THE INTERNATIONAL TELEGRAPH AND TELEPHONE CONSULTATIVE COMMITTEE

(C.C.I.T.T.)

FIFTH PLENARY ASSEMBLY

GENEVA, 4-15 DECEMBER 1972

GREEN BOOK

VOLUME III-1

Line Transmission

Recommendations (Series G, H and J) and Questions (Study Groups XV, XVI, Special Study Groups C and D) relating to line transmission

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CONTENTS OF THE C.C.I.T.T. BOOKS
APPLICABLE AFTER THE FIFTH PLENARY ASSEMBLY (1972)

GREEN BOOK

Volume I	— Minutes and reports of the Vth Plenary Assembly of the C.C.I.T.T. Resolutions and Opinions issued by the C.C.I.T.T. — General table of Study Groups and Working Parties for the period 1973-1976 — Summary table of Questions under study in the period 1973-1976. — Recommendations (Series A) on the organization of the work of the C.C.I.T.T. — Recommendations (Series B) relating to means of expression. — Recommendations (Series C) relating to general telecommunication statistics.
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, Special Study Groups C and D) relating to line transmission.
Volume IV	— Recommendations (Series M, N and O) 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, telephone sets equipment.
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 and U) and Questions (Study Groups VIII, IX, X and XIV) relating to telegraph technique.
Volume VIII	— Recommendations (Series V and X) and Questions (Study Group VII and 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 also contains, where appropriate:

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— Supplements for information and documentary purposes.

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TABLE 1

Summary of the main characteristics specified by the C.C.I.T.T. for international telephone circuits [a] *and international connections*

(This very condensed table is not a recommendation, and reference should be made to the complete Recommendations)

		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	at least 300-3400 (G.151, A)	From international centre to local exchange: 300-3400 (G.124) Four-wire chain of 6 circuits: 300-3400 (G.132)
	Additional attenuation at limits of frequency	9 dB (G.151, A and G.132)	9 dB (G.151, A and G.132)
Attenuation distortion		G.151, A Fig. 1/G.151	Graph No. 1, desirable objective for 12 circuits (Fig. 1/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) [b]		$t_m - t_{min} \leqq 30$ ms [c] $t_M - t_{min} \leqq 15$ ms [c] (G.133)	For the 4-wire chain (G.133) $t_m - t_{min} \leqq 60$ ms $t_M - t_{min} \leqq 30$ ms For each national 4-wire chain (G.133) $t_m - t_{min} \leqq 15$ ms $t_M - t_{min} \leqq 7.5$ ms
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)		$\Delta \geqq 58$ dB (G.151, D, see Note 3)	Extension circuits: as (1) (G.151)

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

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

[c] 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 — see Note 4)	Extension circuits: as (1) (G.151)
Circuit noise			See Table 1 *bis*	
Impedance of the circuit				A single value for one trunk exchange (G.232, M)
Frequency difference at two ends of a carrier circuit			≦ 2 Hz (G.135, G.225)	G.135, G.225
Power at zero relative level point	Telephony, mean power in busy hour		Speech currents, etc. 22 μW [a] (G.223) Electric signals + tones 10 μW [a] (G.223) (see G.224 for the power of signalling pulses)	
Power at zero relative level point	Voice-frequency telegraphy. Maximum power per channel for v.f.t. systems having		Amplitude modulation. Power when sending continuous 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
Power at zero relative level point	Private wire telegraphy and telephony	one or other	Sending continuous mark 0.3 mW maximum (H.31) [b]	
		both	Teleg. level ≦ −13 dBm0 (H.32) [b]	
Power at zero relative level point	Phototelegraphy		Amplitude modulation 1 mW, frequency modulation 0.1 mW (H.41)	
Maximum power for data transmission over leased circuits (H.51, A) [b]			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) [b]			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)	

[a] Calculation target value or conventional value for a hypothetical reference circuit.
[b] This recommendation contains restrictions of use. See also Recommendation H.34.

TABLE 1*bis*

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

(This very condensed table is not a recommendation, and reference should be made to the complete Recommendation)

Types of systems				General objectives					
				Cable[b] or radio-relay link		Single-hop satellite link	Submarine cable[b]	All systems	
Telephone circuits considered[a]				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[c] G.222 G.226	G.153		G.153	G.143	G.143
Recommendations	Of the C.C.I.R.			391, 392 393-1, 394, 395-1, 396-1, 397-2,		352-1, 353-2			
Hypothetical reference circuit (H.R.C.) or typical circuit considered				H.R.C. of 2500 km[d] or similar real circuit	Circuit of 7500 km[d]	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[e]	10 000 pW*	1 pW/km[e]	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 *			
Unweighted power		% of the month during which 10^6 pW (5 ms) can be exceeded		0.01	0.03 *	0.03 *			

TABLE 1*bis (continued)*

Special objectives									
	In national networks	Radio-relay links					Tropo-spheric radio-relay links in special conditions	Open-wire lines	
Noise due to the national transmitter system	Circuits ≤250 km on FDM system	Circuits not very different from H.R.C. 280 < L < 2500 km	Composition of links very different from h.r.c. 50 ≤ L < 280 km	Composition of links very different from h.r.c. 280 < L ≤ 840 km	Composition of links very different from h.r.c. 840 < L ≤ 1670 km	Composition of links very different from h.r.c. 1670 < L ≤ 2500 km	One or two circuits at most in one world connection	Up to 2500 km	More than 2500 km
G.123	G.123							G.311	G.153
		395-1	395-1	395-1	395-1	395-1	396-1, 392-2		
Total length L in km of the long-line FDM carrier systems in the national chain							H.R.C. of 2500 km [d]	H.R.C. of 2500 km [d]	Circuit of 10 000 km
(4000 + 4L) pW or (7000 + 2 L) pW[g]	1000 pW[h]							20 000 pW[f]	50 000 pW[f]
								2500 pW	
		3 L pW	(3 L + 200) pW		(3 L + 400) pW	(3 L + 600) PW		17 500 pW	
		3 L pW	(3 L + 200) pW		(3 L + 400) pW	(3 L + 600) pW	25 000 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		
							0.05		

[a] Special objectives for telegraphy are indicated in Recommendations G.143, G.153, G.222 and G.442. Objectives for data transmission are shown in Recommendations G.143 and G.153.

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

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

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

[e] 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.

[f] Except in extremely unfavourable climatic conditions.

[g] For planning purposes.

[h] 1000 pW is the average for all the channels of the system. 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: ≤ 200 pWp. Limits of unweighted noise through exchange: 100 000 pW.

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 recommendation, and reference should be made to the complete recommendations)

	Systems wholly in cable (G.232)	Systems on open-wire lines	
		3-channel (G.361)	12-channel (G.232)
Level of carrier leak on the line — per channel — per group	 −26 dBm0 −20 dBm0	 −17 dBm0 −14.5 dBm0	 −26 dBm0 −20 dBm0
Attenuation distortion	Fig. 1/G.232 and Fig. 2/G.232		
Group delay	Table 1 (G.232)		
Non-linear distortion	Fig. 3/G.232		
Amplitude limiting	Definition (G.232, H)		
Crosstalk ratio	≧ 65 dB for intelligible crosstalk (G.232, J) ≧ 60 dB for unintelligible crosstalk between adjacent channels (G.232, J)		
Near-end crosstalk ratio (A) between HF points	≧ 47 dB without echo suppressors (G.232, J) ≧ 62 dB with echo suppressors (G.232, J)		
Near-end crosstalk ratio (X) between audio points	≧ 53 dB without echo suppressors (G.232, J) ≧ 68 dB with echo suppressors (G.232, J)		
Relative levels	(G.232, L)		
Impedance	600 Ω (G.232, M)		
Protection and suppression of pilots	(G.232, N)		

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, and reference should be made to the complete Recommendations)

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

[a] For telephony (G.242).
[b] See (G.241) for use of these frequencies.
[c] Also applies to 8-channel groups (G.234).

TABLE 3 *(continued)*

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) after through-connection:	at 1552 kHz (G.242) (dB)	at 11 906 kHz (G.242) (dB)	at 1552 kHz (G.242) (dB)
— intelligible crosstalk [a] — unintelligible crosstalk [a] — possible crosstalk — harmful out-of-band — harmless out-of-band	70 70 35 40 17	70 70 35 40 17	70 70 35 40 17
Variation of insertion loss in pass-band of through-connection equipment	± 1 dB with respect to value at 1552 kHz (G.242)	± 1.5 dB with respect to value at 11 096 kHz ± 1 dB in each master-group (G.242)	± 1.5 dB with respect to value at 1552 kHz ± 1 dB in each super-group (G.242)
Variation of insertion loss between 10° C and 40° C of through-connection equipment	± 1 dB at 1552 kHz relative to insertion loss at 25° C (G.242)	± 1 dB at 11 096 kHz relative to insertion loss at 25° C (G.242)	± 1 dB at 1552 kHz relative to insertion loss at 25° C (G.242)
Relative levels at distribution frames (G.233) — transmit — receive	(dBr) −36 −23	(dBr) −33 −25	(dBr) −33 −25
Return loss at modulator input (G.233)	(dB) ≧ 20	(dB) ≧ 20	(dB) ≧ 20
Master group, supermastergroup or 15-supergroup assembly pilots (G.241) in:	Frequency (kHz)	Accuracy (Hz)	Level (for tolerances, see G.241) (dBm0)
— Basic mastergroup — Basic supermastergroup — Basic 15-supergroup assembly	1 552 11 096 1 552	± 2 ± 10 ± 2	−20 −20 −20

[a] For the telephony (G.242).

TABLE 4

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

(This very condensed table is not a recommendation, and reference should be made to the complete Recommendations)

	Systems acting on each pair		
	3-circuit-systems	8-circuit systems	12-circuit systems
Line frequencies — for a single system — for several systems on the same route	Fig. 1/G.361; (see also G.361, A. a; G.361, B. a; G.361, B. b; G.361, c) Fig. 1/G.361	Fig. 1/G.314 (G.314, c)	Fig. 1/G.311 or Fig. 2/G.311 See Fig. 3/G.311, and Fig. 4/G.311 for examples
Pilots — frequency — level	16.110 and 31.110 kHz or 17.800 kHz [a] (G.361, c) −15 dBm0	(G.314, d)	(G.311, e) −20 dBm0 [b]
Terminal equipment and intermediate repeater output. Relative level per channel at 800-Hz equivalent frequency	≦ 17 dBr (G.361, b)	≦ 17 dBr (G.314, b)	≦ 17 dBr ± 1 dBr (terminal equipment) ≦ 17 dBr ± 2 dBr (intermediate repeater equipment) (G.311, c)
Frequency accuracy of pilot and carrier frequency generators	2.5×10^{-5} (G.361, c and h)	1×10^{-5} (G.314, d)	5×10^{-6} (G.311, f)

[a] Used only by agreement between Administrations.
[b] Provisional recommendation.

TABLE 5

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

(This very condensed table is not a recommendation, and reference should be made to the complete Recommendations)

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

[a] For 12 + 12 systems, see Recommendations G.325 and G.327.
[b] Used only by agreement between Administrations.
[c] 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, and reference should be made to the complete Recommendations)

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

TABLE 6 *(continued)*

	2.6-MHz systems [a] (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)	−10 dBm0 ± 0.5 dB (G.338, b) −1.2 Nm0 for some systems (G.338, b)	−10 dBm0 ± 0.5 dB (G.332, b.1) −1.2 Nm0 for valve-type systems (G.339, b)	as (2)
— error in the level	as (3)	as (3)	± 0.1 dB (G.332, b.1)	as (3)
— variation with	as (3)	as (3)	± 0.3 dB (G.332, b.1)	as (3)
Impedance match between repeaters and line N (as defined on G.332, c)	$N \geqq 40$ dB for $f < 300$ kHz (G.338, e) $N \geqq 45$ dB for $f > 300$ kHz (G.338, e)		$N \geqq 48$ dB for $300 \leqq f \leqq 5564$ kHz (valve-type systems G.339, e) $N \geqq 48$ dB for $f = 300$ kHz and $N \geqq 55$ dB for $f \geqq 800$ kHz (transistorized systems G.332, e)	$N = 65$ dB [c] (G.333, e)
Relative level on line			(G.332, f) and (G.339, f)	(G.333, f)

[a] Use of the 6-MHz for telephony is specified otherwise (see G.337, p. 2).
[b] Only used by agreement between Administrations.
[c] 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, and reference should be made to the complete Recommendations)

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

[a] Provisional recommendation.

[b] Only used by agreement between Administrations.

[c] 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, and reference should be made to the complete Recommendations)

Type of circuits [a], [b]	15 kHz [c]	10 kHz	6.4 kHz
Frequency band effectively transmitted by the complete link (kHz) Additional attenuation at these limits	0.04 to 15 2 dB at 0.04 kHz 3 dB at 15 kHz (J.21)	0.05 to 10 4.3 dB (J.22, a)	0.05 to 6.4 4.3 dB (J.23, a)
Attenuation distortion	± 0.5 dB; 0.125 to 10 kHz (J.21)	Fig. 1/J.22	Fig. 1/J.23
Group delay at frequency f (τ_f) relative to the minimum value of group delay	$\tau_{15000} \leqq 12$ ms $\tau_{14000} \leqq 8$ ms $\tau_{75} \leqq 24$ ms $\tau_{40} \leqq 55$ ms (J.21)	$\tau_{10000} \leqq 8$ ms $\tau_{100} \leqq 20$ ms $\tau_{50} \leqq 80$ ms (J.22, d)	$\tau_{6400} \leqq 8$ ms $\tau_{100} \leqq 20$ ms $\tau_{50} \leqq 80$ ms (J.23, d)
Maximum absolute voltage level at a sound-programme zero relative level point	+ 9 dB (J.14) — Peak voltage 3.1 V (Fig. 3/J.13)		
Definition of zero relative level at a point in a carrier circuit	Level to give no greater load than that for the telephone channels replaced (J.31, A)	As for telephony is within ± 3 dB (J.14)	
Nominal relative voltage level at the input and output of the circuit defined in J.13	6 dB (J.14)		
Variation of relative level with time	≦ 0.5 dB (daily variation) (J.21)	≦ ± 2 dB (during a programme transmission (J.22, g)	≦ ± 3 dB (during a programme transmission (J.23, g)
Intelligible crosstalk attenuation (near-end or far-end) ratio [d]	0.04 kHz ≧ 50 dB 0.5 kHz ≧ 74 dB 5 kHz ≧ 74 dB 15 kHz ≧ 60 dB (J.21)	Between 2 programme transmissions circuits or telephony into sound programme: ≧ 74 dB (cables) ≧ 61 dB (open wire) Sound programme into telephony: ≧ 58 dB (cables) ≧ 47 dB (open wire) (J.22, f and J.23, f respectively) [d], [e]	
Circuit noise including non-linear crosstalk [f]	Level ≦ −47 dBm0 (new weighting network according to the Annex to Rec. J.16)	Psophometric voltage at the end of 1) cable circuit ≦ 6.2 mV 2) open-wire circuit ≦ 15.6 mV	

[a] Characteristics applicable to the hypothetical reference circuits, defined in Rec. J.11.
[b] Types of circuits described in Rec. J.12.
[c] For the additional characteristics specified by the C.C.I.T.T. for 15 kHz stereophonic sound-programme circuits (see Rec. J.17).
[d] Provisional recommendation.
[e] Special precautions needed for crosstalk between the two directions of transmission (see Rec. J.18 and J.22).
[f] Measures taken to reduce the effects of noise in a group link (see Rec. J.17).

TABLE 9

Principal characteristics of analogue signals at audio frequencies, at terminals of PCM equipments

(This very condensed table is not a recommendation, and reference should be made to the complete Recommendations)

Analogue characteristics measured at input and output parts [a, b]	Test signal			
	Signal	Frequency range	Power level dBm0	
Attenuation distortion			0	Figure 1/G.712
Envelope delay distortion			0	Figure 2/G.712
Idle channel noise: — weighted — single frequency — due to receiving equipment				 −65 dBm0p −50 dBm0 −75 dBm0p
Image frequency	sine wave	4.6-72 kHz	×	< × −25 dBm0
Level of out-of-band image signals	sine wave	300-3400 Hz	0	< −25 dBm0
Intermodulation products: — $2f, -f_2$ — Any intermodulation product	 two sine wave sine wave sine wave	 f_1 and f_2 (Hz) 300-3400 Hz 50 Hz	 −21 < × < −4 −9 −23	 < × −35 dBm0 < −49 dBm0
Variation of gain: — with input level (reference = gain at input level of −10 dBm0) — with time (stability)	 white noise sine wave sine wave	 700-1100 Hz 700-1100 Hz	 −60 < × < −10 −10 < × < 3 −55 < × < 3	 Figure 6A/G.712 Figure 6B/G.712 Figure 6C/G.712 ± 0.2 dB in 10 minutes ± 0.5 dB in 30 days ± 1.0 dB in 1 year
Crosstalk: — interchannel — go and return	 sine wave white noise sine wave	 700-1100 Hz 300-3400 Hz	 0 0	 < −65 dBm0 < −60 dBm0 > 60 dB
Distortion	Gaussian noise sine wave	 700-1100 Hz	−55 < × < 3 −45 < × < 0	Figure 4/G.712 Figure 5/G.712

[a] Parameters of input and output ports:
— 600 Ω balanced, 4 wire ports
— return loss better than 20 dB over frequency range 300-3400 Hz (provisional recommendation).

[b] For correct application to the equipments, see p. 1 of Recommendation G.712.

NOTICE TO VOLUME III OF THE GREEN BOOK

Volume III of the *Green Book* fully supersedes Volume III of the C.C.I.T.T. *White Book* (Mar del Plata, 1968).

It is indicated (immediately after the titles of Recommendations or Supplements) whether the texts are new ones approved by the Plenary Assembly of Geneva 1972 or are texts amended at the same period. Texts without any such 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

The units used in this volume are in conformity with C.C.I.T.T. Recommendations B.3 and B.4 (Volume I of the *Green Book*).

The indication "amended Geneva, 1972" has not been affixed to those Recommendations in which the only amendment has been an editorial change concerning units.

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

dBm	the absolute (power) level in decibels;
dBm0	the absolute (power) level in decibels referred to a point of zero relative level;
dBr	the relative (power) level in decibels;
dBm0p	the absolute psophometric power level in decibels 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.

INTRODUCTORY NOTE

To lighten the text of the Recommendations in this volume, the term "Administration" has been used as a brief designation for both a telecommunication Administration and a recognized private operating agency.

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PART I

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 at Mar del Plata, 1968, and at Geneva, 1972)

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/G.101.

— *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.

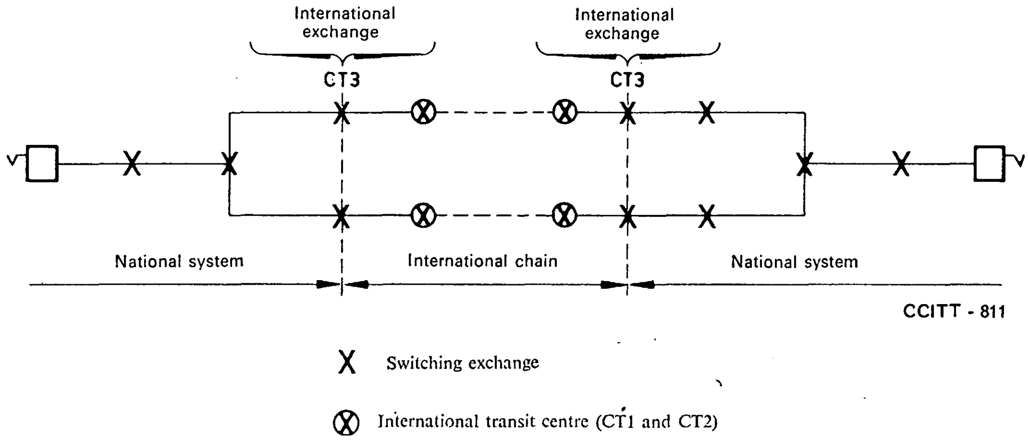


Figure 1/G.101. — **Definition of the constituent parts of an international connection**

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/G.101; 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.*

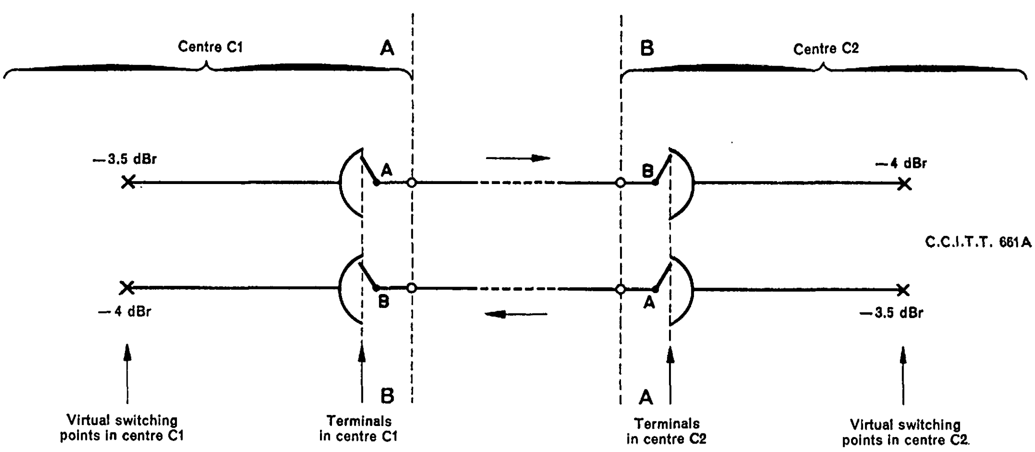
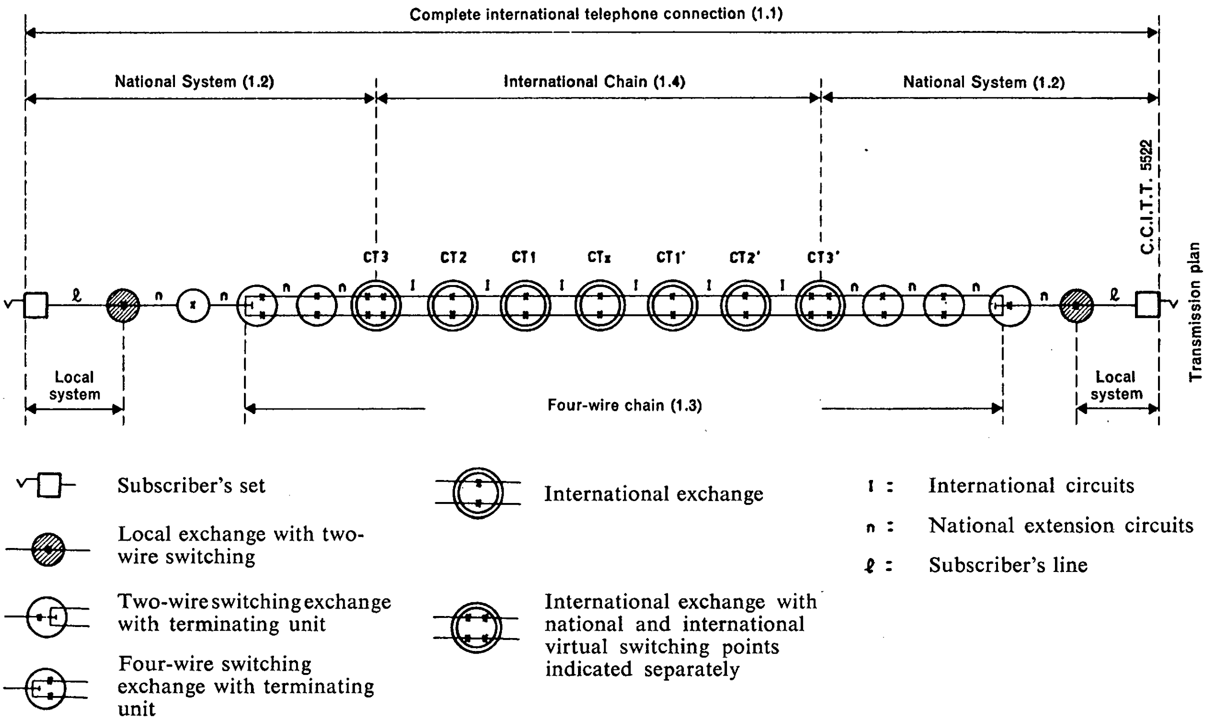


Figure 2/G.101. — **Definitions for an international circuit**



Note. — The arrangement shown for the national systems are examples only. The numbers given in brackets refer to the sub-section of Section 1 (of Volume III, Part I) in which recommendations may be found relevant to that part of the connection. In addition, the circuits making up this chain must individually meet the requirements of sub-section 1.5.

FIGURE 3/G.101. — **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 1000 km or, exceptionally, 1500 km, the country concerned is considered as of average size. In such countries, in most cases, not more than three national circuits are interconnected on a four-wire basis between each other and to international circuits. These circuits should comply with the recommendations of sub-section 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 sub-section 1.5).

Note. — The abbreviation "a four-wire chain" (see Figure 3/G.101) 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, all of which may 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/G.101 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, *Green 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 CTls, may be encountered as shown in Figure 3/G.101. 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, revised at Geneva, 1972)

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/G.103, 2/G.103 and 3/G.103.

Figure 1/G.103 — 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/G.103 — 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/G.103 — 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/G.103, 2/G.103 and 3/G.103, maximum and average noise values have been shown separately, wherever possible, to facilitate studies.

General remarks on Figures 1/G.103, 2/G.103 and 3/G.103

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 in 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 indicated 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 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 associated with the extreme right-hand circuit in the four-wire chain.

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/G.103 (Note 2), the arbitrary value of 5.5 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 on 21 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 if national and international circuits (i.e. primary centre) gives 17.5 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 5.5 dB for the toll circuit, switching losses being included (see general remark 10).[1]

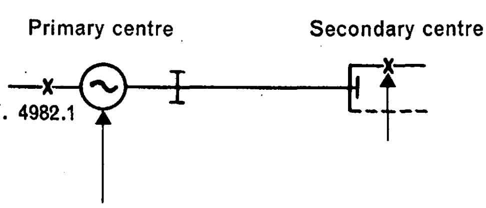
9) The standard deviation of transmission loss of circuits is in accord with the objectives of Recommendation G.151, C and also with the results obtained in practice and specified in Section 4 of the supplements to Volume IV of the *Green Book*.

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.

In this way switching and exchange cabling losses are included in the values of transmission loss assigned to the circuits. If it is required to separately distinguish exchange losses, an additional pad symbol of appropriate value may be used.

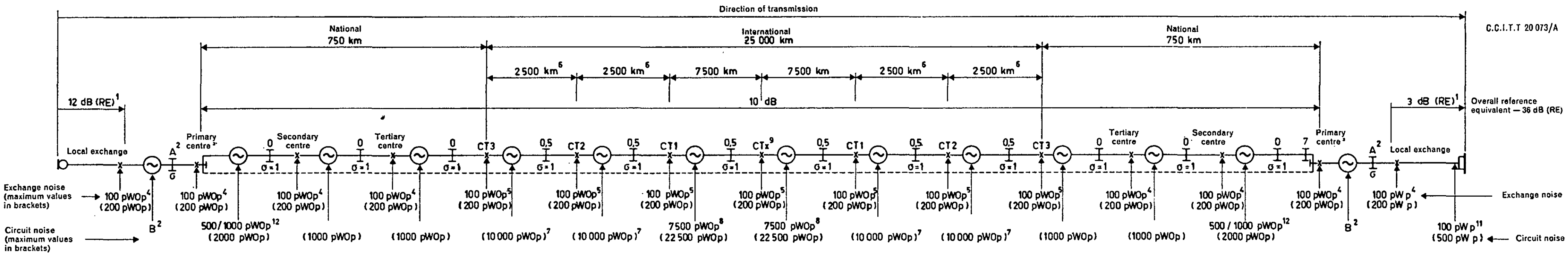
It should also be noted that, according to this convention, the 3.5 dB loss ordinarily assigned to a terminating set does not figure explicitly in two-wire/four-wire circuits; its value is also included in the loss assigned to the circuit.

11) In the diagram, the terminating set is taken to be at the same location as the two-wire switch. This need not always be the case in practice. In particular, it may be associated with the four-wire switching exchange, for which arrangement an appropriate diagram is:



C.C.I.T.T. 4982.1

[1] Further information can be found in the C.C.I.T.T. *Handbook on transmission planning of switched telephone networks.*

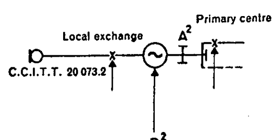


Notes

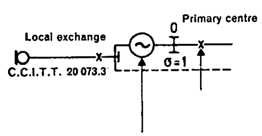
1. 10 dB is a typical line loss at 1600 Hz for maximum length subscriber's line. (See also general remark 8.)

2. When this circuit is a FDM or TDM short distance carrier circuit ($\leq$ 250 km), the value of B will be 500/1000 pW0p (2000 pW0p) — Recommendation G.123 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 5.5 dB with $\sigma = 0$. (See general remark 8.) This circuit may also be provided on a PCM circuit, using either 7-bit encoding ($\mu = 100$ or $A = 87.6$) or 8-bit encoding ($\mu = 225$ or $A = 87.6$).

3. The following arrangements may be encountered if four-wire switching (space-division or time-division) is used at the primary centre.



(a)



(b)

If arrangement (b) is adopted then, in principle, the nominal loss of the tertiary-centre/CT3 circuit should be augmented to 0.5 dB in accordance with Recommendations G.121 and G.121, A, since there are now four national circuits in the four-wire chain. Analogous arrangements may be encountered at the other end of the connection.

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 (*Green 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 10000 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 22500 pW0p. Companders would be used to improve noise only if it exceeded 40000 pW0p (see Recommendation G.143).

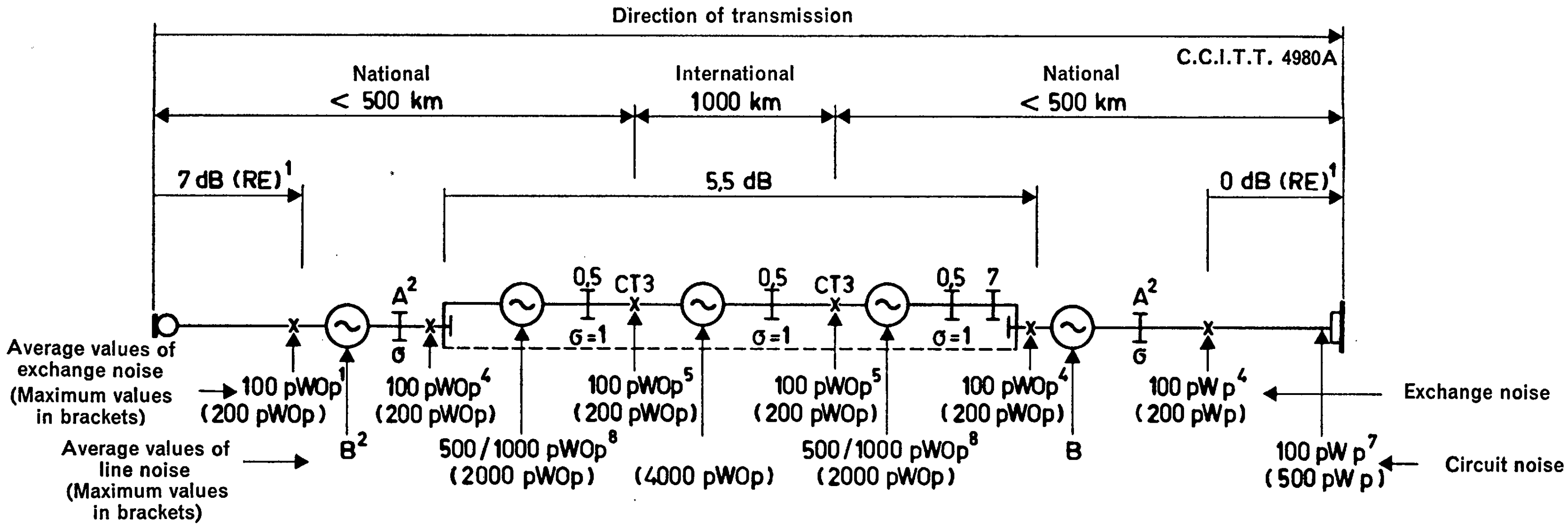
9. Exceptionally there may be an additional CTX to that shown. The overall length of the connection is not thereby affected.

10. The receiving country is assumed 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 (see general remark 10).

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.123 gives a precise definition of these values as 500/1000 pW0p (2000 pW0p).

FIGURE 1/G.103. — **Longest international connection envisaged with C.C.I.T.T. recommendations**



Notes

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

2) See Note 2 in Figure 1/G.103.

3) See Note 3 in Figure 1/G.103.

4) See Note 4 in Figure 1/G.103.

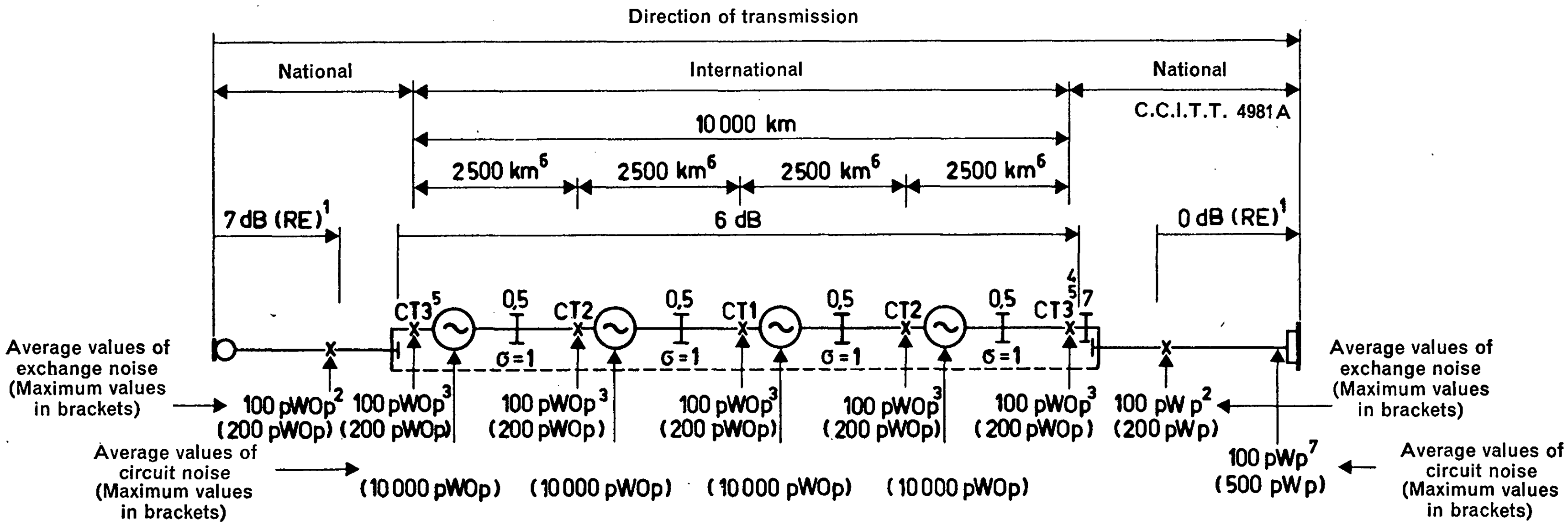
5) The value of 200 pW0p for the maximum noise power in an international exchange is that recommended in Recommendation Q.45 (*Green Book*, Volume VI).

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 (see general remark 10).

7) See Note 11 in Figure 1/G.103.

8) See Note 12 in Figure 1/G.103.

FIGURE 2/G.103. — **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/G.103.

3) See Note 5 in Figure 1/G.103.

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 (see general remark 10).

5) The local exchange is assumed to be co-sited with the CT3.

6) See Note 6 in Figure 1/G.103.

7) See Note 11 in Figure 1/G.103.

FIGURE 3/G.103. — **A typical international connection within a CT1 area between subscribers situated near terminal CT3 exchanges**

Clearly, in principle, the terminating set may be at any point between the two-wire switch and the four-wire switch, although in practice it is ordinarily associated with one or the other.

c) *Modulation and demodulation equipments*

For the study of transmission performance, the longest international connection envisaged (see Figure 1/G.103) 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.

d) *Possible future developments arising from the introduction of PCM systems*

It is possible to distinguish two phases of development, at least initially:

1) In the first phase PCM systems will be increasingly employed to provide trunk junctions between a local exchange and a primary centre and relatively short circuits between primary and secondary centres, space switching being retained. That being so, the corresponding circuits will often be set up on PCM systems as in Figures 1/G.103, 2/G.103 and 3/G.103 of this Recommendation. Furthermore, in certain cases and depending on the distances in Figures 2/G.103 and 3/G.103, the CT3 may be reached entirely by circuits on PCM systems.

During the same period, satellite systems with demand-assigned circuits will be brought into service, all using telephone channel digital modulation procedures. In Figures 2/G.103 and 3/G.103 a circuit set up on demand on such a system may replace the circuit between CT3s or the chain of circuits between CT2s or CT3s, according to the arrangements prescribed in paragraph 4.4 of Recommendation Q.13 (*Green Book*, Volume VI).

2) In the second phase, which might begin around 1975, PCM systems will be used over ever greater distances and time division switching will start to appear. Transmission and switching may be expected to be often integrated in the primary centre. Time division exchanges will be used even between analogue circuits, pending the time when PCM transmission becomes economic on longer stretches.

High-capacity communication-satellite systems using PCM even for pre-assigned circuits may be expected to make their appearance during this phase; it is further possible that technical advances may enable them to be employed with greater flexibility than in the present routing plan.

In view of this, all national circuits and several international circuits in reference connections *may possibly* be established on PCM systems and the same remark applies to time division switching exchanges, every combination of analogue and digital systems being found.

The exact duration of this phase is difficult to estimate but it will certainly be long and might, for instance, stretch from 1975 to well beyond 1985. Accordingly, the complex situation obtaining during this phase will have to be taken into account and adequate transmission performance maintained. It would be dangerous to count on the network's reaching its final stage of full integration and relax the requirements regarding the transmission performance which will have to be ensured during this very long transitional period.

1.1 General recommendations on the transmission quality for an entire international telephone connection [1]

Recommendation G.111 (P.11) (Geneva, 1964; amended at Mar del Plata, 1968, and Geneva, 1972)

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/G.111 (P.11) (for a country of average size).

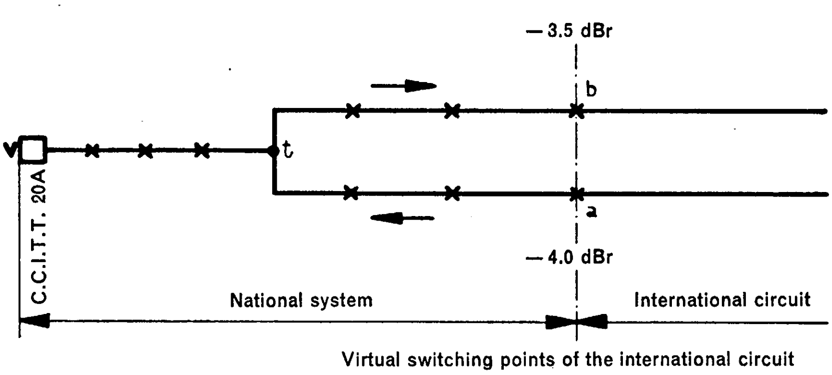


FIGURE 1/G.111 (P.11). — **Definition of the virtual switching points**

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, sending
−4.0 dBr, receiving

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

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

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 21 dB; and

— the nominal reference equivalent of the receiving system between the same two points should not exceed 12 dB.

[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 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 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

a) *Nominal values for each direction of transmission*

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, *Green Book*, Volume V.)

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

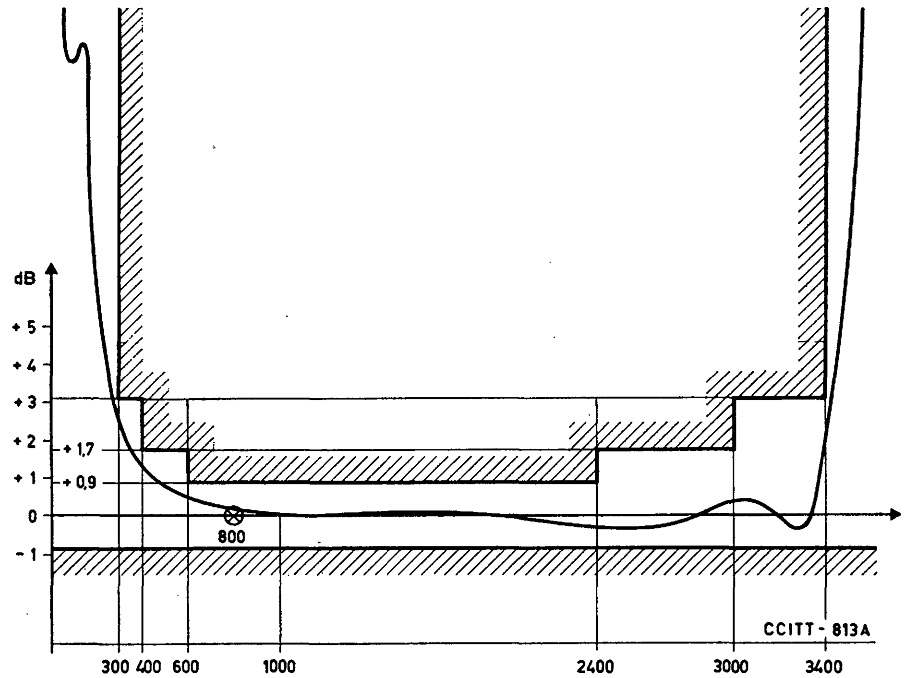


FIGURE 2/G.111. — **Characteristic of A.R.A.E.N. filter**

Figure 2/G.111 shows the actual characteristic of one A.R.A.E.N. filter and reproduces Graph 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.

b) *Difference in transmission loss between the two directions of transmission in national systems*

It is recommended that the absolute value of the difference between loss *t–b* and loss *a–t* (see Recommendation G.122) should not exceed 4 dB so that in theory no greater nominal difference than 8 dB could be introduced in international connections.

The following points should be noted:

1. Bearing in mind that most Administrations allocate the losses of their national extension circuits in much the same sort of way (see Annex 1 to Recommendation G.121), connections set up in practice should not exhibit nominal differences much in excess of 3 dB.

2. As far as speech transmission is concerned, from the studies carried out by several Administrations in 1968-1972, it is clear that for connections with overall reference equivalents falling within the range found in practice no great disadvantage attaches to any reasonable difference in nominal overall reference equivalent between the two directions of transmission.

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 0.6 dB per annum, a systematic increase due to ageing of the microphone. [See also Note 3 of paragraph B, b of Recommendation G.121 (P.21).]

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, and reproduced in the table of the Appendix to Section 1 are not applicable to the transmission plan now recommended by the C.C.I.T.T.

Recommendation G.112 (P.12) (modified at Geneva, 1964, and at 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 *Green 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,

L = length of the trunk-junction in kilometres,

K = coefficient which depends on the type of trunk-junction considered, in decibels 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. 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 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.

[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 (*Green 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;

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

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 G.111 (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 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 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* of the C.C.I.F. (Geneva, 1954), 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 trunk-junctions

A trunk-junction 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 United Kingdom Post Office, 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]

Therefore, the A.E.N. of the trunk-junction 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.

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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 $3 \times 500 = 1500$ Hz.

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 trunk-junction, 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 trunk-junction (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;

L = length of trunk-junction in kilometres;

K = coefficient, which depends on the type of trunk-junction considered, in decibels 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 trunk-junction 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 trunk-junction in the national network considered.

Recommendation G.113 (P.13) (amended at 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/G.113 (P. 13) 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 dB.

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.

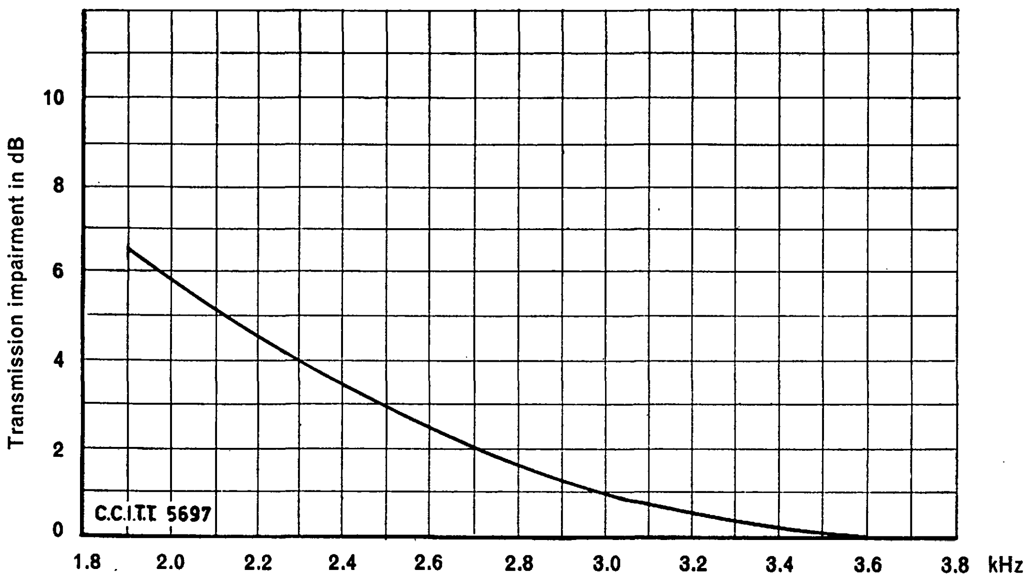

FIGURE 1/G.113 (P.13). — **Transmission impairment due to bandwidth limitation (cut-off impairment)**

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) [1] 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 referred to the input of the first circuit in the chain of international circuits.

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.

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[1] The power density spectrum of the room noise used in A.E.N. measurements is given in Figure 2/G.113 (P.13). 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.

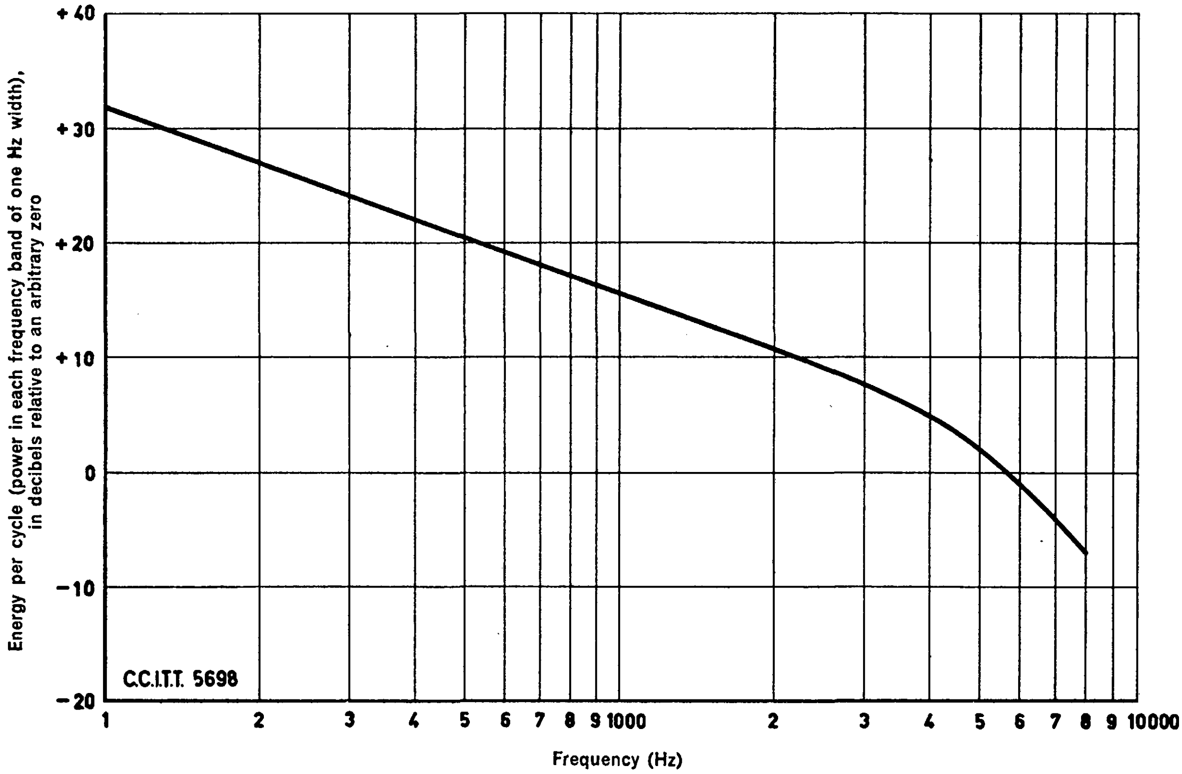


FIGURE 2/G.113 (P.13). — **Power density spectrum of the room noise produced in the listening cabinet of the C.C.I.T.T Laboratory**

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

Recommendation G.114 (P.14) (Geneva, 1964, amended at 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 References below, particularly with regard 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 References in selecting, from alternatives, plans involving delays in range b above.

References

C.C.I.T.T. *Red Book*, Volume V*bis*, Annex E (United States).

C.C.I.T.T. *Red Book*, Volume V*bis*, Annex F (United Kingdom).

C.C.I.T.T. *Red Book*, Volume V*bis*, Annex 4 to Question 6/XII (Italy).

C.C.I.T.T. *White Book*, Volume V, Supplements 1-6.

Barstow, J. M.: Results of user reaction tests on communication via Early Bird satellite, *Progress in Astronautic Aeronautics*, *19*, 1966, Academic Press, New York and London.

Helder, G. K.: Customer evaluation of telephone circuits with delay, *Bell System Technical Journal*, *45*, September 1966, pp. 1157-1191.

Richards, D. L.: Transmission performance of telephone connexions having long propagation times, *Het P.T.T.-Bedrijf*, XV, No. ½, May 1967, pp. 12-24.

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.

de Jong, C.: Observations on telephone calls between the Netherlands and the U.S.A., *Het P.T.T.-Bedrijf*, May 1967, pp. 32-36.

Hutter, J.: Customer response to telephone circuits routed via a synchronous-orbit satellite, *P.O.E.E.J.*, Volume 60, p. 181, October 1967.

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

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

Here the factor 0.004 is based on the assumption that national trunk circuits will be routed over high-velocity plant (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 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)

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 14 000 km altitude	110 ms
Satellite at 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 4.

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* (No. 04-17); the numerical values are calculated at a frequency of about 800 Hz.

* * *

Recommendation G.115 does not exist. Recommendation P.15 (Volume V) is identical to Recommendation G.133 of the present Volume III of the *Green Book*.

Recommendation G.116 (P.16) (Geneva, 1972)

SUBJECTIVE EFFECTS OF DIRECT CROSSTALK

Thresholds of audibility and intelligibility

1. *Factors which affect the crosstalk thresholds*

The degree of audibility and intelligibility of a crosstalk signal depends on a large number of factors.

A simple and generally applicable method for estimating the required loss in the crosstalk path as a function of the factors affecting the audibility or the intelligibility of the speech crosstalk signal can be obtained if certain simplifications are made.

The main factors influencing the intelligibility of the vocal crosstalk signal are listed below:

a) *Quality of transmission of telephone apparatus*

The sending and receiving reference equivalents are decisive factors. The same is true of the reference equivalent of sidetone when room noise is present. The use of modern telephone apparatus with smooth frequency curves is assumed.

b) *Circuit noise*

The circuit noise on the connection of the disturbed call must be taken into account. This is measured by a psophometer equipped with a weighting network for telephone circuits.

c) *Room noise*

Room noise affects the ear directly through ear-cap leakage between the ear and the receiver and indirectly by sidetone. Sidetone also depends on operating conditions. Unlike circuit noise, the effect of room noise can be reduced to some extent by the user of the telephone. For this reason and to allow for unfavourable cases, the measurements were made with slight [40 dB (A)] room noise as well as with negligible room noise.

d) *Conversation on the disturbed connection*

While there is active speech on the disturbed connection practical levels of crosstalk are inaudible. However, before the conversation starts or during long pauses in the conversation it is possible for crosstalk to be heard and perhaps understood. The information given in this Recommendation assumes no conversation on the disturbed connection.

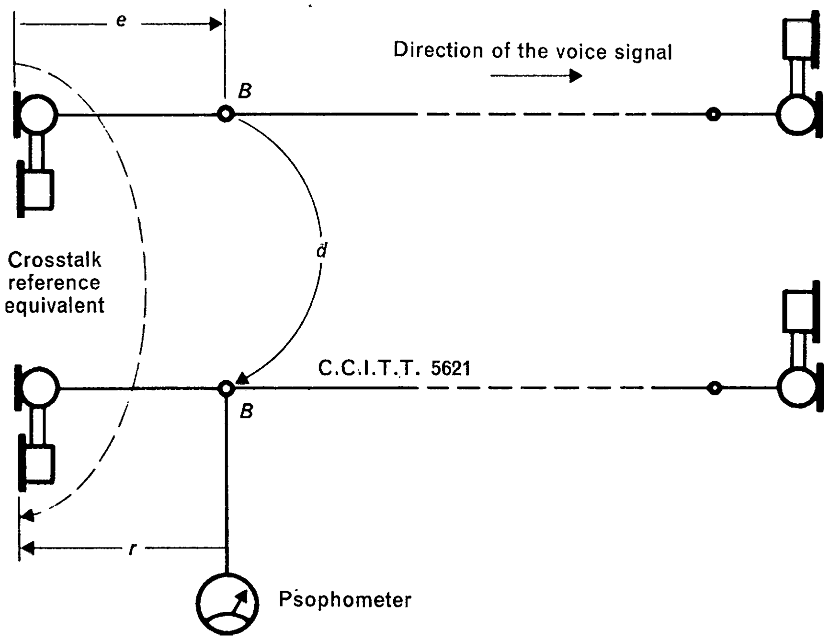
e) *Microphone noise*

The noise produced by the carbon microphone of the disturbed telephone may slightly reduce the intelligibility of the vocal crosstalk signal owing to sidetone. Good quality modern microphones have been assumed in this Recommendation.

f) *Crosstalk coupling*

The intelligibility of a crosstalk signal also depends on the nature of the crosstalk coupling which is generally a function of frequency. The reference equivalent of the crosstalk transmission path can be conventionally divided into the sending reference equivalent of the subscriber's set causing the disturbance, the receiving reference equivalent of the subscriber's set subject to disturbance, and the transmission loss of the crosstalk transmission path. Figure 1/G.116 (P.16) illustrates this conventional subdivision.

In the absence of further information, the reference equivalent of the crosstalk coupling may be taken to be the attenuation measured or calculated at a frequency of 1100 Hz, as advocated in Recommendation G.134 (*Green Book*, Volume III) for telephone exchanges.



e = Sending reference equivalent of the disturbing subscriber's set;

r = Receiving reference equivalent of the disturbed subscriber's set;

d = Crosstalk path attenuation, so that: crosstalk reference equivalent = $e + d + r$;

B = Terminals of subscriber's set.

Disturbing and disturbed subscriber's sets at the same end: near-end crosstalk.

Disturbing and disturbed subscriber's sets at opposite ends: far-end crosstalk.

FIGURE 1/G.116 (P.16). — **Conventional subdivision of crosstalk reference equivalent**

2. *Median listener thresholds of the audibility and intelligibility of vocal crosstalk*

The curves in Figure 2/G.116 (P.16) represent the nominal overall reference equivalents of the crosstalk transmission path corresponding to the thresholds of audibility and intelligibility as a function of the receiving reference equivalent; their parameter is the circuit noise; room noise is negligible or equal to 40 dB (having Hoth spectrum and measured with A weighting).

These curves represent median values for the various conditions such that in each case 50% of subscribers' opinions are respectively above and below the particular curve. The standard deviation for listeners has been observed to lie in the range 4 to 6 dB.

The results of the original experiments [which form the basis of the curves in Figure 2/G.116 (P.16)] were expressed in terms of speech level (e.g. in volume units) and on that basis showed a satisfactory degree of agreement among themselves.

The thresholds are based on the assumption that a subscriber set with a sending reference equivalent of 0 dB corresponds in practice to a speech level of −10 VU at the subscriber set terminals with a load of 600 ohms.

However, in order for the results to be directly useful for planning purposes for networks designed and characterized on the basis of reference equivalents, it is necessary to introduce a factor (c) which effectively establishes the relationship between speech level and sending reference equivalent.

The correction factor c has been defined in the following manner:

$$c = V_c - V_L \text{ dB}$$

where

V_c = speech level in decibels under normal conversational conditions at a particular point on the disturbing connection;

V_L = speech level in decibels at the same point on the disturbing connection under conditions corresponding to a speech level of −10 VU at the output of a subscriber set with a sending reference equivalent of 0 dB (i.e it is assumed that the listening tests have been carried out at this speech level).

Thus the correction factor c is positive for conditions in which the speech level on the disturbing circuit is greater than that corresponding to −10 VU at the output of a subscriber set with 0 dB sending reference equivalent. This correction factor must be added to the value of nominal crosstalk reference equivalent given in Figure 2/G.116 (P.16).

In general the values of c will be a function of the overall reference equivalent and to some extent of the circuit noise and sidetone reference equivalent on the disturbing circuit. Typical values have been estimated from speech level measurements made by several Administrations and are given in Table 1 together with standard deviations.

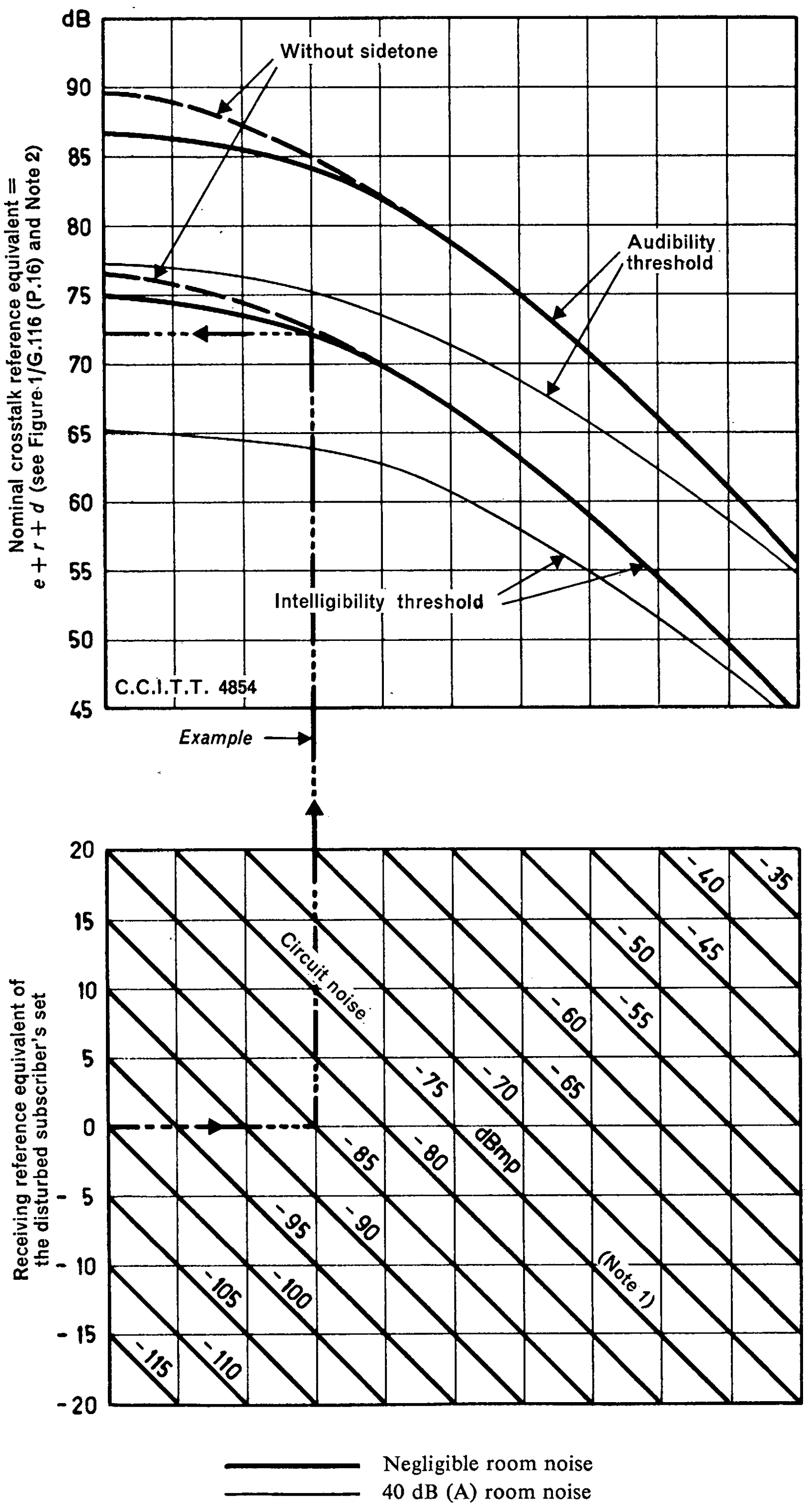
TABLE 1

MEAN VALUES AND STANDARD DEVIATIONS OF THE FACTOR c FOR VARIOUS ADMINISTRATIONS

Administration	Nominal overall reference equivalent of the disturbing connection	Estimated mean value of factor c $\bar{C}$	Estimated standard deviation of the factor c σ_c
	dB	dB	dB
American Telephone & Telegraph. . .	10 20 30	−2 +2 +5	4
Switzerland	35	+3.5	4
Sweden (Note 1)	10	−6	5
United Kingdom Post Office (Note 2) .	10 20 30	+3 +4 +5	4.8

Note 1. — Preliminary results.

Note 2. — With a circuit noise level of −60 dBm on the disturbing connection.



The sidetone reference equivalent of the disturbed subscriber's set appropriate to these curves is +13 dB.

FIGURE 2/G.116 (P.16). — **Crosstalk reference equivalent as a function of the receiving reference equivalent and of circuit noise**

Note 1. — The circuit noise is referred to the terminals of the subscriber's set having the reference equivalent indicated.

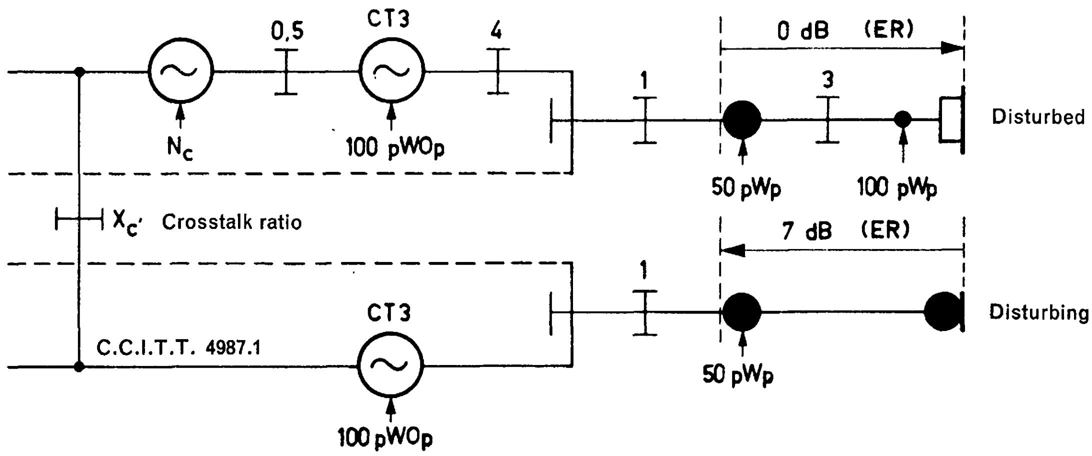
Note 2. — The value of factor *c* must be known before the curves can be used (see text).

ANNEX

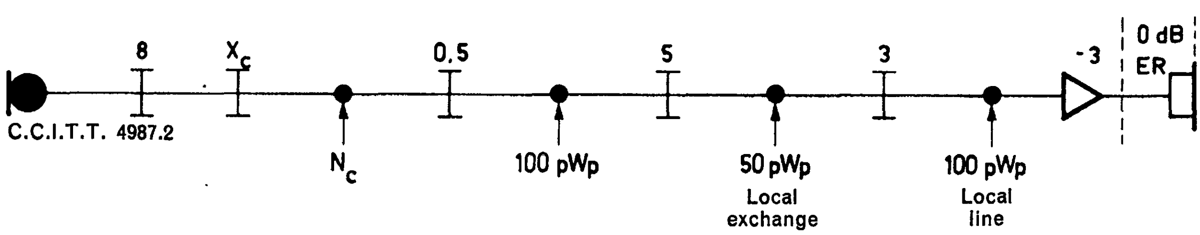
[to Recommendation G.116 (P.16)]

An example of the method of calculation

In order to demonstrate the method of using the information given in Recommendation G.116 (P.16) to calculate the probability of encountering (for example) intelligible crosstalk, a hypothetical reference connection is needed. An example of an important class of connection is given in Figure 3/G.103, *Green Book*, Volume III and appropriate portions of two such connections with crosstalk between them introduced by, for example, the international circuit, are shown below:

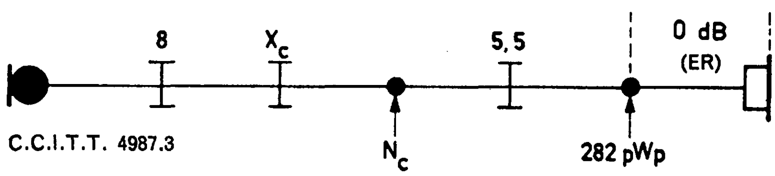


The crosstalk path of interest may be redrawn as shown:



(The 50 pWp and 100 pWp sources prior to the X_c-pad are ignored, for after traversing the X_c-pad, the resultant noise power contributions will be negligibly small.)

The diagram may be further simplified by referring all the given noise powers to the input of a local system having a reference equivalent of 0 dB and summing (as far as possible) the various losses.



Considering for the sake of example two specific cases, namely $X_c = 58$ dB; $N_c = 500$ pW0p and $X_c = 62$ dB; $N_c = 200$ pW0p, the corresponding values of overall X and total N are:

Examples studied	Corresponding values X	N
58 dB; 500 pW0p	71.5	−63.7
62 dB; 200 pW0p	75.5	−64.7

associated with the arrangement:

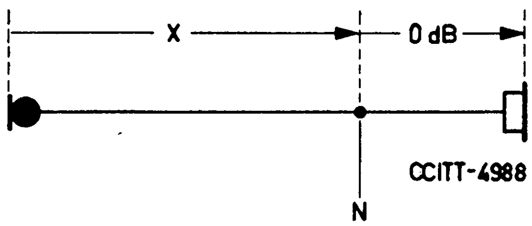
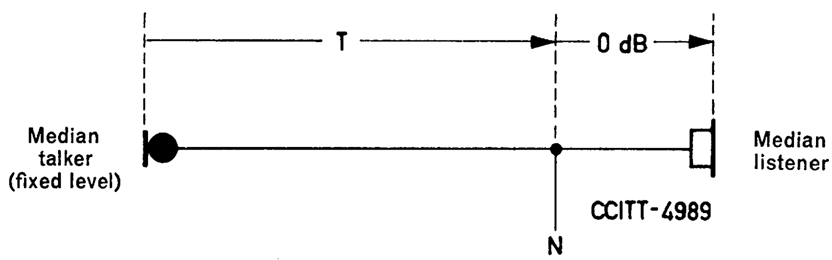


Table 1 records the values of the median threshold of intelligible crosstalk between an active talker and a silent listener. The values have been taken from the curves given in Figure 2/G.116 (P.16).

TABLE 1

MEDIAN LISTENER THRESHOLDS OF INTELLIGIBLE CROSSTALK AS A FUNCTION OF THE NOISE POWER LEVEL AT THE INPUT TO A 0 dB REFERENCE EQUIVALENT RECEIVING END, FOR A VARIETY OF LISTENING CONDITIONS [BASED ON FIGURE 2/G.116 (P.16)]



<table>
<tr><th rowspan="3">N dBm0p, noise power level at input to 0 dB RRE</th><th colspan="3">T dB, nominal overall reference equivalent of the crosstalk path</th></tr>
<tr><th colspan="2">Negligible room noise</th><th rowspan="2">+40 dB(A) room noise with sidetone</th></tr>
<tr><th>Without sidetone</th><th>With sidetone</th></tr>
<tr><td>−100</td><td>76.5</td><td>75.0</td><td>65.1</td></tr>
<tr><td>−95</td><td>75.7</td><td>74.5</td><td>64.9</td></tr>
<tr><td>−90</td><td>74.0</td><td>73.0</td><td>64.2</td></tr>
<tr><td>−85</td><td>72.5</td><td>72.0</td><td>64.0</td></tr>
<tr><td>−80</td><td colspan="2">70.0</td><td>62.5</td></tr>
<tr><td>−75</td><td colspan="2">67.0</td><td>60.5</td></tr>
<tr><td>−70</td><td colspan="2">63.0</td><td>58.0</td></tr>
<tr><td>−65</td><td colspan="2">59.0</td><td>55.0</td></tr>
<tr><td>−60</td><td colspan="2">54.5</td><td>51.5</td></tr>
<tr><td>−55</td><td colspan="2">49.5</td><td>47.5</td></tr>
<tr><td>−50</td><td colspan="2">44.0</td><td>43.0</td></tr>
</table>

Note. — The sidetone reference equivalent is +13 dB. For intermediate values, use linear interpolation. The talker delivers −10 VU from a 0 dB reference equivalent end.

The distribution of pairs of connections between which there is intelligible crosstalk is in general a combination of three separate distributions:

1) the distribution of talker volumes on the disturbing connection;

2) the distribution of crosstalk reference equivalent introduced by cables and equipment;

3) the distribution of listener perception of the speech crosstalk levels received on the disturbed connection.

In order to take account of the distribution of real talker volumes a correction factor, c, is needed which, being characteristic of national networks, at this present time must be supplied by the user. As indicated in Table 1 of Recommendation G.116 (P.16) the value of $\overline{C}$ lies in the range -6 to $+5$ dB and σ_c in the range 4 to 5 dB.

For this example we will use $\overline{C} = 4$ dB, and $\sigma_c = 4$ dB.

We do not have a distribution of crosstalk reference equivalents to take account of at this time; just two specific values.

The standard deviation of the listeners' threshold about the median value is in the range 4 to 6 dB. We will take the value $\sigma_t = 5$ dB in this example.

If t is the threshold value for a particular listener, c the speech volume correction factor for a particular talker and x the actual value of the reference equivalent of the crosstalk path between them, then when x is equal to or less than $t + c$, intelligible overhearing occurs. Denoting the difference $x - (t + c)$ by z, intelligible overhearing for this particular pair arises when z is zero or less.

If x, t, and c are each normally distributed (or may fairly be assumed to be so) with mean values $\overline{X}$, $\overline{T}$, and $\overline{C}$ and standard deviations σ_x, σ_t, and σ_c, then z is also normally distributed with mean value $\overline{Z} = \overline{X} - (\overline{T} + \overline{C})$ and standard deviation $\sigma_z = \sqrt{\sigma_x^2 + \sigma_t^2 + \sigma_c^2}$.

The normal deviate at $z = 0$ is given by $\overline{Z}/\sigma_z$ and the probability of $z \leqq 0$ can be found from tables of the cumulated normal distribution (single upper tail).

Taking the particular case of 58 dB; 500 pW0p and considering +40 dB (A) room noise with +13 dB sidetone then $N = -63.7$ gives $T = 54.1$ (by interpolation of Table 2) so that $\overline{Z} = \overline{X} - (\overline{T} + \overline{C}) = 71.5 - (54.1 + 4.0) = 13.4$ and $\sigma_z = \sqrt{(\sigma_x^2 + \sigma_t^2 + \sigma_c^2)} = \sqrt{(0 + 25 + 16)} = \sqrt{41} = 6.4$. Hence $\overline{Z}/\sigma_z = 13.4/6.4 = 2.10$ corresponding to 1.8% risk of intelligible overhearing.

Table 2 displays the results for each combination used in this example.

TABLE 2

PROBABILITIES OF INTELLIGIBLE OVERHEARING BETWEEN ACTIVE TALKERS AND SILENT LISTENERS

$(\sigma_x = 0;\ \sigma_t = 5;\ \sigma_c = 4;\ \overline{C} = 4)$

Example studied	+40 dB(A) room noise; 13 dB sidetone	Negligible room noise; 13 dB sidetone (or no sidetone) [a]
58 dB; 500 pW0p	1.8%	6.7%
62 dB; 200 pW0p	0.5%	2.4%

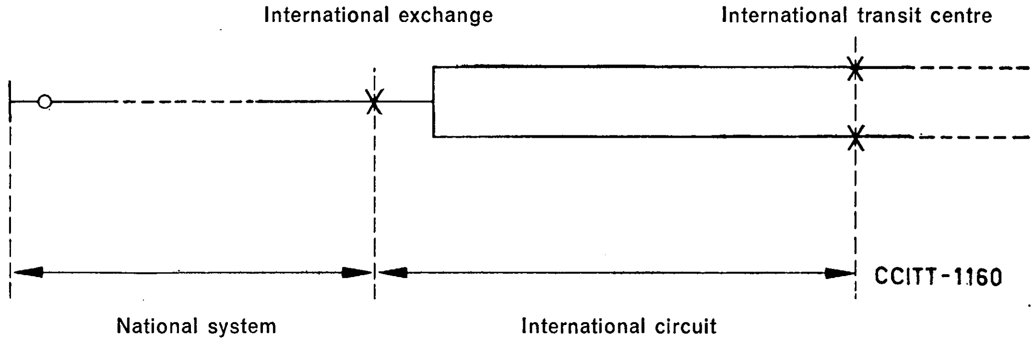
[a] With the values used in the examples, the presence or absence of sidetone has no effect.

Another method of calculating the probability of intelligible crosstalk using Monte Carlo methods is described in the C.C.I.T.T. handbook *Transmission Planning of Switched Telephone Networks*.

1.2 General characteristics of national systems forming part of international connections

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) [1]

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.

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 circuits to Recommendation G.123.

3. National trunk circuits should have characteristics enabling them to conform to Recommendations G.131, G.132 and G.134 in the *Green 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.

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[1] Former Recommendation P.21 of Volumes V and V*bis* of the *Red Book* amended at Mar del Plata, 1968. The Recommendations (series G) referred to in this text appear in Volume III of the *Green Book*; references are also given to those Recommendations which likewise appear in Series P in Volume V of the *Green Book*.

4. International centres should satisfy Recommendation Q.45 in the *Green Book*, Volume VI.

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 the new C.C.I.T.T. handbook *Transmission Planning of Switched Telephone Networks*.

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 equivalents [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.

The new handbook *Transmission Planning of Switched Telephone Networks* contains descriptions of the transmission plans adopted by various countries and also some indications concerning the methods that can be used to establish such a plan.

Recommendation G.121 (P.21) (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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/G.111 (P.11) and the Figure 1/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.

B. Maximum nominal sending and receiving reference equivalents

a) *Nominal values for each direction of transmission*

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 21 dB;

— the nominal reference equivalent of the receiving system between the same two points should not exceed 12 dB.

In a large country, these limits shall be, respectively: 21.5 dB and 12.5 dB if a fourth national circuit is part of the four-wire chain, or 22 dB and 13 dB if five national circuits form part of the four-wire chain.

In Figures 1/G.121 (P.21) and 2/G.121 (P.21), 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 21 dB and 12 dB cannot be met immediately, but an attempt should be made to abide by them when telephone sets of a new type are introduced.

Note 2. — The 97% limit refers to the traffic-weighted distribution of calls (including the distribution of the length of subscriber's lines) and is provisional at this stage. It is desirable to use a higher percentage when planning new networks.

Note 3. — The nominal reference equivalents given for national systems are to be based upon the average values of the sensitivities of the transducers of a large number of working telephone sets. As far as carbon microphones are concerned, the average value of the sensitivity of the carbon microphones in the national network is effectively represented by the value of sensitivity corresponding to the long stable period of their lifetime.

As regards systematic differences between actual and nominal sensitivities, if the average sensitivity is obtained by measuring a sample of working sets, any systematic differences will automatically be taken into account. However, if this average value is calculated, then the systematic difference must be part of the calculation.

The average values of sensitivity do not include fortuitous variations introduced by subjective methods used when reference equivalents are assessed.

Note 4. — The variations with time of circuits and other items of equipment connecting the local exchange with the international centre are not included in the estimated values of nominal reference equivalent.

b) *Difference in transmission loss between the two directions of transmission in national systems*

It is recommended that the absolute value of the difference between loss $t-b$ and loss $a-t$ (see Recommendation G.122) should not exceed 4 dB so that in theory no greater nominal difference than 8 dB could be introduced in international connections.

The following points should be noted:

1. Bearing in mind that most Administrations allocate the losses of their national extension circuits in much the same sort of way (see Annex 1 to this Recommendation), connections set up in practice should not exhibit nominal differences much in excess of 3 dB.

2. As far as speech transmission is concerned, from the studies carried out by several Administrations in 1968-1972, it is clear that for connections with overall reference equivalents falling within the range found in practice no great disadvantage attaches to any reasonable difference in nominal overall reference equivalent between the two directions of transmission.

Supplement No. 7 to Volume V of the *Green Book* is a résumé of the test results from various Administrations concerning the subjective effects of such asymmetry.

3. When devising national transmission plans Administrations should take into account the needs of data transmission between modems complying with C.C.I.T.T. Recommendations (e.g. V.2, V.21, V.23). Annex 2 gives some information on this point.

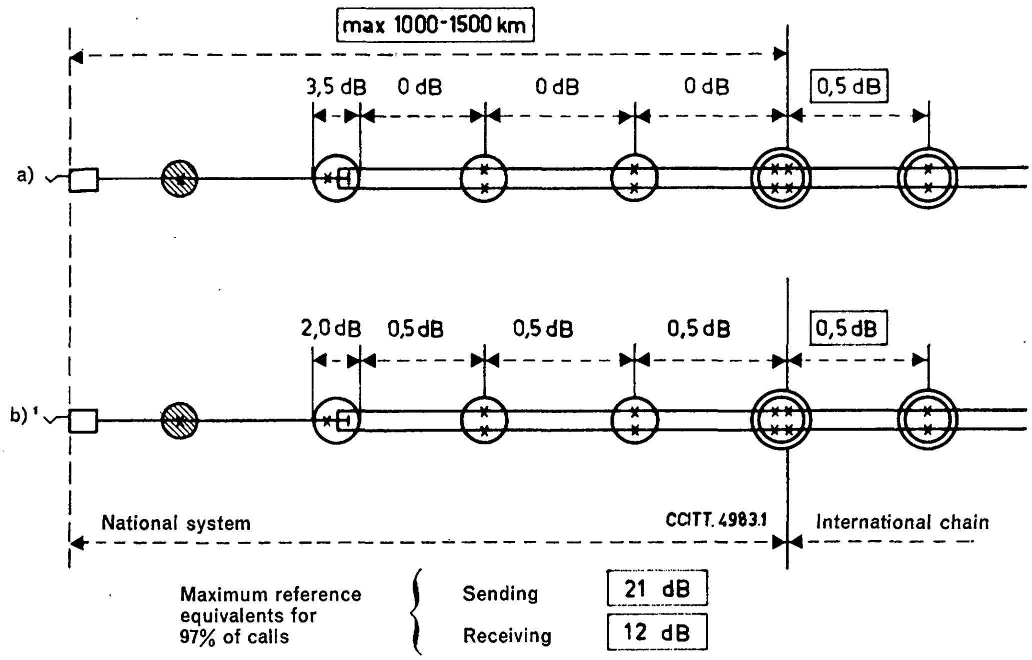


FIGURE 1/G.121 (P.21). — **Distribution of equivalents for an international call in a country of average size**

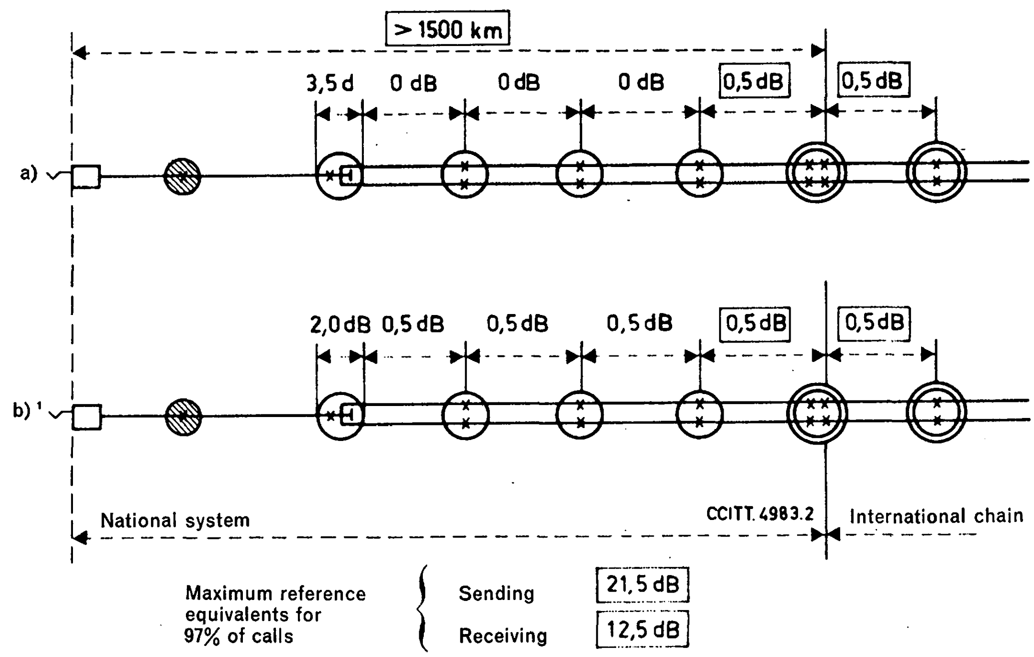
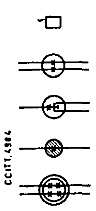


FIGURE 2/G.121 (P.21). — **Distribution of equivalents for international call in a large country**

Legend for figures 1/G.121 (P.21) and 2/G.121 (P.21)



Subscriber's set

Four-wire switching exchange

Exchange with terminating unit [2]

Local exchange, with two-wire switching

International exchange with national and international virtual switching points indicated separately

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

[2] 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.

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.

Provisionally, a nominal minimum value of 6 dB sending reference equivalent referred to the send virtual switching point of the international circuit is recommended in order to control the peak value of the speech power applied to international transmission systems. It should be noted that the imposition of such a limit does not serve to control the long-term mean power offered to the system.

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 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, trunk-junctions, 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 (N.O.S.F.E.R.) or with a working standard system already compared with N.O.S.F.E.R. 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). Due account must be taken of the send relative levels at highest order two-wire switching exchanges in the national system when making these calculations.

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 Section 5.2 of the handbook *Transmission Planning of Switched Telephone Networks*. 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:

$$q = Q - Q_0$$

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

Note 2. — Annex 2 to Question 1/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 N.O.S.F.E.R. 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 (*Green 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.

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 are to be expected.

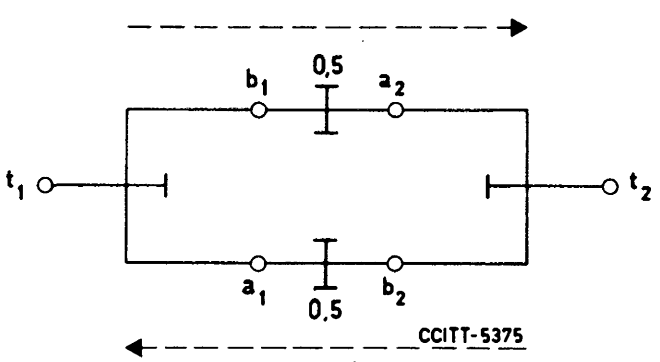
Note 1. — Strong sidetone (corresponding to a low value for sidetone reference equivalent) impairs transmission in two ways. At the sending end a subscriber who hears himself clearly is tempted to lower his voice; at the receiving end the room noise is transmitted as sidetone to the ear of the listener thus increasing the total noise received.

Note 2. — Even when the value of 17 dB is attained, room noise at the expected levels may still have an adverse effect. See Recommendation G.113 (P.13).

ANNEX 1
[to Recommendation G.121 (P.21)]

Evaluation of the nominal differences of loss between the two directions of transmission

a) Consider an international connection between primary centres in two countries, established over one international circuit as shown below:



The nominal overall losses in each of the two directions of transmission are:

$1 \rightarrow 2 = t_1b_1 + 0.5 + a_2t_2$ (dB)

and

$2 \rightarrow 1 = t_2b_2 + 0.5 + a_1t_1$ (dB)

Where *at* and *tb* are defined as in Recommendation G.122, so that the difference between the two directions is:

$$(t_1b_1 - a_1t_1) - (t_2b_2 - a_2t_2)$$
$$= (tb - at)_1 - (tb - at)_2$$
$$= d_1 - d_2$$

in which d signifies $tb - at$.

b) The value in decibels of losses *at* and *tb* for each of several countries is given in the table below together with the corresponding values of d, their difference. It will be seen that a maximum nominal difference of 3 dB between the two directions of transmission can arise on connections between any of the countries with $d = 0$ dB (e.g. Netherlands) and any of the countries with $d = 3$ dB (e.g. North America). It will also be noted that most nominal differences are $d = 0$ dB, so that the nominal differences on connections between the countries concerned is also 0 dB.

c) The nominal differences of loss between the two directions of transmission on international connections between local exchanges and also between subscribers' premises (i.e. telephone instrument disconnected) may also be calculated from the table, but the results will be true only if national two-wire switched trunk-junctions etc., are nominally symmetrical. This is usually the case.

d) The last column in the table indicates the sum of *tb* and *at*. This value represents that component of the loss *a–t–b* that is attributable to the national transmission plan and if, for example, the loss of the path *a–t–b* from the point of view of stability (or echo) is required, the value in the last column must be augmented by the stability (or echo) balance return loss at *t*.

TABLE

	at	*tb*	$d = tb - at$	$s = tb + at$
* Australia	−0.5	0.5	1.0	0.0
Belgium	3.5	3.5	0.0	7.0
* Denmark	1.9	1.9	0.0	3.8
Federal Republic of Germany	3.5	3.5	0.0	7.0
* France	2.2	2.2	0.0	4.4
Hong Kong	1.5	3.0	1.5	4.5
Japan	4.0	4.0	0.0	8.0
* Netherlands	3.5	3.5	0.0	7.0
* New Zealand	−1.5	1.5	3.0	0.0
* North America	−0.5	2.5	3.0	2.0
* Norway	0.5	3.5	3.0	4.0
* Sweden	3.5	3.5	0.0	7.0
Switzerland	3.5	3.5	0.0	7.0
United Kingdom (old)	3.5	3.5	0.0	7.0
United Kingdom (new)	0.5	3.5	3.0	4.0
U.S.S.R.	0.0	0.0	0.0	0.0

Note. — For countries marked * a range of values is appropriate and in each case the nominal minimum values of *at* and *tb* are given. In each case the nominal difference is maintained for all values within the range. For such countries, the indicated sum is the nominal minimum value. North America signifies A. T. & T. and the Canadian Telecommunications Carriers Association. Values shown in decibels.

ANNEX 2

[to Recommendation G.121 (P.21)]

The influence of the telephone transmission plan on data transmission

(Contribution of the Netherlands Administration)

The application of "differential gain" will often result in a higher circuit loss in one direction of transmission and a lower loss in the other one, because the sum of both will be held constant for stability reasons. This means that in international connections with an unfavourable combination of "differential gains" at both ends, one direction of transmission indeed can have an extra loss of 4 dB.

A rough calculation, based on the existing Recommendations and taking into account the following aspects:

— maximum circuit losses in national networks, estimated from national transmission plans (see the handbook *Transmission Planning of Switched Telephone Networks*);

— a reasonable number of international circuits;

— variation of transmission loss of international circuits and national extension circuits (Recommendation G.151);

— the sending and receiving levels for data equipment and the attenuation range indicated for the design (Recommendations V.2, V.21 and V.23),

shows that, in some cases, the maximum loss which can be expected on international connections is such that data transmission may encounter problems.

The introduction of "differential gain" will influence this situation in an unfavourable way.

Recommendation G.122 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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/G.122.

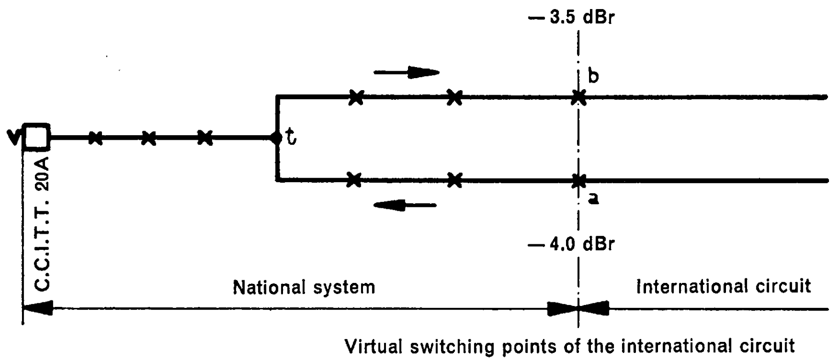


FIGURE 1/G.122. — **Definition of the virtual switching points**

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 reflexion 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/G.122 along the path *a–t–b* in the national network should have a value not less than $(6 + n)$ dB, 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[1]:

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
100—200	Not less than 1 dB
200—300	Not less than 0 dB
Above 3400	Not less than 0 dB

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 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 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 $\sqrt{(6.25 + 4n)}$ dB. 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.

[1] See also Recommendation G.232, B.

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.

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. 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 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, this figure referring to the distribution of actual calls.

Note 1. — In the C.C.I.T.T. handbook *Transmission Planning of Switched Telephone Networks* there are described some of the methods proposed, and in some cases successfully applied, by 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 and a standard deviation of 1.5 dB, 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 with a standard deviation from the mean of $\sqrt{(9 + 4n)}$ dB 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 with a standard deviation from the mean, not exceeding $2\sqrt{n}$ dB accompanied by a balance return loss from the point of view of echo at the terminating set, *t*, of not less than 11 dB with a standard deviation from the mean, not exceeding 3 dB.

ANNEX

(to Recommendation G.122)

Measurement of the transmission loss of the path a–t–b

The transmission loss of the path *a–t–b* from the points of view of stability and of echo as defined in Recommendation G.122, A,a and B,b may be measured by apparatus at the international centre in accordance with the principle of Figure 2/G.122.

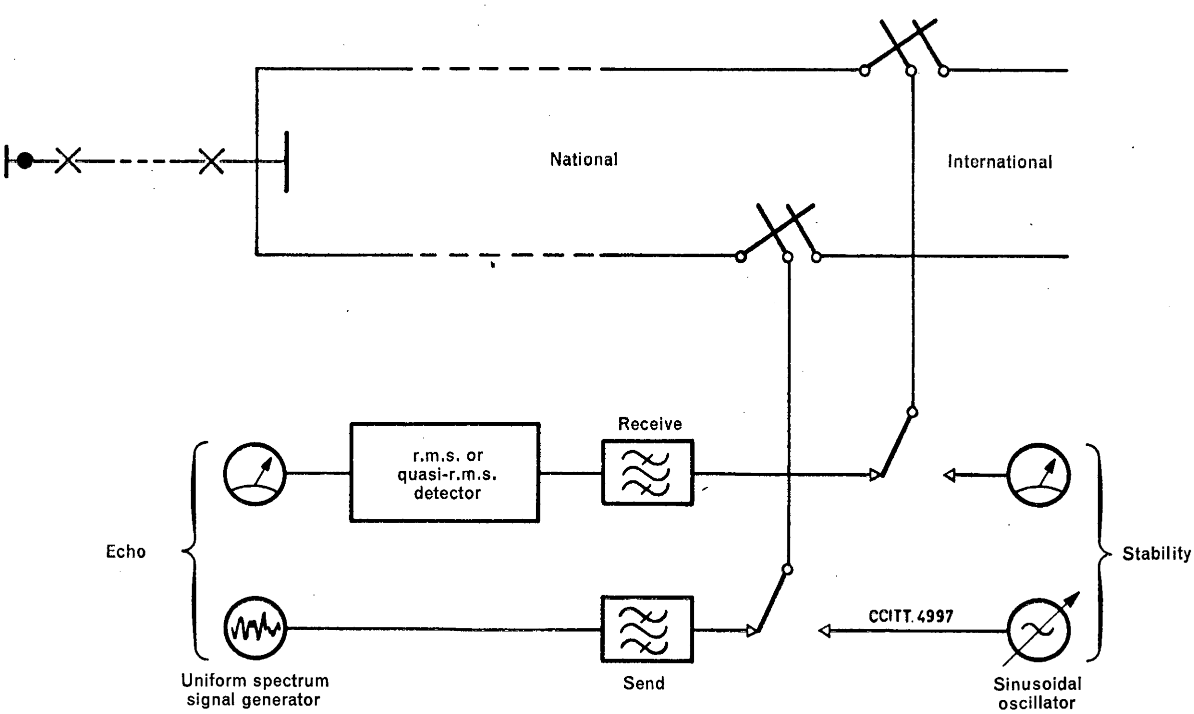


FIGURE 2/G.122. — **Principle of measuring the transmission loss of the path a–t–b from the points of view of stability and of echo**

In respect of the echo measurement, the combined response of the send and receive filters must be such that the provisional definition given in Recommendation G.122 B,b is effectively implemented, e.g. such that the difference between a measured echo loss and one calculated from the loss/frequency characteristic does not exceed 0.25 dB.

The allocation of the total response between send and receive is not critical and any reasonable division may be used provided that:

— excessive interchannel interference is avoided in national transmission systems due to an unrestricted spectrum of the transmitted signal;

— unwanted signals that may give rise to errors, e.g. hum, circuit noise, carrier leak signals, are prevented from entering the receiver.

Appropriate arrangements (not shown) are needed to gain automatic or manual access to the four-wire switches at the international centre and also to ensure that due account is taken of the transmission levels at the actual switching points.

As far as the stability measurement is concerned, if a sweep oscillator is used, attention must be paid to the risks of engendering false operation of national signalling systems.

For both measurements anomalous results may be obtained if echo suppressors are encountered in the national extension.

Recommendation G.123 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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 network, 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) *Analogue systems*

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). This implies that the line noise in channels used to provide these circuits should not exceed 2 pW0p/km.

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/G.103).

3. *Circuits of length up to about 250 km*

In the present stage of technique and for economic considerations 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 level per hour exceed a maximum of 2000 pW for any of the channels of the system.

These figures allow for crosstalk effects.

In any case, the noise level in a circuit is acceptable if it meets the requirements of Recommendation G.152, taking into account Recommendation G.226 (Noise on a real link).

Note. — The attention of Administrations is drawn to a conclusion of studies carried out by the C.C.I.T.T. during the 1964-1968 study period, that if the additional percentage of "poor or bad" opinions on the quality of connections due to noise introduced by terminal links is not to exceed one half of that caused by the presence in the connection of all other sources of circuit noise, then the noise contributed by each one of these links should be limited to about 500 pW0p (mean for all the channels of the system during any hour).

b) *Digital systems*

Circuits provided by PCM systems which accord with the G.700 series of Recommendations, in particular Recommendation G.712 (Performance characteristics of PCM channels at audio frequencies), will have an acceptable noise performance which is substantially independent of their length.

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 pWp (i.e. a level of −67 dBm0p).

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 pW (i.e. a level of −40 dBm0).

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

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*

In any four-wire exchange, busy-hour mean impulsive noise counts should not exceed 5 counts in 5 minutes at a threshold level of −35 dBm0. The method of measurement is described in Recommendation Q.45, Annex 1, *Green Book*, Volume VI.

D. Noise allocation for a national system
(guide for planning purposes)

The noise powers indicated in the following text are nominal values.

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 $(4000 + 4\,L)$ or $(7000 + 2\,L)$ pWp, whichever is less, and where L is the total length in kilometres of the long-distance FDM 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. — 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 $A + BL$ 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.

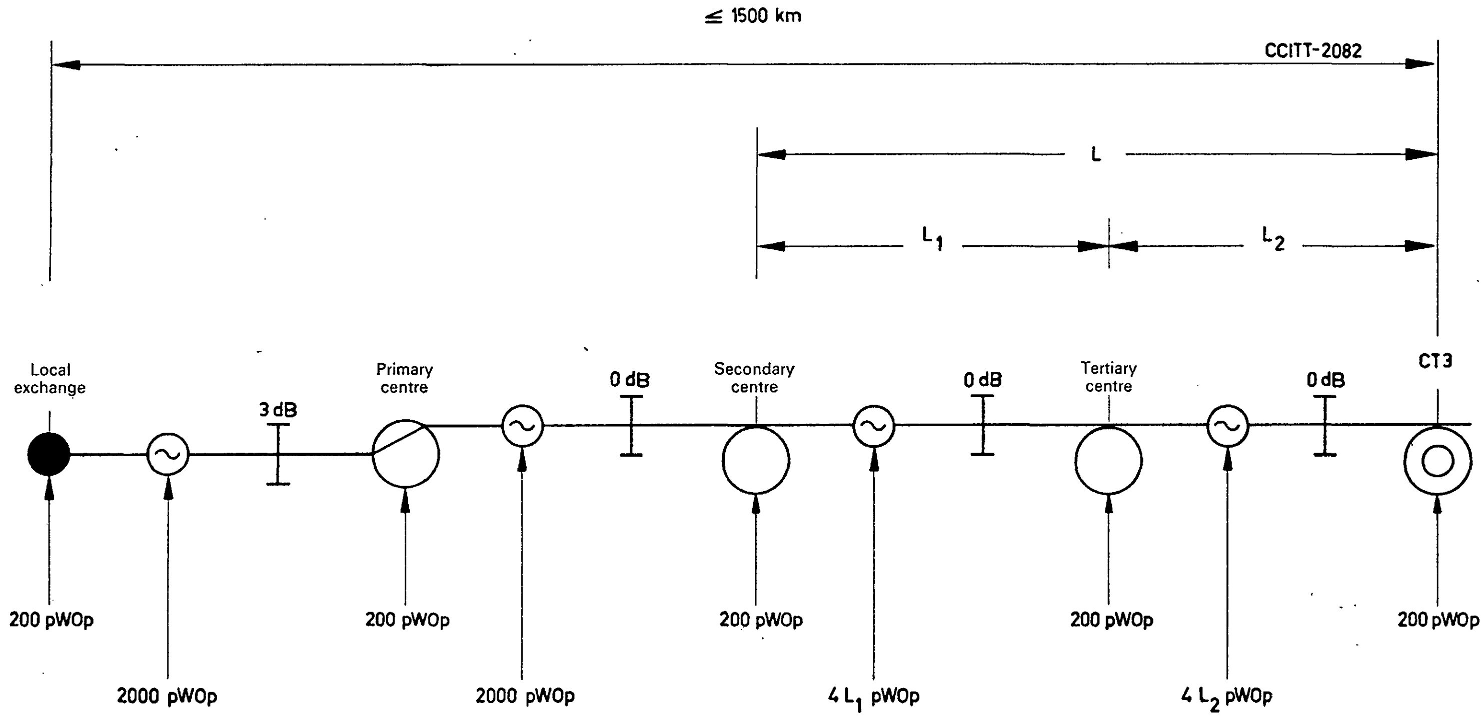


FIGURE 1/G.123

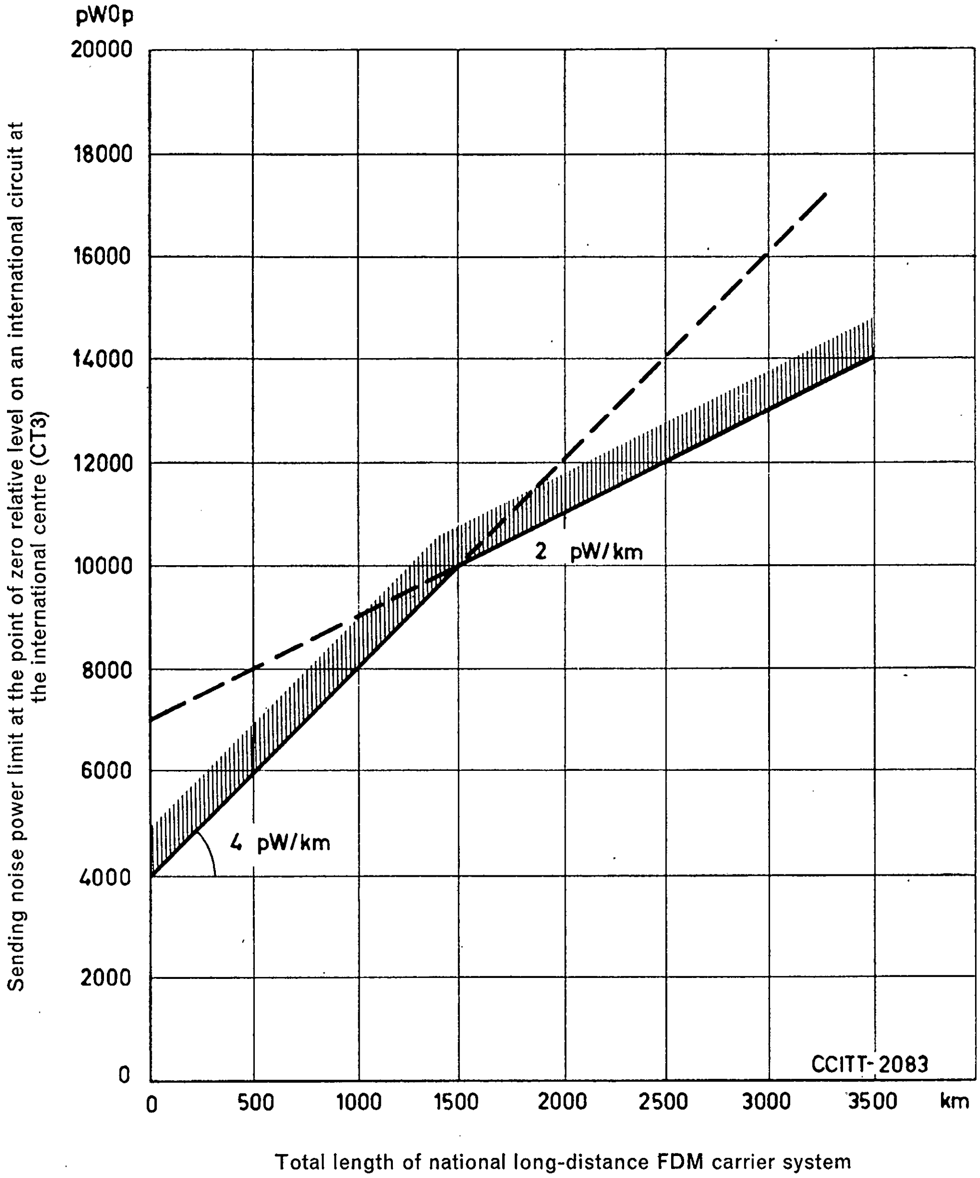


FIGURE 2/G.123

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/G.123.[1] The circuit between the local exchange and the primary centre is assumed to be routed on an FDM carrier system of length not exceeding 250 km and operated at a nominal loss of 3 dB. In accordance with paragraph B, a,3 of Recommendation G.123, 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 an FDM carrier system of the same type.

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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/G.103.

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/G.123 approaches the limit of 1500 km arbitrarily defining "a country of average size" in Recommendation G.121. It is thus assumed that 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 pWp 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):

$$200 + 4\,L_2 + 200 + 4\,L_1 + 200 + 2000 + 200 + \tfrac{1}{2}(2000) + \tfrac{1}{2}(200) = 3900 + 4\,L \text{ pW0}$$

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/G.123 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 circuit; 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 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 should, for preference, follow the indications given in Recommendation G.543.

Recommendation G.125 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

CHARACTERISTICS OF NATIONAL CIRCUITS ON CARRIER SYSTEMS

Carrier circuits which are likely to form part of international connections should meet the requirements of Recommendation G.132 as far as attenuation distortion is concerned. The 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.

Recommendations relating to the noise performance of national circuits are now to be found in Recommendation G.123 (Circuit noise in national networks).

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 at Mar del Plata, 1968 and at Geneva, 1972)

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/G.131, 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 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 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.

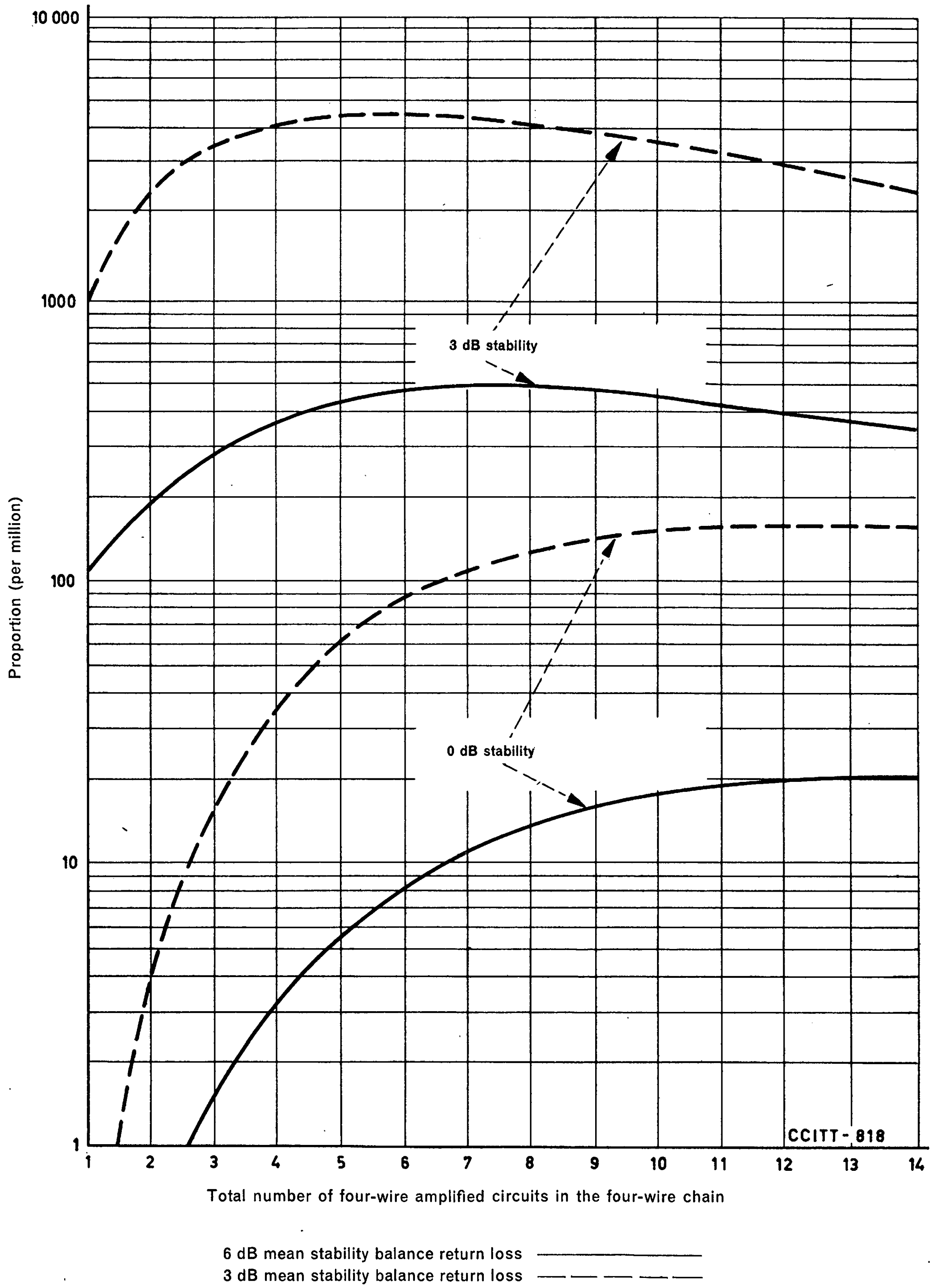


FIGURE 1/G.131. — **Proportion of possible connections with a stability equal to or less than 0 dB or 3 dB**

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. This accords with the assumptions used in Recommendation G.122, A,b, 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 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.

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 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

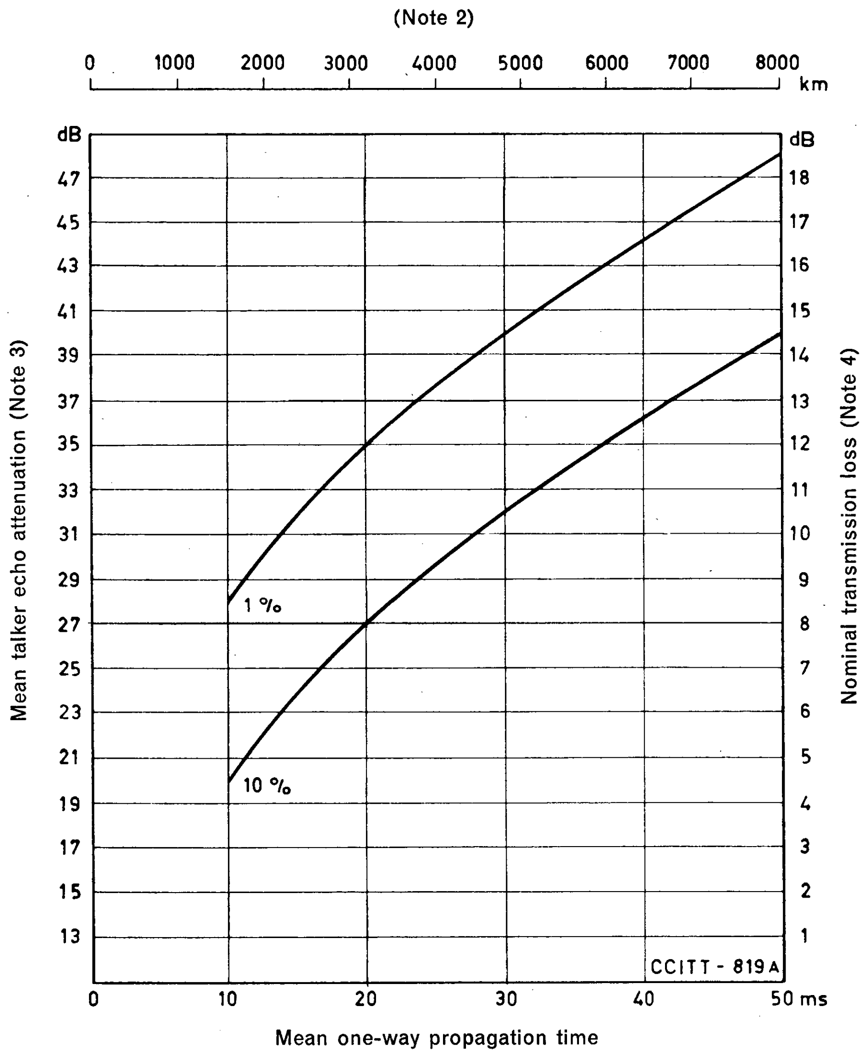
The main circuits of a modern telephone network providing international communications are high-velocity carrier circuits on symmetric or coaxial pairs or radio-relay systems and echo suppressors are not normally used except on connections involving very long international circuits. There is often no 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/G.131 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 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 with a standard deviation of 3 dB.



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

Note 2. — The distance scales assume a velocity of propagation of 160 km/ms.

Note 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.

Note 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 values 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.

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

FIGURE 2/G.131. — **Echo tolerance curves**

In the case of international circuits reserved for traffic between terminal countries (see the Appendix to Section 1 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 nominal transmission loss:	0.5 dB
between 500 and 1000 km nominal transmission loss:	1.0 dB

and 0.5 dB for every additional 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.

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, of this volume. 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.) Compatibility with signalling systems for the switched telephone service is ensured by Recommendation Q.115 (*Green Book*, Volume VI).

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. However, each half-echo suppressor should be located sufficiently near to the respective subscribers for the end delays not to exceed the maximum value recommended in Recommendation G.161, B, b. For countries of average size, this will normally mean that the originating and terminating half-echo suppressors will be in the countries of origin and destination of the call.

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.

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.)

Where a terminating international exhange is accessible from an originating international exchange by more than one route, and

1) at least one route requires echo suppressors, and at least one route does not; and

2) the originating exchange is unable to determine which route is to be used;

echo suppressors should be connected in all cases.

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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.

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 no 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.

Whichever method is used, due regard must be paid to the last sentence of section B, a above. Methods of achieving the required reduction of circuit losses are under study by the C.C.I.T.T. 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 and at Geneva, 1972)

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/G.132, 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 are such that for a chain of 6 circuits (international and national extensions) in tandem, each circuit being equipped with one pair of channel translating equipment, the attenuation distortion would in most cases be less then 9 dB between 300 and 3400 Hz. For the case of 12 circuits in tandem it can be expected that in most cases the attenuation distortion will not exceed 9 dB 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.

Note 4. — Studies are carried out by Study Group IV and Study Group XVI about how well this objective is being met in practice, about the expectation with which it should be met in future (taking account of Note 2) and about any possible consequential need for modifications to recommendations referring to equipments.

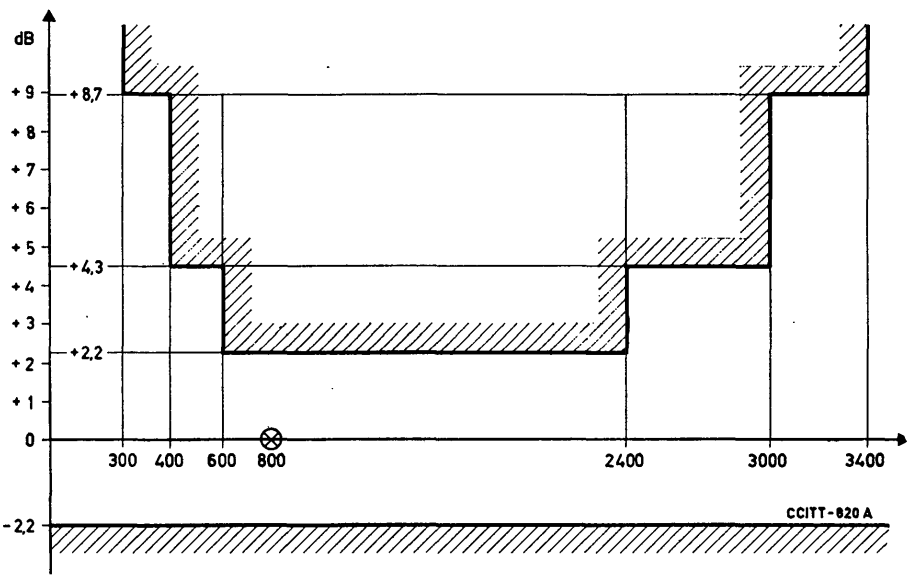

FIGURE 1/G.132. — **Permissible attenuation variation with respect to its value measured at 800 Hz (objective for world-wide four-wire chain of 12 circuits in terminal service)**

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:

	Lower limit of frequency band (ms)	Upper limit of frequency band (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 (*Green 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 Q.45 as regards international centres.

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 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 [2]:

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

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[1] Recommended methods for the measurement of crosstalk are described in the Annex to this Recommendation.

[2] 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 Supplement No. 2.4 to Volume IV of the *Green Book*.

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.

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/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.

[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) (New Delhi, 1970).

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 and at Geneva, 1972)

TRANSMISSION LOSSES, RELATIVE LEVELS AND ATTENUATION DISTORTION

A. Conventions and definitions

a) *Relative level 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:

sending:	−3.5 dBr
receiving:	−4.0 dBr.

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

Note 1. — See the definitions in section b. The position of the virtual switching points is shown in Figure 2/G.101, and in Figure 1/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 difficulty.

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*

The C.C.I.T.T. 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 Recommendations M.64, B and M.58 (*Green Book*, Volume IV), are included for information. Further explanation is given in the Annex to this Recommendation.

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 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, are such 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 in most cases meet the limits of Figure 1/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 6 and 21 dB (with a mean of about 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 (*Green 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 and at Geneva, 1972)

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 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).

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 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 1. — Noise objectives for maintenance purposes are the subject of Recommendation M.58, *Green Book*, Volume VI. Table D of that Recommendation is reproduced below:

TABLE D

(of Recommendation M.58)

Maintenance noise objectives for public telephone circuits

Distance (km)	<320	321 to 640	641 to 1600	1601 to 2500	2501 to 5000	5001 to 10 000	10 001 to 20 000
Noise (dBm0p)	−55	−53	−51	−49	−46	−43	−40

Note 2. — 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. See also Recommendation M.58, Note 1.

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 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.

[1] See Figure 1/G.103.

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* [1]

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.

B. Use of syllabic compandors [2]

The limit recommended in Section A 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 (at a point of zero relative level on the circuit) no compandor is necessary.

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

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

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

If the circuit noise power level is greater than —36 dBm, 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.[1]

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) for frequency modulation voice-frequency 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 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 bit/s. 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.

b) *Switched connections*

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

[1] See Note 1 of Paragraph A, a above.

1.5 General characteristics of international telephone circuits and national extension circuits

Recommendation G.151 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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 in general 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 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 and in a large number of equipments should not average more than 2 dB (see Graphs No. 2A and No. 2B in Figure 1/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/G.151; to ensure that these limits are respected, equalizers are inserted, if necessary, when the circuits are set up (Recommendation M.58, *Green 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 C.C.I.T.T. transmission plan to international communications.

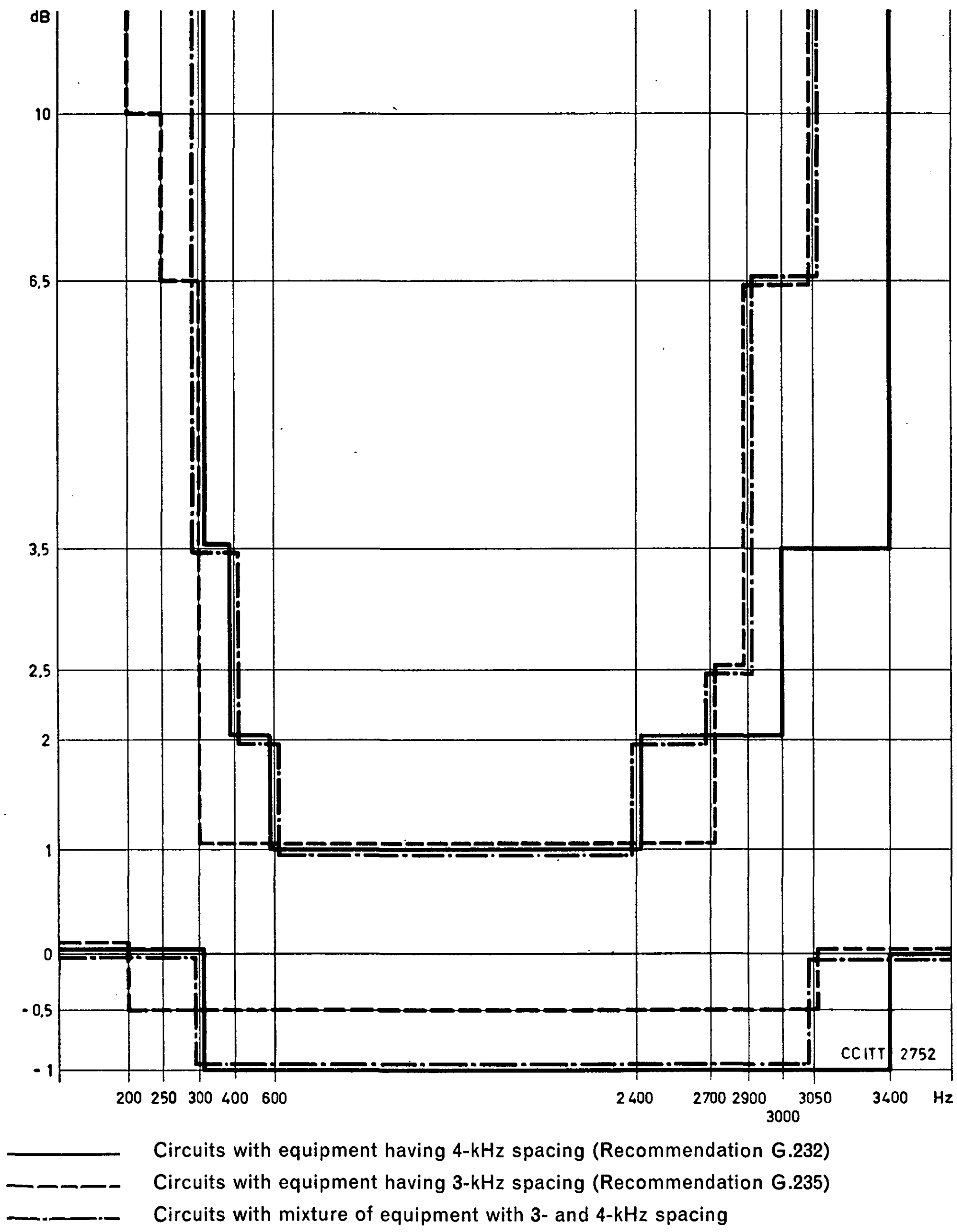


FIGURE 1/G.151. — **Attenuation-frequency characteristics of circuits with 3-kHz and 4-kHz channel equipment**

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. 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 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.

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. 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.

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. (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. 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

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

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 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 equipments just conforming to Recommendation G.232, J, a are used on a circuit comprising three circuit-sections, then assuming rms addition of crosstalk paths the crosstalk ratio would be approximately 60 dB which complies with the limit of a above concerning crosstalk between circuits.

Note 4. — If channel equipments used on a circuit comprising three circuit-sections just comply with Recommendation G.232, J, c, then the least go/return crosstalk ratio, assuming rms addition of the various paths, would be approximately 56 dB which is 2 dB less than is required for speech concentrators in b, 2 above. However, the assumptions are most pessimistic and there is not likely to be any difficulty in practice. The limit for echo suppressor in b, 3 above is complied with.

Note 5. — 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.

G. Interference at harmonics from the mains and other low frequencies

Signals carried by transmission systems are sometimes modulated by interfering signals from mains frequency power supplies, induced voltages caused by railway traction currents and from other sources. This unwanted modulation can take the form of amplitude or phase modulation or a combination of both. This interference may be characterized by the level of the strongest unwanted side component when a sine wave signal is applied with a power of 1mW at the point of zero relative level (0 dBm0) on a telephone circuit. The maximum admissible level of the unwanted side components on a complete telephone circuit should then not exceed −45 dBm0 (i.e. the minimum side component attenuation should be 45 dB). This limit should apply to all low frequency interfering signals up to about 400 Hz.

Note 1. — This level was found to be acceptable for circuits for FM and AM v.f. telegraphy, facsimile transmission, speech, telephone signalling and data transmission.

Note 2. — For limits applicable to sound programme circuits, see new Recommendation J.21, paragraph 3.1.7.

Note 3. — 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.

Note 4. — 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 ± 50, f ± 100, f ± 150 Hz, etc.

Recommendation G.152 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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 ($L \leq 2500$ km), 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 397-2 respectively (Volume IV, Part I, New Delhi 1970).

C. Circuits on open-wire carrier systems

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

Note. — Recommendation M.58 (*Green Book*, Volume IV) deals with noise objectives for maintenance purposes. See Note 1 of Recommendation G.143, A, a.

Recommendation G.153 (Geneva, 1964; amended at Mar del Plata, 1968, and at Geneva, 1972)

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.

Noise objectives or limits [a] for very long circuits providing various services [b]

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).	

[a] 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.

[b] 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 1*bis*, *Green Book*, Volume III.

Note 1. — 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 summarizes these Recommendations).

Note 2. — Recommendation M.58 (*Green Book*, Volume IV) deals with noise objectives for maintenance purposes. See Note 1 of Recommendation G.143, A, a.

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) 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) 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 more than 2500 km 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 (*Green 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 352-1) and the allowable noise power in this reference circuit (C.C.I.R. Recommendation 353-2).

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.).

[1] See footnote 2, at the bottom of page 62.

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 radio transmitters, should not exceed 50 000 pW (level of —43 dBm0p).

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

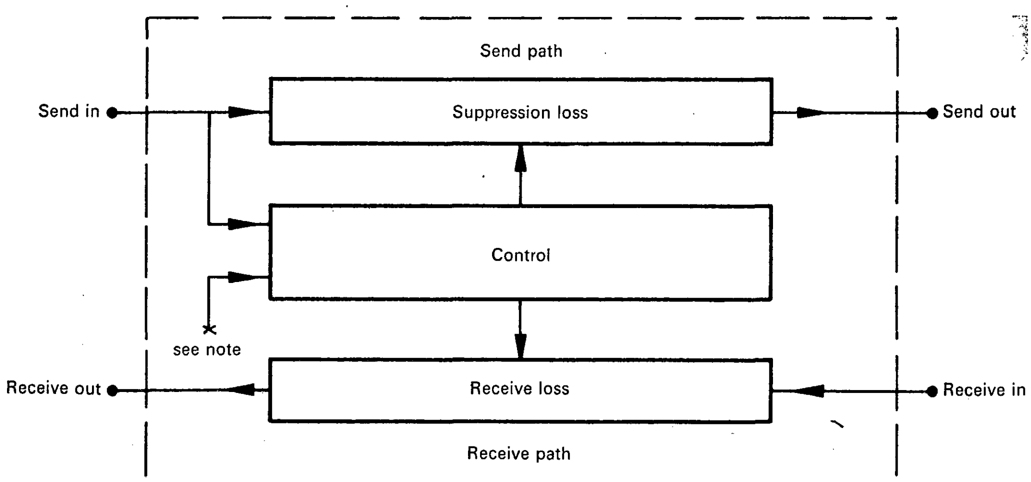
Recommendation G.161 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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

A. Definitions relating to echo suppressors

a) *Echo suppressor* (see Figure 1/G.161)

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.



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

Figure 1/G.161

b) *Full echo suppressor*

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

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/G.161)

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.

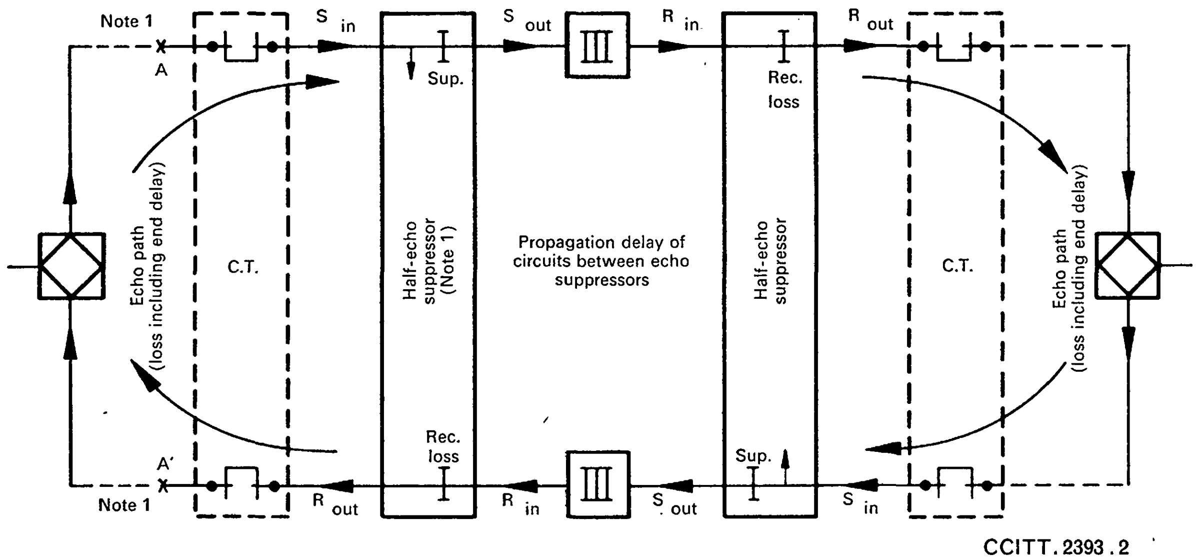
l) *Differential sensitivity*

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



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

FIGURE 2/G.161

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.[1]

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 ms. It should be noted that only on circuits having one-way propagation times less than 50 ms will these old echo suppressors be compatible with the new ones. Thus the following typical arrangements (Figure 3/G.161) 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.

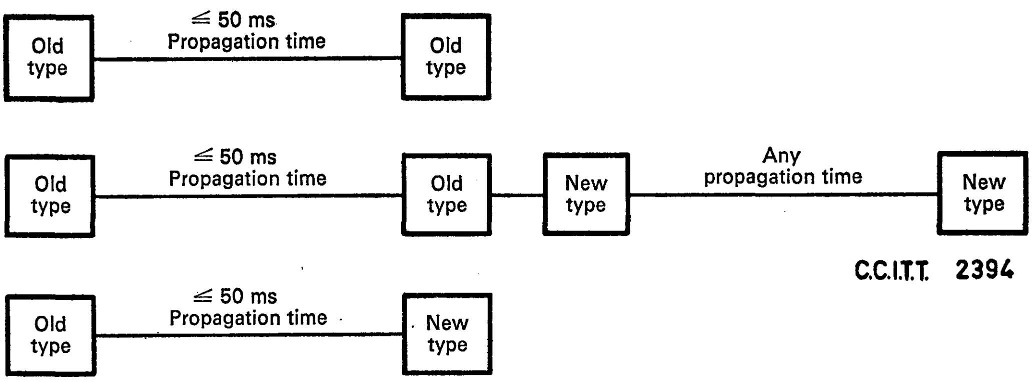


FIGURE 3/G.161. — **Typical arrangements for echo suppressors**

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 ms. For delays longer than this, too much circuit loss is needed to suppress echo, and echo suppressors are required.

[1] The degradation has been studied by COMSAT and its extent determined by objective and subjective tests of six pairs of echo suppressors and an echo canceller. The results of this study are given in Supplement No. 3 to this Volume.

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 performance characteristics apply to both the send and receive paths separately, except as noted. The limits on transmission characteristics specified in paragraphs 1.1 to 1.11 shall be observed over the temperature range +10° C to 40° C and over the power supply variations permitted by individual Administrations.

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 ≤ 0 dBm0.

1.2 *Loss-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 and at 200 Hz, within the range of $(Q + 1.0)$ dB to $(Q - 0.2)$ dB.

1.3 *Delay distortion*

The delay distortion shall not exceed 30 μs measured between any two frequencies in the band 1000-2400 Hz and 60 μs in the band 500-3000 Hz.

1.4 *Impedance*

The values of impedance and return loss shall apply to all states of operation of the echo suppressors.

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 from 300-600 Hz nor less than 25 dB from 600-3400 Hz.

3) The impedance unbalance to earth of each port shall not be less than 50 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 for test tone levels from 0 to +5.0 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*

For frequencies $f_1 = 900$ Hz and $f_2 = 1020$ Hz applied simultaneously each at a level of −5 dBm0, the difference between the output levels of either frequency f_1 or f_2 and the level of either of the intermodulation products at $(2f_1 - f_2)$ or $(2f_2 - f_1)$ should be at least 45 dB. When speech compressors are used to provide loss during double talking this requirement is reduced during the double talking mode to 26 dB.

1.8 *Transient response*

If loss devices which are inserted in the receive path operate at a syllabic rate, the transient performance of such devices should conform to clause g of Recommendation G.162 (which deals with the overall transient response of compandors) that is:

— the attack time should not exceed 5 ms;

— the recovery time should not exceed 22.5 ms.

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*

When an echo suppressor is installed in a working circuit, the crosstalk attenuation between the send path and the receive path (and conversely) shall be such that the signal power in the disturbed path due to crosstalk from the disturbing path shall not exceed −65 dBm0 for any sinusoidal signal in the disturbing path having a power of +5 dBm0 or less and within the band 300-3400 Hz.

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 mV 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/G.161. The significant combinations of input signals are represented by the areas X, Y, Z, W and V.

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

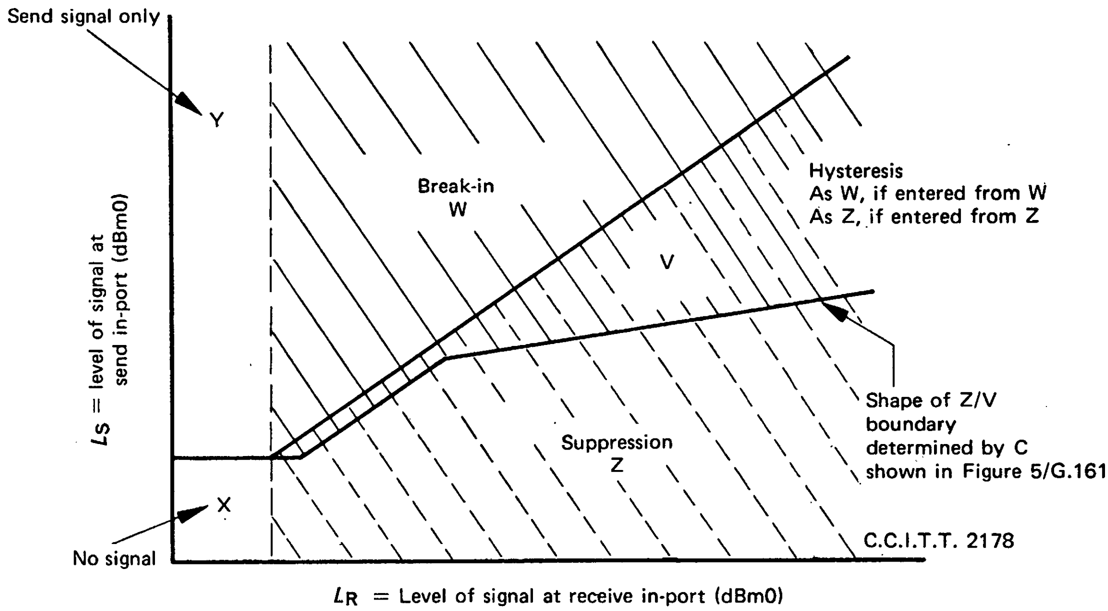


FIGURE 4/G.161. — **Conceptual diagram showing operational states of echo suppressors under ideal conditions**

TABLE 1

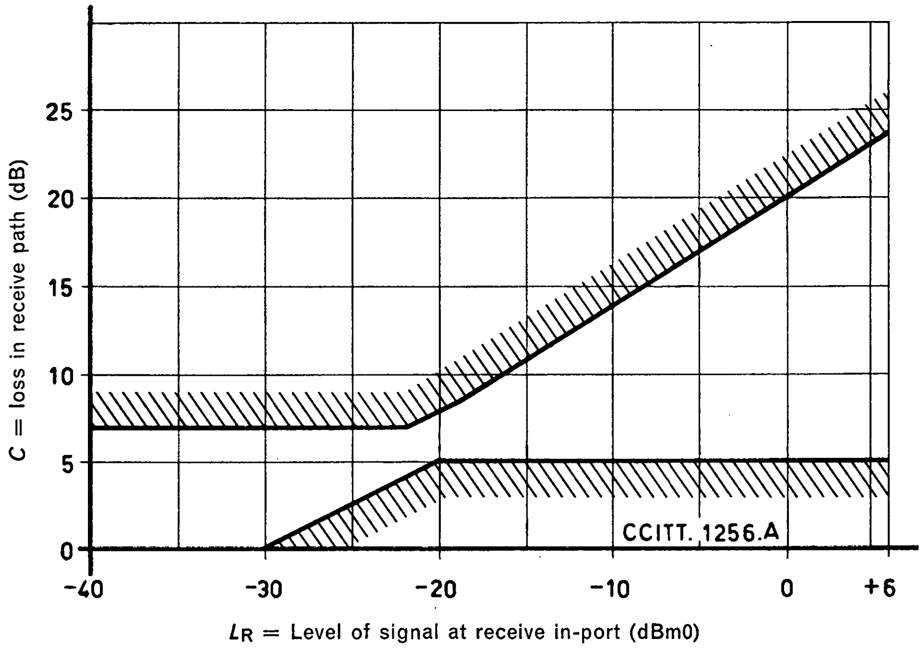
KEY TO OPERATIONAL DIAGRAM FIGURE 4/G.161

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/G.161
Z	50 minimum	0
V	As W if entered from W As Z if entered from Z	

each of the five areas X, Y, Z, W and V is occupied continuously. Figure 5/G.161 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/G.161 and 5/G.161 and in Table 1 applies for steady-state signals with the inter-area boundaries being crossed very slowly.

The features shown in Figure 4/G.161 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 signal levels that define the various thresholds are given in Table 2.



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

FIGURE 5/G.161. — **Recommended loss *C*, to be inserted in receive path during break-in**

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 Z to X	*T*xz *T*zx$_{max}$ *T*zx$_{min}$	$-33 \leqq T$xz $\leqq -29$ For $L_S = -40$ Txz — 0 dB Txz — 3 dB	 *T'*xz = *T*xz ± 1 *T'*xz — 0 dB *T'*xz — 3 dB	Figure 6/G.161
X to Y Y to X	*T*xy *T*yx$_{max}$ *T*yx$_{min}$	$-36 \leqq T$xy $\leqq -29$ For $L_R = -40$ *T*xy — 0 dB *T*xy — 3 dB	*T'*xy = *T*xy ± 1 *T'*xy — 0 dB *T'*xy — 3 dB	Figure 7/G.161
Break-in V to W (previous input Z)	*T*vw	$L_S = L_R \pm 1.5$ dB $(-26.5 \leqq L_R \leqq +4.5)$		*T'*vw = *T*vw ± 1.5 dB between 500 and 3000 Hz (Note 2)
V to Z (previous input W)	*T*vz$_{max}$ *T*vz$_{min}$	*T*vw — *C* dB *T*vw — *C* — 3 dB (Note 1) $(-26.5 \leqq L_R \leqq +4.5)$		*T'*vz = *T*vz ± 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/G.161.

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.

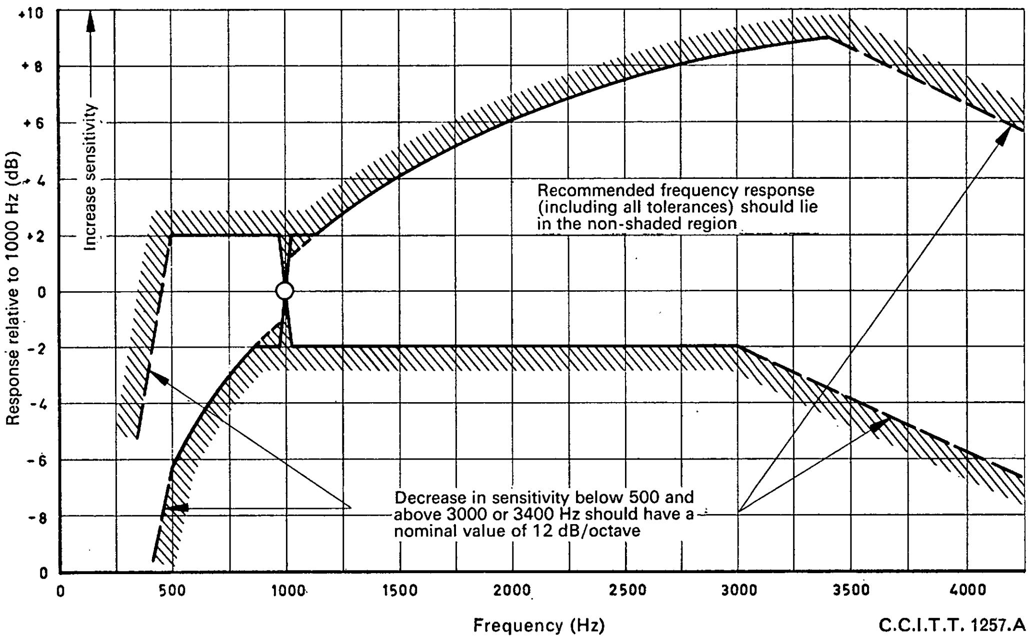


FIGURE 6/G.161. — **Recommended frequency response of suppression control path of echo suppressor**

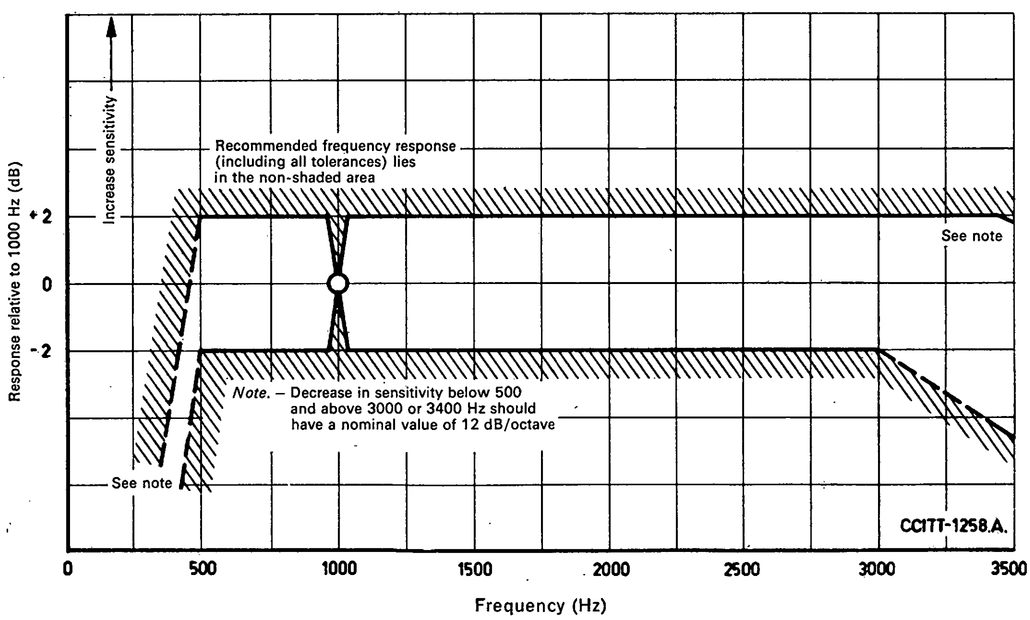


FIGURE 7/G.161. — **Recommended frequency response of each control path of break-in detector of echo suppressor**

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/G.161	14/G.161
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/G.161	16/G.161
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 } Note 3 70 75	5	h ⟶ i g ⟶ i f ⟶ i e ⟶ i	11/G.161 or 12/G.161	15/G.161

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 −40	−25 −11	−40 −40	−40 −40	40 to 75 40 to 75 (Note 2)	4	b ⟶ a d ⟶ a	11/G.161	14/G.161
Break-in W/V/Z L_R constant	−19 − 9	−25 −15	−40 −40	−25 −15	Within range 150 to 350 (Note 1)	6	k ⟶ b j ⟶ c	13/G.161	16/G.161

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/G.161). 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.

The nominal suppression threshold is −31 dBm0 when there is essentially no speech in the send path. The release from suppression is also nominally −31 dBm0 but can be as much as 3 dB below the suppression threshold. When signals above the threshold exist in both the send and receive paths, the intent of the requirement is that the echo suppressor be in the suppress (Z) state if $L_R > L_S$, should transfer to the break-in (W) state for $L_S > L_R$ and should revert to the suppression state for $L_R > L_S + C$. Tolerances are provided to account for filter, power supply and temperature variations.

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/G.161 and 9/G.161). 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.

The suppression (X/Z) operate time should be nearly constant for the sudden application of any signal in the receive path greater than the threshold (−31 dBm0) and less than +4.5 dBm0 (in the absence of any appreciable signal in the send path). Similarly, for transitions from suppression to break-in for L_R constant (Z/V/W), the operate time should be constant and less than 30 ms for the sudden application of a signal in the send path which is greater than the signal in the receive path for the complete range of possible signal pairs (L_R and L_S) not just the two pairs shown in Table 3.

The hangover times shown in Table 4 should obtain whenever suppression or break-in has occurred irrespective of the levels of the causative signals.

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.

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/G.161) 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/G.161)

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 possibly other disabling tones used within national networks). At the same time, the 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/G.161 will permit disabling by the 2100-Hz disabling tone as well as others used in North America. The figure indicates that in the frequency band 2079 Hz to 2121 Hz disabling *must* be possible whilst in the band 1900 Hz to 2350 Hz it *may* be possible.

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 300-3400 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.

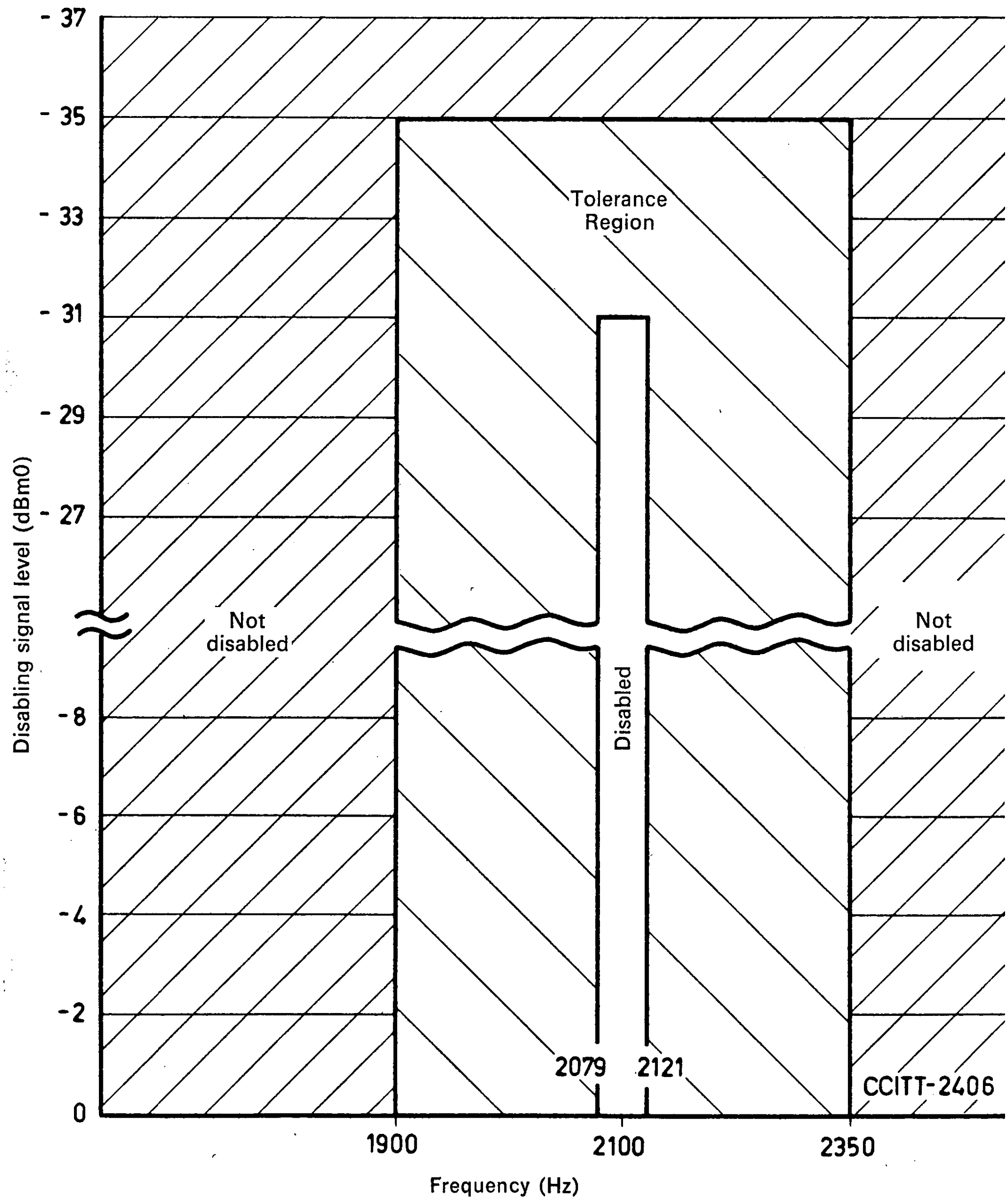


FIGURE 8/G.161. — **Required disabling band characteristics**

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 390-700 Hz having a level of —27 dBm0 or greater, and from 700-3000 Hz having a level of —31 dBm0 or greater. The tone disabler should release for any signal in the band from 200-3400 Hz having a level of —36 dBm0 or less.

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 the sustained 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) *False operation due to speech currents*

It is desirable that the tone disabler should rarely operate falsely on speech. To this end, a reasonable objective is that, for an echo suppressor installed on a working circuit, usual speech currents should not, on the average, cause more than 10 false operations during 100 hours of speech. In addition to the talk-off protection supplied by the disabling channel bandwidth, by guard band operation and by the operate time, talk-off protection can be supplied 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.

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.

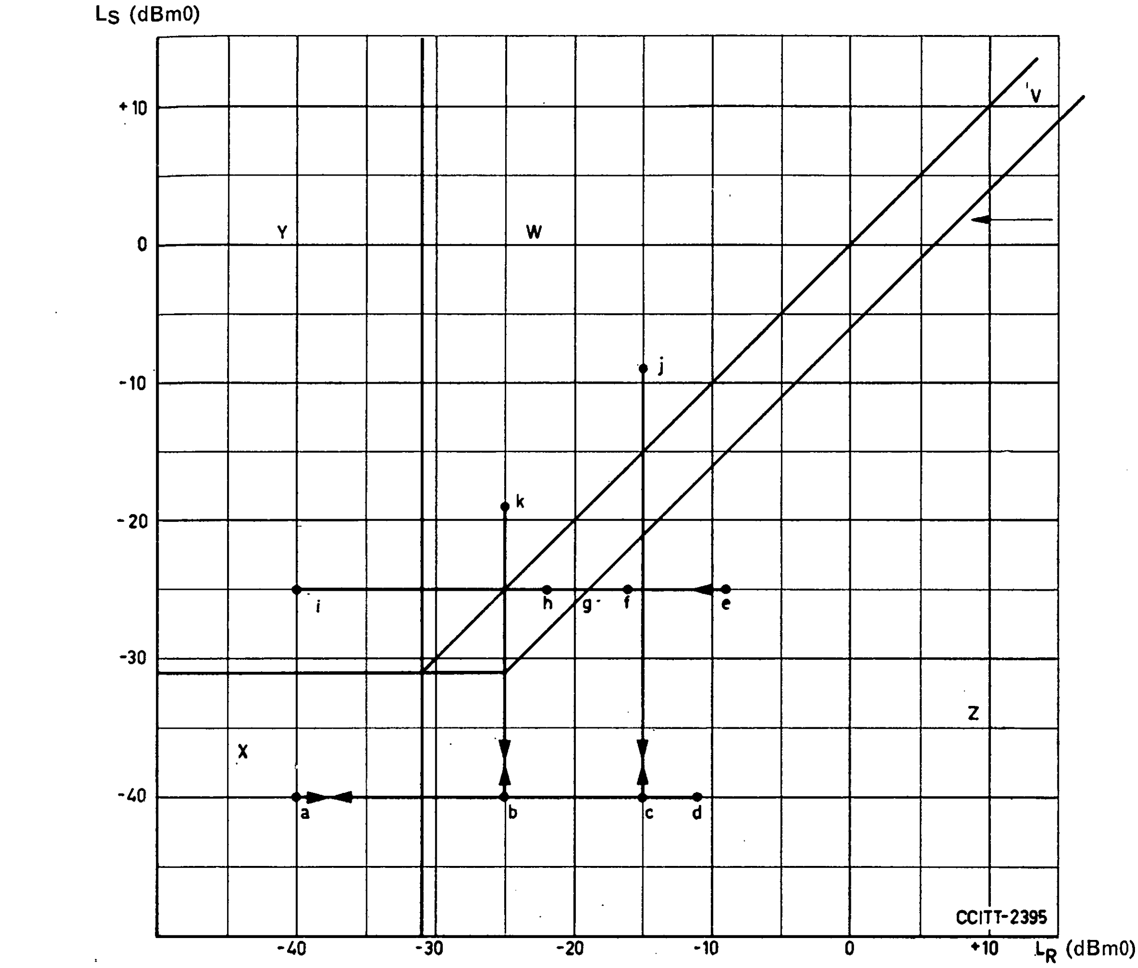
ANNEX

(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/G.161). 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/G.161. — **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/G.161.

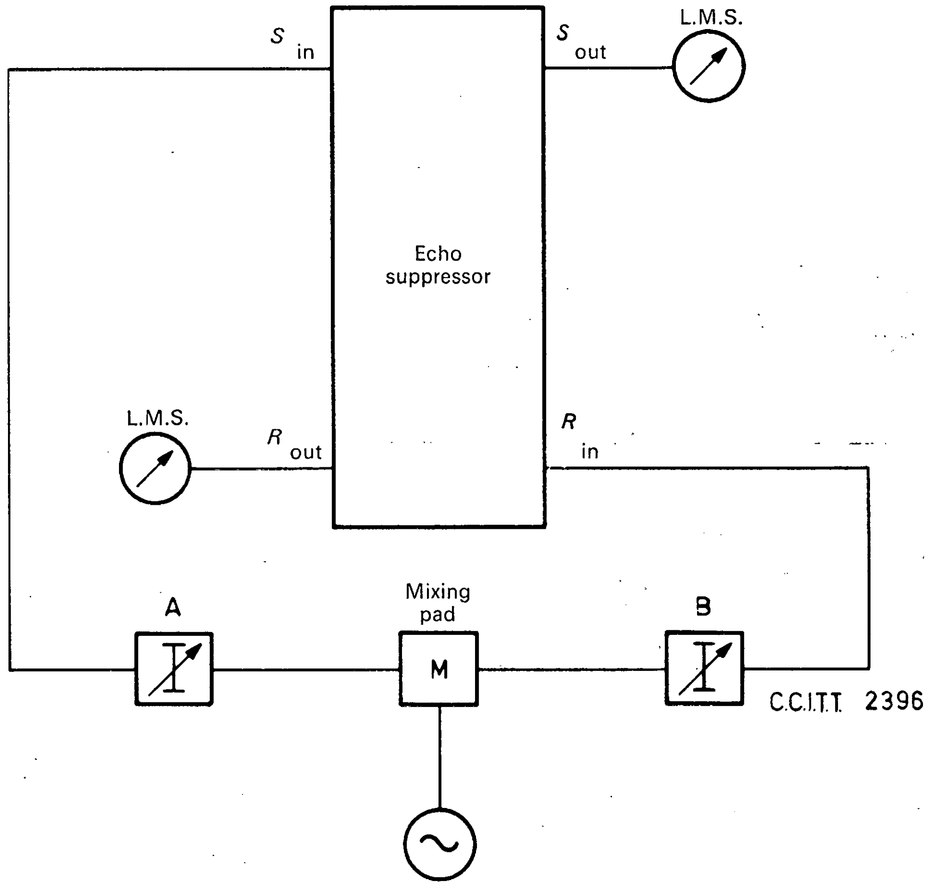


FIGURE 10/G.161. — **Test circuit for measurement of static characteristics**

Test No. 1 — Suppression threshold and loss

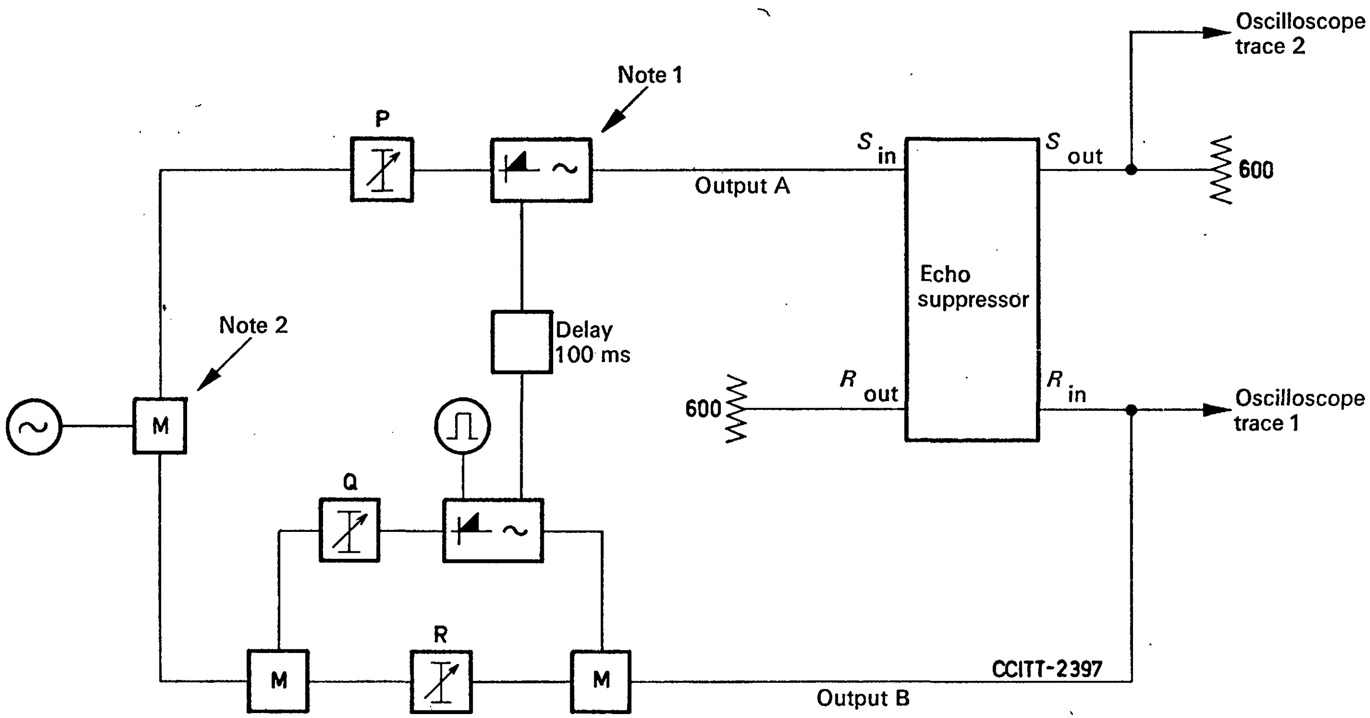
1. Set the oscillator to 1000 Hz.
2. Adjust A so that $L_S = -40$ dBm0.
3. Adjust B so that $L_R = -40$ dBm0.
4. Increase L_R until suppression occurs and note the value of L_R and the suppression loss.
5. Decrease L_R until suppression releases and note the value of L_R.
6. Set the oscillator to appropriate frequencies to check for conformity within the bounds shown in Figure 6/G.161 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.
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/G.161 and repeat steps 2 to 5.

Test No. 3 — Break-in differential sensitivity and receive loss

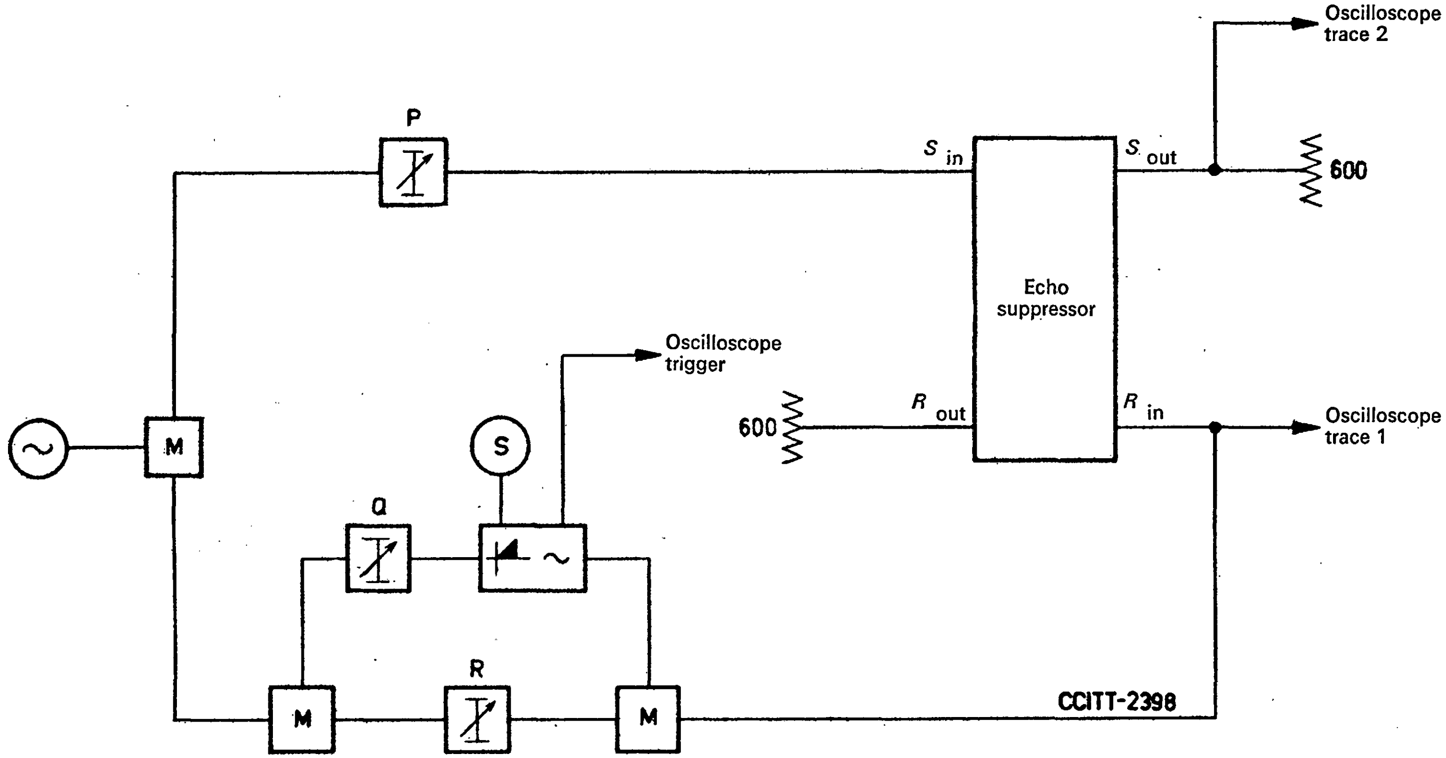
1. Set the oscillator to 1000 Hz.
2. Adjust A so that $L_S = -40$ dBm0.



Note 1. — For suppression operate and hangover times, this modulator is maintained in the conducting state.

Note 2. — *M* denotes mixing pad.

FIGURE 11/G.161. — **Test circuit for measurement of dynamic characteristics (Suppression, X/Y and break-in, Z/V/W/Y, L_S 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/G.161. — **Alternative test circuit for measurement of dynamic characteristics (Break-in, Z/V/W/Y, L_S constant)**

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/G.161 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/G.161 to produce the L_R and L_S values of Tables 3 and 4.
2. Read times as shown in Figure 14/G.161.

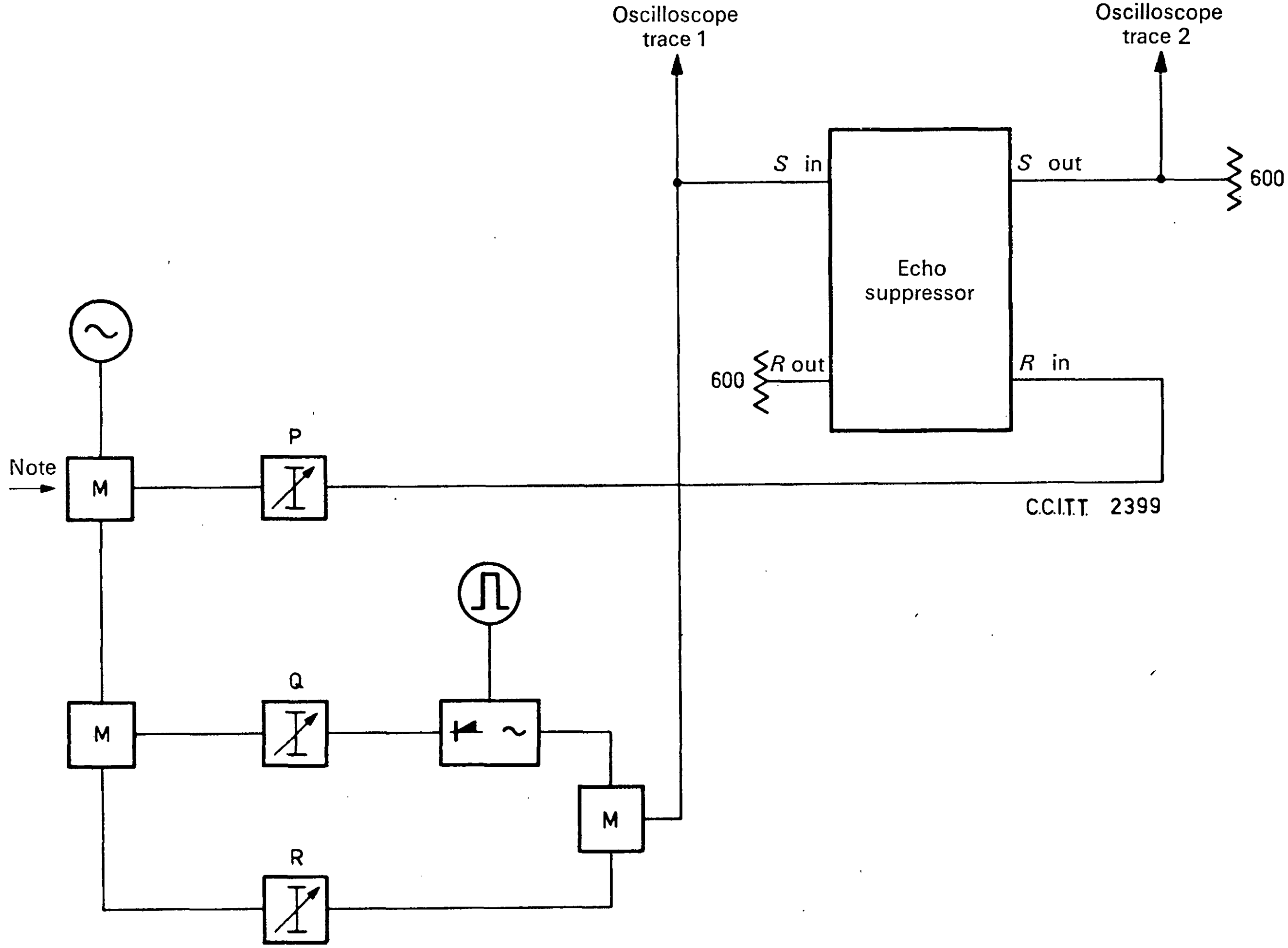
Test No. 5 — Break-in operate time, L_S constant

1. Adjust attenuators P, Q and R shown in Figure 11/G.161 to produce the L_R and L_S values of Table 3.
2. Read times as shown on Figure 11/G.161.

Test No. 5 — Alternative method

The circuit diagram is shown in Figure 12/G.161. 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 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/G.161.
7. Repeat steps 1 to 6 for initial values of L_R given in Table 3.



Note. — *M* denotes mixing pad.

FIGURE 13/G.161. — **Test circuit for measurement of dynamic characteristics (Break-in, Z/V/W, L_R constant)** 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 in Figure 13/G.161 to produce the L_R and L_S values of Tables 3 and 4.
2. Read times as shown in Figure 16/G.161.

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/G.161, 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/G.161: the equipment required comprises the same items as for Test No. 7, together with an adjustable audio-frequency delay device. As an alternative to the use of an adjustable audio-frequency delay device, a variable delay log element can be used in lieu as shown in Figure 19/G.161. 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.
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/G.161 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/G.161) 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.

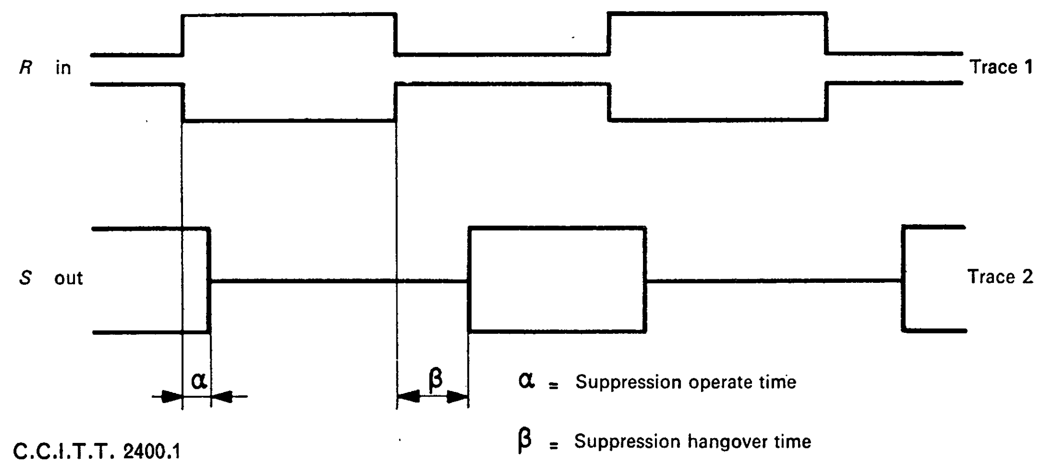


FIGURE 14/G.161. — **Trace for suppression operate and hangover times**

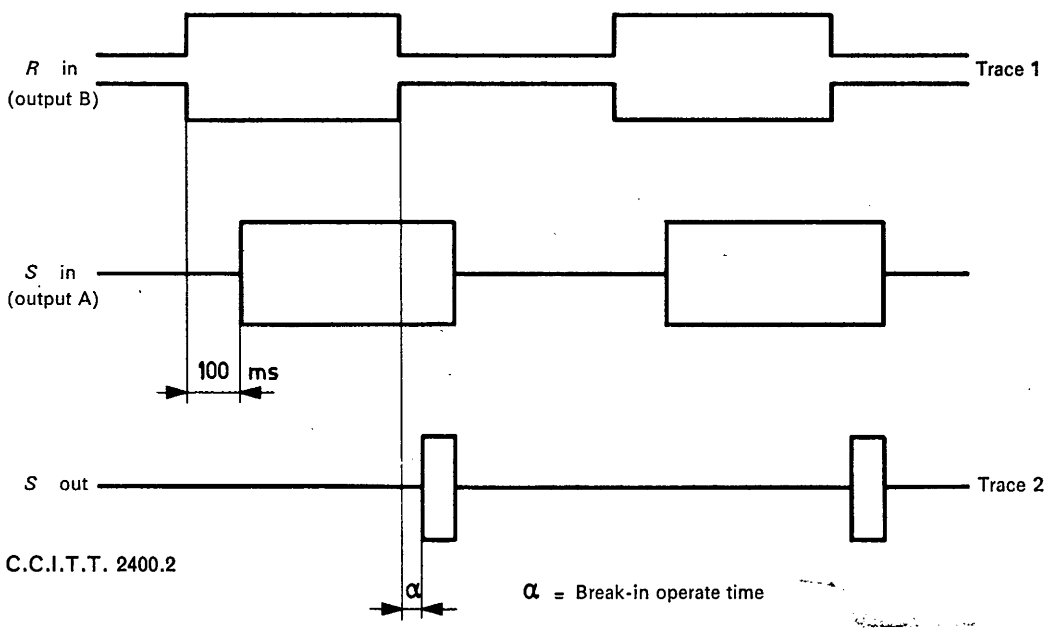


FIGURE 15/G.161. — **Trace for break-in operate time, L_S constant**

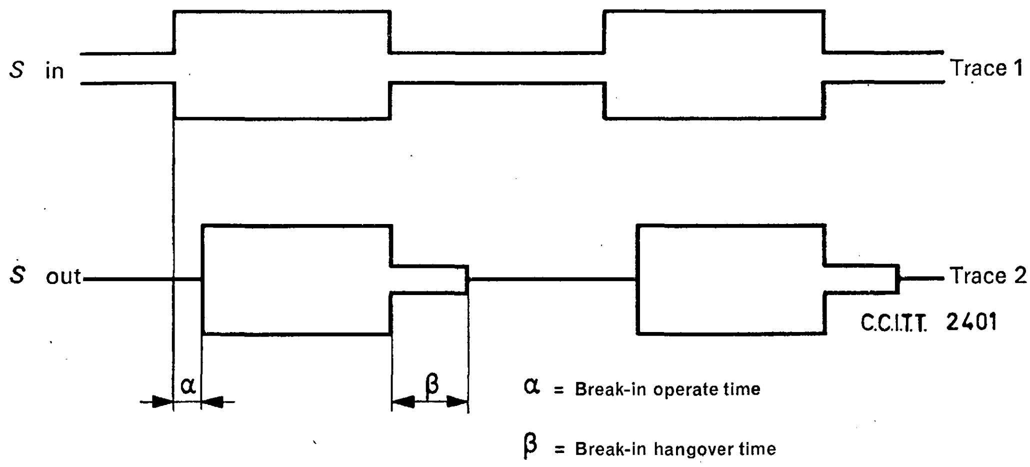


FIGURE 16/G.161. — **Trace for break-in operate and hangover times, L_R constant**

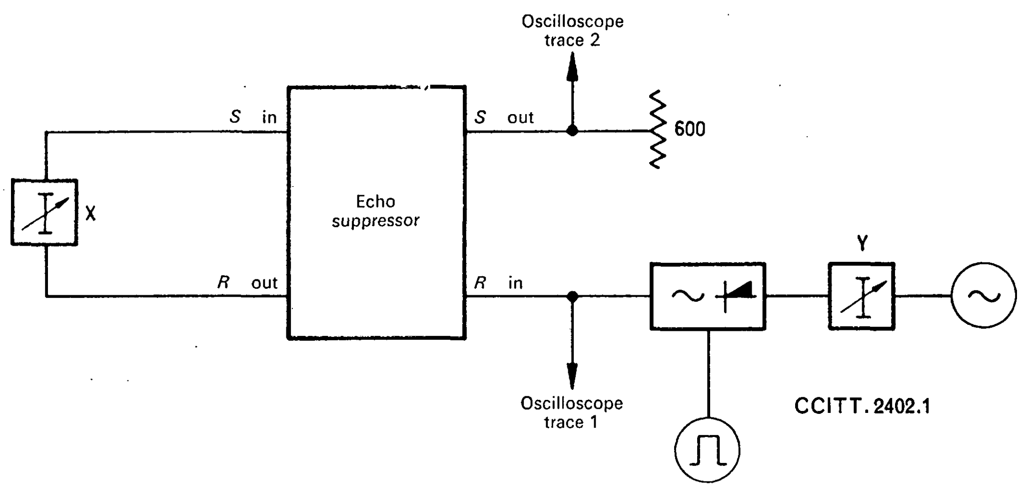
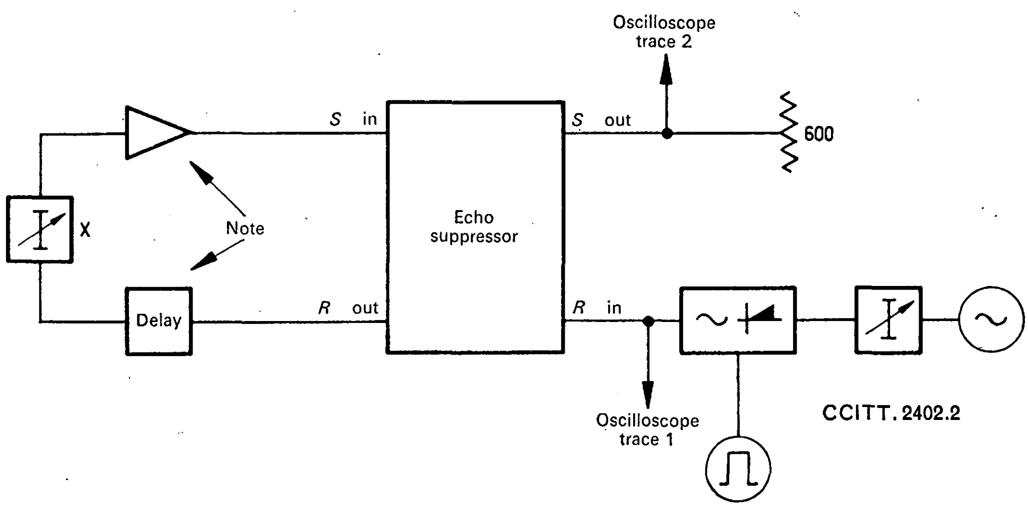


FIGURE 17/G.161. — **Test circuit for false break-in with no end delay**



Note. — Basic loss of the delay device may be compensated or allowed for in the setting of X.

FIGURE 18/G.161. — **Test circuit for false break-in with end delay present**

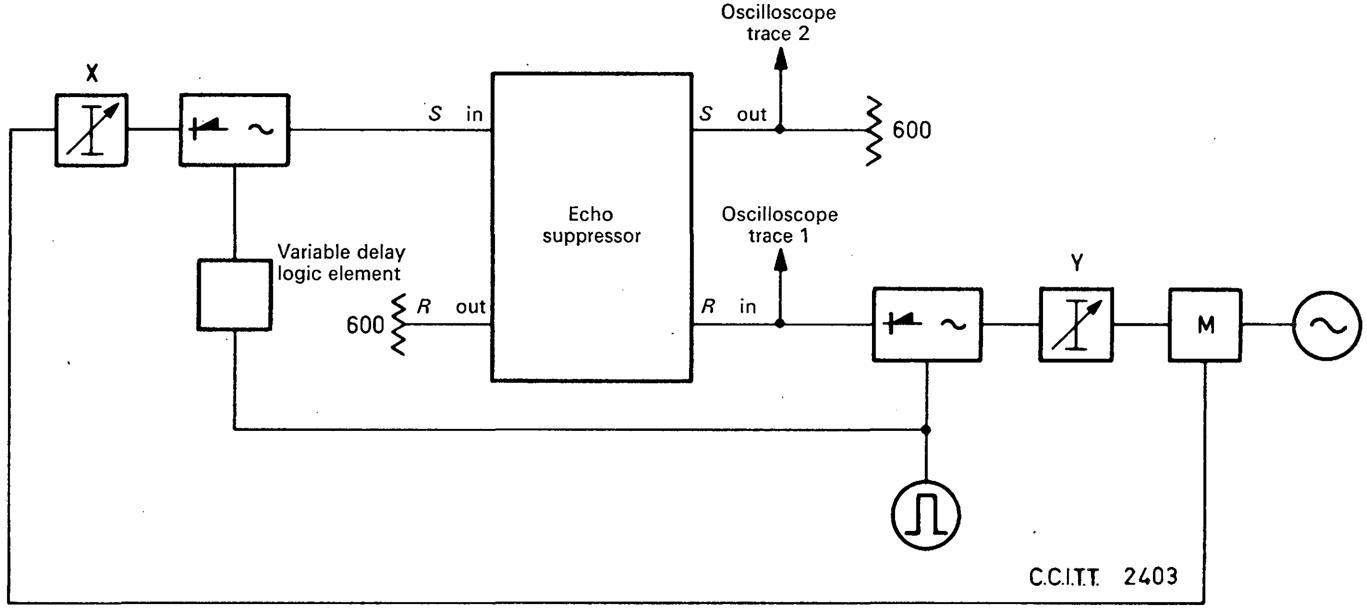


FIGURE 19/G.161. — **Alternative test circuit for false break-in with end delay present**

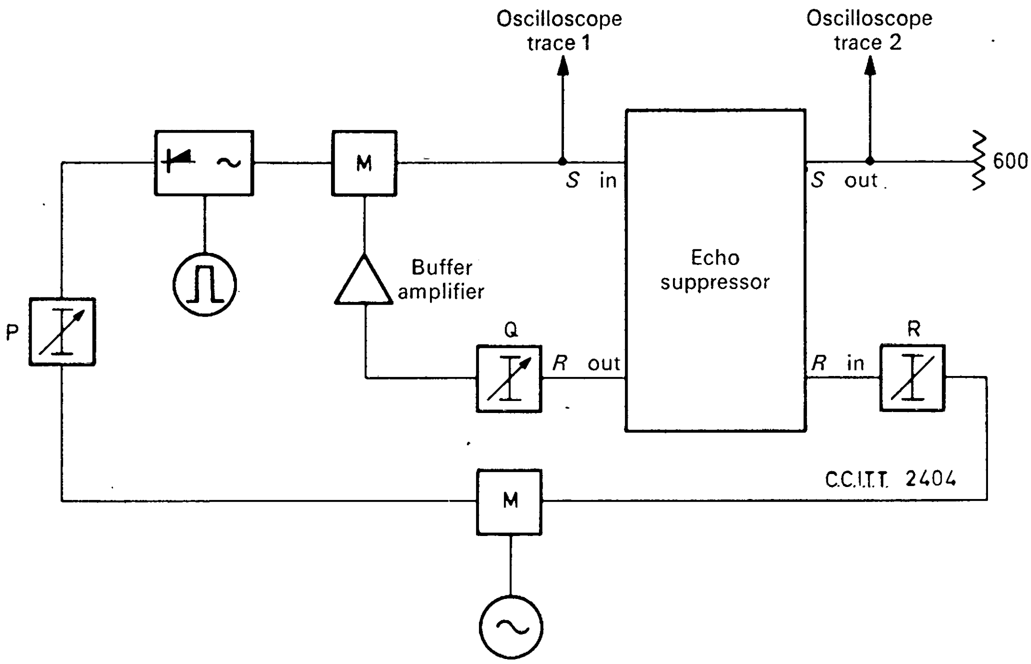


FIGURE 20/G.161. — **Test circuit for false retention of break-in due to provision of excessive hysteresis**

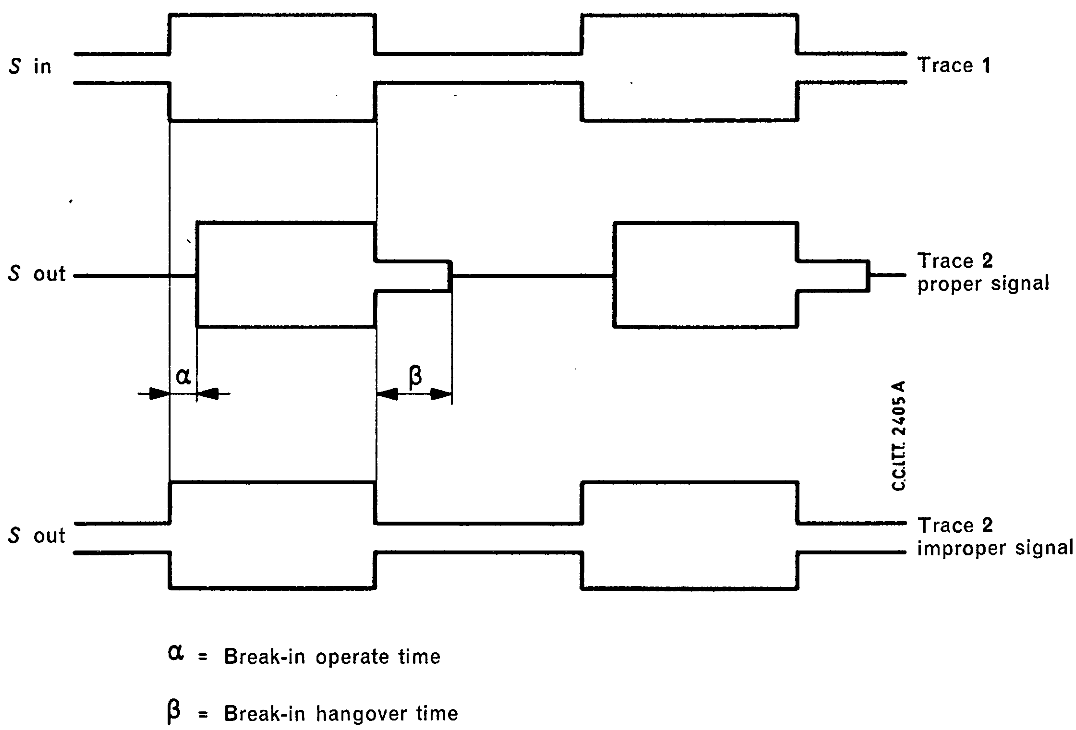


FIGURE 21/G.161. — **Traces for false retention of break-in due to provision of excessive hysteresis**

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 cooperation 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. 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. 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 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.

b) *Ratio of compression and expansion*

1. *Definition and preferred value of the ratio of compression.* — The ratio compression of a compressor is defined by the formula:

$$\alpha = \frac{n_e - n_{e0}}{n_s - n_{s0}}$$

where: n_e is the input level;
n_{e0} is the input level corresponding to 0 dBm0;
n_s is the output level;
n_{s0} is the output level corresponding to an input level of n_{e0}.

The preferred value of α 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;
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 to −45 dBm0 at the input of the compressor and
from +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, should not vary from its nominal value by more than ± 0.5 dB 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, should not vary from its nominal value by more than ±1 dB 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. 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/G.162 shows, as a function of level of 800 Hz input signal to the compressor, the permissible limits of difference between expander 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.

Note. — The change of gain (or loss) of 2 dB 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).

The return loss with respect to the nominal impedance of the input and the output of both the compressor and the expander should be no less than 14 dB over the frequency range 300 to 3400 Hz and for any measurement level between +5 and −45 dBm0 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

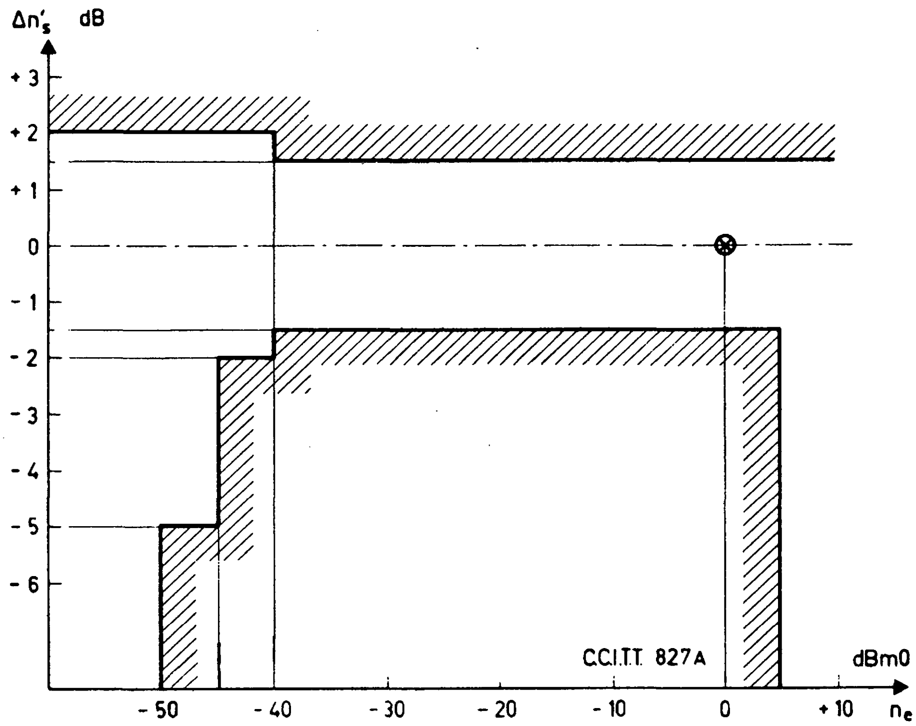


FIGURE 1/G.162

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 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 1/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.

The 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.

For the expander, under the same conditions of measurement, the limits can be deduced from the figure 1/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, 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 $(2f_1 - f_2)$ and $(2f_2 - f_1)$, 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 and the second in which they are each at a level of −15 dBm0. These levels are to be understood to be at the input to the compressor or at the output of the expander (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 $(2f_1 - f_2)$ or $(2f_2 - f_1)$.

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 for the compressor and the expander separately.

Note 1. — These values seem suitable for 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 voltages*

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)
	(7 mV	weighted	−41 dBm0p)
at the output of the expander	(0.5 mV	weighted	−84 dBm0p)

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 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 for attack, and from −4 to −16 dBm0 for recovery. The envelope of the expander output is observed. The overshoot (positive or negative), after an upward 12-dB 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 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 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 permissible limits shall be not greater than:

— 5 ms for attack,
— 22.5 ms for recovery.

The following additional test shall be used 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 sinusoidal 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.

Provided the measurement is effected with an interval at of least 50 ms between the pulses, the limits shown by an unbroken line in Figure 2/G.162 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 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 should be applied to its input for measurement of the attack time, and from −2 to −8 dBm0 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.

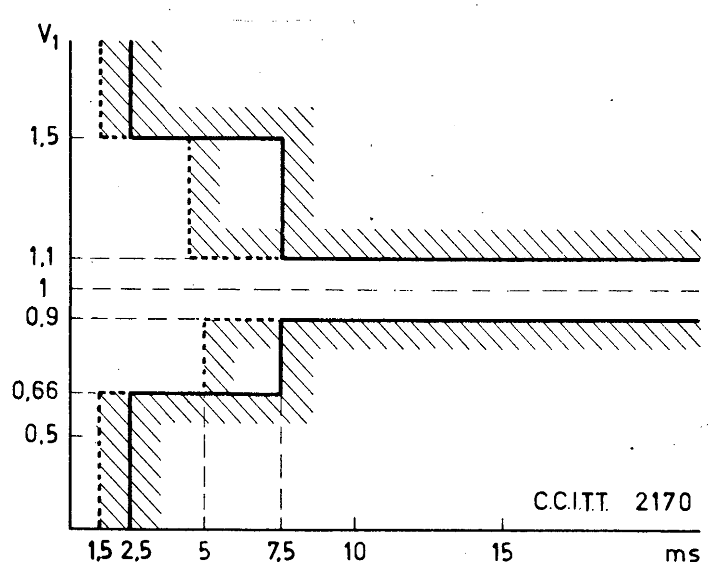


FIGURE 2/G.162

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, *Green Book*, Volume VI.

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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 *Green 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 concerned may make suitable arrangements to connect these circuits. Similarly, the method of connection between a national and international circuit may be chosen by Administrations, 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. 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 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, 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.

The reference equivalent of the national sending system (from the ends of the international circuit) should not exceed 18.2 dB.

The reference equivalent of the national receiving system (from the ends of the international circuit) should not exceed 13 dB.

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 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 should allow for the fact that it is possible to have variations of about 3 dB 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 (40 dB 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	International circuit disconnected	International circuit connected	Subscriber's line disconnected	Subscriber's line connected
21.8 dB	28.7 dB	22.2 dB	25.7 dB	30.9 dB	34.4 dB

Note. — To ensure that the limits indicated for reference equivalents are not exceeded, Administrations 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 at Geneva, 1964, at Mar del Plata, 1968 and at Geneva, 1972)

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 equipments*

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 mastergroup 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 five basic groups B into the basic supergroup and vice versa;

[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.

— supergroup-translating equipment for translating five basic supergroups into the basic mastergroup and vice versa;

— mastergroup-translating equipment for translating three 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/G.211, 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/G.211, 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".

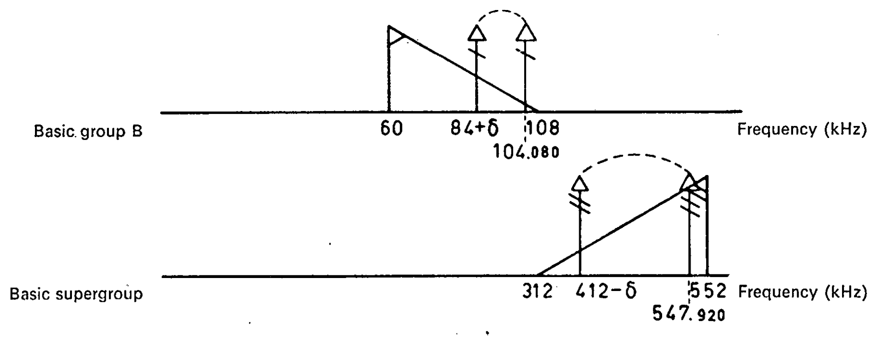
b) *Through-connection filters*

Through group, supergroup, etc., filters and direct through-connection filters (see Recommendation G.242).

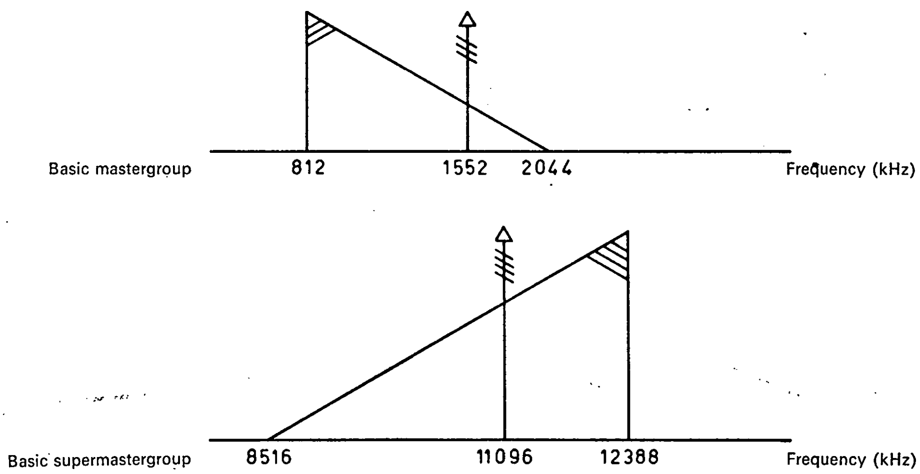
The equipment listed under a and b above can be interconnected for setting-up long groups, supergroups, etc., over several carrier systems. An example of such a link is shown in Figure 2/G.211 together with the expressions defined below that are recommended for describing the various parts of a circuit on such a group or supergroup, etc.

Figure 3/G.211 refers to definitions 2 to 11.

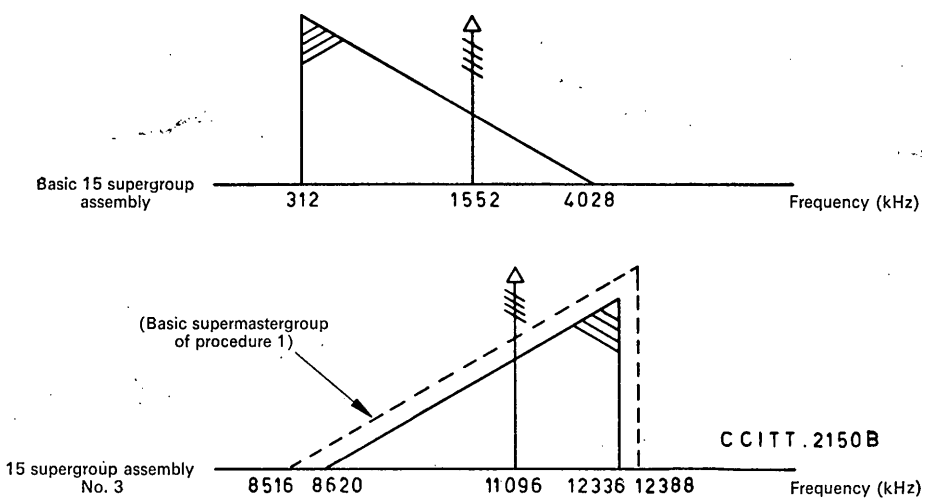
Those of the following definitions that concern "links" or "sections" apply, unless otherwise stated, to the combination of both directions of transmission. A distinction between the two directions of transmission may, however, be necessary in the case of unidirectional, multiple-designation "links" or "sections" set up over multiple-destination telecommunication satellite systems.



a) *Frequency bands occupied by basic groups and supergroups*

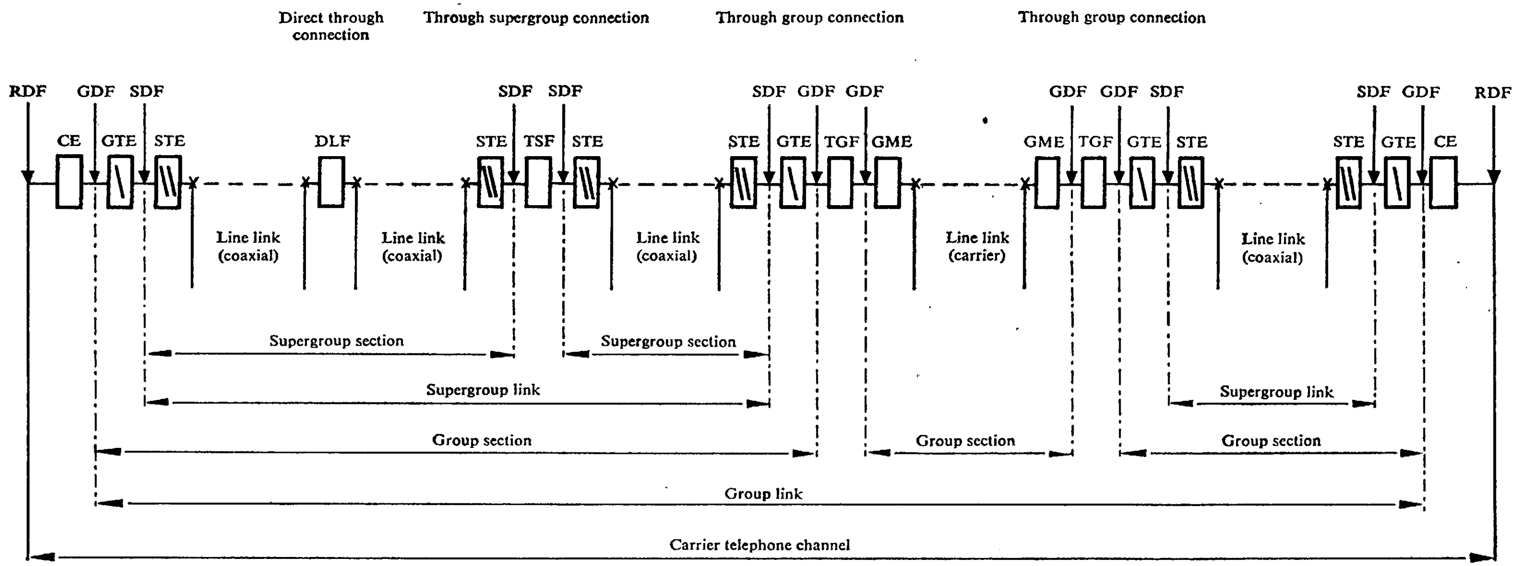


b) *Frequency bands occupied by basic mastergroup and supermastergroup in procedure 1 (mastergroup working)*



c) *Frequency bands occupied by basic 15-supergroup assemblies and by 15-supergroup assembly No. 3*

FIGURE 1/G.211. — **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**



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 and vice versa)
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/G.211

1. *Line link (using symmetric pairs, coaxial pairs, etc.)* (liaison en ligne)

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.

Within the link there are no direct filtration points nor any through-connection points for groups, supergroups, etc., and the ends of the link are the points at which the band of line frequencies is changed in some way or other.

2. *Group link* (liaison en groupe primaire)

The whole of the means of transmission using a frequency band of specified width (48 kHz) connecting two terminal equipments, for example channel translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on group distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more group sections.

3. *Supergroup link* (liaison en groupe secondaire)

The whole of the means of transmission using a frequency band of specified width (240 kHz) connecting two terminal equipments, for example group translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on supergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more supergroup sections.

4. *Mastergroup link* (liaison en groupe tertiaire)

The whole of the means of transmission using a frequency band of specified width (1232 kHz) connecting two terminal equipments, for example supergroup translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on mastergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more mastergroup sections.

Note. — As translating procedure 2 described under a does not enable mastergroups to be set up, the "mastergroup link" concept applies only in procedure 1.

5. *Supermastergroup link* (liaison en groupe quaternaire)

The whole of the means of transmission using a frequency band of specified width (3872 kHz) connecting two terminal equipments, for example mastergroup translating equipments, wideband sending and receiving equipments (modems, etc.). The ends of the link are the points on supermastergroup distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more supermastergroup sections.

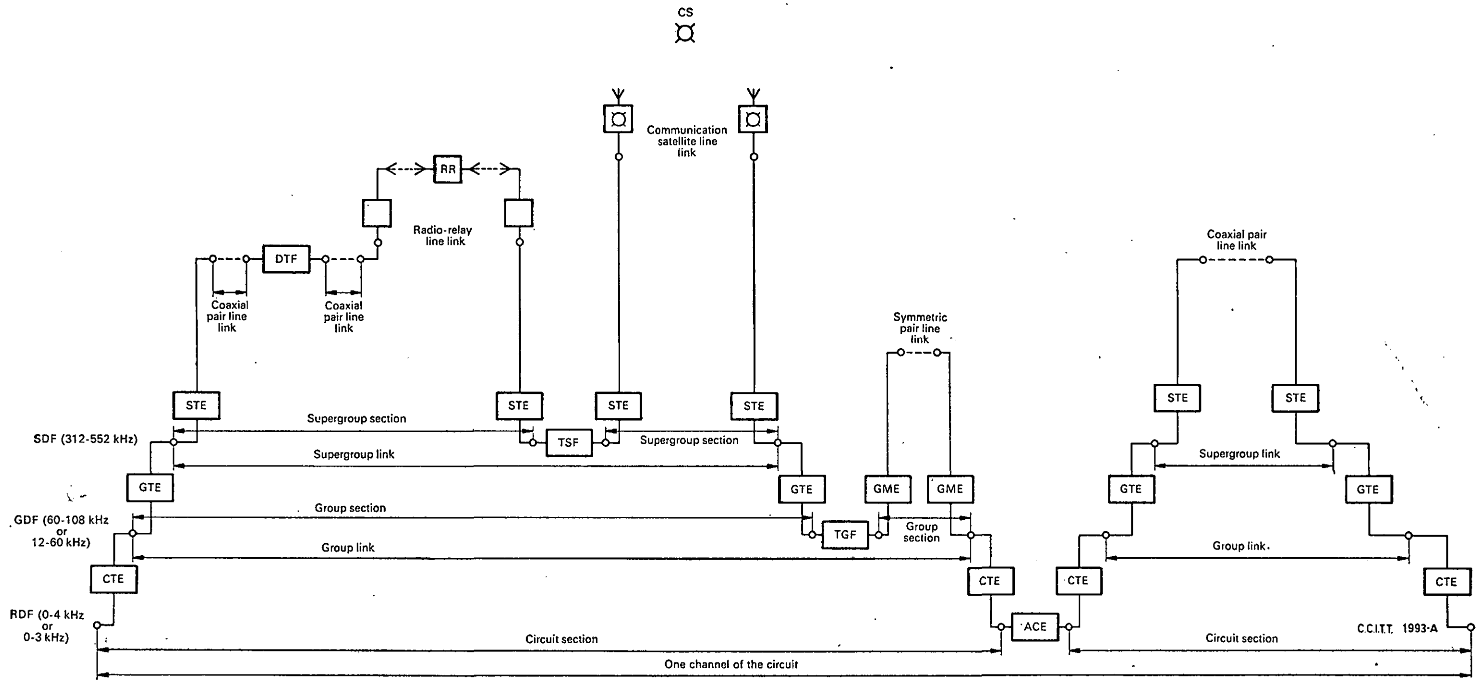
Note. — As the frequency band occupied by 15-supergroup assembly No. 3 (8620 to 12 336 kHz) lies within the frequency band occupied by the basic supermastergroup (8516 to 12 388 kHz), the basic supermastergroup link can transmit one supermastergroup or an assembly of 15-supergroups.

6. *15-supergroup assembly link* (Liaison en assemblage de 15 groupes secondaires)

The whole of the means of transmission using a frequency band of specified width (3716 kHz) connecting two terminal equipments (supergroup modems permitting the setting-up of a 15-supergroup assembly). The ends of the link are the points on 15-supergroup assembly distribution frames (or their equivalent) to which the terminal equipments are connected.

It can include one or more 15-supergroup assembly sections.

Note. — The notion of "15-supergroup assembly" link relates to translating procedure 2 mentioned in a at the beginning of this Recommendation. It is the equivalent of the "supermastergroup link" concept of the translating procedure 1 (900 telephone channels).



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 or vice versa)

STE — Supergroup-translating equipment (translation of the basic supergroup into the line frequency on coaxial cable, or radio-relay system or vice versa)

CS — Communication satellite

GME — Group-modulating equipment

TSF — Through-supergroup filter

TGF — Through-group filter

RDF — Repeater distribution frame

GDF — Group distribution frame

SDF — Supergroup distribution frame

RR — Radio-relay system

DTF — Direct transfer filter

FIGURE 3/G.211. — **Channel of a group set-up on several systems in tandem**

7. *Group section* (section de groupe primaire)

The whole of the means of transmission using a frequency band of specified width (48 kHz) connecting two consecutive group distribution frames (or equivalent points) via at least one line link.

8. *Supergroup section* (section de groupe secondaire)

The whole of the means of transmission using a frequency band of specified width (240 kHz) connecting two consecutive supergroup distribution frames (or equivalent points) via at least one line link.

9. *Mastergroup section* (section de groupe tertiaire)

The whole of the means of transmission using a frequency band of specified width (1232 kHz) connecting two consecutive mastergroup distribution frames (or equivalent points) via at least one line link.

Note. — As translating procedure 2 described in a does not enable mastergroups to be set up, the "mastergroup section" concept applies only in procedure 1.

10. *Supermastergroup section* (section de groupe quaternaire)

The whole of the means of transmission using a frequency band of specified width (3872 kHz) connecting two supermastergroup distribution frames (or equivalent points) via at least one line link.

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 section* (section d'assemblage de 15 groupes secondaires)

The whole of the means of transmission using a frequency band of specified width (3716 kHz) connecting two consecutive 15-supergroup assembly distribution frames (or equivalent points) via at least one line link.

Note 1. — Same note as for definition 6 above.

Note 2. — 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 interconnection 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 multi-channel 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 or C.C.I.R. Recommendations 391 and 392);
2) On tropospheric-scatter radio-relay systems (see C.C.I.R. Recommendation 396-1);
3) For satellite systems (see C.C.I.R. Recommendation 352-1).

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, these hypothetical reference circuits for telephony can be used to study not only the case 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 [2] 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:

$$\text{psophometric power} = \frac{(\text{psophometric e.m.f. in mV})^2}{0.0024} \ (\text{pW}).$$

Recommendation G.213 (Geneva, 1964; amended at Mar del Plata, 1968 and at Geneva, 1972)

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

[1] With the exception of the hypothetical reference circuit for satellite systems.

[2] The number is not specified for the tropospheric-scatter radio-relay systems.

paragraphs and the C.C.I.R. has adopted the same definitions when preparing its Recommendation 380-2 (see also Recommendation G.423).

a) *Definitions of telephony input and output points for the line link* [1]

These are points (marked *T* and *T′* in Figure 1/G.213) located in principle in a main repeater [1] station where the standard conditions given below are found at the input and output of a 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 [2], according to whether the station is at the end of a regulated-line section or not.[3]

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 381-2 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 poisitions 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/G.213 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).

[1] See definitions of Recommendation G.211.

[2] The recommended suppression attenuations are given in Recommendations G.242 and G.243.

[3] 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 381-2) and hence all these pilots are suppressed at that point.

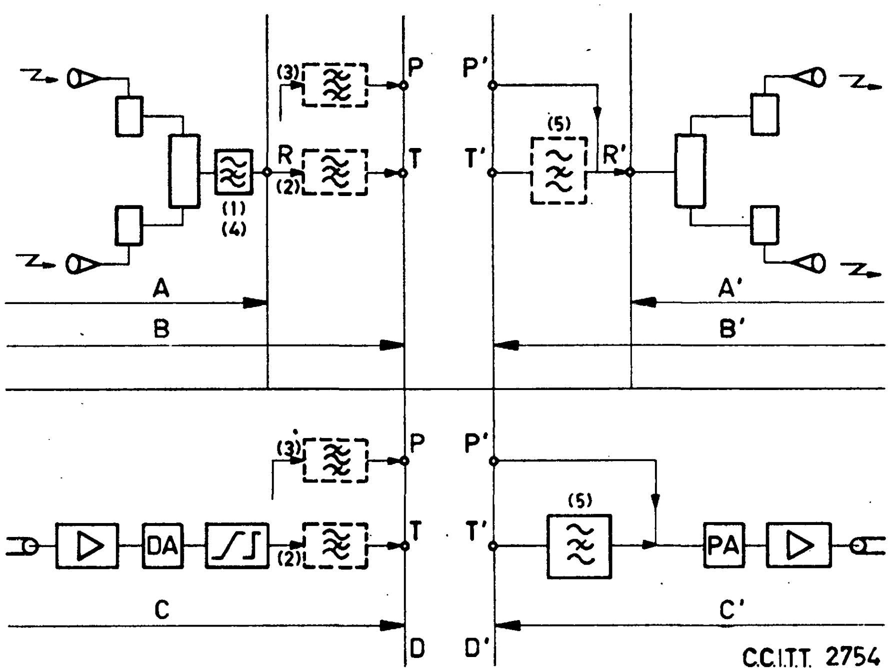
4. The levels at points T and T' have been chosen so as to permit the insertion of the various direct through connecting and translating equipments which may be necessary in the main station. The difference in level between points R and T and between points T' and R' allows for the cabling interconnecting 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.

b) *Definition of the points of international connection at baseband frequencies of a radio-relay system*

The points of international interconnection at baseband frequencies, called R' and R, form the input and output of a radio-relay system, conforming to C.C.I.T.T. Recommendation G.423 and the C.C.I.R. Recommendation 380-2.

At the output of the radio-relay system (point R), the following conditions are found in the baseband:

1. All the telephony groups (groups, supergroups, mastergroups, etc.), and the pilots (line regulating, frequency comparison and monitoring pilots) included in the baseband are assembled in the position in which they are transmitted, as defined in the C.C.I.T.T. and C.C.I.R. Recommendations mentioned above.



A, A'	— radio-relay system
B, B'	— line link by means of radio-relay system
C, C'	— line link by means of cable system
D, D'	— boundary of the high-frequency line equipment
R	— radio-relay system output
R'	— radio-relay system input
Point P'	— provided for possible injection of regulating pilots
Between T and T'	— telephony terminating equipment and/or direct through-connection equipment
DA	— de-emphasis network
PA	— pre-emphasis network

(1) — blocking of continuity pilots and, if necessary, of regulating 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; 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 (B or C, as the case may be).

FIGURE 1/G.213

2. All the continuity and switching pilots and other signals transmitted in a radio-relay system outside the telephony band, inherent to the radio equipment, are suppressed in accordance with C.C.I.R. Recommendation 381-2.
3. Any radio-relay protection switching shall be performed as part of the radio-relay system. With diversity reception, the combined output of the receivers used corresponds to point *R*.
4. Any de-emphasis networks are part of the radio equipment, so that the relative levels of the telephone channels are independent of frequency, within the limits of the tolerances stated in Note 7 of C.C.I.R. Recommendation 380-2 (±2 dB relative to the nominal value).

A similar point *R'* is defined for the baseband input of a radio-relay system, where similar conditions are to be 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/G.213)

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. and the C.C.I.R. for radio systems of corresponding capacity—see Recommendation G.423 and C.C.I.R. Recommendation 380-2).

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*) (dBr)	Sending (point *T'*) (dBr)	
24, 36, 48	150 (bal.)	−23	−36	
60 120	150 (bal.) or 78 (unbal.)	−23	−36	
300	75 (unbal.)	−23	−36	
600, 960, 1200, 1260	75 (unbal.)	−23 or −33	−36 or −33	Note 1
2700	75 (unbal.)	−33	−33	See also Rec. G.333 and J.73
10 800	75 (unbal.)	−33	−33	Provisionally

Note. — 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 at point *T*
   −36 dBr at point *T'*.
2) The following levels apply in other cases, for example, to new stations wholly equipped with transistor equipment:
   −33 dBr at each of the points *T* and *T'*.

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.

Recommendation G.214 (Mar del Plata, 1968)

LINE STABILITY OF CABLE SYSTEMS

Line regulation has a threefold purpose:

1) to keep actual line relative levels within such limits that thermal or intermodulation noise never exceeds acceptable values;

2) to keep levels at the ends of regulated-line sections within such limits that the group regulators are able to function;

3) 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 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.

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 15/XV).

2.2 General recommendations

Recommendation G.221 (amended at Geneva, 1972)

OVERALL 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*

1. *Overall requirements*

The requirements as regards crosstalk ratio between circuits in the case of telephony are the subjects of Recommendations G.134 and G.151, D, a; for go-return crosstalk Recommendation G.151, D, b applies.

As carrier transmission systems are also used for setting up sound-programme circuits, the relevant requirements given in the series J Recommendations should be taken into consideration. Recommendation J.18 gives general guidance on how the higher crosstalk ratios appropriate to sound-programme transmissions are achieved in a telephone network.

In any case 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.

2. *Intelligible crosstalk caused by intermodulation with a signal which is a multiple of 4 kHz*

Intelligible crosstalk may arise between circuits by way of intermodulation with a signal which is a multiple of 4 kHz, e.g. a line regulating pilot. A design objective is that the intelligible crosstalk ratio in a single homogeneous section of the appropriate hypothetical reference circuit should be not less than 74 dB.

c) *Noise transmitted between interconnected systems*

A failure or malfunction in a chain of repeaters may lead to large values of noise in one or several signal bands being transmitted by that chain. It is known that such high noise levels are generally caused by the operation of particular types of automatic line regulators. Given that such high noise levels may be transmitted to other chain links, and may overload those to which they are interconnected, it is desirable and recommended that care should be taken in the future in order to avoid such troubles.

Possible methods of dealing with this problem are described in Supplement No. 4 of this *Green Book*.

In respect of radio-relay links, it will be the concern of C.C.I.R. to enumerate suitable precautions.

Recommendation G.222 (amended at Geneva, 1964, and at 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 composition 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 VII of the *Green Book*) and to obtain the quality shown in Recommendation F.10 of the C.C.I.T.T. (Volume II-B of the *Green 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 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 Recommendation 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);

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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.

— 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.)

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 397-2).

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.

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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.

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 352-1 and 353-2.

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.[1] The mean psophometric power, which corresponds to the noise produced 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 at Geneva, 1964; at Mar del Plata, 1968; and at Geneva, 1972)

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 (mean power = 31.6 microwatts); this is the mean with time and the mean for a large batch of circuits.

[1] Called, in C.C.I.R. Recommendations, "frequency-division multiplex equipments".

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 leaks,

— telegraph signals, assuming that few telephone channels are used for v.f. telegraphy or photo-telegraphy.

On the other hand, the power of pilots in the load of modern carrier systems has been treated as negligible.

The reference to "the busy hour" in Section 1 of this Recommendation is to indicate that the limit (of −15 dBm0) applies when transmission systems and telephone exchanges are at their busiest so that the various factors concerning occupancy and activity of the various services and signals are to be those appropriate to such busy conditions.

It is not intended to suggest that an integrating period of one hour may be used in the specification of the signals emitted by individual devices connected to transmission systems. This could lead to insupportably high short-term power levels being permitted which give rise to interference for durations of significance to telephony and other services.

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. 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 was therefore set for study during the 1968-1972 study period to deal with all aspects of the problem.

At this point in time there is no sufficiently firm information to justify an alteration to the value of the *conventional* load per channel of −15 dBm0 (32 μW0) long-term mean, currently recommended.

Indeed, the steps envisaged by Administrations to control and reduce the levels of non-speech signals indicate that the situation could be contained despite the increase in the non-speech services.

The economic aspects of changing (in particular increasing) the conventional load per channel would need to be thoroughly investigated before a change could be recommended.

Nevertheless there are sufficient indications that the study of all relevant factors must continue. Accordingly, the question has been retained (Question 1/C for the period 1973-1976).

As regards the subdivision of the 32 μW into 10 μW signalling and tones and 22 μW speech and echo, carrier leaks, and telegraphy, again there is no evidence which would justify proposals to alter this subdivision.

As a general principle, it should always be the objective of Administrations to ensure that the *actual* load carried by transmission systems does not significantly differ from the *conventional* load assumed in the design of such systems.

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.

6. For *transmission systems not exceeding 1000 km* the permissible number of telegraph systems may be increased if the power per telegraph channel is reduced according to the following table:

Total number of circuits provided by the transmission system (N)	Approximate number of circuits that may be used for 24-channel FM voice frequency telegraph systems with the indicated power level/TG channel (dBm0)			
	−22.5	−25.5	−27.0	−28.5
12	12	12	12	12
60	20	60	60	60
120	14	42	84	120
300 or more	N/30	N/10	N/5	N

A similar table in respect of transmission systems longer than 1000 km cannot be drawn up at this time. There is evidence to suggest that for systems considerably longer than 1000 km a reduction in telegraph signal power gives rise to unacceptable levels of telegraph distortion and character error rates.

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 weights 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 the 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.

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
for 60-channel supergroup modulators	6.1 dB
for 300-channel mastergroup modulators	9.8 dB

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 per channel at a zero relative level point, while the sixth disturbing channel will be assumed to carry telegraphy, photo-telegraphy 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 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 at the output, at which the absolute power level of the third harmonic increases by 20 dB when the input signal to the amplifier is increased by 1 dB.

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 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 in both of their separate levels at the input to the amplifier causes an increase, at the output of the amplifier, of 20 dB 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 1/G.223 shows the equivalent peak power level in terms of the number of channels in the four-wire system. It is derived from Curve B, Figure 7 of the Holbrook and Dixon article[1] taking into account the conventional value (−15 dBm0) 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.

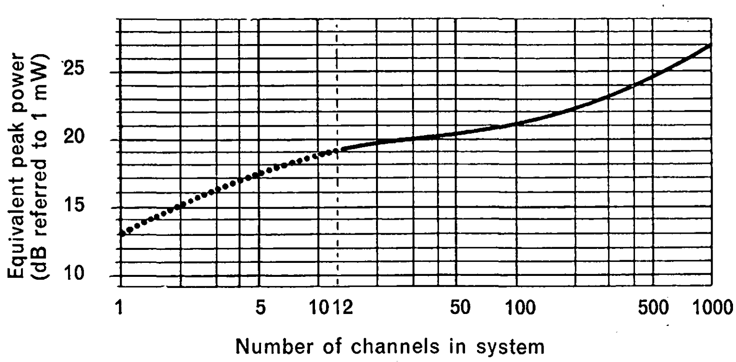


Figure 1/G.223. — **Equivalent r.m.s. sine wave power of the peak of a multiplex signal at the zero relative level point, as a function of the number of telephony channels in a system, without pre-emphasis or peak limiting assuming a mean power per channel of —15 dBm0, with a standard deviation of 5.8 dB**

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.

[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.

6.3 *Margin against saturation.* — In planning, a margin of a few decibels 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.

TABLE OF COMMERCIAL TELEPHONE CIRCUIT PSOPHOMETER WEIGHTING COEFFICIENTS

Frequency (Hz)	Weight		
	Numerical value	Numerical value squared	Value in decibels
16.66	0.056	0.003136	−85.0
50	0.71	0.5041	−63.0
100	8.91	79.3881	−41.0
150	35.5	1 260.25	−29.0
200	89.1	7 938.81	−21.0
250	178	31 684	−15.0
300	295	87 025	−10.6
350	376	141 376	− 8.5
400	484	234 256	− 6.3
450	582	338 724	− 4.7
500	661	436 921	− 3.6
550	733	537 289	− 2.7
600	794	630 436	− 2.0
650	851	724 201	− 1.4
700	902	813 604	− 0.9
750	955	912 025	− 0.4
800	1 000	1 000 000	0.0
850	1 035	1 071 225	+ 0.3
900	1 072	1 149 184	+ 0.6
950	1 109	1 229 881	+ 0.9
1 000	1 122	1 258 884	+ 1.0
1 050	1 109	1 229 881	+ 0.9
1 100	1 072	1 149 184	+ 0.6
1 150	1 035	1 071 225	+ 0.3
1 200	1 000	1 000 000	0.0
1 250	977	954 529	− 0.20
1 300	955	912 025	− 0.40
1 350	928	861 184	− 0.65
1 400	905	819 025	− 0.87
1 450	881	776 161	− 1.10
1 500	861	741 321	− 1.30
1 550	842	708 964	− 1.49
1 600	824	678 976	− 1.68
1 650	807	651 249	− 1.86
1 700	791	625 681	− 2.04
1 750	775	600 625	− 2.22
1 800	760	577 600	− 2.39
1 850	745	555 025	− 2.56
1 900	732	535 824	− 2.71
1 950	720	518 400	− 2.86
2 000	708	501 264	− 3.00
2 050	698	487 204	− 3.12
2 100	689	474 721	− 3.24
2 150	679	461 041	− 3.36
2 200	670	448 900	− 3.48
2 250	661	436 921	− 3.60
2 300	652	425 104	− 3.72
2 350	643	413 449	− 3.84

TABLE OF COMMERCIAL TELEPHONE CIRCUIT PSOPHOMETER WEIGHTING COEFFICIENTS *(contd.)*

Frequency (Hz)	Weight		
	Numerical value	Numerical value squared	Value in decibels
2 400	634	401 956	− 3.96
2 450	626	390 625	− 4.08
2 500	617	380 689	− 4.20
2 550	607	368 449	− 4.33
2 600	598	357 604	− 4.46
2 650	590	348 100	− 4.59
2 700	580	336 400	− 4.73
2 750	571	326 041	− 4.87
2 800	562	315 844	− 5.01
2 850	553	305 809	− 5.15
2 900	543	294 849	− 5.30
2 950	534	285 156	− 5.45
3 000	525	275 625	− 5.60
3 100	501	251 001	− 6.00
3 200	473	223 729	− 6.50
3 300	444	197 136	− 7.05
3 400	412	169 744	− 7.70
3 500	376	141 376	− 8.5
3 600	335	112 225	− 9.5
3 700	292	85 264	−10.7
3 800	251	63 001	−12.0
3 900	214	45 796	−13.4
4 000	178	31 684	−15.0
4 100	144.5	20 880.25	−16.8
4 200	116.0	13 456	−18.7
4 300	92.3	8 519.29	−20.7
4 400	72.4	5 241.76	−22.8
4 500	56.2	3 158.44	−25.0
4 600	43.7	1 909.69	−27.2
4 700	33.9	1 149.21	−29.4
4 800	26.3	691.69	−31.6
4 900	20.4	416.16	−33.8
5 000	15.9	252.81	−36.0
>5 000	<15.9	<252.81	<−36.0

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 above, the following values may be used:

5 000 to 6 000	<15.9	<252.81	<−36.0
>6 000	< 7.1	< 50.41	<−43.0

ANNEX

(to Recommendation G.223)

(supplied by the United Kingdom Post Office)

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 of each component of a short duration signal should not exceed the values given in table.

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 (dBm0)
800	750	−1
1200	500	−3
1600	400	−4
2000	300	−5
2400	250	−6
2800	150	−8
3200	150	−8

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 below the above values.

Note 2. — The values given in this table result from a compromise between the characteristics of various channel filters now in existence.

[1] This recommendation is the same as Recommendation Q.16 (*Green Book*, Volume VI); it applies both to national and to international signalling systems.

Recommendation G.225 (amended at Geneva, 1964, and at 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/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 $\pm 10^{-6}$, 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.

[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), New Delhi, 1970.

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 "coordinated". This "coordination" 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 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 *Green 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

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.

Recommendation G.227 (Geneva, 1964; amended at 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:

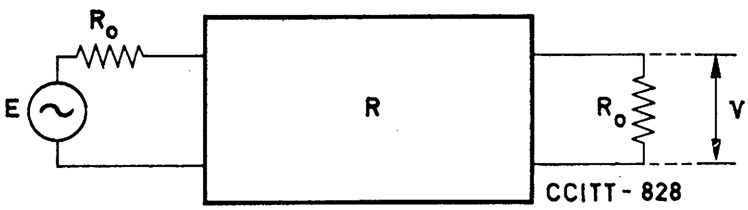


FIGURE 1/G.227

$$\frac{E}{2V} = \frac{18\,400 + 91\,238\,p^2 + 11\,638\,p^4 + p\,[67\,280 + 54\,050\,p^2]}{400 + 4001\,p^2 + p^4 + p\,[36\,040 + 130\,p^2]}$$

where $p = j\frac{f(\text{Hz})}{1000}$, E and V are defined by Figure 1/G.227.

The response curve of the network is shown in Figure 2/G.227, and an example of the design is given in Figure 3/G.227 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/G.227 represents the network and indicates the values of the various components normalized to R_0.

A tolerance of $\pm$ 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:

$$\frac{E}{2V} = e^{\theta} = e^{\theta_1 + \theta_2 + \theta_3}$$

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

$$p = j\frac{f(\text{Hz})}{1000}$$

The minimum composite loss[1] of the complete network lies in the vicinity of 600 Hz and equals $a_0 \simeq 2.9$ dB for this example.

The curve in Figure 2/G.227 represents, as a function of frequency, the composite loss[1] of the network in Figure 3/G.227 relative to the minimum loss a_0.

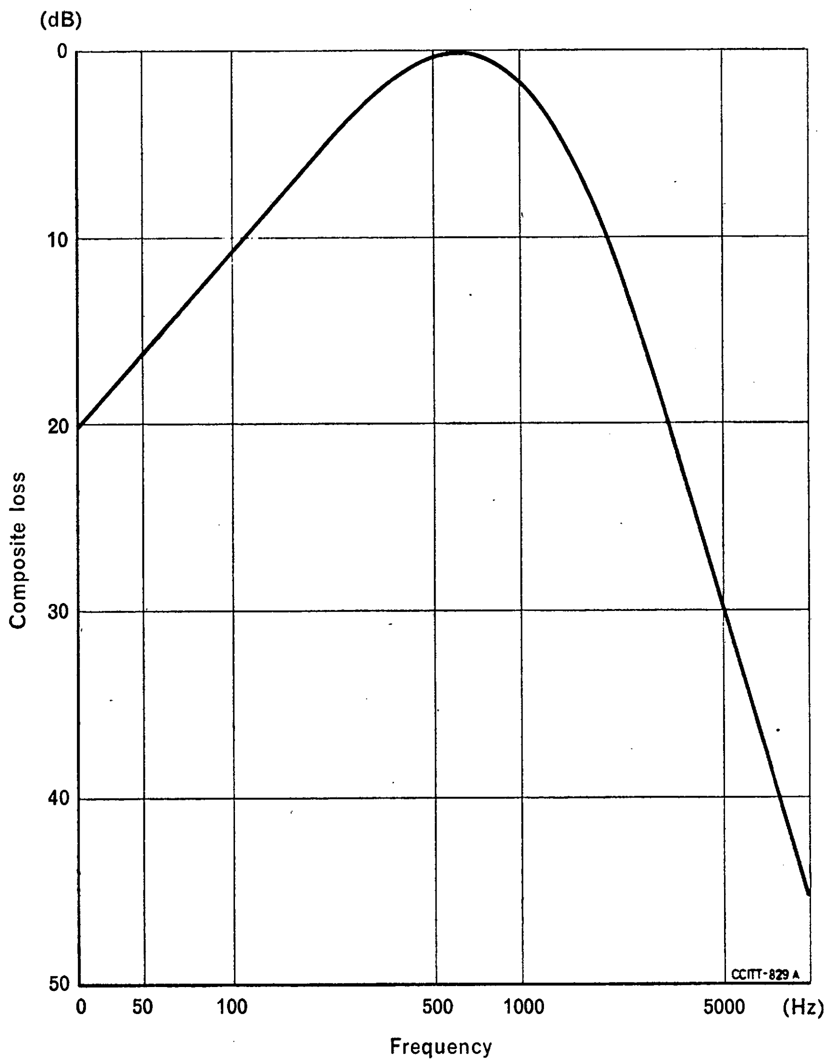
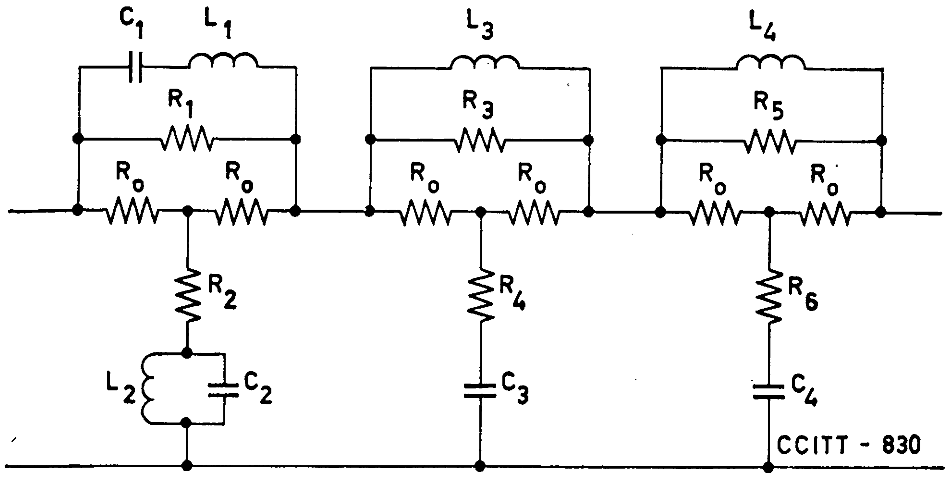


FIGURE 2/G.227. — **Relative response curve of the weighting network of the conventional telephone signal generator**

[1] Composite loss equals the insertion loss in this particular case since the source and the load impedances are equal.



Section 1	Section 2	Section 3
$\frac{R_1}{R_0} = 45$	$\frac{L_1 \omega_0}{R_0} = 0.5$	$R_0 C_1 \omega_0 = 2$
$\frac{R_2}{R_0} = 0.0222$	$\frac{L_2 \omega_0}{R_0} = 2$	$R_0 C_2 \omega_0 = 0.5$
$\frac{R_3}{R_0} = 10$	$\frac{L_3 \omega_0}{R_0} = 0.5$	$R_0 C_3 \omega_0 = 0.5$
$\frac{R_4}{R_0} = 0.1$	$\frac{L_4 \omega_0}{R_0} = 1.11$	$R_0 C_4 \omega_0 = 1.11$
$\frac{R_5}{R_0} = 22$		
$\frac{R_6}{R_0} = 0.0455$	with $\omega_0 = 2\pi \times 10^3 \times \text{second}^{-1}$	

FIGURE 3/G.227. — **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.[1] That apparatus would be used solely for objective measurements, in which a psophometer served as measuring instrument.

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[1] A speech simulating noise generator is studied in the Annex 3 to Question 5/C, *Green Book*, Volume III.

Recommendation G.228 (Geneva, 1964; amended at 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 [Volume IV (1), New Delhi, 1970] 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 o 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.

Recommendation G.229 (Geneva, 1972)

INTERFERENCE AT HARMONICS FROM THE POWER SUPPLY AND OTHER LOW FREQUENCIES

a) *Requirements on carrier transmission systems*

To enable the limit indicated in Recommendation G.151, G to be met, it is recommended that a minimum side component attenuation of 45 dB should be obtained when a signal is transmitted over a channel having the same composition as the 2500 km hypothetical reference circuit for the system concerned.

This limit is subdivided as indicated in paragraphs b and c following into allocations to terminal and to line equipment.

b) *The combined effect due to all translating equipment* on the hypothetical reference circuit should correspond to a minimum side component attenuation of 48 dB.

For each translating equipment, send and receive side taken separately, and measured at the signal output, a side component attenuation of at least 63 dB should be obtained under normal operating conditions. Under adverse power supply conditions a minimum of 60 dB should be met. (These values are provisional.) It is expected that then an overall value of 48 dB, indicated above, will only rarely be exceeded.

Note. — The exact method to be applied for subdividing the overall limit is still under study.

c) *The combined effects due to all line equipment* on the hypothetical reference circuit should correspond to a minimum side component attenuation of 48 dB.

Line equipments can be subject to two types of interference which will cause side components on a transmitted signal:

— effects from power supplies (for example, a residual mains frequency ripple may be superimposed on the d.c. power feeding current). These are potentially systematic on the complete length of the circuit;

— effects from voltages caused by induction (for example, from railway traction currents). They are not expected to occur as systematically as the effects from the power supplies.

The influence caused by *power supply ripple* should be such that a minimum side component attenuation of 51 dB is observed for the combined effects of all line equipment on the hypothetical reference circuit. The subdivision of this value to obtain limits to be recommended for homogeneous sections or power feeding sections is still a matter for further study.

The influence caused by *induced voltages* should be such that a minimum side component attenuation of 51 dB is observed for the combined effects of all line equipment on the hypothetical reference circuit. However, voltages caused by induction vary considerably with time. The effect of a source of induction is very often confined to one power feeding section. It seems very unlikely that the induced voltage reaches its maximum value in more than one section at the same instant.

It is recommended that the r.m.s value of the longitudinal voltage in a power feeding section caused by induction under normal operating conditions (excluding short circuits and arcing on railways, etc.) should not exceed 150 volts. (This limit has been recommended regarding safety aspects and is contained in the C.C.I.T.T. *Directives*, Chapter IV, paragraphs 6, 7 and 71. It seems reasonable to adopt the same value for the present purpose.)

Calculations indicate that an allowance of 6 dB for the combined effect of several sections under the influence of induction should cover the majority of likely cases. It is therefore recommended that a minimum side component attenuation of 57 dB should be observed on a power feeding section under the influence of the maximum allowed induced voltage. It is estimated that then the value of 51 dB on a circuit of 2500 km would only be exceeded in rare circumstances and infrequently, particularly in view of the fact that only a fraction of the total length would be exposed to interference by induction.

2.3 Translating equipment used on various carrier-transmission systems

Recommendation G.231 (amended at Geneva, 1964; at Mar del Plata, 1968; and at Geneva, 1972)

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 cm 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 cm.

In principle, 30 cm should be allowed for overhead cable-runs, and also about 30 cm for access to these cables, which makes at the most 60 cm between the top of the rack and the ceiling; nevertheless, some Administrations consider that a total height of 40 cm 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 m to facilitate access to the various cables.

Thickness. — The thickness of a rack should not be greater than 45 cm. For racks which may be placed back to back the total suite thickness may be up to 52 cm, including all maintenance controls, cooling fins, etc., which may protrude from the nominal face of the equipment.

B. Use of standard components in transmission equipment [1]

While acknowledging that the International Electrotechnical Commission (I.E.C.) is competent to devise 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.

[1] This Recommendation applies both to carrier systems and to audio equipment.

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.

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. 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 (amended at Geneva, 1964; at Mar del Plata, 1968, and at Geneva, 1972)

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 equipment should provide 12 channels in a basic group, with 4-kHz spaced carrier frequencies, in conformity with the present Recommendation.

[1] This recommendation applies both to carrier systems and to audio equipment.

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/G.232.

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/G.232.

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/G.232 where:

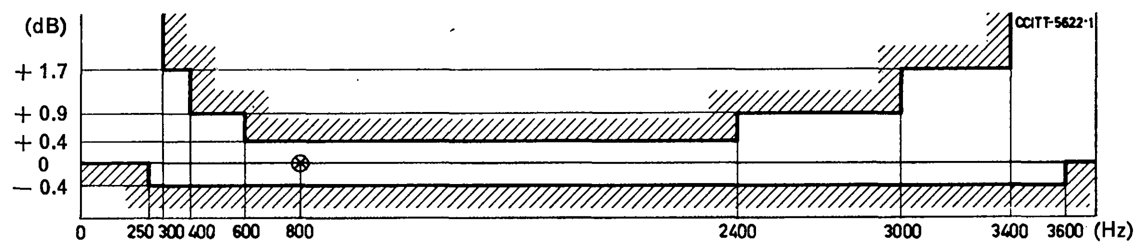
— the frequencies shown as abscissae are audio frequencies, before modulation,

— the ordinates give the limits of relative power level measured at carrier frequency.

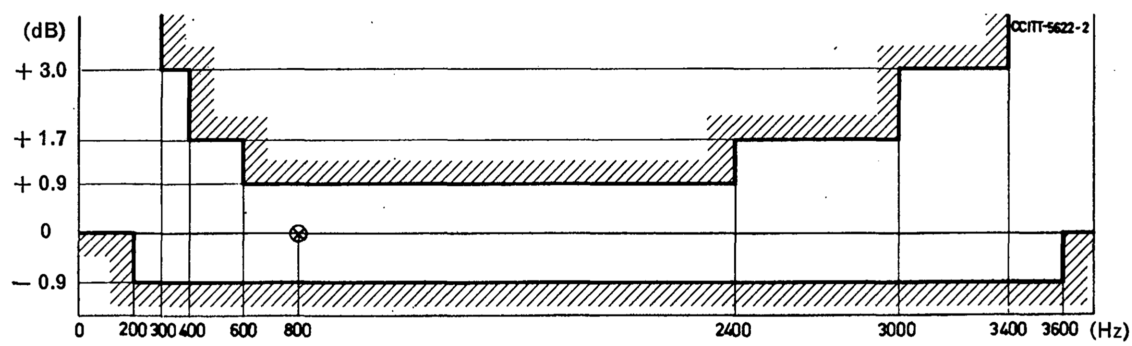
For the receiving equipment of any channel, the attenuation frequency distortion should not exceed the limits of this same Graph No. 2 C where, this time:

— 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/G.232. — **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**

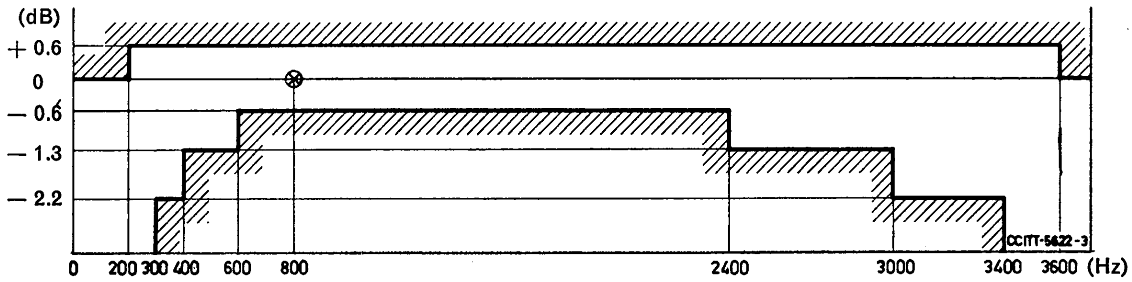


FIGURE 2/G.232. Graph No. 2 C. — **Allowable limits for the variation, as a function of frequency, of the relative power level at the output**

— 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 Administrations use, for circuits interconnecting international centres of the higher orders, i.e. CT1s 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

The C.C.I.T.T. recommends that in order to secure the values referred to in the table of the note of Recommendation G.122-A, a, these terminal equipments should show a loss (and not a gain) in relation to the value for 800 Hz at all frequencies below a value f and all frequencies above a value F.

For Graph 2 B of figure 1/G.232 the recommended values are the following.

f = 200 Hz and F = 3600 Hz

The value recommended for Graphs 2 A and 2 C are:

Graph 2 A: f = 250 Hz and F = 3600 Hz
Graph 2 C: f = 200 Hz and F = 3600 Hz

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.

However, the limits for group delay distortion are being studied in Question 14/XV.

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]	2.6	2.2	1	1.4	2.6
	[b]	4.2	2.7	1.2	1.8	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/G.232 (Graph No. 3), the measurements of the output power being made by means of a square law device.

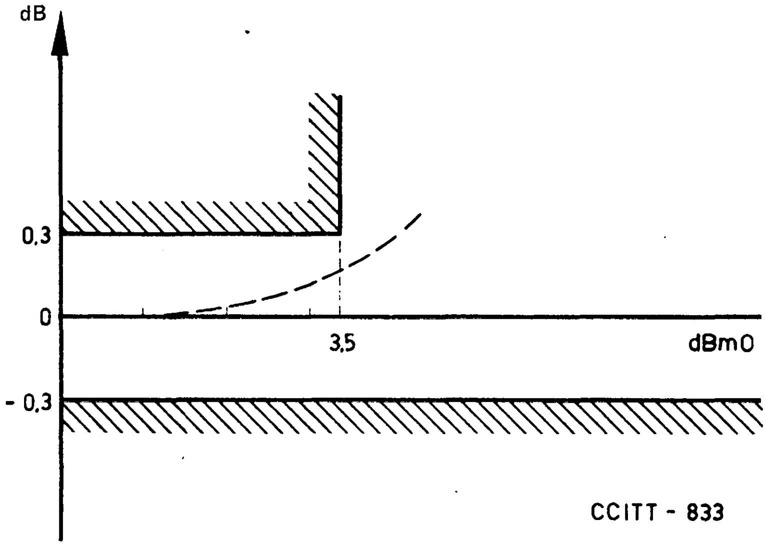


Figure 3/G.232. Graph No. 3. — **Permissible limits for the variation with applied audio power level, of the overall loss of the combination of sending and receiving 12-channel terminal equipments. The curve shows the variation of overall loss as a function of the power level applied to the audio input terminals of one channel and referred to the overall loss when the applied power is 1 mW**

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, 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.

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.

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) *Unintelligible 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.

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.

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 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/G.232) should be at least X dB when the high-frequency access points are suitably terminated.

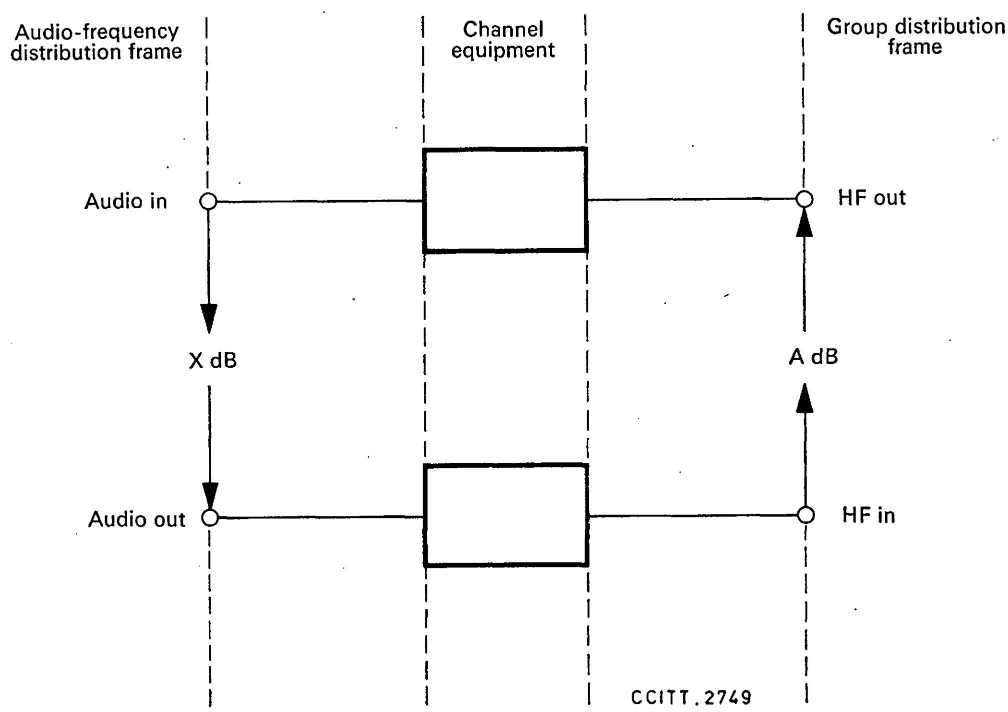


FIGURE 4/G.232

In addition the near-end crosstalk ratio measured between the "HF in" and the "HF out" points should be at least A dB when the audio points are appropriately terminated.

The C.C.I.T.T. recommends the following figures which are minimum values to be included in specifications (not objectives):

For all channels $X = 53$ dB, $A = 47$ dB. The method of measurement is given in Note 2 of the Annex to Recommendation G.134.

For channels of circuits which may be used with echo suppressors or call concentrators $X = 68$ dB $A = 62$ dB. The method of measurement should be the one described in paragraph 3, b) of the Annex, Recommendation G.134.

d) *Station cabling*

The contribution of the station cabling to go-return crosstalk arising in channel translating equipments as measured at audio frequency or group distribution frames should be small, i.e. about an order of magnitude lower than that of the equipment itself. There seems no reason to propose more precise subdivisions of the limits proposed in parts a), b) and c) above.

Calculation methods

Recommendation J.18 states the various contributory sources to the go-return crosstalk which may reasonably be assumed for the near limiting cases which should serve as a basis for equipment specifications.

Annex 1 to Recommendation J.18 contains general considerations concerning calculation methods based on power addition of the various contributions.

e) *Go-to-return crosstalk*

The following limits are recommended for crosstalk ratios (single frequency measurements) for group and higher order translating equipments; they will apply to both the low and high frequency sides:

— group translation: 80 dB;
— higher order translation stages: 85 dB.

Note. — On the basis of telephony considerations alone, a limit of 80 dB would have been proposed for all translation stages; this would also have sufficed to meet the recommended limit for intelligible crosstalk between programme circuits (74 dB, Recommendation J.21) in networks where programme circuits are systematically equipped with compandors. However, importance was attached to adopting a single requirement for each translation stage which would suffice for the most demanding network conditions to be encountered.

K. Noise

Recommendation G.222 refers to the noise produced by channel translating equipments.

L. Level at audio frequency terminals

Taking into consideration the different ways in which Recommendation G.121 (Reference equivalents of national systems) can be applied and the modern devices now available, it is recommended that new designs of channel translating equipment should meet the following conditions (see Figure 5/G.232), in which the adjustable attenuation pads A_R and A_S enable the relative levels to be adjusted over a certain range. When these attenuation pads are set to zero loss, the relative level at the S and R terminals of the equipment must have one of the two series of values shown in Table 2.

TABLE 2

	Maximum receive level at R	Minimum send level at S
Case 1	+4 dBr	−14 dBr
Case 2	+7 dBr	−16 dBr

It was not considered necessary to recommend a value for the adjustment range, which may even be reduced to zero. The choice between these two solutions and the determination of the adjustment range must be left to the Administration involved, taking into account the economical aspects, its own network configuration, its transmission plan and that of the countries with which it will interwork.

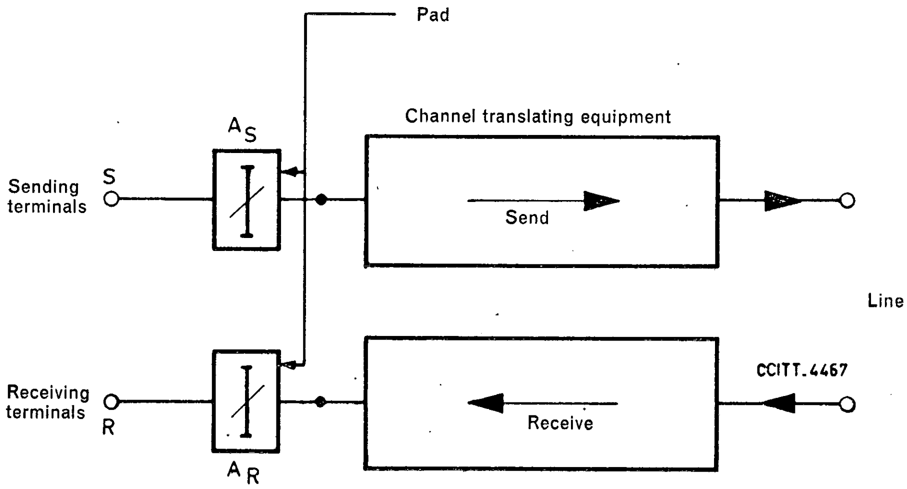


FIGURE 5/G.232

M. 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 nominal value of 600 ohms for the impedance of national or international trunk circuits.

N. Protection and suppression 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 N 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 3.

TABLE 3

Pilot frequency	Channel No.	Interference frequency	Minimum loss (relative to 800-Hz loss)	
			Send equipment	Receive equipment
(kHz)		(Hz)	(dB)	(dB)
(1)	(2)	(3)	(4)	(5)
84.080	6	3920	20	40
	7	−80	20	20
84.140	6	3860	20	35
	7	−140	30	20

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, HF 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 audio-frequency and HF, filtration on the audio-frequency filters could have a much reduced effect on high level audio-frequency interference signals compared with the effect on low level signals. The relative losses quoted in columns (4) and (5) of Table 3 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 (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 4.

TABLE 4

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 (dB)	Receiving (dB)
(1)	(2)	(3)	(4)	(5)	(6)
411.920	104.080	1	3920	20	40
		2	−80	20	20
411.860	104.140	1	3860	20	35
		2	−140	30	20

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 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 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. The disturbed channels are Nos. 6 and 7.

Table 5 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 5

Pilot frequency (kHz)	Pilot level (dBm0)	Channel No.	Interfering frequency in the channel (Hz)	Psophometric weighting at the interfering frequency (dB)	Minimum attenuation (dB)
84.080	−20	6	3920	13	40
		7	−80	48	5
84.140	−25	6	3860	13	35
		7	−140	31	17

Note. — Psophometric weights have been rounded off, allowance being made for the tolerances set forth in Recommendation P.53, Volume V of the *Green 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 tests 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 6 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 6

Pilot frequency (kHz)	Pilot level (dBm0)	Channel No.	Disturbing frequency in the channel (Hz)	Minimum attenuation (dB)
84.080	−20	6	3920	20
		7	−80	20
84.140	−25	6	3860	20
		7	−140	30

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 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 be provided in both transmission directions.

b) A further possible source of interference between one group pilot and another is the inter-connection 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 at the two-four-wire termination of channel 7 and the losses of associated circuitry are low at 80 Hz or at 140 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.

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 3920 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 at 3920 Hz
	35 dB at 3860 Hz
Channel 2 (sending):	5 dB at −80 Hz
	17 dB 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 attenuation are, according to the pilot used:

Channel 1 (sending):	20 dB at 3920 Hz
	20 dB at 3860 Hz
Channel 2 (receiving):	20 dB at −80 Hz
	30 dB 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 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 is necessary in the translating équipment 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 *Green Book*):

— Virtual carrier frequency signalling, at level −3 dBm0

— 3825-Hz high level: −5 dBm0

— 3825-Hz low level: −20 dBm0

A pilot at 84.140 kHz (at a level of −25 dBm0) is associated with virtual carrier frequency signalling and a pilot at 84.080 kHz (at a level of −20 dBm0) 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 at 3860 ± 25 Hz

— 3825-Hz high level: 17 dB at 3920 ± 25 Hz

— 3825-Hz low level: 2 dB at 3920 ± 25 Hz

2. *Protecting of signalling*

Assuming that the threshold of sensitivity of the receiver is 11 dB 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 at 3920 ± 3 Hz

— 3825-Hz low level: 21 dB at 3920 ± 3 Hz.

Recommendation G.233 (amended at Geneva, 1964; at Mar del Plata, 1968, and at Geneva, 1972)

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/G.233 for group-translating equipments (procedures 1 and 2);
2. Figure 2/G.233 for supergroup-translating equipments (procedure 1);
3. Figure 3/G.233 for mastergroup-translating equipments (procedure 1);
4. Figure 4/G.233 for supergroup-translating equipments (procedure 2);
5. Figure 5/G.233 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.

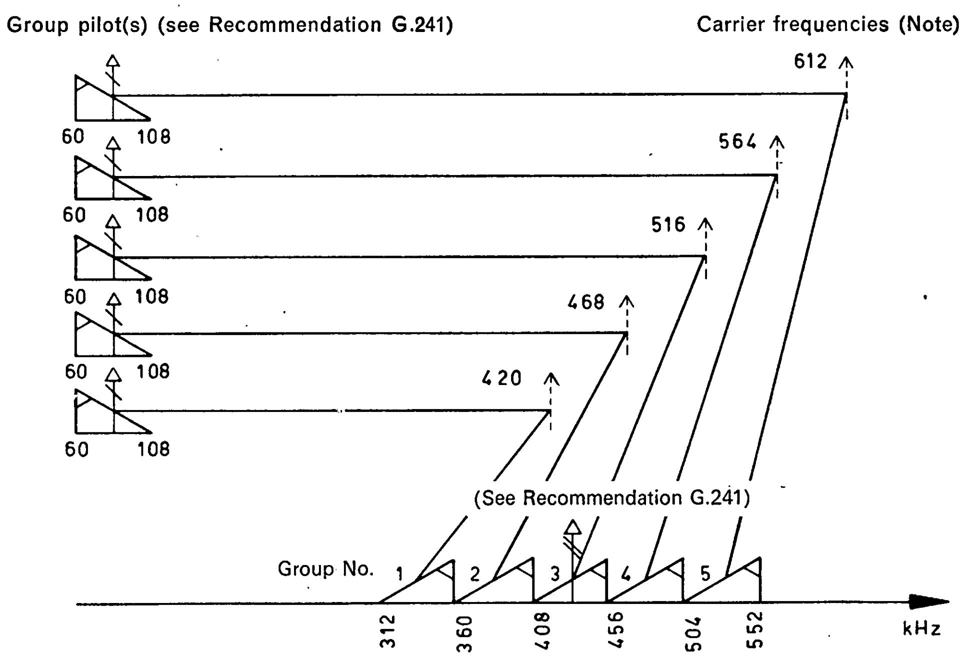


FIGURE 1/G.233. — **Constitution of the basic supergroup**

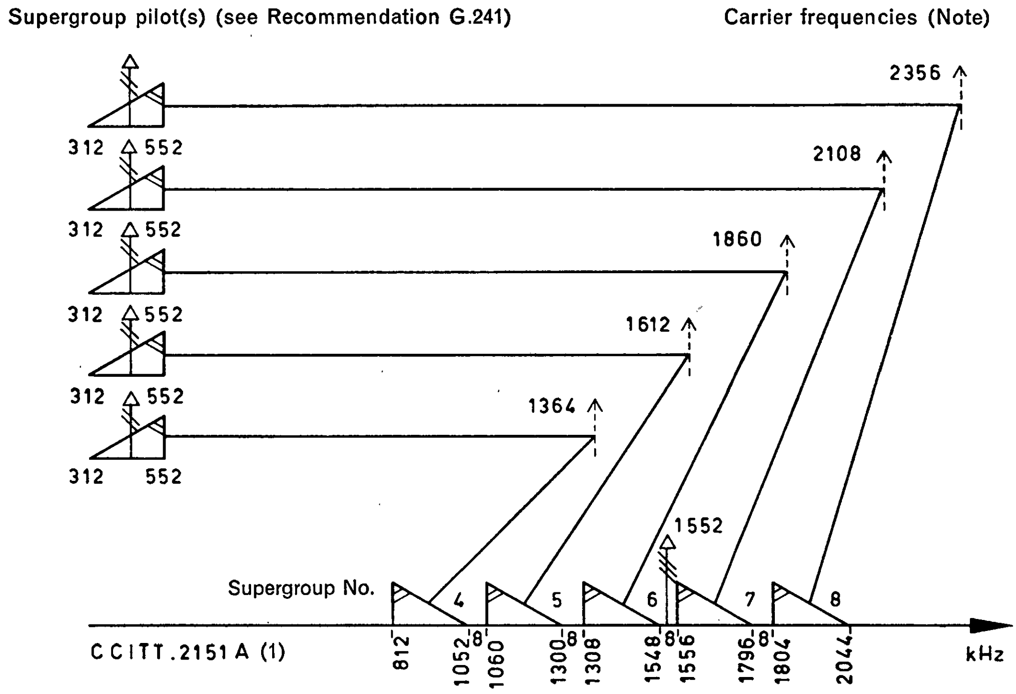


FIGURE 2/G.233. — **Constitution of the basic mastergroup**

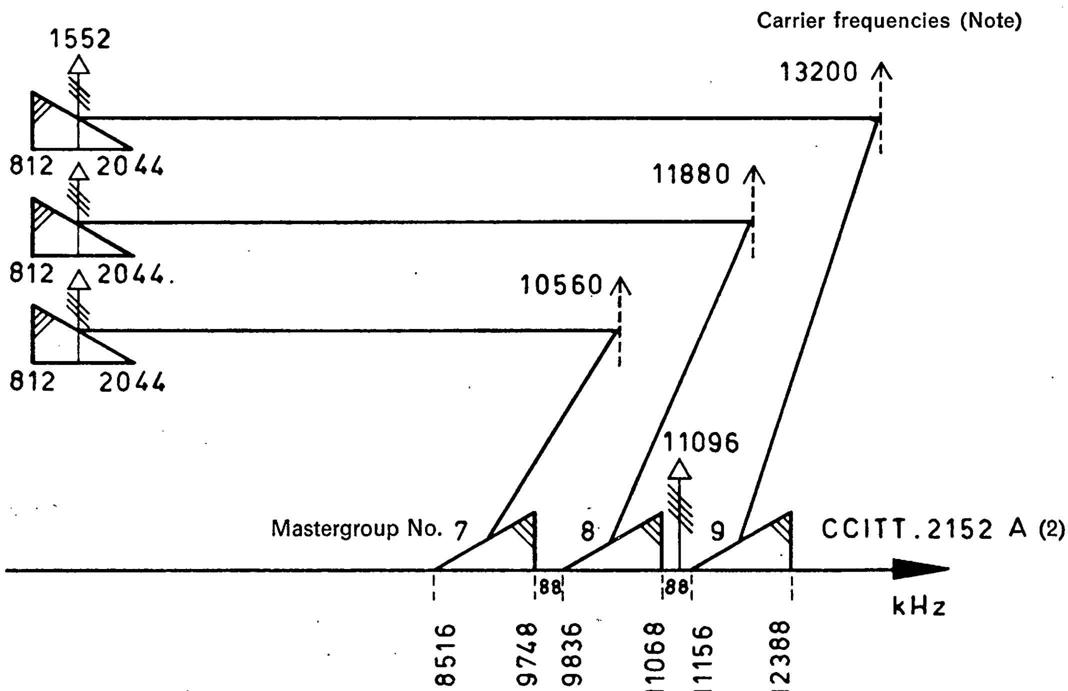


FIGURE 3/G.233. — **Constitution of the basic supermastergroup**

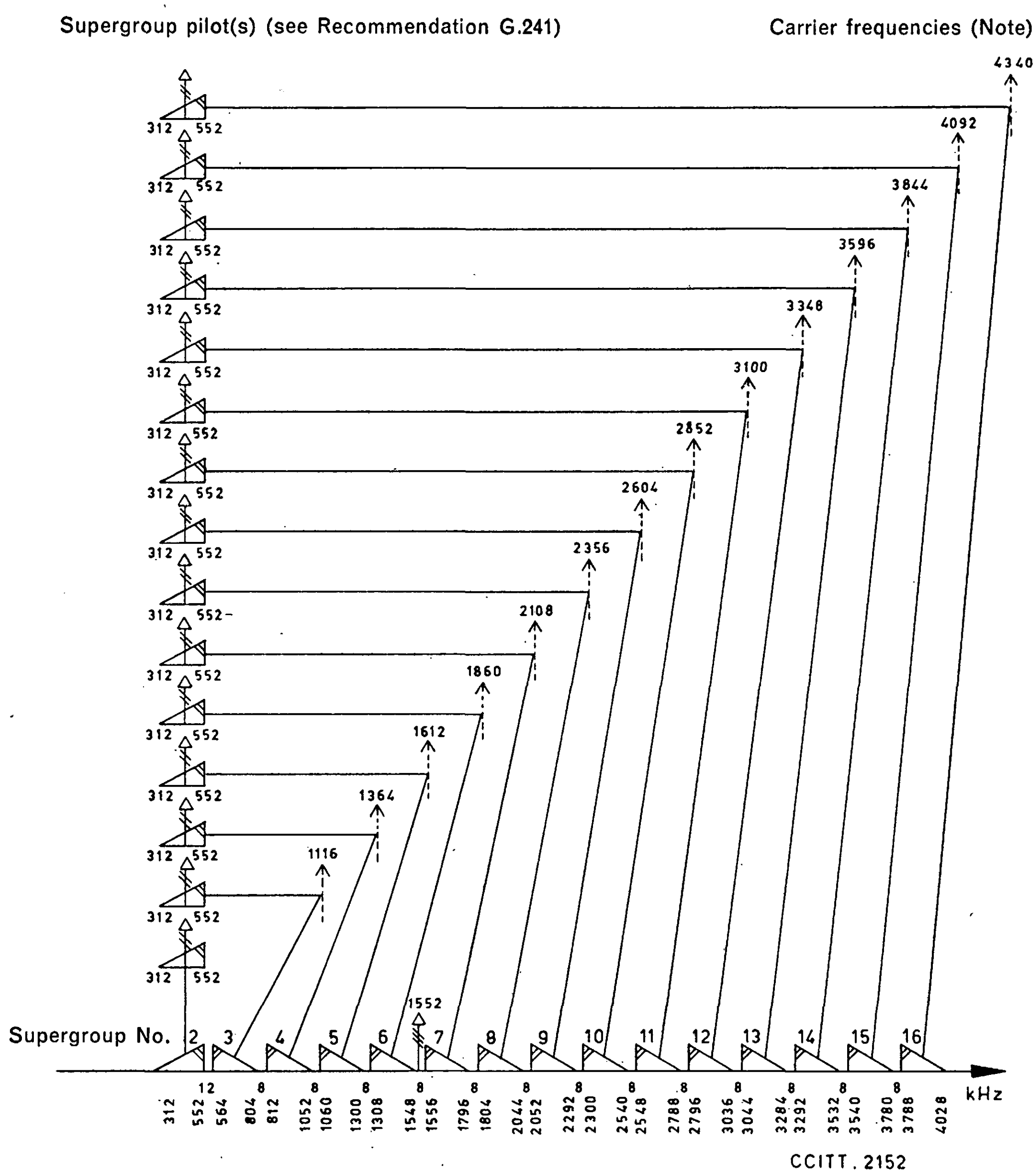


FIGURE 4/G.233. — **Constitution of the basic 15-supergroup assembly**

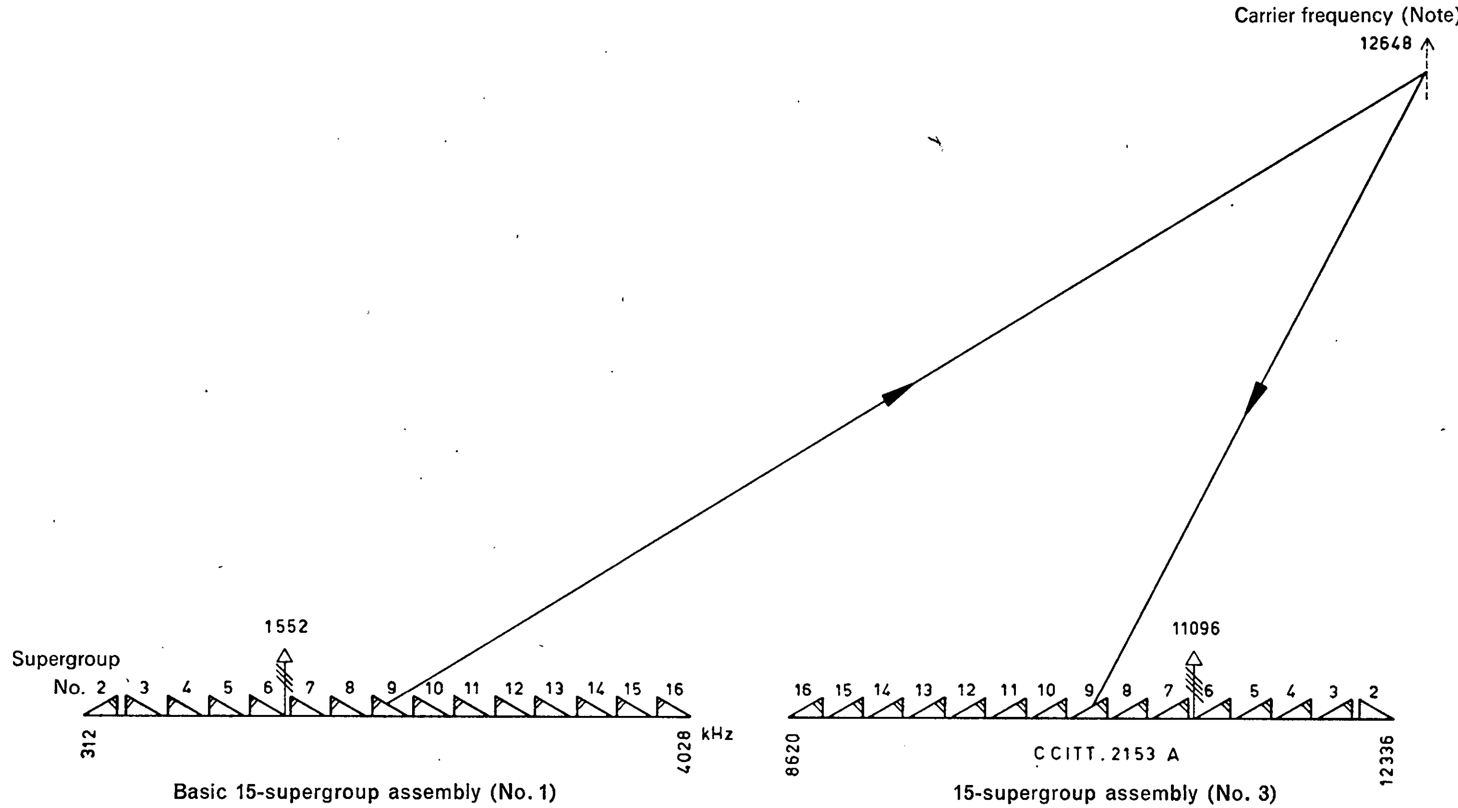


FIGURE 5/G.233. — **Constitution of 15-supergroup assembly No. 3**

Note to Figures 1/G.233 to 5/G.233. — The virtual carrier frequencies shown in Figures 1/G.233 to 5/G.233 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.

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, 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 was not possible before the Plenary Assembly of 1972 to recommend such a standardization internationally, because of the diversity of carrier systems already in service. The table shows, for information, the level used by different Administrations.

The C.C.I.T.T. concerned itself solely with recommending preferred values for countries which have not yet fixed these values for their national networks. Accordingly:

— a relative sending level of −36 dBr is recommended at group and supergroup distribution frames;
— for reception, it is recommended that a choice be made between −23 and −30 dBr;
— the following values are recommended for the impedance:
  — 150 ohms balanced for group distribution frames,
  — 75 ohms unbalanced for supergroup distribution frames.

d) *Relative power levels at mastergroup distribution frames*

The relative power levels at mastergroup distribution frames (see Figure 6/G.233) should be adjusted to the following values:

— transmit: −36 dB
— receive: −23 dB

across a 75-ohm impedance, unbalanced to earth.

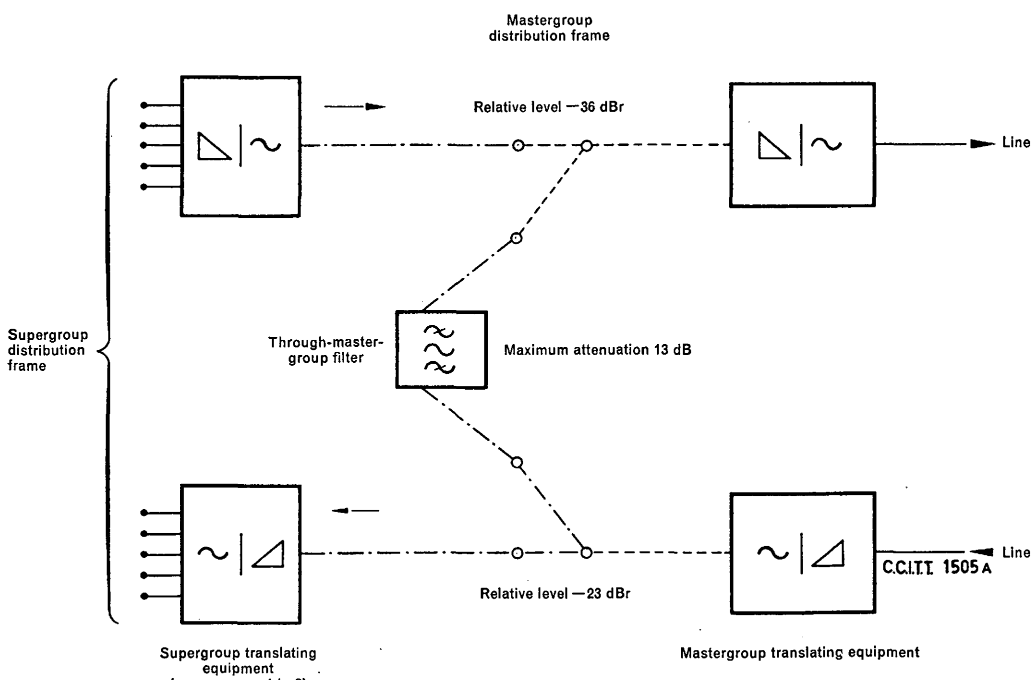


FIGURE 6/G.233. — **Relative levels at mastergroup distribution frame**

RELATIVE POWER LEVELS AT THE GROUP AND SUPERGROUP DISTRIBUTION FRAMES IN THE CARRIER SYSTEMS OF VARIOUS ADMINISTRATIONS

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 (dBr)	Receive (dBr)			Transmit (dBr)	Receive (dBr)	
Federal Republic of Germany	−36	−30	B	150 ohms, balanced	−35	−30	75 ohms, unbalanced
Australia — System 1	−36.5	−30,5	B	150 ohms, balanced	−35	−30.5	id.
Australia — System 2	−42	− 5	B	135 ohms, balanced	−35	−30	id.
Austria	−37 −36 [a]	− 8 −30 [a]	B	75 ohms, unbalanced 150 ohms, balanced	−35	−30	id.
Belgium	−37	− 8	B	150 ohms, balanced	−35	−30	id.
People's Republic of Bulgaria	−36 [a]	−23 [a]	B	150 ohms, balanced [a]	−36 [a]	−23 [a]	id.
Denmark, Spain, Ireland, New Zealand, Norway, United Kingdom	−37	− 8	B	75 ohms, unbalanced	−35	−30	id.
U.S.A. (American Telephone and Telegraph Company)	−42	− 5	B	135 ohms, balanced	−25	−28	id.
France	−52 −33 [a]	−17 −15 [a]	B	150 ohms, balanced	−45	−35	id.
Hungary, Italy, Netherlands	−37	−30	B	150 ohms, balanced	−35	−30	id.
India	−36.5	−30.4	B	150 ohms, balanced	−34.8	−30.4	id.
Japan (Nippon Telegraph and Telephone Public Corporation)	−36	−18	B	75 ohms, balanced	−29	−29	id.
Mexico (Teléfonos de México)	−47	−10	B	150 ohms, balanced	−47	−24	id.
People's Republic of Poland	−36	−23 [a] −30	B	150 ohms, balanced	−36	−23	id.
Democratic German Republic	−36 −36	−30 −23 [a]	B	150 ohms, balanced	−35 −36 [a]	−30 −23 [a]	id.
Sweden					−35	−30	id.
Switzerland	−41 −36.5 [a]	− 7.8 −30.5 [a]	A or B	75 ohms, unbalanced	−35	−26	id.
U.S.S.R.	−36	−23	B	150 ohms, balanced	−36	−23	id.

[a] Values proposed for new equipments.

e) *Relative levels at supermastergroup distribution frames*

Relative power levels at supermastergroup distribution frames should be adjusted to the following values:

— transmit: —33 dB
— receive: —25 dB

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
receive: —25 dB

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.

h) *Noise*

Paragraph d 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, N, 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 at the frequency of the supergroup pilot.

1.2 Moreover, when an Administration wishes to route 8- or 12-channel groups free 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 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

– 43 dBm0 for group modulation,

– 50 dBm0 for supergroup modulation,

– 45 dBm0 for mastergroup modulation.

For supermastergroup and 15-supergroup assembly modulation, the value of −50 dBm0 has been recommended provisionally. However in the case of 12 MHz systems it is sufficient to limit this carrier leak to −40 dBm0.

Note. — Special precautions may be necessary for a television programme transmission in the upper part of a 12 MHz system band (Recommendation J.73).

Recommendation G.234 (Geneva, 1964; amended at Mar del Plata, 1968, and at Geneva, 1972)

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 bandwidth allocated to a channel 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/G.234.

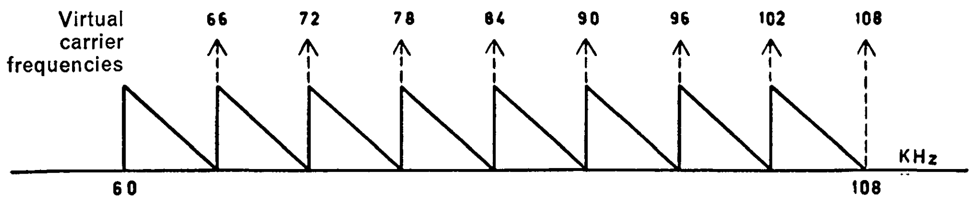


FIGURE 1/G.234. — **Arrangement of telephony channels in an 8-channel group**

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 at a zero relative level point should be:

discontinuous signals: —6 dBm0
semi-continuous signals: Value between —20 dBm0 and —17.4 dBm0.

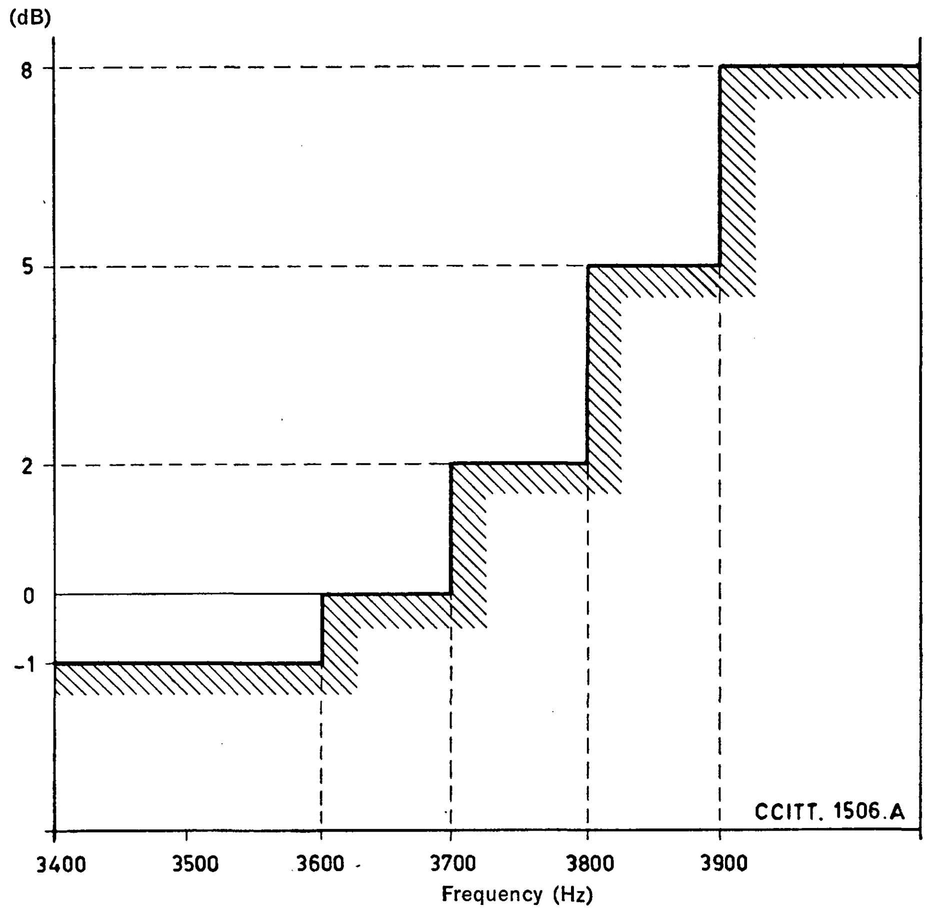


FIGURE 2/G.234. Diagram No. 2*bis*. — **Lower limit for the variation with frequency of the overall loss of a channel above 3400 Hz referred to the value at 1800 Hz**

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/G.234.

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 N 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 (dB)	Receive (dB)
84.08	4	5920	20	20
	5	−80	20	20
84.14	4	5860	20	20
	5	−140	30	20

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, N, a.

2) *Protection and suppression of the supergroup reference pilot*

The same considerations as are outlined in Recommendation G.232, N, 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, N, 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*

Sixteen 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/G.235 with reference frequency of 800 Hz or 1000 Hz.

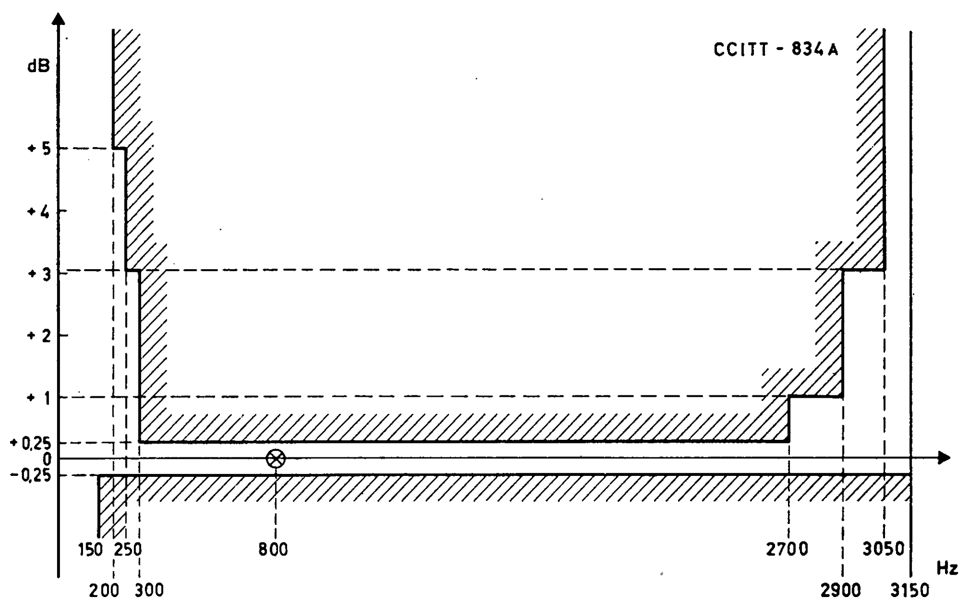


FIGURE 1/G.235. Diagram No. 2 D. — **Permissible limits for the variation, as a function of the frequency, in the attenuation:**

— **of the sending equipment of any channel,**
— **of the receiving equipment of any channel,**
in a 16-channel terminal.

c) *Group delay*

The following conditions should be met both by sending and receiving equipments:

— group delay at 1000 Hz $\leqq$ 1 ms;

— over the band 565-2550 Hz the difference between the maximum and minimum group delay should not exceed 0.75 ms;

— over the bands 300-565 Hz and 2550-3000 Hz on the group delay should not exceed the value at 1000 Hz by more than 2 ms.

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 for each channel carrier current;

-60 dBm0 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 zero with a 0 dBm0 input:

-60 to $+4$ dBm0 input; gain: 0 ± 0.1 dB
$+15$ dBm0 input; gain: between -3 -5 dB.

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.

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.

h) *Noise*

The basic noise in each transmit and receive channel should not exceed -73 dBm0 psophometrically weighted.

i) *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 at Geneva, 1964, and at Mar del Plata, 1968, and at Geneva 1972)

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. 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.

The conditions governing the use of these regulators are given in Recommendation M.18 (Volume IV of the *Green 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 nearby 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 (dBm)
Basic group B	84.080 [1] 84.140 [1] 104.080 [1,2,3]	−20 −25 −20
Basic supergroup	411.860 [1] 411.920 [1,3] 547.920 [1,2]	−25 −20 −20
Basic mastergroup	1552	−20
Basic supermastergroup	11 096	−20
Basic 15-supergroup assembly (No. 1)	1552 [4]	−20

Notes to the table:

[1] The group pilots 84.080 and 84.140 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:

a 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 1 as shown in Figure 1/G.311;

— symmetric-pair systems using variant **B** as shown in Figure 5/G.322, especially the transistorized system described in Recommendation G.323.

b 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.

c 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.

d 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 *Green 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 frequency 11 096 kHz, which is the frequency 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.

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 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, 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, supergroup, 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.

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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.

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.

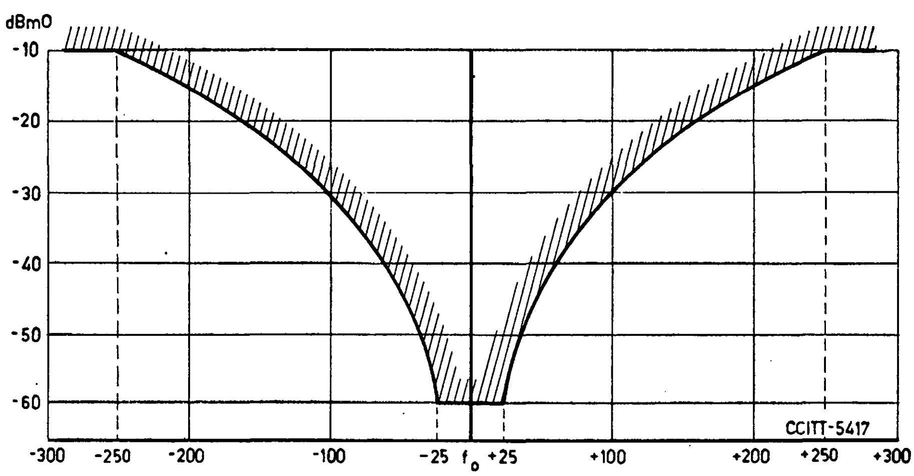
In view of this, a supermastergroup regulator is not necessarily suitable for the transmission of a 15-supergroup assembly over a supermastergroup link.

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, N 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.



Frequency difference from f_0 (pilot frequency) (Hz)

FIGURE 1/G.241 — **Maximum permissible level of discrete frequency components of wide-spectrum (group and supergroup signals) in the vicinity of group and supergroup pilot frequencies**

This limitation is so calculated that the group or 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 fixed by the Figure 1/G.241 which allows for the existing characteristics of regulators activated by pilots at frequencies (f_0) of 84.08 or 104.08 kHz in group links and of 411.92 or 547.92 kHz in supergroup links.

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, in order 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/G.241. 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.

The use of a group containing the supergroup pilot should always be avoided (see Recommendation H.14). This means that no special suppression of the wideband signal has to be provided in the group for the purpose of the supergroup pilot.

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 stop filter providing an attenuation of at least 40 dB 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 stop 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 at Geneva, 1964, at Mar del Plata, 1968, and at Geneva, 1972)

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 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.332, G.333 and G.337.

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.

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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.

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;
2. unintelligible crosstalk components	70 dB;
3. possible crosstalk components	35 dB wherever possible components appear;
4. harmful out-of-band components	40 dB;
5. harmless out-of-band components	17 dB.

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 107.7 kHz[2]) should not depart from the loss at 84 kHz[3] by more than ± 1 dB.

The loss between 10° and 40° C at 84 kHz should not differ by more than ± 1 dB 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 value of 70 dB 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 is 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 3. — 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.

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[1] This equipment comprises a group demodulation equipment, the through-group filter proper and a group modulation equipment.

[2] 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.

[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.

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;
2. unintelligible crosstalk components 70 dB;
3. possible crosstalk components 35 dB wherever possible components appear;
4. harmful out-of-band components 40 dB [1];
5. harmless out-of-band components 17 dB.

All these separations must be provided by the through-supergroup 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.

At any temperature between 10° and 40° C, insertion loss for all the through-supergroup connection equipment [2] at any frequency of the passband (312.3 to 551.4 kHz[3]) should not depart from the loss at 412 kHz[4] by more than ± 1 dB.

The loss between 10° and 40° C at 412 kHz should not differ by more than ± 1 dB 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 2 below.

Note 2. — The ratio of 70 dB 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 is advocated for the bands liable to be used for programme transmission in each supergroup adjacent to the transferred supergroup.

Note 3. — 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 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;
2. unintelligible crosstalk components 70 dB;
3. possible crosstalk components 35 dB wherever possible components appear;
4. harmful out-of-band components 40 dB[5];
5. harmless out-of-band components 17 dB.

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[1] 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.

[2] This equipment comprises a supergroup demodulation equipment, the through-supergroup filter proper and a supergroup modulation equipment.

[3] When supergroups contain group A in an attitude different from that of groups B to E (see Figure 2/G.322), the limits of the passband are: 312.3 and 551.7 kHz.

[4] 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.

[5] 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.

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 from the loss at 1552 kHz.

The loss between 10° and 40° C, at 1552 kHz, should not deviate by more than ± 1 dB from the loss at 25° C.

Within each supergroup the total variation of the insertion loss should not exceed ± 1 dB relative to the loss at the frequency of the supergroup reference pilot.

Note. — The ratio of 70 dB 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 is 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;
2. unintelligible crosstalk components	70 dB;
3. possible crosstalk components	35 dB; wherever possible components appear;
4. harmful out-of-band components	40 dB[2];
5. harmless out-of-band components	17 dB.

All these ratios should be achieved by the through-supermastergroup filter itself. They refer to the nominal level of the 11 096 kHz reference frequency (supermastergroup pilot) by which the loss of the combined supermastergroup equipment[3] 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 from the loss at 11 096 kHz. Within each mastergroup the total variation in insertion loss should not exceed ± 1 dB relative to the loss at the frequency of the mastergroup pilot.

The loss between 10° and 40° C, at 11 096 kHz, should not deviate by more than ± 1 dB from the loss at 25° C.

Note. — The ratio of 70 dB 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 is advocated for the bands liable to be used for programme transmission in each mastergroup adjacent to the transferred mastergroup.

[1] This equipment comprises a mastergroup demodulation equipment, the through-mastergroup filter proper, and a mastergroup translating equipment.

[2] 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.

[3] 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;
2. unintelligible crosstalk components 70 dB;
3. possible crosstalk components 35 dB wherever possible components appear;
4. harmful out-of-band components 40 dB[1];
5. harmless out-of-band components 17 dB.

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 passband (312 to 4028 kHz) of the combined through-15-supergroup equipment[2] should not deviate by more than ± 1.5 dB from the loss at 1552 kHz.

The loss between 10° and 40° C at 1552 kHz should not deviate by more than ± 1 dB from the loss at 25° C.

Within each supergroup, the total variation of the insertion loss should not exceed ± 1 dB relative to the loss at the frequency of the supergroup reference pilot.

Note. — The ratio of 70 dB 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 is 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., in so far as they are not in contradiction with those recommended in Recommendation G.243, E (pilot signals and additional measuring frequencies in direct-through connections).

Recommendation G.243 (amended at Geneva, 1964, at Mar del Plata, 1968, and at Geneva, 1972)

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.

[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 15-supergroup assembly 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.

It is therefore recommended that Recommendations G.232, N and G.234 be met, which specify an attenuation of at least 20 dB 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, k, 1.2, have to be followed. Otherwise, it is necessary at least to follow the recommendation of G.233, k, 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 Recommendation G.233, k, 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 suppression filter immediately preceding 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;

— over the range 308 kHz ± 40 Hz, and the range 556 kHz ± 40 Hz, not less than 20 dB.

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, an additional attenuation giving a discrimination of at least 40 dB 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 (multipurpose 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.

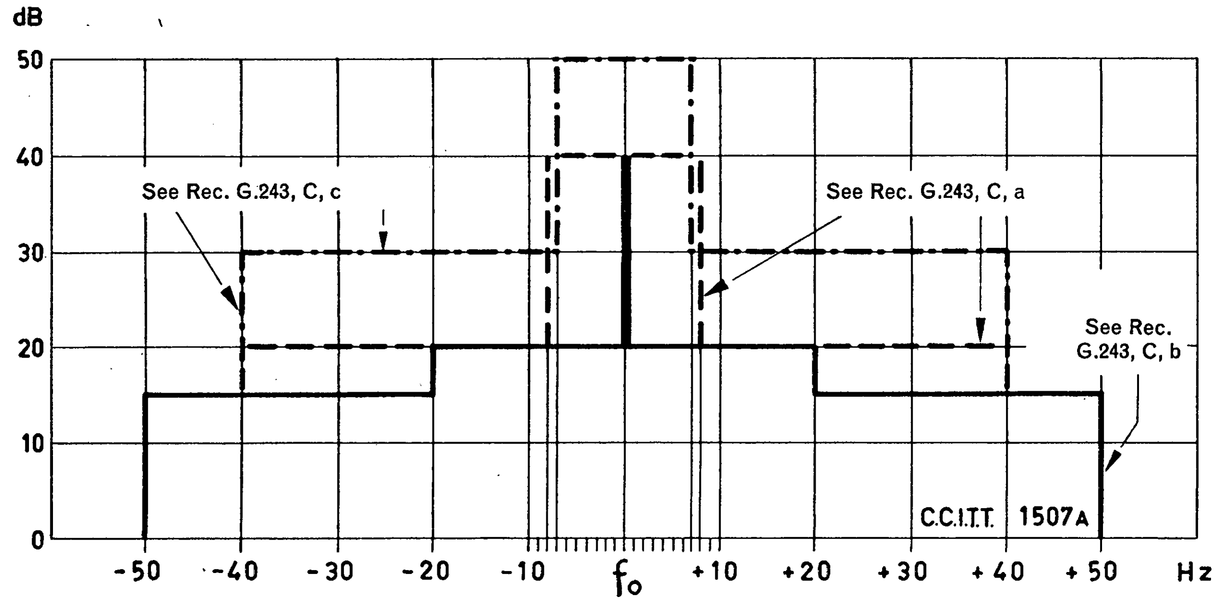
b) *Protection of additional measuring frequencies*

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;

— over the range 308 kHz ± 20 Hz and the range 556 kHz ± 20 Hz, not less than 20 dB;

— at frequencies of 308 kHz and 556 kHz, not less than 40 dB.



Note 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 — · — · — · —

Note 2. — This graph applies both to f_0 = 308 kHz and to f_0 = 556 kHz.

FIGURE 1/G.243. — **Minimum recommended relative attenuation around 308 kHz and 556 kHz for various cases of through-supergroup connection**

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;

— over the range 308 kHz ± 40 Hz and the range 556 kHz ± 40 Hz, 30 dB.

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.

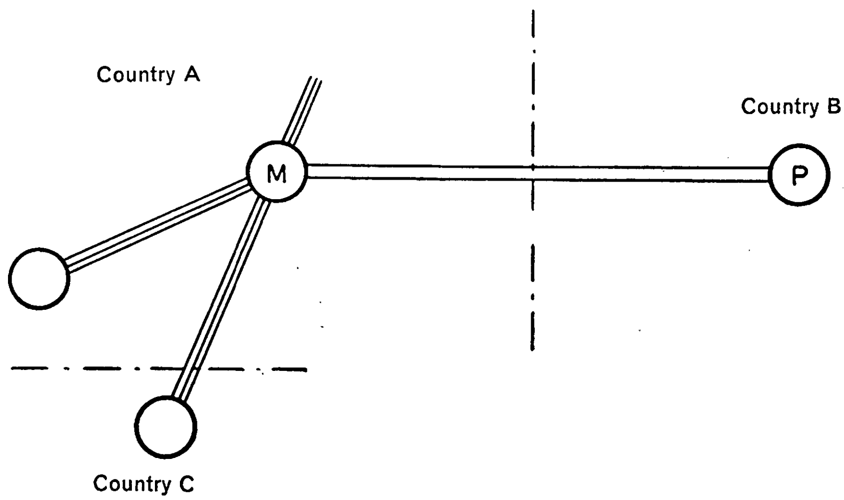
Note. — Figure 1/G.243 recapitulates all the attenuations recommended over the range 308 kHz and 556 kHz.

D. End of a supermastergroup 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/G.243, point M is the end of a supermastergroup link, at which point the supermastergroup pilot should not be transmitted to country 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 link PM.

In any case, the supermastergroup pilot is considered as blocked when it undergoes an additional attenuation of 40 dB.



O 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.

FIGURE 2/G.243. — **Definition of a supermastergroup link**

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 section BC (see Figure 3/G.243). 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.

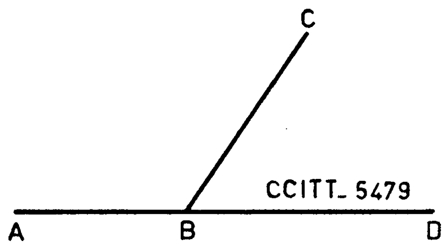


Figure 3/G.243

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 the regulation of line section BD is to be performed together with the regulation of line section AB (and with that section only), the regulated line section extends from A to D and point B is not the end of the regulated line section AB. If one or two line-regulating pilots are outside the frequency band of the supergroups, mastergroups or supermastergroups diverted over BD, or lie at the edge of this frequency band, special arrangements must be made at point B for these pilots to be extended beyond B on to section BD (see Recommendation G.213, a, General remarks, 2).

In the direction of C, however, the line-regulating pilots of section AB should be stopped, in the same conditions as at the end of the regulated-line section, so as not to be transmitted on section BC.

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 the frequency bands of the supergroups, mastergroups or supermastergroups are diverted as a whole.

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 one of these pilots also be a line-regulating pilot (multipurpose pilot) the rules defined above for line-regulating pilots should be applied.

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[1] If the supergroups are in the basic supergroup frequency band, this becomes the case dealt with in part C.

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 all the interconnected sections (in this case, BC and BD), they are at least 40 dB below the pilots used on these sections.

When some (or all) of the pilots used on line-regulating section AB are not on the same frequency as those used on a line-regulating section connected to it, suppression of these pilots by 20 dB only (which implies a residue of not more than −30 dBm0 on the connected line-regulating section) may be tolerated at direct through-connection point B, if this residue is further suppressed by 20 dB before reaching the injection point of a line-regulating pilot with the same frequency on another line-regulating section connected at a distant point (for example, at D). However, the line-regulating pilot should be suppressed by 40 dB whenever it is applied to an international line-regulated section crossing at least one frontier. It therefore follows that the line-regulating pilot should be suppressed by 40 dB if the following section is an international section, even with a line-pilot at a different frequency. Similarly, if a line-regulating pilot is suppressed by 20 dB only, a supplementary attenuation of 20 dB must be introduced on the line frequency at the end of the corresponding line-regulating section before this pilot residue reaches a distant international section.

With reference to the example in Figure 1/G.213, the sum of the suppression of (2) and (5) (see legend) at the frequency of any received line-regulating pilot should therefore be at least 40 dB when the frequencies of these pilots are the same on both interconnected regulated-line sections. Division of this suppression between filters (2) and (5) may be made in different ways. As 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.

If it is considered necessary always to have a filter (5) before the point of injection of an outgoing line-regulating pilot, for the suppression of unwanted signals from other equipments, and if the line-regulating pilots of the two interconnected regulated-line sections are on the same frequency, the division may be made in the following way:

filter (2) = 20 dB   filter (5) = 20 dB.

Thus, if the frequencies of the pilots do not coincide and there is no interconnection with an international section, the 20 dB suppression recommended above will remain. Nevertheless, this provision may necessitate the addition of a further suppression at the adequate frequency at some point before reaching an international section.

To avoid the latter difficulty, it may be considered preferable, in order to facilitate network arrangements, to adopt the value of 40 dB for (2). If the frequencies of the pilots are the same on both interconnected regulated-line sections and if it has been considered desirable always to have a filter (5) before the point of injection of an outgoing line-regulating pilot, the suppression of the received line-regulating pilot will be very much greater than the recommended value of 40 dB. There is no technical objection to this.

Additional measuring frequencies. — The additional measuring frequencies within the frequency band occupied by all the through-connected supergroups, etc., 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 *Green Book*).

[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 at 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 ouput 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.

Intermediate repeater equipment: ± 2 dB for a route of length comparable to a typical homogeneous section—i.e. some 450 km or comprising about four repeater sections.

The maximum value of the nominal level should be + 17 dBr 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 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 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 a tolerance of ± 0.5 dB;

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 a tolerance of ± 1 dB.

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/G.311 and 2/G.311 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 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 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.

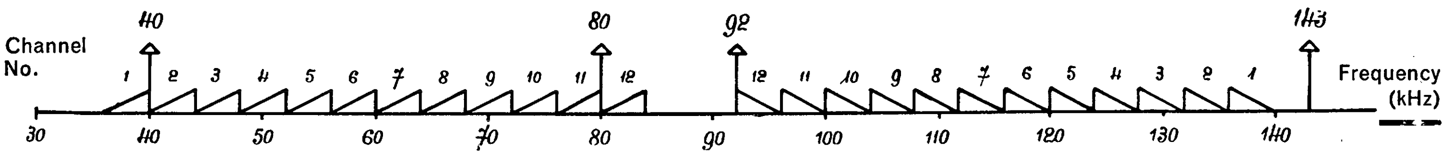

FIGURE 1/G.311. — **Frequency allocation for a 12-channel open-wire carrier telephone system—Scheme I**

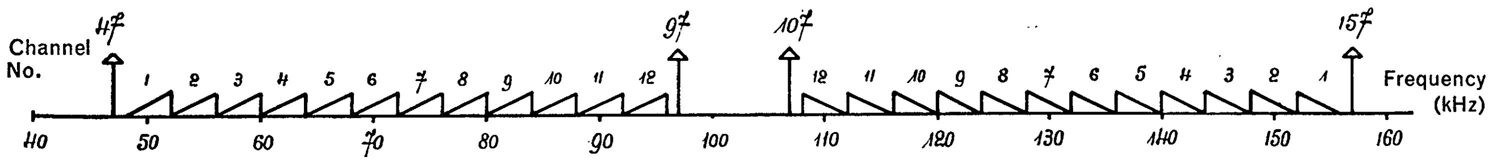

FIGURE 2/G.311. — **Frequency allocation for a 12-channel open-wire carrier telephone system—Scheme II**

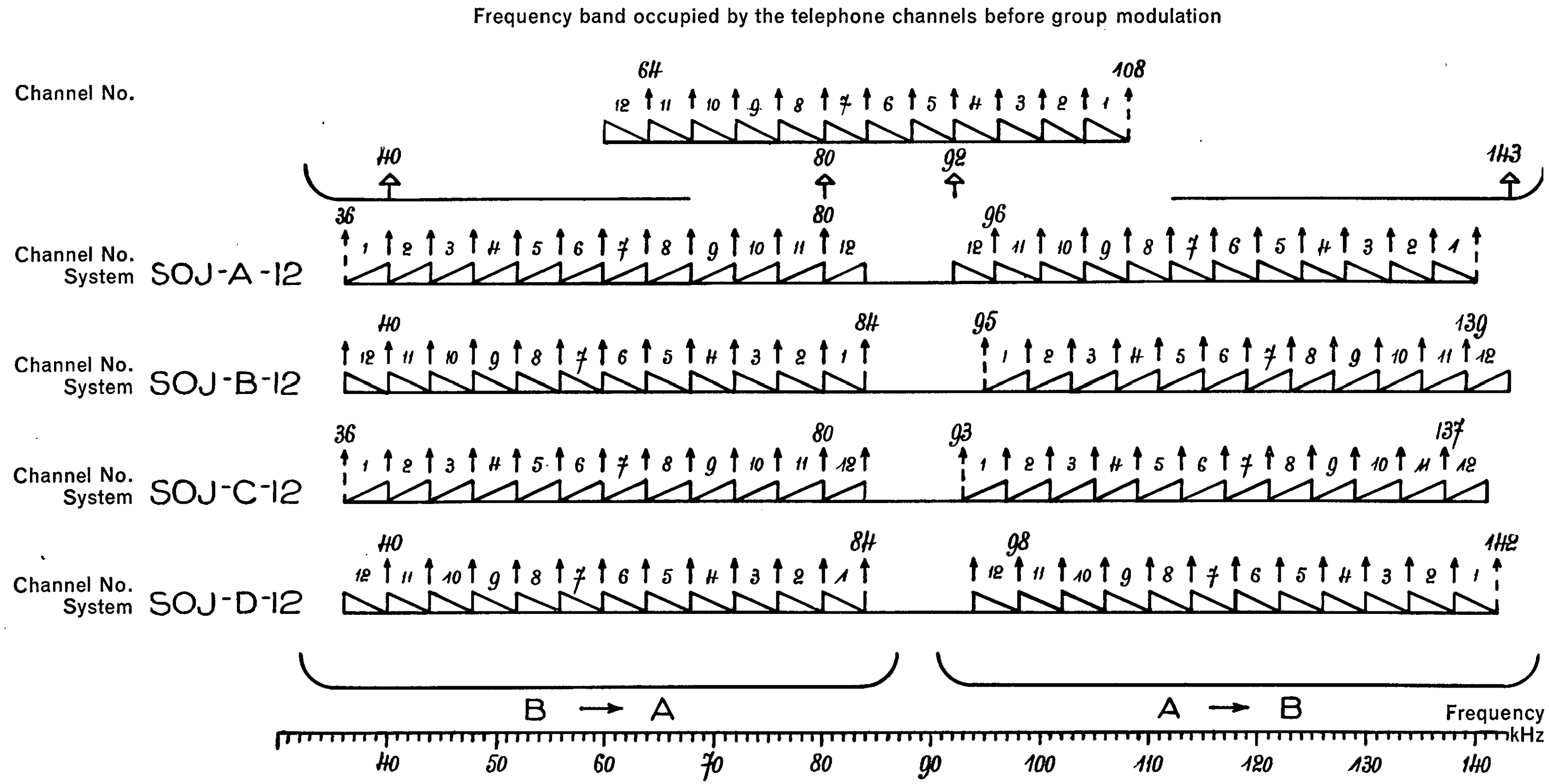

FIGURE 3/G.311. — **Frequency allocation for a 12-channel open-wire carrier telephone system, using Scheme I** *(continued on following page)*

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/G.311 *(continued)*. — **Table showing carrier frequency allocation**

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/G.311 and 4/G.311 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 not been reached on the choice of a particular division of the line-frequency spectrum. It is left to Administrations 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/G.311 or Scheme II of Figure 2/G.311), 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.

The nominal power 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 dBm0. 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 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}.

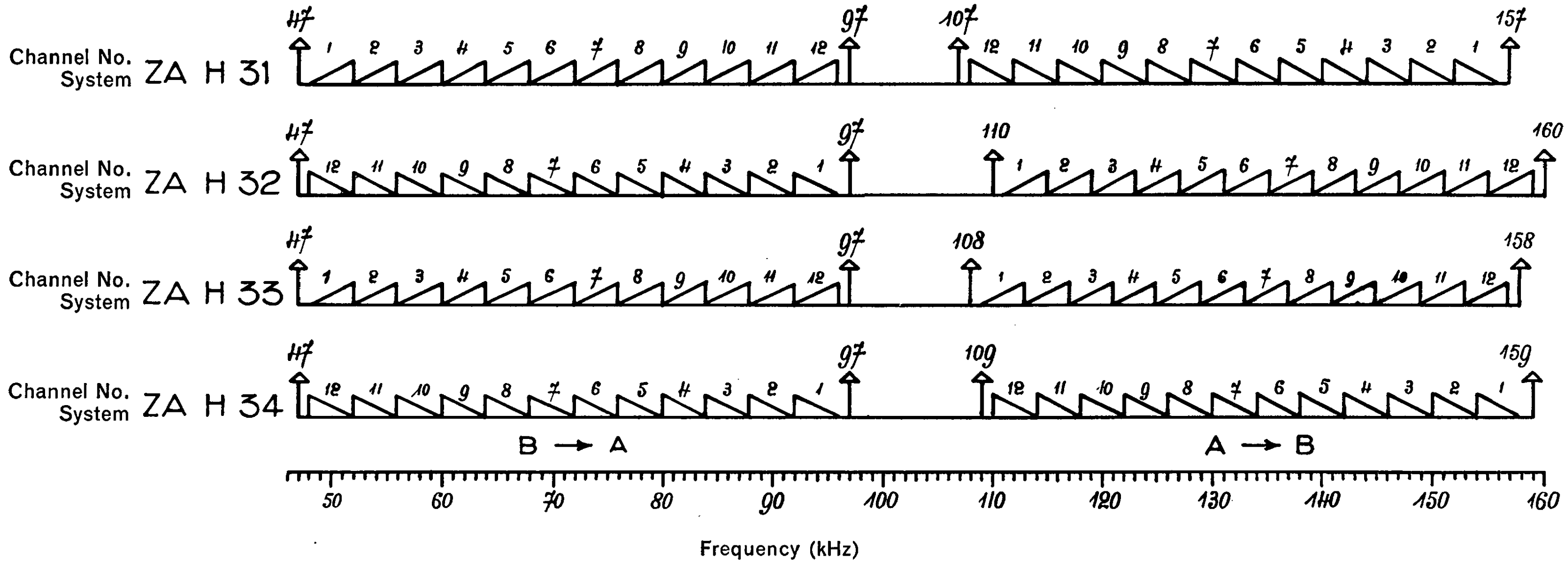

FIGURE 4/G.311. — **Frequency allocation for a 12-channel open-wire carrier telephone system, using Scheme II**

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:

— pairs of channel modulators and demodulators,

— pairs of group modulators and demodulators.

Figure 5/G.311 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.

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 distribution among the various components of total line noise is shown in Supplement No. 6 of this volume.

[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.

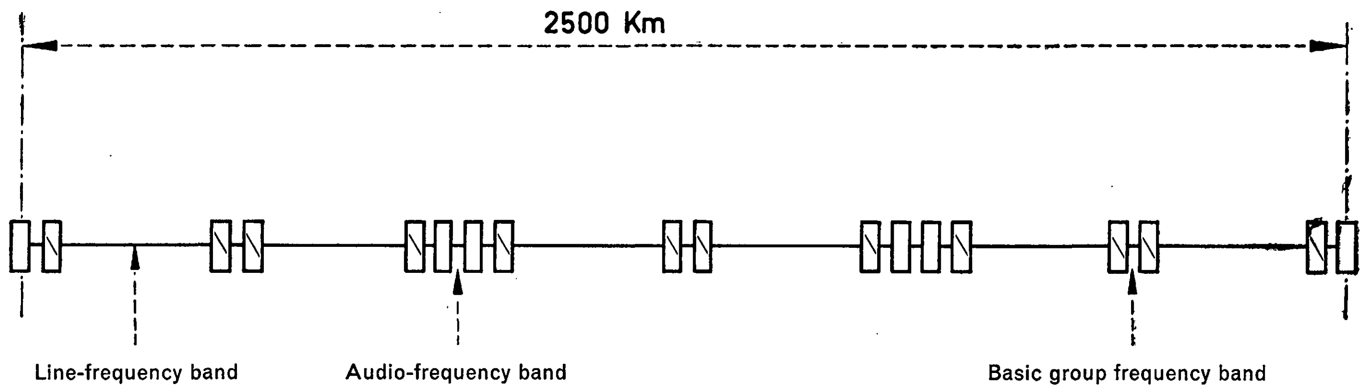

FIGURE 5/G.311. — **Diagram of the hypothetical reference circuit on open-wire lines**

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 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 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 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 powei 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; the third order harmonic margin (ratio of the third harmonic to the fundamental) should be not less than 80 dB.

d) *Overload point.* — The overload point of a repeater should be not less than 33 dB.

This overload point is the value of the total power at the ouput for which an increase of 1 dB would be accompanied by an increase of 20 dB 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, 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 relative level to be transmitted on open-wire lines has been fixed at +17 dBr. The lowest level on an open-wire line should not be allowed to fall below −17 dBr 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, these 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 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 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 intended 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. Aurell (*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.

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 25 m 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 following protective methods were used by the Cuban Telephone Company:

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 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 8 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, c). 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 dBr already recommended for 12-channel systems (Recommendation G.313, a).

c) *Frequencies transmitted to line*

The system should have 8 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/G.314 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 these modulation procedures in preference to the other.

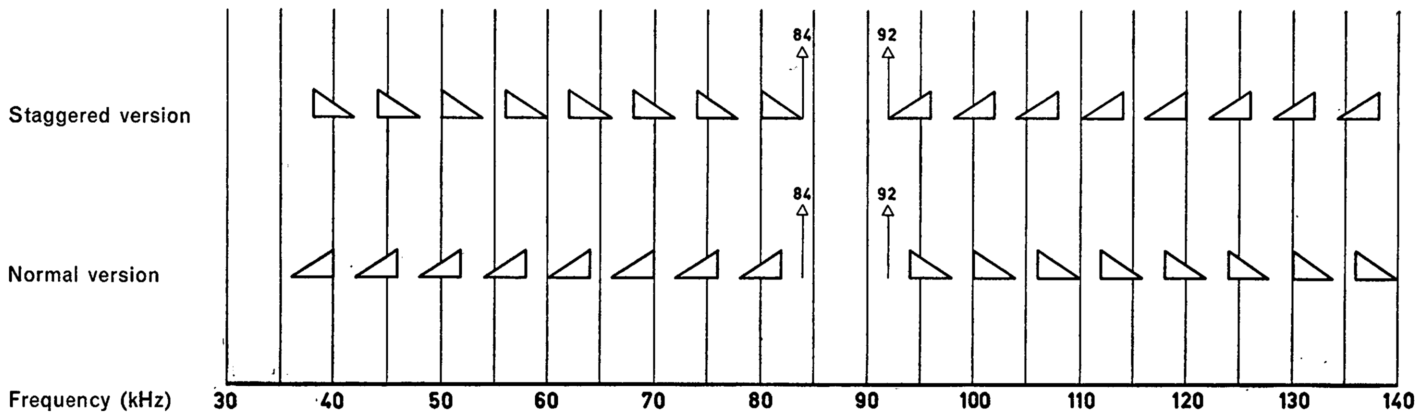

FIGURE 1/G.314. — **Line-frequency allocation of 8-channel open-wire system**

By way of information, when more than 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/G.314 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/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/G.314 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/G.314, 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}.

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.324
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 at 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.

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.

[1] In Volume III of the *Blue Book* (Geneva, 1964).

	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 (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 (dB/km)					
at 60 kHz	26 (22.6)	—	—	—	—
at 120 kHz	36 (31.3)	23 (20.0)	17 (14.8)	21 (18.2)	16 (13.9)
at 240 kHz	—	33 (28.7)	24 (21.0)	31 (26.9)	23 (20.0)
at 552 kHz	—	55 (47.8)	36 (31.3)	51 (44.3)	34 (29.5)

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* (types 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;

— near-end crosstalk attenuation should be greater than 56 dB.

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, the above limits will be reduced by

$$20 \log_{10} \frac{L}{230} \text{ dB}$$

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 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 in picofarads:				
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 nanohenrys:				
between pairs of the same quad	150	125	600	500
between pairs of adjacent quads in the same layer	100	40	400	150
between pairs in non-adjacent quads	50	20	350	150
between pairs in quads in adjacent layers . .	100	40	600	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, 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.

[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.

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 for low-gain systems with 1, 2 or 3 groups and 36 dB 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 ratio 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.

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 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.

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 for the highest frequency. For 20% of the sections, a maximum value of 61 dB.

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 for repeater sections of 12-channel systems;

65 dB 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 at 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/G.322 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]

This hypothetical reference circuit consists of 6 homogeneous sections of equal length (see Recommendation G.212).

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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".

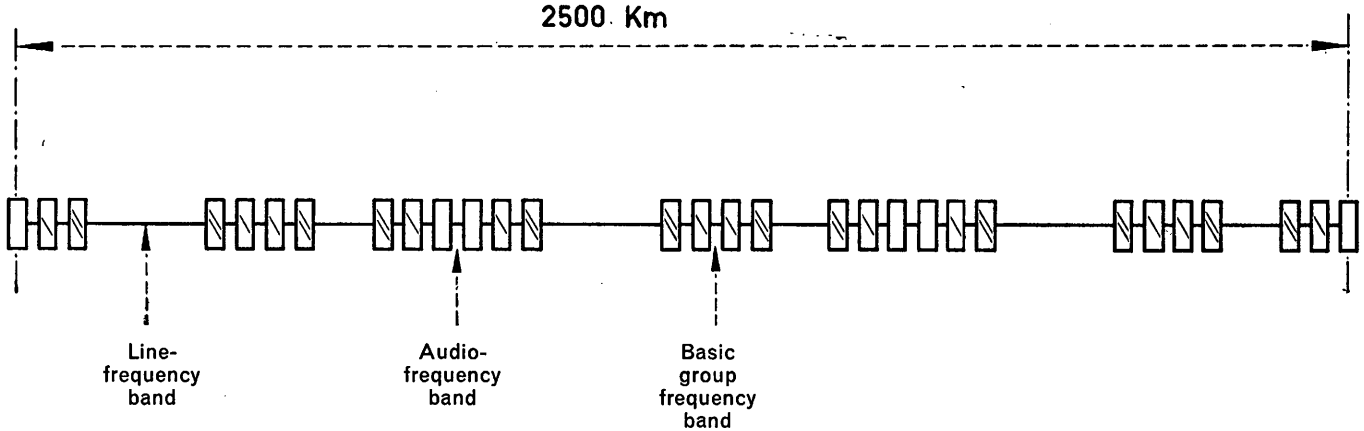


FIGURE 1/G.322. — **Diagram of the hypothetical reference circuit on symmetric cable pairs**

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 Recommendation G.338, c).

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 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*/G.322.

2. *Systems providing 4 groups*

The frequency spectrum transmitted to line should be in accordance with scheme 1 of Figure 2*b*/G.322.

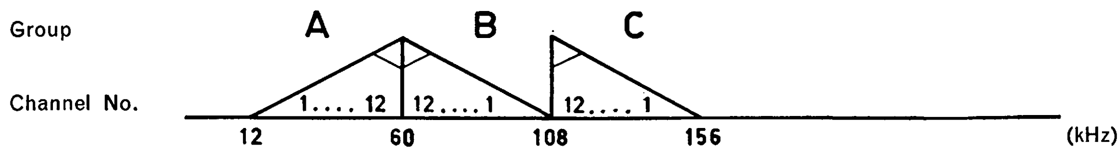
Note. — By agreement between the Administrations concerned, it is possible to omit one group of supergroup 1* shown in scheme 2 of Figure 2*c*/G.322, for systems with five groups; if this is done, scheme 1*bis* of Figure 2*b*/G.322, is obtained.

3. *Systems providing 5 groups*

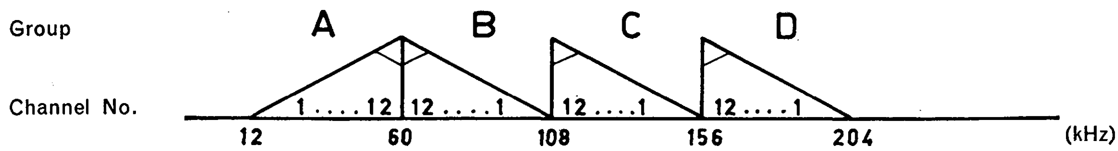
The frequency spectrum transmitted to line should be in accordance with scheme 2 of Figure 2*c*/G.322.

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 concerned, the system with 5 groups, shown in scheme 2*bis* of Figure 2*c*/G.322, may be used.

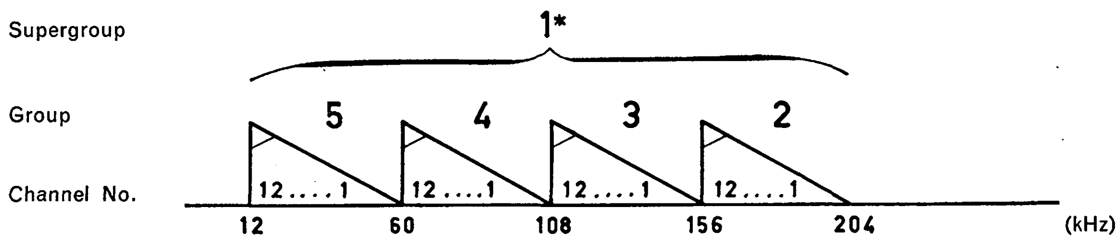
Note 2. — By agreement between the Administrations concerned, the arrangement in Figure 3/G.322 can be used for a supergroup on a coaxial cable system which is to be interconnected at basic supergroup frequencies (312–552 kHz) with either a 5-group system on symmetric pairs using scheme 2*bis* (Figure 2*c*/G.322, or with a 4-group system using scheme 1 (Figure 2*b*/G.322).



a) Systems providing one, two or three groups

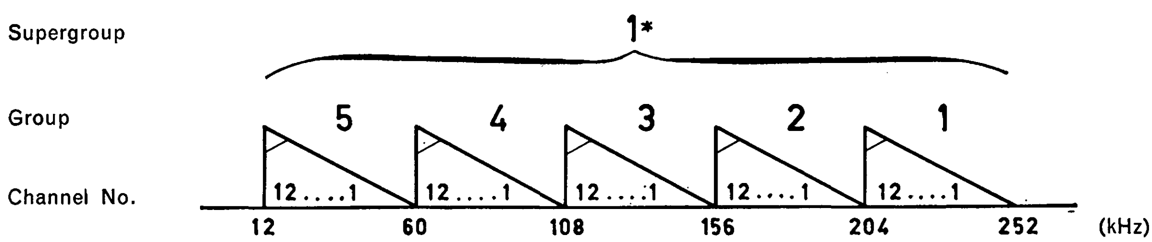


Scheme 1 (recommended)

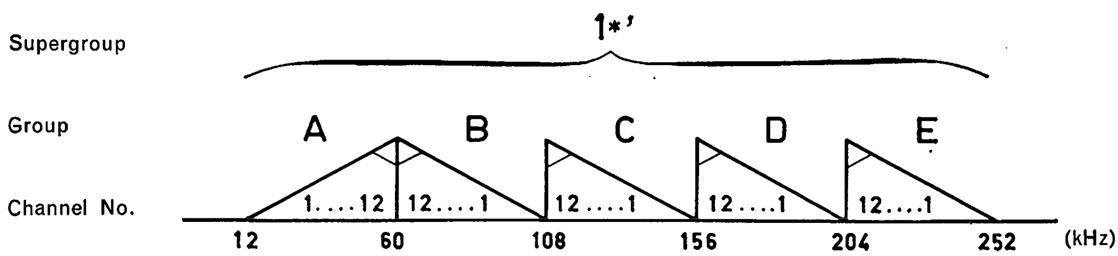


*Scheme 1*bis (which may be used by agreement between Administrations)

b) Systems providing four groups



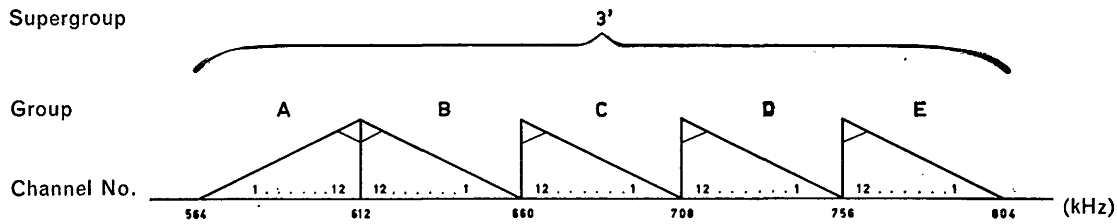
Scheme 2 (recommended)



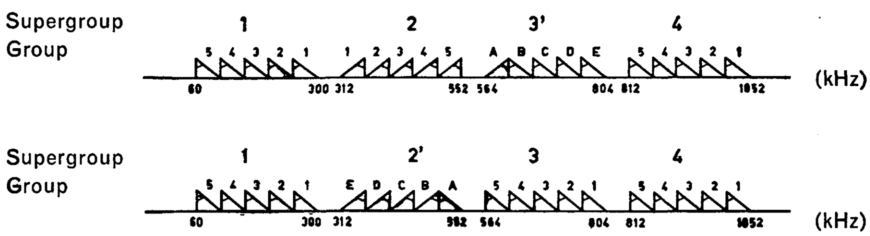
*Scheme 2*bis (which may be used by agreement between Administrations)

c) Systems providing five groups

FIGURE 2/G.322. — **Line-frequency allocation for international carrier systems on symmetric cable pairs.**

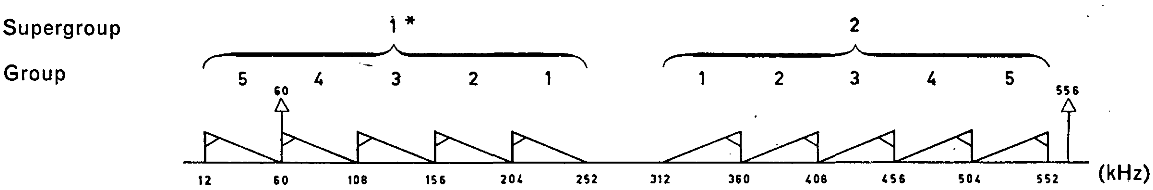


a) Arrangement of groups and channels (supergroup 3′ has been shown as an example)

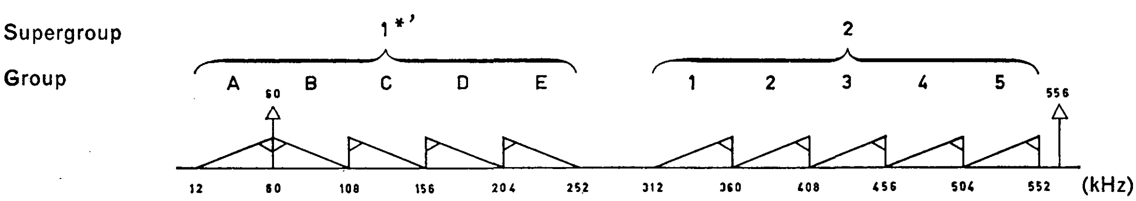


b) Example of possible positions, in the coaxial line-frequency band of the supergroup corresponding to Scheme 2*bis* of Figure 2*c*/G.322.

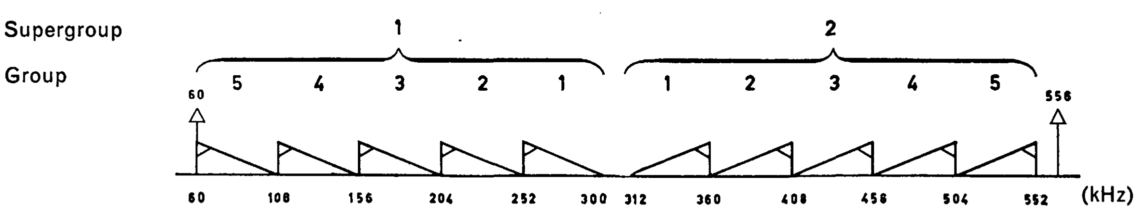
FIGURE 3/G.322. — **Arrangement of groups in a supergroup, which may be used in coaxial carrier systems interconnected with systems on symmetric pairs**



Scheme 3 (recommended)



*Scheme 3*bis (may be used by agreement between Administrations)



Scheme 4 (recommended)

FIGURE 4/G.322. — **Line-frequency allocation for international carrier systems providing 2 supergroups on symmetric pair cables**

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/G.322 and in Figure 1/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/G.322, 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 concerned, for five group systems on symmetric cable pairs, instead of supergroup 1*, supergroup 1*′ may be used (scheme 2*bis*, Figure 2*c*/G.322), which gives the arrangement shown in scheme 3*bis* of Figure 4/G.322.

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/G.322).

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 a power level of —15 dBm0, 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 a power level of —15 dBm0.

Note. — There are in existence systems with five 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:

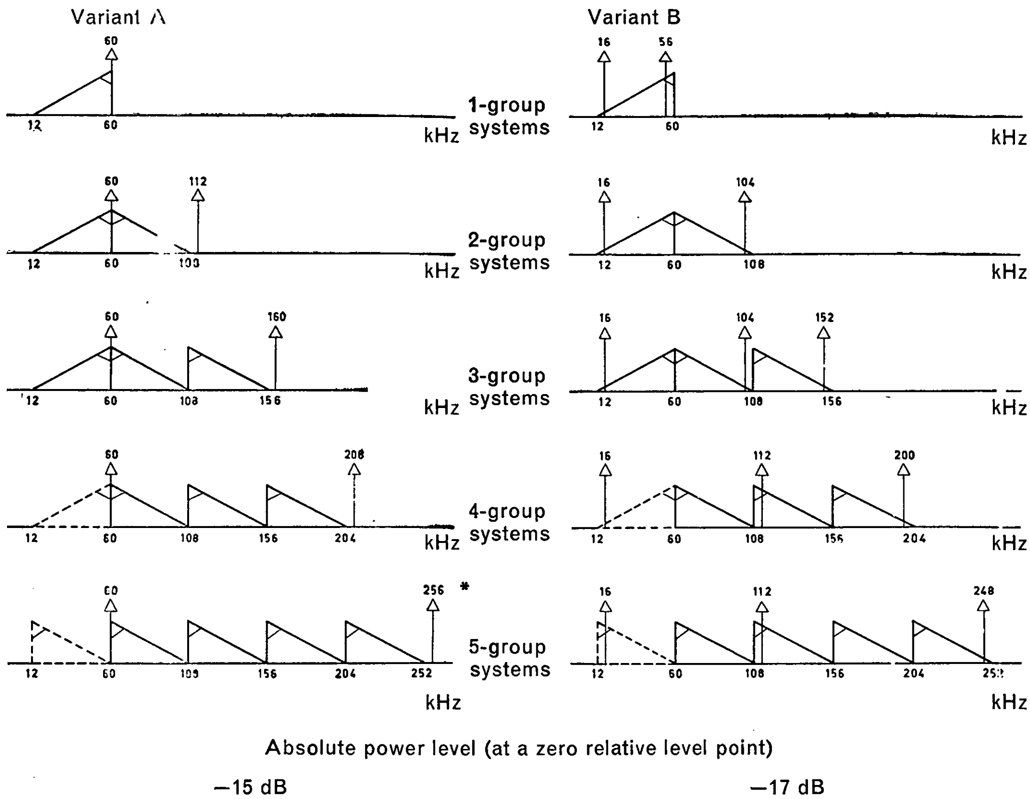
± 1 Hz for the 60-kHz pilot;

± 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 a power level of —17 dBm0.

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.



Note. — The group shown dotted can be invertedwithout changing the frequencies recommended for pilots.

* Recommended frequency; there are systems using 253 kHz.

FIGURE 5/G.322. — **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 power level of —15 dBm0;

upper pilot: 4 kHz above the highest transmitted frequency, i.e. 556 kHz power level of —15 dBm0.

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 regulating 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 a power level of −10 dBm0. So that there will be no interference with the 120-circuit system line-regulating pilot sent at −15 dBm0, this system should incorporate its own additional protection of 5 dB 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 and which meets the limit for far-end crosstalk ratio (direct far-end crosstalk) of at least 69.5 dB (the cable being between impedances equal to its characteristic impedance), 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 polythene or styroflex-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 ouput of each repeater shall be:

−11 dBr for systems with 1, 2 or 3 groups;
−14 dBr 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 of a repeater should not exceed a value corresponding to the limits shown in the table:

Limits for	Systems providing		
	1, 2 or 3 groups	4 or 5 groups	2 supergroups
2nd-order harmonic margin [a]	79 dB	82 dB	85 dB
3rd-order harmonic margin [a]	92 dB	98 dB	104 dB

[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.

e) *Overload point*

The overload point, defined in paragraph 6.1 of Recommendation G.223, is at least 14 dB 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. 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 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 Recommendation 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 equipments. 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 interconnection 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	−1.30 Np
	at 252 kHz	−0.10 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 amplification
(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 −15.20 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 resistance of the cable $P \leqq 0.1 \sqrt{\frac{f_{max}}{f}}$ and less than 0.2 Np

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 $2f_1 - f_2$ 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 recommendation

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 measured at the highest frequency transmitted.

The above value is a nominal value and a factory tolerance of ± 1 dB, 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 dBr. (Any equalizers are considered to be a part of the repeater.)

The nominal value of the relative power level, measured at the output of the repeater, under the same conditions as above, is as follows:

— systems providing 1, 2 or 3 groups: +4.5 dBr;
— systems providing 4 or 5 groups or 2 supergroups: +1.75 dBr.

Interconnection conditions at frontier repeaters. — For lining-up and for reference (see Maintenance Instructions, *Green 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 of the relative level measured at each of these frequencies should normally be +4.5 dBr for systems with 1, 2 or 3 groups and +1.75 dBr 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.

c) *Harmonic distortion*

The harmonic distortion of a repeater should not exceed a value corresponding to the limits shown in the table:

Limits for	Systems providing		
	1, 2 or 3 groups	4 or 5 groups	2 supergroups
2nd-order harmonic margin [a]	77 dB	80 dB	83 dB
3rd-order harmonic margin [a]	84 dB	90 dB	100 dB

[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 and for a fundamental power of 1 mW at a point of zero relative level, and assuming that valves with average characteristics are used.

[1] Not applicable to power-fed repeaters.

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 and for the repeaters of systems providing two supergroups it should be at least 29 dB.

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.

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 pair 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/G.325.

Administrations concerned in setting up such an international system should agree to use either one or the other of the two schemes.

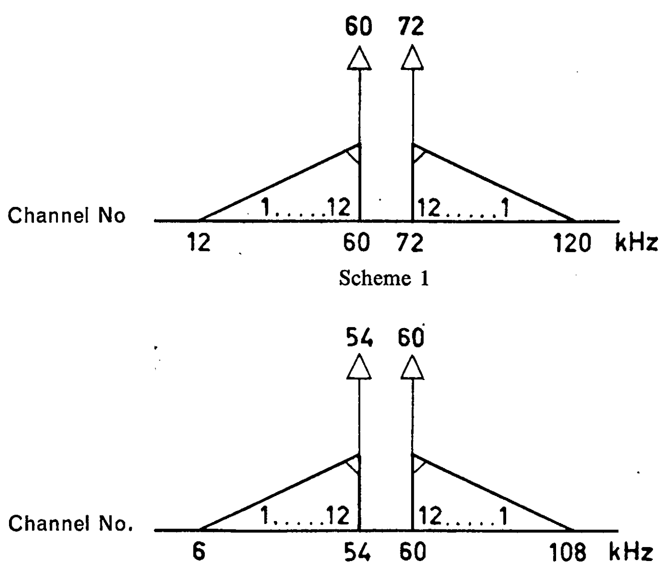


FIGURE 1/G.325. — **Arrangement of line-transmitted frequencies for international (12 + 12) cable systems using transistors**

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 power level of −15 dBm0.

c) *Hypothetical reference circuit for (12 + 12) symmetric-pair system*

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, with pairs assumed to be of conductors of 0.9 mm diameter, with an effective capacitance of 35 to 40 nF/km.

Figure 2/G.325 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/G.325).

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 pW 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.

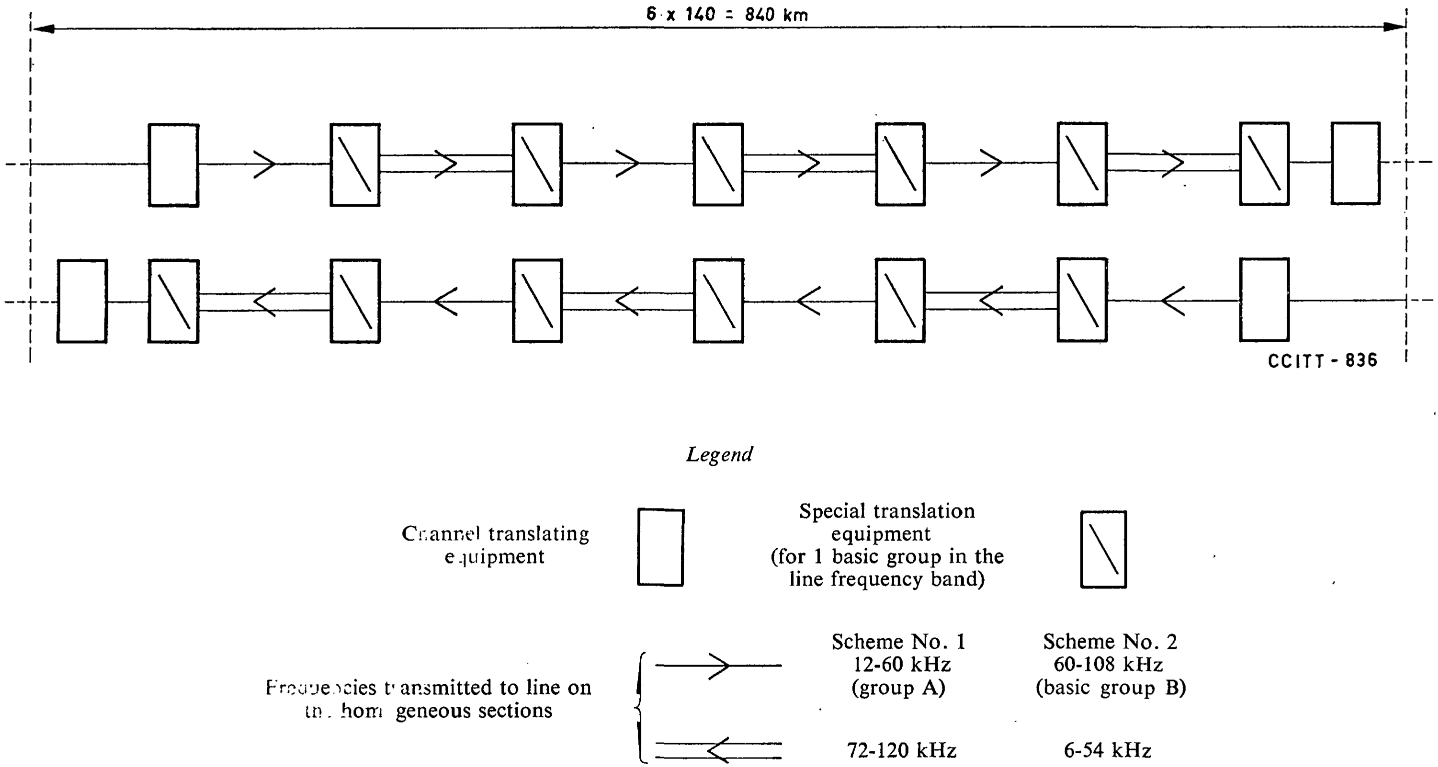


FIGURE 2/G.325. — **Basic diagram of one-third of the hypothetical reference circuit for symmetric pair (12 + 12) systems**

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/G.325) and the frequency received at the end of that section, 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):

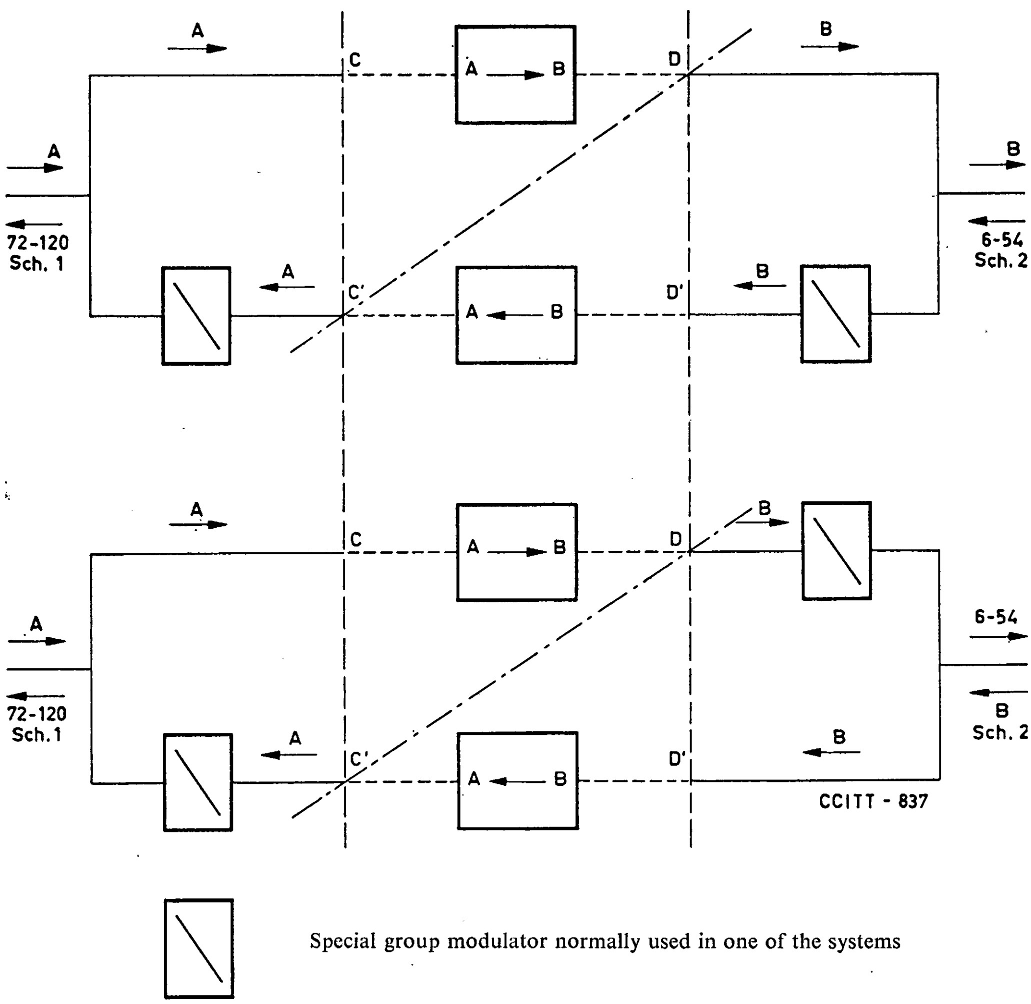


FIGURE 3/G.325. — **Direct interconnection of two (12 + 12) systems using different allocations of frequencies transmitted to line**

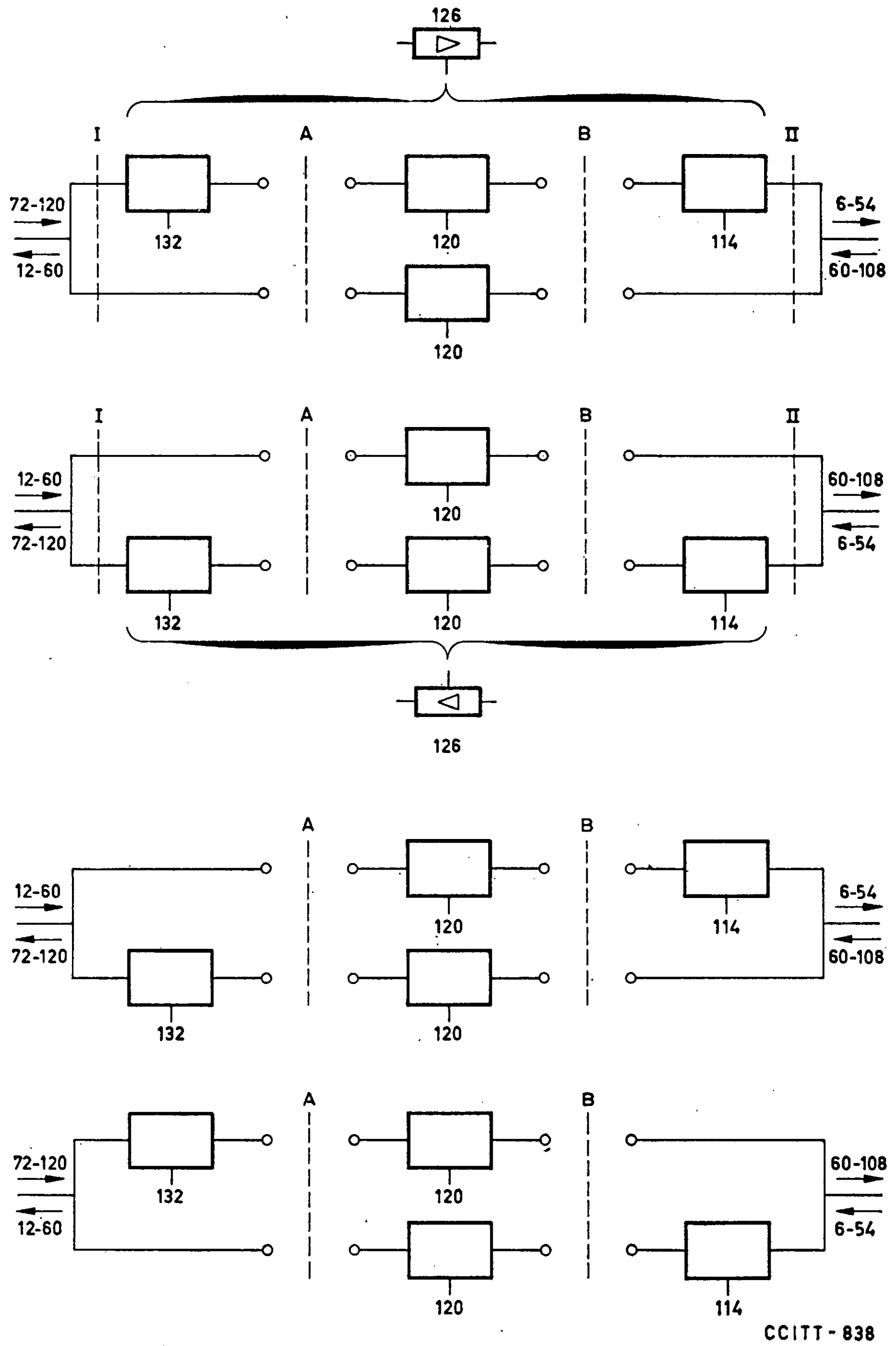


FIGURE 4/G.325. — **Method of interconnection that can be used by agreement between Administrations (the numbers on this diagram show frequencies in kHz ; A and B indicate the basic group concerned)**

1. Relative level per channel, at all frequencies, at the output of the frontier repeaters: −15 dBr.[1]

2. Attenuation of the frontier repeater section at the highest frequency transmitted to line: 25 dB.[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/G.325).

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/G.325 would then be the oblique DC′).

Unless there is a specific agreement, the relative power level will be −36 dBr at sending (input of each system—points C′ and D in the case of Figure 3/G.325). The points 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/G.325, a method whereby it is possible to replace three modulators by one.

h) *Essential clauses for a model specification*

See Recommendation G.326.

Recommendation G.326 (former Recommendation G.328, Geneva, 1964)

TYPICAL TRANSISTORIZED SYSTEMS ON SYMMETRIC PAIRS OF THE (12 + 12 SYSTEMS) 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

[1] These values apply to low-gain systems. High-gain systems (i.e. substantially above 30 dB) are still under study.

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 different 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. Furthermore, 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, for a repeater section and a repeater output level of −10 to −13 dBr, 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, attenuation for a repeater section and either 0 dBr or +7 dBr 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 table:

System	Harmonic margin [a]		3rd order intermodulation products
	2nd order	3rd order	
Low-gain without frequency-frogging (A)	78 dB	92 dB	
High-gain			
without frequency-frogging (B)	74 dB	78 dB	
with frequency-frogging (C)			
(1)	70 dB	90 dB	
(2)			75 dB

[a] See the *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 the 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 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 in type A systems

80 dB 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 at Geneva, 1964)

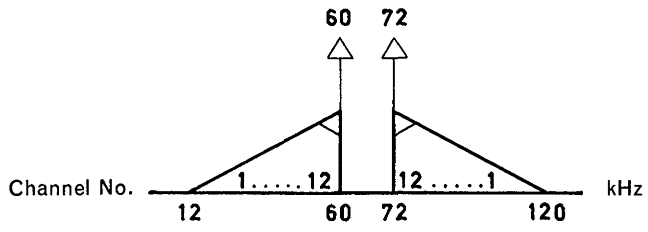
VALVE-TYPE SYSTEMS OFFERING 12 TELEPHONE CARRIER CIRCUITS ON A SYMMETRIC PAIR IN CABLE (12 + 12) SYSTEMS

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.

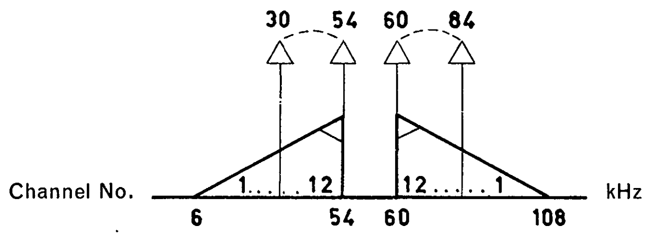
a) *Frequency spectrum transmitted to line*

The C.C.I.T.T. recommends that the line-frequency spectrum should be in accordance with Scheme 1 or 2 of Figure 1/G.327.

Administrations concerned in setting up such an international system should agree to use either one or the other of the two schemes.



Scheme 1



Scheme 2

FIGURE 1/G.327. — **Line-frequency arrangements for international (12 + 12) cable systems using valves**

b) *Line-regulating pilots*

For valve-type (12 + 12) channel carrier telephone systems on symmetric pairs where 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.

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 power level of −15 dBm0.

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 systems 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)		
Recommendations *(Green 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)		
Recommendations *(Green Book)*	G.341	G.343	G.344	G.345	G.356

Note. — See also Recommendation G.352 (G.336).

Recommendation G.331 (former Recommendation G.334, amended at Mar del Plata, 1968, and at Geneva, 1972)

CHARACTERISTICS OF COAXIAL CABLE PAIR, TYPE 2.6/9.5 mm [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 having the following characteristics. The centre conductor is a solid copper wire of 2.6 mm diameter. The outer conductor consists of a soft copper tape, 0.25 mm thick, formed into a cylinder around the insulation, the axis of this cylinder being the axis of the centre conductor; the interior diameter of the outer conductor is 9.5 mm. The insulation is such that the mean permittivity 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.

[1] These pairs may be used for the following systems: 2.6 MHz, 4 MHz, 6 MHz, 12 MHz, 40 MHz or 60 MHz (see Recommendations G.332 to G.339).

b) *End impedance*

The impedance characteristic of the coaxial pair follows a well-defined law depending on frequency given by:

$$Z = 74.4 \left[1 + \frac{0.0123}{\sqrt{f}} (1 - j)\right] \text{ ohms}$$

where f is the frequency measured in MHz.[1]

There is therefore no point in specifying values at all frequencies. The figure 74.4 (impedance at infinite frequency) is subject to a tolerance of $\pm$ 1 ohm.

To check that this condition is met, either steady-state measurements or pulse measurements can be made.

For steady-state measurements, the check is often made in terms of the smooth impedance-frequency curve.

For pulse measurements, one approximate sine-squared pulse having a half amplitude with less than 100 ns should be used. The deviation may be determined either by balancing against a variable reference impedance or alternatively measuring the reflection coefficient against a fixed reference standard.

c) *Impedance regularity*

Measurements of impedance regularity are carried out by means of pulses sent over the coaxial cable with the echoes of the pulses being observed.

Measurements can be made from either or both of the ends of a factory length; the pulse is that defined in A, b above and is about 50 ns wide. The results are expressed in terms of "echo attenuation". This, for a peak in the response curve, is the logarithmic ratio in dB 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 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 (which are valid regardless of the system considered):

50 dB for all coaxial pairs;

56 dB for at least 95% of coaxial pairs measured.

Moreover, for systems at 12 MHz or less, not more than 20% of the coaxial pairs constituting a repeater section on one direction of one system may have corrected echo attenuation less than 56 dB.

In one 60 MHz repeater section not more than one of the factory lengths of coaxial pair on one direction of one system should have a corrected echo attenuation of less than 56 dB.

Note. — To detect systematic irregularities, steady-state reflection attenuation measurements should be carried out on a few factory lengths (5% for instance)

It should also be checked that one of the following three conditions is met:

1. The equivalent ratio [2] should not exceed 0.6 ohm for lengths of less than 300 metres or 0.8 ohm for lengths of 300 metres or more.

---

[1] This formula is equivalent to $Z = 74.4 + \frac{0.92}{\sqrt{f}} (1 - j)$ ohms. If this latter formula is used, a correcting factor should be applied to the tolerance indicated in the text.

[2] *Note by the Secretariat.* — The equivalent ratio is measured with a 50 ns pulse as described in point c above.

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.

2. *Steady-state measurements*

These measurements are made from each end of the factory length (or repeater section) using a swept sine wave test signal in the range 4-62 MHz. The far end of the pair under test is terminated with an impedance such that no appreciable reflection is produced by the termination.

The reflection measured is that arising between the effective impedance of the pair under test and a termination matching as well as possible the end impedance of the particular pair under test. The test result takes the form of the returned power in a 10 MHz band averaged over that band.

It is usually sufficient to determine the average only in the band 52-62 MHz. The returned average power (average power reflection coefficient) should not exceed 10^{-4} relative to the input power (−40 dB).[1]

This applies for a length of 500 metres or more. When the length of the pair is about 250 metres, the corresponding figure should be −41 dB.[1]

This method is used for 60 MHz systems.

3. The arithmetic mean of the three smallest echo attenuations for a coaxial pair should be at least 55 dB.

This latter method is used for systems in which the maximum frequency does not exceed 12.5 MHz.

d) *Dielectric strength*

The insulating material should withstand for two minutes a voltage of 2000 volts r.m.s. 50 Hz (or 2800 volts 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. 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

The repeater section begins at the output connector of one repeater and ends at the input connector of the next repeater. Hence, it comprises the 2.6/9.5 mm coaxial pair and the connection cables to the repeaters.

It will be a matter for agreement between the Administration and the supplier whether tests are to be carried out on all sections or whether some percentage or even a type-approval test alone will be sufficient, especially in the case of measurements which are difficult to carry out under field conditions.

a) *End impedance*

The conditions described in A, b above are applicable.

b) *Impedance regularity*

The impedance regularity of a repeater section can be checked by making either steady-state measurements or pulse measurements.

---

[1] Provisional figure.

b.1 *Steady-state measurements*

The conditions described in A, c, 2 above are applicable.

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:

about 50 ns for 12 MHz systems (or systems using lower frequencies);

about 10 ns for 60 MHz systems.[1]

The results of these measurements should meet the following limits, whether the coaxial pairs are for telephony or television:

1. The corrected echo attenuation of the largest reflection should not be less than:

   50 dB for 12 MHz systems (or systems using lower frequencies);

   46 dB for 100% of pairs and 50 dB for 95% of the pairs measured in the case of 60 MHz systems.

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.

   The echo attenuation for the mean square value of the three largest reflections after correction should not be less than 51 dB.

   The figures in 2.1 above are applicable to all systems (using the corresponding pulse).

   2.2 The uncorrected "equivalent ratio" (described in A, c) should not exceed:

   1 ohm in 12 MHz systems (or systems using lower frequencies);

   1.5 ohm (provisional figure) in 60 MHz systems.

   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 kilometres of the half repeater section concerned. The equivalent ratio thus reduced to one kilometre should be less than:

   0.8 ohm in 12 MHz systems (or systems using lower frequencies);

   2 ohms in 60 MHz systems.

c) *Attenuation*

The nominal attenuation coefficient of the coaxial pair at a frequency of 60 MHz and a temperature of 10° C should be within the limits of 18.00 ± 0.3 dB/km.

The rate of the variation of the attenuation with frequency, for a nominal value of 18.00 dB/km at 60 MHz, is indicated by the following table:

Frequency (MHz)	0.06	0.3	1	4	12	20	40	60
Attenuation (dB/km)	0.59	1.27	2.32	4.62	8.00	10.35	14.67	18.00

[1] The possibility of also using 50 ns pulses for 60 MHz systems is under study.

If reference is made to the length measured on the cable sheath, the values in decibels per kilometre should be increased, according to the type of cable construction. The percentages of increase below are given as an indication:

Cable with 4 or 6 pairs:	0.25 to 0.3%
Cable with 8 pairs:	0.8%
Cable with 12 pairs:	0.9%
Cable with 18 pairs:	1.2% for the outer layer.

Once the nominal attenuation of the pair is fixed between these limits for any given manufacture, a limit to the difference between the maximum and minimum values, for each repeater section of about 1.5 km, can be set. This limit is being studied under Question 16/XV.

The measured value of attenuation should be corrected for the mean temperature of the cable, using a coefficient of attenuation change with temperature of 0.002 per °C at frequencies above 1 MHz.

d) *Crosstalk*

The far-end crosstalk ratio between two coaxial pairs of a cable at any frequency in the band transmitted should be at least:

in repeater sections about 9 km long:	85 dB
in repeater sections about 4.5 km long:	91 dB
in repeater sections about 1.5 km long:	130 dB.[1]

With cables operating at 60 MHz, the near-end crosstalk attenuation at 60 MHz should be at least 140 dB.[1] No limit is fixed for other systems, previous studies having shown that the near-end crosstalk ratio under service conditions was greater than the far-end crosstalk ratio. These values include the contribution of the input cables and the coaxial connector.

Note. — The limits given in this Recommendation are easy to obtain on cables conforming to this Recommendation although in the present state of the art it is difficult to test them with ordinary measuring equipments. Attention must, however, be drawn to the fact that the values given for cables operated at 60 MHz are derived from the general considerations on crosstalk between sound programme circuits given in new Recommendation J.18, whereas the values for cables operated at 12 MHz or at lower frequencies are those already specified in the *White Book* and should perhaps be reconsidered in the light of this new Recommendation J.18.

The values for 60 MHz equipments are being studied under Question 16/XV; all the values quoted in the Recommendation which apply solely to cables need to be confirmed, and perhaps revised, according to the result of the study with reference to equipments.

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. The measurement of the insulation resistance should be made after the dielectric strength test. This measurement should be made on every repeater section.

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[1] Provisional values.

Recommendation G.332 (Mar del Plata, 1968)

12-MHz TRANSISTORIZED SYSTEMS ON STANDARDIZED 2.6/9.5-mm 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) coaxial cable (see Recommendation G.331) with a nominal repeater station spacing of 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/G.332.

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/G.332 (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/G.332 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/G.332 is identical with that of Figure 1/G.332.

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/G.332. In this figure, the virtual carrier frequencies of 15-supergroup assemblies Nos. 2 and 3 are shown.

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.

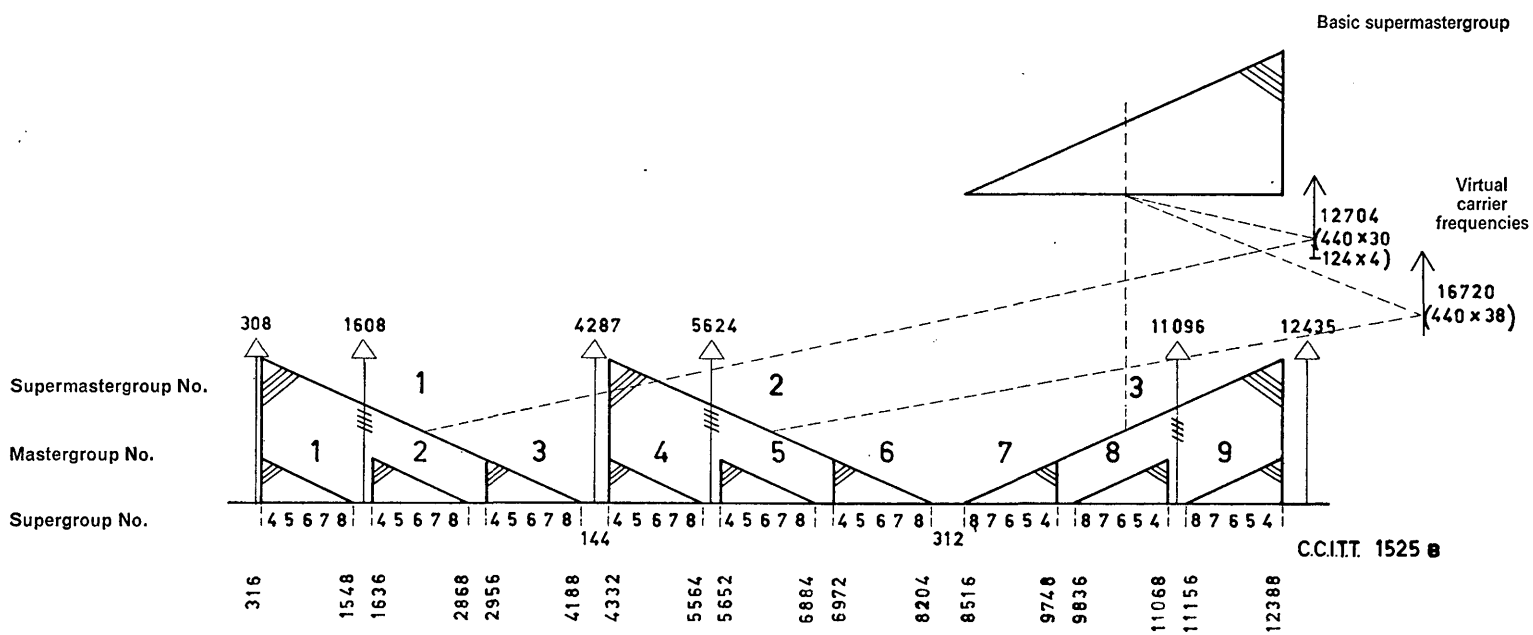


FIGURE 1/G.332. — **Plan 1A frequency arrangement for 12-MHz systems**

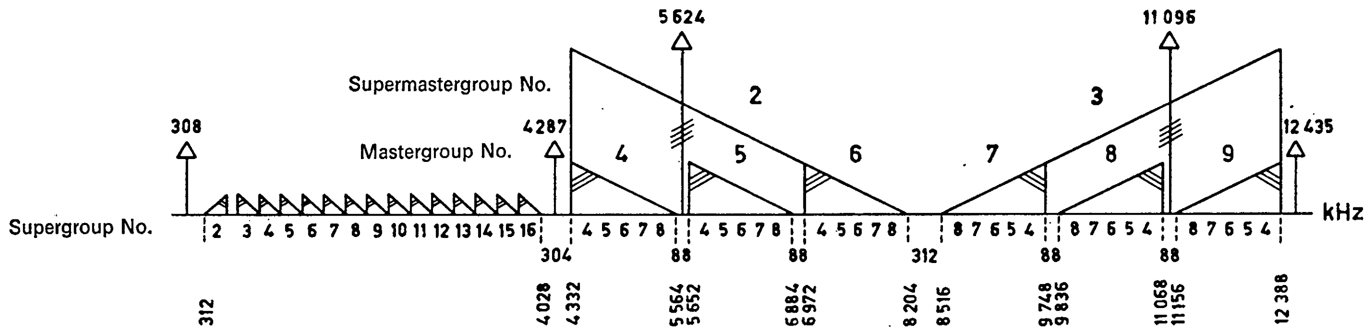


FIGURE 2/G.332. — **Plan 1B frequency arrangement for 12-MHz systems**

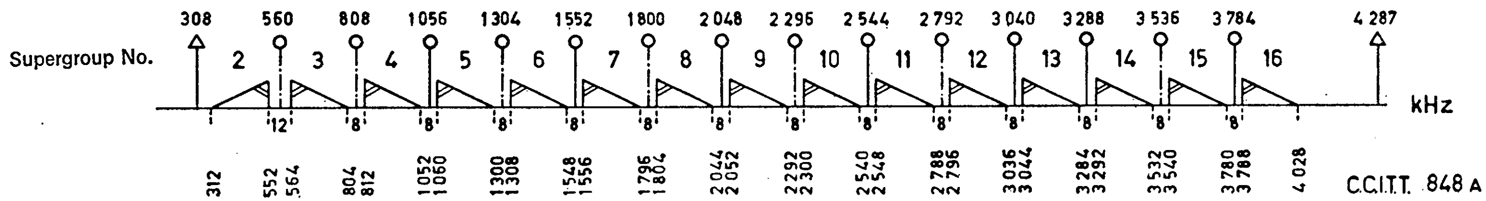


FIGURE 3/G.332. — **Plan 1B frequency arrangement for 12-MHz systems : frequencies below 4287 kHz**

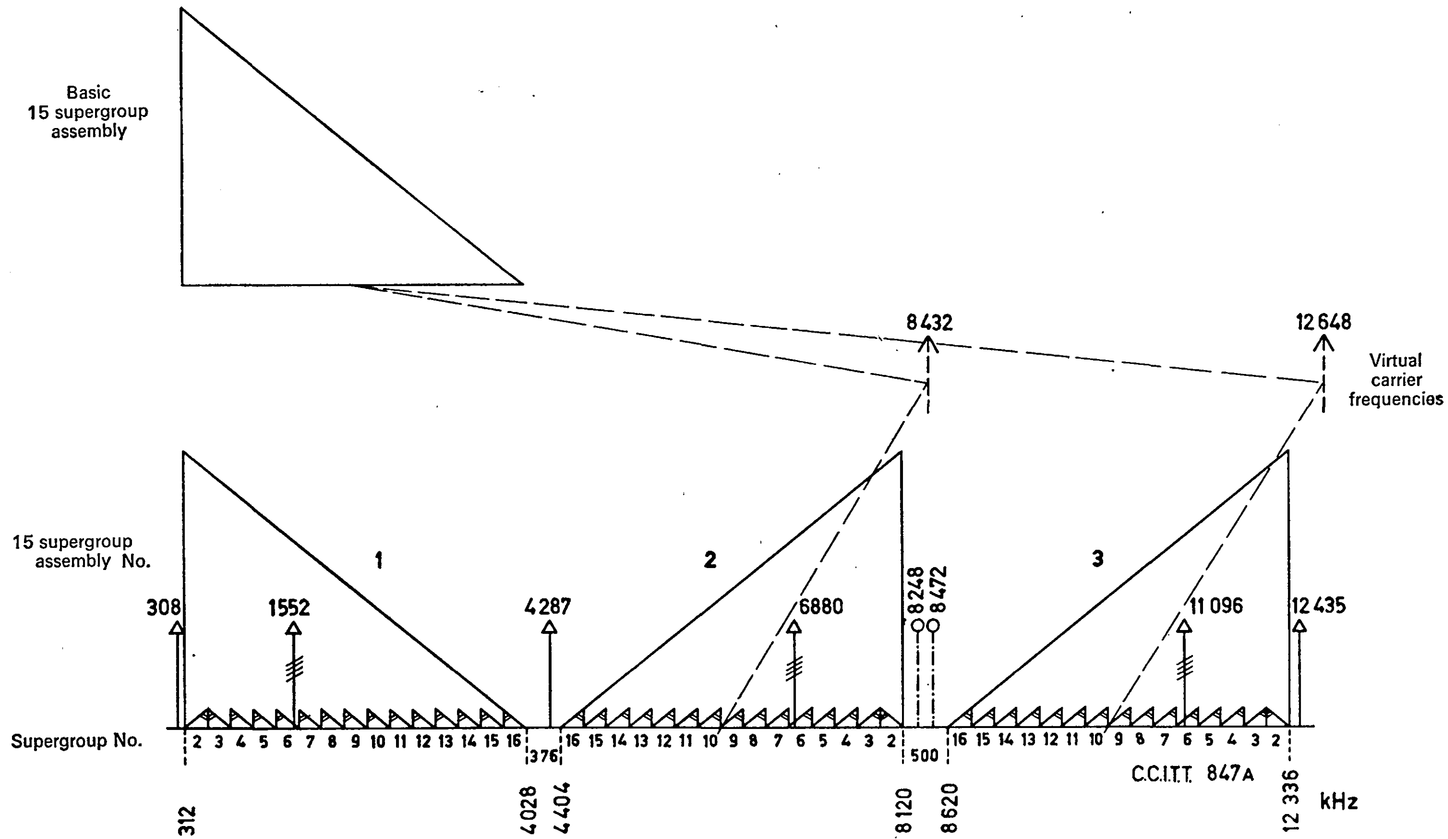


FIGURE 4/G.332. — **Plan 2 frequency arrangement for 12-MHz systems**

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 power level of the main and auxiliary line-regulating pilots should be adjusted at the point of injection to have a value of −10 dBm0.

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 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.

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 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, the zero of the warning device being aligned as accurately as possible with the lining-up level of the transmitted pilot.

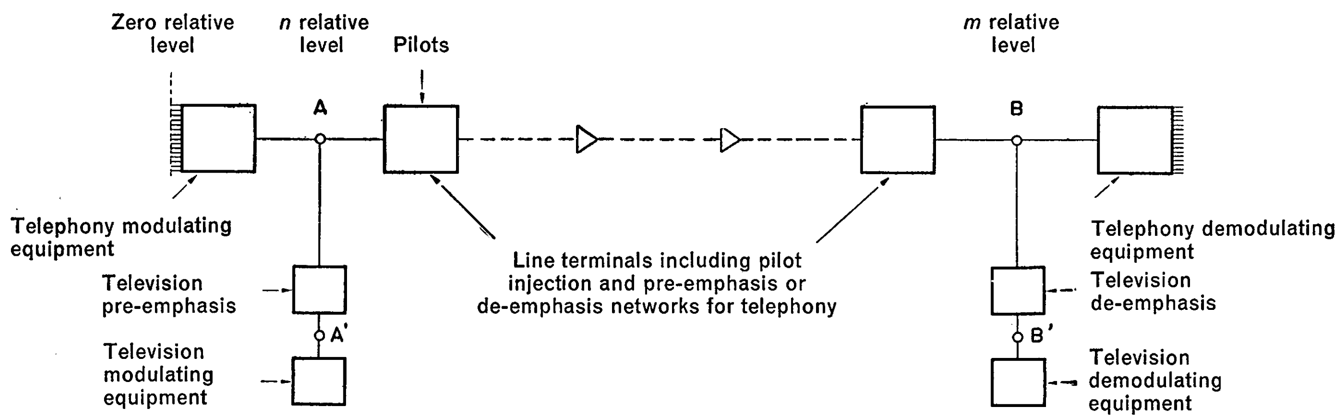
The attention of Administrations is drawn to the difficulty which could result from an appreciable reduction in the absolute power level of the pilot sent to line; such a reduction is liable to cause "near singing", resulting from the operation of the automatic gain-control amplifiers. It would be desirable 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/G.332 and 6/G.332 show two hypothetical arrangements for the purpose of this definition.

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 a power level of −10 dBm0.



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/G.332. — **To illustrate the definition of line-regulating pilot levels on a line suitable for carrying both telephony and television**

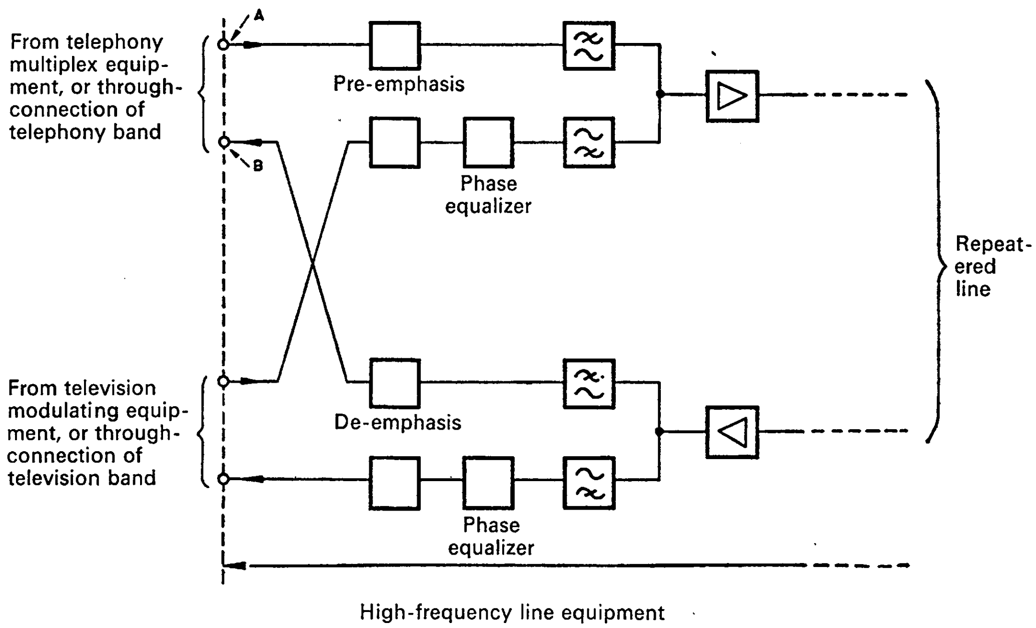


FIGURE 6/G.332. — **An example of high-frequency line equipment for a 12-MHz "mixed" system for simultaneous telephony and television transmission. The relative levels for telephony would be defined for the points A and B**

3. *Additional measuring frequencies.* — If the frequency allocation without mastergroups is used at frequencies below 4 MHz (Figures 3/G.332 and 4/G.332), 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/G.332) is used:

560, 808, 1304, 1592 and 2912 kHz.

2. At frequencies above 4 MHz: if Plan 1A (Figure 1/G.332) or 1B (Figure 2/G.332) is used:

5608, 6928, 8248 [1], 8472, 9792 and 11 112 kHz.

Plan 2 (Figure 4/G.332) 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, 7128, 8248, 8472, 8864, 9608 and 11 344 kHz

[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.

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/G.332 and 4/G.332)	560, 808, 1304, 1800, 2296, 2792 and 3536 kHz	1056, 1552, 2048, 2544, 3040, 3288 and 3784 kHz
	all mastergroups (Figure 1/G.332)	560, 808, 1304, 1592 and 2912 kHz	
>4 MHz	in mastergroups (Figures 1/G.332 and 2/G.332)	5608, 6928, 8248 [a], 8472, 9792 [a] and 11 112 kHz	
	in 15-supergroup assemblies (Figure 4/G.332)	5392, 7128, 8248, 8472, 8864, 9608 and 11 344 kHz	

[a] 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.

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 $\pm 1 \times 10^{-5}$.

The power level [1] of the additional measuring frequencies should be adjusted at the point of injection to have a value of −10 dBm0.

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 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;

[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.

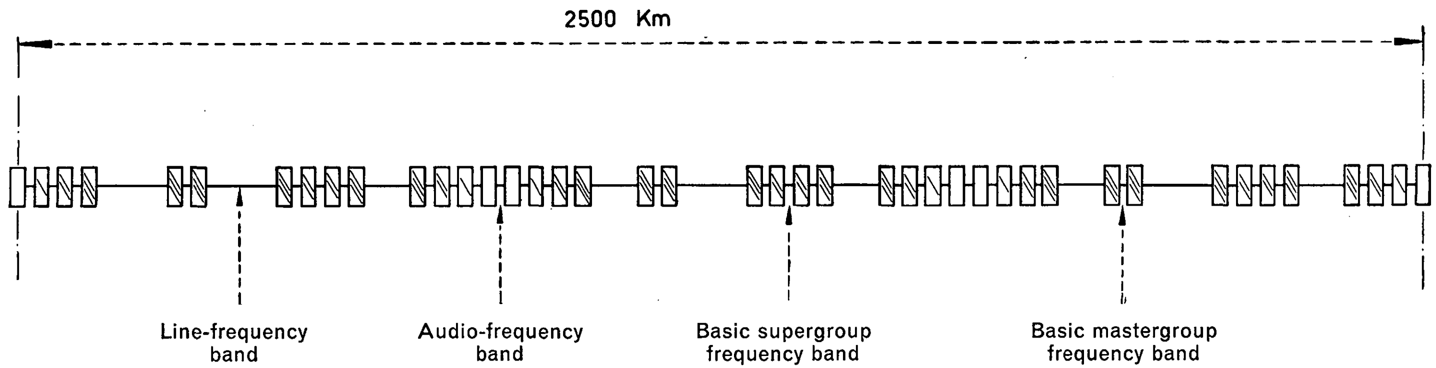


FIGURE 7/G.332. — **Diagram of a hypothetical reference circuit for 12-MHz coaxial-pair systems** three pairs of group modulators, each pair including translation from the basic group to the basic supergroup and vice versa;

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/G.332 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, 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 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/G.332);

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.

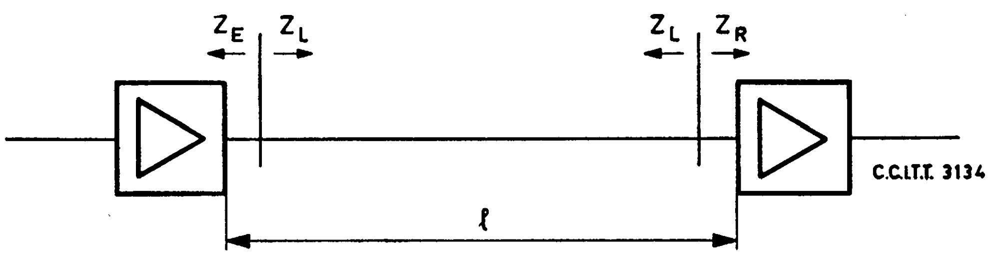


FIGURE 8/G.332. — **Repeater section of coaxial cable**

Then N is defined by the formulae:

$$N = 2A + 20 \log_{10} \left| \frac{Z_E + Z_L}{Z_E - Z_L} \right| + 20 \log_{10} \left| \frac{Z_L + Z_R}{Z_L - Z_R} \right| \text{ (dB)}$$

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 at 300 kHz and to at least 55 dB at all frequencies above 800 kHz. Between 300 and 800 kHz the permissible limit in decibels varies linearly with the frequency.

Note.— The C.C.I.T.T. has defined the permissible limits for N, as a sum of the three terms (see the above formula). It is recommended that Administrations 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 dBr 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. 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 Annex)

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. — A fault-tracing system was used by the Chile Telephone Company 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; amended at Geneva 1972)

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/G.333)

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/G.333. 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/G.332.

Plan 2. — Line-frequency allocation and modulation stages for 40-MHz and 60-MHz systems (Figure 2/G.333)

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 $68 \times 124 = 8432$ 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/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 and additional measuring frequencies*

1. *Line-regulating pilots*

The C.C.I.T.T. recommends that 61 160 kHz should 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 temperature correction of the cable attenuation.

In any regulated-line section crossing a frontier, it is recommended that in both directions of transmission the Administration on the transmitting side should permanently transmit so as to provide, for example, for additional regulation, one or more auxiliary line-regulating pilots chosen by the Administration on the receiving side from the following list: 4287 kHz, 12 435 kHz, 22 372 kHz and 40 920 kHz.

The frequency stability recommended for the pilots is 10^{-5} (provisional value).

The power level of these pilots should be adjusted at the output of the transmit amplifier to a nominal value of -10 dBm0.

The tolerances for this level are the same as those given in paragraph b, 1 of Recommendation G.332.

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/G.333 and 2/G.333).

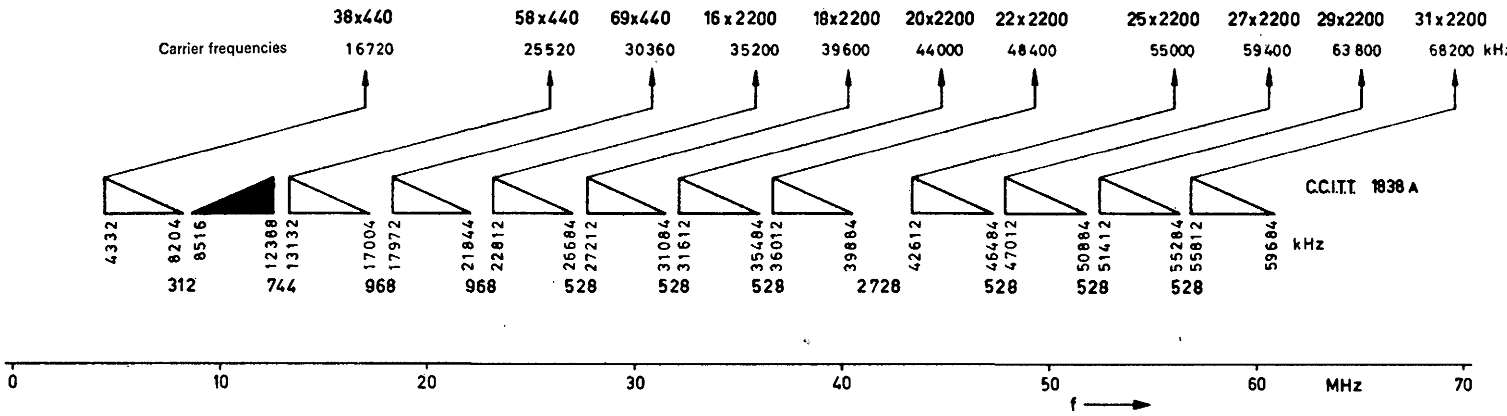


FIGURE 1/G.333. — Line-frequency allocation recommended for 40-MHz and 60-MHz systems on 2.6/9.5-mm coaxial cable pairs using Plan 1

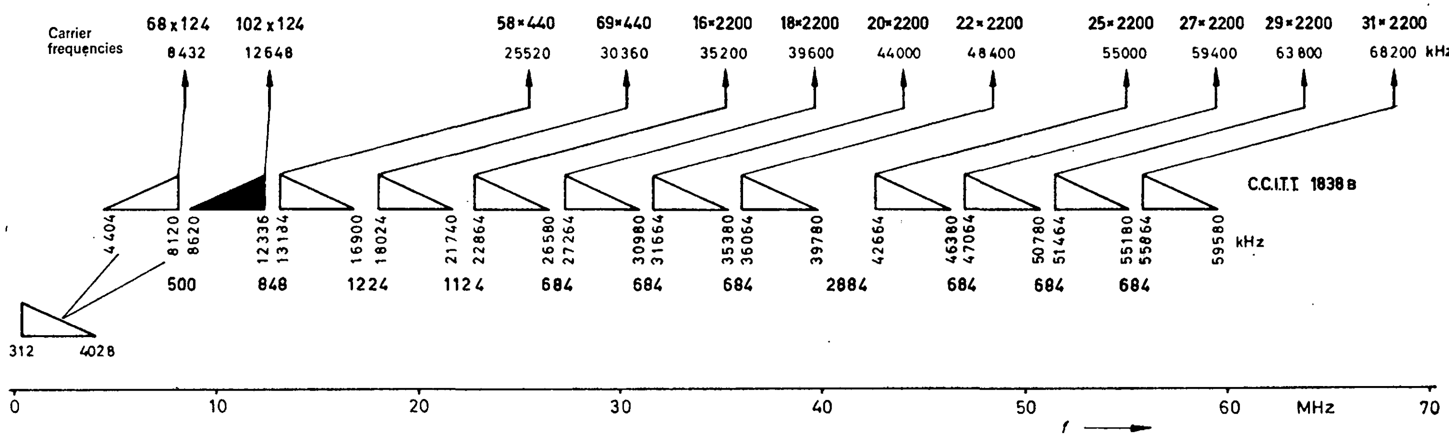


FIGURE 2/G.333. — Line-frequency allocation recommended for 40-MHz and 60-MHz systems on 2.6/9.5-mm coaxial cable pairs using Plan 2

3. *Additional measuring frequencies*

Frequencies that can be used for additional measuring frequencies are as follows:

below 12 MHz as in the system 12 MHz;

(12 435), 13 928 (Plan 2) or 14 408 (Plan 1), 17 488, (22 372), 26 948, 31 344, 35 748, (40 920), 46 748, 51 148, 55 548 kHz.

Note. — The frequencies in brackets may be used for auxiliary line-regulating pilots.

The power level of these additional measuring frequencies should be adjusted, at the output of the transmit amplifier, to have a nominal value of −10 dBm0. The frequency stability recommended is 10^{-5}. (provisional value).

The additional measuring frequencies should not be permanently transmitted. They will be transmitted only for so long as is necessary for actual measurement purposes.

4. *Band reserved for monitoring and fault-tracing signals*

These signals should be below the 4200 kHz frequencies comparison pilot. In the case of television transmission, it might be useful to fix an even lower upper limit for this band; this point is being studied within the C.C.I.T.T. in connection with Question 20/XV.

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*

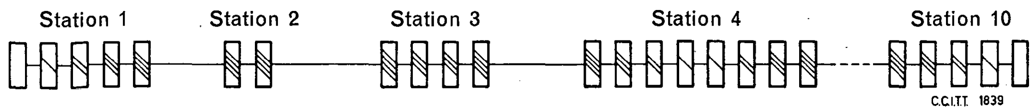
With either of the line-frequency allocations recommended in paragraph a, five modulation stages are generally needed to place a particular channel in its position in the line-frequency band.

On the above basis, the hypothetical reference circuit shown in Figure 3/G.333 is recommended by the C.C.I.T.T.

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 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 on coaxial pairs (see Figure 3/G.333) without incurring a noise penalty (see the Appendix to Annex 1 of Question 16/XV).



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.

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.

FIGURE 3/G.333. — **Diagram of a hypothetical reference circuit for 60-MHz systems on 2.6/9.5-mm coaxial cable pairs**

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 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 2-5 inclusive provided that the adjacent frequency bands containing supermastergroups 6-9 and 10-13 are transmitted on normal length homogeneous sections. 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.

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 is provisionally recommended[1] for the magnitude N defined in paragraph e of Recommendation G.332.

Note. — The value of 65 dB is valid for telephone transmission but is still under study for television programme transmission. (Question 20/XV.)

[1] See Supplement No. 9.

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 is provisionally recommended at the output of the direct through-connection filter.

Recommendation G.337 (former Recommendation G.331, amended at Mar del Plata, 1968)

GENERAL CHARACTERISTICS OF SYSTEMS ON 2.6/9.5-mm. COAXIAL CABLE PAIRS

The various systems which can be set up on standard C.C.I.T.T. 2.6/9.5-mm coaxial cable pair (see Recommendation G.331) are defined as follows:

1. *2.6-MHz system.* — A coaxial cable system with about 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 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 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 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 1.5-km repeater spacing, providing up to 180 supergroups for telephony (see Recommendation G.333).

A. 2.6-MHz VALVE-TYPE SYSTEM

This system can be used only by agreement between the Administrations 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/G.337 (derived from Figure 1/G.338) applies, but using only supergroups 1 to 10.

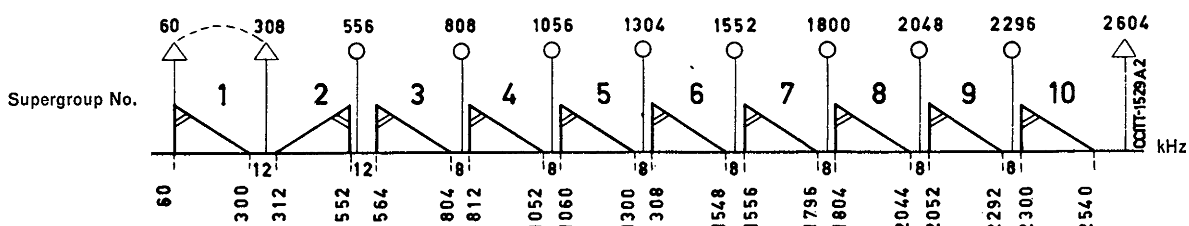


FIGURE 1/G.337. — **Line-frequency allocation recommended for the 2.6-MHz system.**

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.

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 television 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/f.72 the relative level of the telephone channels is −15 dBr.

The 4142-kHz and 308-kHz line pilots are transmitted at levels of −6 dBm0 and −15.1 dBm0 respectively.

2nd system. — The sending levels of the pilots are −13.1 dBm0.

Recommendation G.338 (former Recommendation G.332, amended at Geneva 1964)

4-MHz VALVE-TYPE SYSTEMS ON STANDARDIZED 2.6/9.5-mm 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 Figure1/G.338.[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.

It is convenient to use supergroups 1 to 3 for short circuits. Administrations 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 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 coaxial cables (see Recommendation G.331) allow the use of 16-carrier telephone supergroups with suitable repeater spacing, and a line-frequency spectrum as indicated in Figure 1/G.338. 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.

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[1] However, if it is desired to use mastergroups, adoption of the line-frequency allocation in Figure 2/G.338 is recommended.

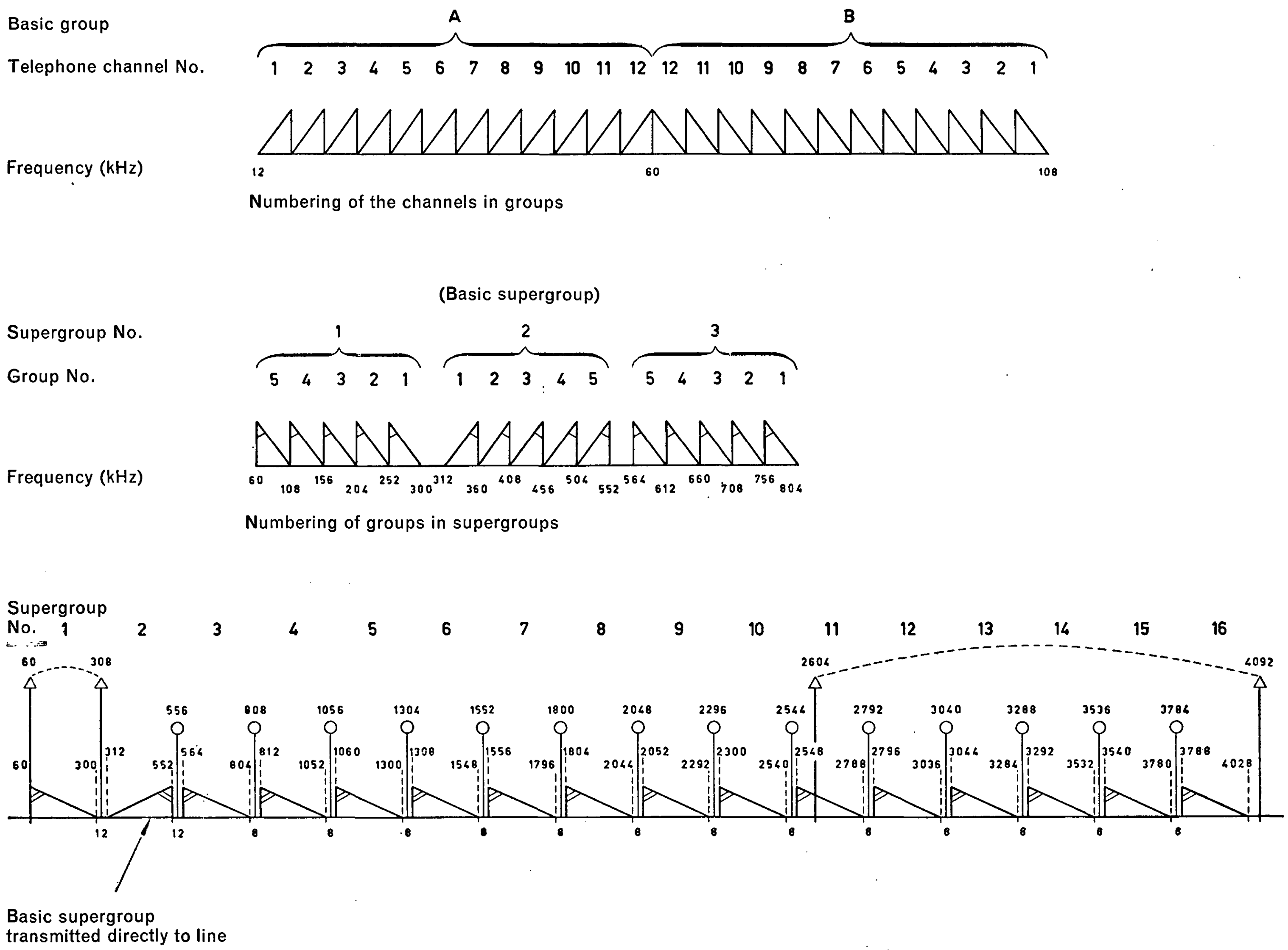


FIGURE 1/G.338. — **Line-frequency spectrum from 60 kHz to about 4-MHz for international 2.6/9.5-mm coaxial cables used for multichannel carrier telephony**

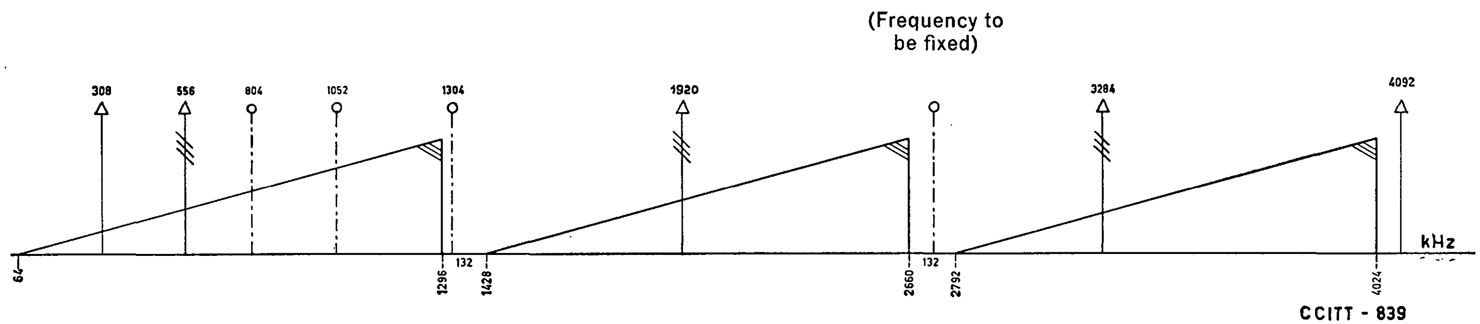


FIGURE 2/G.338. — **Allocation of line frequencies in international 4-MHz carrier system on 1.2/4.4-mm coaxial pairs, in the case of the use of mastergroups**

It is 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 power level of these pilots should be adjusted at the ouput of the transmit amplifier to have a nominal value of −10 dBm0.

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 Nm0.

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 power level of a frequency-checking pilot should be adjusted at the ouput of the transmit amplifier, to a nominal value of −10 dBm0.

Note. — Some systems in use employ a pilot at −1.2 Nm0.

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 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 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 power level of these additional measuring frequencies should be adjusted at the output of the transmit amplifier to have a nominal value of −10 dBm0.

Note. — Some systems in use employ a pilot at −1.2 Nm0.

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 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/G.338. 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.

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 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 0.1 Np (i.e. about 1 dB, this being considered a reasonable limit) will arise. This seems sufficient, if it is considered very improbable that very long international

[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.

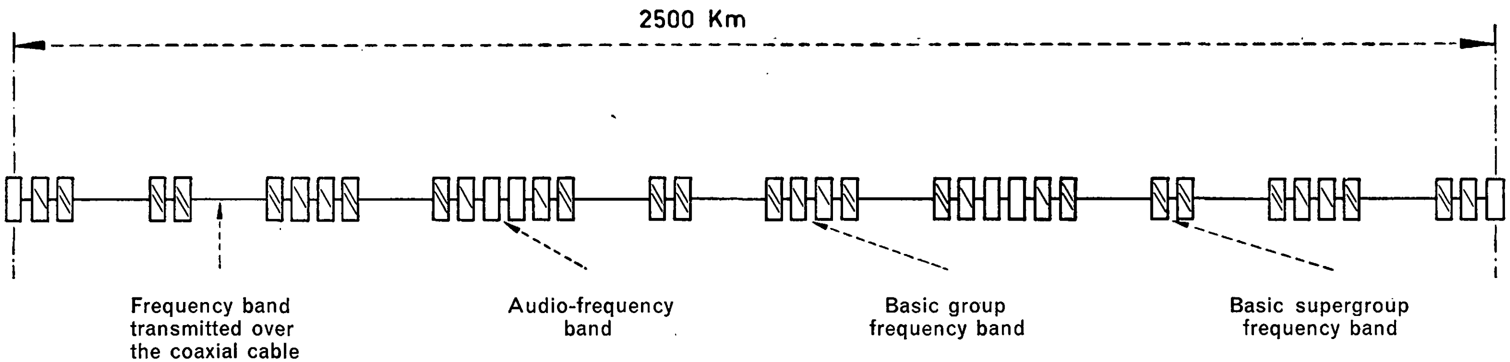


FIGURE 3/G.338. — **Diagram of the hypothetical reference circuit for 4-MHz systems on coaxial cable** circuits will be set up throughout on channels of supergroup 1 (60-300 kHz) since it is particularly easy to extract this supergroup at intermediate points, making its use preferable for relatively short circuits.

In order to obtain an equivalent/frequency characteristic having rolls not greater than 0.1 Np (i.e. about 1 dB) at the end of a 2500 km 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.

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/G.338) it may be hoped that the condition that irregularities in the equivalent/frequency characteristic should not exceed 1 dB 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.

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 formula in paragraph e of Recommendation G.332). It is recommended that the Administrations 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 $\pm 1 \times 10^{-5}$.

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 Nm0.

2. *Frequencies comparison pilots* and 3. *Additional measuring frequencies*

Recommendation G.332; however, some systems in use employ pilots or additional measuring frequencies at −1.2 Nm0.

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.

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 e 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 relative power levels at such interconnection points are as follows for the "all-telephony" case:

−32 dBr at the output of the de-emphasis network;
−35 dBr 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/J.73 and 2/J.73).

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;

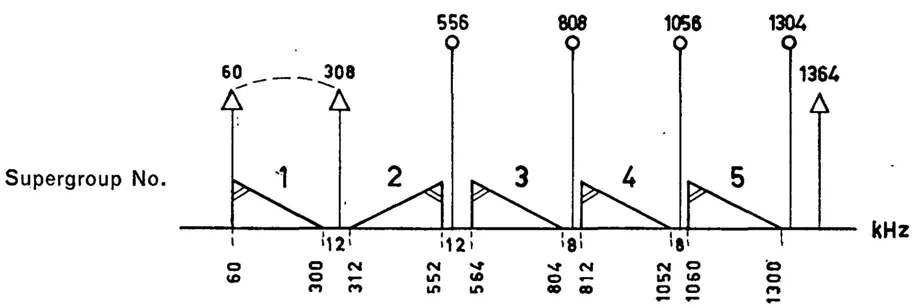
— a system with 8-km repeater sections, if they wish to go on to operation with 900 or 960 telephone channels.

a) *Line frequencies*

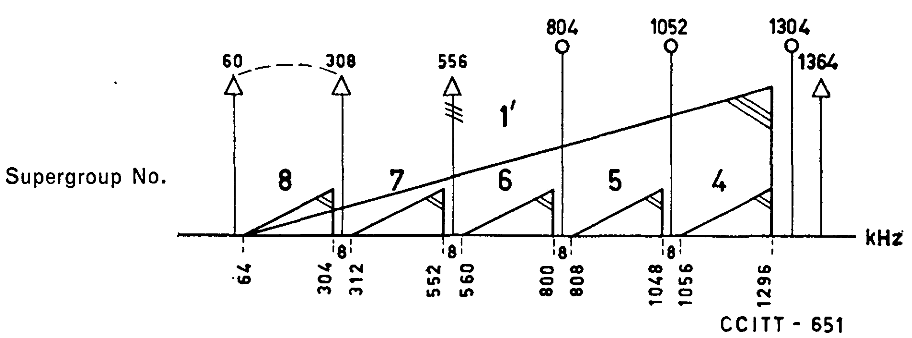
The system will carry 300 telephony channels, transmitted to line:

— either between 60 kHz and 1300 kHz as supergroups Nos. 1-5 of the 4-MHz system (Figure 1, *a*/G.341);

— or between 64 kHz and 1296 kHz as a mastergroup with erect channel sidebands (Figure 1, *b*/ G.341).



a) Supergroups Nos. 1 to 5 arrangement



b) Mastergroup arrangement

FIGURE 1/G.341. — **Line-frequency arrangements for international carrier 1.3-MHz systems on 1.2/4.4-mm coaxial pair**

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.

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 power level of these pilots should be adjusted at the output of the transmit amplifier to have a nominal value of −10 dBm0.

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 Nm0.

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 power level of these additional measuring frequencies should be adjusted, at the output of the transmit amplifier, to have a nominal value of −10 dBm0.

Note. — Some systems in use employ additional pilots at −1.2 Nm0.

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, 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, 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 for a 6-km repeater section;
52 dB for an 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 (0.8 dB) 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 at 1300 kHz. The relative power level at the input of the cable section (output of the repeater equipment) should be −13 dBr 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 dBr.

1.2 The nominal loss on any 8-km repeater section should be 49 dB at 1300 kHz. The relative levels at the input of any cable section are not strictly standardized, values of −3.5 dBr and −4.3 dBr 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 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 relative power level at 1300 kHz may be less than −13 dBr. 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 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 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 at 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.

[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 "nominal real part of the 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 ms. The results are expressed in terms of "echo attenuation". This, for a peak in the response curve, is the logarithmic ratio in decibels 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. 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 for all coaxial pairs;

not less than 54 dB 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 meghom-kilometres after electrification for one minute, at a temperature not lower than 15°C. 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 ms for a 3-km repeater section; not exceeding 0.4 ms for a 6-km repeater section. Also, there is correction of amplitude and phase. This corrected value should be at least 42 dB.

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 might be recommended for the worst section. In addition, an echo attenuation of roughly 52 dB 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. The actual value must not differ from this nominal value by more than ± 0.2 dB.

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 Table 3.

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 (dB)	
	without phase inversion	with phase inversion at repeaters
8	87	
6	89	80
4	93	
3	95	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, for a repeater section about 6 kilometres long, and 87 dB, for a repeater section about 3 kilometres long.

Note. — These limits are based on 58 dB 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, 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. 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
Specific attenuation (dB/km)	1.49	1.80	2.42	2.91	3.73	4.43	5.30	6.05	11.2
Tolerance (dB/km)	± 0.1	± 0.1	[a]	[a]	[a]	[a]	± 0.2	± 0.2	± 0.2

[a] 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 for a 4-MHz system.

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/G.343.

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/G.343.

Plan 2 uses the three lowest mastergroups in the 12-MHz system on a 2.6/9.5-mm coaxial pairs. It permits in particular direct interconnection with a 12-MHz coaxial system using the 1 A frequency allocation shown in Figure 1/G.332 and with a radio-relay link of 900 or 1800 channels operated according to Recommendation G.423 (Figures 4/G.423 and 8/G.423).

b) *Pilots and additional measuring frequencies*

1. *Line-regulating pilots*

The frequencies recommended for the various cases indicated in paragraph a and shown in Figure 1/G.343 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 power level recommended is -10 dBm0, 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, b, 2 and b, 3).

Plan 2. — The same recommendation as for the 12-MHz system (Recommendation G.332, b, 2).

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*

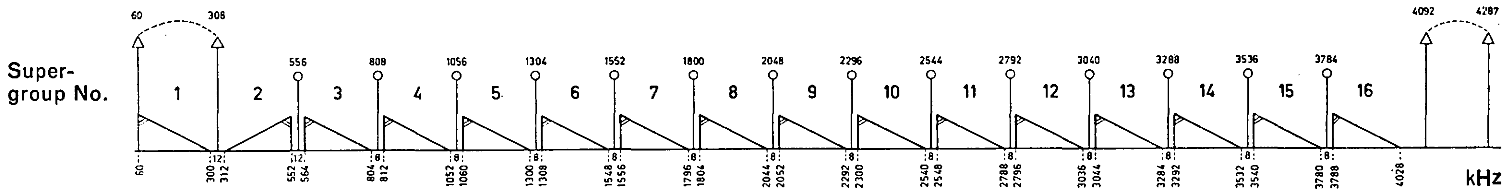
Recommendation G.341, c and d apply.

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 Recommendation G.332, e must be at least equal to the following:

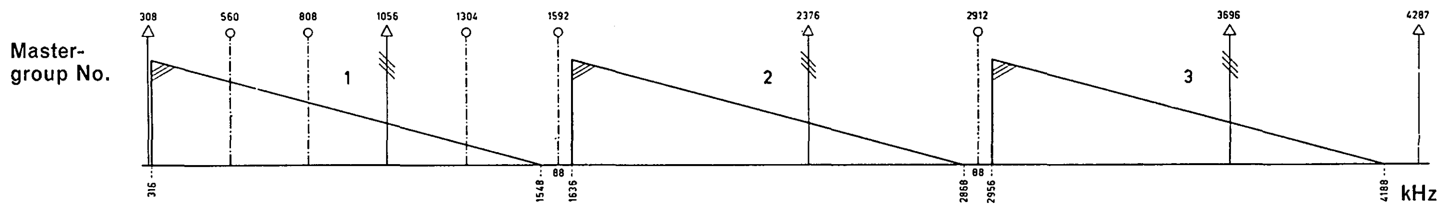
50 dB at 60 kHz
57 dB above 300 kHz

with linear variation from 50 dB to 57 dB in the 60-300 kHz band, in the case of a linear frequency scale.



Plan 1

a) Supergroup allocation



Plan 2

b) Mastergroup allocation

FIGURE 1/G.343. — **Allocation of line frequencies in international 4-MHz carrier system on 1.2/4.4-mm coaxial pairs**

Note. — These values are based on the assumption that the attenuation-frequency characteristic does not show any ripple exceeding ± 1 dNp (about ± 1 dB) at the end of a homogeneous section 280 km long. A relaxed 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:

$$A = 10 \log_{10} \left[1 + \frac{a}{1 + \frac{b}{\left(\frac{f}{f_r} - \frac{f_r}{f}\right)^2}} \right] \text{(dB)}$$

in which the constants are so selected as to give between 9 and 11 dB of pre-emphasis.

Both of the sets of values 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 Administration on the receiving side can receive the other Administration'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/G.344, 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).

2. *Transmission of television signals*

Administrations considering such transmission should refer provisionally to Recommendation J.72.

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 $\pm 10^{-5}$, the power level recommended is -10 dBm0, 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, b, 2 and b, 3).

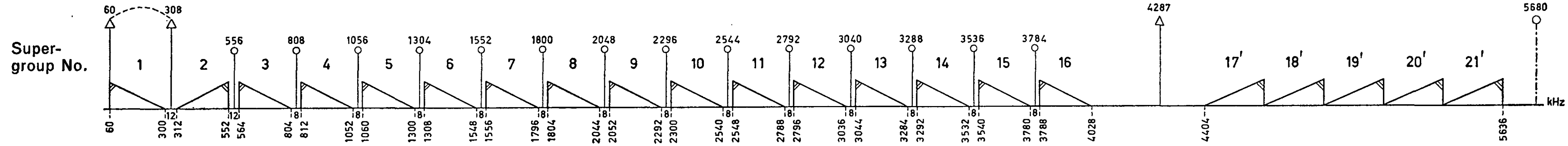
Plan 3. — The same recommendations as for the 12-MHz system (Recommendation G.332, b, 2).

3. *Additional measuring frequencies*

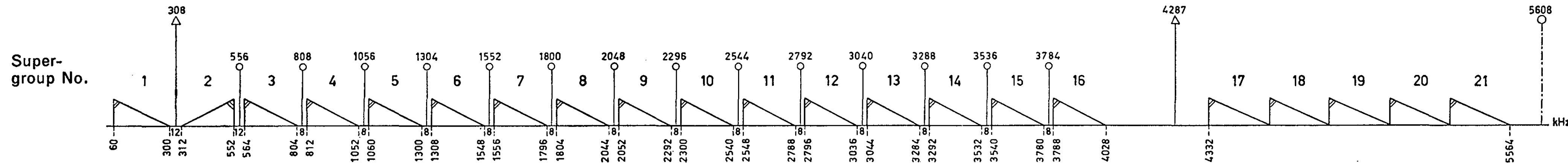
Plans 1 and 2. — All the additional measuring frequencies given in Recommendation G.338 (supergroups) should be used. In addition, in the frequency band above 4287 kHz, the following additional measuring frequencies are recommended:

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.

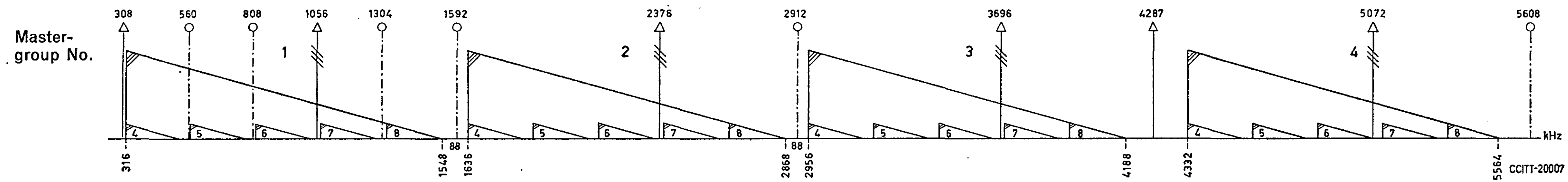


Plan 1



Plan 2

a) Supergroup allocations



Plan 3

b) Mastergroup allocation

FIGURE 1/G.344. — **Allocation of line frequencies in international 6-MHz carrier system on 1.2/4.4-mm coaxial pairs.**

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 Recommendation G.332, e must be at least equal to 60 dB at all frequencies above 300 kHz.

A figure of 50 dB is recommended at 60 kHz. Between 60 and 300 kHz the acceptable limit varies progressively.

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:

$$A = 10 \log_{10} \left[1 + \frac{a}{1 + \frac{b}{\left(\frac{f}{f_r} - \frac{f_r}{f} \right)^2}} \right] \text{(dB)}$$

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, f3 to f5.

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; amended at Geneva, 1972)

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, the recommended value of N is 63 dB throughout the transmitted frequency band, N being defined as in Recommendation G.332, e.

Recommendation G.352 (former Recommendation G.336, amended at Mar del Plata, 1968)

INTERCONNECTION OF COAXIAL CARRIER SYSTEMS OF DIFFERENT TYPES [1, 2]

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 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 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 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 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.

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[1] This Recommendation applies to 2.6-MHz, 4-MHz, 6-MHz and 12-MHz systems.

[2] Recommendation G.351 of the *White Book*, Volume III, has been deleted.

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 Recommendation G.332, e.

It is recommended that Administrations 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 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/G.352. 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 inter-connecting 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.

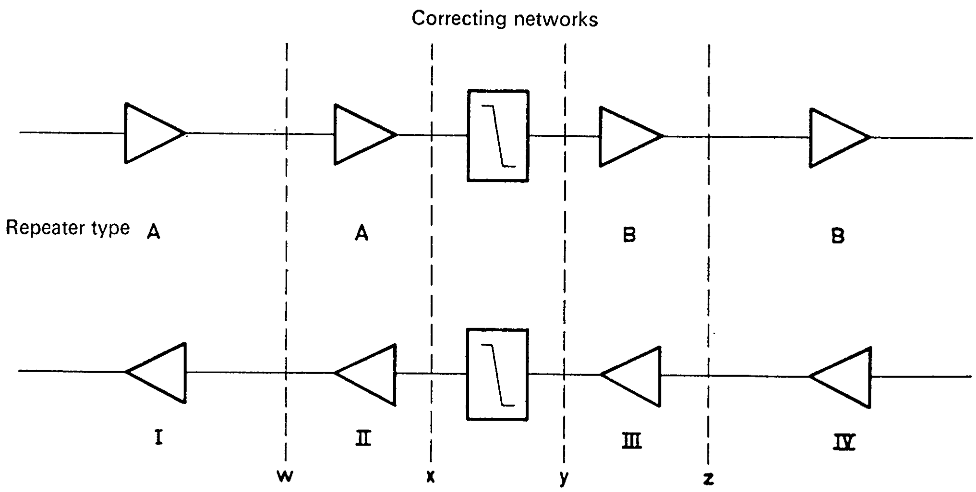


FIGURE 1/G.352

ANNEX 2
(to Recommendation G.352)

An alternative method is shown in Figure 2/G.352, in which the ordinary length of repeater spacing with the nominal loss a is maintained in the frontier cable section. The nominal 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

$$\Delta_{\text{pre}} = n_{\text{I}} - n_{\text{II}}$$

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/G.352, 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/G.352 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.

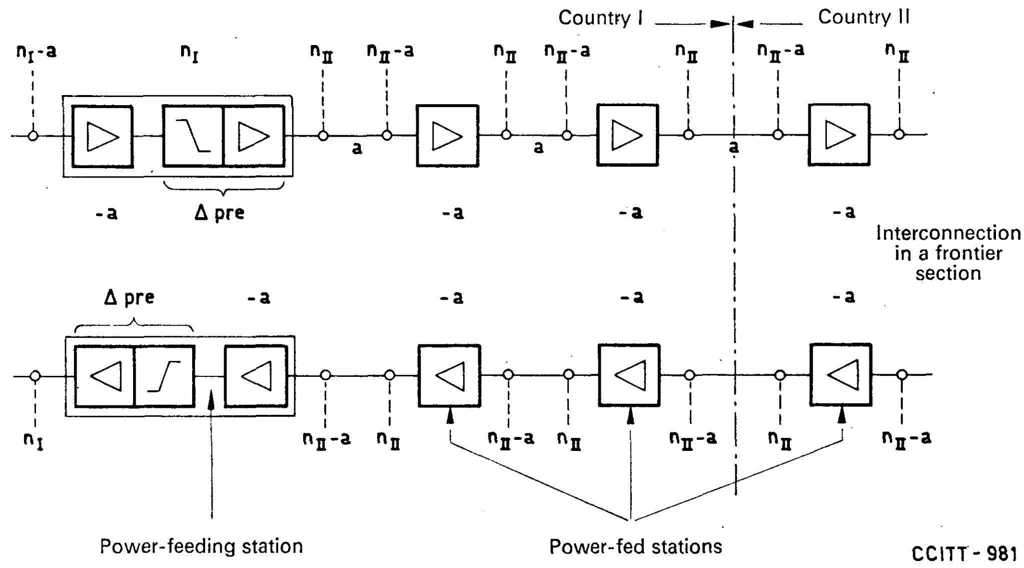


FIGURE 2/G.352

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*

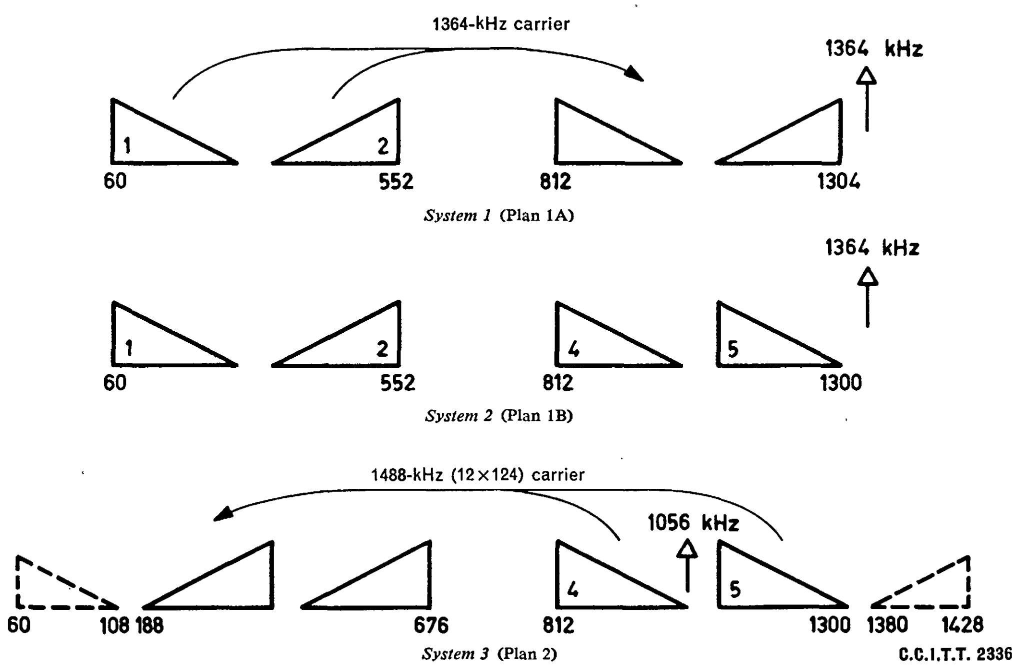
In systems of the first category, the two supergroups are transmitted to line in the position of supergroups Nos. 1 and 2 for one direction of transmission and in the 812-1304-kHz band for the other direction. In systems of the second category, the two supergroups are transmitted to line in the position 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/G.356 (Plans 1A and 1B for the first category, Plan 2 for the second category).

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.



Plan 2

Figure 1/G.356. — **Frequency allocation plans**

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 monitoring	1364 kHz 52 or 60 kHz	432 and 1056 kHz
Additional measuring frequencies:		
(if required) Lower band Upper band	60 and 308 kHz 808, 1056 and 1304 kHz	124 and 677 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-channels four-wire system	Rec. G.223 for (240 + 24)-channels four-wire system

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 (approximately 0.5 dB), 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 for both 1st and 2nd categories (i.e.: Plans 1A and 1B or Plan 2).

Input send: —36 dBr;
Output receive: —23 dBr.

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.

[1] Corresponding to points T and T′ as defined in Recommendation G.213.

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, i.e. approximately 1 dB according to Recommendation G.332, e) can be met using cables 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/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 sound-programme circuit, 6.4 kHz type or 10 kHz type[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, if it is later decided to use a second similar system on the same pole route (see paragraph j below and Figure 1/G.361).

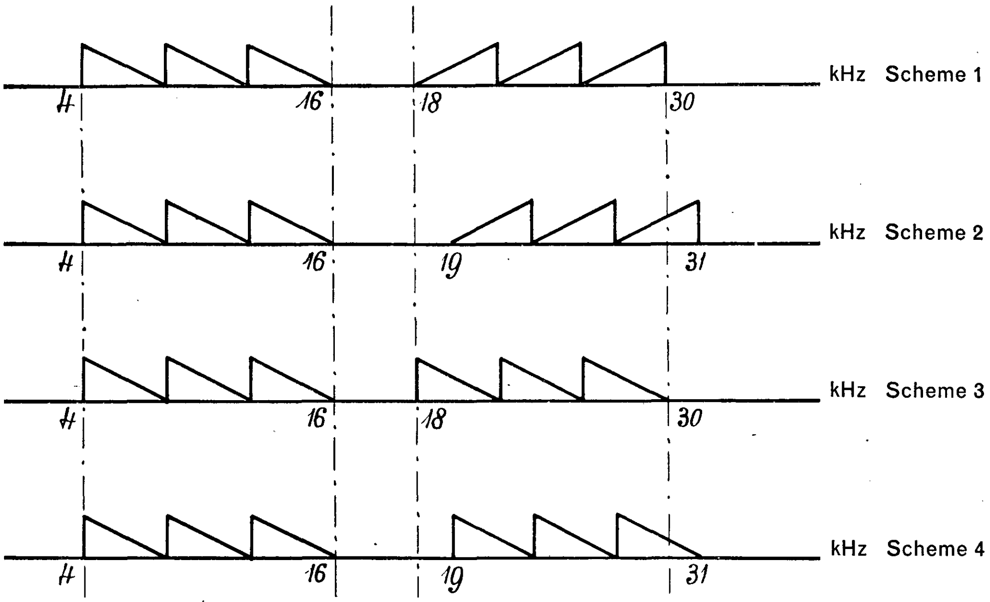


FIGURE 1/G.361. — **Frequency spectra for four systems, each providing three carrier telephone circuits which can be set up one after another on the same pole route**

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 dBr.

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 power level of the line pilots should be −15 dBm0.

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1 See Recommendations J.22, J.23 and J.32, J.33.

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*

The power level of the carrier leak should not be greater than:

−17 dBm0 for one channel and for each direction of transmission;

−14 dBm0 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/G.361. No order of preference has been decided and in each particular case the Administrations concerned will choose the most appropriate scheme(s).

[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.

Note. — Also, by agreement between Administrations concerned, the lower frequency band transmitted to line schemes 2 and 4 may be inverted.

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 kHz

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 dBm0.

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. (*Green 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 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 and crossings,

   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 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, and at Geneva, 1972)

CARRIER SYSTEMS FOR SUBMARINE CABLE

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 points are defined as the output(s) S' and the input(s) S 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/G.371).

If the signal at an interconnection point is that of a single C.C.I.T.T. multiplexing unit (i.e. group, supergroup, etc.) in its basic frequency position, the relative levels should conform with those of Recommendation G.233 for group, supergroup, etc., distribution frames and all the conditions for through connection (especially Recommendations G.242 and G.243) should apply at that point.

Otherwise, an interconnection at points S and S' is considered to be the T (input) or T' (output) point of a line link as defined in Recommendation G.213. The relative levels will be as specified in Recommendation G.213 for an overland system of capacity corresponding to that of the signal at the interconnection point (see paragraph b for further details). Furthermore, C.C.I.T.T. Recommendations (especially Recommendation G.243) relating to interconnection of systems and direct through connection of groups, supergroups, etc., apply at these points.

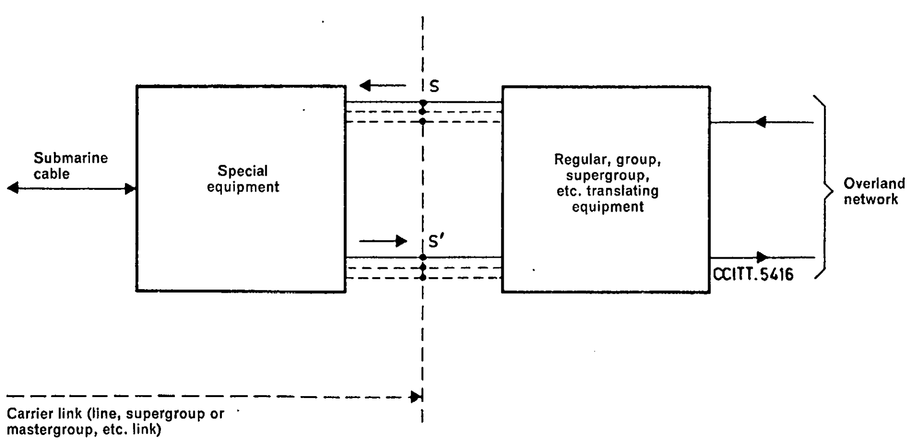

FIGURE 1/G.371. — **Interconnection of a submarine cable system with the overland network**

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. recommends that submarine cable systems should not use any pilot inside the band of any block transferred to the submarine system across the interface with the overland network and that, as far as economically possible, the repeater monitoring (supervisory) signals and remote signalling frequencies should be located outside the band of each such block and preferably outside the limits of the band occupied by the telephone channels 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.

b) *Frequency plans*

It is recommended that circuits be assembled in the basic group, supergroup, mastergroup, etc., specified by the C.C.I.T.T. (Recommendation G.211). To obtain a capacity of more than eight groups and up to eight supergroups systems should be limited to those providing two, five or eight supergroups. Because of the need, in broadband submarine cable systems, to maximize the economic use of the baseband, the C.C.I.T.T. does not recommend any specific values for larger capacity systems. In no case does the C.C.I.T.T. consider it necessary to standardize the line frequency band, which in each case is subject to agreement between the two Administrations concerned.

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 interconnection between radio-relay links and systems on metallic lines; these allocations are given in Table 1 of Recommendation G.423. If the capacity does not correspond to one of those mentioned in this table, the capacity immediately above should of course be taken.

It should be noted that these arrangements include the possibilities of the frequency allocation being a single group, supergroup or mastergroup, etc., in its basic frequency position.

c) *General transmission conditions*

The systems should satisfy all recommendations in Sections 1 and 2 of Part I of this Volume, including: noise, 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 of C.C.I.T.T. Recommendation G.223 which applies to carrier systems on land cables or radio links. Either of two load values per 4-kHz band may be applied according to the mode of application:

— 11 dBm0, which makes allowance for the use of equipments providing 16 channels per group and to the presence of call concentrators;

— 13 dBm0, which makes allowance for twelve channels per group of which two are occupied by VF telegraphy systems — no call concentrators [1].

d) *Cables*

This question is being studied. Supplement 11 to this Volume contains documentation on the cable-laying vessels used in various countries.

[1] *Note.* — This value is recommended provisionally pending the results of study of Question 2/IX.

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, New Delhi, 1970, are shown in brackets).

Subject of recommendation	Multiplex radio-relay systems using			Communication-satellite system [d]
	frequency division		time division [c]	
	line-of-sight [a]	tropospheric scatter [b]		
Use of radio links	G.411 (335-2)	G.411 (335-2)	G.411 (335-2)	
Terminal equipment	G.412	G.412	G.412	
Interconnection at audio-frequencies	G.422 (268-1)	G.422 (268-1)	G.422 (268-1)	
In-band interconnection (levels, pilots, frequency distribution in band, etc.)	G.423 (380-2, 381-2)	G-423 (380-2, 381-2)		
Hypothetical reference circuits . .	G.431 (391, 392)	G.433 (396-1)	G.432 (300) [e]	G.434 (352-1)
Circuit noise	G.441 (393-1, 395-1), G.442	G.444 (397-2)	G.443 (394) [e]	G.445 (353-2)

[a] Or near line-of-sight.

[b] For the capacities (number of telephone circuits) concerned.

[c] Recommendations applicable only to the characteristics between audio-frequency terminals.

[d] In the present section, use of these systems for telephony only is considered.

[e] Recommendations in Volume III of the *White Book* which corresponded to C.C.I.R. Recommendations do not appear in this volume. See also Note 1 of Recommendation G.421.

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,

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.

[1] This Recommendation is the same as an extract from C.C.I.R. Recommendation 335-2 (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 XIIth Plenary Assembly* (New Delhi, 1970) — Volume IV (Part 1 for radio-relay systems, and Part 2 for communication satellite systems).

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 [1]. Operational requirements may be such that it is also necessary in the case of frequency-division multiplex and of systems on metallic lines.

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, super-mastergroups or in 15-supergroup assemblies [1].

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 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/G.211, 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, 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

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[1] *Note from the Secretariat.* — This text relates to FDM radio-relay systems which were the subject of Recommendations G.432 and G.443 (now both deleted). As far as PCM radio-relay systems are concerned see (provisionally) C.C.I.R. Report 378-1 which is, in any case, being revised.

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

C.C.I.R. Recommendation 268-1 states that, as far as is practicable, radio-relay systems for telephony providing circuits which may form part of an international connection should be such that these circuits conform with the relevant C.C.I.T.T. recommendations for modern types of telephone circuit in the following respects:

1. the transmission characteristics of the circuits between audio-frequency terminals (the relevant recommendations are contained in C.C.I.T.T. Vol. III, Part I, Section 1);
2. the characteristics of the multiplex terminal equipment, wheie applicable (see C.C.I.T.T. Recommendations G.232 and G.412, Vol.III);
3. the method of signalling over international circuits the relevant recommendations are contained in C.C.I.T.T. Vol.VI; see also the following note:

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 380-2 [3] and 381-2 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.

[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.

[3] This Recommendation is being revised.

Notes to Table 1

[a] See paragraph c of the present Recommendation.

[b] This is the bandwidth occupied by the telephone channels, the associated pilots and reference frequencies, excluding the continuity pilots of the radio-relay system.

[c] For 12-channel radio-relay systems either of the 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.

[d] 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 380-2, reproduced below).

[e] This frequency arrangement is obtained from the basic mastergroup by modulating with multiples of the supergroup carriers.

[f] The special case of 600 channels comprising two mastergroups in the band 316-2868 kHz (Figure 3/G.423) is regarded as a partially equipped 960-channel system.

[g] According to C.C.I.R. Recommendation 380-2, other limits of the band occupied by telephone channels may be used by agreement between the Administrations concerned.

[h] Figure 1/G.344.

[i] For the use of 15-supergroup assemblies, see Recommendation G.211.

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 [a] (kHz)		Total bandwidth [b] (kHz)
				below (4)	above (4)	
1	2	3	4	5		6
24	2 G [c] 2 G [d]	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 [e]	1-b/G.341	64-1296	60	1364	
600	10 SG	1/G.423	60-2540	—	2604	60-2792
	2 MG [e]	2/G.423	64-2660	—	2792	
900	3 MG or 1 SMG [f]	4/G.423	316-4188	300, 308	4287	60-4287
960	16 SG	5/G.423	60-4028	—	4092	
1260 [g]	21 SG 21 SG 4 MG	Plan 1 [h] Plan 2 Plan 3	60-5636 60-5564 316-5564	— — 308	5680 5608 5608	60-5680
1800	15 SG + 3 MG	6/G.423	312-8204	300, 308	8248	300-8248
	15 SG + 15 SG [i]	7/G.423	312-8120			
	6 MG or 2 SMG	8/G.423	316-8204			
2700	15 SG + 6 MG	9/G.423	312-12388	300, 308	12435	300-12435
	15 SG + 15 SG + 15 SG [i]	10/G.423	312-12336			
	9 MG or 3 SMG	11/G.423	316-12388			

G = group
SG = supergroup
MG = mastergroup
SMG = supermastergroup

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 frequency. Consequently, interconnection with multiplex telephone equipment in the baseband of a radio-relay link (which in accordance with C.C.I.R. Recommendation 381-2 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 380-2 [2], 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 (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 frequency arrangements, corresponding to the baseband frequency limits in C.C.I.R. Recommendation 380-2 [2], 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/G.423 TO 11/G.423. — **Diagrams of the frequency arrangement for the radio-relay baseband, recommended for purposes of interconnection with coaxial cable systems**

Note 1. — All the diagrams in Figures 1/G.423 to 11/G.423 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).

Note 2. — The symbols used in these figures are shown on the inset at the end of this volume.

Note 3. — Some of the diagrams in the figures of other recommendations also apply to radio-relay links (see Table 1 of this Recommendation).

[1] Described in point 18 of Recommendation G.211.
[2] This Recommendation is being revised.

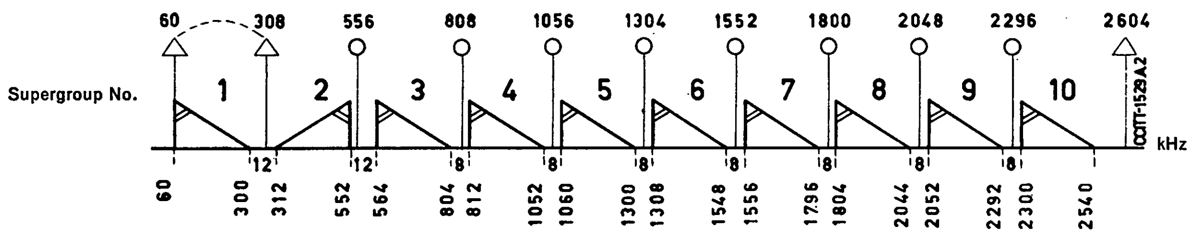


FIGURE 1/G.423

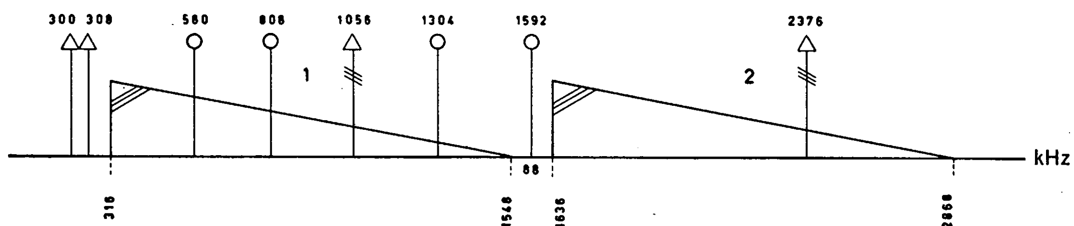


FIGURE 2/G.423

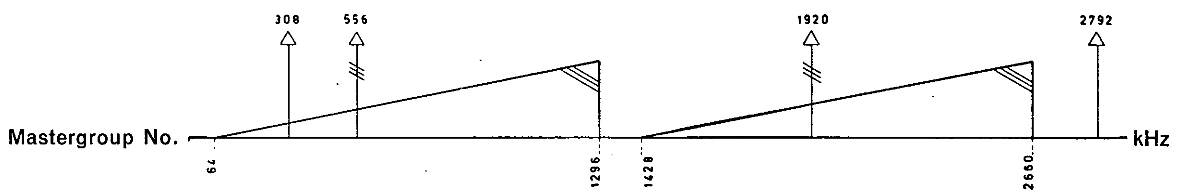


FIGURE 3/G.423

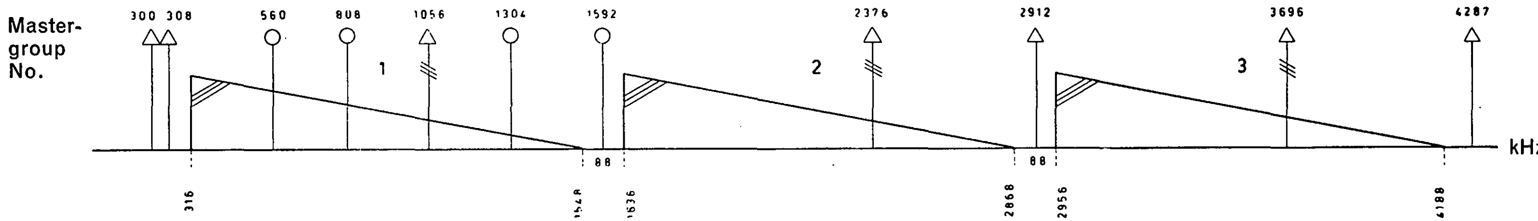


FIGURE 4/G.423

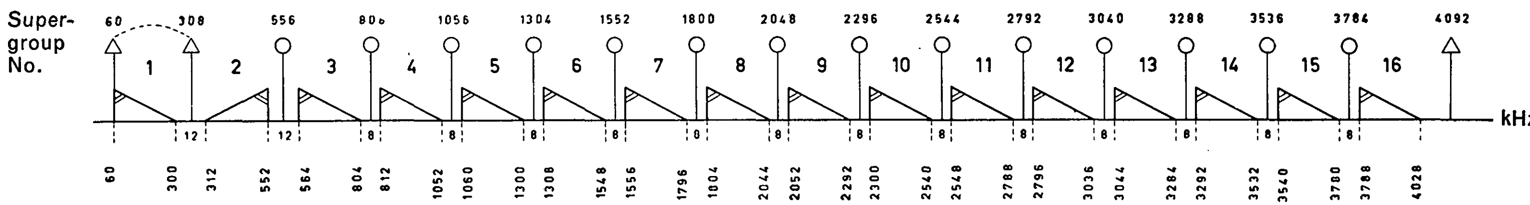


FIGURE 5/G.423

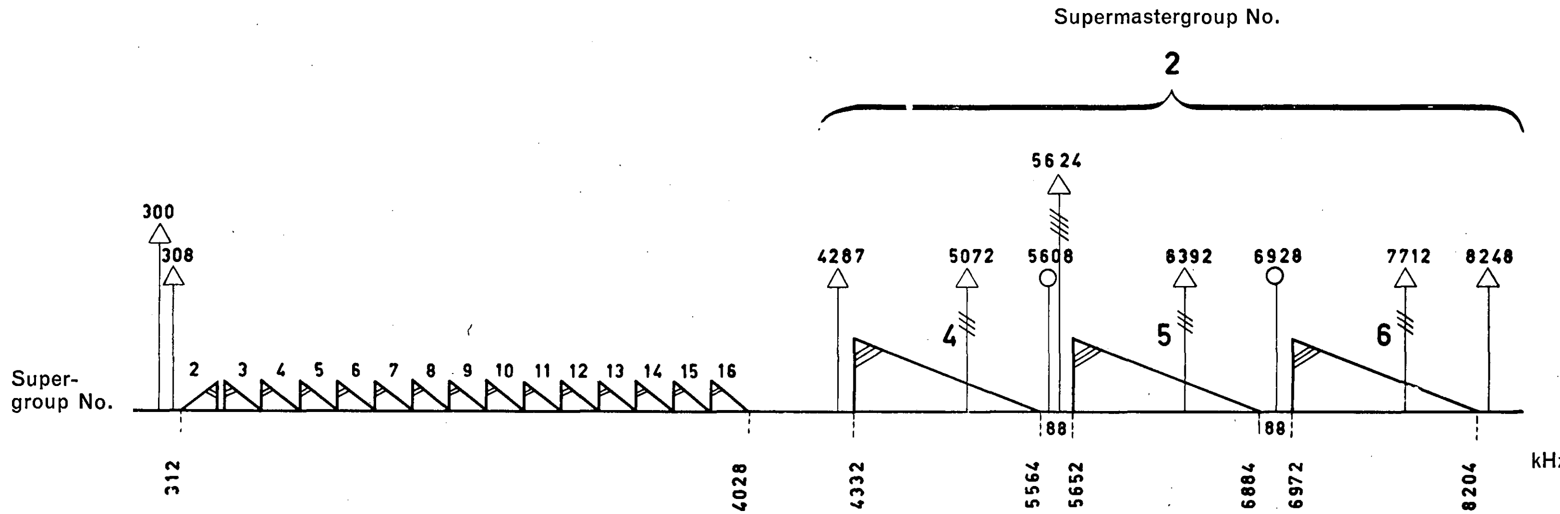


FIGURE 6/G.423

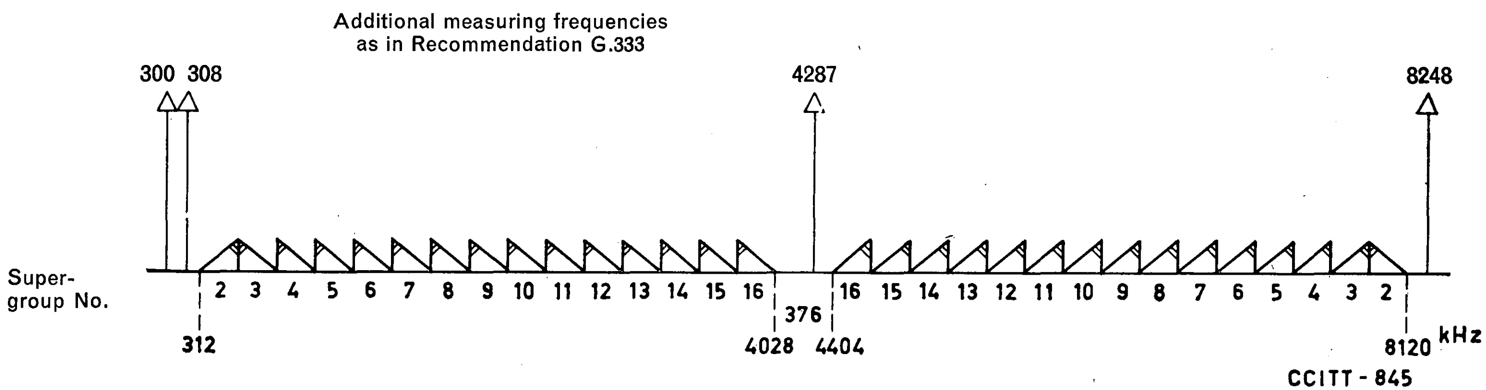


FIGURE 7/G.423

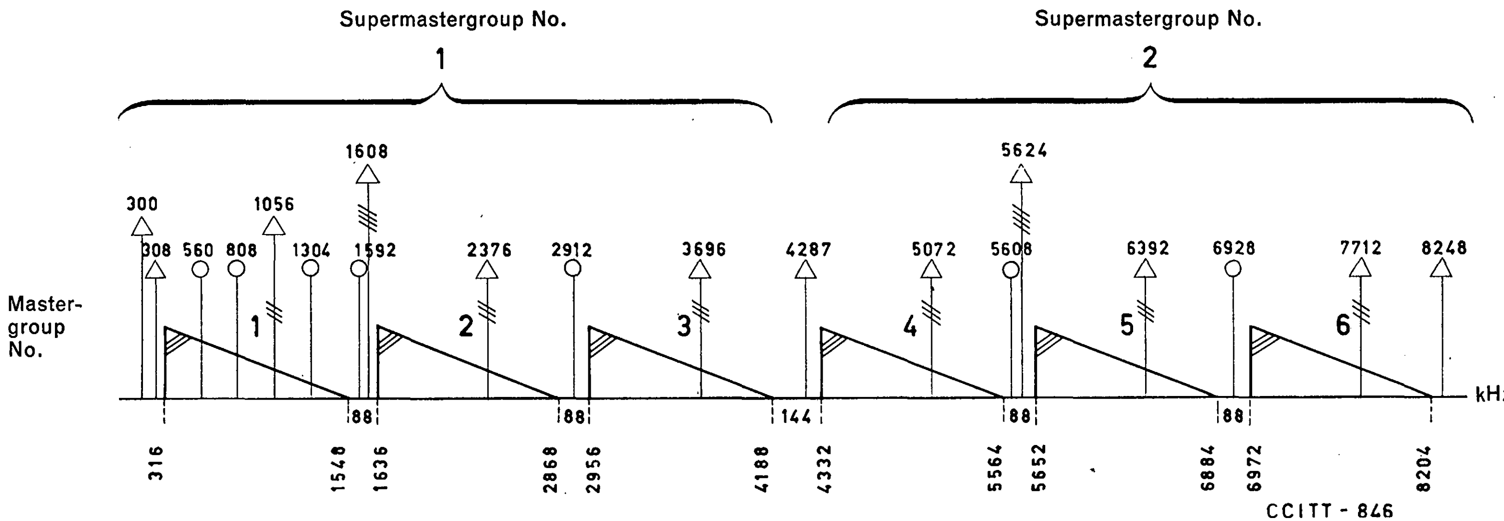


FIGURE 8/G.423

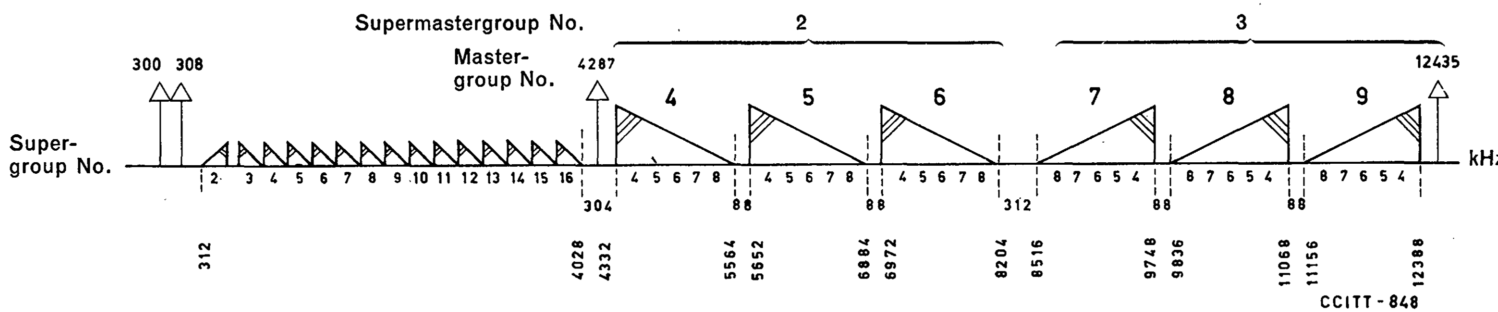


FIGURE 9/G.423

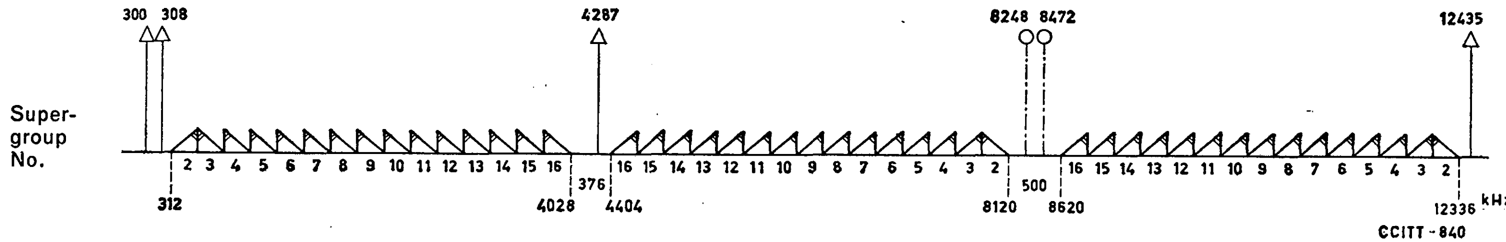


FIGURE 10/G.423 [1]

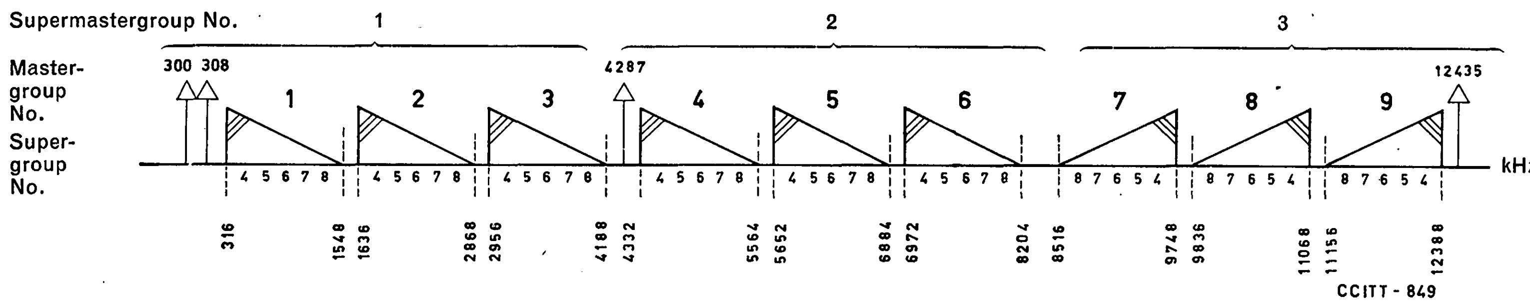


FIGURE 11/G.423

[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 381-2, 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*.

[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, 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 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 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 380-2, 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, 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 2 a of the same Recommendation. The C.C.I.R., in its Recommendation 380-2 (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, M.53 and 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.

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/G.431).

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.322).

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,

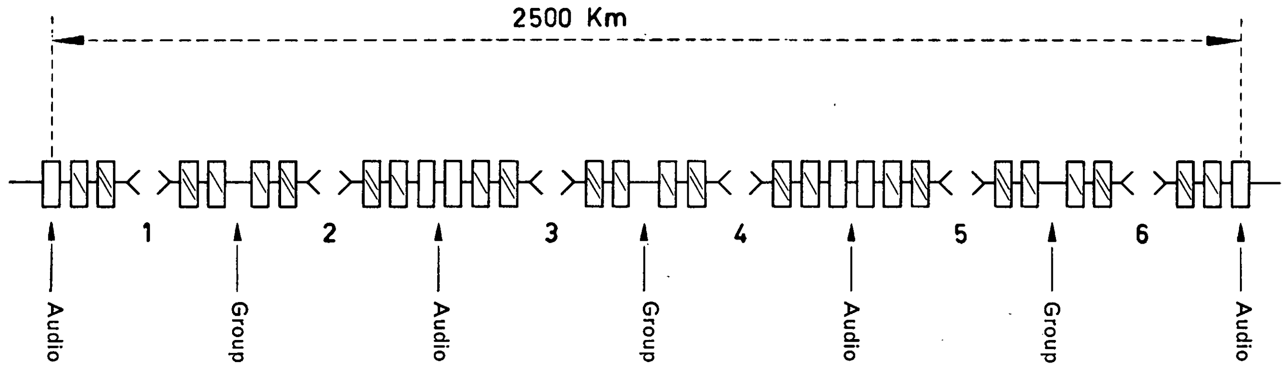
— six pairs of group modulators,

— nine pairs of supergroup modulators,

it being understood that a "pair of modulators" comprises a modulator and a demodulator (see Figure 2/G.431).

This circuit also has nine sets of radio modulators and demodulators for each direction of transmision so that they divide the circuit into nine homogeneous sections of equal length (see Recommendation G.322).

[1] This Recommendation applies only to line-of-sight or near line-of-sight radio-relay systems.



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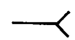
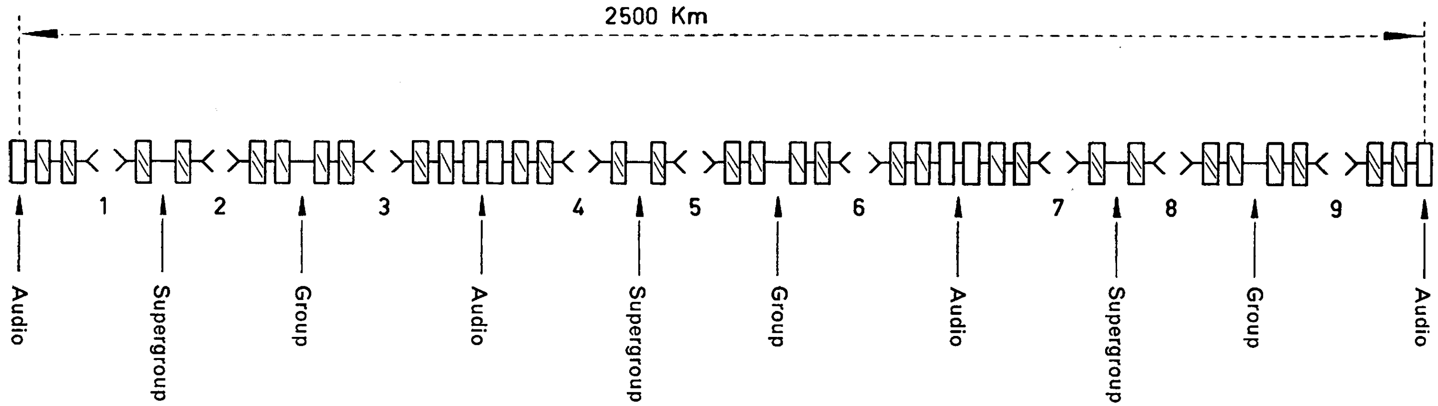

Radio modulator or demodulator
(baseband input or output)

(for other symbols, see the inset at the end of this volume)

FIGURE 1/G.431. — **Hypothetical reference circuit for frequency-division multiplex radio-relay systems with a capacity of 12 to 60 telephone channels per radio channel**



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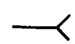
Radio modulator or demodulator
(baseband input or output)

(for other symbols, see the inset at the end of this volume)

FIGURE 2/G.431. — **Hypothetical reference circuit for frequency-division multiplex radio-relay systems with more than 60 telephone channels per radio channel**

Recommendation G.433 (Geneva, 1964)[1]

HYPOTHETICAL REFERENCE CIRCUIT FOR TROPOSPHERIC-SCATTER RADIO-RELAY SYSTEMS USING FREQUENCY-DIVISION MULTIPLEX

(See C.C.I.R. Recommendation 396-1)

Recommendation G.434 (Geneva, 1964)

HYPOTHETICAL REFERENCE CIRCUIT FOR COMMUNICATION-SATELLITE SYSTEMS

(See C.C.I.R. Recommendation 352-1)

4.4 Circuit noise

Recommendation G.441

PERMISSIBLE CIRCUIT NOISE ON FREQUENCY-DIVISION MULTIPLEX RADIO-RELAY SYSTEMS[2]

a) *Design objectives for noise on hypothetical reference circuits*

In C.C.I.R. Recommendation 393-1[3] 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)[3] should not exceed the provisional values given below:

1.1 7500 pW mean psophometric power in any hour[4];

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 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.

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[1] Recommendation G.432 has been deleted, as has C.C.I.R. Recommendation 300.

[2] Brought up to date by the Secretariat in the light of the C.C.I.R. (New Delhi, 1970) Recommendation quoted.

[3] This Recommendation applies only to line-of-sight or near line-of-sight radio-relay systems.

[4] See Recommendation G.222, Note 1 of paragraph b.

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)

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 ms 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 ms 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.444 (Geneva, 1964) [1]

ALLOWABLE NOISE POWER IN THE HYPOTHETICAL REFERENCE CIRCUIT FOR TROPOSPHERIC SCATTER RADIO-RELAY SYSTEMS USING FREQUENCY-DIVISION MULTIPLEX

(See C.C.I.R. Recommendation 397-2)

Recommendation G.445 (Geneva, 1964)

NOISE OBJECTIVES FOR COMMUNICATION-SATELLITE SYSTEM DESIGN

(See C.C.I.R. Recommendation 353-1)

[1] Recommendation G.443 has been deleted, as has C.C.I.R. Recommendation 394.