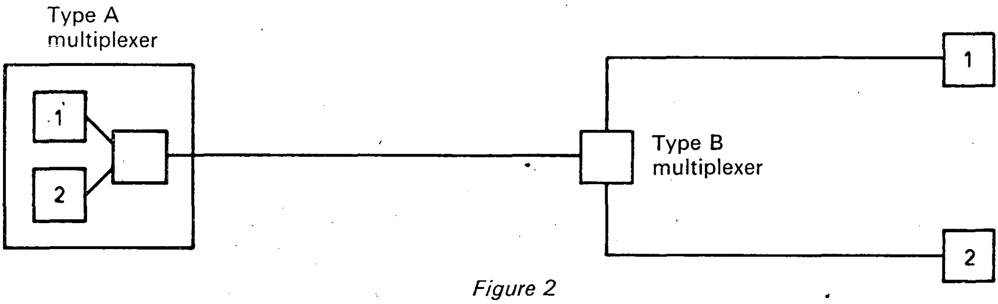


Figure 2

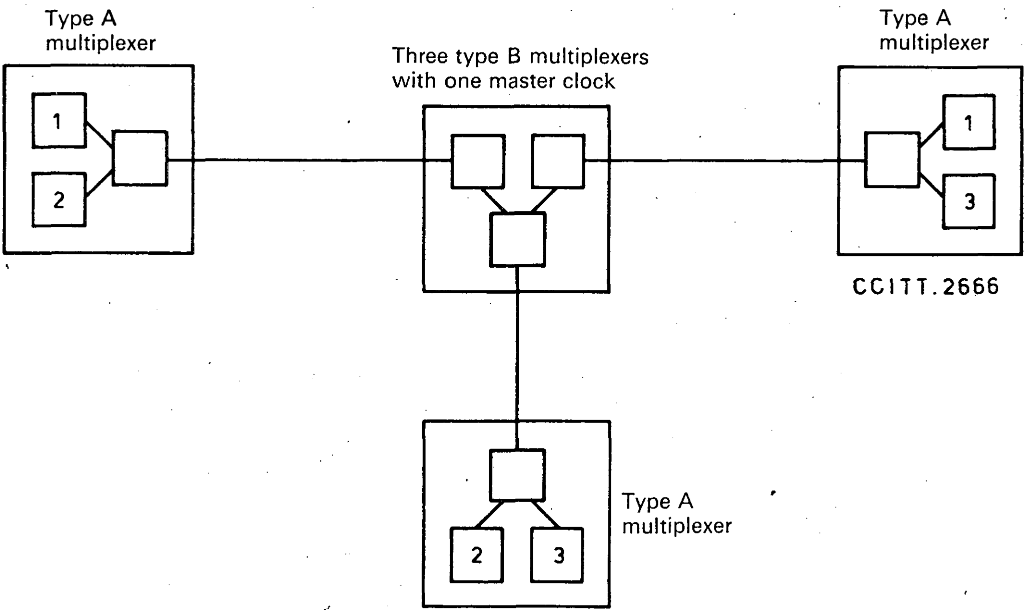


Figure 3

FIGURE 1-2-3. — **Examples of systems using multiplexers** (numbered squares indicate basic group terminals)

Type B equipment differs as follows from type A:

a) the demultiplexing part checks directly the outgoing split signals for correct distribution at the respective outputs;

b) the multiplexing part accepts any phase of the incoming basic group clocks and allows both for jitter and for propagation delay variations on the basic group signals by means of temporary memories of low capacity.

With regard to item a, it is to be pointed out that one frame counter is enough to recover frame synchronization and to recognize the address bits on one of the basic groups contained in the entering multiple signal; as the basic groups are interleaved in a prescribed sequence, recognition of one of them is sufficient.

The single counter, nevertheless, is switched over another basic group, if framing is not recovered in a prescribed time, so that the absence of a basic group will not prevent the correct operation of the whole demultiplexer.

As for item b, the multiplexer is equipped either with a 4-bit storage on each incoming basic group, or, if desired, with an 8-bit storage on one group and a 2-bit storage on the other (in the present implementation for two basic groups).

Fairly wide freedom is thereby achieved in the design of the whole system, and in particular in the limits to be fixed for the length of the repeatered cable connections between the multiplexer and the terminal equipment (if radio-link connections are used, there is no limitation in practice).

Allowance can be made, rather conservatively, for a maximum peak-to-peak jitter of 1/20 of the bit time-slot per repeater and delay variations of 5 ns/°C per repeater section [1] with such data, and considering a 20-repeater buried cable connection and an 8-bit storage, one can expect not more than three short reframings, due to storage capacity exhaustion, *per seasonal temperature change*.

P.c.m. terminals connected to a type B multiplexer recover the clock for their transmitting parts from the received pulse train.

5. *Conclusion*

The equipment described here exhibits a certain flexibility in use, as shown in Figures 1 to 3 (which do not cover all possible cases where it can be adopted). Among such cases, that of Figure 2 is deemed the most significant one. It is felt that the techniques described can be considered with a certain interest for the comparative simplicity of the devices involved.

Reference. – [1] CROFT-MUMFORD: Compensation for the variation of junction delay with temperature; *Proceedings of the International Colloquium on Electronic Switching*, Paris 1966.

ANNEX 5

(to Question 6/D)

The study of higher-order multiplexes

(Contribution by the United Kingdom)

1. At the meeting of Study Group XV in September/October 1967, although no agreement was reached on the frame structure and aggregate line-rate of a basic multiplex system a plea was made for the consideration of a hierarchical multiplex structure in which some compatibility could be achieved at the next order above the various basic systems contemplated by various administra-

tions. This annex is concerned with a brief, preliminary study of whether and how different basic systems favoured or adopted by various administrations could be accommodated in a higher stage of multiplexing. Such a higher stage of multiplex does not by itself achieve any amelioration of the incompatibilities of the basic systems but only permits them to be assembled in groups (usually but not necessarily restricted to their being identical) for transmission at a common rate. On being demultiplexed the component basic multiplexes resume their original forms and for resolution into their component channels will require either completely compatible terminal equipment or suitable adaptors to perform digital manipulation to effect compatibility.

2. To avoid the necessity of absolute synchronism between the digital rates of the basic and higher-order multiplexes, the method of pulse-stuffing has been proposed (J. S. Maye: Experimental 224 Mb/s p.c.m. terminals, *B.S.T.J.* 44, 9, November 1965) and such a process will be assumed in the following considerations. The basic multiplexes will be termed the *channels* of the higher-order *multiplex* and the aim is to arrive at possible frame structures of the multiplex. A frame will comprise a number of digit time-slots allocated to each channel, a number of digit time-slots allocated for signalling a " stuffed " digit in each channel and a number of digits for frame-synchronizing signal. It is desirable to make the stuffing signal resistant to mutilation in order to reduce the probability of the basic multiplex receivers becoming out of phase. This may be done by using three or more digits for the stuffing signal.

3. Let

$d =$ the number of digit time-slots per multiplex frame for transmitting the signal from a channel,

$f =$ the number of digits for signalling that a digit time-slot has been stuffed + digits for contributing to the synchronizing signal,

$n =$ number of channels,

then $n\ (d + f)\ =$ number of digit time-slots per multiplex frame.

Let

$M =$ aggregate rate of transmission of digits by the multiplex,

$m = M/n$,

$c =$ rate of input of digits from a channel.

The maximum rate at which the digits from a channel can be transmitted by the multiplex is d per multiplex frame-cycle and the minimum is $d—1$, because only one digit per channel per frame can be stuffed.

Therefore

$$c/m < d/(d + f) \tag{1}$$

$$c/m > (d - 1)/(d + f) \tag{2}$$

from which

$$(m + fc)/(m - c) > d > fc/(m - c) \tag{3}$$

If speed tolerances are taken into account, $\pm\ a$ for c and $\pm\ b$ for m (or M), then in (1), $c\ (1 + a)$ and $m\ (1—b)$, and in (2), $c\ (1—a)$ and $m\ (1 + b)$ should be used in place of c and m.

4. From the basic multiplexes in use or being studied by administrations, those with digit rates of 1.536, 1.544 and 2.048 Mbit/s have been selected together with a higher-order multiplex of 6.312 Mbits/s, which has been proposed, and limits of d have been calculated. For the present, speed tolerances have been disregarded. It will be seen that the limits of d are the same when $n \times c$ is the same.

TABLE 1

System	A	B	C	D
n	4	4	3	1
c	1.536 Mbits/s	1.544 Mbits/s	2.048 Mbits/s	6.144 Mbits/s
f	*d*	*d*	*d*	*d*
3	110-147	137-182	110-147	110-147
3.25	119-156	148-194	119-156	119-156
3.5	129-165	159-205	128-165	128-165
3.75	138-174	171-216	138-174	138-174
4	147-183	182-228	147-183	147-183
5	183-220	228-273	183-220	183-220
5.6	208-244	258-303	208-244	208-244
7	257-293	318-364	256-293	257-293

For systems A and B the ranges of *d* overlap when $f \leqslant 4$, indicating the possibility of a common frame structure which would permit one multiplexer to accept indiscriminately channels of either rate.

5. Some examples of possible multiplex frame structures derived from the foregoing considerations will now be given.

5.1 $M = 6.312$ Mbits/s, $c = 1.536$ Mbits/s, $n = 4, f = 3.75, d = 172$

Frame length = 703 digits and composition:

Sync/4 ×/control/4 ×/control/4 ×/control/4 ×
3 43 4 43 4 43 4 43

4 ×
43 indicates 43 digit time-slots for each of the four channels; " control " indicates digit time-slots for signalling stuffing. Sum of the tolerances of M and c must not exceed Y parts per million = 422

5.2 $M = 6.312$ Mbits/s, $c = 1.544$ Mbits/s, $n = 4, f = 3.75, d = 172$

Frame length = 703 digits and composition:
The same as for 5.1, but $Y = 213$
The mean time T for recovery of synchronization is estimated to be 5.6 ms.

5.3 $M = 6.312$ Mbits/s, $c = 2.048$ Mbits/s, $n = 3, f = 5.6, d = 220$

Frame length = 677 digits and composition:

Sync/3 ×/control/3 ×/control/3 ×/control/3 ×
8 55 3 55 3 55 3 55

$Y = 1530$ $T = 0.14$ ms.

5.4 $M = 6.312$ Mbits/s, $c = 6.144$ Mbits/s, $n = 1, f = 7, d = 280$

Frame length = 287 digits and composition:

Sync/1 ×/control/1 ×/control/1 ×/control/1 ×
4 70 1 70 1 70 1 70

$Y = 1284$ $T = 0.43$ ms.

The examples 5.1 and 5.2 were chosen to illustrate the possibility of a common frame-structure, but wider speed tolerances would be available if different frame structures suitable for only the individual cases were used.

6. The conclusion which may be drawn at this time is that a stage in the multiplex hierarchy with a rate of 6.312 Mbits/s can accommodate a number of different types of basic multiplex and further detailed consideration is warranted. The adoption of that speed or one near to it may provide a basis for higher orders in the multiplex structure or at least a level of interchange between transmission links.

ANNEX 6

(to Question 6/D)

Characteristics of secondary multiplex systems and interfaces

Administration or organization	A. T. & T. — (U.S.A.)	N.T.T. (Japan) [2]
Number of interleaved primary order systems	4	5
Time-slots in primary order systems	24	24 (+ 1 digit for framing)
Primary MUX gross digit rate	1.544 Mbits/s	1.544 Mbits/s
Method of interleaving	Bit by bit	Bit by bit
Homochronous or word-stuffing multiplexing?	One bit word-stuffing	Asynchronous (plesiochronous) and multiplexing with pulse stuffing
Clock adjustment information included?	No	No
Second-order framing added or included in primary MUX?	Added	Added
Stuffing control information added or included in primary MUX?	Added	Added
Secondary MUX frame length (number of digits)	1176 bits [1]	1.530 digits
Gross digit rate	6.312 Mbits/s	7.876 Mbits/s
Type of interface signal	B6ZS (as defined in the Annex to Question 8/D)	Bipolar (pseudo-ternary)
Limitations of sequences 1s or 0s	None	30 zeros
Amplitude of pulses	± 4.8 volts	± 3.0 volts (zero to peak)
Duty cycle of pulses	50%	50%
Impedance	93 ohms	120 ohms

[1] The number of primary order system frames or fractions of frames in the secondary frame is variable, depending on required stuffing rates.

[2] (See following page).

[2] *Secondary multiplexing method used by the N.T.T.*

The secondary multiplex is based on the existing 24-channel p.c.m. system in which a frame is made up of 24 channel time-slots and one framing digit. Each 24-channel system has an independent clock, whose nominal frequency is 1.544 Mbits/s. The pulses from five different 24-channel systems are bit-interleaved and form a secondary multiplex pulse train of 7.876 Mbits/s with stuffing pulses.

The secondary multiplex frame consists of 1530 digits and is called an S-frame. An S-frame is made up of 30 G-frames where a G-frame is composed of a G-pulse and 10 G-units. A G-unit is a time-slot of five interleaved pulses, including a stuffing pulse when necessary. These multiplexing processes are shown in Figures 1 a, b and c.

As a result of this multi-frame construction, an S-frame includes 30 G-pulses as indicated in Figure 1 d. These G-pulses are used for pulse stuffing control, framing and alarm information transmission to the opposite terminal.

The odd-numbered G-pulses are divided into five groups which are respectively made up of three consecutive odd G-pulses as shown in Figure 1 e. This three G-pulse combination forms a pulse stuffing control code for a primary system.

The even-numbered G-pulses, except for the 30th G-pulse, transmit framing information. Framing information pattern is shown in Figure 1 f. The 30th G-pulse is used for alarm information.

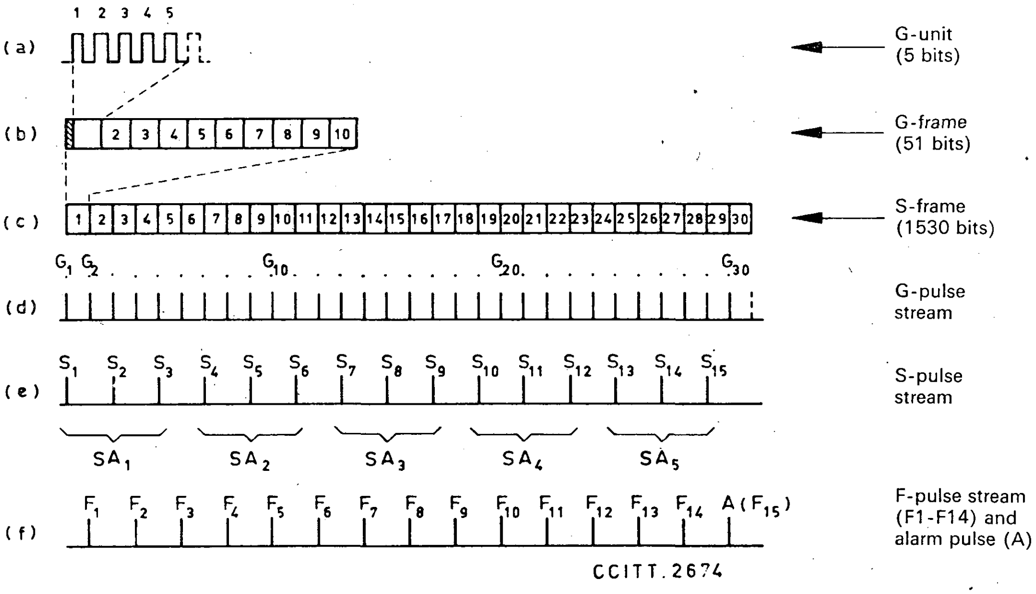


FIGURE 1. — **Frame configuration of p.c.m. secondary multiplex**

Question 7/D — Interfaces for digital systems

(new question)

In the general study of digital transmission systems and integrated digital networks, what digital and analogue interfaces will need to be defined and what general rules should apply to their specification?

Note 1. — General rules should cover the principles that should be observed at all interfaces. Specific interface specifications will be defined during the study of various types of equipment.

Note 2. — See Annex to Question 8/D and Annex to Question 6/D. Note should be taken of Annex 2 to Question 4D.

ANNEX 1

(to Question 7/D)

Digital interfaces

(Extract from the report of the Lisbon meeting of the PCM Working Party, September 1967)

It will be necessary to define standard interfaces to allow full freedom of interconnections between digital lines, terminals, and multiplexes. The following are characteristics proposed by the United Kingdom and A. T. & T. as those which must be specified at a digital interface:

1. Impedance—over the appropriate frequency range.
2. Voltage level (pulse height) – including tolerances on absolute voltage and balance between pulses at opposite polarity.
3. Pulse rate—including pulse width.
4. Pulse shape—including duty cycle and limitations on precursors and tails.
5. Pulse train characteristics—for example, for bipolar format:
   a) maximum number of consecutive zeros;
   b) maximum number of consecutive pulses of the same polarity and level;
   c) maximum number of pulses of the same polarity between two pulses of opposite polarity.

In the event that maxima are impossible to specify, some point on the probability distribution function should be specified such that this value is exceeded only rarely.

It may also be necessary to prevent encoded forms of information signals from imitating system control formats. This is usually not a problem with quasi-random signals such as speech, but may become a problem with data signals which have certain special codes. One solution to this problem would be to allow a data rate slightly less than the standard interface rate, and to add additional pulses just before the interface in such a manner as to prevent control signal imitation and also satisfy the requirements of item 5 above.

This Appendix contains a summary of the specifications prepared by the U.K. Administration for the interface of the digital line.

APPENDIX (to Annex 1)

Line/multiplex interface standardized in the United Kingdom

To ensure flexibility of interconnection between digital line systems and multiplex equipment, it is proposed that a standard interface should be defined. The present United Kingdom system is specified in the following terms:

1. The impedance at the multiplex input shall be 75 ohms unbalanced with a return loss of not less than 20 dB at 768 kHz and not less than 15 dB at other frequencies in the band 100 kHz to 2 MHz.

Note. — This requirement also applies to the multiplex side of the transmit line transformer when the line side is terminated with 120 ohms.

2. The digital output signal of the multiplex equipment shall be bipolar at a rate of 1.536 Mbit/s with a tolerance of ± 75 bits/s. The pulse height with a 75-ohm load shall be 2.37 volts ± 10% with an overriding tolerance on the ratio of positive to negative pulse height in the range 0.95 to 1.05. The pulse width at half pulse height shall be 0.326 microsecond. The overshoot at the leading and trailing edges of the pulse shall not exceed 10% of the pulse height.

Note. — This requirement also applies to the output of the terminal receive regenerator.

ANNEX 2

(to Question 7/D)

Interface between the terminal multiplex and line terminal equipments

(Contribution by the French Administration)

The French Administration considers that the specification of such an interface is fundamental from the point of view of integrated networks; this interface in fact gives maximum operational flexibility while meeting all the requirements at present foreseeable:

— to provide a single interface with the line, whether this line be connected to a p.c.m. terminal, a t.d.m. exchange or a multiplexer,

— to offer a convenient access point for the introduction of digital data, or coded signals other than telephone signals, in the t.d.m. channels.

Moreover, the interface thus defined enables the line signal to be adapted to the transmission medium and, if necessary, different types of lines to be interconnected.

By line terminals the French Administration understands all equipments which ensure:

— conversion of binary codes to line code;

— at transmission, adaptation of synchronization to the line type, if necessary; at reception, extraction of frame and multiframe synchronizations;

— protection against long series of zeros (whether by code conversion it self, or by stuffing with non-coded signals), to make the line perfectly code-conscious.

The following wires at least will exist at the interface:

— a wire carrying the bit clock (at a frequency equal to the data signalling rate);

— a wire carrying the binary series signal complete with its binary synchronization;

— a frame synchronization wire;

— a multiframe synchronization wire;

Moreover, at reception there should be:

— an alarm wire for loss of synchronization;

— an alarm wire for the error rate.

The transmission and reception interfaces should be compatible so that closed-circuit looping will be possible.

The electrical characteristics of the signals at the interface should be discussed. The following could be taken, *inter alia:*

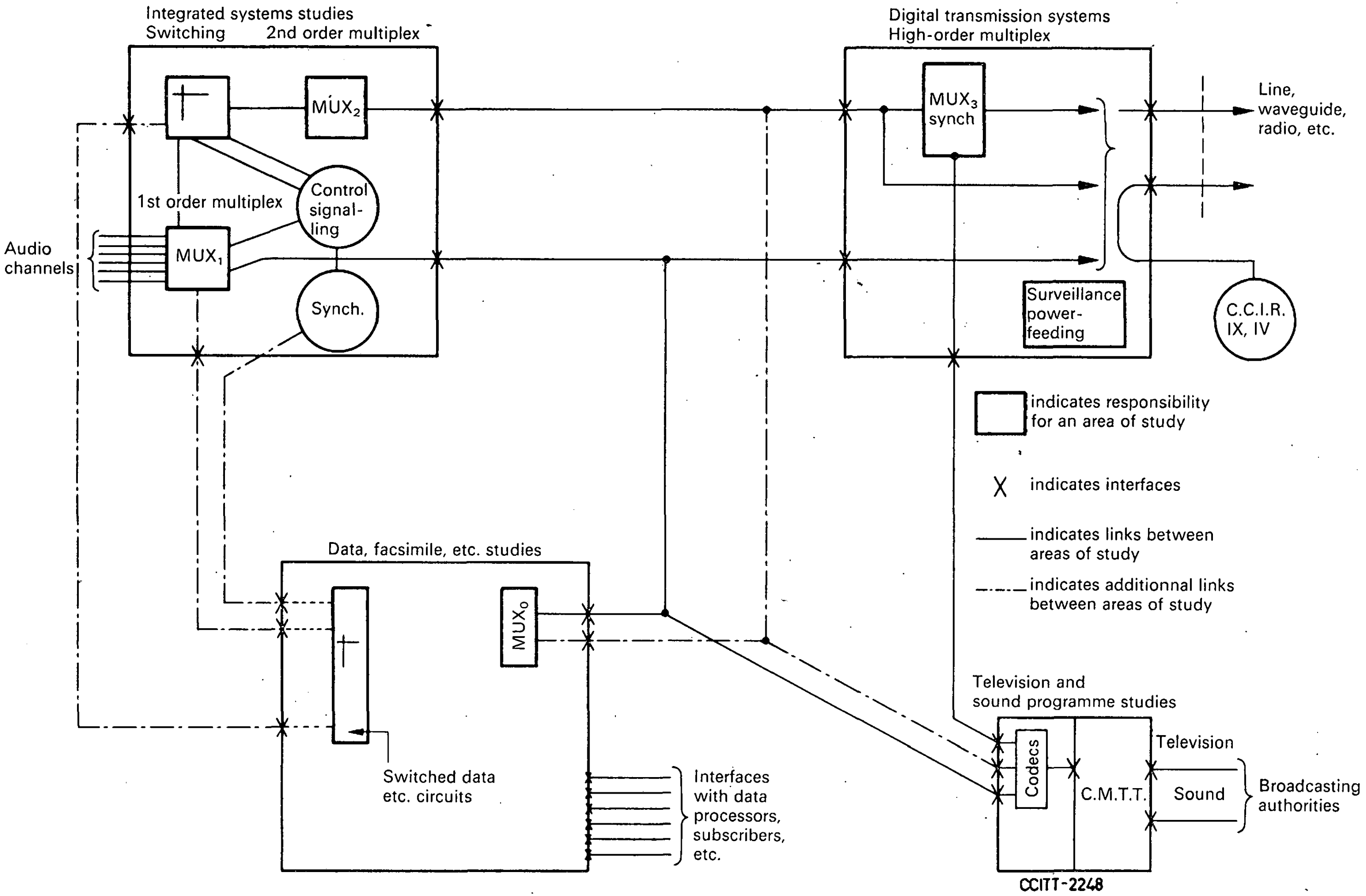
— impedance: 75 ohms,

— form: binary signal $^1/_2$ baud.

ANNEXE 3

(to Question 7/D)

Diagram for further study of digital systems and networks



Question 8/D — Digital transmission systems over cable and radio links

(new question)

What characteristics are to be recommended for digital transmission links set up on the following types of path:

a) Symmetric pair cables (underground and aerial),

b) Coaxial cables,

c) Terrestrial radio relay,

d) Communication satellites?

Note 1. — For each type of link the following characteristics will need to be studied (study of c and d will need to be co-ordinated between C.C.I.T.T. and C.C.I.R.):

1. Digit rate.
2. Interface at input and output.
3. Characteristics of propagation path, including existing and new types of cable.
4. Design and spacing of regenerative repeaters for cables.
5. Power-feeding of cable repeaters.
6. Surveillance of cable repeaters and maintenance facilities.
7. Mode of operation of cable systems, e.g. one- or two-cable, staggered spacing.
8. Line signal structure, code, code-restrictions.
9. Overall performance, including mean rate, mean jitter and temporal distribution of digital errors and jitter.

Note 2. — This question should be studied in conjunction with Question 1/D. In studying item 2, note should be taken of Question 7/D.

Note 3. — Point d will also need to be studied in relation with Questions 3/D, 4/D and 7/D. The interface between terrestrial and satellite p.c.m. systems will require particular study in view of the satellite system's point-to-multipoint transmission characteristics and the p.c.m. techniques envisaged to provide satellite multiple access.

Note 4. — Taking into account that p.c.m. systems with 24 or 32 time-slots may be expected in national networks, it is desirable to recommend systems that will convey primary blocks of either 24 or 32 time-slots or both. Characteristics should be recommended for such systems which would facilitate their so doing; for example, a digital transmission capacity which would accommodate convenient multiples of either type of primary block.

ANNEX (to Question 8/D)

Characteristics of p.c.m. line systems

Administration or organization	United Kingdom	Netherlands		Switzerland	U.S.A.			N.T.T. (Japan)
		P.T.T.	Philips		A.T.T. T1	A.T.T. T2	Lenkurt 91A	
Digit rate on line [1] (Mbits/s)	1.536	6.144	1.536	2.56	1.544	6.312	1.544	1.544
Type of line signal [1] (binary, ternary etc.)	bipolar	binary	bipolar	balanced binary (B-code)	bipolar	B6ZS [2]	bipolar	bipolar
Limitation in sequential 1's or 0's	15 of 0's	about 50 0's or 1's	20 of 0's	4	14 of 0's	none	13 of 0's	13 zeros
Broad category of cables (pairs, phantoms, coaxial single or two cables	quad 0.6; 0.9 mm single or two cable	quad layered cable using phantom circuits 0.8; 1.0; 1.25 mm	quad 0.5; 1.0 mm single or two cable	quad layered 0.6; 0.8; 1.0 mm single	pairs, 22 g.a. [3] 19 g.a. 1 or 2 cable	pairs, 22 g.a. [3] 2 cable	pairs, 22 g.a. 19 g.a. 1 or 2 cable	quad, 0.5, 0.65; 0.9 mm single or two cable
Duty cycle of pulse [1] (%)	50	100	50	50	50	50	50	50
Amplitude of pulse [1] (volts)	± 3	pulse form with pre-equalization, peak values about ± 2 (50 Ω)	± 3	± 3	± 3	± 4.2	± 3	± 3
Repeater spacing (m) (on typical cable)	1830	up to 1800 depending on wire diameter	2500	1830	1830 (22 g.a.)	1830 or more	1830	2000 (0.65 mm) 3000 (0.9 mm)
Power feed	75-0-75 V 50 mA	9 V 27 mA	65-0-65 V 45 mA 5.6 V per one way repeater	70 V max 30 mA	± 130 V max 140 mA	± 130 V max 160 mA	± 130 V 140 mA	75-0-75 volts, 170 mA
Distance between power feed points (km)	33			ea. 30	33 (22 g.a.)	depends on cable	48	20 (0.65 mm) 38 (0.9 mm)

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[1] At repeater output.

[2] B6ZS (Bipolar with 6 Zero Substitution), a variant of bipolar transmission in which 5 or fewer consecutive zeros are transmitted unchanged. Six consecutive zeros are replaced by a specific code group containing complementary violations of the bipolar constraint, which is removed at the receiver. The specific substitute codes used are +, 0, +, −, 0, −, or −, 0, −, +, 0, +, depending on whether the previous pulse was negative or positive respectively.

[3] 22 g.a, diameter 0.64 mm; 19 g.a, diameter 0.91 mm.

Question 9/D — High-order digital multiplex equipment

(new question)

What characteristics are to be recommended for high-order multiplexing equipment with particular reference to high-capacity transmission systems?

Note 1. — This question should be studied in conjunction with Questions 1/D, 5/D, 6/D, 7/D and 8/D.

Note 2. — Account should be taken of the following:

a) convenient assemblies of telephone channels, lower-order multiplexes, or other forms of coded signals;
b) multiplexing techniques;
c) synchronization and framing;
d) compatibility with other coded signals which are the subject of Question 10/D.

Note 3. — Account should also be taken of section 3 of Annex 2 to Question 1/D and Annex 2 to Question 2/D.

Question 10/D — Digital coding of signals for sound and television programme transmissions, etc.

(new question)

a) What coding terminals should be considered for the digital transmission of:

1. visual information (especially television),
2. f.d.m. assemblies,
3. sound programmes?

b) What characteristics should be recommended for such terminals?

Note 1. — Points 1 and 3 should be studied in co-operation with C.M.T.T. as appropriate.

Note 2. — This question should be studied in liaison with Questions 1/D, 6/D and 7/D. See Annexes 1 and 2 to Question 5/D and Annex 2 to Question 6/D.

Question 11/D — Data transmission over digital systems

a) What facilities should be provided in digital transmission systems for data transmission circuits in digital form?

The study should cover both the use of digital signals equivalent to one or more telephone channels and the use of digital signals identified in the higher-order levels of the multiplex hierarchy.

b) What should be the specification for synchronous and asynchronous interfaces with data-transmission systems?

c) How should switched digital data communications be studied in conjunction with an integrated digital network?

Note 1. — An integrated system can be used for very fast switched data calls. These calls may be of short duration and calling rate may be high. These factors will require a high signalling speed and the ability for rapid set-up of calls.

Note 2. — This question is related to several others but primarily to Question 1/D. The results of the study will be transmitted to Special Study Group A (point AB of Question 1/A).

ANNEX 1

(to Question 11/D)

Interconnection of a p.c.m. channel with a 48-kHz group modem link

(Contribution by International Telephone and Telegraph Corporation)

The study will need to include consideration of a leased circuit for point-to-point wideband data transmission, envisaged as being capable of operating either synchronously at data signalling rates up to 48 kbits/s or asynchronously, and being wholly or partially provided by means of p.c.m. channels.

ANNEX 2

(to Question 11/D)

Data transmission up to 200 bauds in switched telegraph networks

(Contribution COM X–No. 26 by the Chile Telephone Co., 1964-1968)

As far as telegraph and data services are concerned, the introduction in the switched telephone network of digital transmission and, ultimately, digital switching, systems may lead to the emergence of a switched network catering for telegraphy and for data at rates up to about 2000 bits/s.

The following comments concerning points which are to be studied under Question 11/D are made on the assumption that such an approach will be adopted for future telegraph services.

Economic aspects

An economic study by Study Group X compared telegraph-type and telephone-type network solutions for a 200-baud switched service requirement—the information-carrying capacity of a telephone-type circuit being estimated, according to present techniques, at 900 bauds (4.5 × 200) for the telegraph-type solution and 200 bauds for the telephone-type solution. In a digital network the transmission rate corresponding to that of a voice channel will be 56 kbits/s or thereabouts (ignoring any capacity added for signalling). New networks established for data and telegraphy should clearly be such as to exploit the characteristic of the digital network, i.e. very economical transmission of binary information.

Modulation rates

Because of the synchronous character of the digital network restraints will be desirable on the speeds at which data terminal equipments operate. The nominal speeds for general use over the network should be that of the network itself (we have assumed 2000 bits/s as a suitable speed) or certain simple fractions of that speed. This ensures that the interface requirements between the subscribers' lines and the network are kept simple.

Over a range of very low modulation rates, up to 200 bauds say, it would be possible, in a completely digital network, to allow any modulation rate. However, in a transitional stage when the presence in the network of conventional telegraph-type links may require the insertion of regenerators, restriction to integral speeds such as 50, 100 and 200 bauds even at the low end would permit regeneration to be effected on a code insensitive basis.

For special applications, requiring more complex interface equipment, it should still be possible to provide data transmission at any rate up to the maximum.

Signalling

For main network signalling the use of common channel signalling should be seriously considered. This solution would satisfy the requirements of code insensitivity and of rapid call establishment, both of which are important to data users of the network. Additionally, studies of this type of signalling as applied to the telephone network have shown that it becomes economical relative to inband signalling once the number of circuits in the group being served reaches a very small number depending on circuit length.

The possibility should be borne in mind of unification of signalling with that of the voice network.

A completely separate channel signalling solution might not be realizable initially; in that event code insensitivity of the communication channels could be achieved through outband channel associated signalling. In any case, it is considered that future switching equipments provided for this network should be compatible with separate channel signalling.

Verification of the called subscriber identity for data users should be a function of the data terminal equipment. This would be as for data calls established over the telephone network. It is recognized that for calls established between stations having alphabet No. 5 type teleprinters the existing telex procedure may be more appropriate. The different types of users of the network should be distinguished on a class-of-service basis.

Transmission method (start-stop or synchronous)

The interface units, and regeneration, when required, in the digital network are simplified and transmission performance is better if all transmissions are isochronous. This is not necessarily inconsistent with start-stop operation but requires that the length of the stop period is an integral number of signal elements.

Further, it is advantageous with synchronous operation that data terminal equipments operate according to a timing signal received from the network itself.

Subscriber line transmission and signalling

The Study Group X suggestion that this area should be the subject of standardization is supported. There would be advantages in accepting d.c. suppressed base-band transmission methods, leaving the d.c. path clear for line supervisory signals.

For control signalling (call selection and call progress etc.) a procedure common to all users of the network, irrespective of the type of data terminal equipment used, will be desirable. It should be acceptable to data users that this be based on the signals of a teleprinter equipment using alphabet No. 5.

Basic switching methods

For the data network envisaged, evolving from the new digital network, circuit switching was assumed. This, however, does not imply any incompatibility with store and forward methods which can play an important part not only in improving efficiency of access to expensive plant but could also contribute in such areas as speed conversion and even code translation. If store and forward methods are used in conjunction with basically adequate provision of main line plant, overall response times can be kept satisfactorily short and acceptably rapid reply service can be preserved. The two methods should be regarded as partners rather than mutually exclusive.

For the subscriber switching stage of any network there are considerable economic gains possible if unification can be achieved so that the same plant is used for data at different speeds and for voice.

Question 12/D — Incorporation of circuits on p.c.m systems in the existing telephone network

(new question)

What recommendations should be made to enable circuits (and assemblies of circuits) set up on pulse-code modulation (p.c.m.) systems to be successfully incorporated in the existing world telephone network?

Note. — This question was put by Study Group XVI to which the results of the study will be transmitted. Account should be taken of the studies relating to Annex 6 to Question 2/D.

Summary of Questions assigned to Special Study Group D

Question No.	Short title	Comments
1/D	Planning of digital systems	
2/D	Basic p.c.m. multiplex terminal equipments	
3/D	Signalling for p.c.m. systems	
4/D	Digital switching systems	
5/D	Synchronization of digital networks	
6/D	Digital multiplex hierarchy	
7/D	Interfaces for digital systems	
8/D	Digital transmission systems over cable and radio links	
9/D	High-order digital multiplex equipment	
10/D	Digital coding of signals for sound and television programme transmissions, etc.	
11/D	Data transmission over digital systems	
12/D	Incorporation of circuits on p.c.m. systems in the existing telephone network	

PART 5

SUPPLEMENTS TO SERIES G, H AND J RECOMMENDATIONS (TRANSMISSION)

SUPPLEMENT No. 1

(Geneva, 1964; referred to in Recommendation G.131, A)

CALCULATIONS OF THE STABILITY OF INTERNATIONAL CONNECTIONS ESTABLISHED IN ACCORDANCE WITH THE TRANSMISSION AND SWITCHING PLAN

1. *Method of calculation*

Let the nominal transmission loss (in dB) between two-wire points of the terminating sets at the ends of a chain of national and international circuits interconnected on a four-wire basis be T dB and the mean stability balance return loss (in dB) B. The mean loop loss (in dB), M, of the four-wire portion of the total connections will be

$$M = 2\,(T + B)\ \text{dB}$$

If the standard deviation of loop loss is m (in dB), the critical equation used to determine the proportion of the population of connections with a stability of S (in dB) or less is:

$$M - Km = 2S$$
$$\text{or } K = (M - 2S)/\text{m}$$

where K is the displacement coefficient. By consulting tabulated values of the probability function [1]

$$P\,(K) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{K} \exp\left(-\frac{t^2}{2}\right) \cdot \mathrm{d}t$$

the quantity $1 - P\,(K)$ can be evaluated, which is the probability of a connection exhibiting a stability at least equal to S dB.

2. *Mean loop loss*

The national extension circuits are assumed to be added according to the $2 + \frac{1}{2} + \frac{1}{2} + \frac{1}{2}$ dB plan so that the nominal transmission loss between the two-wire points, T, is $4 + 0.5n$ dB where n

---

[1] $P\,(K)$ is the probability that a random variable, normally distributed, with zero mean and unit variance, will be less than K.

is the total number of four-wire circuits both national and international. The mean values of stability balance return loss assumed are either 6 dB, the target for the future, or 3 dB, the likely present value in some networks.

Hence

$$M = 2(T + B) = 2(4 + 0.5n + 6 \text{ or } 3) = 20 + n \text{ or } 14 + n \text{ dB}$$

3. *Standard deviation of loop loss*

Assuming that the variation of the two balance return losses are uncorrelated, that the variations of either balance return loss are uncorrelated with the variations of the transmission loss, and that the two directions of transmission are correlated with a correlation factor r, the variance (the square of the standard deviation) of the loop loss of a chain of n independently-maintained circuits is given by

$$m^2 = n(t_1^2 + 2rt_1t_2 + t_2^2) + 2b^2 \qquad \text{dB}^2$$

where

t_1, t_2 = the standard deviation of transmission loss in the two directions of transmission of one four-wire circuit,

b = the standard deviation of balance return loss, which is assumed to be either 2.5 dB or 1.5 dB, associated with the mean values 6 dB and 3 dB respectively.

Setting $t_1 = t_2 = 1$ dB; $b = 2.5$ or 1.5 dB; $r = 1$ gives

$$m^2 = 12.5 + 4n \text{ or } 4.5 + 4n \text{ dB}^2$$

The corresponding numerical values of M and m and the probabilities have been calculated as functions of n and the values are given in the table below. Figure 1 of Recommendation G.131 was constructed from these figures.

Total number of four-wire amplified circuits, both national and international	Stability balance return loss; $B = 6$ dB; $b = 2.5$ dB				Stability balance return loss; $B = 3$ dB; $b = 1.5$ dB			
	Mean loop loss	Standard deviation of loop loss	Number of connections per million which will exhibit a stability equal to or less than S		Mean loop loss	Standard deviation of loop loss	Number of connections per million which will exhibit a stability equal to or less than S	
n	M dB	m dB	$S = 0$ dB	$S = 3$ dB	M dB	m dB	$S = 0$ dB	$S = 3$ dB
1	21	4.06	< 1	112	15	2.92	< 1	1000
2	22	4.53	< 1	200	16	3.54	3	2330
3	23	4.95	2	301	17	4.06	17	3360
4	24	5.34	3	376	18	4.53	36	4020
5	25	5.70	6	434	19	4.95	62	4270
6	26	6.04	9	466	20	5.34	88	4400
7	27	6.36	11	483	21	5.70	117	4270
8	28	6.67	14	483	22	6.04	136	4020
9	29	6.96	16	483	23	6.36	153	3800
10	30	7.25	17	466	24	6.67	159	3470
11	31	7.52	19	434	25	6.96	165	3170
12	32	7.78	20	419	26	7.25	165	2890
13	33	8.03	20	390	27	7.52	165	2640
14	34	8.28	21	350	28	7.78	160	2330

SUPPLEMENT No. 2

(Geneva, 1964, amended at Mar del Plata, 1968; referred to in Recommendation G.131, B)

TALKER ECHO ON INTERNATIONAL CONNECTIONS

The curves of Figure 2 of Recommendation G.131 may be used to determine whether a given international connection requires an echo suppressor. Alternatively they may be used to find what value of nominal over-all transmission loss shall be adopted for the four-wire chain of a complete connection so that an echo suppressor is not needed.

Before the curves can be used it must be decided what proportion of calls are to be allowed to exhibit an objectionable echo and Recommendation G.131, B gives guidance on this matter.

The co-ordinates of the graph are two of the parameters of a telephone connection that govern echo—the transmission loss and total length of the four-wire chain. By making certain assumptions (discussed below) these two parameters become the principal ones.

Each curve divides the co-ordinate plane into two portions and the position, relative to the curve, of the point describing the connection indicates whether an echo suppressor is needed bearing in mind the percentage of calls permitted to exhibit an objectionable echo.

Factors governing echo

The principal factors which must be considered in order to decide whether an echo suppressor is needed on a particular connection are:

a) the number of echo paths;

b) the time taken by the echo currents to traverse these paths;

c) the attenuation of the echo paths;

d) the tolerance to echo exhibited by subscribers.

These factors are discussed in turn in the following paragraphs.

When circuits are switched together four-wire there is only one echo path, assuming negligible go-to-return crosstalk. This is also substantially true if the circuits are switched together two-wire and reasonable values of echo return losses are achieved at the connection points because the principal echo currents are those due to the relatively poor echo return losses at the ends of the two extreme four-wire circuits, where the connection is reduced to two-wire.

The time taken to traverse the echo path is virtually dependent solely on the length of the four-wire connection because the main circuits of modern national and international networks are high-velocity circuits.

The attenuation of the talker echo path for a symmetrical connection is approximately given by the sum of twice the transmission loss of the complete connection between the two-wire points in the terminal local exchanges and the echo return loss presented at the two-wire point in the far-end terminal local exchange. The loss of the subscriber's lines connected to these two-wire points may be assumed to be very low so that strictly the results are applicable only to such favourably-placed subscribers. The echo experienced by subscribers on lines with more loss will be further attenuated. This is therefore a safe assumption.

The echo return loss is assumed to have a mean value of not less than 11 dB (12.7 dNp) with a standard deviation of 3 dB (3.5 dNp) expressed as a weighted mean power ratio over the band 500-2500 Hz. The mean value of the transmission loss is assumed to be uniform over this band and the standard deviation of transmission loss for each four-wire circuit is assumed to be 1 dB or 12 cNp for each direction of transmission. The correlation between the variations of loss of the two directions of transmission is assumed to be unity.

The tolerance to echo exhibited by subscribers is under active investigation by some Administrations and, until their findings are known, the C.C.I.T.T. has adopted the echo tolerance data published by the American Telephone and Telegraph Co., in "Notes on Distance Dialing", September 1956, which are reproduced below. They give the mean threshold of objection to echo—i.e., each pair of values for delay and attenuation is a combination to which 50% of the test subjects objected and which 50% tolerated. The data were obtained with a subscriber loop having a loss of about 1 dB. The standard deviation of subscriber opinion is quoted as 2.5 dB.

One-way propagation time	Threshold echo attenuation, E
ms	dB
10	11.1
20	17.7
30	22.7
40	27.2
50	30.9

Construction of Figure 2 in Recommendation G.131

The mean margin against objectionable echo is given by

$$M = 2T + B - E$$

where T = mean overall loss between the two-wire points in the terminal local exchanges. The loss is assumed to be the same in both directions of transmission;

B = mean echo return loss at the listener end;

E = mean threshold attenuation.

The standard deviation of the margin is given by

$$m^2 = n\ (t_1^2 + 2rt_1t_2 + t_2^2) + b^2 + e^2$$

where m = standard deviation of the margin;

t_1, t_2 = standard deviation of the transmission loss in the two directions of transmission of one four-wire circuit, national or international;

b = standard deviation of echo return loss;

e = standard deviation of the threshold of objection;

r = correlation factor between t_1 and t_2;

n = the number of four-wire circuits in the four-wire chain.

Inserting $t_1 = t_2 = 1$ dB; $r = 1$; $b = 3$ dB; $e = 2.5$ dB gives

$$m^2 = 4n + 15.3.$$

In Recommendation G.131, B, c), Rules A and E refer to 10% and 1% probabilities of encountering objectionable echo and for these cases 9 four-wire circuits will be assumed (3 national + 3 international + 3 national). For both the 1% and 10% curves therefore m = 7.2 dB.

For 10% probability, the margin may fall to 1.28 times the standard deviation. The corresponding factor for the 1% curve is 2.33. Hence the corresponding values of M are:

$$M = 1.28 \times 7.2 = 9.2 \text{ for } 10\% \text{ probability}$$
$$M = 2.33 \times 7.2 = 16.8 \text{ for } 1\% \text{ probability.}$$

Putting these values into $M = 2T + B - E$ and setting $B = 11$ dB gives the following values for the mean talker echo attenuation, $2T + B$:

$$2T + B = 9.2 + E \text{ for } 10\% \text{ probability}$$
$$2T + B = 16.8 + E \text{ for } 1\% \text{ probability.}$$

The values in the table below have been calculated (to the nearest whole unit) using these equations. The figures in the "length of connection" column have been calculated assuming a velocity of propagation of 100 statute miles/ms or 160 km/ms.

Mean one-way propagation time	Length of connection		Mean echo path attenuation, $2T + B$			
			10%		1%	
ms	miles	km	dB	dNp	dB	dNp
10	1000	1600	20	23	28	32
20	2000	3200	27	31	35	40
30	3000	4800	32	37	40	45
40	4000	6400	36	42	44	51
50	5000	8000	40	46	48	55

Figure 2 of Recommendation G.131 has been constructed from these values. The scale of ordinates on the right-hand side of the figure has been determined on the assumptions that:

a) there is no difference between the nominal value and the mean value of the loss of the connection between the two-wire points in the terminal local exchanges;

b) the nominal loss is the same in both directions of transmission;

c) the mean value of the echo return loss at the listener end is 11 dB (12.7 dNp).

SUPPLEMENT No. 3

(Mar del Plata, 1968; referred to in Recommendation G.161)

DEVICE USED BY THE AMERICAN TELEPHONE AND TELEGRAPH COMPANY FOR OBJECTIVELY MEASURING IMPAIRMENTS DUE TO ECHO SUPPRESSORS

Circuit impairments due to echo suppressors are of a complex nature, which makes it difficult to obtain meaningful measurements of performance. Commonly used measuring methods consist of the opinion of experts and of unbiased subjective testing. Expert opinion is often unconvincing and subjective testing is usually time-consuming and expensive. For the last three years Bell Telephone Laboratories have been using a specially designed test set, called the degradation counter, as an auxiliary method of determining echo suppressor performance. It is an objective test which has proven to be in agreement with subjective evaluations whenever comparisons have been possible. It is believed that an improved version of the degradation counter would be of considerable help in resolving current questions concerning the compatibility of echo suppressors of different design, tandem echo suppressor connections, and the effect of varying certain echo suppressor design requirements.

This supplement discusses the principles involved in the degradation counter and describes the present device. Some test results are included for illustration and compared with the results of subjective tests where possible. Finally, possible improvements in the test set which would increase its usefulness are discussed.

1. *Principles of operation*

Speech degradations due to echo suppressors fall generally into the following categories:

1) the return of echo,
2) speech mutilation or chopping,
3) lockout (transmission blockage in both directions simultaneously).

The degradation counter provides objective measurements of these three types of degradation.

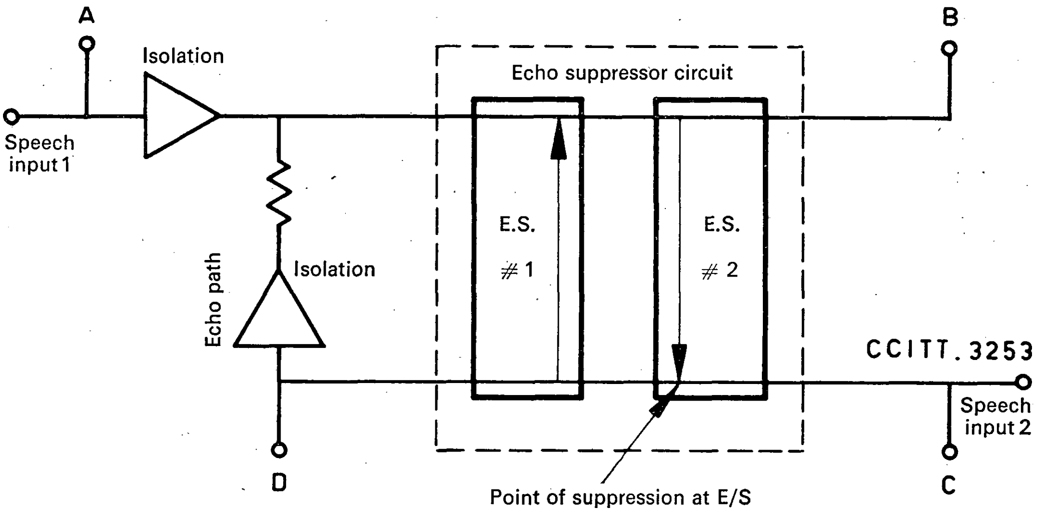
The logic employed will be explained with reference to Figure 1. Here a speech circuit, including an echo path, is equipped with echo suppressors. Assume that we can simultaneously determine whether or not speech is present at the points A, B, C and D, and that there are no time delays in the circuit. We could then draw the following conclusions:

a) if speech is present at A but not at B (denoted by AB′), then the speech from input 1 is being chopped by echo suppressor number 1;
b) if speech is present at B but not at A (denoted by A′ B), then the speech at B must be the echo of input 2;
c) if speech is present at A but not B and, at the same time, speech is present at C but not D (denoted by AB′CD′), then lockout has occurred due to simultaneous suppression of echo suppressors 1 and 2.

The degradation counter essentially performs these observations and its logic circuits draw the same conclusions. It should be noted that an important adverse condition of echo suppressor operation is the return of echo during double talking. Here speech is present at A and B, the speech at B containing both the speech at input 1 and the echo of the speech at input 2. No attempt is made to measure this condition.

The assumption that there are no time delays between the points A and B and between C and D may seem to be overly restrictive since all real echo suppressor circuits have considerable time delays associated with them. However, the operation of a single echo suppressor is affected only by the speech patterns appearing at its ports at any instant of time. The echo suppressor is not aware of, or concerned with, the history or future of these speech patterns. Time delay in the circuit has basically a subjective effect. The listener is insensitive to echoes when time delays are very short and becomes increasingly more sensitive as the time delay increases. However, the degradation counter sensitivity is not affected by time delays. It will count all echoes which get by the echo suppressor, whether these echoes are delayed in time or not. For this reason, time delay is not required in the circuit for most applications of the degradation counter, and the present device makes no allowance for it. There are applications, such as the testing of tandem echo suppressors, where time delay within the echo suppressor circuit could conceivably affect the overall performance. Later we shall suggest a modification to the test set which will allow including such delays.

The degradation counter makes use of a recorded conversation of a male and a female talker. The conversation is a rapid exchange with a considerable amount of double talking, and is representative of the type of conversation which would most likely cause difficulties with an echo suppressor circuit. The same recording is used for all measurements and provides a common base for comparing the results of different tests. The recording is described in detail in Appendix 1.



Note. — Echo suppressors apply suppression at point indicated by arrowhead.

FIGURE 1

2. *General circuit description*

A block diagram of the degradation counter is shown in Figure 2. A speech path similar to that of Figure 1 is shown, and means for incorporating end delay and for varying the return loss of the echo path are provided. Speech is detected at A, B, C and D by Schmitt triggers at these points after rectification and smoothing.

To be explicit we shall confine our attention to the Schmitt triggers labelled A′ and B and to the echo gate. The echo gate is an AND gate requiring the presence of three signals, one from B

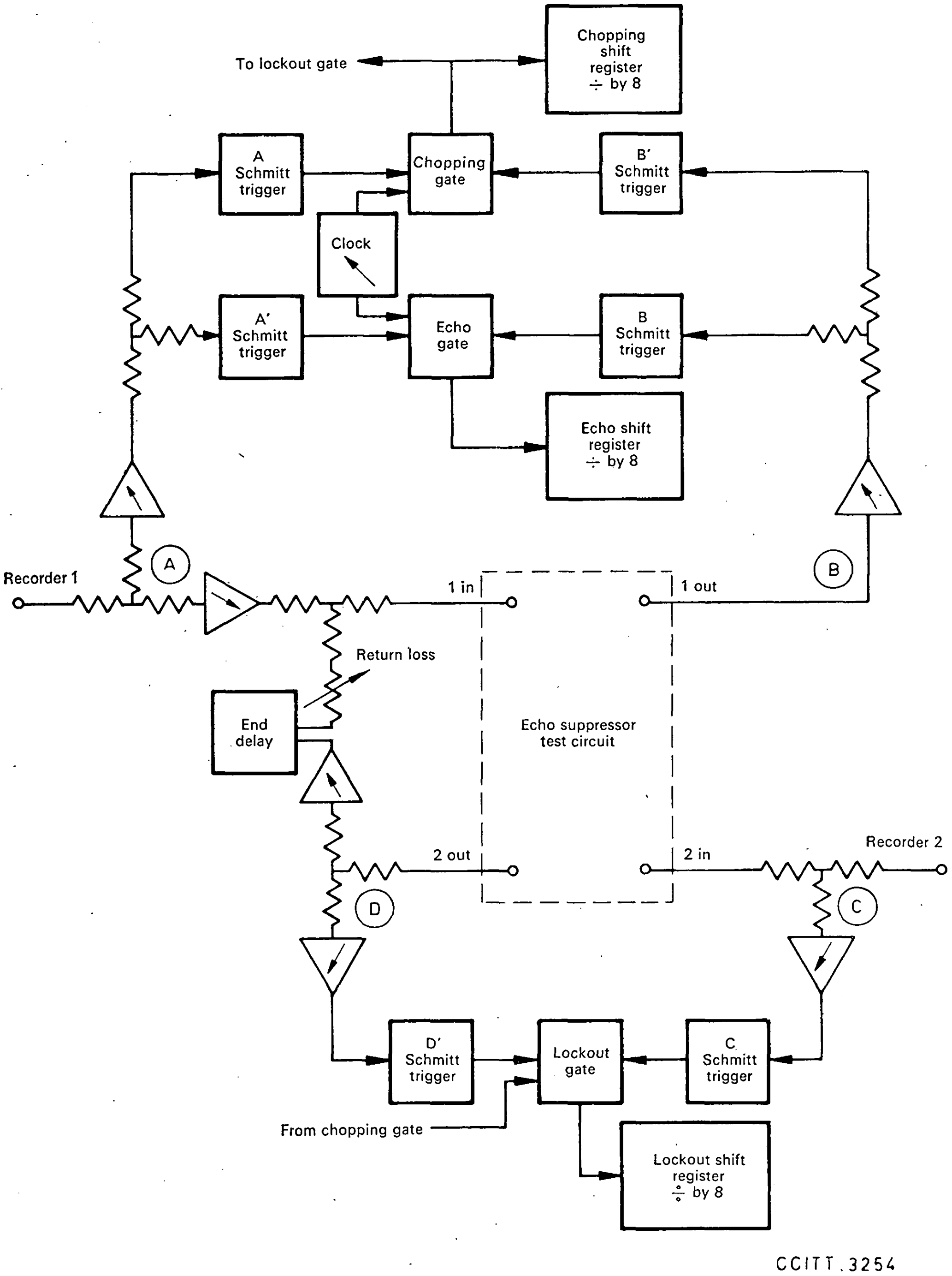


FIGURE 2. — **Degradation counter**

Schmitt trigger, one from A′ Schmitt trigger and one from a clock. The A′ Schmitt trigger is a two-state device which applies an enabling signal to the echo gate when speech is not present at A. If speech is present at A then the A′ Schmitt trigger will disable the echo gate. The B Schmitt trigger is a similar device which enables the echo gate when speech is present at B. Hence, the echo gate is enabled whenever an A′B state exists (which has been shown to represent echo), and the gate will transmit the clock pulses. These pulses are then applied to a shift register to be counted as instances of echo.

The clock is a square wave generator supplying output pulses of 10 μs duration at a variable (100-200 Hz) rate. The shift register indicates one count for each eight pulses which enter. Thus each echo count is roughly equivalent to an echo burst or a sum of echo bursts of from 40 to 80 ms, depending upon the clock speed used. A clock speed of 160 Hz, corresponding to a 50-ms burst, is usually used.

The operation of the chopping gate is similar to the above, with B′ Schmitt trigger providing an enable signal when speech is not present at B and the A Schmitt trigger providing an enable signal when speech is present at A. Then, during the AB′ state (chopping), clock pulses will be transmitted and counted by the chopping shift register. The lockout gate operates similarly, the gate being enabled by the CD′ state. The clock pulses for the lockout gate are derived from the chopping gate and, hence, the output of the lockout gate corresponds to the AB′ CD′ state (lockout).

The sensitivities of the Schmitt triggers are set by adjusting the amplifiers which precede them. There are also two amplifiers in the speech path used for blocking purposes and to obtain proper signal levels. The above-mentioned amplifiers and the repetition rate of the clock are the only adjustments required.

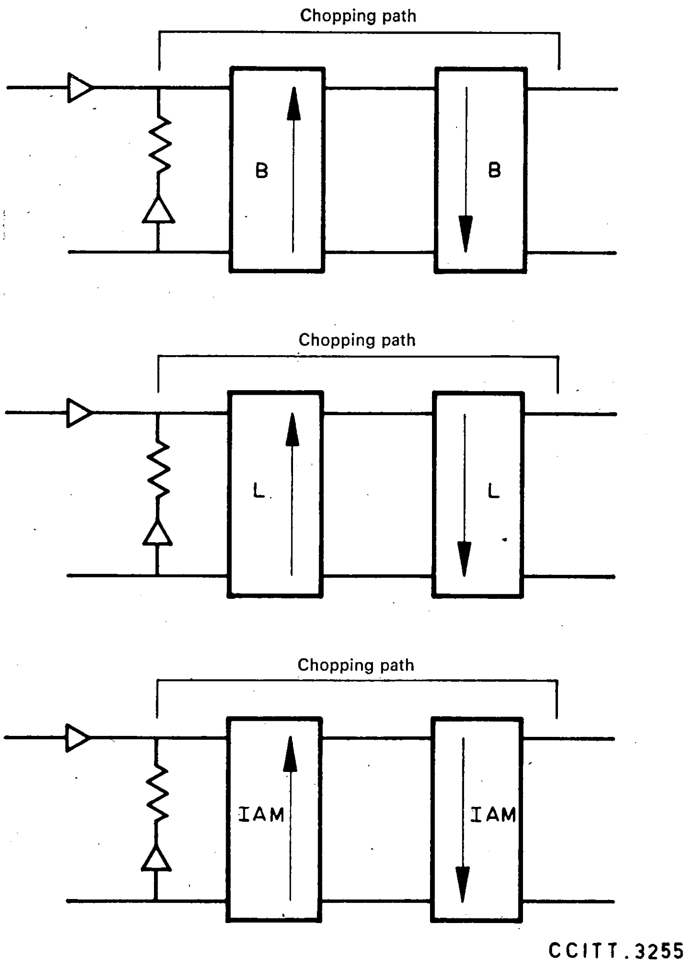
The Schmitt trigger circuits are speech detectors with binary outputs. Their design is rather critical, and one must guard against false outputs from the gates due to the order in which the two detectors associated with a particular gate change states as the speech patterns vary. For this reason a detailed description of the Schmitt triggers used is given in Appendix 2. Other circuits used in the device are not critical and designs are readily obtainable.

3. *Samples of degradation counter results*

When making a counting test, the echo suppressor circuit in question is patched to the counter as indicated in Figure 2. Chopping is counted only in the path between 1 IN and 1 OUT, and echo counts correspond to the echo of Recorder 2 speech. The sensitivity of the Schmitt trigger detectors is usually set to a value slightly less sensitive than the echo suppressor's sensitivities. For example, if the echo suppressor sensitivities are −31 dBm at OTL, then the counter sensitivity would be set to −30 dBm at OTL.

The numbers obtained in a counting test cannot be used to predict a subjective rating of the circuit at the present time, although it may be possible to do so in the future if enough counter and subjective data become available for correlation. At present, the numbers obtained are meaningful only on a relative basis when compared with the results of other counting tests, and should be used only to *rank order* different conditions without implications pertaining to the *degree* of any corresponding subjective differences. Also, the examples which follow span a long period of time during which the degradation counter has been modified a number of times. Because of this the numbers reported are meaningful only relative to a particular experiment, and no attempt should be made to compare numbers which are the results of different experiments.

Figure 3 illustrates how the degradation counter may be used to compare the performance of different types of echo suppressors. The experimental echo suppressors labelled B, L, and 1 AM are the same echo suppressors used during a subjective test on the transatlantic cables with added delay in 1964. The results of the subjective test have been previously reported [1] and the ranking



Echo	Chopping	Lockout
12	234	0
12	1160	12
67	1667	0

Note. — Echo suppressors apply suppression at point indicated by arrowhead.

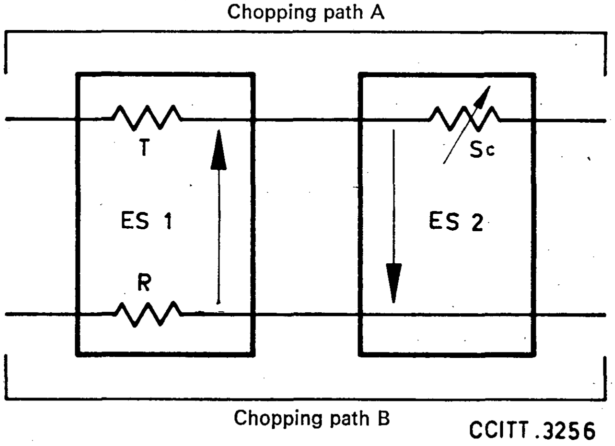
Implied ranking in order of poorer performance:

1-B
2-L
3-1AM

FIGURE 3. — **Echo suppressors of different types**

of echo suppressors from that test is identical with that implied by the degradation counter. The subjective data indicated that the most pronounced differences in the echo suppressors were in the chopping category, which agrees with the results from the degradation counter.

Figure 4 shows how the degradation counter can be used to investigate echo suppressor parameter variations. In this case echo suppressor Number 1, which inserts fixed losses in the transmit and receive paths during double talking, is working with echo suppressor Number 2, which inserts a speech compressor. The division of T and R losses in echo suppressor Number 1 is varied. The results indicate that, even if the total round trip losses $(T + R + S_c)$ remain the same, chopping performance is dependent upon the division of these losses. For example, a more symmetrical performance is obtained for the case where the transmit fixed loss is 0 and the receive fixed loss is 12 dB. This points out the need for similarity among echo suppressors in this characteristic for them to be compatible.



T = fixed transmit loss.
R = fixed receive loss.

S_c = variable speech compressor loss. Average loss approximately 9 dB.

	Chopping	
	A path	B path
$T = 6$ dB; $R = 6$ dB	1049	390
$T = 0$ dB; $R = 12$ dB	645	981

A more symmetrical circuit with respect to chopping results is obtained if the echo suppressors introduce an approximately equal amount of loss at the same location relative to the echo suppressors.

FIGURE 4. — **Distribution of double talking losses**

Another example of the counter being used in parameter investigations is shown in Figure 5. Echo suppressors with differential action must be designed to protect against break in on echo for a certain maximum end delay on the subscriber side of the echo suppressor. Means for providing this protection usually degrade the break in ability of the echo suppressor, resulting in more chopping. Figure 5 shows how the chopping counts increase as the end-delay protection is increased in an echo suppressor with a differential circuit similar to that of the Western Electric 3A.

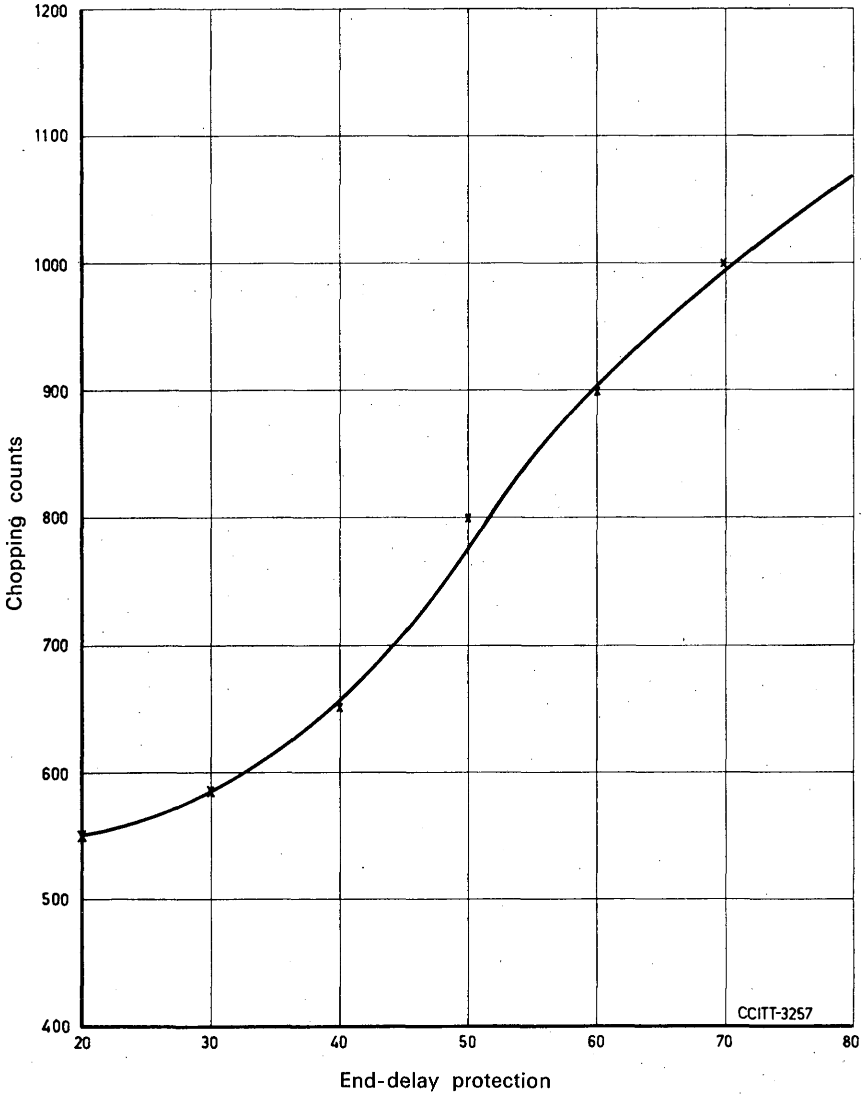
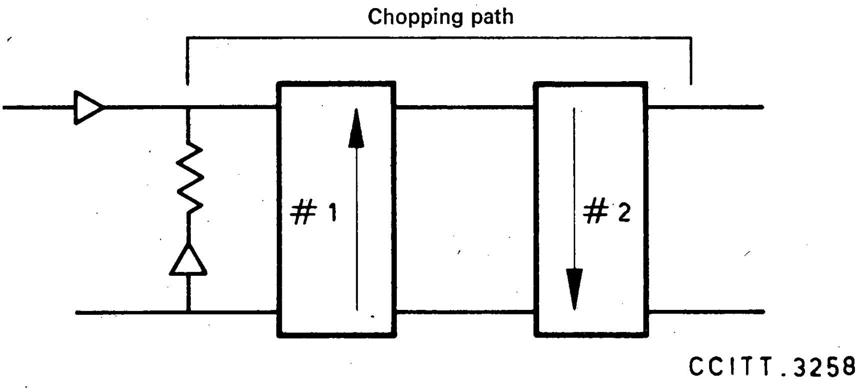


Figure 5. — **Chopping as a function of end delay protection**

Figure 6 shows counting results of an echo suppressor circuit equipped with dissimilar echo suppressors. The echo suppressors are those which were used in the transatlantic cable test mentioned previously. Examination of the counting results indicates, first, that a subject will observe echo suppressor performance that is characteristic of the echo suppressor at the far end of the circuit, but there also is some evidence of an interaction effect, where the performance of one echo suppressor is either improved or deteriorated by the presence of the other echo suppressor. The degradation counter promises to be of considerable value in determining the compatibility of echo suppressors of different design.

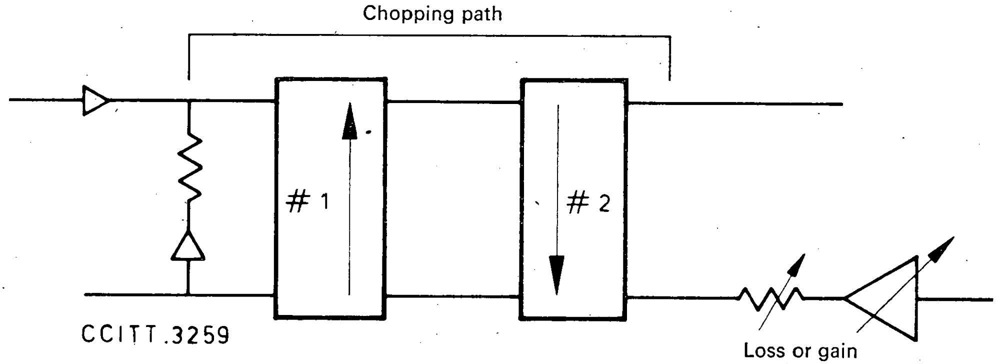


Conditions			Echo	Chopping	Lockout
	Nº 1	Nº 2			
1	B	B	12	234	0
2	L	L	12	1160	12
3	1 AM	1 AM	67	1667	0
4	B	L	22	236	7
5	L	B	8	1652	4
6	B	1 AM	182	182	0
7	1 AM	B	12	1681	0

Chopping as observed from right-hand end of circuit is characteristic of echo suppressor at the other end of the circuit. However, some interaction is apparent as evidenced by the increase in chopping in condition 5 compared with 2, condition 7 compared with 3, and the decrease in condition 6 compared with 1.

FIGURE 6. — Dissimilar echo suppressors in circuit

A last example is shown in Figure 7 where the effect of asymmetry in end circuit losses is investigated. In this case the level of the speech in the lower path was varied to simulate three losses in the right-hand end link. The nominal case is when the loss is zero, in which case the speech levels are those used in other degradation counter tests. The results are consistent with those reported by K.D.D. [2], which indicate more difficulty for the party at the end of the circuit having less loss.



Condition	Chopping
Loss = 0	526
Loss = 5 dB	376
Gain = 5 dB	742

FIGURE 7

4. *Possible improvements of the degradation counter*

The present version of the degradation counter can be improved so as to make it a more versatile tool. It was designed primarily for testing a single echo suppressor, while more recent applications, such as those described above, test circuits equipped with two or more echo suppressors. If we are interested in obtaining information about both paths of such circuits, two tests must be performed with the circuit inverted between tests. This deficiency can be corrected by adding another chopping gate and shift register to count the CD′ state (see Figure 1), which corresponds to chopping in the lower path. The CD′ state is already available for use in the lockout gate. Also, an echo path can be added to the right-hand side of the circuit, with isolation, and echo at that side (given by C′D) can be counted.

When echo suppressors introduce loss during double talking, some of the chopping counts are due to these losses rather than a complete absence of speech. For this reason it may be desirable to provide a number of chopping counters which can detect losses of speech ranging from complete absence to moderate amounts of attenuation. It may also be desirable in some cases, such as the testing of tandem echo suppressor connections, to insert delay in one or both transmission paths. At present this would result in chopping counts which are due only to the delay, but such counts would not be registered if an *identical* delay were inserted in one of the Schmitt trigger circuits. The Schmitt trigger delay could probably be added with binary circuitry.

5. *Summary*

In most cases the objective measurements of the degradation counter agree with what experts instinctively feel to be right. Where conducted, the subjective tests confirm the objective measurements. More detailed analysis of the subjective test data probably would provide further confirmation. Although much work remains in relating objective measurements to subjective opinions and in possible refinements of the test set, the test set today provides a quick method of assessing the quality of echo suppressor combinations.

References

[1] C.C.I.T.T. *Red Book*, Volume V *bis*, Annex E (United States of America).

[2] C.C.I.T.T. Study Group XII, 1964-1968, Contribution No. 22 (K.D.D., Japan).

APPENDIX 1

Standard conversation for degradation counter

The tape recording used with the degradation counter is a conversation between a male and a female talker. It was recorded while the two talked over a four-wire circuit with no echo or delay. From the original conversation a 1½ minute rapid exchange, with a considerable amount of double talking, was selected. Volume (vu) measurements of the segment for each talker were obtained, and this calibrated segment was used to make the tape used during counting tests.

The 1½-minute segment is replayed many times on the test tape, with the vu level of one or both parties being varied between each segment. Also, the position of each talker is interchanged for each vu level. The position and vu level of each talker for each segment is shown in Table A1-1. About 30 minutes are needed for a complete test.

TABLE A1-1

Segment	Channel 1		Channel 2	
	Talker	Speech level	Talker	Speech level
		vu		vu
1	M	−18	F	−18
2	M	−18	F	−12
3	M	−18	F	− 6
4	M	−18	F	−24
5	M	−18	F	−30
6	M	−12	F	−18
7	M	− 6	F	−18
8	M	−24	F	−18
9	M	−30	F	−18
10	F	−18	M	−18
11	F	−18	M	−12
12	F	−18	M	− 6
13	F	−18	M	−24
14	F	−18	M	−30
15	F	−12	M	−18
16	F	− 6	M	−18
17	F	−24	M	−18
18	F	−30	M	−18

M = male talker; F = female talker.

Note. — The volume levels (vu) are referred to OTL.

APPENDIX 2

Circuit description of Schmitt trigger used in the degradation counter

All Schmitt triggers are identical, with two exceptions to be noted below. The circuit diagram is shown in Figure A.2.1. Transistor and diode types are Western Electric.

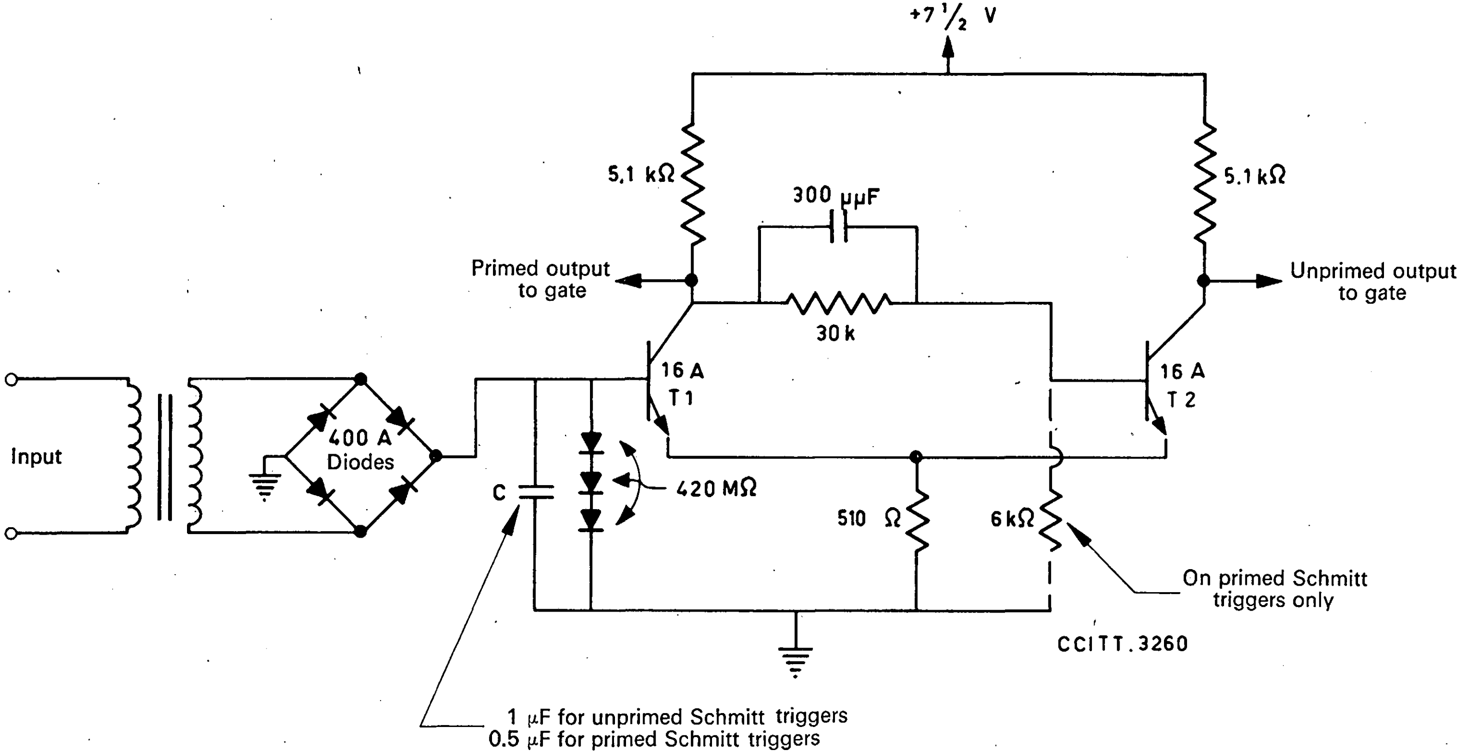


FIGURE A.2.1. — Schmitt trigger

When there is no speech input, T2 is biased full on (collector voltage low) and T1 is cut off (collector voltage high). Using positive two-level logic we associate the collector of T2 with unprimed variables and the collector of T1 with primed variables.

Speech inputs are full-wave rectified and smoothed by the capacitor C. If the input is of sufficient magnitude, the positive voltage across C will start to turn T1 on. The circuit then switches regeneratively so that T1 is full on and T2 is cut off by the voltage drop across the common emitter resistor. The collector of T2 is now high and the collector of T1 is low. The Schmitt trigger will remain in this state until the speech input is removed, whence it will return to the original state.

For large input signals the base current of T1 is limited by the three 420 M diodes in series. This provides more uniform collector voltage levels and decreases the switching time.

Since the Schmitt trigger inputs can change at random times, we must guard against improper asynchronous behaviour. Consider the circuit for counting chopping (AB′). Assume that there is no actual chopping and that A Schmitt trigger switches on faster than B′ Schmitt trigger. Then, when the speech inputs change from speech not present to speech present, the condition AB' will occur before AB and false chopping counts will be registered. Also, if B′ Schmitt trigger switches off faster than A Schmitt trigger and speech inputs change from speech present to speech not present, the condition AB′ will occur before A′B′ and false chopping counts will again be registered. Consideration of the echo and lockout counting circuits yield similar results. In all cases, in order to prevent false counts, the primed Schmitt trigger must turn *on* faster than the unprimed Schmitt trigger and the unprimed Schmitt trigger must turn *off* faster than the primed Schmitt trigger.

Proper asynchronous behaviour is ensured by the following design. For unprimed Schmitt triggers C equals 1 μF. For primed Schmitt triggers C equals 0.5 μF. This will ensure that the primed Schmitt trigger turns on first since the charge time of C is shorter. On primed Schmitt triggers only the base of T2 is shunted with a 6-KΩ resistor. This makes T2 harder to turn on and slows down the release time of the primed Schmitt trigger. Hence the unprimed Schmitt trigger will turn off first. This resistor also aids the turn-on phase since its presence renders the unprimed Schmitt trigger slightly less sensitive than the primed Schmitt trigger.

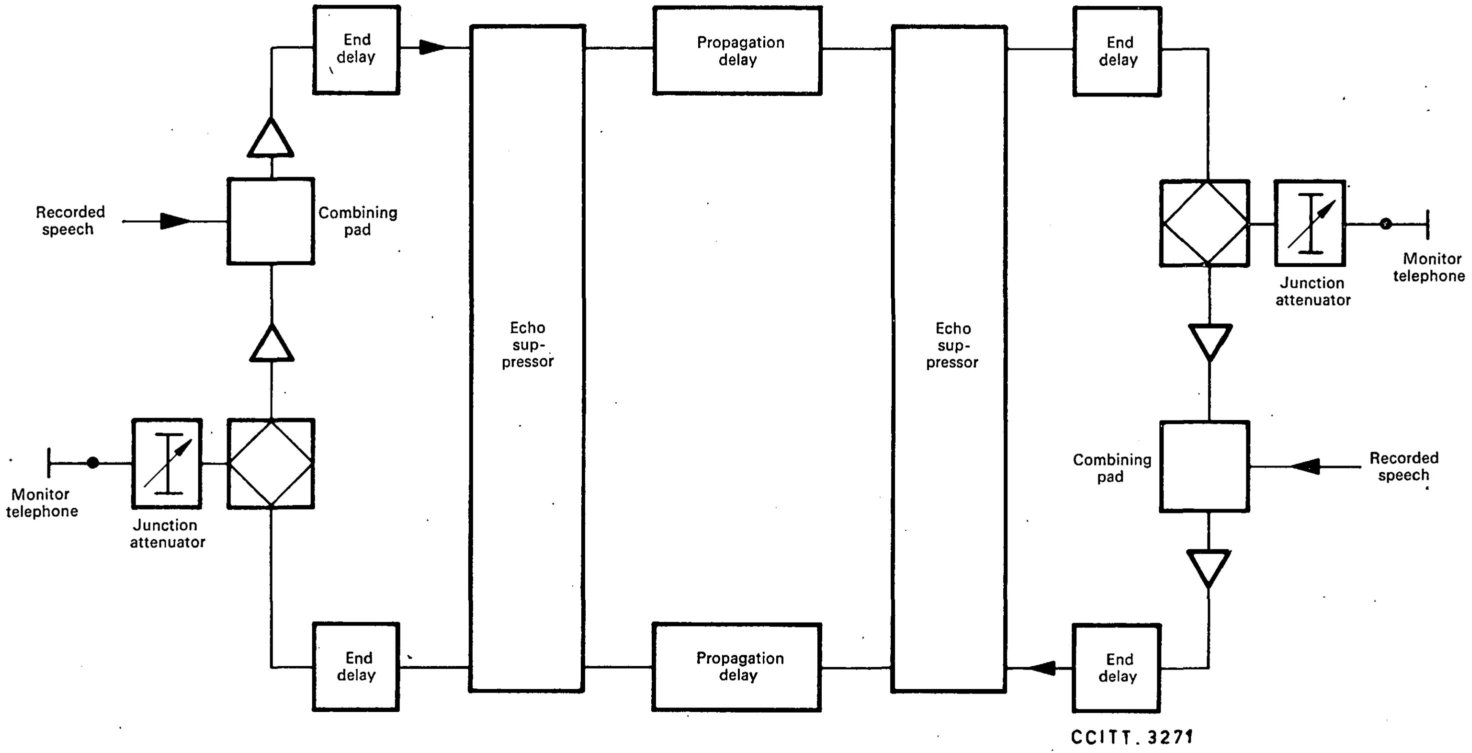
SUPPLEMENT No. 4

(Mar del Plata, 1968; referred to in Recommendation G.161)

METHOD USED IN THE UNITED KINGDOM OF STUDYING THE COMPATIBILITY OF ECHO SUPPRESSORS

This supplement is concerned with a method of studying the compatibility of echo suppressors under controlled working conditions set up in the laboratory. The principles on which it is based are somewhat similar to those described in Supplement No. 3 above.

The method makes use of all the essential components of a complete telephone connection which is set up in the laboratory and into which the echo suppressors under investigation can be inserted. Arrangements are made to vary in a controlled manner all the characteristics of the connection that affect the behaviour of the echo suppressors. Arrangements are also made for observations of various kinds to be made at suitable points in the connection.



Note. — Line amplifiers and attenuators to provide correct lining-up levels have not been shown.

FIGURE 1. — **Laboratory assembly**

1. *Description of the method*

a) *Laboratory assembly*

The laboratory assembly, shown in Figure 1, is symmetrical and possesses a number of adjustable parameters. These are listed in Table 1.

TABLE 1

Adjustable parameter	Values used in tests
Overall loss of circuit	7 dB
End-delay	0 and 20 milliseconds (Note 1)
Propagation time	300 milliseconds (Note 2)
Circuit noise	−50 dBm0p (Note 3)
Two-wire junction circuit attenuation	None (Note 4)
Return loss	2 dB

Notes :

1. End-delay of 20 milliseconds was included only for free conversation tests.
2. Propagation delay is required only for free conversation tests.
3. Measured across a 600-ohm resistive load at the two-wire points of the terminations.
4. Account was taken of the junction circuit loss by the use of a range of values of injected speech level.

Arrangements are provided for the injection of recorded speech material at adjustable levels into each 4-wire send side of the circuit at the termination, with amplifiers to compensate for the loss of the combining pad and to prevent injected speech passing into the two-wire line via the termination. Monitoring or recording facilities are provided at each two-wire point.

The speech material comprises two different sentences of approximately equal duration, recorded on the two tracks of a twin-track tape recorder such that, initially, there is a short time interval between the cessation of one sentence and the commencement of the other. During replay, this interval is gradually reduced and progressive overlapping of the sentences occurs. Finally the sentences move out of phase again and the initial condition is re-established. The time taken to complete one such test cycle is about 3 minutes, with approximately 12/13 repetitions of the sentences. Four test cycles have been made available: these include the two sentences spoken by two male talkers, two female talkers, and the two male-female combinations.

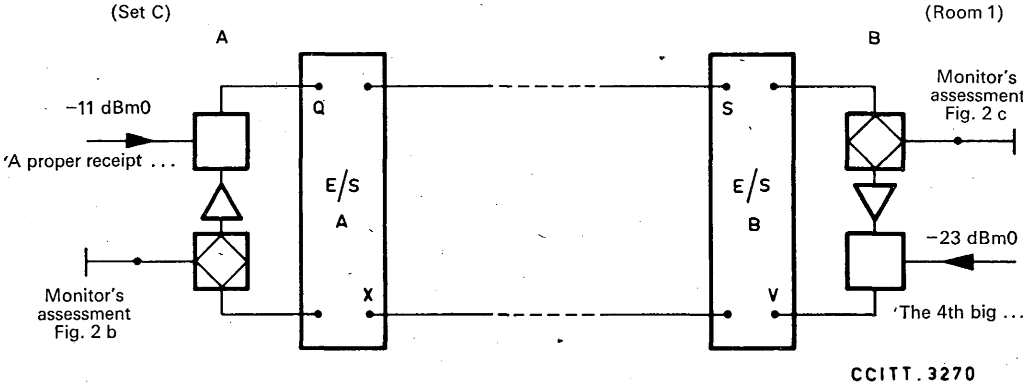
Owing to the large number of parameters that can be varied in the test assembly, it is necessary to assign constant, rather than adverse, values to several of these; this restricts the experiment to reasonable proportions. The values used in the series of tests so far conducted by the United Kingdom Administration are given in Table 1.

b) *Conduct of tests*

To take account of the range of variation in the mean power level of different talkers, junction circuit loss attenuation and sending reference equivalents of local telephone connections under practical conditions, the injected speech levels have been made adjustable over a wide range. Values of −11, −17 and −23 dBm0 at each end of the assembly have been used in the present case.

Tests for compatibility involve the application of the speech test cycle, with all nine combinations of the three levels specified above, to the laboratory assembly containing two echo suppressors of the same type. This is followed by a repetition, under identical circuit conditions, but with one half-echo suppressor replaced by one of alternative type.

The speech present on the two-wire lines during the test cycles is monitored, either directly or via recordings, by observers who are instructed to note the time of occurrence and duration of mutilation and other impairments in each sentence. In addition, the observers record their opinion of each received sentence on a five-point scale (i.e. excellent, good, fair, poor, bad). An extract from a typical set of observations is shown in Figure 2.



Notes. — Figures 2 b and 2 c show typical monitoring observer's assessments of the circuit conditions shown in Figure 2 a.

So far as the monitor at A is concerned, a high received level at point S and low (break-in) level at point V produce a high value for percentage mutilation (25 %) and a low mean opinion score (1.8).

So far as the monitor at B is concerned, a low received speech level at point X and a high send (break-in) level at point Q give rise to a low value for percentage mutilation (2.7 %) and a high mean opinion score (2.7).

FIGURE 2 a. — **Typical test conditions**

c) *Treatment of results*

In tests of this type, normal echo-suppressor action can, during the break-in period, give rise to chopping of received speech, bursts of echo due to break-in hangover, and, with certain types, silent periods at times when speech ought to be received by the listener. Occurrences of all these types would be noted and recorded separately by monitoring observers. The principal effect that was present to any extent in these tests was the chopping of received speech, denoted by mutilation (indicated by M in Figure 2). It is important to distinguish mutilation from complete absence of wanted signal. Mutilation, in the sense used here, is an intermittent effect and does not always destroy intelligibility; in any case it still permits the user, while he is talking, to know that the other participant is trying to draw his attention. No attempt has been made in the recording so far to distinguish different intensities of mutilation—only the total duration for which it persists.

The percentage of mutilated received speech, expressed as a percentage of total duration of the speech, and summed over each test cycle has been calculated for two typical echo suppressors and the results are shown in Figures 3 to 6.

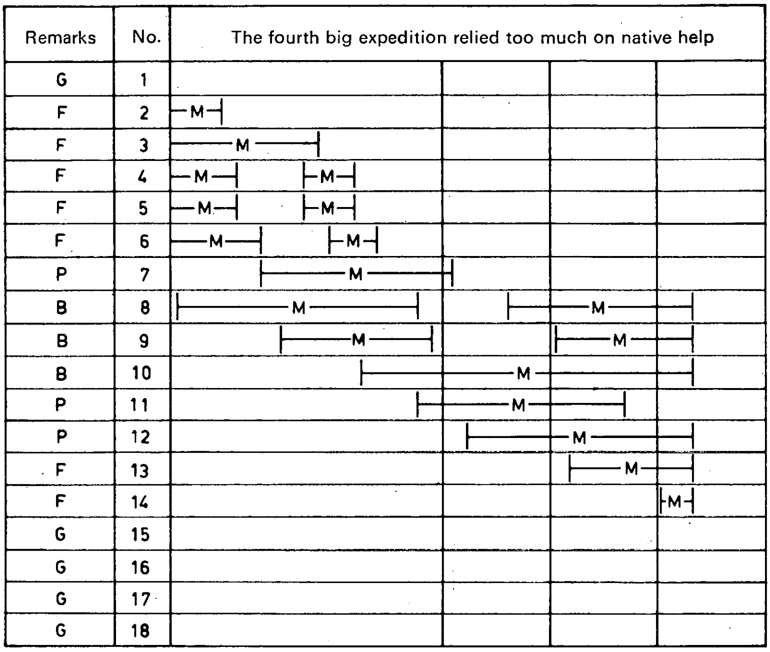


FIGURE 2 b. — **Monitor's assessment at A** (see notes above)

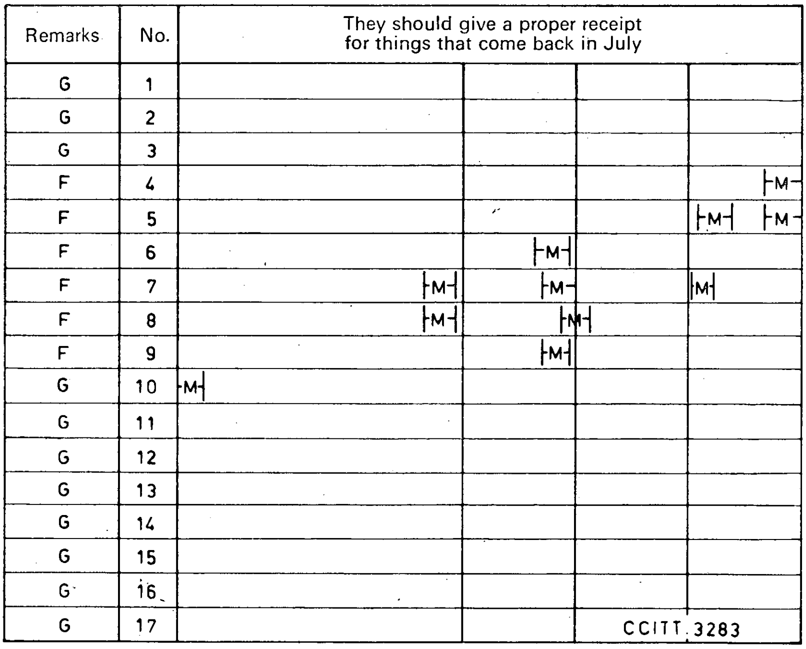


FIGURE 2 c. — **Monitor's assessment at B** (see notes above)

(a) = Sent speech level (S_s) −11 dBm0.
(b) = Sent speech level (S_s) −17 dBm0.
(c) = Sent speech level (S_s) −23 dBm0.

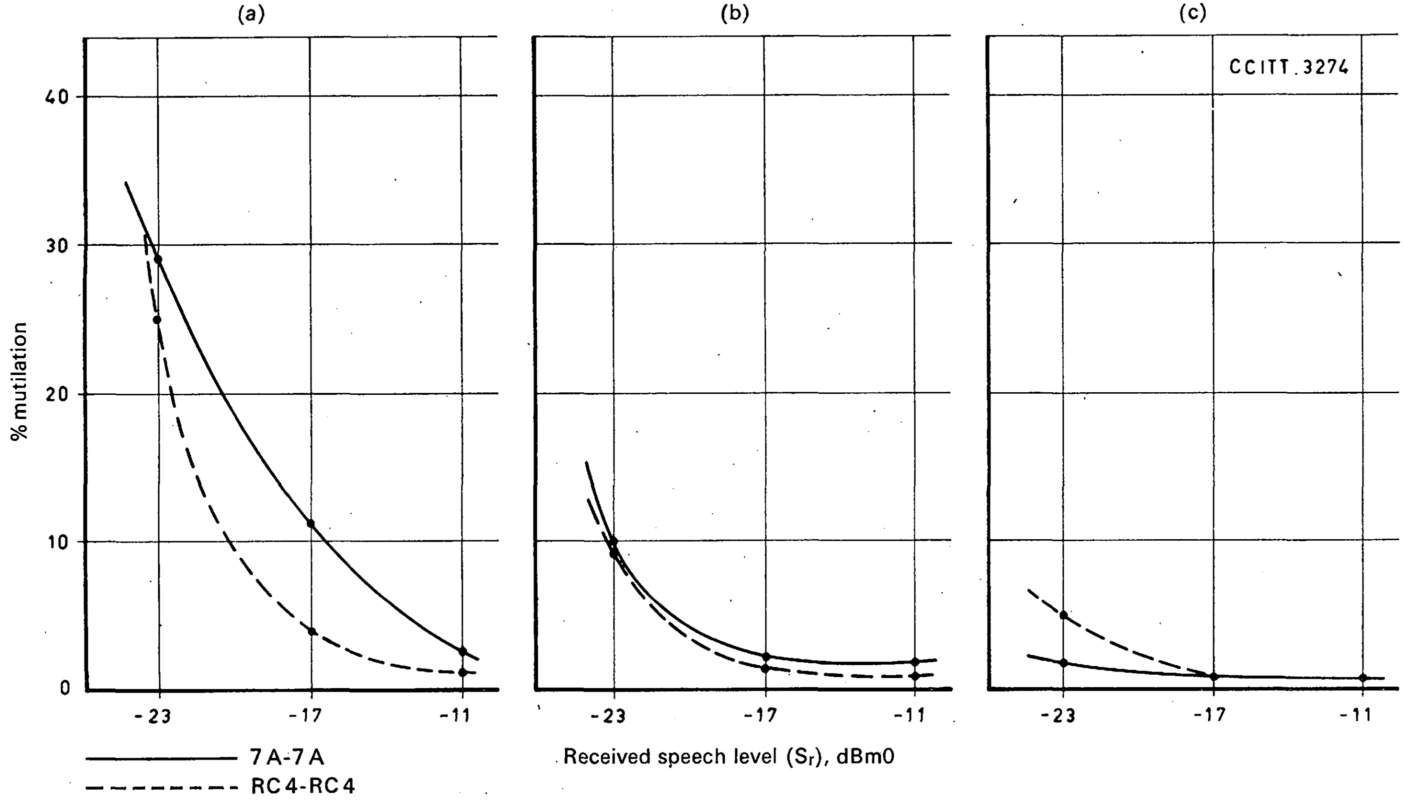


FIGURE 3

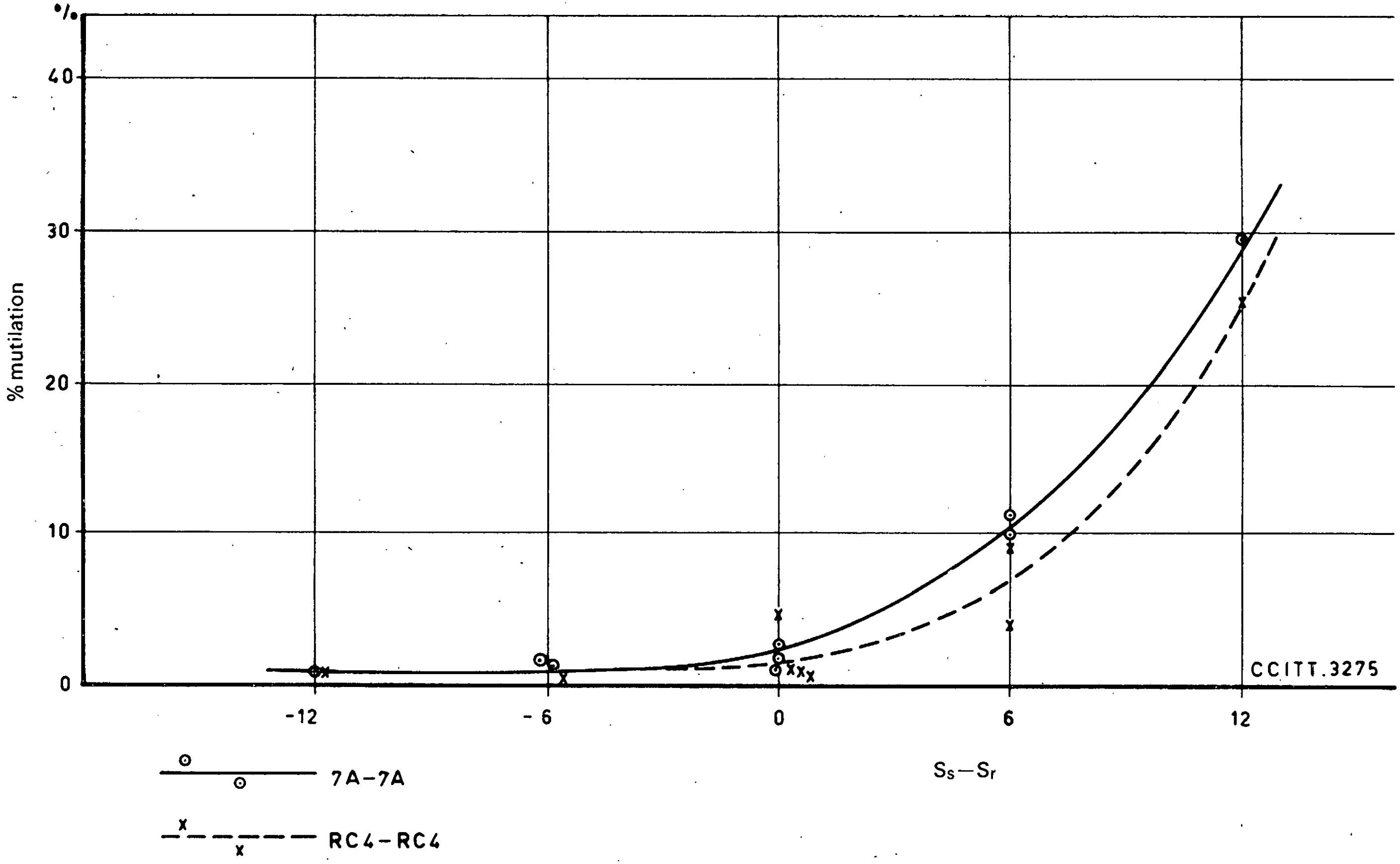


Figure 4

(a) = Sent speech level (S_S) −11 dBm0.
(b) = Sent speech level (S_S) −17 dBm0.
(c) = Sent speech level (S_S) −23 dBm0.

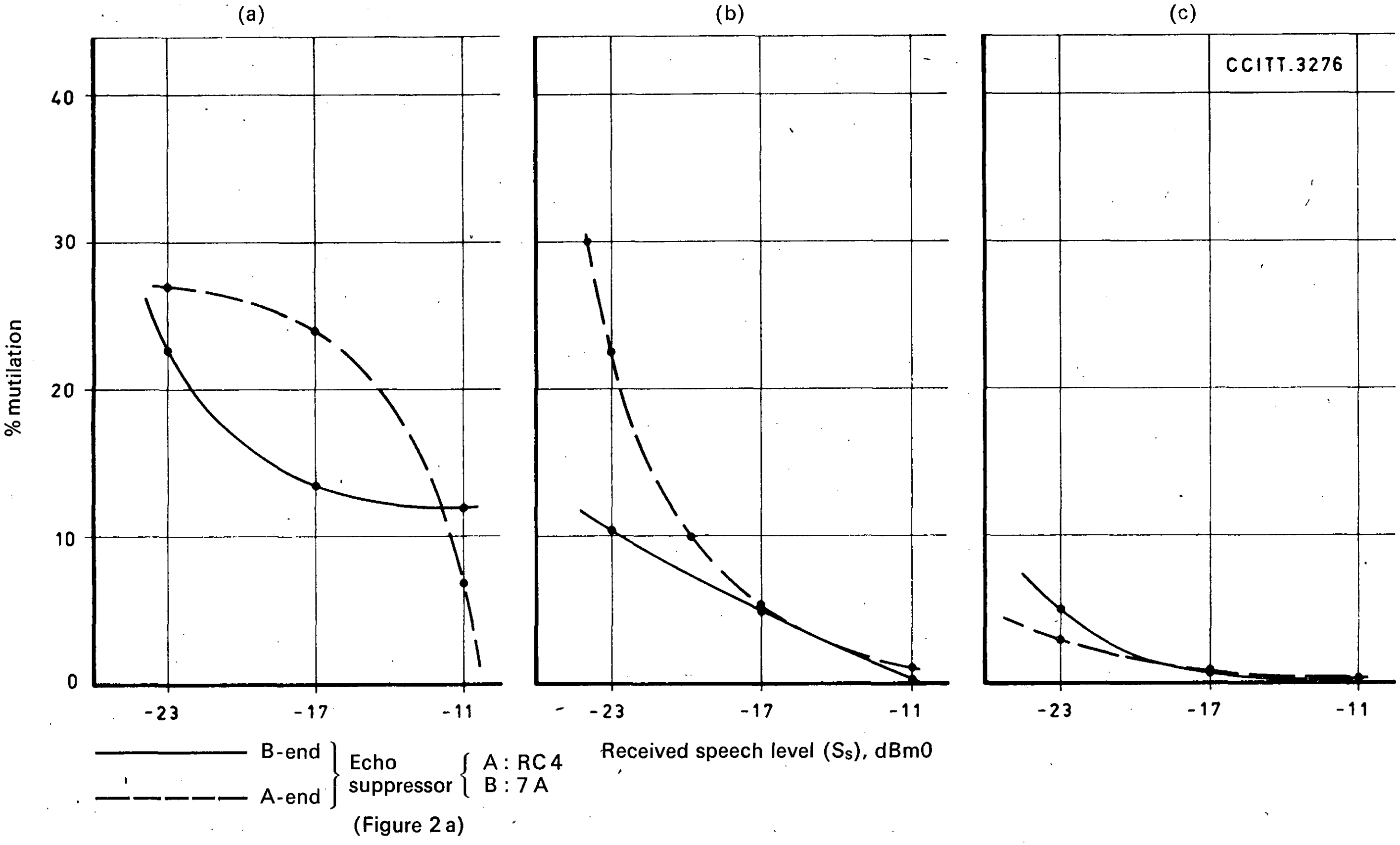


FIGURE 5

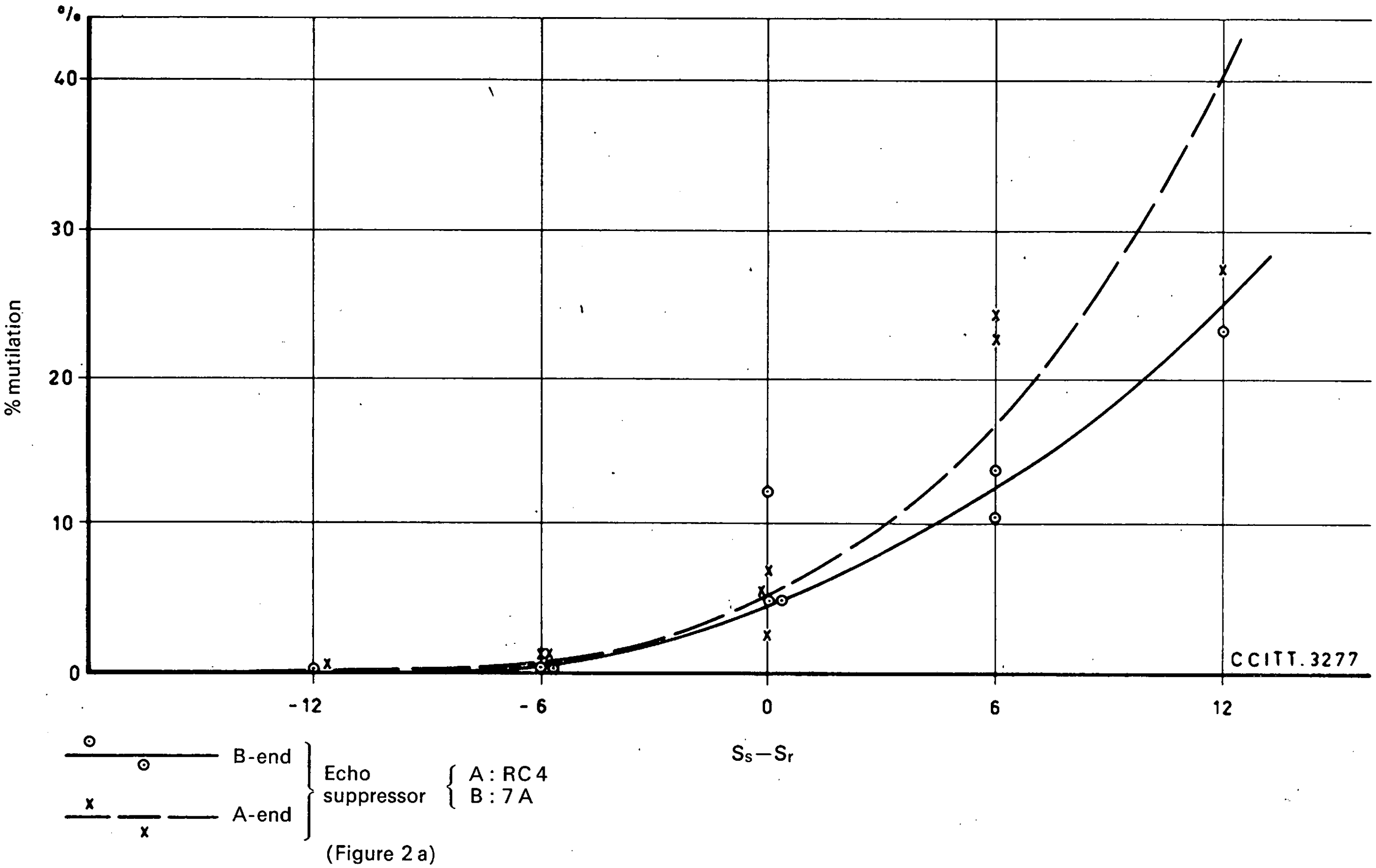

°/o
40
30
20
10
0
% mutilation
-12
-6
0
6
12
Ss—Sr
CCITT.3277
B-end
A-end
Echo suppressor
A : RC 4
B : 7 A
(Figure 2 a)

FIGURE 6

(a) = Sent speech level (S_s) −11 dBm0.
(b) = Sent speech level (S_s) −17 dBm0.
(c) = Sent speech level (S_s) −23 dBm0.

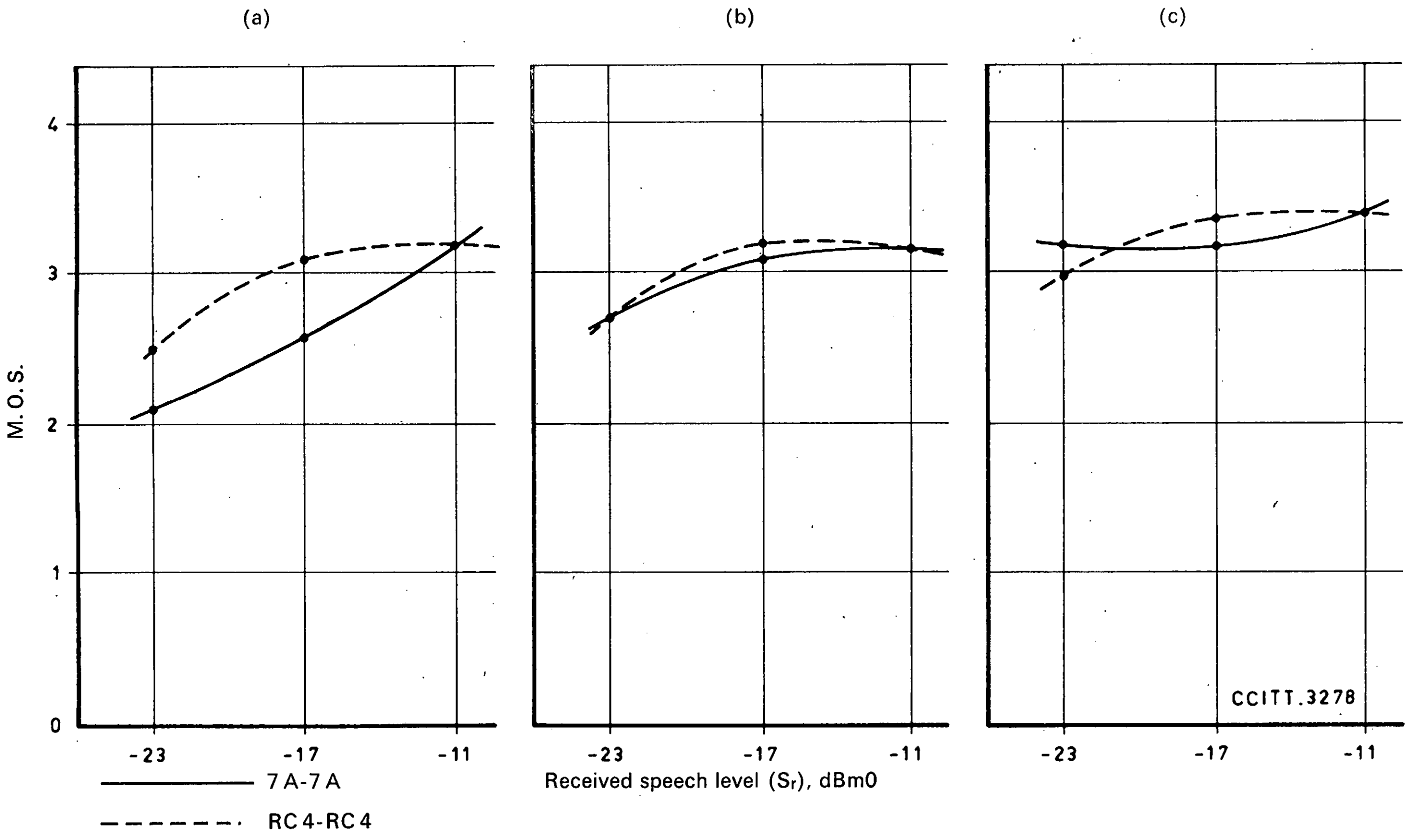


FIGURE 7

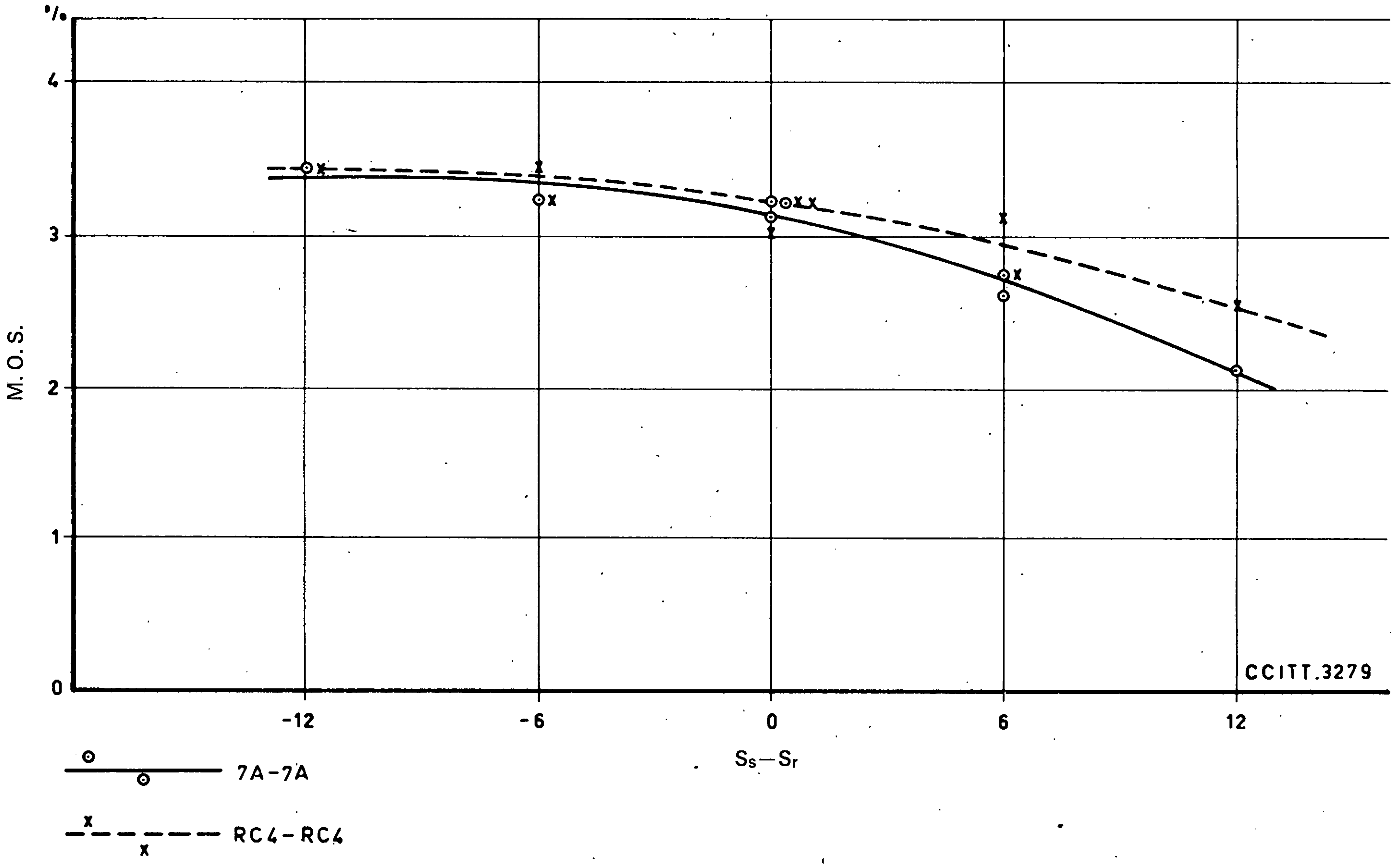


FIGURE 8

(a) = Sent speech level (S_s) −11 dBm0.
(b) = Sent speech level (S_s) −17 dBm0.
(c) = Sent speech level (S_s) −23 dBm0.

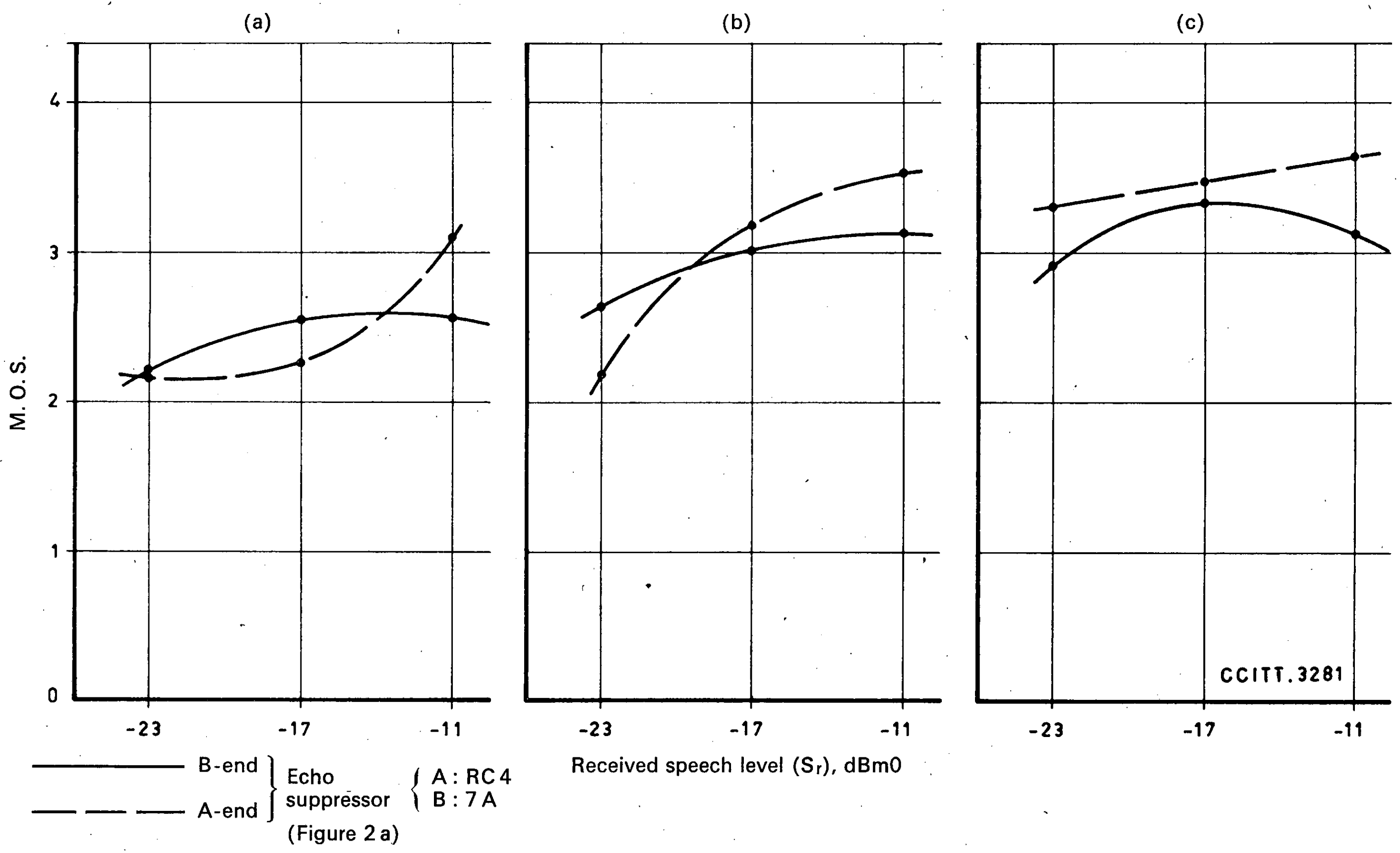


FIGURE 9

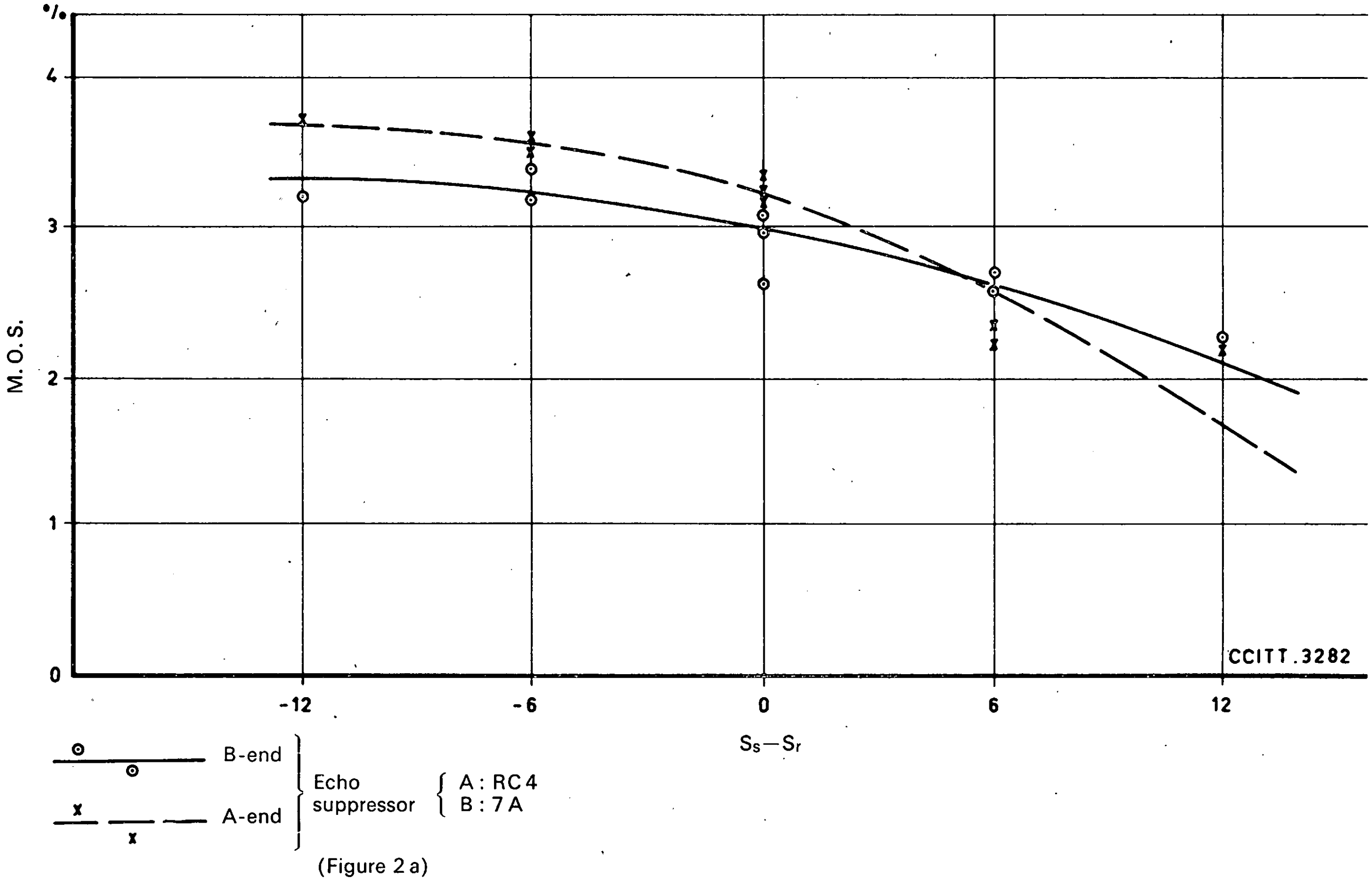

°/o
4
3
2
1
0
M.O.S.
-12
-6
0
6
12
Ss—Sr
CCITT.3282
B-end
A-end
Echo suppressor
A : RC4
B : 7A
(Figure 2 a)

FIGURE 10

The observers' rating of each sentence received (as shown individually in Figure 2) is given a mean opinion score by assigning weightings 4, 3, 2, 1, 0 respectively to the observers' opinions. It may be expected that these scores during periods of mutilation give some indication of the intensity of mutilation (as distinct from the percentage of time for which it persists). Figures 7 to 10 show some of the opinion scores in graphical form.

d) *Conversation tests*

Until further experience of the above method has been obtained, the tests must be supplemented by a series of conversation tests. These have been carried out by trained engineering personnel to detect any misoperation of the echo suppressors under realistic conditions. Means were provided whereby the insertion of the various types of echo suppressor in the circuit was under the control of the participants, thus facilitating comparison of performance. End-delay, and various values of junction circuit attenuation, were included for these tests.

e) *Conclusions*

Work is not yet complete but the method has been found to yield informative results; it is too soon, however, to say conclusively whether percentage mutilation and mean opinion score are sufficient criteria on which to base a judgement of compatibility. The method, however, permits very penetrating and reproducible observations to be made enabling detailed examinations of particular aspects of echo-suppressor action. The initial work indicates that a technique, similar to the method described in this Supplement, will be sufficiently sensitive to detect unsuitable performance, but further study is required in interpreting the information.

SUPPLEMENT No. 5

(Mar del Plata, 1968; referred to in Recommendation G.223)

MEASUREMENT OF THE LOAD OF TELEPHONE CIRCUITS

Several Administrations have sent in the results of telephone speech power measurements presented in a uniform manner (see Annex 1 to Question 11/C), and from these it has been possible to compile the attached comparative table.

The notes to the table explain how the various figures were obtained.

Appendices 1 and 2 explain the special features of the measuring methods and instruments used by the Administrations of the Netherlands and of Switzerland.

Appendix 1

(to Supplement No. 5)

Contribution of the Netherlands Administration concerning speech power measurements

The Netherlands Administration carried out speech power measurements in the following manner.

		Distribution of power throughout the " active " periods of the call											
		median dBm0 (1)	standard deviation dB (2)	Long-term mean during calls dBm0 (3)	Activity coefficient during the call (4)	Circuit utilization coefficient during the busy hour (5)	Long-term mean during the busy hour dBm0 (6)	Total power measured directly in a group or supergroup, etc. 10 log P dBm0 (7)	Number of telephone channels in operation A (8)	Number of non-telephone channels in operation B (9)	Calculated power for non-telephone channels 10 log P_B dBm0 (10)	Power per channel $10 \log \left(\frac{P}{A+B}\right)$ dBm0 (11)	Power per telephone channel $10 \log \left(\frac{P-P_B}{A}\right)$ dBm0 (12)
Switzer-land	Group			−13.3		0.72		− 3.9	12			−14.7	−14.7
	Group			−14.2		0.78		− 4.6	12			−15.4	−15.4
	Group							− 3.1	12			−13.9	−13.9
	Group			−12.2		0.58		− 3.7	12			−14.6	−14.6
	Group			−12.6		0.53		− 4.6	12			−15.4	−15.4
	Supergroup			−11.2		0.62		+ 4.6	59	1		−13.2	
	Three supergroups			−12.65 (Note 2)	0.33 (Note 3)	0.67 (Note 1)		+ 7.75	162	2		−14.4	
F. R. Germany		(Note 4)											
	Local connection	−17.2 (Note 5)	2.7	−18.7 (Note 5)									
	National connection	−17.6	4.2	−20.4									
	International connection	−15.2	2.8	−17.8									
	Intercontinental connection	−14.2	3.6	−17.5				(Note 6)				(Note 8)	
	Pregroup							−15.7	3			−20.5	−20.5
	Group							− 8.9	12			−19.7	−19.7
	Supergroup							− 3.2	56	(Note 7) 4	unknown	−21	unknown
A.T. & T.	New York-Paris	−14.4	5	−15.6 (Note 9)	0.396								
Nether-lands	Amsterdam-New York	−17.7	4.8	−18.7 (Note 11)	0.44								
France	Paris-New York	−17.1	5.3	−19.7	0.26								
	Paris-Francfurt	−17.3	4.7										
	Paris-Nice	−16.8	3.8										
United Kingdom	International circuits	−15.8	5.7	−17.8 (Note 10)	0.27								

As soon as an observer noticed that a call was in progress, a sampling machine was switched to the line. This machine takes samples of the instantaneous values of the speech signal seven times a second. The bandwidth of the equipment is such that up to 10 kHz sampling is carried out instantaneously. The equipment was switched off the measured line just before the end of the conversation, so that signalling was excluded from the measurements. The measuring apparatus gives the absolute value of the results of the measuring in a five-unit code, corresponding to 31 levels at 1.5-dB intervals. Each absolute value is approximated to the nearest level. The levels were chosen in such a way that the distribution of the absolute instantaneous values of the signal was covered by the level range.

For each call the mean power of actual speech is computed by leaving out all combinations of two or more consecutive samples of the lowest category ("zeros").

By dividing the number of samples used for the calculation of the mean power by the total number of samples, an activity factor is obtained.

Results are given for 60 calls (7 hours of sampling) on outgoing lines (The Netherlands–New York).

The distribution of the values for the mean power per call was nearly Gaussian with:

— a mean value of −17.7 dBm0 (column 1 of the table);

— a standard deviation of 4.8 dB (column 2).

The measurements indicated that for 56% of the time there were two or more consecutive samples of the lowest category (lower than −37.8 dBm0). From this figure it is perhaps possible to define an activity factor of 44% (column 4).

By averaging the power of all samples during the total observation time (7 hours) the mean power during the calls (excluding signalling, etc.) is obtained. A value of −18.7 dBm0 is found (column 3). This value can also be calculated from the above-mentioned values.

$$-17.7 + 0.115 \times (4.8)^2 + 10 \log (0.44) = -18.7$$

The measurements were carried out in the Amsterdam repeater station on four Netherlands lines from Frankfurt/Main to New York.

APPENDIX 2

(to Supplement No. 5)

Equipment for measuring the load and the busy factor on multichannel carrier telephony systems used by the Swiss Administration

This Appendix gives information on the equipment used by the Swiss Administration for measuring the load and the busy factor on multichannel carrier telephony systems.

Note 1 (Switzerland) — $\frac{N_b}{N_0}$ has been entered; this is the mean circuit utilization factor, N_b being the mean number of channels occupied (during several busy hours) in the group under consideration and N_0 in the number of channels in the system.

Note 2 (Switzerland) — $10 \log \frac{P}{N_b}$ has been entered; this is the mean power in the occupied channel.

Note 3 (Switzerland) — It has been shown experimentally that the ratio between the activity factor and the occupancy factor is about 1:2.

Note 4 (F.R.G.) — To evaluate the activity, only inactive periods of more than 1 second were excluded.

Note 5 (F.R.G.) — This figure is related not to the point of zero relative level but to the first local service group selector.

Note 6 (F.R.G.) — Mean of several busy hours.

Note 7 (F.R.G.) — 3 amplitude-modulated carrier channels for VF telegraphy + 1 for frequency-modulated VF telegraphy.

Note 8 (F.R.G.) — The differences between the groups of channels are due to random differences in the circuit utilization factor.

Note 9 (A.T. & T.) — Value *calculated* from the other measured values: $-14.4 + 0.115 \times (5)^2 + 10 \log (0.396) = -15.6$.

Note 10 (U. K.) — Value *calculated* from the other measured values: $-15.8 + 0.115 \times (5.7)^2 + 10 \log (0.27) = -17.8$.

Note 11 (Netherlands) — Measured value; the same value is found by the formula used in Notes 9 and 10 (see Appendix 1).

1. *The amplitude spectrograph*

This spectrograph enables the characteristics of a complex signal to be measured and described in statistical terms. The probability of exceeding a threshold level can be obtained from a series of measurements. The threshold can be varied in order to cover the dynamic range of the signal. The spectrograph contains a discriminator consisting of a tunnel diode circuit. This discriminator is supplied with sampling pulses which occur with a repetition frequency of 200 kHz. It can be shown [1] that this sampling rate is sufficient for the purpose of obtaining statistical information of signals with a bandwidth of up to 6 MHz.

When the voltage of the signal to be investigated exceeds a certain threshold level, the sampling pulse is gated to the output of the instrument; if the threshold is not reached, no pulse appears at the output. The output pulses can be counted with an electronic counter. The result is printed and it can be interpreted in terms of the percentage of the time during which the selected threshold is exceeded.

The instrument is designed for a nominal sensitivity of −2 Nm (−17.4 dB). A white noise signal having this r.m.s. value gives an average reading of 31.74%; in the case of a sine wave signal with the same power an indication of 50% is obtained.

Variation of the threshold is achieved by using a suitable amplifier, if necessary, and an attenuator which can be switched in 0.25 Np steps, preceding the spectrograph.

The information obtained in this way can be used to draw distribution curves. From these curves the mean power and the peak loading (level exceeded, for example with a 1% or 0.1% probability) can be evaluated.

2. *Measurement of the busy factor*

An instrument was designed for the measurement of the number of simultaneously busy channels in a group or a larger assembly of channels. A criterion is available from the exchange indicating the entire busy time of a channel (i.e. the time the channel is not available for setting up another call). For each busy channel a d.c. current is derived. The current of 12 channels of a basic group is combined; it is therefore proportional to the number of busy channels. The magnitude of this current can be recorded with a chart recorder. From the charts statistical information (probability distribution, mean value etc.) can be derived.

More detailed information about the equipment and its application can be found in [2] and [3].

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[2] G. FONTANELLAZ, H. K. PFYFFER and H. EMMENEGGER: Belastungsmessungen an Trägerfrequenz-Telephoniesystemen (Load measurements on carrier telephony systems); *Techniche Mitteilungen P.T.T.*, No. 5, 1967.

[3] H. K. PFYFFER: Die Belastung von Mehrkanal-Trägerfrequenz-Telephonieanlagen (The load on multichannel carrier telephony systems), ibid. No. 10, 1967.

SUPPLEMENT No. 6

(New Delhi, 1960; referred to in Recommendations G.223 and G.311)

EXAMPLE SHOWING HOW THE TOTAL VALUE OF LINE NOISE SPECIFIED FOR THE HYPOTHETICAL REFERENCE CIRCUIT ON OPEN-WIRE LINES MIGHT BE BROKEN DOWN INTO ITS VARIOUS COMPONENTS

The following figures can be used as a guide to the composition of the total value of line noise specified as an objective in Recommendation G.311:

Crosstalk	10 000 pW
Thermal (repeater) and intermodulation noise	2 500 pW
Noise induced from power lines	insignificant
Other line noise	5 000 pW
Total	17 500 pW

In determining the limit for line noise it was borne in mind that this noise determines the spacing of repeater stations and hence the overall cost of repeater stations and buildings.

A high proportion of the total noise has been allocated to crosstalk because the reduction of this component is known to be difficult and expensive.

The crosstalk induced in channels of 12-circuit carrier systems may be regarded as noise when:

a) there is inversion of the transmitted frequency bands,

b) there is staggering of carrier frequencies, and

c) there are a number of disturbing channels.

The mean noise due to crosstalk from one disturbing pair in one homogeneous section may be calculated from the mean power of a channel (speech and signalling) according to the formula:

$$N\,(\text{dBm0p}) = S - A\mu - X\mu + 10 \log_{10} n$$

where N (dBm0p) = mean psophometric weighted noise (reference 1 mW at a zero level point) during any hour in the disturbed channel due to one disturbing system,

S = long term (busy hour) mean power (speech and signalling) in a disturbing channel (−15 dBm0) (reference 1 mW at a zero level point),

$A\mu$ = the mean value of the line signal to crosstalk ratio (far-end, including reflected near-end) for one repeater section. This mean value is determined on a power basis over a homogeneous section for the two lines considered, on which the position of the channels, according to the recommended frequency arrangement, remains constant. This mean value is obtained from the expression

$$\overline{A}\mu = -10 \log_{10} \frac{1}{m} \sum_{k\,=\,1}^{k\,=\,n} 10^{-\frac{1}{10} A\mu k}$$

where m is the number of repeater sections over which the mean is taken,

$A\mu k$ is the line signal to crosstalk rato in one repeater section for the two lines considered,

$X\mu$ is the psophometric weighting factor expressing the advantage derived from staggering the carrier frequencies and/or inversion of the transmitted frequency bands,

n is the number of repeater sections in a homogeneous section

In order to estimate the total mean noise due to crosstalk at the end of the hypothetical reference circuit, the contributions from the different disturbing pairs and from the different homogeneous sections can be added on a power basis.

SUPPLEMENT No. 7

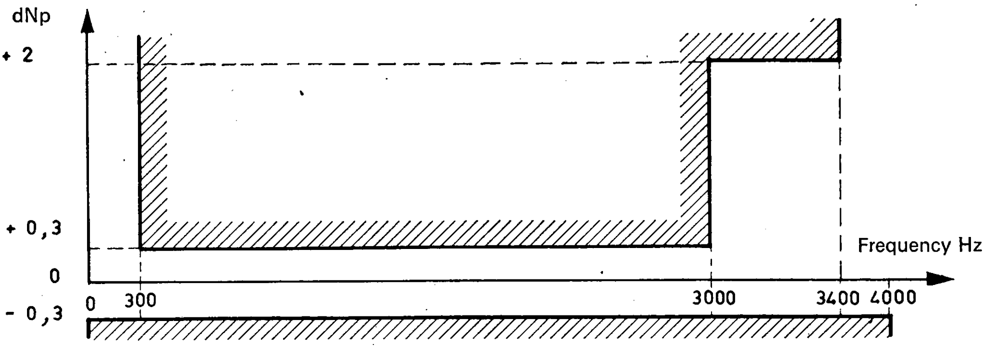
(Mar del Plata, 1968; referred to in Recommendation G.232)

LOSS-FREQUENCY RESPONSE OF CHANNEL-TRANSLATING EQUIPMENT USED IN SOME COUNTRIES FOR INTERNATIONAL CIRCUITS

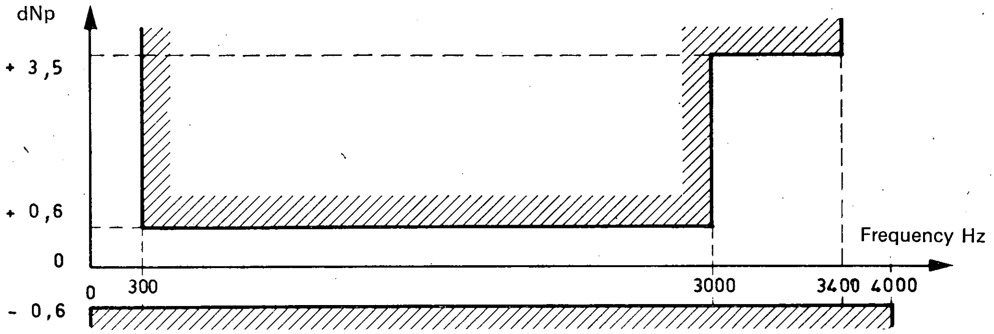
The attenuation distortion limits met by the equipment used by the United Kingdom are indicated in Figure 1.

Some countries have adopted the following limits as objectives for the attenuation distortion of either the send or the receive equipment on any channel:

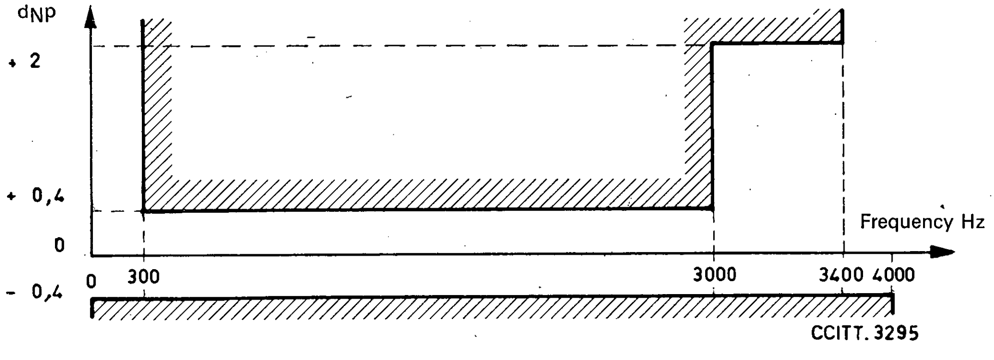
Frequency range	Loss relative to that at 800 Hz at any temperature in the range			
	+10 °C to +40 °C		+19 °C to +25 °C	
(Hz)	dB	dNp	dB	dNp
Below 200	−0.5	−0.6	−0.25	−0.3
	Otherwise unspecified		Otherwise unspecified	
200- 250	−0.35 to +1.5	−0.4 to +1.7	−0.25 to +1	−0.3 to +1.2
250- 300	−0.35 to +0.75	−0.4 to +0.9	−0.25 to +0.5	−0.3 to +0.6
300-3000	−0.35 to +0.35	−0.4 to +0.4	−0.25 to +0.25	−0.3 to +0.3
3000-3200	−0.35 to +0.75	−0.4 to +0.9	−0.25 to +0.5	−0.3 to +0.6
3200-3400	−0.35 to +1.5	−0.4 to +1.7	−0.25 to +1	−0.3 to +1.2
Above 3400	−0.5	−0.6	−0.25	−0.3
	Otherwise unspecified		Otherwise unspecified	



a) Limits for the average of the variation of overall loss of 12 pairs of channel equipments of a terminal equipment



b) Limits for any pair of channel transmitting and receiving equipments of one terminal equipment



c) Limits for the variation, as a function of frequency, of the relative power level at the output:
- — of the sending equipment of any channel,
- — of the receiving equipment of any channel,
- — of a 12-channel terminal.

FIGURE 1. — **Attenuation distortion limits applied in the United Kingdom for channelling equipment designed for intercontinental circuits (effects of signalling circuitry excluded)**

SUPPLEMENT No. 8

(Geneva, 1956; referred to in Recommendation G.322)

METHOD PROPOSED BY THE BELGIAN TELEPHONE ADMINISTRATION FOR INTERCONNECTION BETWEEN COAXIAL AND SYMMETRIC PAIR SYSTEMS

In systems providing 1, 2, 3 and 4 groups on symmetric pairs, additional groups beyond the first are not usually installed until all the cable pairs (in practice 14 or more, often 24) are taken up. Usually the cable pairs are equipped with 12 channels per pair in each direction of transmission, thus providing 12 × 24 = 288 circuits in a cable with 24 pairs; if the number of circuits required exceeds this number, the cable is equipped with 24 channels per pair, which gives 288 additional circuits, then with 36, 48 and 60 channels per pair.

In short, the highest frequency transmitted is kept low, so as to simplify the equipment and avoid the construction of intermediate repeater stations for as long as possible, having regard to the circuit requirements.

As a result there is an arrangement of frequencies within the groups, which is in accordance with the recommendations of the C.C.I.T.T. for systems with 1, 2, 3 and 4 groups, and now allowed (by agreement between the Administrations concerned) for systems with 5 groups. This arrangement is such that the frequency spectrum of the first group is inverted as compared with the frequencies in the other groups, and the systems have developed in such a way that it is virtually impossible to change this arrangement.

On the other hand, with coaxial systems where there is only one pair, the *initial* installation is for at least 60 circuits or a basic group, and as the system is built up an orderly arrangement of frequencies of different groups within the supergroups is obtained.

To interconnect these two apparently incompatible arrangements, the following is necessary:

1. If only single groups pass from one system to the other, there is no difficulty because it is necessary to use, in both directions, a basic group, e.g. the basic group B (60-108 kHz). From this basic group the stages of modulation can be chosen so as to provide the correct arrangement of frequencies transmitted to line on both the coaxial and the symmetric pair systems.

2. Where it is desired to transmit, on the symmetric pair, a band from 12 to 204 kHz or 12 to 252 kHz, in which the band 12-60 kHz is inverted with respect to the others, there is nothing to prevent the translation of this band into the band 312-552 kHz by a modulation of the whole. But, in the supergroup thus obtained, the part of the band between 504 and 552 kHz is inverted with respect to the others. When demodulating this supergroup it is necessary to use a frequency of 444 kHz instead of 612 kHz to obtain the groups with correct orientation.

For the other direction of transmission, i.e. for the modulation process, where the complete supergroup (5 groups) or incomplete supergroup (4 groups) are intended then to be transmitted over a symmetric pair system, it is necessary to use the same special modulating frequency for one of the five groups, so as to obtain a supergroup of 48 to 60 circuits which will suit existing symmetric pair equipments.

The only complication which results from so doing is the need to provide on all supergroup tacks a sixth frequency (444 kHz) and, in certain cases, the replacement or preferably the modification of the 504-552 kHz band filter, so as effectively to suppress any sidebands above and below these frequencies. This changed filter seems to be necessary only for the modulation process.

SUPPLEMENT No. 9

(referred to in Question 20/XV)

(Note of the International Telephone and Telegraph Corporation (I.T.T.)

ROLL EFFECT IN COAXIAL PAIR SYSTEMS

This supplement deals generally with the problem of the summation of irregularities arising from reflections in repeater sections of coaxial pair systems. It is therefore relevant to the calculation of the required accuracy of matching of line and repeater impedances in the 60-MHz system (Question 20/XV) and the 12-MHz systems on 9.5 mm pairs and 4.4 mm pairs (Question 30/XV).

Introduction

In a repeater section of a coaxial system a part of the forward travelling wave is reflected at the input terminals of the repeater, reaches the sending end where it is again reflected, finally reaching the input terminals where the doubly reflected wave is now combined with the main wave. This effect in filter design is referred to as interaction effect. The amplitude of the doubly reflected wave depends on the return loss between cable and repeater at the two ends of the section and on double the normal transmission loss of the section at the frequency in question (sum of three terms). When the frequency considered on the line is varied, the interaction effect will also vary, and in a sinusoidal manner. For small frequency variations this variation will be caused almost entirely by the phase delay of the cable section loop.

When the interaction effect is small the amplitude r (in nepers) of the roll will be fairly accurately equal to e^{-N} where N is the sum of the three terms in nepers.

If all the repeater sections are of exactly the same electrical length the roll effects will add systematically, and for n sections the roll amplitude will be nr nepers.

If, however, the lengths of individual sections vary from the main length of all the sections the overall effect will be smaller than nr by a factor which will depend on the degree of departure of the interaction phase angle A from its mean value.

The exact frequency at which a single section gives maximum interaction effect will depend on the phase angle of the return loss at each end of the section, but fortunately the exact frequency is not a matter of great concern; it is more important to find the frequency separation of roll peaks.

Frequency spacing of roll peaks

This depends almost entirely on the rate of change of phase and, therefore, on the group delay of the coaxial transmission circuit. For a section of length l km the frequency spacing will be:

$$\frac{10^6}{2 \times l \times d\beta / d\omega} \text{ Hz}$$

the group delay being expressed in microseconds per kilometre. According to the cable pair and the position in the frequency band the group delay will vary between about 3.4 and 3.7 microseconds per kilometre.

For recommended systems having section lengths varying from 9 to 1.5 km the roll frequency spacing will vary between 15.8 and 95 kHz.

Whereas in general the objective is in terms of roll amplitude, when the spacing of peaks is very close in frequency the resulting slope of the transmission gain curve may be a more significant parameter.

Standard deviation of roll angle

If for the average repeater section length a frequency is chosen such that the interaction effect has zero phase angle, then this frequency for an average section will give a roll peak, i.e. maximum gain. Sections which are slightly shorter or longer will have a different roll phase at the chosen frequency, and consequently make a smaller contribution to the sum of roll effects.

The interaction phase angle depends on the phase delay of the coaxial pair. This delay is slightly larger than the group delay; a compromise value of 3.7 microseconds per km is sufficiently accurate. If now the length of a section differs by $\varDelta\ l$ metres from the mean length, the phase angle difference from the mean (zero) phase angle will be:

$$2 \varDelta\ l \times 2\ \pi f \times 3.7 \times 10^{-3} \text{ radians } (f \text{ in MHz})$$

Thus, if the standard deviation of the repeater spacing is $\Delta\ l$ metres the standard deviation A of the interaction phase angle will be $0.0465\, f \varDelta\ l$ radian.

Example—For a 60-MHz system the interaction phase angle change at the minimum frequency of about 4.3 MHz will be 0.2 radian per metre section length.

For a lowest frequency of 300 kHz on the same cable the interaction phase angle change will be 0.014 radian per metre section length.

Summation of roll in n *repeater sections*

Figure 1 shows, for various numbers of repeaters n, the reduction factor which may be applied to the maximum possible sum nr, when the interaction phase angle has standard deviation A. A peak in n repeater sections in tandem may not occur at exactly the frequency at which a peak occurs in an average section; this fact has been allowed for and Figure 1 relates to the envelope of the summed roll effect. Even with large values of A, such as 3 radians, the summation will not destroy the sinusoidal variation with frequency of the roll effect.

The summation assumes that r has the same value for each individual repeater section and, therefore, that the values of N are also equal. When a minimum value is specified for N it is to be expected that in practice the value will be 1 or 2 dB higher on the average. It may be considered justifiable to make a small allowance for this in specifying the required value of N.

The information is calculated for a 1% probability of the values shown being exceeded. In practice, as r will generally become smaller with increasing frequency, due to increase in the line loss component of N, and as A is proportional to frequency, the probability of exceeding any given roll amplitude objective will become correspondingly less with increasing frequency.

The derivation of Figure 1 is explained in the Appendix.

Figure 2 shows, with particular reference to the 300-circuit, 12-MHz and 60-MHz C.C.I.T.T. systems using transistorized repeaters, how the value of N (the sum of return losses and twice line loss in a repeater section) required to meet a 0.1 Np maximum roll in a 280-km homogeneous section varies with the standard deviation of repeater section lengths.

Systems with the shorter repeater sections tend to require higher values of N.

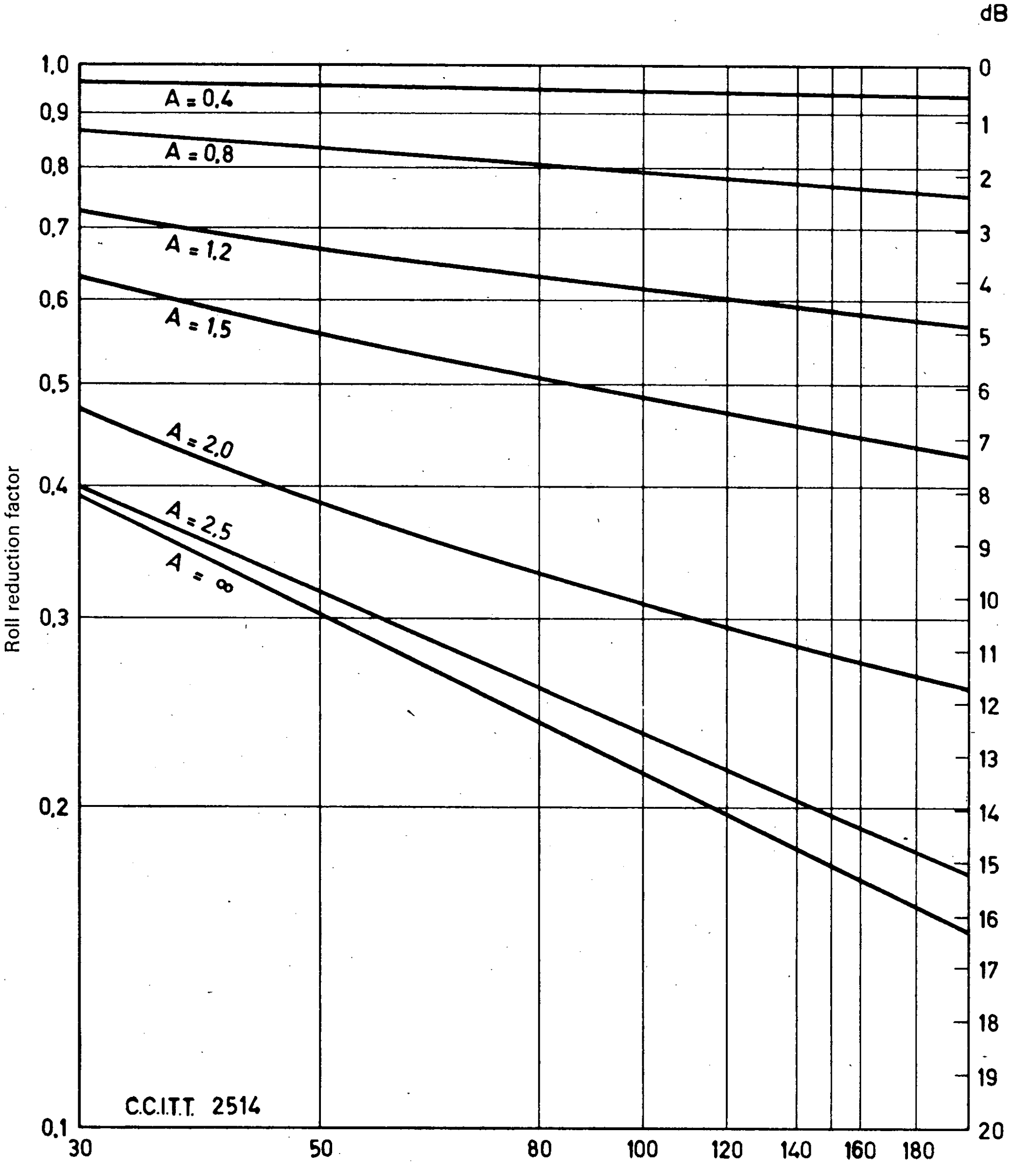


FIGURE 1. — Roll reduction factor as a function of number of repeater sections n and standard deviation of interaction phase angle A in radians

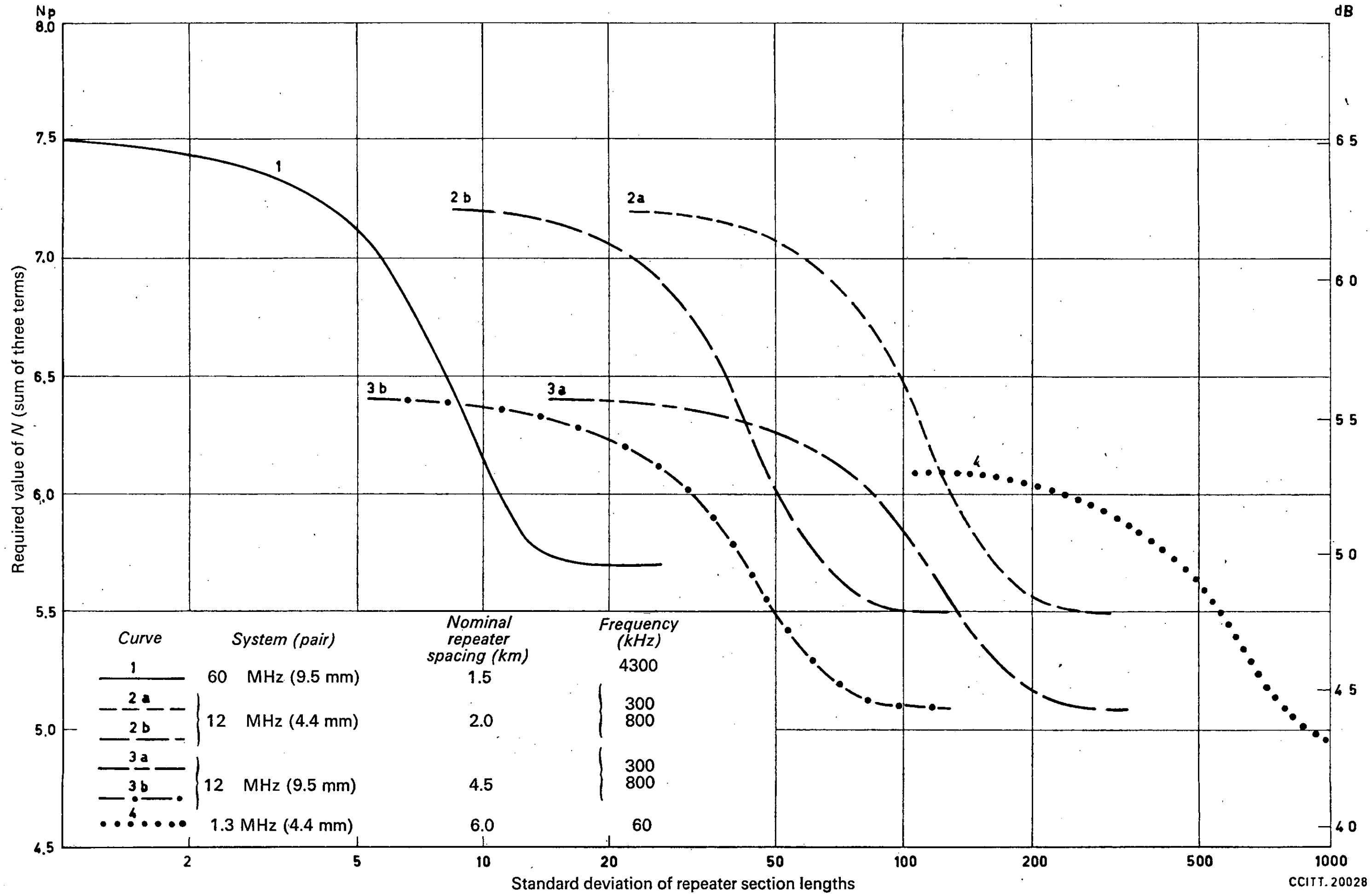


FIGURE 2. — **Variation of required value of *N* (sum of three terms) with the standard deviation of repeater section lengths for a given maximum roll amplitude objective (1 % probability of exceeding 0.1 Np in a 280-km section).**

However, the shorter the section, and the higher the minimum transmitted frequency of the system, the greater is the effect of deviations of repeater section lengths as regards reducing the summated roll effect over a homogeneous section.

Conclusions

In the case of the 300-circuit system and the 12-MHz system on 9.5-mm pairs it is shown that the effects of variations of repeater section lengths do not significantly influence the summation of the rolls in the individual repeater sections until the standard deviation of such variations has reached a value larger than is likely to be encountered in practice. It is appropriate that the recommended values of N for these systems should be on the basis that the roll summation is systematic or very nearly so.

On the other hand, in the case of the 60-MHz system, systematic addition will occur only when the spacing of repeaters is very precise indeed. This is in consequence of the shorter repeater section (1.5 km) and the high minimum transmitted frequency of 4300 kHz. Only where measures are specifically taken to ensure precise spacings would it be appropriate to adopt a value of N based on systematic addition; it does not appear that there is any advantage to be gained in deliberately seeking such precision. For the normal case it would suffice to recommend a value of N based on the standard deviation of repeater lengths which might be expected.

Similar considerations apply to the 12-MHz system on 4.4-mm pairs.

APPENDIX

Derivation of roll reduction factor F

The problem is one of summating n sine waves of the same frequency and with the phase angles of individual terms normally distributed with a standard deviation of A radians. Each term has amplitude r and phase θ relative to mean phase.

If the standard deviation A of phase angle is zero the sum is obviously nr; this is systematic addition.

At the other extreme, if A is very large the problem is identical with the "random walk" problem for which Rayleigh gave the solution:

$$p = e^{-(S^2/nr^2)}$$

S being the value of the sum which is exceeded with probability p. For $p = 0.01$, $S = 2.14\ r\ n^{\frac{1}{2}}$. This is valid for $n > 10$ to 12.

Comparing these two cases it is seen that $A \rightarrow \infty$ reduces the sum by a factor $F = 2.14\ n^{-\frac{1}{2}}$. The factor F is referred to as the reduction factor; its value depends on p, n and A.

It is now possible to draw a curve of F as a function of n when $p = 0.01$ and $A \rightarrow \infty$. This is the lowest line in Figure 1. The upper edge of the graph is the curve for $A = 0$.

In the following the method of deriving intermediate curves for other A values is outlined.

The first step is to calculate the mean and variances of the sum of n unit amplitude sine waves with phase θ when θ is normally distributed with standard deviation A and has a mean value of zero.

The mean sum is $rne^{-A^2/2}$ in the direction of zero phase. The quadrature component has zero mean. The two variances are respectively:

$$\frac{1}{2}nr^2(1 + e^{-2A^2} - 2e^{-A^2})$$

and

$$\frac{1}{2}nr^2(1 - e^{-2A^2}).$$

When n is large it is reasonable to assume that the two components described by these variances are each normally distributed.

When A is small the variances are also small compared with the mean and the contribution from the quadrature variance can be neglected. The sum is then the mean plus a normally distributed component.

For large A values, the two variances are both significant and, moreover, tend to become equal; in that case the sum is equal to the mean plus a Rayleigh distributed phasor. This sum has been worked out (see Norton et al. *Proc., IRE*, October 1955, page 1360).

For the purposes of Figure 1 the sum has been normalized so that $A = 0$ gives $F = 1$ for all values of n.

SUPPLEMENT No. 10

(brought up to date in 1961; referred to in Recommendation G.351)

POWER FEEDING AND EARTHING OF 2.6/9.5-mm COAXIAL PAIR CABLES

a) *Power-feeding methods*

Various methods of power feeding over the cable which have been used are:

1. In the United States of America, Great Britain and Italy, the power-feeding circuit consists of the two centre conductors of two coaxial pairs; this provides a circuit balanced with respect to earth. In Great Britain and in Italy, this circuit is fed with constant voltage. In the United States of America, the current (at 60 Hz) is monitored and is not allowed to fall below 80% of its nominal value; also the difference between the currents in the two conductors is monitored and is not allowed to reach a value of 25%.

2. In France, the power-feeding circuit consists of the centre and outer conductors of the same coaxial pair. There are thus as many power-feeding circuits as there are coaxial pairs in the cable.

The French Administration takes advantage of this arrangement to increase reliability in the following manner: each line amplifier has two "amplification paths" with common negative feedback. Each power-feeding circuit on one of the coaxial pairs provides power for the operation of the valves in one "amplification path" of the corresponding line amplifier and one "amplification path" of the line amplifier of the coaxial pair used for the other direction of transmission. In this manner, power failure or a break in the power-feeding circuit does not noticeably interfere with transmission, each amplifier continuing to operate over one path.

Constant current power feeding is used.

b) *Earthing of coaxial cables*

The practices followed vary according to the country and the systems used for power feeding.

The United Kingdom Administration uses coaxial pairs having the outer conductor separately insulated with paper lappings.

At the ends of each repeater section, each coaxial pair is separately terminated on the repeater rack by means of a gas-tight "sealing-end" of such a design that the insulated condition of the outer conductor from earth and from other outer conductors is maintained.

The coaxial pairs are extended from the sealing ends by means of insulated coaxial cable (sometimes via coaxial chokes so as to limit crosstalk) to the power-separating filters at which point earth connections are made between the outer conductors and the rack.

The a.c. power-feeding systems now standardized in the U.K. are the so-called "balanced" type in which the two inner conductors are fed symmetrically about earth in anti-phase by means of a transformer winding having a centre tap connected to earth.

The only earth connection on the power-feeding circuit is that at the power-feeding station.

In the 4-MHz system, the French Administration fits a transformer on every coaxial pair, so as to isolate the outer conductor from earth. The same arrangement is used in the 12-MHz system on repeater sections especially subject to induction from external sources.

SUPPLEMENT No. 11

(Mar del Plata, 1968; referred to in Recommendation G.361)

DATA ON THE CABLE SIHPS OF VARIOUS COUNTRIES

UNITED STATES OF AMERICA

Name of ship	Year of construction	Gross tons	Overall length	Draft	Normal speed	Range (autonomy)	No. of tanks	Cable capacity			Cable gear			Max. operating depth	Capability
								Cable		Repeaters	Forward cable drum (diam.)	Bow sheave (diam.)	Stern sheave (diam.)		
								Cubic metres	Weight tons						
			m	m	Knots	Nautical miles					m	m	m	m	
Long Lines	1963	11 326	156	7.9	15	10 000	3	4420	7000	125	3.66	3.05	3.66	all	Cable ship belonging to A.T.T. Lays/repairs all types of telephone cable
FRANCE															
			m	m	Knots	Days					m	m	m	m	
M. Bayard	1961	7 197	121.2	6.43		55	4	2235	400	60	2.10	3.0		all	Lays/repairs all types of cable. Can lay in one operation 850 nautical miles of 8.38/25.4 central carrier cable with repeaters every 20 nautical miles
Ampère	1950	3 465	91.3	5.14		25	3	415	900		1.80			all	Repair ship for all types of cable (not usable in winter in North Atlantic)
Alsace	1940	3 350	88.05	5.30		21	3	415	550		1.80			all	Repair ship for all types of cable (not usable in winter in North Atlantic)

ITALY

Name of ship	Year of construction	Gross tons	Overall length	Draft max.	Normal speed	Range (autonomy)	No. of tanks	Cable capacity			Cable gear			Max. operating depth	Capability
								Cable		Repeaters	Cable drum (diam.) cabling machine	Bow sheave (diam.)	Stern sheave (diam.)		
								Cubic metres	Weight tons						
			m	m	Knots	Nautical miles					m	m	m	m	
Salernum	1956	2 834	102	5.60	16	10 000	3	850 (30 000 cubic feet)	1800		2.50	2.00	2.00	all	Lays and repairs cables

FEDERAL REPUBLIC OF GERMANY[1]

Name of ship	Year of construction	Gross tons	Overall length	Draft max.	Normal speed	Range (autonomy)	No. of tanks	Cable capacity			Cable gear			Max. operating depth	Capability
								Cable		Repeaters	Cable drum (diam.) cabling machine	Bow sheave (diam.)	Stern sheave (diam.)		
								Cubic metres	Weight tons						
			m	m	Knots	Nautical miles					m	m	m	m	
Kabeljau	1944	499	52	3.94	8	1 500	2	375	670		2.20	2.20	2.20	700	Lays and repairs cables. Property of Norddeutsche Seekabelwerke AG, Nordenham

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[1] The Administration of the Federal Republic of Germany points out that a number of cable ships are described in the publication *Underseas Cable World*, Volume 1, No. 5, June-July 1967.

UNITED KINGDOM

Ships belonging to Cable & Wireless Limited

Name of ship	Year of construction	Gross tons	Overall length	Draft	Normal speed	Range (autonomy)	No. of tanks	Cable capacity			Cable gear			Max. operating depth	Capability
								Cable		Repeaters	Forward cable drum (diam.)	Bow sheave (diam.)	Stern sheave (diam.)		
								Cubic metres	Weight tons						
			m	m	Knots	Nautical miles					m	m	m		
Wilshaw	1949	2 564	96	5.8	10.5	6 000	3	540	1000	—	2.01	1.03	none	all	Repairs telegraph cables
Angwin	1952	2 604	98	5.8	10.5	7 000	3	516	1000	9	2.13	2.13	none	all	Lays/repairs armoured cables. Repairs light-weight cables
Recorder	1954	3 349	103	5.6	11.5	10 000	3	602	1100	8	2.13	2.13	none	all	ditto
Retriever	1961	4 218	112	5.81	13	8 000	3	618	1545	11	2.13	2.13	1.52	all	ditto
Mercury	1962	8 962	144	7.5	14.5	8 000	3	2 980	5290	144	3.04	3.04	1.82	all	Laying by 5-sheave gear aft. Lays/repairs armoured and light-weight coaxial cables
Cable Enterprise	1964	4 358	113	5.84	13	6 000	3	875	2150	13	2.13	2.13	1.52	all	Lays/repairs armoured cables. Repairs light-weight cables

UNITED KINGDOM *(contd.)*

Ships belonging to the Post Office

Name of ship	Year of construction	Gross tons	Overall length	Draft	Normal speed	Range (autonomy)	No. of tanks	Cable capacity			Cable gear			Max. operating depth	Capability
								Cable		Repeaters	Forward cable drum (diam.)	Bow sheave (diam.)	Stern sheave (diam.)		
								Cubic metres	Weight tons						
			m	m	Knots	Nautical miles					m	m	m	m	
Monarch		8 567	147	8.54	13	10 000	4	3 240	5426	128	2.0	2.0	2.1	all	Lays/repairs all types of cable
Alert		6 515	127.2	6.86	13	6 000	3	1 583	2 677	48	2.1	2.1	2.7	all	ditto
Ariel		1 509	76.9	4.88	11	2 500	3	456	693	limited	1.9	1.9	none	3660	Lays/repairs armoured cables
Iris		1 512	76.9	4.88	11	2 500	3	456	693	limited	1.9	1.9	none	3660	Repairs light-weight cables

SUPPLEMENT No. 12'

(Mar del Plata, 1968; referred to in Recommendation J.22)

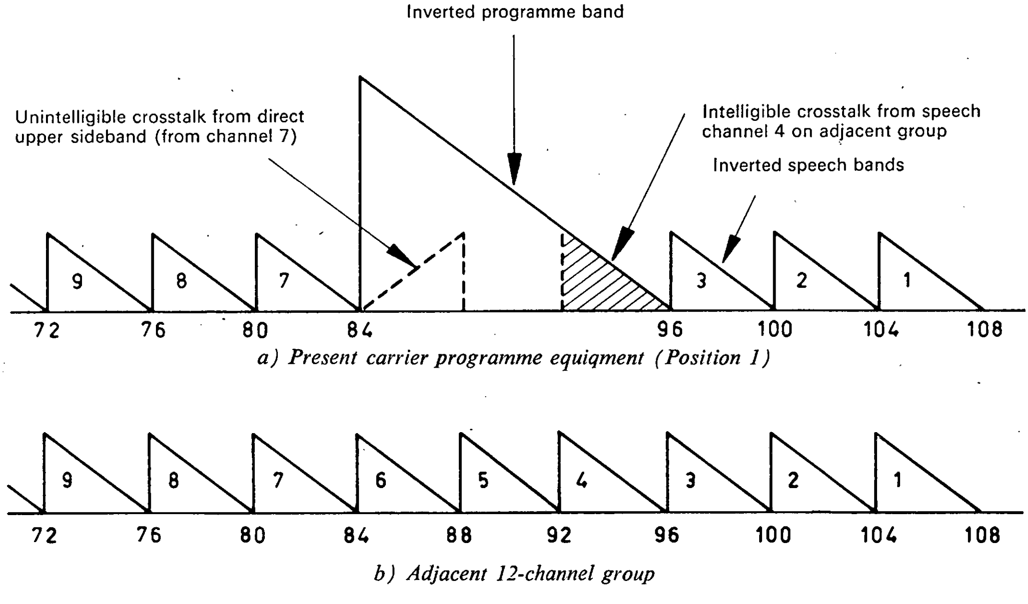
INTELLIGIBILITY OF CROSSTALK BETWEEN TELEPHONE AND PROGRAMME CHANNELS

(Note by the United Kingdom Administration)

1. *General*

This contribution is concerned with means whereby intelligible crosstalk may be reduced in level or rendered unintelligible when it arises on programme channels routed on carrier telephony systems. The permissible limits for intelligible crosstalk from a telephone channel into a programme channel are much more severe than those for unintelligible crosstalk between programme channels or for intelligible crosstalk between two telephone channels. The limits can readily be met when the programme circuits are provided on unloaded or lightly-loaded screened pairs, or on the phantoms of 12- or 24-circuit carrier cables; when the programme circuits are routed on carrier systems designed for telephony, however, it is more difficult to meet the intelligible crosstalk limits.

The chief sources of crosstalk in a carrier telephone or programme channel are a) mutual coupling between groups on different cable pairs but occupying the same frequency, and b) upper sideband interference from the adjacent telephony channel of the same group. Figures 1 and 2 illustrate these two cases. Figure 1 a shows the programme band inverted, as are the telephony speech bands, and occupying the space of three speech bands; this is the arrangement used on the Transatlantic Telephone Cable (TAT 1). The out-of-band interference from the adjacent telephone channel 7 of the same group will be unintelligible and not usually troublesome; interference from channel 4 of a group on an adjacent cable pair and occupying the same frequency band (Figure 1 b) will, however, be intelligible, its magnitude depending upon the coupling between the cable pairs.



a) Present carrier programme equiqment (Position 1)

b) Adjacent 12-channel group

FIGURE 1. — **Intelligibility of crosstalk between telephone and programme channels**

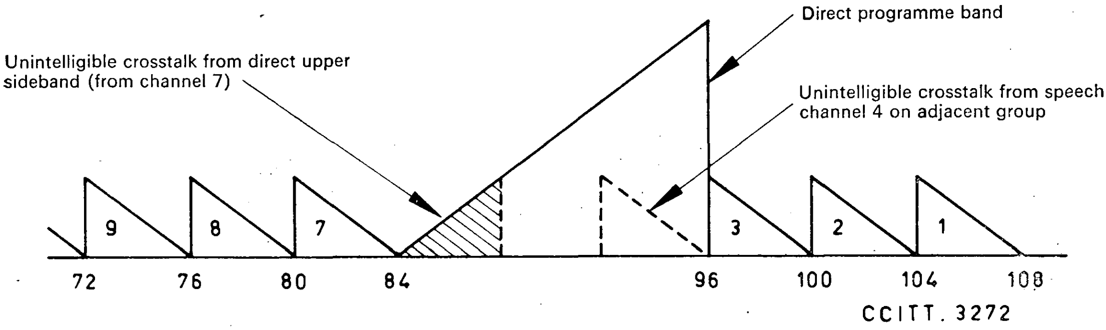


FIGURE 2. — **Proposed alternative method of transmitting a programme channel**

In an attempt to render group-to-group crosstalk unintelligible, programme material may be transmitted as an erect sideband as shown in Figure 2. Group-to-group crosstalk is then unintelligble but there is danger of intelligible crosstalk from the nominally suppressed sideband of telephony channel 7. The level of this crosstalk and to some extent its intelligibility depend upon the out-of-band characteristics of the channel filter associated with channel 7.

The situation in Figure 2 may be improved by displacing the programme channel upwards in frequency, as shown in Figure 3; there is sufficient margin at the upper edge to permit a displacement of up to 1.5 kHz. In the example shown in Figure 3 the displacement is 1 kHz and so an interfering component of frequency f Hz will appear at the output of the programme channel at a frequency of $f - 1000$ Hz; this will considerably reduce the intelligibility of any speech transmitted over such a crosstalk path.

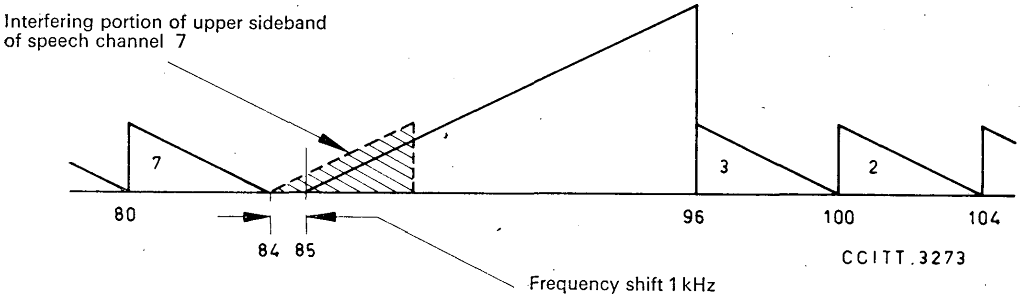


FIGURE 3. — **Effect of shifting the carrier frequency of the programme channel**

Pre- and de-emphasis networks are used to improve the signal-to-noise ratio of programme circuits; the subjective effect of crosstalk may be affected by the presence or otherwise of a de-emphasis network in the programme channel.

2. *Experiments*

Two experiments were conducted in which subjects were seated in front of a high-quality loudspeaker adjusted to reproduce programme material at the preferred listening level. With the programme material disconnected, speech from a telephone was reproduced at various levels to simulate crosstalk. The appropriate frequency characteristics of the crosstalk paths discussed above were included, together with various values of frequency displacement. Noise was introduced on the programme channel at a suitable level to represent the practical situation.

3. *Results*

The median values a) to reduce the crosstalk to inaudibility and b) to reduce it to unintelligibility are given in Table 1. The crosstalk attenuations are those at 1000 Hz and, for these results, there was no frequency displacement.

TABLE 1

Crosstalk path	Crosstalk attenuation (dB)					
	Circuit noise −41.5 dBm0p		Circuit noise −31.5 dBm0p		Circuit noise −60 (estimate)	
	(a)	(b)	(a)	(b)	(a)	(b)
Figure 1 (Position I)	46	36	39	29	68	58
Figure 2 (Alternative arrangement)	49	39	46	33	74	62

Unfortunately, the noise generated locally by the loudspeaker equipment used for these experiments was rather high and this accounts for the fact that the effect on the necessary crosstalk attenuation of reducing circuit noise level from −31.5 dBm0p to −41.5 dBm0p is much less than 10 dB. For this reason the last two columns have been added to the table; these show estimates of the crosstalk attenuation needed if the circuit noise in the programme channel had been at a practical value of −60 dBm0p [1] and the local noise generated in the loudspeaker equipment had been very low. Alternatively, the listener might have been able to increase the gain of his receiving equipment without raising the level of the noise emitted by the loudspeaker. This locally generated noise does not affect the validity of the other conclusions that can be drawn from the results. These are as follows:

The presence of de-emphasis has a negligible effect.

Frequency displacement of 0.5 kHz enables crosstalk attenuation to be reduced by approximately 18 dB for the same intelligibility or about 8 dB for the same audibility. This effect is the same at both the circuit noise levels included in the experiment (−41.5 and −31.5 dBm0p) and whether the de-emphasis was present or not. Additional displacement to 1 kHz or 1.5 kHz render the crosstalk unintelligible at any level (so far as median values are concerned) but the audibility is reduced only by a further 2 or 3 dB respectively.

The shaping of the attenuation/frequency characteristic of the crosstalk path corresponding to Figure 2 increases by approximately 4 dB the attenuation corresponding to the median threshold of intelligibility (without frequency displacement); this is due to the much lower loss in the region of 300 Hz as compared with that at 1000 Hz. The median threshold of audibility is also increased by about the same amount under the same conditions. The magnitude of this effect is (statistically) independent of noise level and of the presence or absence of de-emphasis.

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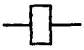
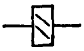
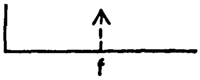
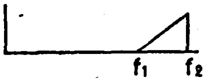
[1] The maximum value permitted by C.C.I.T.T. Recommendations is −48 dBm0p.

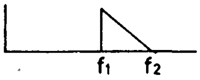
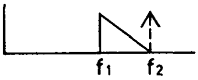
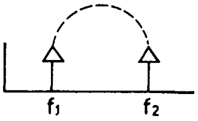
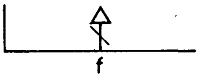
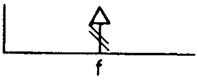
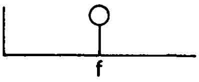
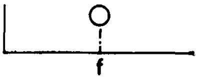
4. *Application*

The values of necessary attenuation given in Table 1 apply for a median listener and for the case where the interfering speech signal in the telephone channel is at its median value. To ensure that, say, 99% of combinations of telephone talker and broadcast listener taken at random do not incur 1) audibility of crosstalk or 2) intelligibility of crosstalk, allowance must be made for the distributions of both these populations. The present tests reveal a standard deviation of about 3.5 dB for the listener population and it is usual to find telephone speech volumes distributed with about 5 dB standard deviation; combining these and catering for 99% of combinations involves adding 14 dB to the above results. Taking the estimates given in the last two columns (which apply for rather unfavourable circumstances) the total crosstalk attenuation to satisfy 99% of combinations of telephone talker and broadcast listener amounts to 72 and 76 dB for the cases represented by Figures 1 and 2 respectively; this is very close to the present C.C.I.T.T. recommended limit of 74 dB, thus justifying the choice of this value. When a frequency displacement of 500 Hz is present in the crosstalk path the limit could be relaxed by about 18 dB for intelligible crosstalk.

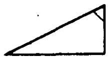
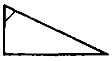
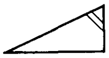
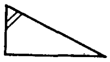
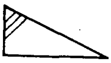
GRAPHICAL SYMBOLS MOST COMMONLY USED IN VOLUME III OF THE WHITE BOOK

Description	Symbols
Channel-modulating equipment (translation from audio to basic group band, and vice versa)	
Group-translating equipment (translation from basic group to basic supergroup and vice versa)	
Supergroup-translating equipment (translation from basic supergroup to basic mastergroup and vice versa)	
Mastergroup-translating equipment (translation from basic mastergroup to line frequencies and vice versa)	
Carrier frequency [1]	
Carrier frequency, suppressed	
Pilot frequency	
Erect sideband	

GRAPHICAL SYMBOLS MOST COMMONLY USED IN VOLUME III OF THE WHITE BOOK

Description	Symbols
Inverted sideband	
Single sideband, suppressed carrier (lower sideband only transmitted)	
Two pilot waves of which one or the other is transmitted	
Group pilot	
Supergroup pilot	
Mastergroup pilot	
Supermastergroup pilot	
Additional measuring frequency, general symbol	
Additional measuring frequency, which is transmitted or measured on request [2]	

GRAPHICAL SYMBOLS MOST COMMONLY USED IN VOLUME III OF THE WHITE BOOK

Description	Symbols
Group in which the channel sidebands are erect (group frequency increases with increasing audio-frequency)	
Group in which the channel sidebands are inverted (group frequency increases with decreasing audio-frequency)	
Supergroup in which the channel sidebands are erect (supergroup frequency increases with increasing audio-frequency)	
Supergroup in which the channel sidebands are inverted (supergroup frequency increases with decreasing audio-frequency)	
Mastergroup in which the channel sideband frequencies are erect (mastergroup frequency increases with increasing audio-frequency)	
Mastergroup in which the channel sideband frequencies are inverted (mastergroup frequency increases with decreasing audio-frequency)	
Supermastergroup in which the channel sidebands are erect (supermastergroup frequency increases with increasing audio-frequency)	
Supermastergroup in which the channel sidebands are inverted (supermastergroup frequency increases with decreasing audio-frequency)	

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[1] In this and following symbols, f, f_1, f_2, indicate the frequencies.

[2] In Volume III, this symbol indicates an additional measuring frequency from the preferred list; for all other additional measuring frequencies, the preceding general symbol has been used.

ALPHABETICAL INDEX TO THE FIRST THREE PARTS OF VOLUME III OF THE WHITE BOOK