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

RED BOOK

VOLUME VII

TELEGRAPH TECHNIQUE
AND
DATA TRANSMISSION

Published by the
INTERNATIONAL TELECOMMUNICATION UNION
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CONTENTS OF THE C.C.I.T.T. RED BOOK

Each volume contains extracts from contributions received in the 1957-1960 period dealing with the subject of the volume concerned and considered worth publishing owing to their interest.

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RECOMMENDATION R.4

METHODS FOR THE SEPARATE MEASUREMENTS OF THE DEGREES OF VARIOUS TYPES OF TELEGRAPH DISTORTION

(New Delhi, 1960)

For separate measurement of the degree of characteristic distortion, bias distortion and fortuitous distortion affecting a telegraph modulation or restitution, the following is recommended.

1. Measure the overall distortion (at the actual mean modulation rate) on text, for instance on the text of Recommendation R.51 (called Q9S text)

   Let Δ be the measurement obtained.

2. Measure the distortion on reversals at the modulation rate used in measurement 1

   Let Δ_1 be the measurement obtained.

   Δ_1 is the sum of the bias and fortuitous distortions.

   By using a compensator fitted to the distortion measuring equipment, for example a compensating winding on the distortion meter relay, reduce the distortion reading obtained to its minimum value.

   Let this figure be δ .

   For practical purposes δ is the fortuitous distortion.

   $\Delta_1 - \delta$ is, for practical purposes, the bias distortion.

3. Keep the distortion meter adjusted as for the measurement of δ.
   Measure the distortion at the actual mean modulation rate on text (text Q9S, for instance).

   Let Δ' be the reading.

   $\Delta' - \delta$ is, for practical purposes, the characteristic distortion.

Notes.—

1. This method gives approximate results; it is possible that the equation $\Delta_1 + \Delta' - \delta = \Delta$ may not be exactly satisfied.

2. The method can be applied by using either an isochronous distortion measuring set or a start-stop distortion measuring set.

3. The fact that the separate measurement of degrees of different types of distortion is said to be possible, and that a method is recommended for such a measurement, does not mean that separate measurements of the degrees of different types of distortion are to be recommended when international routine maintenance measurements are carried out.

RECOMMENDATION R.5

OBSERVATION CONDITIONS RECOMMENDED FOR ROUTINE MEASUREMENTS OF DISTORTION ON INTERNATIONAL TELEGRAPH CIRCUITS

(New Delhi, 1960)

The C.C.I.T.T., in view of Recommendations R.51, R.54 and R.55

CONSIDERING

that, for the measurement of signal distortion on an international telegraph circuit, it is necessary to specify the best condition of observation in order to be sure that the measurement obtained gives a good indication of what the performance of the circuit will be during periods of normal traffic;

that the observation conditions should be such that their duration or their complexity do not unduly increase the load on the maintenance services;

that certain Administrations, to determine these conditions, have carried out statistical measurements of the degree of individual start-stop distortion using distortion analysers, the results of which seem to be in agreement;

UNANIMOUSLY DECLARES THE VIEW

that the text transmitted during measurements should be that of Recommendation R.51;

that, during normal maintenance testing, the duration of the observation should be approximately 30 seconds whatever the type of distortion meter used, isochronous or start-stop;

that, for tests with a start-stop distortion meter, the observation time could be divided into two periods: 15 seconds during which the significant instants in advance of their theoretical position could be observed, and 15 seconds during which the significant instants coming after their theoretical position could be observed.

RECOMMENDATION R.11

CALCULATION OF THE DEGREE OF DISTORTION OF A TELEGRAPH CIRCUIT IN TERMS OF THE DEGREES OF DISTORTION OF THE COMPONENT SECTIONS

(New Delhi, 1960)

In general the isochronous standardized test distortion (reference 33-07 and 33-12 of the List of Definitions) of a telegraph circuit consisting of a number " n " of links in tandem, lies between the arithmetic sum and the square root of the sum of the squares of the degrees of distortion of the individual links,

$$\sum_{i=1}^{n} \delta_i > \delta > \sqrt{\sum_{i=1}^{n} \delta_i^2}$$

n being the number of sections in tandem.

The few exceptions to this rule which have been observed related to extremely long circuits (for example, 4 links, each of approximately 3500 km looped at voice-frequency at the distant end to give the equivalent of 4 links (each 7000 km go and return) and a total length of approximately 28000 km on cable and open wire carrier telephone channels).

For such purposes as the planning of network, the degree of distortion of a telegraph circuit consisting of n channels or links in tandem in the telex service (where a great number of channels will be interconnected at random) is given fairly approximately by:

$$\delta_{\text{inherent}} = \sum_{1}^{n} \delta_c + \sqrt{\sum_{1}^{n} (\delta_{\text{bias}})^2 + \sum_{1}^{n} (\delta_{\text{irreg.}})^2}$$

Similarly, for the combination of a transmitter and a telegraph circuit consisting of n channels or links in tandem in the telex service, the degree of distortion is given fairly approximately by:

$$\delta_{\text{text}} = \sum_{1}^{n} \delta_c + \sqrt{\delta_t^2 + \delta_v^2 + \sum_{1}^{n} (\delta_{\text{bias}})^2 + \sum_{1}^{n} (\delta_{\text{irreg.}})^2}$$

where

δ_{inherent} = the probable degree of inherent standardized test start-stop distortion

δ_{text} = the probable degree of gross start-stop distortion in service

δ_c = the degree of characteristic start-stop distortion of a single channel or link

δ_t = the degree of synchronous start-stop distortion of the transmitter

δ_v = the degree of start-stop distortion due solely to the difference between the mean transmitter speed and the standardized speed. (The difference to be considered is equal to six times the mean difference for one element.)

δ_{bias} = the degree of asymmetrical (bias) distortion of one channel measured using 1 : 1 or 2 : 2 signals (either 1 : 1 or 2 : 2 signals should be used according to which is normally employed for adjusting the channels).

$\delta_{irreg.}$ = the degree of fortuitous distortion of one channel measured using 1 : 1 or 2 : 2 signals.

The values of distortion (with exception of δ_c) inserted in the foregoing formulae must have the same probability of being exceeded (p).

The degree of characteristic distortion δ_c of a channel is fairly constant for each type of voice-frequency channel and can be determined in laboratory tests.

Nevertheless, the maximum degree of characteristic distortion is reached for only about 20% of the signals of international telegraph alphabet No. 2.

Empirical values for δ_c can be obtained with reasonable accuracy by measuring the total distortion with Q9S signals after bias has been adjusted to minimum, and subtracting from it the irregular distortion measured using 1:1 or 2:2 signals. Except in the case of old V.F. telegraph systems incapable of transmitting accurately a long train of 1: 6 signals, one may use instead of the degree of distortion of Q9S signals, the degree of distortion of 1:6 or of 6:1 signals, if either of these is larger than the degree of distortion of the Q9S signals.

The probability of exceeding the degrees of distortion $\delta_{inherent}$ and δ_{text} calculated with the aid of the above formulae is $\frac{20}{100} \times p$.

Note. In connection with this Recommendation, see the Supplement published in the *Red Book*, Volume VII, page 226: Statistical distribution of start-stop telegraph distortion in tandem-connected voice-frequency telegraph channels (United Kingdom).

RECOMMENDATION R.20

TYPES OF INTERNATIONAL TELEGRAPH LINES

(former C.C.I.T. Recommendations B.22 and B.27, Warsaw 1936, amended, New Delhi, 1960)

The C.C.I.T.T.

CONSIDERING

that cable lines are better protected from disturbance than aerial lines;

that it will however be necessary in certain cases to continue to employ aerial lines,

UNANIMOUSLY DECLARES THE VIEW

that for the international high-speed telegraph service as much use as possible should be made of the circuits of the long-distance cable system;

CONSIDERING

that the standardization of the modulation rate of telegraph circuits serves to ensure an economical organization of the international telegraph network,

UNANIMOUSLY DECLARES THE VIEW

1. that the telegraph transmission channels making use of telephone cables should allow the operation of standardized equipment with a modulation rate of 50 bauds;

2. that, for the services using equipment which work at a different speed, Administrations should reserve the right of mutual agreement among themselves on the employment of special circuits;

3. that the existing aerial lines should be excepted from modulation rate standardization.

RECOMMENDATION R.21

CHARACTERISTIC FACTOR OF THE QUALITY OF BALANCE

(former C.C.I.T. Recommendation B.4, Brussels, 1948, amended at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that the quality of a telegraphic communication is best characterized by distortion;

that the measurement of telegraphic distortion is now a common practice,

UNANIMOUSLY DECLARES THE VIEW

a) that the quality of balance of a duplex telegraph circuit can provisionally be characterized by the difference in the degrees of distortion of the signals restituted:

1. when no signals are transmitted on the sending channel;
2. when signals are transmitted over that channel;

b) that measurements should be made at both ends of the circuit.

Comment: The quality of balance thus characterized is applicable to standardized telegraph systems for which measurements of the degree of distortion are usually made.

RECOMMENDATION R.22

EARTHING OF TELEGRAPH INSTALLATIONS

(former C.C.I.T. Recommendations B.6 and B.7, Warsaw, 1936, amended at Geneva, 1956, and New Delhi, 1960)

When a local cable is not exposed to any induction phenomena, the earthing of the centre point of the common source of transmission currents may have the advantage of ensuring better balance of the supply voltages of the telegraph circuit with respect to the cable sheath and to other telegraph circuits.

Further, it is advisable not to have any earth connection at any point in a long-distance cable circuit.

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW:

1. that, when common batteries are used for transmission currents on line circuits, it is advisable to earth the centre point of these batteries in cases when no induction phenomena are to be feared;

   that, in the case of a local network cable exposed to induction phenomena, it is advisable to use a separate source with no earthing for each telegraph circuit;

2. that there should be no earth at any point in a telegraph installation or line having metallic connection to a long-distance cable circuit; the connection with a long-distance cable should be made by means of a transformer providing a metallic discontinuity in the telegraph circuit;

3. that if, however, for special reasons it is necessary to earth a line or an installation connected to the conductors of a cable, the following precautions should be taken:

   a) the earthing must be carried out in such a way that the balance of the circuits with respect to earth and to adjacent circuits is not disturbed;

   b) the break-down voltage of all the other conductors of the cable together, with respect to the earthed circuit, must be appreciably higher than the highest voltage which could exist between these conductors and the earthed circuit as a result of induction from adjacent power lines;

4. that an investigation must be made of installations already earthed to ascertain whether condition 3 *b)* will continue to be satisfied in the event that new distribution networks or new electric railway lines are put into operation, in which case suitable measures must be taken.

RECOMMENDATION R.23

STANDARDIZATION OF DIRECT CURRENT TELEGRAPH CIRCUITS EMPLOYING TELEPHONE CABLES

(former C.C.I.T. Recommendation B.8, Warsaw, 1936, amended at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that, to effect smooth co-operation of direct current telegraph devices functioning on channels in telephone cables (telegraphy on phantom or double phantom cables) as much from the technical as from the operational point of view, it is necessary that the equipment of the circuits should be established on uniform principles,

UNANIMOUSLY DECLARES THE VIEW

that in the matter of direct current telegraph circuits,

making use of telephone cables,

terminated at their extremities by telegraph relays,

served at the modulation rate of 50 bauds,

and making use of currents taking only two values in steady state,

circuit and supervisory equipment should satisfy the following conditions:

a) for the excitation of relays and the transmission of signals, a working current and a resting current of equal intensity in steady state, but in opposite directions, should be used;

b) as a general rule, arrangement will be in differential duplex; however, in certain special cases, particularly those of telephone cables with unidirectional transmission, operation will be carried out by separate channels for the two directions of transmission;

c) the excitation current of the receiving relay will be between 4 and 8 milliamperes for telegraphy on phantom and double phantom circuits;

d) in general, repeaters will comprise separate receiving and transmitting relays; however, in special cases, the same relay may serve for both functions;

e) equipment will be constructed in such a way that one may, easily and speedily:

— replace the source of current by a resistance equal to the internal resistance of that source;

— insert, during operation, an apparatus for measuring distortion;

— change lines and apparatus by means of jacks and plugs;

f) supervisory equipment should allow the following operations to be accomplished in the minimum time:

— emission of symmetrical alternations at the modulation rate of 50 bauds;

— measurement in steady state of the effective of operational currents, receiving relays and currents coming from transmitting relays;

— measurement of currents in local circuits;

— determination of data concerning the quality of the circuit balance.

RECOMMENDATION R.24

COEXISTENCE IN A SAME CABLE OF TELEPHONY AND DIRECT CURRENT TELEGRAPHY

(former C.C.I.T. Recommendation B.9, Warsaw, 1936, amended at Arnhem, 1953, at Geneva, 1956, and at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that technical processes exist by which telephone traffic and telegraph traffic can be passed through the same cable either on separate conductors or even on common conductors; that by these processes, if the precautions described below are observed, the telephone circuits, including phantom circuits, are to all intents and purposes uninfluenced by the telegraphy as regards both their electrical properties and the flow of traffic;

that, even when the cable is subject to the influence of electric power installations (particularly AC railway lines), undisturbed telephone and telegraph services can be obtained by the use of devices which have been proved to be effective;

that, moreover, the simultaneous use of a long-distance cable for international telephony and telegraphy is to be recommended for economic reasons,

UNANIMOUSLY DECLARES THE VIEW

that it is possible to allow in a same cable the coexistence of telephony and D.C. telegraphy, provided that the conditions listed below are fulfilled:

A. *Simultaneous telegraphy on single or double phantom circuits.*

(*Note :* The VIth Plenary Assembly of the C.C.I.T., Brussels, 1948, considered that the study of questions concerning infra-acoustic telegraphy had become pointless and should be abandoned.)

1. The e.m.f. introduced by the telegraph transmitter into the circuit containing the cable conductors must not exceed 50 volts.

2. Where a resistance of 30 ohms, substituted for the cable conductors, is placed across the terminals of this telegraph transmitter, the current flowing through this resistance must not exceed 50 milliamperes.

This limit is raised to 100 milliamperes if the cable is fitted with coils having a powdered iron core or a core of some other material with equally satisfactory characteristics.

3. Noise produced by all the telegraph apparatus on a telephone circuit must not exceed, at the point of relative level of—1.0 neper or—8.7 decibels and with

an impedance of 600 ohms, a value which corresponds to a psophometric e.m.f. of 1 millivolt. To fulfil this condition, it is advisable to insert low-pass filters in the transmission on all telegraph circuits operated by direct current. This limit may have to be lowered when the telephone circuit is already subject to considerable disturbance from an adjacent power-line.

4. The simultaneous telegraph installations must not introduce unbalance relative to earth in the telephone circuits (Directives for the protection of telecommunication lines against the harmful effects of industrial power-lines).

5. The increase in crosstalk produced by the simultaneous telegraphy installations in the telephone circuits must not exceed a value corresponding to a decrease of 0.5 neper or 4.34 decibels in the near-end crosstalk attenuation.

6. The circuits of which the single or double phantom circuits used for telegraphy are composed must not be used for broadcast relays.

B. *Telegraphy and telephony coexistent on separate conductors.*

1. Case in which the telegraph uses coil-loaded conductors which may afterwards be used for telephony:

The conditions set out above under A. 1, 2 and 3 must be fulfilled.

2. Case in which the telegraph uses unloaded conductors:

The conditions set out above under A. 3 only must be fulfilled.

RECOMMENDATION R.25

COEXISTENCE ON THE SAME CONDUCTORS OF A CABLE OF V.F. TELEGRAPHY AND TELEGRAPHY ON PHANTOM OR DOUBLE PHANTOM CIRCUITS

(former C.C.I.T. Recommendation B.10, Warsaw, 1936)

The C.C.I.T.T.,

CONSIDERING

that it is advisable not to complicate V.F. telegraphy circuits,

UNANIMOUSLY DECLARES THE VIEW

that, when the telegraph current on phantom or double phantom circuits does not influence the magnetic field of the loading coils, the technical conditions stipulated for the coexistence of telephony and telegraphy on phantom or double phantom circuits are also applicable for the coexistence of harmonic telegraphy or phototelegraphy, on the one hand, and telegraphy on phantom or double phantom circuits, on the other;

that when the telegraph current influences the magnetic field of the loading coils and there is doubt about their qualities as far as the effects of these fluctuations are concerned, it is not advisable to resort to such coexistence;

that, in general, it is not advisable to resort to such coexistence.

RECOMMENDATION R.26

STANDARDIZATION OF AERIAL TELEGRAPH CONDUCTORS

(former C.C.I.T. Recommendation B.28, Warsaw, 1936)

The C.C.I.T.T.,

CONSIDERING

that it is desirable to standardize the characteristics of international telegraph conductors;

that the tests made with the object of obtaining circuits not subject to contact and to variations of insulation, by using wires provided with insulation other than rubber and paper, have not given satisfactory results;

that the use of wires insulated by rubber would not guarantee the perfect handling of traffic for a very long period and would increase expenses;

that the use of wires insulated by paper and lead would greatly increase costs,

UNANIMOUSLY DECLARES THE VIEW

1. that, for aerial conductors used in the international high-speed telegraph service, it is desirable to employ copper or bronze wires answering the following specifications:

	diameter at least	tensile strength at least	resistivity at 20 degrees centigrade maximum
Copper	3	40	1.820
Bronze	2.5	60	2.780
	mm	kg/mm²	microhms-cm

2. that it is not desirable to replace open wires by insulated wires with the aim of improving the electrical properties of the conductors.

RECOMMENDATION R.30

CHOICE OF METHODS OF MODULATION FOR VOICE-FREQUENCY TELEGRAPH SYSTEMS

(former C.C.I.T. Recommendation B.47, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that most voice-frequency carrier telegraph systems are applied either to audio circuits conforming to C.C.I.T.T. Recommendation H.14 (*Red Book*, Volume III) or to carrier telephone channels conforming to C.C.I.T.T. Recommendation H.13 (*Red Book*, Volume III);

2. that some voice-frequency telegraph systems are applied to telephone channels subject to greater variations of equivalent than are permissible according to C.C.I.T.T. Recommendation G.13 (*Red Book*, Volume III) but that, in general, the variations in equivalent of these telephone channels are not rapid, being due, for example, to climatic variations causing changes in telephone circuits in aerial lines;

3. that some voice-frequency telegraph systems are applied to telephone channels, which are subject to excessive noise and whose equivalent may vary widely and rapidly, for example, some carrier telephone channels working on open wire lines;

4. that, despite improvements that have been made by telephone Administrations, there remain many telephone circuits of all types whose equivalent varies suddenly to an extent and with a frequency of occurrence which is important, and that it may prove impossible to reduce this trouble to a negligible degree,

UNANIMOUSLY DECLARES THE VIEW

1. that amplitude-modulated voice-frequency telegraph systems standardized by the C.C.I.T.T. do give satisfactory service when applied to telephone circuits conforming to C.C.I.T.T. Recommendations, provided the frequency and amplitude of sudden variations in the equivalent of these telephone circuits is small;

2. that amplitude-modulated voice-frequency telegraph systems can give satisfactory service on telephone lines whose equivalent varies slowly by about $\pm$ 1 neper, provided that there are very few large and sudden variations of equivalent, and provided that special measures are taken (such for example as the provision of a pilot channel), but that, on the other hand, at least equally satisfactory service can readily be obtained in these same circumstances by a frequency-shift modulated voice-frequency telegraph system;

3. that when the equivalent of a telephone circuit varies widely and rapidly, and particularly when noise is severe, a frequency-shift modulated voice-frequency telegraph system is less adversely affected than any other known type of voice-frequency telegraph system.

RECOMMENDATION R.31

STANDARDIZATION OF AMPLITUDE-MODULATED VOICE-FREQUENCY TELEGRAPH SYSTEMS, FOR A MODULATION RATE OF 50 BAUDS

(ex C.C.I.T.T. Recommendations B.11, B.12, B.13, B.14, B.15, Brussels, 1948, amended at Arnhem, 1953, Geneva, 1956, and New Delhi, 1960)

The conditions of use of international telephone-type circuits for voice-frequency telegraphy are described in detail in Recommendations H.11, H.13 and H.14 (Volume III of the *Red Book)* *.

It is recalled that heavy or semi-heavy load audio-frequency circuits can take 12-channel, 50-baud voice-frequency telegraph systems, while 18 channels are feasible over audio-frequency circuits having a lighter load.

High-speed carrier circuits permit of 24 channels 50 bauds.

4-wire circuits are to be preferred for voice-frequency telegraphy. The composition of a 4-wire circuit for voice-frequency telegraphy differs from that of a telephone circuit in that there are no terminating sets, ringing repeaters and echo suppressors.

With 2-wire circuits, a duplex assembly would be out of the question since these circuits cannot be balanced with the necessary precision to avoid reciprocal influence. If the low frequencies are used for transmission in one direction and high frequencies for the other direction, a 2-wire circuit can be used for voice-frequency telegraphy.

Taking the foregoing into consideration, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. It is advisable to adopt, for amplitude-modulated voice-frequency telegraph systems and for a modulation rate not exceeding 50 bauds, the series of frequencies formed by odd multiples of 60, the lowest frequency being 420 c/s.

Channel Number	Frequency c/s	Channel Number	Frequency c/s
1	420	13	1860
2	540	14	1980
3	660	15	2100
4	780	16	2220
5	900	17	2340
6	1020	18	2460
7	1140	19	2580
8	1260	20	2700
9	1380	21	2820
10	1500	22	2940
11	1620	23	3060
12	1740	24	3180

* Some extracts of these Recommendations are published in the *Red Book*, Volume VII, pages 241 and following.

This numbering is valid whatever use is made of the channel (e.g. traffic channel, pilot channel, etc.) or the method employed to obtain the line frequencies, e.g. by group modulation;

2. However, in special cases (for example, circuits using long submarine telegraph cable on a section of their route), the Administrations concerned may agree upon the use of a different series of frequencies;

3. The frequencies applied to the bearer telephone circuit should not deviate by more than 6 c/s from the nominal value when the telegraph channels supplied are operating over a telephone circuit composed exclusively of audio-frequency sections, and not more than 3 c/s in other cases;

4. The power levels of carrier waves transmitted on the line and measured successively in as short a period as possible should not differ from one another by more than 0.2 neper when they are operating on a constant impedance;

5. The power of each of the carrier waves transmitted on the line should not vary in operation by more than $\pm$ 0.1 neper when it operates on a constant impedance;

6. The amplitude of the signals transmitted should remain within the tolerances of the following diagram 1 in which the values t_0, y_2 and y_1 are fixed as follows:

t_0 = 11 milliseconds
y_1 = 95
y_2 = 110

Amplitude in % of the reference amplitude

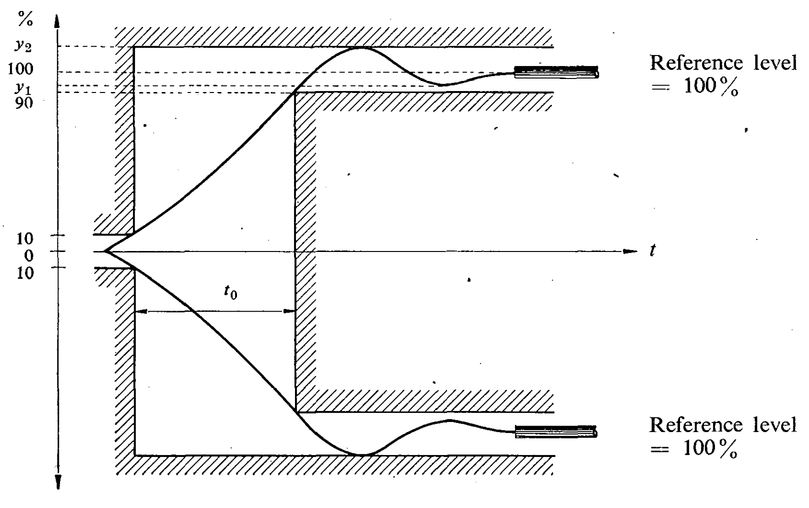

FIGURE 1. — *Diagram of tolerances to assess the signal-wave form sent in amplitude-modulated voice-frequency telegraphy systems.*

7. If 1 to 1 reversals at frequency f_p corresponding to the modulation rate are sent over a channel with mid-frequency F_0, the voltage at frequency $F_0 \pm 3 f_p$ must not exceed

3% of the nominal voltage of frequency F_0 and the voltage at the frequencies $F_0 \pm 5 f_p$ must not exceed 0.4% of the nominal voltage of frequency F_0.

(*Note.* — These tolerances will only be required for future systems; Administrations should try to bring systems satisfying these tolerances into service on international relations as far as possible).

8. Systems should be able to tolerate slow level variations of at least ± 6 db (0.67 N); Administrations should equip systems which are unable to tolerate such variations with a common amplifier to enable them to tolerate at least variations of ± 6 db (0.67 N);

9. If an audio-frequency telephone-type circuit is used, the voice-frequency telegraph installations should satisfy the following conditions:

The instantaneous maximum voltage produced by the whole of the telegraph signals corresponding to the frequencies simultaneously used on a single circuit must not exceed that of a sine wave with a power of 5 milliwatts at the point of relative level zero calculated from the level diagram of the telephone circuit.

The harmonic frequency telegraph emitter is not, in the majority of cases, connected to the input of the telephone circuit, but to a point where the relative level h is different from zero. The power of the sine wave corresponding to the instantaneous maximum power permissible in that point is thus:

$$P_{\max} = 5\, e^{2h} \text{ milliwatts } (h \text{ in nepers}).$$

The maximum voltage for an impedance Z of the circuit is thus:

$$U_{\max} = [(5.10^{-3})\, e^{2h} \,.\, Z]^{1/2} \text{ volts.}$$

In the frequency division multiplex telegraph with N frequencies, this voltage $U_{\max}$ will not be exceeded, if, for any of the frequencies, the r.m.s. value U_f of the voltage does not exceed the *Nth* part of $U_{\max}$.

$$U_f = \frac{1}{N}\, U_{\max}.$$

Or, introducing the relative voltage level h_v in the place of the relative power level h,

$$h_v = h + \log_e \sqrt{\frac{Z}{600}}$$

it comes:

$$U_f = \left(\frac{1}{N}\right) e^{h_v} \cdot \sqrt{3} \text{ volts.}$$

The measurements are taken during transmission of a continuous dash on each frequency in the circuit one after the other. For this purpose, each generator is adjusted in such a way as to attain, for each frequency, the voltage indicated above. The measurement of the voltage which is to be taken at the input of the circuit used for multiplex harmonic frequency telegraphy may be taken with any standard voltmeter.

If usual level measuring sets are used, which are calibrated for absolute levels, the value of the absolute level not to be exceeded is, for a N channels system:

$$h_{\text{meas}} = \log_e \frac{U_f}{0.775} = h_v + 0.8 - \log_e N \text{ in nepers.}$$

If the relative voltage level rises at the input of the harmonic frequency telegraph circuit to $h_v = 0.7$ neper, or 6.1 decibels, for example, it will be necessary to make adjustments according to the following measurement scale:

3-channel system: $h_{\text{meas}} = 0.7 + 0.8 - \log_e 3 = +0.4$ neper or $+3.5$ db.
6-channel system: $h_{\text{meas}} = 0.7 + 0.8 - \log_e 6 = -0.3$ neper or -2.0 db.
12-channel system: $h_{\text{meas}} = 0.7 + 0.8 - \log_e 12 = -1.0$ neper or -8.7 db.

TABLE I

Normal power limits per telegraph channel in amplitude-modulated voice-frequency telegraph system routed over a telephone circuit of the audio-frequency type

Voice-frequency telegraph system	Mean admissible power per telegraph channel at a point of 0 relative level		
	expressed in microwatts	expressed by an absolute power level	
		nepers	decibels
3 channels at least	555	—0.295	— 2.55
6 channels	140	—0.985	— 8.54
12 channels	35	—1.67	—14.5
18 channels	15	—2.1	—18.25
24 channels	9	—2.4	—20.9

It is considered that there is no necessity to check the voltages and the powers in operation;

10. If a telephone-type 24-channel carrier circuit is used, the permissible limit for the power of the telegraph current on each telegraph channel, when a continuous tone is being transmitted, is equal to a maximum of 9 microwatts at the point of zero relative level.

The power of 9 microwatts corresponds to

$$\frac{5 \text{ milliwatts}}{(24)^2}$$

This number is subject to revision if a statistical study of the peaks of the total telegraph current (on a telephone channel providing 24 telegraph channels) shows this to be advisable.

It may happen that a telephone channel gives a relatively high level of noise, in which case the telegraph service must abandon the use of 24 telegraph channels on such a telephone channel and limit itself to 18 channels only. In such a case, the maximum permissible power for each telegraph channel is

$$\frac{5 \text{ milliwatts}}{18^2} = \text{about 15 microwatts}$$

The power per telegraph channel should never in any case exceed

$$\frac{5 \text{ milliwatts}}{12^2} = \text{or about 35 microwatts,}$$

calculated for a 12-channel telegraph system in accordance with the principles indicated above;

TABLE II

Normal limits for the power per telegraph channel in amplitude-modulated voice-frequency telegraph systems routed on a carrier type telephone circuit

Voice-frequency telegraph system	Allowable power per telegraph channel at a point of zero relative level		
	In microwatts	In an absolute power level	
		nepers	decibels
12 telegraph channels, or less	35	—1.67	—14.5
18 telegraph channels	15	—2.1	—18.25
24 telegraph channels	9	—2.4	—20.9

11. The audio frequency is transmitted to line when a stop unit, in conformity with International Telegraph Alphabet No. 2, is sent.
12. It must be possible to subject any channel to a test without withdrawing from service a channel other than the return channel of the circuit planned;
13. Local tests must be made at each of the ends before making the two terminal offices work together, if this is necessary;
14. In graded harmonic frequency telegraphy, it is desirable that the same frequencies be used separately for circuits established on different successive sections of a 4-wire circuit;
15. In graded harmonic frequency telegraphy, the attenuation of the filters which pass a group of frequencies must, in the suppressed frequency band, be higher by at least 4 nepers than that shown in the transmission band;
16. In graded harmonic frequency telegraphy, in order to facilitate local tests, the frequencies used for communications set up between two international offices in one direction should also be used in the opposite direction, if possible.

RECOMMENDATION R.32

USE OF STATIC RELAYS FOR TRANSMISSION

(former C.C.I.T. Recommendation B.16, Brussels, 1948)

The C.C.I.T.T.,

CONSIDERING

that the substitution of static relays utilizing the properties of metal rectifiers for electromagnetic transmitting relays for voice-frequency telegraphy is already widely adopted and ensures a reduction of distortion of the transmitted signals, great stability, and dispenses with all necessity for adjustment once the device is in service;

that the devices in use in different countries differ in detail but operate satisfactorily, so that it appears unnecessary to recommend any particular one, and that it seems sufficient to indicate how the characteristics of interest in the practical application of such devices can be defined, without specifying the values of these characteristics, with the exception of the difference in the attenuation introduced by the relay in the transmitting and the non-transmitting conditions;

UNANIMOUSLY DECLARES THE VIEW

a) that the use of static relays utilizing metal rectifiers properties for transmission on voice-frequency telegraph channels is advantageous;

b) that in the study of the specification of a static relay the following quantities should be considered:

1. Band of carrier frequencies to which the device is adapted;
2. Input resistance (or impedance characteristics) of the direct current control circuit;
3. Maximum value of the controlling direct current (as determined by the dimensions and properties of the rectifiers used);
4. Minimum value of the controlling direct current (as determined by the curvature of the characteristics of the rectifiers used);
5. Impedance of the system as measured from the carrier current input terminals *a)* in the case of transmission and *b)* in the case of non-transmission of signals;
6. Impedance of the system as measured from the line terminals *a)* in the case of transmission and *b)* in the case of non-transmission;
7. Voltage of the carrier frequency;
8. Loss introduced by the relay in the case of transmission, in the case of non-transmission, and in the absence of any controlling direct current;

9. Maximum coefficient of harmonic distortion;

10. Particulars of the variations in the essential properties of the relay with changes of temperature, ageing, etc.;

11. Symmetric quality of the device;

c) that the difference in the loss introduced by the relay in the cases both of transmission and of non-transmission should be as high as possible and, in any case, at least equal to 3.5 nepers or 30 decibels.

RECOMMENDATION R.33

STANDARDIZATION OF OPERATING CONDITIONS FOR STATIC SENDING RELAYS OF AMPLITUDE-MODULATED VOICE-FREQUENCY TELEGRAPH SYSTEMS

(former C.C.I.T. Recommendation B.46, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that it is essential that voice-frequency telegraph receivers should operate to the condition corresponding to a start element (clearing signal) when the control current fails in the sending relay;

2. that it is necessary under the foregoing condition for the sending static relay to have adequate attenuation even in the presence of parasitic currents such as may occur in the sending line associated with the channel;

3. that it is not considered to be very objectionable if the receiver operates to the condition corresponding to stop polarity for short intervals (e.g. false calling signals) as the result of the combined effects of line noise and the incompletely suppressed signal from the sending relay;

4. that it is of little consequence whether the suppression of the signal resulting from the interruption of the control current is instantaneous or occurs after a short delay (e.g. due to a slow relay);

UNANIMOUSLY DECLARES THE VIEW

1. that, in the event of failure of the control current in the sending static relay, the attenuation of the residual signal relative to the nominal level should be at least 3.1 nepers (27 decibels);

2. that this attenuation of the signal need not occur immediately after the failure of the control current.

RECOMMENDATION R.34

THRESHOLD OF SENSITIVITY FOR AMPLITUDE-MODULATED VOICE-FREQUENCY TELEGRAPH RECEIVERS

(former C.C.I.T. Recommendation B.45, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that, in the absence of a voice-frequency signal, the detectors of a voice-frequency telegraph system should not respond to noise;

2. that, in accordance with C.C.I.T.T. Recommendation R.31, the power allocated to one channel of a 24-channel voice-frequency telegraph system is 9 microwatts at a point of zero level (corresponding to a level of – 2.4 nepers);

3. that the C.C.I.T.T. is at present engaged in studies regarding the maximum values of noise which may be experienced on carrier telephone circuits, but it is nevertheless necessary to make a provisional recommendation regarding the threshold of sensitivity for the receiving equipment of amplitude-modulated voice-frequency telegraph systems now;

4. that the experience of certain Administrations has shown that the operation of the receiving equipment of a voice-frequency telegraph system is not in general disturbed by noise, if during no-tone periods a signal whose frequency corresponds to the nominal frequency of the channel and whose voltage corresponds to an absolute level of – 4.5 nepers at a point of zero relative level is applied without producing any response in the receiving relay;

UNANIMOUSLY DECLARES THE VIEW

1. that it is necessary to fix a threshold of sensitivity for the detector of an amplitude-modulated voice-frequency telegraph channel;

2. that, when a signal the frequency of which is equal to the nominal frequency of the channel, and whose level is 2.1 nepers below the normal signal level of the channel, is applied to the detector of a 24-channel voice-frequency telegraph system, the receiving relay should not respond.

Note. — It will be useful to review this Recommendation when the studies now in progress regarding the maximum value of noise have been finished.

RECOMMENDATION R.35

STANDARDIZATION OF FREQUENCY-SHIFT MODULATED VOICE-FREQUENCY TELEGRAPH SYSTEMS (FOR A MODULATION RATE OF 50 BAUDS)

(former C.C.I.T. Recommendation B. 48, Geneva 1956, amended at New Delhi, 1960)

Frequency-shift modulated voice-frequency telegraph circuits are being used more and more on telegraph networks, and it should be possible to introduce them into international services; it may even be necessary to use them on international long-distance telephone circuits operating in unfavourable conditions.

It is, moreover, important to be able to make the maximum use of telephone-type bearer circuits and to be able to use frequency-modulated voice-frequency telegraph circuits in switched telegraph networks.

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. Frequency-shift modulated voice-frequency telegraph systems should be able to provide 24 channels.

2. The nominal modulation rate should be standardized at 50 bauds.

3. For the nominal mean frequencies, the series formed by the odd multiples of 60 c/s should be adopted, the lowest frequency being 420 c/s in accordance with Recommendation R.31, paragraph 1, the mean frequency F_0 being defined as the half-sum of the two characteristic frequencies corresponding to the permanent "start polarity" F_1 and "stop" polarity F_2.

4. The mean frequencies at the sending end should not deviate from their nominal value by more than 2 c/s.

   If there are no sudden changes in the telegraph current at the input to a channel, the current at which this mean frequency

$$F_0 = \frac{F_1 + F_2}{2}$$

   is reached will have to be less than $I.k.\Delta$ *.

   where I is the nominal telegraph current
   k is the minimum value of the ratio of the unit interval to the time taken by the current to change from one steady value to the other
   Δ is the maximum tolerable bias distortion of the transmitting modulator.

5. The difference between the two characteristic frequencies (corresponding to the start and the stop conditions) should be 60 c/s, although a difference of 70 c/s may be used by mutual agreement between the Administrations concerned.

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* The explanation of this formula is given on page 275 of Volume VII.

6. The tolerance permitted in this difference should be at most ± 3 c/s.

7. The total average power transmitted to the telephone line by all the channels of a system is normally limited to 135 microwatts at a point of zero relative level. This sets, for the average power of a telegraph channel (at a point of zero relative level), the limits given in Table 1.

TABLE 1

Normal limits for the power per telegraph channel in frequency-modulated voice-frequency telegraph systems

Voice-frequency telegraph system	Allowable power per telegraph channel at a point of zero relative level		
	In microwatts	In an absolute power level	
		nepers	decibels
12 telegraph channels, or less	11.25	— 2.25	— 19.5
18 telegraph channels	7.5	— 2.45	— 21.25
24 telegraph channels	5.6	— 2.6	— 22.5

Nevertheless, by agreement between interested Administrations or Private Operating Companies and taking into account the possibilities offered by carrier telephone systems, these power limits may be raised for frequency-modulated telegraph signals established on an audio-telephone circuit or on a very long voice-frequency telegraph circuit routed on a channel of an open wire-carrier system, or on the channel of a radio-relay system, or on a channel of a cable carrier system. The limits thus raised should never exceed those which have been fixed for the power (at a point of zero relative level) corresponding to the transmission of a continuous tone for amplitude-modulated voice-frequency telegraphy and which are recalled in Table 2.

TABLE 2

Limits which may be applied, by agreement between Administrations, for the power per telegraph channel in frequency-modulated voice-frequency telegraph systems

Voice-frequency telegraph system	Allowable power per telegraph channel at a point of zero relative level		
	In microwatts	In an absolute power level	
		nepers	decibels
12 telegraph channels, or less	35	— 1.67	— 14.5
18 telegraph channels	15	— 2.1	— 18.25
24 telegraph channels	9	— 2.4	— 20.9

(R.35)

8. The tolerance for the variation in the mean level of signals at the frequency corresponding to start polarity and at the frequency of stop polarity is ± 0.2 neper.

   The tolerance for the ratio of the signal level at the frequency corresponding to start polarity and the signal level at the frequency corresponding to stop polarity on the same channel is 0.2 neper.

9. The frequency for the corresponding transmitted condition to the start polarity is the higher of the two characteristic frequencies and that corresponding to the stop polarity is the lower.

10. In the absence of telegraph current controlling the channel modulator, a frequency should be transmitted, within ± 5 c/s of the frequency normally transmitted for the start polarity. This frequency need not be sent immediately after interruption of the control current.

11. That the receiving equipment should restore to start polarity when the receiving level falls to 2.4 $N \pm 0.3$ N below the nominal level.

    The nominal level is the level resulting from the choice of power per channel (Table 1 or Table 2 under 7) and the number of channels (12, 18 or 24) on the circuit.

    Choice of the level to control an alarm is left to individual Administrations.

12. The degree of tolerable telegraph distortion on the channels should have the following values, which are applicable to measurements made after the channel has been adjusted, when bias distortion has been eliminated and when neighbouring channels are in operation and in adjustment:

    a) in the case of normal transmission level and without frequency error in the telephone circuit; 5% for inherent isochronous distortion;

    b) in the case of slow variations from + 1 neper (+ 8.7 db) above to 2 nepers (17.4 db) below the normal level of the received signals: 7%;

    c) in the case of abrupt variations in the level of the received signals, by steps of 1 neper (8.7 db), in the range from + 1 neper (+ 8.7 db) to – 2 nepers (– 17.4 db): 10%;

    d) owing to the presence of a sinusoidal interference whose level is 2.3 nepers (20 db) below the level of the signal and whose frequency is equal either to the mean frequency, or to either of the frequencies corresponding to the stop and start polarities:

       10% for the degree of overall distortion, it being understood that there it is a question of overall distortion including the increase caused by the presence of an unwanted frequency and not the distortion due merely to the unwanted frequency;

    e) if the frequencies are displaced by 3 c/s and by 5 c/s by transmission through the telephone circuit:

       3 c/s, 10% at normal level, total distortion being understood (including that due to the drift);

       5 c/s, 15% at normal level, total distortion being understood (including that due to the drift).

Note. — These values are given by way of information and should be considered as provisional; see Question 14/IX.

(R.35)

13. Frequency deviations on modern telephone circuits are generally less than 2 c/s. Hence, it is not indispensable to recommend frequency drift control.

    For circuits where the frequency deviation of ± 2 c/s cannot be guaranteed, compensation of drift seems necessary. Two methods can be used:
    — drift can be compensated for each channel up to about 15 c/s;
    — drift can be compensated for all the channels by pilot. In this case, the receiving end must be able to request and obtain a pilot frequency. Administrations should agree among themselves on the advisability of sending the pilot and the choice of frequency. 3300 c/s or, preferably, 300 c/s are recommended, with a tolerance of ± 1 c/s. The mean power emitted at the relative zero point on this frequency should not exceed that recommended for a telegraph channel in the case of a 24-channel group, i.e. – 2.6-*N* (– 22.5 db).

14. The number of significant conditions of the modulation is fixed at two; this number may be increased if necessary, by mutual agreement between the Administrations concerned.

RECOMMENDATION R.36

CHANNELS FOR MODULATION RATES GREATER THAN 50 BAUDS COEXISTING WITH 50-BAUD VOICE-FREQUENCY TELEGRAPH CHANNELS

(New Delhi, 1960)

There is a need to introduce for international traffic frequency shift voice-frequency channels for speeds of at least 75 bauds capable of coexisting with 50-baud channels in a single voice-frequency telegraph system on a telephone circuit.

For that reason, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW:

1. It is convenient to adopt for the nominal mean frequencies of these channels the series of frequencies $480 + n \times 240$ cycles per second in such a way that one or more channels of 240 cycles per second bandwidth can replace one or more pairs of normal channels of 120 cycles per second bandwidth.

2. The difference between the two characteristic frequencies of a channel of the greater bandwidth is fixed at 120 cycles per second corresponding to one half the spacing between the mean nominal frequencies as for 50-baud channels.

3. The mean power transmitted to line at a point of zero relative level remains normally limited to 135 microwatts for the aggregate of the channels of the system. Each of the wider band channels can then be transmitted with a power equal to twice that

of each of the normal channels it replaces (i.e. at a level 3 db above the normal channel level) without ever exceeding the value of 35 microwatts fixed for a 12-channel system.

4. It should be possible to establish these wider band channels of 240 cycles per second either on an amplitude-modulated or a frequency-modulated voice-frequency telegraph system.

Notes. — See contribution by F. R. of Germany in the Supplements to series R Recommendations concerning frequency-shift voice-frequency telegraphy systems with channel separation of more than 120 c/s.

— See Question 16/IX.

RECOMMENDATION R.39

VOICE-FREQUENCY TELEGRAPHY ON RADIO CIRCUITS

(former C.C.I.T. Recommendation B.49, Geneva, 1956)

A. *Radio circuits the frequency of which is below approximately 30 Mc/s*

The C.C.I.T.T.,

CONSIDERING

1. that it is necessary to distinguish between the case in which the radio frequency used is below approximately 30 Mc/s, and the case in which the radio frequency used is greater than approximately 30 Mc/s;

2. that, in the case of radio circuits whose frequency is less than approximately 30 Mc/s, it appears that the use of amplitude-modulated voice-frequency telegraph systems, as defined by C.C.I.T.T. Recommendation R.31, cannot be recommended;

3. that, in the case of radio circuits whose frequency is less than approximately 30 Mc/s, the nature of the telephone channels available for telegraph operation may vary widely according to the radio system used, and that several systems of telegraph transmission are available (e.g. two or four tone telegraph systems, frequency-change modulated systems, etc.);

4. that as a result of this third consideration, a general standardization of the characteristics of the voice-frequency telegraph systems to be used on radio circuits whose frequency is below approximately 30 Mc/s cannot be recommended at present;

UNANIMOUSLY DECLARES THE VIEW

1. that amplitude-modulated voice-frequency telegraph systems as standardized by C.C.I.T.T. Recommendation R.31 cannot be recommended;

2. that, in general, frequency-change modulation is the method to be recommended

(two and four-tone telegraph systems being considered, for the purpose of this Recommendation, as frequency-change modulated systems);

3. that frequency-change modulated systems, if designed for cable circuits, must often be specially adapted for use on radio circuits as mentioned in the 19th Report of the C.C.I.R. (London 1953), paragraph 2.

B. *Radio circuits the frequency of which is above approximately 30 Mc/s*

The C.C.I.T.T.,

CONSIDERING, FURTHER

1. that it would be very desirable if telephone circuits which are derived from radio systems whose frequency is above about 30 Mc/s and which are allocated for telegraph service, could be suitable for the application (without modification) of standardized voice-frequency telegraph systems conforming with C.C.I.T.T. Recommendations R.31 or R.35;
2. that the C.C.I.T.T. does not know whether the quality of the telephone circuits thus derived would be adequate for the standardized voice-frequency telegraph systems, nor in what ranges of radio frequencies operation would eventually be satisfactory;
3. that on the other hand the C.C.I.T.T. is studying the standardization of frequency change modulated systems;

DECLARES THE VIEW

that attention should be drawn to the difficulties (frequency or level variations, interruptions, etc.) which may result from the use of telephone circuits derived from radio telegraph systems whose frequency is above approximately 30 Mc/s for telegraphy,

and that regular tests of the operation of voice-frequency telegraph systems on telephone circuits derived from such radio systems should be made.

Notes. — See the Supplements to series R Recommendations, page 269 and following.
— See Questions 3/IX and 17/IX.

RECOMMENDATION R.40

COEXISTENCE IN THE SAME CABLE OF TELEPHONY AND SUPRA-ACOUSTIC TELEGRAPHY

(former C.C.I.T. Recommendation B.17, Brussels 1948, amended at Geneva, 1951)

The C.C.I.T.T.,

CONSIDERING

that this process provides only one telegraph channel, in addition to the telephone channel, and that it can be applied only in comparatively few cases (lightly loaded, or unloaded circuits, which cannot be used for multi-channel carrier telephony);

that in such cases, the Administrations and Private Operating Agencies concerned could in most cases by common agreement contemplate the possibility of making use of some other more suitable process, which would provide, in addition to the V.F. telephone channel, more than one telegraph channel;

UNANIMOUSLY DECLARES THE VIEW

that the use of supra-acoustic telegraphy should not prejudice the quality of transmission over the adjacent telephone channel and that, in particular, it should not limit the band of frequencies necessary for good speech reproduction (300 to 3400 c/s at least).

RECOMMENDATION R.41

UTILIZATION OF THE INTERCHANNEL FREQUENCY BAND OF CARRIER TELEPHONE CIRCUITS FOR TELEGRAPH TRANSMISSION

(former C.C.I.T. Recommendation B.18, Geneva, 1951, amended at New Delhi, 1960)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

that in the present state of technical development the utilization for telegraph communication of the interchannel frequency band of telephone channels on cable carrier systems is neither technically nor economically desirable.

RECOMMENDATION R.42

NON-SIMULTANEOUS TRANSMISSION OF TELEPHONY AND TELEGRAPHY ON LEASED INTERNATIONAL TELEPHONE CIRCUITS

(former C.C.I.T. Recommendation B.19, Geneva, 1951, amended at Arnhem, 1953, and at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that the C.C.I.F. has issued Recommendations on the subject of alternate transmission of telegraphy or telephony on leased international telephone circuits (vide C.C.I.F., *Red Book*, Volume III, Recommendation H.21),

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. The frequency of 1500 c/s is recommended for private telegraph transmissions between telephone stations permanently connected by leased international circuits.

2. For the steady telegraph emission of a continuous dash, a maximum power of 0.3 mW (corresponding to an absolute power level of − 0.6 nepers, or about − 5 db) at a point of zero relative level.

   When leasing an international telephone circuit that might be used for such telegraph transmissions, it is advisable to ensure, by measurements, that this limit is not exceeded.

   Administrations and Private Operating Agencies concerned are responsible, as regards their own national networks, for taking the necessary precautions to avoid interference to their domestic telephone services from such telegraph transmissions. Such precautions may consist in limiting the telegraph transmission power or the duration of use of telegraphy, or may concern the method of telegraph transmission.

3. V.F. ringing sets on telephone circuits leased for private telegraph transmissions between two permanently connected telephone stations must be insensitive to telegraph signals. It has been observed that one existing type of ringing set is sensitive to them, but measures may be taken to correct such ringing sets so that there is no great difficulty for the frequency chosen.

4. The maximum limit of 250 milliseconds adopted for the hangover time of echo suppressors on international telephone circuits does not appear long enough to suppress (even partially) the transmission of the answer-back signals when start-stop apparatus reply.

RECOMMENDATION R.43

SIMULTANEOUS COMMUNICATION BY TELEPHONE AND TELEGRAPH ON A TELEPHONE CIRCUIT

(former C.C.I.T. Recommendation B.50, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that the exceptional use of a leased telephone circuit for simultaneous communication by telephone and telegraph is envisaged in Recommendation H.22 of the C.C.I.T.T.;

2. that the C.C.I.F. has indicated conditions under which the simultaneous use of telephone circuits for telephony and telegraphy is technically tolerable;

3. that standardization of the characteristics of apparatus permitting simultaneous use of a telephone circuit for telephony and telegraphy is not justified, but that it is necessary to limit the power of the signals transmitted and to avoid the use of frequencies that will interfere with any telephone signalling equipment which may remain connected to the telephone circuit;

4. that new demands for the allocation of particular frequencies for special purposes frequently arise and the number of frequencies used for any one purpose should not be unnecessarily multiplied,

UNANIMOUSLY DECLARES THE VIEW

1. that in the case of the simultaneous use of a telephone circuit for telephony and telegraphy, the telegraph signal, if continuously transmitted, should be maintained at or below a level of – 1.5 nepers at a point of zero relative level;

2. that not more than three such telephone circuits should be included in any one primary group of 12 telephone circuits nor more than 15 in any one coaxial cable system;

3. that the telegraph signals transmitted must not interfere with any signalling apparatus that may remain connected to the telephone circuit,

AND NOTES

that some Administrations have permitted the use for simultaneous telephony and telegraphy of the frequencies 1680 c/s and 1860 c/s both by amplitude and by frequency-shift modulation.

RECOMMENDATION R.49

INTERBAND TELEGRAPHY OVER OPEN-WIRE 3-CHANNEL CARRIER SYSTEMS

(New Delhi, 1960)

It is considered necessary to introduce, for international traffic, an open-wire carrier system which uses common line repeaters for telephone and interband telegraph channels.

This is important for some Administrations which desire to have a small number of telegraph channels (up to six) without having to use a *standard* voice-frequency telegraph system on one of the telephone circuits, thereby effecting an economy, as all the telephone circuits are retained entirely for telephone traffic.

The arrangement of line frequencies so far as the telephone channels are concerned should be as specified in Volume III of the *Red Book* (Recommendation G.361).

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. Four interband telegraph channels, for a modulation rate of 50 bauds, can be set up over an open-wire carrier system by the use of line repeaters common to the telephone channels and the telegraph channels provided that the system in question conforms to C.C.I.T.T. Recommendation G.361 B (*Red Book*, Volume III).

2. The nominal frequencies of these four telegraph channels are as follows:

   a) Low-frequency direction of transmission

   3.22 — 3.34 — 3.46 and 3.58 kc/s

   b) High-frequency direction of transmission

   ba) telephone channels occupying the frequency band 18 — 30 kc/s:
   30.42 — 30.54 — 30.66 and 30.78 kc/s

   bb) telephone channels occupying the frequency band 19 — 31 kc/s:
   18.22 — 18.34 — 18.46 and 18.58 kc/s.

3. When in-band signalling is employed on the telephone channels (as opposed to out-band signalling outside the 4 kc/s bandwidth), it becomes possible to provide two additional telegraph channels having the following nominal frequencies:

   a) Low-frequency direction of transmission

   3.70 and 3.82 kc/s.

   b) High-frequency direction of transmission

   ba) telephone channels occupying the frequency band 18 — 30 kc/s:
   30.18 and 30.30 kc/s,

   bb) telephone channels occupying the frequency band 19 — 31 kc/s:
   18.70 and 18.82 kc/s.

4. In those cases where, as a result of agreement between the Administrations concerned, the system employs an upper pilot of 17 800 kc/s, the following frequencies may be used as alternatives to those specified in paragraphs 2. *bb)* and 3. *bb)* above. This alternative arrangement permits, in certain types of systems, a more economical modulation process:

   31.42 — 31.54 — 31.66 and 31.78 kc/s.

   instead of 18.22 — 18.34 — 18.46 and 18.58.

   also 31.18 and 31.30 kc/s instead of 18.70 and 18.82 kc/s.

5. This Recommendation applies to amplitude-modulated telegraphy and to frequency-modulated telegraphy.

(R.49)

6. It is not considered desirable to standardize absolutely the power transmitted to the line as this may be dependent upon the conditions on the open-wire route. Under favourable conditions a recommendable value for the power on each telegraph channel would be -2.35 *N* (-20 db) referred to one milliwatt at a point of zero relative level.

   For amplitude modulation the tolerance on the sent frequency will be $\pm$ 6 c/s and for frequency modulation, the tolerances given in Recommendation R.35 will apply.

   In tests made on the local end, equipments should meet the distortion conditions described in Recommendation R50, point 2, of the C.C.I.T.T. for amplitude modulation, and those described in Recommendation R.35, point 12, for frequency modulation.

7. The correspondence between the significant conditions described in paragraph 11 of Recommendation R.31 and paragraph 9 of Recommendation R.35 applies to these channels for interband telegraphy.

RECOMMENDATION R.50

TOLERABLE LIMITS FOR THE DEGREE OF ISOCHRONOUS DISTORTION OF TELEGRAPH CIRCUITS EXCLUDING APPARATUS

(former C.C.I.T. Recommendation B.24, Arnhem, 1953)

The C.C.I.T.T.,

CONSIDERING

that, to facilitate the study of plans for the establishment of international telegraph circuits, it is convenient to set limits for the degree of isochronous distortion of the telegraph circuits and channels;

that, for whatever purpose normally used, these circuits should be capable of use with start-stop apparatus;

that, in certain cases, limits have been set by Recommendations R.57 and R.58 for the isochronous distortions of the trunk sections of circuits and for that of voice-frequency telegraph channels;

UNANIMOUSLY DECLARES THE VIEW

1. that circuits should be established and maintained in such a manner that the degree of isochronous distortion will not exceed 28 %, whether they are equipped with regenerative repeaters or not.

2. that the degree of isochronous distortion of each channel which may form part of a circuit should be as small as possible, and should not in any case exceed 10 %.

RECOMMENDATION R.51

DETERMINATION OF THE STANDARDIZED TEST DISTORTION OF THE ELEMENTS OF A COMPLETE CIRCUIT

(former C.C.I.T. Recommendation B.32, Warsaw, 1936, amended at Geneva, 1956)

The C.C.I.T.T.,

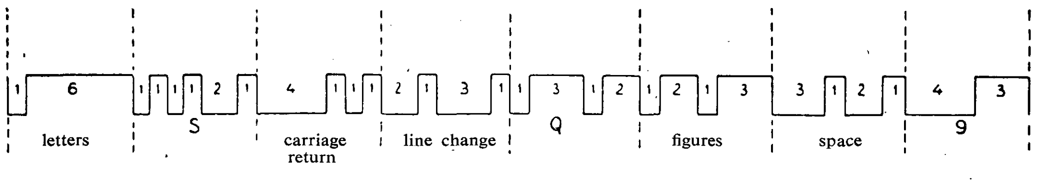
CONSIDERING

that, for a precise definition of the degree of service distortion permitting the comparison of results of measurements obtained under similar conditions in different places, it is advisable to standardize the wording of the text which should be transmitted for the test;

that it is best to choose a text which can be received directly by start-stop apparatus and which also presents a sequence of the combinations recognized as those which generally cause the maximum distortion,

UNANIMOUSLY DECLARES THE VIEW

that the text to transmit in the course of measurements of the degree of service distortion should be the following:



this text corresponds to the following sequence of signals emitted by a start-stop apparatus, letters, S, carriage return, line change, Q, figures, space, 9;

AND CONSIDERING, ON THE OTHER HAND,

that, in maintenance adjustments and in the various distortion measurements that may arise in the study of lines and equipment, it would be necessary to make use of a single apparatus offering the possibility of transmitting the different combinations of signals recognized as the most practical for this purpose;

that the unification of the list of these combinations would permit comparison of results obtained in various places,

UNANIMOUSLY DECLARES THE VIEW

that it is appropriate to recommend the construction of special transmitters for distortion measurements which could transmit, with one or the other polarity:

1. the specified text for the measurement of the degree of distortion;
2. a continuous sequence of alternations, the duration of each element being that of the unit interval corresponding to the anticipated telegraph modulation rate;

3. a continuous sequence of alternations, the duration of each element being double the unit interval corresponding to the anticipated telegraph modulation rate;

4. a continuous sequence of signals, each formed by an emission of a duration equal to that of the unit interval, followed by an emission of a kind distinct from the first and equal duration to that of six unit intervals.

RECOMMENDATION R.52

TESTS OF CIRCUITS EQUIPPED WITH START-STOP APPARATUS

(former C.C.I.T. Recommendation B.33, Brussels, 1948)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that it is not necessary to standardize an international text for the measurement of the margin of a teleprinter;

2. that nevertheless it would be of interest to recommend to the operating Administrations the use of either of the following texts according to choice:

VOYEZ LE BRICK GÉANT QUE J'EXAMINE PRÈS DU WHARF.
THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG.

RECOMMENDATION R.53

PERMISSIBLE LIMITS FOR THE DEGREE OF DISTORTION ON AN INTERNATIONAL AMPLITUDE-MODULATED V.F. TELEGRAPH CHANNEL

(former C.C.I.T. Recommendation B.36, 1951, amended at Arnhem, 1953)

The C.C.I.T.T.,

CONSIDERING

that the numerous tests made on V.F. telegraph equipment in service now make it possible to establish limits for the degree of distortion outside which a V.F. telegraph channel must be regarded as being out of order;

that these tests should be made with reversals and with standard text at the modulation rate used for adjustment;

that, when equipment is put into service and when it is adjusted, the minimum distortion should be sought and therefore limits for the degree of distortion need not be established in this case,

UNANIMOUSLY DECLARES THE VIEW

1. that the degree of bias distortion of reversals on an international voice-frequency telegraph channel at the modulation rate employed for adjustment should not exceed a value corresponding to 4% at the standard modulation rate of 50 bauds;

2. that the degree of isochronous service distortion of an international V.F. telegraph channel on the standardized text should not exceed 10%;

These limits, except where otherwise stated, apply to a modulation rate of 50 bauds and take account of the accuracy of the measuring equipment.

They are provisional and may be amended according to the technical development of V.F. telegraphy and of studies of telegraph distortion.

RECOMMENDATION R.54

CONVENTIONAL DEGREE OF DISTORTION

(former C.C.I.T. Recommendation B.51, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that in telegraph communications used in the general service, in the telegraph subscribers' service and in the leased land-line circuit service using 5-unit start-stop apparatus, a maximum admissible rate of error of 3 per 100 000 alphabetic telegraph signals transmitted should be provisionally recommended;

2. that, at present, interruptions of the telephone circuit account for a much higher error rate than that recommended by the C.C.I.T.T.;

3. that, therefore, without taking into account the degree of distortion caused by apparatus and voice-frequency telegraph channels, it is at present impossible to obtain an error rate of 3 for 100 000 telegraphic signals;

4. that, because the number of interruptions is likely to be diminished in the future, it is appropriate, in anticipation, to recommend a limit for that part of the error rate which is due to distortion;

5. that, in view of the foregoing considerations, it appears reasonable provisionally to recognize an error rate due to distortion of 2 per 100 000 alphabetic telegraph signals transmitted;

6. that, in planning telegraph circuits, it may be convenient to limit the conventional degree of gross start-stop distortion of complete circuits (including telegraph apparatus) to the nominal margin of the receiving apparatus;

7. that, if the conventional degree of gross start-stop distortion of signals is to agree with the margin of a receiver to which they are applied when the error rate is 2 erroneous translations per 100 000 alphabetic telegraph signals, then it is believed that the value assigned to the probability mentioned in the definition of conventional distortion must be 1 occurrence of excessive distortion per 100 000 significant instants of modulation,

UNANIMOUSLY DECLARES THE VIEW

1. that the conventional degree of distortion shall be the degree of distortion the probability of exceeding which is 1 per 100 000, i.e. 1 occurrence of distortion exceeding the conventional degree of distortion per 100 000 significant instants of modulation;
2. that, to make direct observations of this conventional degree of distortion, it is necessary to measure it during one hour as often as may be necessary. These measurements, unless otherwise specified, should be made during " busy hours " and on " busy days ";
3. that, when calculating the degree of conventional distortion from rapid observations, it is necessary to ensure that these basic observations correspond to the average conditions existing during a period of one hour, which unless otherwise stated should be a " busy hour " on a " busy day ".

Note. — See Questions 6/IX and 7/IX.

RECOMMENDATION R.57

STANDARD LIMITS OF TRANSMISSION QUALITY TO BE APPLIED IN PLANNING INTERNATIONAL POINT-TO-POINT TELEGRAPH COMMUNICATIONS AND SWITCHED NETWORKS BY MEANS OF START-STOP APPARATUS (AT 50 BAUDS)

(former C.C.I.T. Recommendation B.25, 1951, amended at Arnhem, 1953, and New Delhi, 1960, see Recommendation R.58)

Administrations must agree on the composition of the international section and the national sections before setting up an international point-to-point telegraph circuit.

For the interconnection of switched public or private national network a distribution plan of telegraph distortion between national networks and international circuits connecting the international terminal exchanges is required.

For this purpose, provisional standards, based on the results of practical experience and on studies of the composition of telegraph distortion, should be laid down for Administrations.

On well maintained channels, with modulation at the standard rate of 50 bauds, the following values should not normally be exceeded on the trunk sections (see Recommendations R.53 and R.75).

Number of channels in tandem within the trunk circuit (excluding the local section at each end)	The limit of distortion on reversals at the modulation rate employed for adjustment shall be equivalent to the following values at 50 bauds:	Limit of the degree of isochronous distortion on standardized text	Limit of the degree of inherent start-stop distortion, in service on standardized text
1	4%	10%	8%
2	7%	18%	13%
3	10%	24%	17%
4	12%	28%	21%
5			25%

(The above values are valid whether the channels are amplitude-modulated or frequency-modulated.)

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

*a)** In planning international point-to-point telegraph communications, the Administrations should use the following standard limits valid for start-stop apparatus and for 50-baud channels conforming to the recommendations of the C.C.I.T.T. and set up by amplitude-modulation or frequency-modulation;

1. Limit of the degree of gross start-stop distortion, measured by a start-stop distortion measuring set at the beginning of the trunk section of the circuit (i.e. at the point where the circuit enters the long-distance line telegraph equipment) and including the effect of the emission distortion of the transmitting apparatus 12%

2. Limit of the degree of standardized test isochronous distortion in the trunk section of the circuit:

   When one voice-frequency telegraph channel is used for the communication 10%

   When two voice-frequency telegraph channels are used for the communication 18%

   When three voice-frequency telegraph channels are used for the communication 24%

   When four voice-frequency telegraph channels are used for the communication 28%

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* *Note 1:* Although the figures in Rec. R.57 are for planning purposes, they do not correspond to conventional degrees of distortion but to routine measurements (see Question 20/IX).

or *

2*bis*. Limit of degree of standardized test inherent start-stop distortion of the trunk section of the circuit:

When one voice-frequency channel is used for the communication . . . 8%
When two voice-frequency channels are used for the communication . . 13%
When three voice-frequency channels are used for the communication . 17%
When four voice-frequency channels are used for the communication . . 21%
When five voice-frequency channels are used for the communication . . 25%

3. Limit of the degree of the gross start-stop distortion, measured by a start-stop distortion measuring set, which can be present in signals at the input of the local section of the circuit 30%

b) These standards take no account of the possibility of including regenerative repeaters in circuits;

c) These standards presuppose that the distortion introduced by the local section of the circuit is negligible, and that, should that not be so, Administrations should agree amongst themselves on the degree of distortion admissible in the various sections of the communication, and on the number of voice-frequency telegraph channels which can be used;

d) Administrations should use them, in order to agree on the maximum number of voice-frequency telegraph channels which may compose the international section of a circuit and in order to determine the characteristics of their national networks due to be connected to the networks of other countries, on the understanding that the synchronous service distortion, originated by the trunk section, may not in any circumstances exceed 28%.

RECOMMENDATION R.58

STANDARD LIMITS OF TRANSMISSION QUALITY FOR THE GENTEX AND TELEX NETWORKS

(New Delhi, 1960)

To enable national switched networks to be interconnected, it is necessary to have a distribution plan of the telegraph distortion between national networks and the international junction circuits connecting up the international switching centres (international terminal switching centres).

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* *Note 2:* The limits for the degrees of isochronous and start-stop distortions indicated under 2 and 2 *bis* do not establish a law of correspondence between the degree of isochronous distortion and the degree of start-stop distortion; this law of correspondence depends on the composition of the distortion (relative importance of characteristic and fortuitous distortions).

The following diagram (fig. 2) shows the points of entry and exit of the national network and the ends of the international junction circuit.

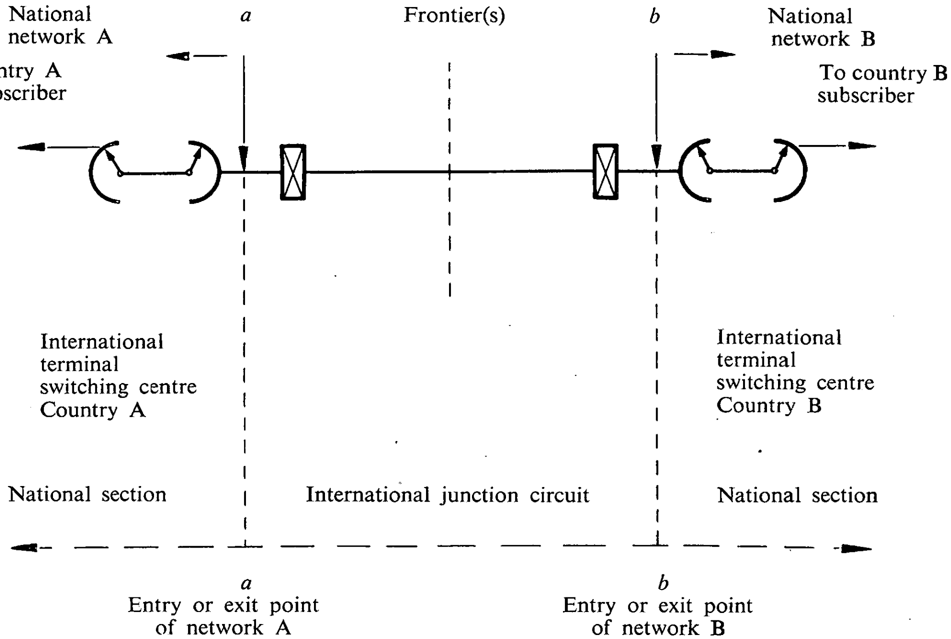

FIGURE 2

It is difficult to lay down standards applicable both to small and to large national networks.

However, it has been possible to fix limit values for large countries and they could apply to the great majority of telex subscriber stations or gentex stations taking part in the international service.

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. The following standards of transmission quality are observed for the interconnection of 50-baud national networks set up by means of telegraph channels and start-stop apparatus in accordance with C.C.I.T.T. recommendations (national gentex or telex networks):

   a) degree of gross start-stop distortion in service (i.e. including the effect of distortion due to the sending apparatus) at the point of exit of the national network: not more than 22%;

   b) degree of inherent start-stop distortion of the international junction circuit: not more than 13%.

2. Although the degrees of distortion to be inserted in the recommendations relative to the planning of networks are normally conventional degrees of distortion, the maximum

values mentioned under 1 correspond to the results which would be provided by the routine measurements carried out in accordance with Recommendation R.5.

3. These limit values are applicable to large countries which are directly connected without switching in a transit country. The stations taking part in the international service which cannot satisfy condition 1 *a)* will have to be specially equipped, for example with distortion correctors.

4. Small countries (defined as countries in which all stations can be reached with not more than 1 long-distance telegraph circuit in the national network) will have to try to obtain values less than the maximum of 22% for the measurements corresponding to 1 *a)*.

5. The standard limits mentioned under 1 can also apply to private switched networks.

Note. — See Questions 20/IX and 21/IX.

RECOMMENDATION R.60

CONDITIONS TO BE FULFILLED BY REGENERATIVE REPEATERS

(former C.C.I.T. Recommendation B.20, 1952, amended at Geneva, 1956)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that regenerative repeaters for start-stop signals should work at a speed of 50 bauds, with a speed tolerance in service not greater than ± 0.5 per cent;

2. that the effective synchronous margin of regenerative repeaters should be at least 40 per cent;

3. that the difference between the significant instants of modulation retransmitted by a start-stop regenerative repeater and the corresponding instants of modulation of a perfect start-stop apparatus having the same average modulation rate, should not exceed ± 1 millisecond, it being assumed that the significant instants of the commencement of the start signals are the same in the two cases;

4. that the significant instants corresponding to the beginning of the start signals emitted by the start-stop regenerative repeater should in no case be spaced by less than 7-unit intervals.

RECOMMENDATION R.61

CONDITIONS TO BE FULFILLED BY REGENERATIVE REPEATERS EMPLOYED FOR 7-UNIT START-STOP TRANSMISSION

(former C.C.I.T. Recommendation B.21, 1951, amended at Geneva, 1956)

The C.C.I.T.T.,

in view of Recommendation R.62 regarding the siting of regenerative repeaters in international telex circuits;

in view of Recommendation S.3 on the transmission cycle of start-stop apparatus;

CONSIDERING

that as there are at present large numbers of start-stop instruments having a 7-unit transmission cycle, it is necessary to define the conditions to be satisfied by 7-unit regenerative repeaters;

that, since it is unlikely that the growth of the international telex network will demand the use of regenerative repeaters on transit international trunk circuits for some years, the regeneration of 7-unit signals need only concern those Administrations having start-stop instruments which transmit 7-unit signals,

Note. — Administrations are recommended to withdraw any apparatus which does not transmit at the rate of 7.5 (or a minimum of 7.4) units for the international service as far as possible, owing to the difficulty of regenerating 7-unit start-stop signals when they are sent automatically.

UNANIMOUSLY DECLARES THE VIEW

that the duration of the stop element should never be less than 18 milliseconds, and consequently the mean speed must be:

a) either the theoretical speed, with a tolerance of $\pm$ 0.1%, in which case it is necessary to employ a device to control the duration of the stop signal;

b) or the mean speed of the transmitter, with a suitable tolerance, in which case such a device is unnecessary;

that the degree of gross start-stop distortion of the retransmitted signals, including the stop signal, should be less than 10%;

that the synchronous margin should not be less than 40%;

that it seems desirable to permit dialling impulses to bypass the regenerative repeater when the transmission of these impulses has to be envisaged, but that the study of this question should, however, continue;

that the arrangements to be adopted for the present for the transmission of dialling impulses should be bilaterally agreed between the Administrations concerned;

that the regenerative repeaters should be capable of retransmitting the various supervisory signals employed in switching systems (except that when arrangements are made for the dialling impulses to bypass the regenerative repeater it could equally be unnecessary for certain of the supervisory signals to be transmitted by the regenerative repeater).

RECOMMENDATION R.62

SITING OF REGENERATIVE REPEATERS IN INTERNATIONAL TELEX CIRCUITS

(former C.C.I.T. Recommendation B.26, 1951, amended at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that insufficient experience has been acquired in the use of regenerative repeaters;

that it nevertheless seems desirable to lay down a provisional rule governing the siting of regenerative repeaters, with a view to the preparation of plans for international telegraph communications by switching;

that it would also appear desirable that the signals transmitted by an international terminal exchange should not be affected by a relatively high degree of distortion,

UNANIMOUSLY DECLARES THE VIEW

that, when the transmission quality demands it, Administrations agree with one another on the necessity for inserting regenerative repeaters and for taking the necessary steps so that the location chosen ensures that the expenses are equally shared between the Administrations and is appropriate to the organization of their telex and general switching networks and to the quality of transmission which it is possible to provide on complete connections.

RECOMMENDATION R.70

DESIGNATION OF INTERNATIONAL TELEGRAPH CIRCUITS

(former C.C.I.T. Recommendation B.29, 1951, amended at Arnhem, 1953)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

that international telegraph circuits will be designated:

a) first by the localities or terminal offices, arranged in alphabetical order according to the spelling of the country;

b) by an indication of the service using the circuit according to the following table:

Public service, point-to-point circuit	TG
Private service, point-to-point circuit	TGP
Circuit of the public switching network (gentex) . .	TGX
Telex circuit	TX
Circuit of a private switching network	TXP
Service circuit	TS

c) by a serial number, using a separate continuous series for each group of circuits.

Note. — In order to avoid the possibility of confusion in the case of TGP and TXP circuits, a number formerly allotted to a ceased circuit should not be re-allotted to a new circuit until a period of at least 2 years has elapsed.

RECOMMENDATION R.71

ORGANIZATION OF THE MAINTENANCE OF INTERNATIONAL TELEGRAPH CIRCUITS

(former C.C.I.T. Recommendation B.30, Brussels, 1948, amended in 1951 and at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that, in order to ensure satisfactory co-operation between Administrations and Private Telegraph Operating Agencies interested in the maintenance of international telegraph circuits, and in order to ensure the maintenance of satisfactory transmission in the international telegraph service, it is necessary to unify the essential action to be taken for the establishment and maintenance of international telegraph circuits,

UNANIMOUSLY DECLARES THE VIEW

1. that periodical maintenance measurements should be taken on international V.F. telegraph systems, and that documents relating to such measurements should be exchanged;

2. that the responsibilities for the maintenance of satisfactory transmission, and (as and when necessary) the removal of faults on an international V.F. telegraph system should be assumed by one of the terminal stations of the system.

   The terminal station in question to be known as the *system control station.*

   The said station to be appointed for the purpose by the Administrations and Private Telegraph Operating Agencies concerned on the occasion of the establishment of the V.F. telegraph system concerned.

   The system control station to be entrusted with co-ordination of the execution of the maintenance measurements to which paragraph 1 above relates;

3. that the responsibilities for the maintenance of satisfactory transmission, and (as and when necessary) the removal of faults on an international telegraph system should be allocated between the different stations concerned as indicated below.

   One station of the circuit should assume the principal responsibility for the maintenance of satisfactory service on the circuit.

   The station in question should be known as the *controlling testing station.*

   This station should be equipped with testing equipment to enable it to make telegraph transmission measurements and in this connection it exercises an executive control over all the other stations on the circuit.

   It should be appointed by agreement between the Administrations concerned on the occasion of the establishment of the telegraph circuits concerned.

   It should be, wherever possible, one of the terminal stations of the circuit, save in so far as otherwise agreed by the services concerned.

   For example, in the case of V.F. telegraph circuits, the controlling testing station should be one of the terminal voice-frequency telegraph stations as nominated by common agreement between the Administrations concerned.

   The controlling station is responsible for co-ordinating all operations required when there is a breakdown in the circuit. It keeps a record of all circuit breakdowns.

   To facilitate supervision, a reference number must be allocated to each breakdown reported.

   When a fault comes to the notice of another station on the circuit, this station should take steps to secure suitable action on the part of other stations concerned; but the controlling testing station is nevertheless responsible for ensuring that the fault is cleared as soon as possible.

   The controlling testing station should be in a position to furnish all requisite information in reply to enquiries on the subject of faults—e.g. in regard to the time of any fault, the location of the fault, the orders given for dealing with it and the times of restoration of the circuit.

In order, however, to increase the flexibility of the organization and the rapidity of the removal of faults, the controlling testing station will confine itself in each foreign country to securing the co-operation of a *station* to be known as the *sub-control* station of the circuit.

The sub-control station should assume, within its own territory, the responsibilities indicated above in the case of the controlling testing station and should therefore be equipped with testing equipment to enable it to make telegraph transmission measurements.

Such delegation of responsibility shall not affect the authority of the controlling testing station, with which the primary responsibility for the maintenance of satisfactory service on the circuit will continue to rest.

The sub-control station shall be appointed by the technical service of the Administration concerned.

It shall furnish detailed information to the controlling testing station regarding faults occurring in its own country.

Administrations or Private Recognized Telegraph Operating Agencies shall be free to organize the maintenance measurements on those portions of international point-to-point circuits and switched connections (including apparatus) which lie wholly within their control, but the methods adopted should be not less efficacious than those recommended for international circuits.

To facilitate the control of tests, circuits shall be divided into *test sections* (parts of a circuit between two telegraph stations). Each section shall be under the control of a *testing station* responsible for the localization and removal of faults on the section concerned. The testing station shall furnish detailed information as to the faults occurring in the section under its control to the sub-control station (or, if necessary, the controlling testing station).

In the case of V.F. telegraph channels, each channel shall constitute a test section. The testing station will in this case be the principal V.F. telegraph station at the end of the section concerned.

RECOMMENDATION R.72

PERIODICITY OF MAINTENANCE MEASUREMENTS TO BE CARRIED OUT ON THE CHANNELS OF INTERNATIONAL VOICE-FREQUENCY TELEGRAPH SYSTEMS

(former C.C.I.T. Recommendation B.34, 1951, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that for such supervision, maintenance measurements on international voice-frequency telegraph channels are necessary,

UNANIMOUSLY DECLARES THE VIEW

1. that maintenance measurements be carried out on international voice-frequency telegraph channels once every three months;
2. that there is no need to carry out measurements more frequently on channels making up long circuits or circuits used in switching networks.

RECOMMENDATION R.73

MAINTENANCE MEASUREMENTS TO BE CARRIED OUT ON AMPLITUDE-MODULATED V.F. TELEGRAPH SYSTEMS

(former C.C.I.T. Recommendation B.35, 1951, amended at New Delhi, 1960)

The C.C.I.T.T., in view of Recommendation R.72 on the periodicity of maintenance measurements to be made on international V.F. telegraph channels,

CONSIDERING

that it should be clearly laid down what maintenance measurements are indispensable to ensure the correct operation of V.F. telegraph channels,

UNANIMOUSLY DECLARES THE VIEW

1. that maintenance measurements and any necessary adjustments of V.F. telegraph channels should be made of:
   a) the voltages and frequencies of the V.F. carrier supplies (these measurements must be made at least once a month, but in the case of a central V.F. carrier supply, daily tests are recommended);
   b) the power supply voltages (these measurements should be made at least once per month);
   c) the output level of each " send " filter;
   d) the output level of each " receive " filter;
   e) the receiving apparatus, to ensure that it is operating at the optimum point of its level regulation characteristic;
   f) the receiving relay, if necessary;
   g) the distortion with symmetrical signals 1/1 or 2/2 after adjustment of the relay or of the receiving equipment for minimum distortion;
   h) the distortion on the standard text given in Recommendation R.51 (it would be advisable for the last measurement to be made at the levels: normal, maximum and minimum);
2. that, unless otherwise specified, the measurements should be made at a modulation rate of 50 bauds;
3. that the results of the measurements made on the international channels should be exchanged directly by telegraph or telephone between the measuring stations, at the request of a station.

RECOMMENDATION R.74

CHOICE OF TYPE OF TELEGRAPH DISTORTION MEASURING APPARATUS

(former C.C.I.T. Recommendation B.52, Geneva, 1956)

The C.C.I.T.T., in view of Recommendation R.90,

A. CONSIDERING

1. that tests of distortion made with the text specified in Recommendation R.51 are normally applied only to telegraph channels;
2. that it may in principle be desirable to measure the distortion of telegraph channels in terms of start-stop distortion, but that degrees of distortion determined in rapid measurements are at best only indications of the quality of transmission;

3. that appropriate standards for the quality of telegraph channels in terms of isochronous distortion have been established, and that it would be necessary to set other standards for start-stop measurements;

4. that all important terminals of voice-frequency telegraph systems are equipped with isochronous distortion measuring equipment and that their replacement by start-stop instruments would be expensive;

UNANIMOUSLY DECLARES THE VIEW

1. that, for the normal maintenance of telegraph channels, isochronous distortion measuring sets should be used;

2. that Administrations may nevertheless, by common consent, use, for this purpose, start-stop distortion measuring sets, but that if they do, new standards for the quality of transmission of telegraph channels in terms of start-stop distortion should be established;

B. CONSIDERING ALSO

1. that measurements of the quality of start-stop signals cannot normally be made without start-stop distortion measuring sets;

2. that the planning and establishment of telegraph networks are to be judged in terms of conventional degrees of start-stop distortion, and that degrees of start-stop distortion may also prove to be the best basis for calculations of the summation of degrees of distortion and for calculation of conventional start-stop distortion;

UNANIMOUSLY DECLARES THE VIEW

that all international switching and testing centres (I.S.T.C.'s) should be equipped with start-stop distortion measuring apparatus.

RECOMMENDATION R.75

MAINTENANCE MEASUREMENTS ON INTERNATIONAL SECTIONS OF INTERNATIONAL TELEGRAPH CIRCUITS

(former C.C.I.T. Recommendation B.44, Arnhem, 1953, amended at New Delhi, 1960)

The C.C.I.T.T., in view of Recommendations R.50, R.57 and R.90,

CONSIDERING

1. that, for the technical supervision of international telegraph circuits, it is necessary to make periodic measurements of distortion on their international sections when they are made up of two or more channels;

2. that certain Administrations consider it desirable to have available apparatus for making simple measurements automatically and periodically, giving an indication of the performance rating and transmitting an alarm when this rating exceeds the limits permitted for automatic switched channels;

UNANIMOUSLY DECLARES THE VIEW

1. that it is desirable to make distortion measurements every three months on the international sections of international telegraph circuits made up of at least two channels;
2. that these measurements should be made at a modulation rate of 50 bauds
   a) with reversals,
   b) with standard text according to Recommendation R.51;
3. that the following values for the inherent distortion in service must not be exceeded on the international section of a telegraph circuit:

Number of channels in tandem within the international section	Distortion of reversals at the modulation rate employed for adjustment shall be equivalent to the following values at 50 bauds	Isochronous distortion with standardized text	Inherent start-stop distortion with standardized text
2	7%	18%	13%
3	10%	24%	17%
4	12%	28%	21%
5	—	—	25%

4. that these values do not take into account the possibility of inserting regenerative repeaters in the international section;
5. that these values can be regarded only as provisional and the study of them should be continued;
6. that, in future, measurements made with the apparatus mentioned above (item 2 of the consideranda) will no doubt make it possible to eliminate the maintenance measurements referred to in the previous paragraphs.

Note. — The columns giving the limits for degrees of isochronous distortion and start-stop distortion on the test are not intended to establish a law of relationship between the degrees of start-stop distortion and the degrees of isochronous distortion; this law of relationship depends on the constitution of the distortion (relative importance of characteristic and random distortions).

RECOMMENDATION R.76

RESERVE CHANNELS FOR MAINTENANCE MEASUREMENTS ON CHANNELS OF INTERNATIONAL V. F. TELEGRAPH SYSTEMS

(former C.C.I.T. Recommendation B.38, 1951)

The C.C.I.T.T.,

CONSIDERING

that it is desirable that maintenance measurements on the channels of international voice-frequency telegraph systems should disturb communications as little as possible,

UNANIMOUSLY DECLARES THE VIEW

that, whenever possible, measurements on a working channel of a voice-frequency telegraph system should be carried out only after the channel concerned has, if necessary, been replaced by a spare channel,

and to this end, the C.C.I.T.T. considers that it is desirable that one channel should be reserved for this purpose in each voice-frequency telegraph system.

RECOMMENDATION R.77

RESERVE CIRCUITS FOR VOICE-FREQUENCY TELEGRAPHY

(former C.C.I.T. Recommendation B.39, Brussels, 1948, amended at New Dehli, 1960)

All necessary action should be taken for the duration of interruption of voice-frequency circuits to be reduced to a minimum and, for this purpose, it is expedient to standardize some of the methods to be adopted for replacing defective 4-wire circuits in voice-frequency system;

Although it does not appear necessary for these methods to be the same in details in every country, it would be advisable to reach agreement regarding the general directives to be followed;

The curves showing the differences in relative power levels, in relation to frequency, between the normal voice-frequency telegraph circuit and its reserve circuit at the sending end and receiving end respectively, should not differ at any frequency by more than 0.2 neper, so that when a voice-frequency telegraph system is switched to its reserve circuit, there should be no variation in power level causing excessive distortion in the voice-frequency telegraph system, especially for the upper and lower frequencies in the frequency band transmitted;

The telephone network being what it is, no such limitation can be guaranteed. Generally speaking, the voice-frequency telegraph circuit and its reserve circuit are made up differently, and it often happens that one is an audio-frequency circuit while the other is a telephone channel of a carrier-system. Although adjustments can be made to the " equivalent frequency " curve of an audio-frequency circuit, it is difficult to modify the curve in the case of a telephone channel in a carrier-system, since it depends essentially on the filter characteristics of the carrier-system;

Moreover the semi-automatic or fully-automatic operation of telephone circuits is gradually becoming general;

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that for each voice-frequency telegraph circuit or group of circuits between the same terminal stations, a reasonable number of *working* telephone circuits be designated as reserve circuits;

2. that the choice of the reserve circuit should be made by taking, if possible, a circuit which is routed differently from that of the normal circuit;

3. that the changeover should be effected at two points at the same relative power level of telephone transmission on the normal voice-frequency telegraph circuit and on the reserve circuit;

4. that the maintenance measurements taken on the reserve circuits should be the same as those carried out on the normal telephone circuits;

5. that the normal circuits and their reserve circuits should pass through the same changeover panel at each of the terminal stations concerned;

6. that, in view of the above recommendations, the reserve circuits should be clearly distinguished from other possible circuits;

7. that the procedure to be adopted for the changeover from the normal circuit to the reserve circuit and vice versa should be jointly agreed upon by both Administrations or Private Operating Agencies concerned;

8. that, should the alarm indicating that the voice-frequency circuit is faulty be received by a station other than the group control station, this other station shall interrupt the return direction of the alarm channel towards the group control station in order to advise the latter to take the necessary action;

9. that the necessary steps must be taken so that the reserve circuits are not faulty or busy for a long period and that if it should happen that all the reserve circuits are faulty or already in use as reserves, the technical departments of the Administrations or Private Operating Agencies concerned should take immediate joint action to find a temporary remedy;

10. that it would be desirable, in view of the distortion which may occur in certain telegraph channels, that when the changeover from the normal to the reserve circuit takes place there should be the greatest possible similarity between the overall response characteristics of these two circuits in respect of relative power levels against frequency;

11. that, when on a given route there are manually operated circuits and automatic or semi-automatic circuits, the use of manually operated circuits as reserve circuits for voice-frequency telegraphy is technically and operationally preferable to the use of automatic or semi-automatic circuits for that purpose;

12. that, with manually operated reserve telephone circuits, it should be possible, after prior agreement between the controlling officers at the international terminal exchanges concerned, for an operator to break into a call in progress to advise the correspondents that the circuit is required and that the call should be transferred to another circuit, if it lasts longer that six minutes;

13. that, with automatic or semi-automatic reserve telephone circuits, direct indication that the reserve circuits are busy should be given at the changeover point mentioned in paragraph 5;

    that, if no reserve circuit is available when needed, all the reserve circuits should be blocked against any further call as soon as the calls in progress are finished;

    that, when a reserve circuit has actually been seized, the preliminary blocking should be removed from the other reserve circuit and the reserve circuit in use should be marked as engaged in the telephone switching equipment.

RECOMMENDATION R.78

PILOT CHANNEL FOR VOICE-FREQUENCY TELEGRAPH SYSTEMS USING AMPLITUDE MODULATION

(New Delhi, 1960)

C.C.I.T. Recommendation B.43 already suggested the use of a pilot channel to give an alarm in the case of an abnormal drop in the receiving level of the telephone bearer circuit in amplitude-modulation systems.

Service channels could have been used as pilot channels for this alarm signal, but since there is not always a service channel in each V.F. group, it is suggested that channels be chosen for the alarm signal.

For these reasons,

the C.C.I.T.T. UNANIMOUSLY DECLARES THE VIEW

1. that it is advisable to use a pilot channel to give the alarm in the case of an abnormal drop in the receiving level of the bearer circuit carrying an amplitude-modulated voice-frequency telegraph system;

2. that the level at which the alarm should work should be fixed by the Administration at the receiving end;

3. that the pilot channel should be on frequency 300 c/s, transmitted with a power level corresponding to that of a frequency-modulated channel in accordance with Table 1 of Recommendation R.35;

4. that, if such an arrangement cannot be adopted, the Administrations concerned should agree on the use of one of the standardized frequencies for the pilot channel used for alarm purposes.

Note. — The case of frequency-modulated systems is dealt with in Recommendation R.35, point 11.

RECOMMENDATION R.80

CAUSES OF DISTURBANCES TO SIGNALS IN V.F. TELEGRAPH CHANNELS AND THEIR EFFECT ON TELEGRAPH DISTORTION

(former C.C.I.T. Recommendation B.41, 1951, amended at Arnhem, 1953 and at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that the great majority of international telegraph circuits are routed on V.F. telegraph channels;

that V.F. telegraph channels are liable to disturbance from the following causes:

1. Variations in the voltage and frequency of the source of telegraph carrier frequency due to variations in the power supply, and variations in the signalling load in the case where the carrier source supplies several channels;
2. Abrupt or gradual changes in the transmission equivalent of the telephone circuit;
3. Intelligible crosstalk from other telephone circuits, particularly near end crosstalk;
4. Unintelligible crosstalk resulting from the cross-modulation of telephone circuits when operated by carrier currents;
5. Noise induced from electrical power and traction systems;
6. Telegraph crosstalk from other telegraph channels, e.g.

   a) production of odd harmonics of the telegraph carrier frequencies in certain channels falling within the pass-band of other channels;

   b) intermodulation in filter coils, etc.;

7. Variations of power supplies affecting the amplifier and detector of the V.F. telegraph channel and sometimes the receiving relay;
8. The effects of mechanical vibration upon valves (microphonicity) and relays;
9. Bad contacts (e.g. test points and valve bases) and badly soldered joints;
10. Deterioration of component parts, e.g. ageing valves;
11. Failure of power supplies, e.g. on changeover from main to reserve supply;
12. Accidental disconnections made during the course of maintenance and construction works;
13. On overhead lines, effects of atmospheric electricity, frost, etc.;

that the disturbances account for practically all the distortion in telegraph channels, except for characteristic distortion (which is chiefly a function of filter and amplifier-detector design), some bias (due to misadjustment of controls and relays, etc.) and, in the case of the lower frequency channels, the distortion which arises from the low ratio of carrier frequency to signalling frequency;

that many of the causes of disturbance are individually negligible and the more important of the others have been found, in the experience of several Administrations, to be capable of elimination by careful maintenance both on the V.F. telegraph equipment and at all points on the telephone circuit;

that the C.C.I.T.T. is also studying the causes of disturbance in telephone circuits and the precautions to be taken to minimize their occurrence;

that the results of the C.C.I.T.T. study will be of great importance to telegraphy;

that, as result of the considerable investigations already made by certain Administrations on the causes of disturbances in telephone and telegraph circuits, the relative order of importance of these causes appears to be approximately as follows:

a) *in the case of telephone circuits:*

high resistance and unsoldered connections;

noisy and microphonic valves, and poor contact between valve pins and valve holders;

working parties engaged on cable operations;

noisy and high-resistance U-links;

changes in line level not compensated at the detector input;

crosstalk;

errors in setting up, for example incorrect equalization, line transformers incorrectly connected, faulty components;

b) *in the case of V.F. telegraph equipment:*

high resistance and unsoldered connections;

valves deteriorated beyond permissible limits;

bad contacts;

faults on power changeover equipment;

frequency error of the carrier supply,

UNANIMOUSLY DECLARES THE VIEW

that it is desirable for Administrations to undertake investigations of the causes, and frequency of occurrence of disturbances on V.F. telegraph channels routed on the various types of telephone circuit likely to be employed for international telegraph circuits;

that in doing these tests and in order that the results may be of the greatest use to telegraphy and telephony, the incidence of disturbances should be measured according to their duration as follows:

a)	Lasting	less than 5 milliseconds
b)	,,	between 5 and 20 milliseconds
c)	,,	,, 20 and 100 ,,
d)	,,	,, 100 and 300 ,,
e)	,,	more than 300 milliseconds

that the results should be classified according to the type of telephone circuit, viz. audio or carrier, cable of overhead line.

" Measurements of disturbances should be made at the direct current output of the voice-frequency telegraph channel which is under observation."

Note. — In connection with the study of these disturbances, attention is drawn to the Netherlands contribution made to the VIIth Plenary Assembly of the C.C.I.T. (document A.P. VII/51, paragraph 2, published in the Supplements to Arnhem Documents, page 200).

See the Supplements to series R Recommendations, page 224 and following.

RECOMMENDATION R.81

MAXIMUM ACCEPTABLE LIMIT FOR THE DURATION OF INTERRUPTION OF TELEGRAPH CHANNELS ARISING FROM FAILURE OF THE NORMAL POWER SUPPLIES

(former C.C.I.T. Recommendation B.40, 1951)

The C.C.I.T.T.,

CONSIDERING

that in switched telegraph networks an interruption of 0.3 second of the telegraph current would be translated into a release of switches, and that the relays controlling the release are arranged to operate in slightly less than 0.3 second,

UNANIMOUSLY DECLARES THE VIEW

that it is desirable that no interruption of the telegraph current should occur as a result of failure of a normal power supply.

If, however, it is impracticable to avoid an interruption, then its duration should in no case exceed 0.150 second.

RECOMMENDATION R.82

APPEARANCE OF FALSE CALLING AND CLEARING SIGNALS IN CIRCUITS OPERATED BY SWITCHED TELEPRINTER SERVICES

(former C.C.I.T. Recommendation B.42, 1951, amended at Arnhem, 1953)

The C.C.I.T.T.,

In view of Recommendation R. 80, on the causes of disturbances affecting signals in telegraph channels, and their effect on the distortion of telegraph signals;

CONSIDERING

that precautions should be taken with circuits used in switched teleprinter services to prevent the appearance of parasitic signals which would give rise to false calling and clearing signals;

that special monitoring or indicating devices should be provided on voice-frequency telegraph systems, the channels of which are used for international switched circuits;

that special steps might well be taken to discover the causes of false signals due to transient changes in transmission level or momentary increases in noise level, on voice-frequency telegraph circuits;

that it would be desirable to draw up operating standards in this connection,

UNANIMOUSLY DECLARES THE VIEW

that the following precautions should be taken:

a) to avoid false clearing signals:

— the security and stability of power supplies and of sources of carrier frequencies, both telegraph and telephone, should be ensured;

— a characteristic marking should be used to denote telegraph and telephone circuits used for the operation of switched teleprinter circuits, both in terminal and intermediate stations;

— precise instructions should be given to staff in order that false entry into the above-mentioned circuits may be avoided;

— the number of non-soldered connections should be reduced as much as possible, together with the number of break points; unsoldered connections, e.g. U links and screw terminals, etc., should be checked with particular care. In this connection, attention is drawn to the methods of inspection by vibration tests used by the United Kingdom Administration (described in the note appearing on page 276 of C.C.I.F. *Green Book*, Volume III *bis*);

— the amplitude of variations in the equivalent of telegraph circuits used for voice-frequency telegraphy should be limited, and abrupt variations in this equivalent should be studiously avoided;

b) to avoid false call signals:

— limit the crosstalk mentioned in Recommendation R.80;

— limit induced voltage caused by electric power of traction systems;

— limit the microphonicity of valves in repeaters and of valves used in voice-frequency telegraphy;

— reduce the sensitivity of voice-frequency modulators and receivers to disturbing signals, while keeping an adequate margin for regulation of level;

— avoid, in switched teleprinter services, the use of supervision signals having a short duration in relation to the transitory phenomena due to filters and time-constants in the level-regulators of voice-frequency telegraph systems;

these precautions, inasmuch as they concern telephone circuits used for voice-frequency telegraphy, must be taken simultaneously on normal and reserve circuits;

for the permanent monitoring of groups of voice-frequency telegraph channels the lines of which are used for international switched circuits, it is advisable to use a monitoring channel. An alarm should be given to indicate when either the system or the monitoring channel is out of order;

it would be advisable to register the transmission level, in order to discover and localize the causes of the false signals on circuits behaving particularly badly;

it is not yet possible to lay down operating standards in this connection.

RECOMMENDATION R.83

CHANGES OF LEVEL AND INTERRUPTIONS IN VOICE-FREQUENCY TELEGRAPH CHANNELS

(former C.C.I.T Recommendation B.53, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that an alarming situation for the telegraph service has been created by interruptions on voice-frequency telegraph channels, and by changes of level which have the same effect as interruptions;

2. that the consequences are such that, at present, the error rate which is attributed to voice-frequency telegraph channels is still very far above the tolerable limit fixed by considerations of operational requirements (3 in 100 000 for international communications, including apparatus);

3. that certain Administrations have observed an improvement in the situation, and that this improvement seems to result from the measures taken by the telephone services, for instance, systematic percussion tests, precautions in the switching of power supplies, etc.;

4. that it has been confirmed that the number of interruptions is much increased during the normal hours when maintenance staff are present, and is reduced when, despite very heavy traffic, maintenance is suspended, so that the Telegraph Administrations are now convinced that one of the principal causes of interruptions on telegraph channels is intervention by maintenance personnel and perhaps by operating personnel;

5. that it has also been observed that the number of interruptions appears greater on international circuits than on national circuits;

UNANIMOUSLY DECLARES THE VIEW

that the drive against interruptions should be continued vigorously and that, in order to observe the progress of this drive, Administrations should continue to make systematic observations of the frequency and duration of interruptions on voice-frequency telegraph channels;

AND DRAWS THE ATTENTION

of the maintenance Study Group of the C.C.I.T.T. especially to the study of practical measures to remedy the situation.

RECOMMENDATION R.90

ORGANIZATION OF LOCATING AND CLEARING FAULTS IN INTERNATIONAL TELEGRAPH SWITCHED NETWORKS

(former C.C.I.T. Recommendation B.55, Geneva, 1956, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that it is desirable that faults affecting communication between stations on international switching networks (e.g. telex and gentex service) should be reported and cleared as quickly as possible;

that it is necessary to unify the essential action to be taken and methods to be employed for locating and clearing faults;

that, for this purpose, it is necessary to determine the essential testing equipment which is to be provided at the switching centres responsible for locating and clearing faults;

UNANIMOUSLY DECLARES THE VIEW

1. that it is necessary to set up switching and testing centres (S.T.C.s) as defined by the following:

   switching centres equipped with measuring apparatus for testing telex subscribers and public station lines and equipment and also telegraph channels;

2. that each telex subscriber and each public station in the general switching service should have access to a S.T.C. for the purpose of reporting faults and co-operating in tests;

3. that the international switching and testing centres (I.S.T.C.s) are the S.T.C.s which are also international line-head offices;

4. that all S.T.C.'s should be subscribers to the telex network, both for the purpose of receiving fault reports and for communication for maintenance purposes. They should also be provided with a telephone exchange line. The telex and telephone numbers should be furnished to the Secretariat of the C.C.I.T.T. and any subsequent changes should be similarly advised. The Secretariat should have a complete list published and arrange for the issue of amendments thereto at regular intervals. The list should indicate the I.S.T.C.s;

5. that each S.T.C. should be responsible for co-ordinating action in locating and clearing faults on all station lines connected to the exchange and on all trunk circuits for which it is nominated as the controlling office. It should also co-operate with other S.T.C.s in locating faults on connections established through two or more exchanges.

   It should carry out a preliminary location of faults by finding out whether they affect channels, switching gear or apparatus. The faults are then accurately located by the engineers responsible for each part of the circuit and the S.T.C. co-operates with them for this purpose: it may assume the direction of the fault-locating procedure should there be disagreement between these services.

   Internationally, it is responsible to the S.T.C.s of other countries with which it has telex connections.

   The organization of the liaison between the S.T.C. and the different technical services is shown in the following diagram (fig. 3):

   The S.T.C.s must check that the performance given by the equipment involved in the switched service, i.e. V.F. channels, switching equipment and apparatus, is satisfactory;

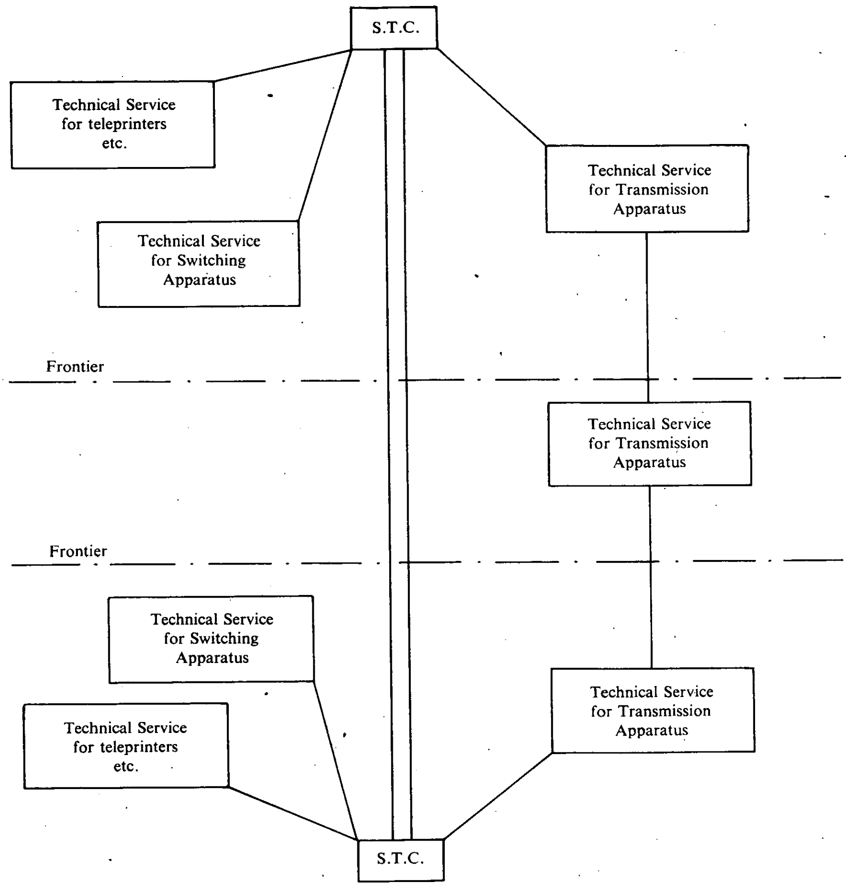

FIGURE 3

6. that the staff employed at S.T.C.s should be selected with a view to avoiding language difficulties and should be conversant with all types of telegraph equipment used in the switching network, i.e. automatic or manual switching equipment, V.F. telegraph equipment, telegraph machines and regenerative repeaters. The staff need not necessarily be fully competent to maintain all these items of equipment, but should have sufficient knowledge of them to be able to form an appreciation of the effect that faults on any of them may have on a switched connection. In addition, the staff of I.S.T.C.s should have some general knowledge of the types of equipment used in the countries to which they are connected, particularly of the signalling conditions which will be encountered;

7. that each S.T.C. should be provided with the following measuring equipment:

   a) A 50-baud start-stop distortion meter;

   b) A test transmitter for generating undistorted 50-baud start-stop signals;

c) Apparatus to measure the modulation rate of teleprinters at a distance;

d) Apparatus for measuring the speed and impulse ratio of dials, where appropriate;

e) Apparatus for measurement of the condition of direct current lines; for example, continuity, resistance, insulation.

The arrangements for access to established connections for making test measurements should be such as not to cause interruption or reduce the quality of transmission.

Considering that some Administrations have found it desirable to have available at the S.T.C. other items of apparatus to expedite the clearing of faults, all Administrations are invited to consider the utility of these devices, namely:

f) Apparatus for measuring teleprinter margin;

g) Recording distortion meters for testing established connections,

h) Apparatus for measuring continuously, periodically and automatically, the distortion on subscribers' lines and apparatus;

8. that the following procedure for reporting, locating and clearing faults should be adopted: faults should be reported to the S.T.C. concerned by the subscribers or operators who have experienced difficulty in operation. In the same way, it would be useful, in order to give the S.T.C.s a full picture of the situation, that the maintenance engineers should inform them of faults noted during the periodic maintenance operations. Faults should preferably be signalled by teleprinter, if their nature does not preclude this procedure.

A reference number should be given by the S.T.C. to the subscriber or service notifying the fault. This number can then be quoted in any subsequent enquiries as to the progress of fault clearance.

On account of the difficulties that may arise in the detection of faults on the international section of a communication (due to lack of knowledge of languages, etc.), care should be taken in each country to see that the national sections of the communication, including subscribers' lines and apparatus, are not involved before approaching the S.T.C. of the corresponding country.

Complete holding of a connection which is reported to be faulty should be avoided.

The S.T.C. notified of a fault should therefore begin by ascertaining that it is not located in the national section of the communication and for this purpose should, if necessary, approach the other S.T.C.s of its country concerned in the circuit. The S.T.C. of the distant country is then advised and, in turn, checks the national section routed over its network. The international section of the communication is not checked until the terminal national sections of telegraph circuit have been definitely exonerated. The S.T.C.s in different countries will communicate with one another, either directly or via their I.S.T.C.s, as determined by the Administrations concerned.

If the tests of the two local ends fail to reveal any fault condition, the S.T.C. should report the fault to its I.S.T.C. which will decide what further action, if any, is necessary.

As a rule, isolated fault reports would not justify a test of all trunk circuits on a route, and it would be assumed that the condition giving rise to the fault would be cleared on the next routine adjustment. If, however, several fault reports were received, some of which might have been due to a faulty circuit on a particular route, then a special routine test of all the circuits on the route might be justified.

In general, it is considered that the procedure will be broadly the same for manual, semi-automatic and automatic systems.

9. that the abbreviations annexed below should be used in calls exchanged between services responsible for the maintenance of telegraph equipment.

ANNEX TO RECOMMENDATION R.90

List of service abbreviations for maintenance of telegraph circuits

No.	Français / English	Abréviation / Abbreviation
	I. *Service général — General Service*	
1	Ici .... Here is	ICI ...
2	Mauvaise transmission sur .... Bad transmission on	BR TR ...
3	Veuillez donner numéro de référence Please give reference number	QREF
4	Veuillez indiquer résultat Please report result	QRES
5	Numéro référence .... Reference number is	REF ...
6	Voici le résultat de l'essai effectué sur .... Here is result of test on	RES ...
7	Appareil en dérangement Machine faulty	DERA
8	Circuit en dérangement Circuit faulty	DER CCT
9	Equipement de position en dérangement Position equipment faulty	DERPS
10	Dérangement relevé Fault now cleared	DERR
11	Aucun dérangement trouvé No fault found	NDER

No.	Français / English	Abréviation / Abbreviation
12	Veuillez transmettre message d'essai avec .... % de distorsion sur .... Please send test message with .... % distortion on	TESTD . . . SVP
13	Veuillez mesurer la distorsion sur .... et indiquer le résultat Please measure distortion on .... and report result	QDIS . . .
14	Appelez-moi dans .... minutes s'il vous plaît Please call me in .... minutes	RAP . . . MNS SVP
15	Je vous rappellerai dans .... minutes I shall recall you in .... minutes	RAP . . . MNS
16	La distorsion sur .... est de .... % The distortion on .... is .... %	. . . DIS . . .
17	Vos signaux sont illisibles Your signals are unreadable	ZSU
18	Portez-vous sur circuit nº .... Meet me on circuit No.	MEET . . .
19	Veuillez vérifier l'abonné nº .... Please check subscriber No.	VERX . . .
20	Veuillez vérifier la vitesse .... Please check the speed	VERS
21	Veuillez vérifier la distorsion à l'émission Please check the transmitter distortion	VERED
22	Veuillez vérifier la marge Please check the margin	VERM
23	Ecart de vitesse est de .... % Speed deviation is .... %	DEVS . . .
24	La marge est de .... % The margin is .... %	MAR . . .
25	La distorsion à l'émission est de .... % The transmitter distortion is .... %	EDIS . . .
26	Aucun signal de connexion de .... No call-connected signal from	NCS . . .
27	Aucun signal de confirmation d'appel sur .... No call-confirmation signal on	NCFM . . .
28	Signal d'occupation en permanence de .... Permanent busy signal from	OCC OCC . . .
29	Signal de prise permanent sur .... Permanent call on	PERC . . .
30	Bloquez s'il vous plaît .... Please hold	BL . . . SVP

No.	Français / English	Abréviation / Abbreviation
30 *bis*	Je bloque ...... Holding	BL
31	Débloquez s'il vous plaît ...... Please clear	NBL . . . SVP
31 *bis*	Je débloque ...... Clearing	NBL . . .
32	Je reçois correctement I am receiving correctly	ZOK
33	Dérangement de télégraphie harmonique sur ...... Fault on voice-frequency system	DER VF . . .
34	Les signaux reçus ont une distorsion biaise de ......% (polarité de départ prolongée) The received signals have ......% bias (start polarity prolonged)	ZKWA . . .
34 *bis*	Les signaux reçus ont-ils une distorsion biaise (polarité de départ prolongée) ? Have the received signals a bias distortion (start polarity prolonged) ?	Q DIS A . . .
35	Les signaux reçus ont une distorsion biaise de ......% (polarité d'arrêt prolongée) The received signals have ......% bias (stop polarity prolonged)	ZKWZ . . .
35 *bis*	Les signaux reçus ont-ils une distorsion biaise (polarité d'arrêt prolongée) ? Have the received signals a bias distortion (stop polarity prolonged) ?	Q DIS Z . . .
36	Réduisez la distorsion biaise Reduce the bias	ZYN
37	Recevez-vous mon signal d'appel ? Are you receiving my calling signal ?	QRCS
37 *bis*	Je reçois votre signal d'appel I am receiving your calling signal	CSR
38	Veuillez mettre hors service le circuit nº ...... Please take out of service circuit No.	CCT . . . OUT SVP
38 *bis*	J'ai mis hors service le circuit nº ...... I have taken out of service circuit No.	CCT . . . OUT
39	Veuillez rétablir le circuit nº ...... Please restore circuit No.	CCT . . . IN SVP
39 *bis*	J'ai rétabli le circuit nº ...... I have restored circuit No.	CCT . . . IN
40	Je ne reçois pas votre signal de polarité de départ permanent I am not receiving your permanent start polarity signal	N PER A

No.	Français English	Abréviation Abbreviation
41	Je ne reçois pas votre signal de polarité d'arrêt permanent I am not receiving your permanent stop polarity signal	N PER Z
42	Je ne reçois pas votre signal d'invitation à numéroter I am not receiving your proceed-to-select signal	NPS
43	La communication est libérée après la sélection sur le circuit n° .... The connection is releasing after dialling on circuit No.	CRD . . .
44	Veuillez envoyer signaux 1/1 Please send 1 : 1 signals	SIG 1/1 SVP
45	Veuillez envoyer signaux 2/2 Please send 2 : 2 signals	SIG 2/2 SVP
46	Signal de départ permanent constaté sur .... Permanent start polarity signal on	PER A
47	Signal d'arrêt permanent constaté sur .... Permanent stop polarity signal on	PER Z
48	Veuillez envoyer signal de départ sur .... Please send permanent start polarity signal on	PER A SVP
49	Veuillez envoyer signal d'arrêt sur .... Please send permanent stop polarity signal on	PER Z SVP
50	Nous ne recevons pas votre indicatif We are not receiving your answer-back code	N IND
51	L'enregistreur ne fonctionne pas Register does not operate	DER REG
52	Votre bande perforée contient des erreurs Your perforated tape is faulty	DER TAPE
53	Bouclez le circuit .... s'il vous plaît Please loop the circuit	LOOP . . . SVP
53 *bis*	J'ai bouclé le circuit .... I have looped circuit	LOOP . . .
	II. *Service Multiplex — Multiplex Service*	
54	A l'émission, votre cycle de répétition contient des erreurs dans le code à 7 moments — Veuillez vérifier la voie n° .... Your repetition cycle transmission contains faults in 7-unit code — Please check channel No.	RQFS
55	Je reçois des erreurs dans le code à 5 moments — Veuillez vérifier la voie n° .... I am receiving errors in 5-unit code — Please check channel No.	RFC
56	Votre manipulation sur voie .... déréglée; veuillez vérifier Your keying on channel .... is affected; please check	ZYK

No.	Français English	Abréviation Abbreviation
57	Passez de téléimprimeur simplex à multiplex Change from single printer to multiplex	ZYM
58	Passez de multiplex à téléimprimeur simplex Change from multiplex to single printer	ZYP
59	Réception mutée sur .... Reception switched over to	RS
60	Emission mutée sur .... Transmission switched over to	TRS
61	Enregistrement muté sur .... Storage switched over to	SS ...
62	Distribution mutée sur .... Distribution switched over to	DS ...
63	Veuillez mettre en phase le système .... Please phase system	PH ...
64	Ecart de vitesse du distributeur à votre extrémité Deviation of distributor speed at your end	DEVD
65	Déphasage sur système .... Out of phase on system	OPH ...
66	Multiplex .... sans protection; veuillez rétablir signal de répétition automatique (ARQ) Multiplex .... unprotected; please re-establish automatic request for repetition (ARQ)	NARQ ...
67	Veuillez envoyer signal alpha sur la voie multiplex .... Please send alpha signal on multiplex channel	TRAS ...
68	Veuillez envoyer signal bêta sur la voie multiplex .... Please send beta signal on multiplex channel	TRBS ...
69	Votre transmetteur envoie ARQ en permanence Your transmitter is sending permanent ARQ	ZYC
70	Je reçois signaux mutilés sur voie multiplex .... Veuillez vérifier votre émission en code à 7 unités I am receiving garbled signals on multiplex channel .... Please check your 7-unit output	RMUT ...
71	Cessez trafic sur toutes les voies; transmettez des A sur la voie A pour repérage Cease traffic on all channels; send A's on A channel for line-up	ZYA

RECOMMENDATION R.91

LIST OF INTERNATIONAL VOICE-FREQUENCY TELEGRAPH SYSTEMS

(New Delhi, 1960)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that the Administrations and Recognized Private Operating Agencies should inform the C.C.I.T.T. Secretariat, not later than 1 October every year, of the international V.F. telegraph systems with which the terminal installations in their respective countries are equipped. The information for each system should indicate the type of modulation (AM or FM), the circuit capacity, the number of channels in service and the name of the system's control station;

2. that the Administrations and Recognized Private Operating Agencies should inform the C.C.I.T.T. Secretariat, not later than 1 October every year, of the switching and testing centres (S.T.C) taking part in the international service, with their telephone and telex call numbers (Recommendation R.90);

3. that the C.C.I.T.T. Secretariat should publish the information assembled in this way in a document entitled " List of international voice-frequency telegraph systems " and send it, upon request, to the Administrations and Recognized Private Operating Agencies.

SERIES S RECOMMENDATIONS

RECOMMENDATIONS CONCERNING ALPHABETICAL TELEGRAPH APPARATUS

Index of Series S Recommendations, pages 9 and 10

RECOMMENDATION S.1

DEFINITIONS OF THE APPARATUS MARGIN (OR OF THE LOCAL END WITH ITS TERMINATION)

(former C.C.I.T. Recommendations C.1 and C.2, amended, New Delhi, 1960)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

that it is advisable to adopt the following definitions:

1. The *margin* of a telegraph apparatus (or the local end with its termination) represents the maximum degree of distortion of the circuit at the end of which the apparatus is situated which is compatible with the correct translation of all the signals which it may possibly receive (definition 34.03 of the List of Definitions);

Note. — The maximum degree of distortion which results in incorrect translation applies without reference to the form of distortion affecting the signals. In other words it is the maximum value of the most unfavourable distortion causing incorrect translation which determines the value of the margin.

2. The *theoretical* margin is that which could be calculated from the construction data of the apparatus, assuming that it is operating under perfect conditions (definition 34.06 in the List);

3. The *effective* margin of an apparatus considered individually is that which could be measured on the apparatus under actual operating conditions (definition 34.04 in the List);

4. The *nominal* margin of a type of apparatus represents the minimum value set for the effective margin of these pieces of apparatus under standard operating and adjustment conditions for the type (definition 34.05 in the List);

For start-stop apparatus (or for the local end with its termination).

5. The margin is the maximum degree of *start-stop distortion* of the modulation, which it is possible to apply to the apparatus compatible with the correct translation of all the signals which it should be able to receive, whether the signals composing the modulation are transmitted at intervals or whether they follow one another with the maximum rapidity corresponding to the modulation rate (definition 34.07 in the List);

6. In particular, it is convenient to consider:

   a) The *net* margin, which is represented by the degree of distortion indicated in 5, when the rate of modulation applied to the apparatus is exactly equal to the standard theoretical rate (definition 34.08 in the List).

   b) The *synchronous* margin, which is represented by the degree of distortion indicated in 5, when the mean unit interval of the modulation applied to the apparatus is equal to that which would result from a transmission from the apparatus under examination, assuming it to include a transmitter as well as a receiver (definition 34.09 in the List).

RECOMMENDATION S.2

TRANSMITTER DISTORTION OF APPARATUS (OR OF THE LOCAL END WITH ITS TERMINATION)

(New Delhi, 1960)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

that the following definitions be adopted:

1. *Transmitter distortion:* a signal transmitted by an apparatus (or a signal at the output of a local line with its termination) is affected by telegraph distortion when the significant intervals of this signal have not exactly their theoretical durations;

2. The definitions of degree of individual distortion (definition 33.06 in the List), of degree of isochronous distortion (33.07 in the List), of degree of start-stop distortion (33.08 in the List), of degree of gross start-stop distortion (definition 33.09 in the List), of degree of synchronous start-stop distortion (definition 33.10 in the List), of degree of distortion in service (definition 33.11 in the List), of conventional degree of distortion (definition 33.14 in the List), of fortuitous distortion (definition 33.16 in the List), of bias distortion (definition 33.17 in the List), of cyclic distortion (definition 33.18 in the List) are applicable to transmitter distortion.

RECOMMENDATION S.3

CHARACTERISTICS, FROM THE TRANSMISSION POINT OF VIEW, OF THE LOCAL END WITH ITS TERMINATION WHEN A 50-BAUD START-STOP APPARATUS IN ACCORDANCE WITH THE INTERNATIONAL ALPHABET No. 2 IS USED

(former C.C.I.T. Recommendation C.4, amended at New Delhi, 1960)

This Recommendation applies — except where otherwise specified (for example, the case of regenerative repeaters which is covered by Recommendations R.60 and R.61) — to start-stop apparatus, in the wide sense of the term as defined in 34.14 of the List of Definitions, Part I, and that it covers reperforators, service signals sent by the switching equipments, the signals of answer-back units, automatic transmitters, etc.

Some apparatus (apparatus for single current working, for instance) cannot be separated during operation from their supply and repeater devices; hence the measurements under operating conditions must apply to the *local end with its termination* (in French: ensemble terminal) defined as follows:

The whole of the apparatus, lines, telegraph repeaters and any control units between the apparatus and the first (or last) point of the connection where the quality of transmission can be measured.

The characteristics laid down below are those which should be evident in service conditions on the local ends with their terminations which are likely to be connected to the international network. It should be noted, however, that they apply to such local ends with their terminations only if the influence of the line in the local end produces negligible distortion.

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW:

Characteristics of apparatus

1. The nominal modulation rate should be 50 bauds;
2. The difference between the mean modulation rate of the signals when in service and the nominal rate should not exceed $\pm$ 0.75%;
3. The nominal duration of the transmitting cycle should be at least 7.4 units (preferably 7.5), the stop element lasting for at least 1.4 unit (preferably 1.5);
4. The receiver must be able to translate correctly in service the signals coming from a transmitter with a nominal transmitting cycle of 7 units;

Transmitter characteristics of a local end with its termination

5. The degree of gross start-stop distortion of transmitted signals, measured at the output of the local end with its termination, must not exceed 10%. This value applies to all working conditions of the apparatus under consideration encountered during normal service, whether the signals are transmitted separately or whether they succeed each other at the maximum rate compatible with the modulation speed, in service. It is recommended that the measurement should be made with a start-stop distortion measuring set for two consecutive periods, each of them corresponding to the trans-

mission of about 300 transitions (i.e. about 15 seconds), early distortion being observed during one period and late distortion during the other;

Receiver characteristics of a local end with its termination

6. The effective net margin measured from the input of the local end with its terminations should not be less than 35%, for signals sent by a transmitter having a nominal cycle equal to or greater than 7 units.

It is recommended that the measurement should be made under the following conditions, in service:

— cycle of 7½ units for the signals;
— use of one of the signal trains specified in Recommendation R. 52;
— first test with an identical distortion rate on all the transitions of the signal train, obtained by lengthening the start element;
— a second test with the same rate of identical distortion on all the transitions of the signal train, but obtained in this case by shortening the start element;
— reading the margin when less than one error per sentence of the Recommendation R.52 is obtained.

Note 1. — It will be up to Administrations using some other measuring method to work out for their own use figures to give equivalent results to those which would have been obtained by the recommended method.

Note 2. — Administrations are recommended to withdraw from the international service apparatus not meeting this Recommendation. If this cannot be done immediately, then, in view of the special difficulties which are encountered in the regeneration of automatically transmitted 7-unit start-stop signals, it is recommended that urgent attention should be given to the replacement of 7-unit automatic transmitters by 7.5 (or 7.4 minimum)-unit automatic transmitters.

RECOMMENDATION S.4

USE OF INTERNATIONAL TELEGRAPH ALPHABET No. 2

(former C.C.I.T. Recommendations C.7, C.8 and C.12, modified at New Delhi, 1960)

A. Secondaries of letters F, G, H-combinations 6, 7 and 8.

Some Administrations exercise, whereas others do not, the right granted by the Telegraph Regulations to assign the secondaries of letters F, G and H to internal use and it is desirable to avoid disadvantages which might result from exercising this right in international services.

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that the use of secondaries of F, G and H should be prohibited in international services, except by direct agreement between Administrations;
2. that, in all services, the secondaries of F, G and H should be shown in some special manner on the keyboard;

3. that services in which these secondaries are not used should place on the secondary position on the printing blocks of the letters F, G and H an arbitrary sign, such, for instance, as a square, the appearance of such sign on the paper to indicate an abnormal impression;

B. Control symbols for operating the " who are you ? " (secondary of letter D, combination 4) and " alarm " (secondary of letter J, combination 10) devices.

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

that such Administrations as are desirous of confirming the reception or the transmission of signals " secondary of D " (" who are you ? " signal) or " secondary of J " shall effect this confirmation by printing:

the symbol  for the confirmation of the signal " secondary of D ";
the symbol  for the confirmation of the signal " secondary of J ":

C. Sequences of combinations used for special purposes.

As quoted in Recommendations S.11, U.21, U.22, certain sequences of combinations from international alphabet No. 2 are devoted to special purposes and they should not be used for other purposes when the equipment on such networks introduces special facilities for which these sequences are reserved.

These are:

a) ZCZC start-of-message signal in retransmission systems using perforated tape or equivalent devices;

b) GGGG start-of-text signal in retransmission systems using perforated tape or equivalent devices (the use of this sequence is recommended only provisionally);

c) + + + + end-of-telegram signal in retransmission systems using perforated tape or equivalent devices;

d) NNNN end-of-message signal, a switching signal in switching systems using perforated tape or equivalent devices for retransmission; also used for restoring the waiting signal device in accordance with Recommendation U. 22;

e) CCCC for switching into circuit, by remote control, a reperforator (or equivalent device);

f) FFFF for switching out of circuit, by remote control, a reperforator (or reperforator device);

Note. — The sequences of secondaries of these combinations — although they are not to be used for the purposes devoted to these sequences — are subject to the same restrictions in use, the equipment having to recognize only the sequence of combinations.

In international services these sequences are:

+ : + : = corresponding to ZCZC (combinations 26, 3, 26, 3),
ZZZZ = corresponding to ++++ (combinations 26, 26, 26, 26),
, , , , = corresponding to NNNN (combinations 14, 14, 14, 14),
: : : : = corresponding to CCCC (combinations 3, 3, 3, 3).

ANNEX TO RECOMMENDATION S.4

Table illustrating the use of various sequences of combinations for special purposes

Purpose of sequence	Sequence recommended in S.4	Method of operation		
		Message switching (including storage)	Through switching (without message storage)	Point-to-point operation
Start of message	ZCZC	Required in most systems	Could be useful in special cases	Not ordinarily required
Start of text *	GGGG	Useful for presentation of address for routing purposes in some semi-automatic systems, etc.	Could be useful in special cases	Not ordinarily required
Suppression of delay signals	HHHH	Not required (delay signal not envisaged)	Required for some types of message (e.g. cypher) when routed over synchronous error-corrected radiotelegraph channels	Not required on public systems (delay signal not envisaged)
End of telegram	++++ ZZZZ	Could be useful in special cases	Could be useful in special cases	Not ordinarily required
End of message	NNNN	Essential in most systems to separate individual messages at relay centres and to control message switching	Required only when it is necessary positively to re-connect delay signal facility after use of suppression of delay signals facility	Not ordinarily required
Connection of reperforator (or equivalent device) Disconnection of reperforator (or equivalent device)	CCCC FFFF	Not normally used (as storage is incorporated in the system); could be used for connection and disconnection of a supplementary storage device	Could be useful for special purposes; requires special equipment at point of reception	Could be useful for special purposes; requires special equipment at point of reception

* *Note:* Objection has been raised to the use of GGGG as "start-of-text" signal — Must be regarded as provisional only.

g) the signal " line feed " (combination 28) followed by 4 signals " carriage return " (combination 27) for the signal of operator recall on a telex connection made over a radio-telegraph circuit (see Recommendation U.21);

h) HHHH to prevent transmission of the delay signals described in Recommendation U.22, made up from combination 32 as described in D below;

D. Use of combination 32.

1. Combination 32, repeated at intervals of 1,2 second can be used as a delay signal to indicate that the error-correcting system is controlling a repetition;

2. Combination 32, repeated at intervals of 5 seconds can be used as a delay signal to indicate that the storage device is not yet empty;

3. The reception of combination 32 shall not cause any spacing of the paper on tape-printing or page-printing teleprinters.

RECOMMENDATION S.5

STANDARDIZATION OF PAGE-PRINTING START-STOP APPARATUS AND CO-OPERATION BETWEEN PAGE-PRINTING AND TAPE-PRINTING START-STOP APPARATUS

(former Recommendation C.6 of C.C.I.T., Warsaw, 1936, amended at Arnhem, 1953)
(former Recommendation C.10 of C.C.I.T., Brussels, 1948, amended at Arnhem, 1953)
(former Recommendation C.8 of C.C.I.T., Brussels, 1948, amended at New Delhi, 1960)

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that the number of characters which the line of text of the page-printing apparatus may contain should be fixed at 69;

2. that tape-printing apparatus required to work in co-operation with page-printing apparatus should be equipped with:

   a) keys for the transmission of the " carriage return " and " line feed " signals;

   b) means to ensure the transmission of the " carriage return " and " line feed " signals in time to prevent any overprinting on the 69th character;

   that for controlling the alarm, several signals " figures J " one signal " carriage return ", one signal " line feed " should be transmitted in the order indicated.

3. That such Administrations as are desirous of confirming on a tape machine the reception or transmission of the signals " carriage return " and " line feed " shall effect this confirmation by printing:

   a) the symbol $<$ for the signal " carriage return ";

   b) the symbol $\equiv$ for the signal " line feed ";

4. that, if the printing of the symbols indicated in paragraph 3 is not desired, the reception of at least one of these signals shall nevertheless cause the paper to move forward. When one only of these signals causes the paper to move forward, the signal should preferably be the " line feed " signal.

RECOMMENDATION S.6

CHARACTERISTICS OF ANSWER-BACK UNITS FOR START-STOP APPARATUS OF THE TELEX SERVICE

(former C.C.I.T. Recommendation C.9, Warsaw, 1936, amended at Brussels, 1948)

The C.C.I.T.T.,

CONSIDERING

that the start-stop apparatus is capable of receiving communications without the help of an operator;

that this advantage may be useful to the subscribers to the international telegraph service operated by start-stop apparatus;

that it is therefore desirable that a calling subscriber should be able to check the identity of his correspondent, if there is no reply;

that it may be necessary to check the correct working of the subscriber's line and of the called terminal equipment from an automatic switching unit or from an international telex position,

UNANIMOUSLY DECLARES THE VIEW

that it is advisable

1. to supply a code transmitter to all the subscribers' sets taking part in the international telex service;

2. to effect the operation of the code transmitter by combination 4 (letter D) in International Telegraph Alphabet No. 2, preceded by the signal " figures ";

3. to compose the code-emission by a series of 20 signals, as follows:

   1 signal " letters ",
   1 carriage return,
   1 line feed,
   1 signal " letters " or, if necessary, " figures ",
   15 signals chosen by each Administration for the code signal of the subscriber,
   1 signal " letters ";

4. when the code signal does not comprise 15 characters, to distribute them by inserting as many " letters " signals as are necessary to make up the total of 15 signals; this would give the calling subscriber the chance of noting clearly the end of the requested code transmission;

5. that the answer-back signals should be 7.5- (minimum 7.4) unit signals sent at the maximum cadence with a modulation rate of 50 bauds and subject to the tolerances specified in Recommendation S.3;

6. that the delay between the beginning of reception of the start unit of combination 4, by the apparatus in the " figures " position, and the beginning of the start unit of the first signal of the answer-back sent by this apparatus should lie between 150 and 600 milliseconds.

Note. — Points 1, 2, 5 and 6 apply to apparatus of the gentex network.

RECOMMENDATION S.7

CONTROL OF THE MOTORS IN START-STOP TELEPRINTER APPARATUS FOR PUBLIC OR PRIVATE POINT-TO-POINT CIRCUITS

(former C.C.I.T. Recommendation C.13, amended at Arnhem, 1953)

The C.C.I.T.T.,

CONSIDERING

that, in the case of public and private point-to-point circuits, it is desirable that the teleprinter motors shall be started with the commencement of traffic signalling, and stopped with the cessation of such signalling;

that the general practice on such circuits is to utilize a time-delay device associated with the teleprinter which allows of such operation,

UNANIMOUSLY DECLARES THE VIEW

a) that, in the case of public and private point-to-point circuits, the terminal apparatus shall be so equipped as to allow of the starting and stopping of the teleprinter motors with the commencement and completion respectively of the traffic;

b) that these facilities shall normally be provided by means of a time-delay device incorporated in the teleprinter, whereby the teleprinter motor is started immediately upon commencement of the signalling of traffic, and is stopped within a time not less than 45 seconds after the last signal of traffic;

CONSIDERING

that more strict unification of the delay-time of these automatic devices might give rise to serious technical complications;

that precautions should thus be taken lest an operator, the motor of whose apparatus is still rotating, should transmit signals to an apparatus of which the motor has just stopped;

UNANIMOUSLY DECLARES THE VIEW

c) that, in the case of a pause in transmission for a period equal to or longer than 30 seconds, operators or subscribers are recommended to send the signal 29 of alphabet no. 2 (" letter-shift ") and to wait at least 2 seconds after the emission of this signal before recommencing transmission;

CONSIDERING

that, for reasons associated with the unification of terminal apparatus and for others, certain Administrations have expressed a preference for the utilization of a method whereby calling and clearing signals are used, as in the telex service, to effect the starting and stopping of the teleprinter motors;

UNANIMOUSLY DECLARES THE VIEW

d) that, notwithstanding *b)* above, Administrations can, if they find it convenient, arrange between themselves to use an alternative method whereby the teleprinter motor is started by the use of a call signal, and stopped by the use of a clearing signal. In such cases the calling and clearing signals employed should conform to those standardized for the telex service, namely Recommendation U.1.

RECOMMENDATION S.8

INTERCONTINENTAL STANDARDIZATION OF THE MODULATION RATE OF START-STOP APPARATUS AND OF THE USE OF THE COMBINATION " SECONDARY OF D "

(former C.C.I.T. Recommendations C.5, and C.11, Arnhem, 1953)

The C.C.I.T.T.,

CONSIDERING

1. that the standardized modulation rate recommended for start-stop apparatus employed in international (including intercontinental) service is 50 bauds, in accordance with Recommendation S.3;
2. that there are nevertheless certain areas (notably in the U.S.A.) in which a different modulation rate for start-stop apparatus is employed;
3. that, even though it is recognized that universal adoption of a standardized modulation rate would be advantageous in the intercontinental service, it is not possible, at present, to secure universal adoption of a standard;

4. that it is essential to do everything possible to facilitate the establishment of intercontinental services, notwithstanding difference in modulation rates which may exist between the start-stop apparatus employed;

5. that there are in existence methods, employing automatic storage equipment in the circuit, which enable start-stop apparatus having different modulation rates to interwork;

6. that, furthermore on certain intercontinental circuits, e.g. radio circuits, the employment of special forms of synchronous equipment in association with storage equipment is sometimes essential and is already in use in the intercontinental sections of start-stop circuits,

UNANIMOUSLY DECLARES THE VIEW

1. that, when it is necessary in the intercontinental service to operate between start-stop apparatus having a modulation rate of 50 bauds, and start-stop apparatus having a non-standard modulation rate, then conversion equipment, for example automatic storage and retransmission equipment, must be inserted in the international circuits concerned in a manner to be agreed bilaterally between the Administrations and/or Private Operating Agencies concerned;

CONSIDERING

that the use of different signs or functions for combination 4 in the figure case of the international alphabet no. 2 on start-stop apparatus having to work together in the same system leads to operational difficulties which ultimately amount to rendering the use of this combination impossible;

that, the use of this combination to operate the answer-back unit, by allowing the caller to check the connection and the satisfactory working of his correspondent's apparatus, results in a considerable reduction in the time of establishing the communication, thereby facilitating operation of the service,

UNANIMOUSLY DECLARES THE VIEW

2. that combination 4 (figure case) of the international telegraph alphabet no. 2, should be reserved exclusively, both in international service, and in intercontinental service, for operating the answer-back unit;

3. that, in intercontinental service, when apparatus not permitting the use of the answer-back unit is being operated, the methods of using combination 4, (figure case), should be the subject of bilateral agreement between the Administrations and/or Private Operating Agencies concerned.

RECOMMENDATION S.9

SWITCHING EQUIPMENT OF START-STOP APPARATUS

(former C.C.I.T. Recommendation F.60, modified at New Delhi, 1960)

In view of Recommendation U.1 relative to signalling conditions to be applied in the international telex service;

in view of Recommendation F.60 relative to Regulations for the telex service (*Red Book*, Volume II *bis*, page 231 et seq.),

the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

1. that start-stop apparatus used in the telex service should be so equipped, or provided with the necessary devices, to permit of operation in accordance with Recommendations U.1 and F.60;

2. that if a subscriber's apparatus is such that he can use his teleprinter outside communication periods in order to prepare perforated tapes, for local checking of those tapes, for staff training, etc. the possibility of taking the answer-back may be delayed for a period not exceeding 3 seconds after connection is established with the called subscriber.

RECOMMENDATION S.11

USE OF START-STOP REPERFORATING APPARATUS FOR PERFORATED TAPE RETRANSMISSION

(former C.C.I.T. Recommendation C.19, Arnhem, 1953, amended at New Delhi, 1960)

When a station is equipped with receiving reperforating apparatus, it is often necessary to clear the perforated tape of the reperforator to ensure transmission of the last characters of a message received during the perforation of the first characters of the next message;

This operation of clearing the tape may lead to mutilation of the beginning of the message which is being perforated (particularly if insufficient message separation signals have been transmitted);

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW:

1. it is recommended that arrangements be made to avoid the mutilation of signals transmitted at the head of a message and received on start-stop reperforating apparatus.

If the reperforating apparatus is provided with local means for feeding the paper, not more than one mutilated signal should be tolerated. The wording of the message must make allowances for this fact.

It is recommended that the " message separation " signals should be sent at the end of a batch of telegrams following a given route at centres equipped with receiving reperforators. The choice of the type and number of signals to be sent for this purpose is left for agreement between the Administrations concerned. Use of a series of " letter shift " signals appears particularly desirable for this purpose;

2. if the reperforator is to be switched into circuit and out of circuit under control of the transmitting station, the following sequences of signals should be used:

Combination 3 repeated 4 times (CCCC)	for switching the reperforator into circuit by remote control.
Combination 6 repeated 4 times (FFFF)	for switching the reperforator out of circuit by remote control.

These operations may equally well be controlled by the secondaries of CCCC and FFFF, but for convenience in operating the primary signals CCCC or FFFF only should be used by operating staff.

If the sequence four times combination 6 has not been received before the arrival of the clearing signal (or the end of message signal), receipt of the clearing signal (or end of message signal) should cause disconnection of the reperforator.

RECOMMENDATION S.12

CONDITIONS WHICH MUST BE SATISFIED BY SYNCHRONOUS SYSTEMS OPERATING IN CONNECTION WITH START-STOP TELEPRINTER SYSTEMS

(former C.C.I.T. Recommendation C.23, Geneva, 1956, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING ON THE ONE HAND

that the receiving portion of the sending end of the synchronous system can be likened to a teleprinter receiver,

UNANIMOUSLY DECLARES THE VIEW

that the receiving portion of the sending end termination shall satisfy the conditions laid down in Recommendation S.3, paragraphs 1, 2, 3 and 4;

CONSIDERING ON THE OTHER HAND

that the retransmitting portion of the receiving end of the synchronous system can be likened to a start-stop transmitter having special characteristics, because of the high speed stability of synchronous systems,

UNANIMOUSLY DECLARES THE VIEW

that the start-stop signals provided by the retransmitting portion of the receiving termination of the synchronous system shall have the following characteristics:

1. Nominal modulation rate, 50 bauds;
2. Gross start-stop distortion of the signals, less than 5%;
3. Interval between the beginnings of successive start elements, 145 $^5/_6$ milliseconds with a tolerance of $\pm$ 1/10 000.

Note. — For a better understanding of the Recommendation, the general arrangement of a communication system involving transmission over a synchronous channel is shown below (fig. 4):

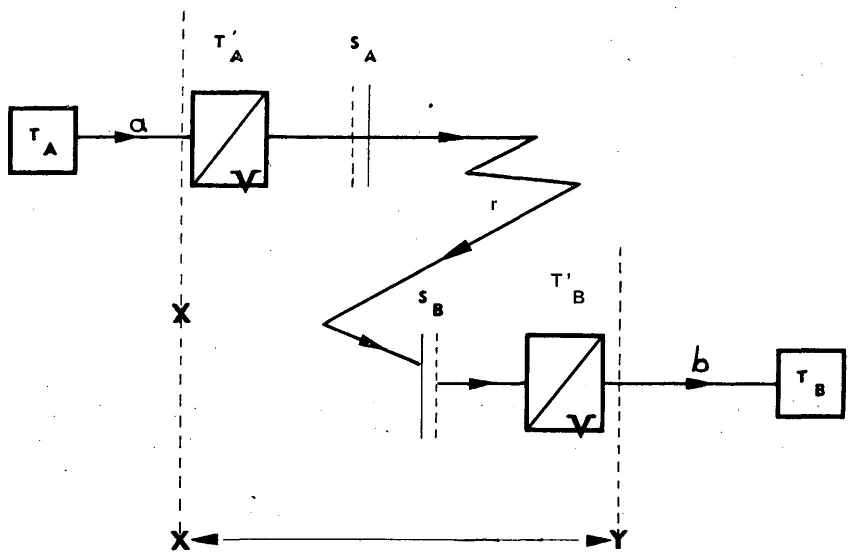

FIGURE 4. *Synchronous system*

In this diagram:

T_A and T_B are start-stop teleprinters.

T'_A and T'_B are repeaters with or without storage.

a and *b* represent the networks connecting teleprinters T_A and T_B to the repeaters T'_A and T'_B. These networks may comprise any number of channels in tandem, relays or regenerative repeaters.

S_A and S_B are the distributors of the synchronous system, the complexity of which it is not necessary to state.

r denotes a synchronous radiotelegraph channel.

It is agreed that, for the study of this question, the synchronous system includes all the equipment shown between lines X and Y on the diagram.

The input and output of the synchronous system are thus directly connected to the start-stop networks.

RECOMMENDATION S.13

USE ON RADIO CIRCUITS OF 7-UNIT SYNCHRONOUS SYSTEMS GIVING ERROR CORRECTION BY AUTOMATIC REPETITION

(former C.C.I.T. Recommendation C.24, Geneva, 1956, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

a) that it is essential to be able to interconnect terminal start-stop apparatus employing International Telegraph Alphabet No. 2 by means of radio-telegraph circuits;

b) that radio-telegraph circuits are required to operate under varying conditions of radio propagation, atmospheric noise and interference that introduce varying degrees of distortion which may at times exceed the margin of the receiving apparatus;

c) that, in consequence, the transmission of 5-unit code signals over radio circuits is liable to errors and that such errors are not automatically detectable by the receiving apparatus;

d) that an effective means to reduce the number of wrongly printed characters is the use of codes permitting the correction of errors, either by their intrinsic constitution or by detecting the error and automatically causing repetition;

e) that the methods using automatic repetition (ARQ) are well known at present;

f) that in certain cases there is a need to subdivide one or more channels in order to provide a number of services at a proportionately reduced character rate,

UNANIMOUSLY DECLARES THE VIEW

1. that when the direct use of a 5-unit code on a radio circuit results in an intolerable error rate and there is a return circuit, a 7-unit automatic error-correction system be considered. In such a case, the 7-unit system described below should be adopted as a preferred system:

I. *Code conversion table.*

II. *Repetition cycles for error-correction.*

— Four characters for normal circuits which are not subject to excessive propagation time;

— Five characters on circuits for which the four-character repetition cycle is inadequate, provided sub-channelling is not required;

— Eight characters on circuits for which the four-character repetition cycle is inadequate and sub-channelling is required. The cycle should comprise one repetition signal, three signals β and four stored characters, or one repetition signal and seven stored characters;

	5-Unit Code	7-Unit Code
A	Z Z A A A	A A Z Z A Z A
B	Z A A Z Z	A A Z Z A A Z
C	A Z Z Z A	Z A A Z Z A A
D	Z A A Z A	A A Z Z Z A A
E	Z A A A A	A Z Z Z A A A
F	Z A Z Z A	A A Z A A Z Z
G	A Z A Z Z	Z Z A A A A Z
H	A A Z A Z	Z A Z A A Z A
I	A Z Z A A	Z Z Z A A A A
J	Z Z A Z A	A Z A A A Z Z
K	Z Z Z Z A	A A A Z A Z Z
L	A Z A A Z	Z Z A A A Z A
M	A A Z Z Z	Z A Z A A A Z
N	A A Z Z A	Z A Z A Z A A
O	A A A Z Z	Z A A A Z Z A
P	A Z Z A Z	Z A A Z A Z A
Q	Z Z Z A Z	A A A Z Z A Z
R	A Z A Z A	Z Z A A Z A A
S	Z A Z A A	A Z A Z A Z A
T	A A A A Z	Z A A A Z A Z
U	Z Z Z A A	A Z Z A A Z A
V	A Z Z Z Z	Z A A Z A A Z
W	Z Z A A Z	A Z A A Z A Z
X	Z A Z Z Z	A A Z A Z Z A
Y	Z A Z A Z	A A Z A Z A Z
Z	Z A A A Z	A Z Z A A A Z
Carriage return	A A A Z A	Z A A A A Z Z
Line feed	A Z A A A	Z A Z Z A A A
Figures	Z Z A Z Z	A Z A A Z Z A
Letters	Z Z Z Z Z	A A A Z Z Z A
Space	A A Z A A	Z Z A Z A A A
Unperforated tape	A A A A A	A A A A Z Z Z
Signal repetition	———	A Z Z A Z A A
Signal α	———	A Z A Z A A Z
Signal β	———	A Z A Z Z A A

Note: Symbols A and Z have the meanings defined in the List of Definitions, Part I, No. 31-38

2. that the start-stop sections of the receiving and transmitting portions of the radiotelegraph circuit should satisfy the conditions of Recommendations S.3 and S.12;

3. that if such systems are used in establishing telex connections, the signalling position should conform to the arrangements shown in:

   U.20,
   U.21,
   U.22.

Note 1. — In conformity with Recommendation S.12, the aggregate keying speed for a 2-channel time division multiplex system will be 96 bauds and for a 4-channel system will be 192 bauds.

Note 2. — This Recommendation will be completed when the C.C.I.R. concludes its study on the channels and sub-channels arrangements (see Question 6/VIII).

RECOMMENDATION S.14

SUPPRESSION OF UNWANTED RECEPTION IN RADIOTELEGRAPH MULTI-DESTINATION TELEPRINTER SYSTEMS

(former C.C.I.T. Recommendation C.22, Geneva, 1956, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

1. that in a radio-telegraph system in which a radio teleprinter transmitter broadcasts messages simultaneously to a number of receiving stations, this broadcast is sometimes required only by a restricted number of these stations;
2. that it is desirable in such cases to prevent the reception of the message at the other offices to avoid wastage of paper;
3. that such wastage can be avoided by the use of selective calling systems whereby only those stations required to receive the transmission are connected whilst it is in progress;
4. that various technical methods are available for achieving this, using either:
   a) pulse signalling (e.g. by dial), or
   b) signalling with 5-unit signals;
5. that a wide variety of systems may be devised based upon the methods in 4 above;
6. that such systems are normally used only for special services in which agreement can be reached on the particular type of system to be adopted,

UNANIMOUSLY DECLARES THE VIEW

1. that when it is desired to avoid wastage of paper at receiving stations in radio-telegraph multi-destination teleprinter systems a selective calling system should be used;
2. that it is neither necessary nor desirable to recommend the use of any particular type of system for international use.

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SERIES T RECOMMENDATIONS

RECOMMENDATIONS CONCERNING APPARATUS AND TRANSMISSION FOR FACSIMILE TELEGRAPHY

Index of Series T Recommendations, page 10

RECOMMENDATION T.1

STANDARDIZATION OF PHOTOTELEGRAPH APPARATUS

(former C.C.I.T. Recommendation D.1, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that the transmission of pictures is possible only if certain characteristics of the transmitting and receiving equipments are identical,

UNANIMOUSLY DECLARES THE VIEW

that phototelegraph apparatus and the associated modulating and demodulating equipment should be constructed and employed according to the following standards:

Direction of scanning

At the transmitting apparatus the plane (developed in the case of a drum transmitter) of the message surface is scanned along lines running from right to left commencing at the top so that scanning commences at the top right-hand corner of the surface and finishes at the bottom left-hand corner: this is equivalent to scanning over a right-hand helix on a drum. The orientation of the message on the scanning plane will depend upon its dimensions and is of no consequence.

At the receiving apparatus scanning takes place from right to left and top to bottom (in the above sense) for " positive " reception and from left to right and top to bottom (in the above sense) for " negative " reception.

Index of co-operation

The index of co-operation *(M)* is defined:

a) for apparatus with drum scanning; by the formula:

$$M = \frac{D}{P} = DF$$

in which D is the drum diameter, P is the pitch of the helix formed by a series of scanning lines, F is the scanning density (or lines per unit length);

b) for apparatus with flat-bed scanning, by the formula:

$$M = \frac{1}{\pi} LF$$

where L is the length of a scanning line, F is the scanning density (or, number of lines per unit length).

The normal index is 352.

The preferred alternative index, for use when less dense scanning is required, or when the characteristics of circuits (and particularly combined line and radio circuits) so demand, is 264.

The foregoing standards assume that the size of the scanning spot bears the most appropriate relationship to the index of co-operation in use.

Drum factor

The drum factor is the ratio:

$$\frac{\text{usable drum length}}{\text{drum diameter}} = \frac{U}{D}$$

Before a picture is transmitted, it is necessary to verify that

$$\frac{\text{transmitter drum length used}}{\text{transmitter drum diameter}}$$

is not greater than the receiver drum factor.

Dimensions of drum and picture

The normal drum diameter is 66 mm.

The preferred alternative drum diameters are 70 and 88 mm.

The drum factor shall be not less than 2.4.

The drum factor of the sending apparatus shall not be more than 2.4.

The drum factor of the receiving apparatus shall not be less than 2.4.

In the case of the normal drum, the width of the two picture-retaining clips together may not exceed 15 mm. An allowance of 5 mm is also made for phasing. Thus, since the total circumference of the drum is about 207 mm, the usable circumference will be 187 mm.

The normal dimensions of the pictures are 130 mm × 180 mm.

The existence of a number of variations from the recommended values of drum diameter and index of co-operation has been observed and it is recommended that Administrations and Private Operating Agencies should for the future endeavour to conform, as far as possible, with the recommended values.

The following table gives corresponding values of M, D, P and F for apparatus in most common use:

M	D(mm)	P(mm)	F(lines/mm)
264	66	1/4	4
264	70	1/3.77	3.77
264	88	1/3	3
350	70	1/5	5
352	66	3/16	16/3
352	88	1/4	4

Drum rotation speed

The following are the normal and approved alternative combinations of drum rotation speed and index of co-operation:

	Drum rotation speed (r.p.m.)	Index of co-operation	
		Metallic circuits	Combined metallic and radio circuits
Normal conditions	60 90	352	352 264
Lower speed for use when radio propagation conditions demand it	45		264
Alternatives for use when the phototelegraph apparatus and metallic circuits are suitable	90 120 150	264 and 352 264 and 352 264	

Note. — In the case of transmitters operating on metallic circuits, the index 264 is not intended to be used with an 88 mm drum. In the case of transmitters operating on combined metallic and radio circuits, the index 264 associated with a drum diameter of 88 mm is intended to be used only exceptionally.

The rotation speed of transmitters must be maintained as nearly as possible to the nominal speed and in any case within $\pm$ 10 parts in 10^6 of the nominal speed. The rotation speed of receivers must be adjustable and the range of adjustment should be at least $\pm$ 50 parts in 10^6 from the nominal speed. After regulation, the speeds of the transmitting and receiving sets should not differ by more than 10 parts in 10^6.

Judder

The stability of the rotation speed should be such that the maximum shift of the drum surface from the average position should not exceed one quarter of the pitch *(P)* of the helix formed by the scanning lines, which, at normal index 352, means that the maximum angle of the oscillations should not exceed 0.08 degree measured from the average position.

(T. 1)

Positive and negative reception

Selection of positive or negative reception should be made by adjustment at the receiver.

Equalization of speeds

When phototelegraph stations have available a standard of frequency which is better than $\pm$ 5 parts in 10^6, verification of the synchronism between the two stations may be dispensed with. In view of the saving of time, this method should be adopted wherever possible.

To compare the speeds of a transmitter and a receiver, an alternating current whose frequency bears an unvarying relationship to the transmitter drum speed, and has a nominal value of 1020 c/s, is used. This current is received by some form of stroboscope at the receiver.

The speed of the receiver is adjusted to within 10 parts in 10^6 of the speed of the transmitter; the required condition is indicated when the phase slip of the stroboscopic display does not exceed one white sector plus one black sector (or their equivalent) in either two minutes or one minute according to whether the flashing frequency is equal to or double the comparison frequency.

Where there is the possibility that the transmitter and receiver may be connected by a circuit liable to introduce frequency changes, for example, by a carrier telephone circuit, the use of the simple 1020 c/s synchronizing tone is unsatisfactory. The preferred method of overcoming this difficulty is to transmit the phototelegraph carrier (1900 c/s or 1300 c/s) modulated by the 1020 c/s synchronizing tone.

At the receiving end, the 1020 c/s synchronizing frequency is restored by detection and can then be used in the normal manner. For technical reasons the use of 1900 c/s is to be preferred and Administrations should endeavour to use this frequency.

Phasing

Phasing is performed after the speeds of the transmitter and receiver drums have been equalized and before scanning of the picture area begins.

The transmitter emits a series of short phasing signals within the periods when the scanning beam is passing across the dead sector (clip position).

The phasing signals are used at the receiver to position the drum so that they fall within the dead sector.

The phasing operation aims to ensure that a given instant in the phototelegraph signal bears the same time relation in both transmitter and receiver to the instant at which the scanning beam passes out of the dead sector.

For amplitude-modulation transmission, the phasing signal should be sent at the level of the white signal. Any frequency convenient for transmission may be used, for example the 1020 c/s synchronizing tone or the phototelegraph carrier.

For frequency-modulation transmission the phasing signals should be at the white frequency.

Modulation and demodulation equipment

1. *Amplitude modulation*

Phototelegraph equipment shall normally provide for transmission and reception of an amplitude-modulated audio-frequency carrier, which is the normal mode of transmission for international metallic circuits.

The level of the output signal of the transmitter shall be greatest for white and least for black. It is desirable that the ratio of nominal white signal to nominal black signal should be approximately 30 decibels.

To simplify multi-destination operation and AM/FM conversion for radio operation, it is desirable that the amplitude of the transmitted signal should vary linearly with the photocell voltage and that no corrections for tone scale should be made at the phototelegraph transmitting station.

For audio-frequency telephone circuits, the frequency of the picture carrier-current is fixed at about 1300 c/s. This frequency gives the least delay distortion on lightly loaded underground cables.

In the case of carrier telephone circuits providing a transmission band from 300 to 3400 c/s, a carrier-current frequency of about 1900 c/s is recommended.

2. *Frequency modulation*

Preferably phototelegraph apparatus should also provide for transmission and reception of a frequency-modulated audio-frequency carrier for use when the characteristics of the metallic portion of the circuit permit:

a) on combined metallic and radio circuits,

b) on wholly metallic circuits.

In such a case, the characteristics of the frequency-modulated output should be:

mean frequency	1900 c/s
white frequency	1500 c/s
black frequency	2300 c/s
phasing signal frequency	1500 c/s

The deviation of frequency should vary linearly with photocell voltage or, in the case of conversion from amplitude modulation to frequency modulation, with the amplitude of the amplitude-modulated carrier.

The stability of the apparatus must be such that the frequency corresponding to a given tone does not vary by more than 8 c/s in a period of 30 seconds and by more than 16 c/s in a period of 15 minutes.

RECOMMENDATION T.3

DIRECTION OF SCANNING FOR DIRECT RECORDING FACSIMILE SYSTEMS NOT REQUIRED TO RECEIVE AND RECORD HALF-TONES

(former C.C.I.T. Recommendation D.6, Geneva, 1956

The C.C.I.T.T.,

CONSIDERING

that there is not yet sufficient information as to the requirements which would need to be met in the use in the international telegraph service of direct recording facsimile systems (not required to receive and record half-tones) to permit full standardization of the equipment;

but that, nevertheless,in order to avoid future difficulties, it is very desirable to standardize the direction of scanning to be employed,

UNANIMOUSLY DECLARES THE VIEW

that the direction of scanning to be employed in connection with direct recording facsimile systems (not required to receive and record half-tones) which are intended for use in the international telegraph service, should be such that the plane (developed in the case of a machine using a drum) of the message surface is scanned along lines running from *left to right* commencing at the top, so that scanning commences at the *top left-hand corner* of the surface and finishes at the bottom right-hand corner; this is equivalent to scanning over a left-hand helix on a drum.

RECOMMENDATION T.11

PHOTOTELEGRAPH TRANSMISSIONS ON TELEPHONE-TYPE CIRCUITS *

(former C.C.I.T. Recommendation D.3, amended at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that both audio and carrier telephone circuits may be used for phototelegraph transmissions **;

that such transmissions on telephone circuits may, in special cases, use frequency modulation as an alternative to amplitude modulation,

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* Recommendation H.31 of Volume III.

** See Question 5/XIV for the extension of this Recommendation to other types of facsimile telegraphy.

UNANIMOUSLY DECLARES THE VIEW

that phototelegraph transmissions on telephone circuits demand that the following conditions be observed:

A. Circuits permanently used for phototelegraphy

It seems that these circuits are few. In any case, they should even more easily meet the characteristics given in para. B below.

B. Circuits used normally (and preferentially) for phototelegraphy

a) *Types of circuit to be used*

Two-wire circuits have no practical value for phototelegraphy because of feed back phenomena.

For the same reason, four-wire circuits should be extended to the phototelegraph stations on a four-wire basis at the appropriate amplifier stations, the terminating units and echo-suppressors always being disconnected.

b) *Overall loss*

The same conditions apply to the overall transmission loss of four-wire circuits used for phototelegraphy as apply, in general, for telephony.

c) *Sent signal power*

The emission voltage for the phototelegraph signal corresponding to maximum amplitude should be so adjusted that the absolute power level of the signal, at the zero relative level point deduced from the hypsogram of the telephone circuit, is 0 neper (0 decibel) for amplitude-modulation facsimile transmission and – 1.15 neper (– 10 decibels) for frequency-modulation facsimile transmissions. In the case of amplitude-modulation the level of the signal corresponding to black is usually about 30 decibels lower than that of the signal corresponding to white.

d) *Relative levels*

If phototelegraph transmissions take place simultaneously from a transmitting station to several receiving stations, arrangements shall be made at the junction point so that, on the circuits following the junction point, the same power levels are maintained as those prescribed for individual transmissions.

e) *Attenuation distortion*

When amplitude modulation is used, the attenuation distortion between phototelegraph stations should not exceed 1.0 neper (8.7 decibels) in the band of frequencies to be transmitted for the facsimile telegraph transmission. As a distortion of 1.0 neper (8.7 decibels) is already assumed for the telephone circuit itself, it may be necessary at times to compensate for the distortion of the lines joining the phototelegraph stations to the amplifier stations.

(T. 1[illegible])

In the case of frequency modulation, it suffices to use telephone circuits conforming to C.C.I.T.T. Recommendations regarding attenuation distortion (see paragraph C of Recommendation G 131 — Volume III).

f) *Variation of equivalent with time*

The overall loss should remain as constant as possible during the picture transmission. In the case of amplitude modulation, abrupt variations of even 0.1 neper (0.9 decibel) have an effect. It is, moreover, necessary to avoid any interruption of the circuit, however rapid. For this reason, the greatest attention should be paid to the measurements made on the amplifiers and lines and to the changing of batteries. To reduce the likelihood of disturbance, it is desirable that the terminal trunk exchanges should be excluded from the circuit when it is extended to the facsimile stations.

Special precautions should be taken to make sure that no modulation of the carrier is caused by the line or the amplifiers, even if the modulation is inaudible. Such modulation may be due, in particular, to variations in the voltage of the supply batteries, or to sub-audio telegraphy equipment.

In the case of frequency modulation, sudden changes of even 1.15 *N* (10 db) can be tolerated and telephone circuits, even when set up without special precautions, have sufficient stability.

This observation does not mean that sudden variations of level should not be avoided just as much in the case of circuits carrying frequency-modulated phototelegraphy.

g) *Phase distortion*

Phase distortion limits the range of satisfactory phototelegraph transmissions. Differences between the group delays of a telephone circuit, in the interval of the phototelegraph transmission, should not exceed

$$\Delta t \leqslant \frac{1}{2f_p}$$

f_p = Maximum modulating frequency corresponding to the definition and scanning speed

(See Recommendation T.12).

h) *Interference*

Interfering currents, whatever their nature, should not exceed the C.C.I.T.T. recommended limits for telephone circuits.

C. Telephone circuits rarely used for phototelegraphy

a) *Transmission characteristics*

It seems that the majority of the characteristics specified by the C.C.I.T.T. for modern telephone circuits are sufficient to permit frequency modulated-phototelegraph transmissions on a circuit chosen at random in a group of circuits normally used for telephone working. However, it is not certain that such a circuit would have a sufficiently low phase distortion for such use, particularly channels 1 and 12 of a 12-circuit group, use of which is not advised. This point is under study.

With amplitude modulation there is a further risk that phototelegraph transmissions will be subject to faulty modulation because the special precautions applied to circuits regularly used for phototelegraphy (see B. f) above cannot be applied to circuits taken at random.

b) *Precautions concerning signalling*

So long as automatic switching for phototelegraph circuits is not envisaged, the signal receiver can be disconnected so that no signalling disturbances can occur even when frequency modulation is used. However, if frequency modulation is used for phototelegraph transmission and if it is impracticable to disconnect the signal receiver, then it would be desirable, in the case of the one-frequency system, that a blocking signal be transmitted along with the picture signal to operate the guard circuit and render the receiver inoperative.

It is also apparent that the frequency of such a blocking signal should lie well outside the range of frequencies involved in the picture transmission and the frequency and the level of the blocking signal must depend on the characteristics of the V.F. receiver (or receivers in the case of a tandem international connection), as designed by different Administrations to meet the specification to be prescribed for international signalling.

In the case of the two-frequency international signalling system, the C.C.I.T.T. has indicated its view that no interference will take place.

RECOMMENDATION T.12

RANGE OF PHOTOTELEGRAPH TRANSMISSIONS ON A TELEPHONE TYPE CIRCUIT *

(former C.C.I.T. Recommendation D.3, amended at New Delhi, 1960)

1. The differences between the group delays of the various frequencies and the width of the transmission band actually usable on a circuit for telephony give rise, when phototelegraph signals are started or stopped, to transient phenomena which limit the phototelegraph transmission speed;

* Recommendation H.32 of Volume III.

2. The range of phototelegraph calls of satisfactory quality, for a given transmission speed, depends especially on the constitution of the circuit, i.e. on:

— the loading and length, in the case of audio-frequency circuits;

— the number of 12-channel group links used in the case of carrier circuits, and on the choice of the carrier frequency for amplitude-modulated phototelegraph transmission, or on the mean frequency in the case of frequency modulation;

3. Phototelegraph transmission of satisfactory quality requires that the limits of difference between the group delays in the transmitted frequency band, as shown in the graph below (fig. 5), are not to be exceeded;

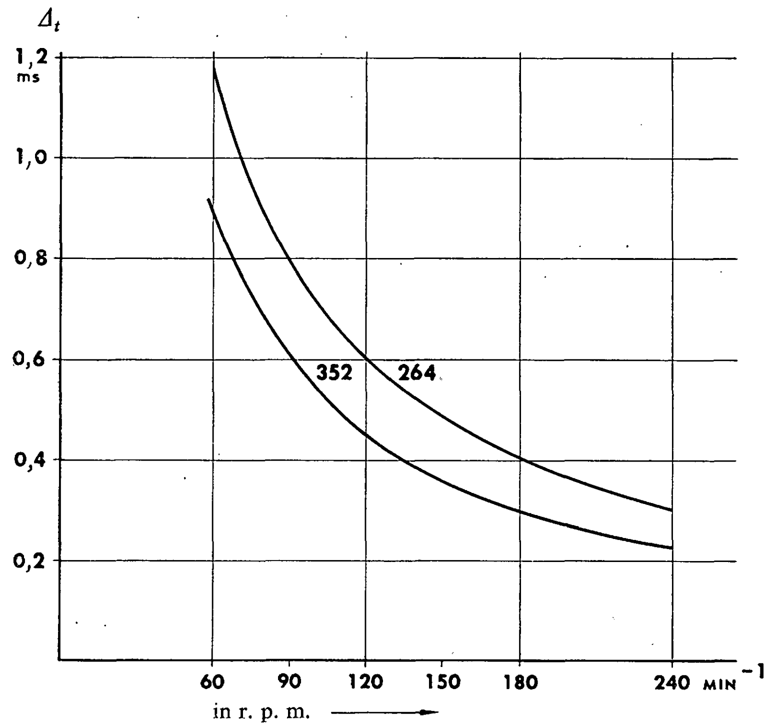


FIGURE 5. — *Permissible delay distortion in the transmitted frequency band as a function of the phototelegraph transmission speed.*

Note. — The spot is assumed to have the same dimensions in both directions (square or circular).

4. The C.C.I.T.T. has recommended the following for international circuits, whether they be audio-frequency circuits of any type or carrier circuit:

if t_m is the group delay for nominal lower limit of the frequency band to be transmitted, if t_M is the group delay for the nominal upper limit of the frequency band to be transmitted,

if $t_{\min}$ is the minimum group delay in the whole of the frequency band to be transmitted, the following must be respected:

$$t_m - t_{\min} \leqq 20 \text{ ms}$$
$$t_M - t_{\min} \leqq 10 \text{ ms}$$

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

As regards the effect of phase distortion on phototelegraph transmission quality, the carrier frequency (where amplitude modulation is used) or the mean frequency (when frequency modulation is used) must be chosen in such a way that it is as near as possible to the frequency which has the minimum group delay on the telephone circuit.

A. Circuits permanently used for phototelegraphy

1. It will generally be possible, by agreement between Administrations, to choose a circuit satisfying stricter limits than those specified above from the point of view of phase distortion.

2. Moreover, it will be possible to compensate phase distortions by inserting phase equalizers and to effect phototelegraph transmissions occupying the whole nominal band of the circuit.

B. Circuits normally (or preferentially) used for phototelegraphy

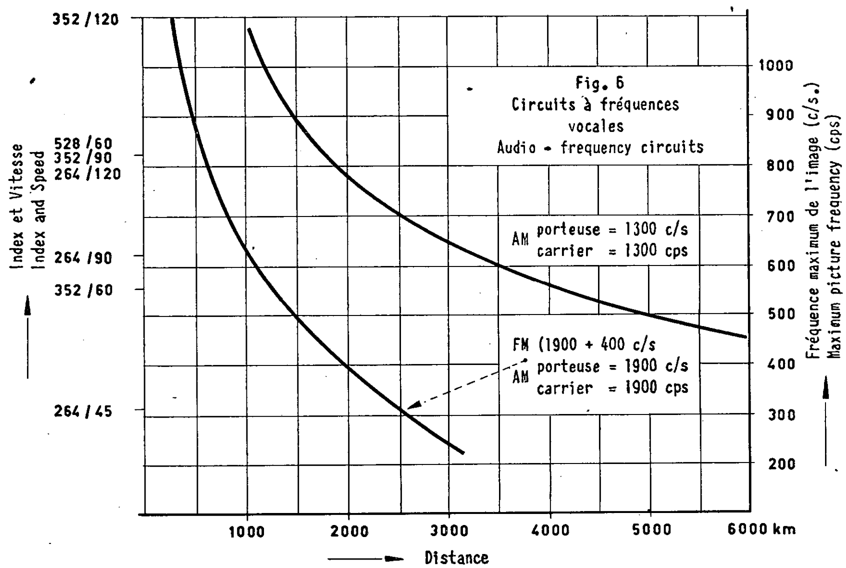
1. The greater the differences between the delays in the transmission intervals, the narrower should be the bandwidth chosen (leading to a lower phototelegraph definition or transmission speed).

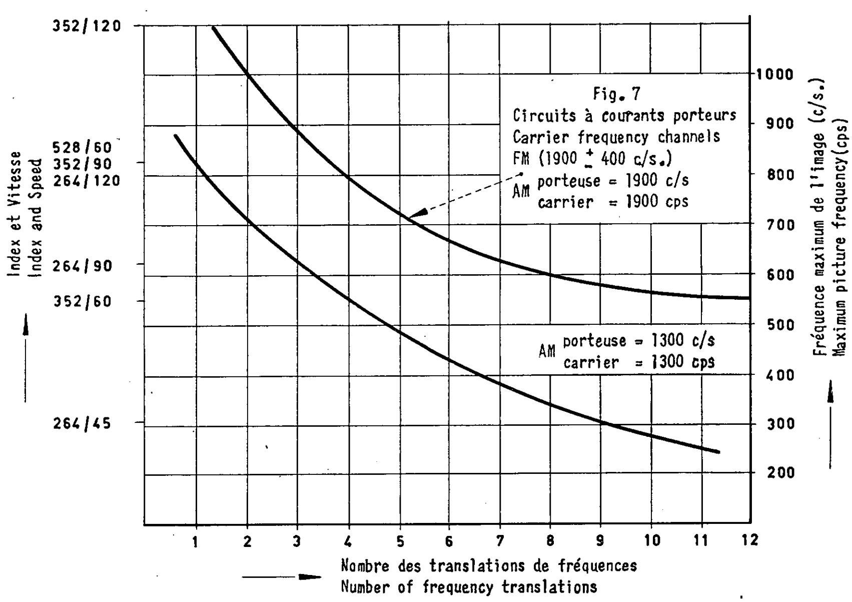
2. Hence, audio-frequency circuits should in any case have only small loads.

3. Phase distortion is well within the limits indicated above, in the case of carrier circuits, if a single modern-type carrier system (providing at least 12 telephone channels) is considered (and considering especially the telephone channels in the middle of a 12-channel group of such a system).

4. Nevertheless, it would be unjustifiable from the financial point of view to make the aforementioned recommendation concerning phase distortion stricter, simply with a view to the occasional use of only a few circuits for high-speed phototelegraph transmissions.

5. The following curves (fig. 6 and fig. 7) give information on the relative performances of amplitude and frequency-modulated phototelegraph transmissions on audio-frequency and carrier telephone circuits. These curves give a provisional idea of the range of phototelegraph transmissions. They still have to be verified by the Administrations.





FIGURES 6 AND 7. — *Range of phototelegraph transmission*

C. Telephone circuits rarely used for phototelegraphy

If phototelegraph connections are set up on circuits selected at random from modern-type groups of telephone circuits (for example, by automatic switching), a circuit may be taken which has too high a degree of phase distortion, particularly if it has been set up on channels 1 or 12 of a 12-channel group, use of which is deprecated. It is impossible, in this case, to draw up general information on the range of phototelegraph transmissions;

however, it will be possible to meet the conditions for a transmission of adequate quality if the phototelegraph connection comprises only one 12-channel group link and if transmission is effected in normal conditions as outlined in Recommendation T.1.

Note. — Documentation on phase distortion, which is practically to be found on carrier systems channels, is given in the Supplements to Series T Recommendations (page 328 et seq.).

RECOMMENDATION T.15

PHOTOTELEGRAPH TRANSMISSIONS OVER COMBINED RADIO AND METALLIC CIRCUITS

(former C.C.I.T. Recommendation D.4, modified at New Delhi, 1960)

Having considered C.C.I.R. Resolution No. 244 (Los Angeles, 1959),

The C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW

That phototelegraph transmissions over combined radio and metallic circuits should conform to the following provisions:

1. over the radio path,

a) when sub-carrier frequency-modulation system is used, the following characteristics should be observed:

centre frequency . . . . 1900 c/s
frequency corresponding to white . . . . . . 1500 c/s
frequency corresponding to black . . . . . . 2300 c/s

(the 1500 c/s frequency is also used for the phasing signal);

b) when a direct frequency-modulation system is employed, the following characteristics should provisionally be observed:

centre frequency (corresponding to assigned frequency) $= f_0$
frequency corresponding to white $= f_0 - 400$ c/s
frequency corresponding to black $= f_0 + 400$ c/s

(The frequency $f_0 - 400$ c/s is also used for the phasing signal.)

c) in both systems the stability of frequencies should be such that the variations are less than:

8 c/s during a period of 30 seconds,
16 c/s during a period of 15 minutes;

2. for the present, the following apparatus characteristics should be used:

	a	b
index of co-operation	352	264
speed of rotation of drum in r.p.m.	60	90 45*

3. frequency modulation or amplitude modulation may be used in the metallic portions of the combined circuit. When conversion from amplitude modulation to frequency modulation (or vice versa) is required, the conversion should be such that the deviation of the frequency-modulated carrier varies linearly with the amplitude of the amplitude-modulated carrier.

   The standards for both amplitude-modulation and frequency-modulation transmissions will be found in C.C.I.T.T. Recommendations T.1 and T.11.

   Each Administration will decide, when the question arises, on the location of modulation converters. They will be placed either at the terminal phototelegraph station or at the control station associated with the radio station, in order to permit speech on the circuit used for phototelegraphy, if the radio channel will carry speech.

Comments: The recommendations of paragraph 2 above are not intended to require the imposition of such standards on users who use their own equipment for the transmission of pictures over private circuits.

Note. — Pending the solution of technical difficulties when the study of Question 9/XIV is concluded, the connection in tandem of a F.M. metallic circuit and a radio circuit with direct carrier frequency modulation should be avoided.

RECOMMENDATION T.16

(C.C.I.R. RECOMMENDATION 243) FACSIMILE TRANSMISSION OF METEOROLOGICAL CHARTS OVER RADIO CIRCUITS

(former C.C.I.T. Recommendation D.7, Geneva, 1956, C.C.I.R., Los Angeles, 1959)

The C.C.I.R. and the C.C.I.T.T.,

CONSIDERING

a) that increasing use is being made of facsimile telegraphy for the transmission of meteorological charts for reception on direct-recording apparatus;

b) that it is desirable to standardize certain characteristics of the radio circuits for this purpose,

---

* Lower speed for use when radio propagation conditions demand it.

DECLARE THE VIEW

1. that when the sub-carrier frequency-modulation system is employed for the facsimile transmission of meteorological charts over radio circuits, the following characteristics should be used:

sub-carrier frequency	1900 c/s
black frequency	1500 c/s
white frequency	2300 c/s

2. that when direct frequency modulation is employed on radio circuits the following characteristics should provisionally be used:

centre frequency (corresponding to assigned frequency)	f_0
frequency corresponding to black	$f_0 - 400$ c/s,
frequency corresponding to white	$f_0 + 400$ c/s;

In special cases, for example on lower frequency circuits, a smaller deviation may be used, but it is too early to fix any standard shift.

Note. — The normal index of co-operation is 576 associated with a speed of 60 r.p.m. The same index of co-operation is also used in association with speeds of 90 and 120 r.p.m. It is to be observed that, whereas with the drum speed of 60 r.p.m. satisfactory reception can usually be expected, the quality of the recording may be impaired at higher drum speeds depending upon the composition of the circuit and the presentation of the original document.

RECOMMENDATION T.20

STANDARDIZED TEST CHART FOR FACSIMILE TRANSMISSIONS (INCLUDING PHOTOTELEGRAPHY)

(New Delhi, 1960)

It will be a great advantage to use a standardized test chart to check the quality of facsimile transmissions. Such a chart would provide the receiving office with a reliable and rapid means of checking the quality of test transmissions according to uniform principles and of making comparisons between different transmission results in a precise way. The chart has been designed both for measuring the quality of both half-tone and black-and-white transmissions and it enables the apparatus used and the communication channels to be judged, by means of objective measurements, the results of which may be expressed in code.

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. Tests of facsimile transmission quality (including phototelegraph transmissions) will be carried out in the international service with the aid of the " C.C.I.T.T. standardized test chart ".

2. This test chart will conform to the specimen and description annexed to the present Recommendation. It will be made by the I.T.U. under the supervision of the C.C.I.T.T. and should be offered for sale by the I.T.U.

Important Note : The specimen of the test chart printed in the Annex cannot be used for measurements.

ANNEX

The C.C.I.T.T. standardized test chart

1. The test chart has the following dimensions:

length = 25 cm
width = 11 cm

It must be fixed to drum apparatus so that the length follows the drum's circumference.

It is divided into reference sections by means of the sectionalized tracings delivered with each test chart.

2. Section 10, upper, and Section 10, lower, serve for adjusting the chart to the size of the drum. Adjustment lines numbered 1 to 6 are traced on each of these two sections. The chart must be shortened according to the drum's circumference so that, finally, adjustment lines bearing the same number appear at the top and the bottom.

In this way, the initial phase can be controlled.

3. Sections 1 and 2 contain 2 tone scales, each of which contains 15 tone steps varying in density from black to white and vice versa.

The density corresponds to the definition:

$$D = \log \frac{I_1}{I}$$

where I_1 = the intensity of the light reflected by the unexposed paper.

I = the intensity of the light reflected by the tone step considered.

If D_{15} is the maximum density, the densities of steps 1, 2, 3, 5 and 8 are fixed as follows:

$$D_1 = 0$$
$$D_2 = 0.01\ D_{15}$$
$$D_3 = 0.03\ D_{15}$$
$$D_5 = 0.13\ D_{15}$$
$$D_8 = 0.33\ D_{15}$$

The densities of the intermediate steps change an equal amount per step between the densities of the steps given above.

Note — The densities actually obtained for each step will be specified when the test charts are delivered.

These sections serve for the examination of the reproduction of the half-tones; they enable the optimum adjustment of phototelegraph apparatus to be checked as well as the suitability of certain photographic material (films, papers) for phototelegraphy.

4. Section 3 is occupied by a group of 9 black lines on a white background, in the shape of hyperbolae. The thickness of the lines decreases gradually from left to right going from 1 mm to 1/6 mm. The white spaces between the black lines likewise decreases regularly from left to right from 1 mm to 1/6 mm.

The abscissae, going from 1 to 6, serve to identify the scanning density (number of scanning lines per mm). The length intercepted on a hyperbola by the vertical line from a figure for scanning density on the abscissae, gives the dimensions of the scanning spot.

This section enables the scanning density to be examined and reveals the effect of the phase distortion due to the transmission channel

5. Section 4 has two groups of hyperbolae similar to those of Section 3 but limited to the scanning densities lying between 3 and 6.

One group is made up of grey lines (step 6 of the tone scale) on a white background.

The other group is made up of grey lines (step 11 of the tone scale) on a black background

These groups are suitable for checking modulation conditions at the edges of the frequency band if frequency modulation is used.

6. Section 5 contains 3 patterns.

The first is composed of 5 black lines on a white background, the lines having a thickness of 0.25 mm, arranged in one group of 2 lines and another of 3 lines; these lines are separated by 0.25 mm, and the two groups are separated by a space of 1.5 mm.

The second pattern is the same as the first but the lines are white on a black background.

The third pattern comprises two similar groups of black lines on a white background as follows:

— line, thickness	1 mm
— separation	0.25 mm
— line, thickness	0.25 mm
— separation	1 mm
— line, thickness	0.25 mm
— separation	0.25 mm
— line, thickness	1 mm

The two groups are separated by a space of 1 mm.

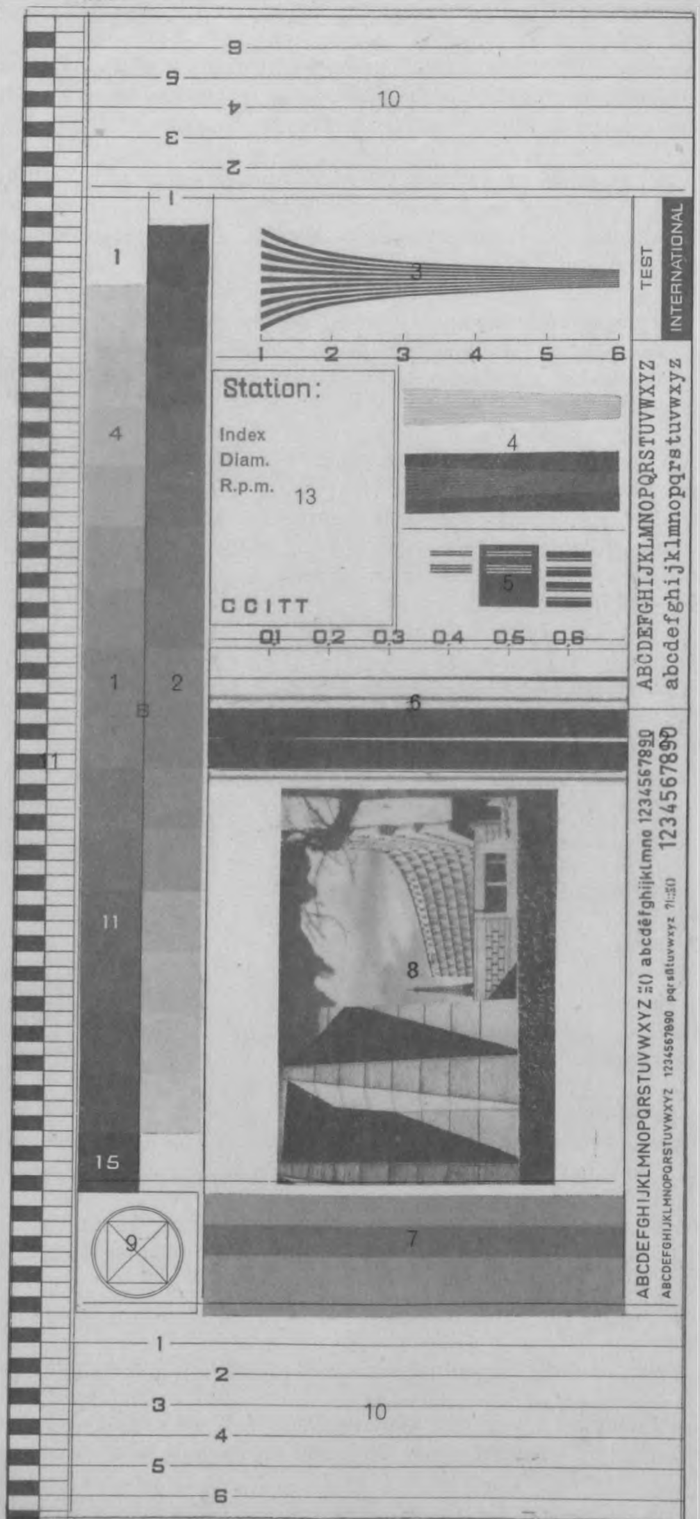
These patterns are intended for examining the effect of transient phenomena when passage is effected from a thin line to a thick line or vice versa, with various spacings.

7. Section 6 contains a black tapering line on a white background and a corresponding white tapering line on a black background with an aperture of 0.7 mm to check the reproduction of single lines of different widths.

At the top of the section is a line calibrated in mm; it shows the width of bands in the form of a tapering line.

This part serves to check the reproduction of isolated lines having different thicknesses.

8. Section 7 contains a strip corresponding to step 11 on a background of density step 5; this is suitable for noting transient phenomena and recognizing level variations and disturbing frequencies.


Station:
Index
Diam.
R.p.m.
CCITT
TEST
INTERNATIONAL
ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
1234567890

9. Section 8 accommodates the photograph of the UNESCO building in Paris, which permits of a subjective assessment of the quality of reception.

10. Section 9 contains two circles separated by 1 mm the shape of which varies when the interworking machines do not have the same index of co-operation or drum speed. Changes of shape should be interpreted as follows:

1. A vertical or horizontal ellipse means that the indexes of co-operation differ;
2. An oblique ellipse means that the drum speeds are not the same.

The square with diagonal lines inside the circle makes it easier to recognize irregularities.

11. Section 11 contains a pattern of lines with a spacing of 2.5 mm. It is divided into two equal parts by a vertical line; the column on the right contains white rectangles, while the column on the left contains alternate black and white rectangles (step 15 of section 1).

This section is used to detect irregularities in the drum rotation.

12. Section 12 contains some typographical signs; these are placed so that they can be read sideways.

Section 12 is divided into three parts:

The bottom part contains typographical signs (letters, figures and a few punctuation marks) as used for printing.

The middle part contains signs, but in typewriter characters 2.3 mm in height.

The top part contains the words TEST INTERNATIONAL in two lines, the first (TEST) being in black on a white background and the second (INTERNATIONAL) being white on a black background.

13. Section 13 is to be completed by the sending station, which should enter the characteristics of the apparatus.

Should the apparatus have several indexes or speeds, the station should enter these indexes and speeds (in revolutions per minute), one after the other. If necessary, the receiving station should underline — on the received picture — the characteristics according to which the transmission was made.

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SERIES U RECOMMENDATIONS

RECOMMENDATIONS CONCERNING TELEGRAPH SWITCHING

Index of Series U Recommendations, page 10

RECOMMENDATION U.1

SIGNALLING CONDITIONS TO BE APPLIED IN THE INTERNATIONAL TELEX SERVICE

(former C.C.I.T. Recommendation E.1, Arnhem, 1953, amended at Geneva, 1956, and New Delhi, 1960)

Signalling conditions in the international telex service require accurate definition of the signals to be used on international telex circuits in putting through, supervising, clearing, and charging for international telex calls.

These signals must be such as to take into account that there are some fairly important differences in make-up between the telex networks of countries. In some countries, selection is done by dialling, in others, by means of start-stop signals; some networks use direct selection while others use register translators between some networks, subscriber-subscriber automatic selection is used whilst in relations with other networks, semi-automatic or manual selection is still being used.

Hence it has not been possible to lay down uniform signals for all international telex relations. While, for certain signals, it has been possible to lay down rules valid for all relations, for others, the choice has been left between two types of signals known as Type A and Type B. Within each type, it has sometimes been necessary to provide alternative forms for certain signals. The signals with regard to which there is a choice are described in Tables I *a)*, I *b)* and II of the Recommendation.

The signalling with which this Recommendation deals applies when telex circuits make use of synchronous devices. If such devices are required (in particular when radiotelegraph circuits are involved), Recommendation U.1 must be applied whenever possible, and for such a case, Recommendation U.20 lays down the conditions for adapting the signalling defined in Recommendation U.1.

The C.C.I.T.T. therefore

UNANIMOUSLY DECLARES THE VIEW:

A. That in general so far as signalling over international telex circuits is concerned, the outgoing country should conform to the signalling requirements of the incoming country. Nevertheless, when in the case of fully automatic service this requirement would entail considerable difficulty, alternative arrangements may be adopted by agreement between the two Administrations concerned.

B. That the following signals shall be employed, under the conditions indicated:

1. *Free line condition.*

The " free line " is characterized by a permanent signal corresponding to the start impulse in accordance with international telegraph alphabet No. 2 on the forward and backward signalling paths.

2. *Call.*

The " call " is characterized by the inversion of the condition specified in paragraph 1 on the forward signalling path.

3. *Call-confirmation signal.*

A " call-confirmation " signal shall be returned over the backward signalling path following the initiation of a call to prove the continuity of the line and the response of the distant terminal equipment.

The call-confirmation signal shall be returned by the receiving end as quickly as possible and in any event with a delay not exceeding 150 milliseconds after the arrival of the calling signal at the receiving end.

4. *a*) *Proceed-to-select signal.*

In the case of international telex circuits terminated on distant automatic switching equipment which cannot accept the selection information immediately (either after the reception of the calling signal or after the sending of the call-confirmation signal), a distinct " proceed-to-select " signal shall be returned over the backward signalling path after the call-confirmation signal, to indicate that the selection information may be transmitted.

For 99 calls in 100, the delay in the return by the receiving system of the " proceed-to-select " signal must not exceed 5 seconds after the reception of the calling signal.

If the automatic switching equipment at the receiving end can receive the selection information immediately after the sending of the call-confirmation signal, the call-confirmation signal shall constitute the proceed-to-select signal.

If the automatic switching equipment at the receiving end can receive the selection information at the time of receiving the call signal, there shall be no proceed-to-select signal.

b) *Proceed-to-transmit signal.*

In the case of international telex circuits terminated on a distant manual switchboard, a " proceed-to-transmit " signal shall be returned over the backward signalling path following the initiation of a call, to indicate that the teleprinter of the distant operator has been connected to the international circuit.

5. *Selection signals.*

a) The selection signals should be in conformity with international alphabet No. 2 or dial signals in conformity with Recommendation U.2.

b) In the case of dial selection into a system employing letters in the national numbering scheme, figures only will be used on international circuits, because of the difficulty in transmitting signals other than figures from dials.

c) In the case of selection into a keyboard selection system, the " prepare for digits " signal will be combinations 30 (figures shift).

d) In those cases where an " end-of-selection " signal is required, this signal shall be combinations 26, possibly followed by another combination characterizing the class of traffic in the incoming country.

e) In systems which use keyboard selection and which require an " end-of-selection " signal, the subscribers' numbers shall consist of a uniform number of characters. A smaller uniform number of characters is however permitted for special services, provided the discrimination of these special services can be affected on the first character.

f) To avoid undue occupation of lines and equipment, Administrations should take all reasonable steps to ensure that the transmission of selection signals over international circuits are completed without undue delay. In particular, where excessive delays are encountered the incoming country may cause the connection to be cleared.

6. *Call-connected signal.*

A " call-connected " signal shall be returned over the backward signalling path to indicate that the call has been extended to a called subscriber. In the case of fully automatic switching between subscribers, this signal will start the equipment for determining the charge for the call.

Switching systems not giving an automatic return of answer-back signals over the international telex circuits shall be arranged to be ready to respond to WRU signals (transmitted from the calling country) with a delay not exceeding 3 seconds from the beginning of the call-connected signal. (See Recommendation S.9.)

7. *Idle-circuit condition.*

On an established connection, the " idle-circuit " is characterized by a permanent signal corresponding to the stop impulse, in accordance with international telegraph alphabet No. 2, on the forward and backward signalling paths.

8. *Clearing.*

a) Clearing signal.

The clearing signal is characterized by a reversion to the condition specified in paragraph 1 on either signalling path maintained until the complete release of the circuit.

The supervisory equipment of the international connection shall be arranged to interpret a signal of " start " polarity as a clearing signal within 300 and 1000 milliseconds.

b) *Clear-confirmation signal.*

The clear-confirmation signal is reversion to the condition specified in paragraph 1 on the other signalling path in response to the clearing signal. When a clearing signal transmitted on an international circuit has reached the receiving end of that circuit the clear-confirmation signal must be sent back in the other direction within 350 to 1500 milliseconds after the initial " start " polarity begins.

The minimum period will be increased to 400 milliseconds for future systems.

c) *Guard delay.*

Guard arrangements at the ends of an international telex circuit should be such that the circuit cannot be used for a new call until the distant equipment is free to accept another call.

The equipment at the incoming end of the international circuit shall be completely released and ready to receive a new call after a maximum period of 2 seconds.

This delay is measured from the moment when in the international switching centre " start " polarity has appeared on both signalling paths of the circuit.

During this guard period, " start " polarity shall be maintained on both signalling paths of the international circuit.

9. *Service signals.*

a) *Signals for ineffective calls.*

If a " busy ", " out of order ", " office closed ", or " number unobtainable " (i.e. not connected, service ceased or barred access) condition is encountered in the distant network, this shall be indicated by the return of a signal to the calling end. If this is done by means of written indications, the code expression mentioned in Article 17 of Recommendation F.60 should be used.

In this case, the code expression should be preceded by the carriage return, line feed and letter shift signals and followed by line feed (preferably together with carriage return) and then immediately by the clearing signal in all cases.

In principle, unsuccessful telex calls are not chargeable. However, unsuccessfull calls are indicated in some networks by character sequences preceded by the " call-connected " signal; it might be difficult for some originating Administrations to prevent the charging equipment being set off upon reception of the call-connected signal and in this way unsuccessful calls might be charged for. To restrict this effect as much as possible the clearing signal should be sent immediately after the service sequences.

The Administrations will do their best to reduce the number of cases giving rise to such exceptions.

b) *Waiting signals.*

Study not concluded.

C. CHARACTERISTICS OF THE SIGNALS
defined in paragraphs 3, 4, 5, 6 and 9

The characteristics of these signals can be divided into two basic groups: Type A and Type B, as given in Tables I *a)*, I *b)* and II.

I. International telex circuits terminated on distant automatic switching equipment

Table I a). — *Semi-automatic working to subscribers*

Signal	Type A	Type B
Call-confirmation (see 3 and 4 *a)* above)	Permanent " stop " polarity	25 ms pulse of " stop " polarity (between 17.5 and 35 ms)
Proceed-to-select (see 4 *a)* above)	Teleprinter signal (s)	25 ms pulse of " stop " polarity (between 17.5 and 35 ms)
Selection (see 5 above)	Teleprinter signals	Dial pulses, or teleprinter signals
Call connected (see 6 above)	Teleprinter signals *Note :* The teleprinter signals may be preceded by a 150 ms (± 11 ms) pulse of " start " polarity	" Stop " polarity for at least two seconds
Busy (see 9 above)	Teleprinter signals followed by clearing signal	i) 200 ms pulse of " stop " polarity followed by " start " polarity for 1500 ms (tolerance: ± 30%) (Note 1) ii) 200 ms pulse of "stop" polarity (tolerance: ± 30%) followed by teleprinter signals and "start" polarity for 1500 ms (tolerance: ± 20%) (Note 1)
Out-of-order and number unobtainable (see 9 above)	Clearing signals normally preceded by teleprinter signals	i) Permanent " start " polarity ii) 200 ms pulse of "stop" polarity followed by " start " polarity for 1500 ms (tolerance: ± 30%) (Note 1) iii) 200 ms pulse of " stop " polarity (tolerance: ± 30%) followed by teleprinter signals and "start" polarity for 1500 ms (tolerance: ± 20%) (Note 1)

Note 1 : This sequence of signals may be repeated until a clearing signal is sent over the forward signalling path.

Table I b). — *Fully-automatic working between subscribers*

Signal	Type A	Type B
Call-confirmation (see 3 and 4 *a)* above	Permanent " stop " polarity	25 ms pulse " stop " polarity (between 17.5 and 35 ms)
Proceed-to-select (see 4 *a)* above)	40 ms (± 8 ms) pulse of " start " polarity	25 ms pulse of "stop" polarity (between 17.5 and 35 ms)
Selection (see 5 above)	Teleprinter signals	Dial pulses, or teleprinter signals
Call-connected (see 6 above)	150 ms (± 11 ms) pulse of "start" polarity followed by "stop" polarity for at least 2 seconds and possibly of teleprinter signals	" Stop " polarity for at least 2 seconds
Busy (see 9 above)	Teleprinter signals followed by clearing signal	i) 200 ms pulse of "stop" polarity followed by "start:" polarity for 1500 ms (tolerance: ± 30%) (Note 1) ii) 200 ms pulse "stop" polarity (tolerance ± 30%) followed by teleprinter signals and " start" polarity for 1500 ms (tolerance ± 20%) (Note 1)
Out-of-order and number unobtainable (see 9 above)	Clearing signal normally preceded by teleprinter signals	i) Permanent "start" polarity (Note 2) ii) 200 ms pulse of "stop" polarity followed by start polarity for 1500 ms (tolerance: ± 30%) (Note 1) iii) 200 ms pulse "stop" polarity (tolerance ± 30%) followed by teleprinter signals and "start" polarity for 1500 ms (±20%) (Note 1)

Note 1: This sequence of signals may be repeated until a clearing signal is sent over the forward signalling path.
Note 2: The use of this signal should be avoided if possible.

II. International telex circuits terminated on distant manual switching equipment

Signal	Type A	Type B
Call-confirmation (see 3 above)	Permanent " stop " polarity	25 ms pulse " stop " polarity (between 17.5 and 35 ms)
Proceed-to-transmit (see 4 *b)* above	Teleprinter signals	" Stop " polarity followed by teleprinter signals
Call-connected (see 6 above)	Teleprinter signals	Teleprinter signals
Busy, out-of-order and number obtainable (see 9 above)	Teleprinter signals	Teleprinter signals

RECOMMENDATION U.2

STANDARDIZATION OF DIALS AND DIAL PULSE GENERATORS FOR THE INTERNATIONAL TELEX SERVICE

(former C.C.I.T. Recommendation E.2, 1951, amended at Arnhem, 1953, and at Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

1. that, when dials and dial pulse generators are used for the process of automatic selection of subscribers to the international telex network, it is advantageous to standardize as far as possible the characteristics of such dials and dial pulse generators;
2. that the standardization of the dialling speed and lost motion periods of dials presents no technical difficulty;
3. that, for the satisfactory working of certain automatic systems, the time between successive pulse trains should not be less than 500 milliseconds, but that experience has shown that the minimum time taken by an experienced operator to rotate the dial is of the order of 300 milliseconds;
4. that pulse ratios from 1.2 : 1 to 1.9 : 1 will ensure the satisfactory working of existing automatic switching systems;
5. that these pulse ratios can be usefully adopted with a view to simplifying direct dialling between subscribers;

UNANIMOUSLY DECLARES THE VIEW

1. that in the international telex service, when dials or dial pulse generators are used for the automatic selection of subscribers:
   a) the dialling speed shall be standardized at 10 pulses per second with a tolerance of plus/minus ten per cent;
   b) the lost motion period of dials shall be not less than 200 milliseconds nominal value;
   c) the inter-digit pause of dial pulse trains generated by dial pulse generators shall not be less than 600 ms;
2. *a)* that the pulse ratio must be between 1.2:1 and 1.9 : 1, the nominal ratio may be chosen as lying between 1.5 : 1 or 1.6 : 1;
   b) that, when the selection signals pass through a regenerative repeater it may be advantageous to use a nominal ratio of 1.5 : 1.

RECOMMENDATION U.3

ARRANGEMENTS IN SWITCHING EQUIPMENT TO MINIMIZE THE EFFECTS OF FALSE CALLING SIGNALS

(former C.C.I.T. Recommendation E.3, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

— that transmission systems at present in use for international telex trunks are liable to generate false calling signals;

— that such false calling signals can seize and engage switching equipment, thereby reducing the grade of service. This is of particular importance with systems in which common equipment normally used only to set up calls is seized by false calling signals;

— that the ill effects of false calling signals can be minimized by delaying the operation of the calling relay at the termination of the international telex trunk circuit;

— that, however, when direct dial selection is employed over an international trunk line, unless it is a manually selected circuit, not preceded by a stage of automatic selection, there is normally insufficient time available between successive digits to permit the use of slow operating relays;

— that, nevertheless, Administrations may agree between one another to use digit storage at the outgoing end of the circuit so that the inter-train pause can be increased to permit the calling relays to be made slow to operate,

UNANIMOUSLY DECLARES THE VIEW

1. that the design and maintenance of transmission systems should be such as to reduce to a minimum the number and duration of false calling signals. In this connection attention is drawn to the merits of F.M. V.F. systems, particularly with long overhead lines;

2. that, wherever possible, calling relays on international telex trunk circuits should have an operation lag of at least 100 milliseconds. Administrations using circuits on lines prone to long duration false calling signals may agree to use calling relays with longer operation lags.

RECOMMENDATION U.4

EXCHANGE OF INFORMATION REGARDING SIGNALS DESTINED TO BE USED OVER INTERNATIONAL CIRCUITS CONCERNED WITH SWITCHED TELEPRINTER NETWORKS

(former C.C.I.T. Recommendation E.4, Geneva, 1956, modified at New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

that certain signals and certain characteristics of signals used in the international telex service have been standardized in Recommendation U.1;

that standardized signals for the European switched network for the public service (gentex network) are advocated in Recommendation U.30;

that in view of the foregoing an exchange of information regarding the precise nature of the signals proposed to be used in the above-mentioned services by interested Administrations would be very useful;

that certain Administrations have already supplied such details regarding their telex services in a useful form (see documents S.G. VII/28, 29, 30, 31 and 32 published in the " Supplements to the documents of the VIIIth Plenary Assembly of the C.C.I.T." pages 184 to 213),

UNANIMOUSLY RECOMMENDS

that Administrations concerned in the international telex service and gentex network be invited to supply to the C.C.I.T.T. time-sequence diagrams showing in each case the signals at present transmitted or proposed to be transmitted over the international circuit for incoming calls. The diagrams should show not only the sequence and characteristics of the signals, but also the timing tolerances to be expected.

RECOMMENDATION U.5

REQUIREMENTS TO BE MET BY REGENERATIVE REPEATERS IN INTERNATIONAL CONNECTIONS

(former C.C.I.T. Recommendation E. 5, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

— that it may be desirable to include regenerative repeaters in teleprinter switching networks;

— that the only signals other than teleprinter signals that must be transmitted by a regenerative repeater are the clearing signal and the call-connected signal (reference 3.1.3 below), since all other signals can be bypassed;

— that other signals may be transmitted by regenerative repeaters;

UNANIMOUSLY DECLARES THE VIEW

1. that when regenerative repeaters are used in switching systems, the clearing signal should be retransmitted with a minimum of delay. This delay is of course the same as for the retransmission of teleprinter signals;

2. that to ensure the correct retransmission of the clearing signal and the call-connected signal (reference 3.1.3 below) the regenerative repeater must not automatically insert the stop element in either of these signals;

3. that for other signals that may pass through regenerative repeaters, the tolerances at the origin and after retransmission through the regenerative repeaters are as stated below.

Note. — The characteristics and tolerances quoted are for the signals at the origin. The tolerances at the input to the regenerative repeater will depend on the degree of distortion in the transmission path from the origin to the input of the regenerative repeater. The tolerances at the output will depend on the normal tolerances for the regenerative repeater.

3.1. *Pulse signals.*

3.1.1. *Call-confirmation (proceed-to-select) signal.* Type " B " signalling.
A pulse of " stop " polarity of duration from 17.5 ms to 35 ms. The nominal duration of the pulse after transmission through the regenerative repeater should not be less than 20 ms nor more than 40 ms.

Note. — This signal will be transmitted over only one international trunk circuit and should thus normally pass through not more than one regenerative repeater.

3.1.2. *Dial selection signals.* Type " B " signalling.

These signals have been standardized (Recommendation U.2 refers) at a dial speed of 10 pulses per second $\pm$ 10%, and a pulse ratio (start : stop) between the tolerance of 1.2 : 1 and 1.9 : 1 with a nominal ratio lying between 1.5 : 1 and 1.6 : 1. Such signals after retransmission through several regenerative repeaters should not fall outside the tolerances above stated.

3.1.3. *Call-connected signals.* Type " A " signalling.

A pulse of " start " polarity lasting 150 $\pm$ 11 ms. The nominal duration of the pulse after retransmission through several regenerative repeaters should be within the limits of 140 to 160 ms.

3.1.4. *Busy signal. Type* " B " signalling.

Pulses of "stop" polarity lasting 200 ms ± 30%, separated by intervals of "start" polarity lasting 1.2 second ± 30%. After retransmission through several regenerative repeaters neither the pulses nor the intervals should be shortened by more than 10%.

3.2. *Sequence signals (involving a single change of polarity)*

3.2.1. *Calling signal.* Types " A " and " B " signalling.

3.2.2. *Call-connected signal.* Type " B " signalling.

These signals (inversion from " start " to " stop " polarity) have no timing tolerances as such. It is, however, essential that they should be retransmitted by a regenerative repeater with a minimum of delay, which in any case should not exceed 20 ms.

RECOMMENDATION U.6.

PREVENTION OF FRAUDULENT TRANSIT TRAFFIC IN THE FULLY AUTOMATIC INTERNATIONAL TELEX SERVICE

(New Delhi, 1960)

With fully automatic working in the international telex service, the possibility of fraudulent routing by subscribers of international calls involving tandem connection of international telex trunks might arise whenever subscribers are given automatic access to international telex trunk circuits which have, at their incoming ends, automatically switched access to other international telex trunk circuits.

By the adoption of a systematic plan, such traffic can be barred without involving either expensive or elaborate equipment arrangements.

To be effective such a plan would need to be adopted by all Administrations and Operating Agencies since failure to provide barring facilities on the traffic between two countries could open the way for irregular routings at the expense of a third country.

The C.C.I.T.T. therefore

UNANIMOUSLY DECLARES THE VIEW:

1. That national telex systems shall be so arranged that the first digit of the selection signals transmitted over incoming international telex trunks will indicate whether an automatic transit call is concerned;

2. That where an international telex trunk carrying fully automatic traffic also carries traffic requiring access at the incoming end to outlets selected by means of the digit

characterizing an automatic transit call, the country of origin will bar irregular routings, by discriminating on the digits transmitted by calling subscribers;

3. That where an international telex trunk carrying fully automatic traffic does not carry traffic requiring access at the incoming end by means of the digit characterizing an automatic transit call, the incoming equipment shall be so arranged that the corresponding outlets are not accessible and that when access is attempted, the "number unobtainable" signal is returned;

4. That it is not admitted that two Administrations can agree to omit the provision of barring facilities on traffic between their respective countries. However, where the incoming country has an existing network in which considerable difficulty would be experienced in barring in accordance with paragraph 3, the responsibility for barring may, by agreement, be assumed by the country of origin in the manner specified in paragraph 2.

Note about paragraph 1. — The use of a common first digit to indicate access to both international telex trunk circuits and manual switchboards leads to complication in the barring arrangements and should therefore be avoided. However, where this would lead to exceptional difficulty in existing systems, the use of a common first digit can be allowed.

RECOMMENDATION U.7.

NUMBERING SCHEMES FOR AUTOMATIC SWITCHING NETWORKS

(former C.C.I.T. Recommendation E.7, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that with fully automatic working between subscribers in the international telex service it is desirable to envisage the possibility:

a) to route traffic over the appropriate international trunk route where more than one such route exists between two countries;

b) to enable the appropriate tariff to be determined automatically (in the originating country), even if the objective country is divided into several tariff zones;

UNANIMOUSLY DECLARES THE VIEW

1. that subscribers' national numbering plans should be systematically arranged;

2. that, where more than one international trunk route exists between two countries, the corresponding geographical division and hence the appropriate point of entry should be identifiable by examination of the initial digits of the called subscriber's number;

3. that where a multiple tariff scale exists, the different tariff zones should be identifiable in the originating country by the initial digits of the called subscriber's number;

4. that the number of initial digits to be examined should be limited, preferably to one, but in any case should not exceed two. When a single digit provides the discrimination it will usually be the first digit, but, where the subscribers' numbers have a uniform initial digit (usually " 0 ") to permit discrimination on internal calls, the following (second) digit should be used.

Note. — The attention of Administrations (and Recognized Private Operating Agencies) is drawn to the considerable technical advantage which would result from the adoption of a single tariff between two countries.

RECOMMENDATION U.8.

INTERNATIONAL NUMBERING PREFIXES

(New Delhi, 1960)

In an international call, the national number of the called subscriber has to be preceded by a prefix which enables access to be given to the called country from the calling one.

A uniform prefix scheme would be one in which the prefix for a called country would be the same, no matter what the calling country might be.

The chief advantage of the uniform prefix scheme is that it affords facilities for the automatic alternative routing of traffic with fully automatic operation, when such re-routing involves a transit country other than the normal one.

In the European system, there is no great point in such automatic re-routing, in view of the facilities afforded by voice-frequency telegraph systems.

Between continents the problem is different, because channels are fewer and are more heavily loaded, and automatic re-routing over a second choice route might conceivably be useful with fully automatic operation.

The uniform scheme would have an advantage in so far as it would prevent Administrations from changing their prefixes too often, which might well cause inconvenience to those countries having to use transit connections.

But the drawbacks of a uniform prefix scheme are as follows:

— complication of national networks,
— lack of flexibility,
— present acceptance of future commitments,
— premature expenditure on equipment not required for a considerable time to come.

The absence of a standardized range of country codes or prefixes would not prevent the provision of facilities for automatic alternative routing and/or re-routing, although there would be some increase in the complexity of the register translators required.

For these reasons, the C.C.I.T.T. realizes that, for the moment, a uniform prefix scheme is not feasible for the European telex and gentex networks, and

UNANIMOUSLY DECLARES THE VIEW

1. that the prefix should characterize the called country from the calling country;
2. that countries providing transit services must avoid frequent changes in the codes used for routing transit traffic.

Note. — See Question 8/X concerning intercontinental traffic.

RECOMMENDATION U.10.

EQUIPMENT OF AN INTERNATIONAL TELEX POSITION

(former C.C.I.T., Recommendation F.60, modified at New Delhi, 1960)

An international telex position, which is a manual position in an international telex exchange and is used to set up international telex calls, should be so equipped as to permit of satisfactory operation in conformity with C.C.I.T.T. Recommendation F.60 (*Red Book*, volume II *bis*).

For the above reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. An international telex position must be equipped in such a way as to receive the clearing signal from both sides.
2. It should not be possible to recall the operator of that position by a signal to an established connection, except if Recommendation U.21 is applied.
3. Precaution must be taken that in the event of the operator of the international telex position delaying to remove the plug on reception of the clearing signals, a new call from a subscriber on one network shall not pass to the other network.
4. When communication has been established, the answer-back signals of apparatus used at the intermediate telex positions must not be sent to line, when figure-shift D is received.
5. The international telex position must be provided with equipment to determine the chargeable time of calls controlled by these positions, this timing equipment to be brought into operation in accordance with the provisions of Article 16 of Recommendation F.60 (*Red Book*, volume II *bis*), but to be stopped on receipt of the first clearing signal.

RECOMMENDATION U.20.

TELEX SIGNALLING ON RADIO CHANNELS

(Synchronous 7-unit systems affording error correction by automatic repetition)

(former C.C.I.T. Recommendation E.6, Geneva, 1956, amended in New Delhi, 1960)

The C.C.I.T.T.,

CONSIDERING

1. that there are radio telegraph circuits working in association with 5-unit start-stop apparatus, which make use of error-correcting synchronous systems having a special error-detecting 7-unit code enabling errors to be corrected;
2. that, on the radio section, these synchronous systems use two combinations α and β which characterize the permanent conditions of " start " polarity and " stop " polarity respectively, in the start-stop part of the connection;
3. that the special make-up of these systems is such that a change in significant condition at the input to the system is not reproduced at the output with a constant delay;
4. that it is desirable to standardize the signalling conditions to be used on synchronous error-correcting radiotelegraph systems;
5. that the experience acquired with manual telex switching through these radiotelegraph systems seems sufficient to justify the laying down of general rules specifying signalling arrangements for manual and semi-automatic working in such international radio channels,

UNANIMOUSLY DECLARES THE VIEW

that the signals enumerated in Recommendation U.1, to be used in setting up international telex calls over radio channels comprising synchronous systems with error correction by automatic repetition, should be characterized as follows:

A. *Free line condition.*

Successive α combinations on the forward and backward paths.

B. *Call.*

Transition from combination α to combination β. Reception of two consecutive β signals over the forward signalling path shall be interpreted as a calling signal.

On circuits automatically operated in both directions, reception of a single β signal at the end of the circuit remote from the calling subscriber must cause the outgoing equipment on this circuit at that end to be marked busy immediately. This busy condition must be applied until two α signals are received.

C. *Call-confirmation signal.*

Transition from combination α to combination β on the backward signalling path. Reception of two consecutive β signals over the backward signalling path shall be interpreted as a call-confirmation signal.

D. 1. *Proceed-to-select signal* (when a separate signal is required).

On the backward signalling path: one or more teleprinter signals.

2. *Proceed-to-transmit signal.*

On the backward signalling path: teleprinter signals indicating the called operator's position.

The sending of the proceed-to-select or the proceed-to-transmit signal should be delayed until two consecutive β signals have been correctly received over the backward signalling path. Two consecutive β signals can be presumed to have been or to be received when four β signals have been accepted by the storage of the error correcting equipment at the sending end.

The receiving equipment shall be arranged so that when two β signals are received and followed immediately by teleprinter signals [representing the call-confirmation and proceed-to-select (or proceed-to-transmit) signals in rapid succession] the recognition of the two β signals as the call-confirmation signal will allow the teleprinter signals to be preceded by 140 ms (minimum) of "stop" polarity.

E. *Selection signals.*

Teleprinter signals over the forward signalling path.

F. *Call-connected signal.*

1. Manual working: the code DF over the backward signalling path.

2. Semi-automatic working: one or more teleprinter signals, over the backward signalling path.

G. *Idle circuit condition.*

Combination β on the forward and backward signalling path.

H. 1. *Clearing signal.*

The appearance of α combinations in the direction in which the clearing signal is sent. Reception of two consecutive α signals will have to be interpreted as a clearing signal.

2. *Clear confirmation signal.*

The appearance of α combinations in the direction opposite to that from which a clearing signals was sent.

Reception of two consecutive α signals will be interpreted as a clear confirmation signal when a clearing signal of * 8 α signals without request for repetition has been transmitted on the other path.

3. *Guard delay.*

The circuit shall be guarded on release as specified in Recommendation U.1 except that the delay shall be measured from the moment when the equipment has both:

a) transmitted * 8 α signals over the radio path without request for repetition,

b) has received two consecutive α signals over the other signalling path.

During the guard period the free line condition shall be maintained on both signalling paths of the international circuit.

I. *Service signals.*

Corresponding teleprinter signals (OCC, NC, NA, NP, DER, ABS), followed by the clearing signal.

Note *. — For radio circuits employing a 4-character cycle, a sequence of 7 α signals is permissible.
Note 1. — See Recommendation S.13 for signals α and β.
Note 2. — See Question 4/X.
See Supplements to Series U Recommendations, page 340.

RECOMMENDATION U.21.

OPERATOR RECALL ON A TELEX CALL SET UP ON A RADIOTELEGRAPH CIRCUIT

(New Delhi, 1960)

Experience has shown that, for telex calls set up over a radiotelegraph circuit, it was useful to enable the telex subscriber to cause an operator to re-enter on a call in progress without interrupting it.

Such re-entry may be of interest in the following cases as well as in the case of a defective connection:

1. When a subscriber decides, in the course of a call, to change from a plain text to a cypher he can call the operators in the terminal radio exchanges and ask them to interrupt the delay signal which might otherwise disturb the synchronism between the cyphering apparatus used at the two ends.

2. When a subscriber has sent a message but waits a very long time for a reply from his correspondent, he can ask the operator whether his message is still being stored or whether it is expected that any interruption to the radio circuit will continue. If

need be, he can then choose another means of communication (telegram or telephone call) to send an urgent message to its destination.

Although it seems that re-entry by an operator will be limited mainly to national networks (for example by a subscriber calling the controlling telex operator on the radiotelegraph circuit), international standardization of an " operator recall " signal would be useful if the controlling telex operator on the radiotelegraph circuit is located in a transit country, and also for intermediate manual switches; this would no doubt prove to be a great advantage when this possibility is generally utilized.

The C.C.I.T.T. therefore

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. If the Administrations concerned agree on the use of a special signal enabling a subscriber to recall an international telex operator's position making use of radiotelegraph circuits, such a recall must not cause release of a call in progress;

2. This " operator recall " signal will consist of the following sequence: combinations 28 (line feed) followed four times by combinations 27 (carriage return);

3. The detection device causing re-entry by the operator will be controlled by the receipt of four consecutive combinations 27; combinations 28 will only be used to avoid superposition of the text on the receiving teleprinter and will not have to be recognized by the detection device.

RECOMMENDATION U.22.

SIGNALS INDICATING DELAY IN TRANSMISSION ON CALLS SET UP BY MEANS OF SYNCHRONOUS SYSTEMS WITH AUTOMATIC ERROR CORRECTION BY REPETITION

(New Delhi, 1960)

Traffic observations on radio telex channels have shown that the possible delay in the reception of text transmitted by one subscriber to another is a drawback from the operating point of view. The delay may be caused by repetitions and/or difference in the modulation rate of the teleprinters (traffic from Europe to the U.S.A.). In case of such delays a subscriber is left in doubt whether he simply has to await transmission of his message over the radio path or whether the delay is due to the tardy answering of his correspondent for which he will have to pay. Furthermore, in the case of delays due to long repetition periods a receiving subscriber may be tempted to answer prematurely, which causes garbling of the text.

To a certain extent this drawback can be offset by the application of a strict operating procedure (" + ? " signal to invite the correspondent to transmit). However, supplementary technical measures have proved to be desirable.

A good technical solution of this problem is to use combinations 32 as a delay signal in the following manner:

a) combinations 32 are returned to the transmitting subscriber at the rate of one every 5 seconds if he stops transmission during an interval of 10 seconds and the local storage device still contains untransmitted tape;

b) combinations 32 are sent to a subscriber at the rate of one every 1.2 second if transmission is delayed by repetitions whenever condition *a)* does not apply.

The slow delay signals inform a sending subscriber that his message has not yet been received by his correspondent. The rapid delay signals inform a receiving subscriber that the received message is not yet complete and that he should not cut in.

In the case of cipher messages where combinations 32 may result from the coding procedure, delay signals should not be used. Also in the case of full duplex working, waiting signals cannot be used. Furthermore it is desirable not to transmit waiting signals during the setting-up of semi or fully-automatic calls, since interpolated waiting signals would complicate the discrimination of the selection signals and the call-connected signal. Therefore, the best solution seems to be to put the switching on and off of the delay signal facility under the control of the subscribers: four consecutive combinations 8 or 14 could be used for this purpose.

The transmission of these delay signals can obviously not be imposed on an Administration which makes the connection by an international land line and a radio channel.

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE VIEW:

1. That, when the Administrations concerned agree that it is necessary to signal to telex subscribers about a delay in transmission over the radio telex channel, delay signals shall be used having the following characteristics:

   a) Combinations 32 at the rate of one every 5 seconds, returned to a sending subscriber when he has stopped transmission for a period of 10 seconds and if there is still text stored;

   b) Combinations 32 at the rate of one every 1.2 second sent to a subscriber whenever transmission over the radio channel is delayed by repetitions and condition *a)* above does not apply.

2. Sending of combinations 32 is cut off as soon as the subscriber starts to transmit again.

(U.22)

3. No delay signal will be transmitted while the call is being put through.

4. The calling and also the called subscriber can suppress sending of the waiting signal at the two ends of the radio circuit by transmitting four successive combinations 8. The waiting signal can also be started off again by transmitting four successive combinations 14.

Note. — Administrations must take precautions to ensure that the reception of combinations 32 should not cause spacing of the paper on page-printing or tape-printing apparatus.

RECOMMENDATION U.30.

SIGNALLING CONDITIONS FOR USE IN THE INTERNATIONAL GENTEX NETWORK

(New Delhi, 1960)

The conditions in recommendation U.1 concerning signalling in the international telex service, the specifications in Recommendation U.2 for standardization of dials and dial pulse generators in the international telex service, in Recommendation U.3 for the reduction of the effect of false calling signals, and in Recommendation U.5 on the characteristics of regenerative repeaters used in international calls, will hold good in the gentex network, except those referring specifically to manual or semi-automatic working. In some countries, indeed, no distinction is made between the gentex and the telex networks.

The differences between signalling conditions in the telex and the gentex networks are essentially due to the possibility of using overflow or waiting in the gentex network, and the absence of charges in it.

Hence, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. The recommendations in sections A and B of Recommendation U.1 (signalling conditions for use in the international telex service) shall also apply to the gentex network subject to the following changes.

Section B — paragraph 4 b) (Proceed-to-transmit signal)

The proceed-to-transmit signal is not used in the gentex network, since switching is always automatic.

Section B — paragraph 5 (Selection signals)

This paragraph should be read as follows for the gentex network:

c) If there is selection towards a system in which selection is by teleprinter signal, the prepare for digits signal will normally be combinations 30 (figures shift). By agreement between the Administrations concerned, this combination could be replaced by another combination for gentex calls over circuits used for gentex and telex traffic simultaneously, if the network of the country of arrival can ensure barring between the two kinds of traffic.

Section B — paragraph 9 (Service signals).

Should a call be waiting for connection to the called office (see Recommendation F.22, Article 16) the signal MOM can be sent to the calling exchange as soon as the waiting period begins. The waiting period cannot exceed one minute; it shall be followed by the transmission of the answer-back of the called station (or possibly by the answer-back of an overflow teleprinter if overflow facilities are provided) or in the case where there is no teleprinter available at the expiry of the waiting period by the transmission of the busy signal.

2. Table I *b)* of the characteristics of signals of Section C of Recommendation U.1 applies to the gentex network.

3. Recommendations U.2 = Standardization of dials and dial pulse generators for the international telex service,
U.3 = Arrangements in switching equipment to minimize the effects of false calling signals,
U.5 = Requirements to be met by regenerative repeaters in international connections apply to gentex network.

RECOMMENDATION U.31.

PREVENTION OF CONNECTION TO FAULTY STATIONS AND/OR STATION LINES IN THE GENTEX SERVICE

(former C.C.I.T. Recommendation E.9, Geneva, 1956)

The C.C.I.T.T.,

CONSIDERING

that correct reception of the answer-back code at the beginning and end of a telegram should safeguard the correct transmission of the telegram;

that it accordingly becomes essential to provide adequate signalling for cases when a teleprinter is temporarily unable to participate in the international service, on account of paper trouble, faults, etc.,

A. UNANIMOUSLY DECLARES THE VIEW

that faults during the transmission of a telegram shall be signalled as far as possible by the automatic transmission of a clearing signal;

RECOGNIZING, HOWEVER,

that it will be impossible to signal all faults that may occur on an established connection,

UNANIMOUSLY DECLARES THE VIEW

that it is essential that absence of paper on a receiving teleprinter should be signalled by the clearing signal,

B. UNANIMOUSLY DECLARES THE VIEW

that, since the receiving administration is responsible for the receipt of the telegram when the answer-back signals have been correctly exchanged, it is responsible for making the necessary arrangements to ensure security of operation (for example, if the tape should break or become jammed);

that in the case of a faulty station line or teleprinter at the moment of the call, the existing automatic switching networks use one or more of the following signalling conditions: no " call-connected " signal, " busy " signal, service code " DER " or no return of answer-back. All these signalling conditions ensure that a telegram is not transmitted over a faulty connection;

that in the case of a faulty station line out of an office group it is essential that the faulty line should be busied out as quickly as possible so that traffic may be offered automatically to all the other lines in the group.

LIST OF THE QUESTIONS ON TELEGRAPH TECHNIQUE TO BE STUDIED DURING THE PERIOD 1961-1964

QUESTIONS TO BE STUDIED BY STUDY GROUP VIII: ALPHABETIC TELEGRAPH APPARATUS

Chairman: Mr. KERR (Australia)

Vice-Chairman: Mr. SAVITZKY (Ukrainian S.S.R.)

Question 1/VIII — Telemargin measurements.

(Continuation of Question 2/8 of Study Group 8, 1957-1960)

In attempting to measure the margin of a local end (with its terminations) from a distant point, through the intermediary of a transmission channel, what relation is there between the result of this measurement, the true margin of the local end and the degree of inherent distortion in the transmission channel ?

Should such measurements be recommended ?

ANNEX TO QUESTION 1/VIII

The Administrations will undertake a measurement programme as described below:

1. The measurements should consist of:

a) a margin measurement M (telemargin) towards the receiving apparatus from the end of the transmission channel remote from the receiving apparatus (1 in diagram of fig. 8);

b) a margin measurement μ towards the local end (with its terminations) made from the last point at which the signals are repeated (2 in diagram of fig. 8);

c) a measurement of the inherent distortion δ of the transmission channel between points 1 and 2.

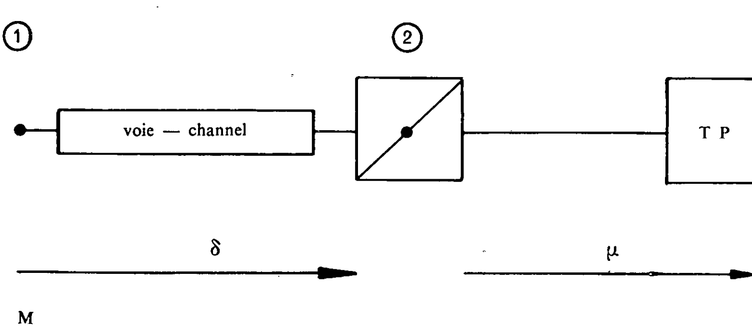


FIGURE 8

The following characteristics are recommended for the measuring apparatus to be used:

a) the mean speed accuracy of the margin measuring apparatus should be $\pm$ 1/1000; the apparatus can, if necessary, be calibrated before each measurement or series of measurements;

b) nominal transmission cycle of 7.5 units;

c) use of one of the texts recommended in C.C.I.T.T. Recommendation R. 52;

d) production of distortion by lengthening all the start signals (" late " distortion) or shortening all the start signals (" early " distortion), the code elements retaining their nominal theoretical length, and the intervals between successive start signals being constant and equal to the duration of the nominal transmitting cycle;

e) measurement of the effective net margin, i.e. for a modulation speed equal to the standard theoretical speed (to $\pm$ 1/1000).

2. The aim of the first series will be to find, for *terminal sets*, the curve giving the error rate as a function of the distortion of signals at the input of the terminal set.

In practice, this curve showing error rate as a function of distortion at the terminal set input, with logarithmic scale for the ordinates, can be assumed to be a straight line.

A first point in this straight line was laid down: error rate: 1/100; degree of distortion: 35%.

Measurements should be made to fix other points, for example, those corresponding to the error rates, $\frac{10}{100}, \frac{5}{100}, \frac{1}{1000}$.

3. The aim of a second series will be to establish diagrams giving similar curves for telemargin, i.e. for the margin measured across a channel with an inherent distortion degree δ.

Measurements will have to be taken with channels with different degrees of inherent distortion — degrees of $\delta 1, \delta 2$, $\delta 3$, etc. in order to arrive at the curves for values of $\delta 1$, $\delta 2$, $\delta 3$, etc.

These distortion rates will be measured in the conditions indicated in Recommendation R. 5.

4.*a)* Results of margin measurements on local ends are given:

- in Supplements to the *Violet Book* (page 92 and ff., contribution of France);
- by the curves below (curves fig. 9, 10, 11 and 12) extracted from a contribution by the Federal Republic of Germany (COM 8, No. 7, 1957-1960);
- in Supplements to Recommendations of Series S, page 302;

b) Results of margin measurements over a voice-frequency telegraph channel are given:

- in Supplements to the *Violet Book* (page 97 and ff., contribution of France);
- by the curves below (curves fig. 13 and 14), extracted from a contribution by the Federal Republic of Germany (COM 8, No. 8, 1957-1960).

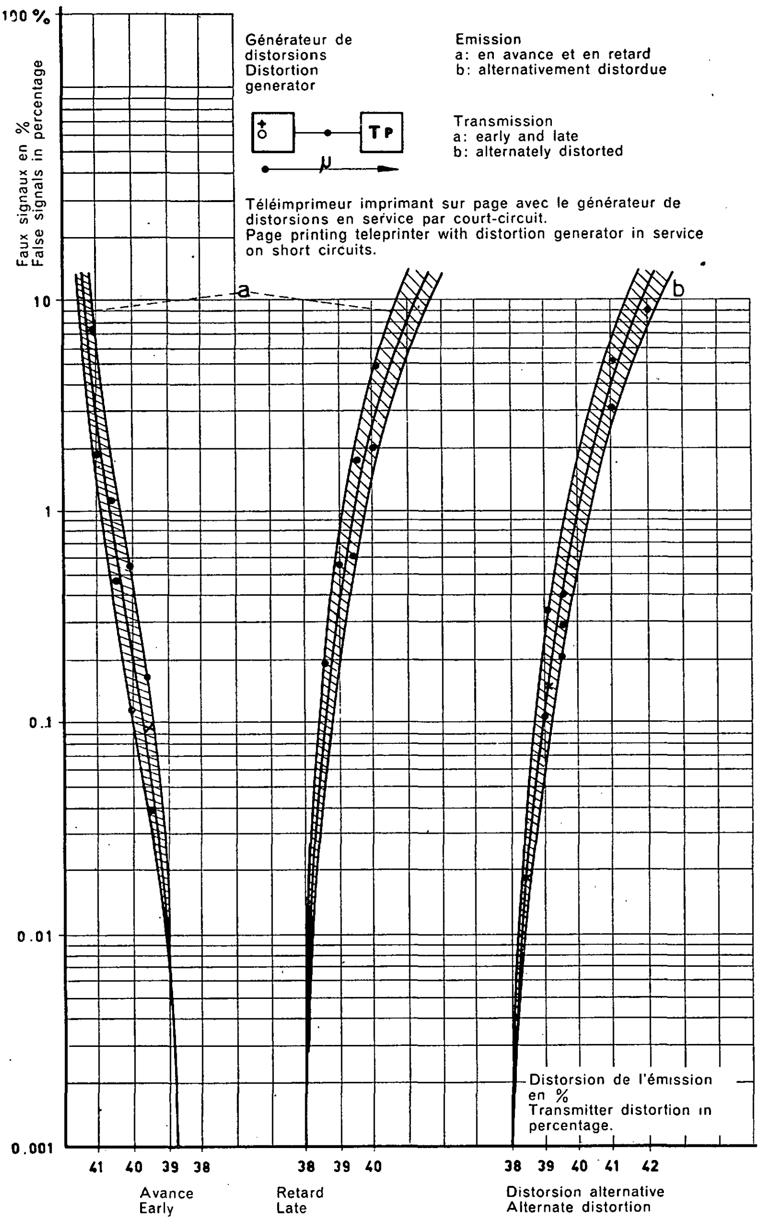


FIGURE 9. — *Statistical study of Lorenz Lo 15 No. 13618 page-printing teleprinter receiver margin*

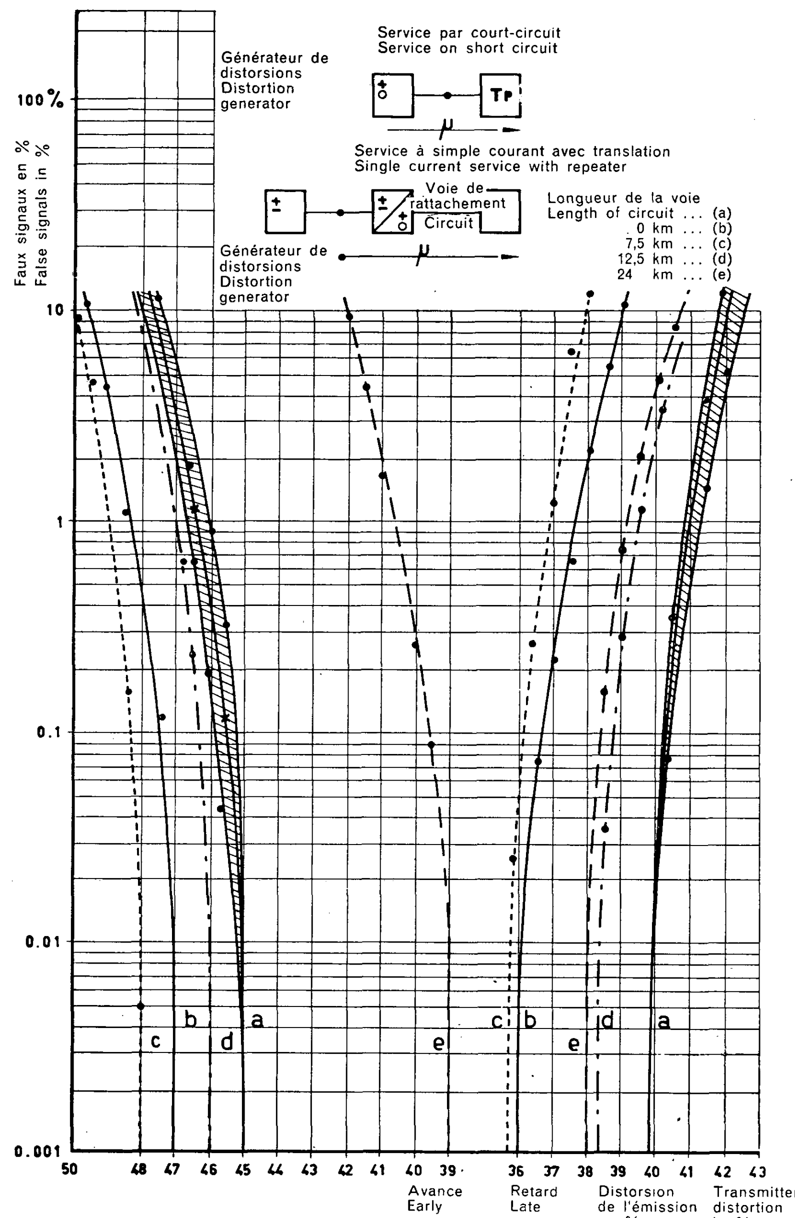


FIGURE 10. — *Statistical study of Siemens & Halske page-printing T type 37 i No. 15141 teleprinter margin in service on short circuit and with repeaters, taking account of circuit length*

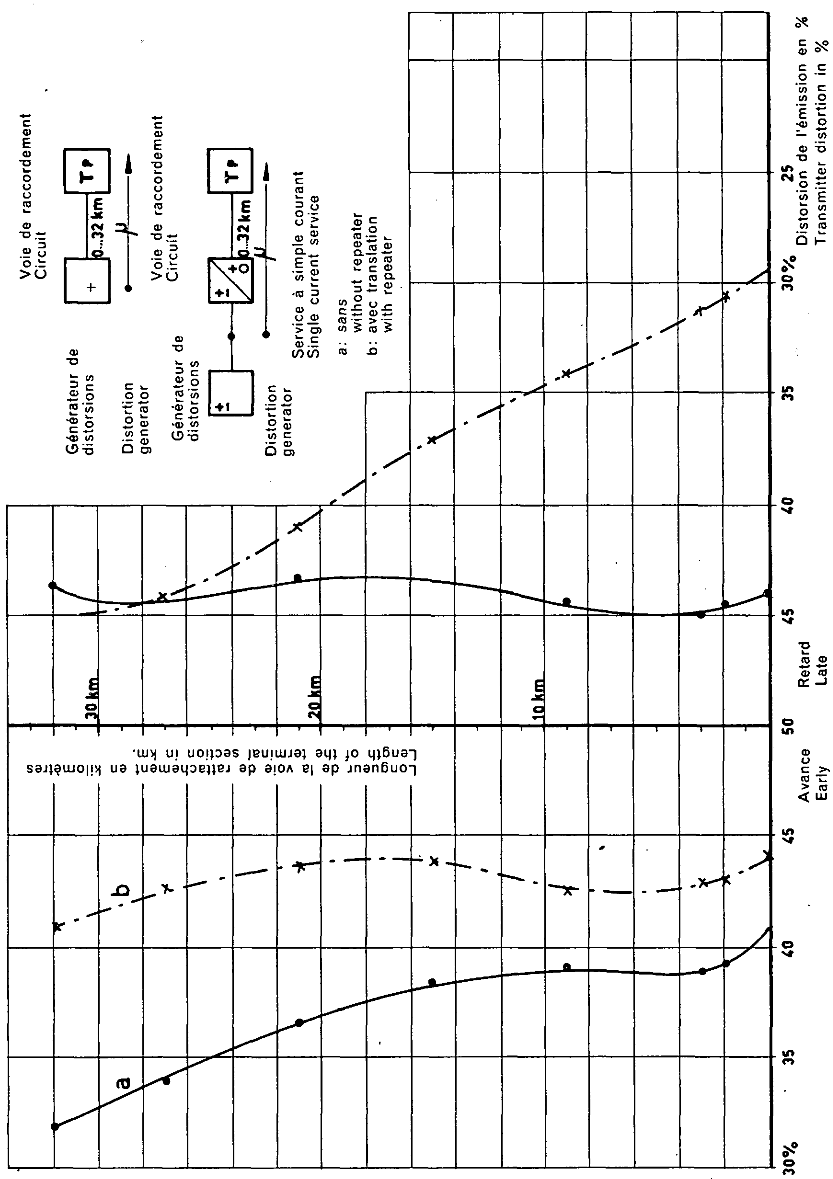


FIGURE 11. — *Margin of Lorenz Lo 15 No. 10593 page-printing teleprinter with error rate of 2 × 10^{-2} as a function of the circuit length*

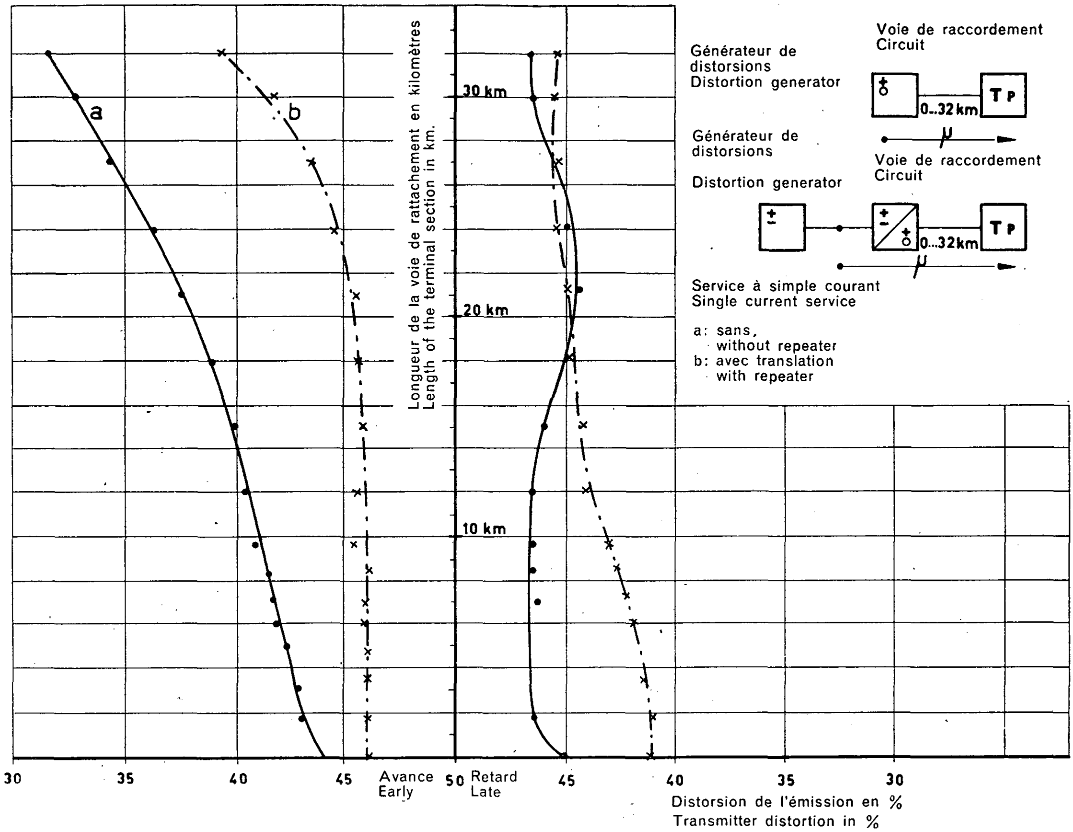


FIGURE 12. — *Margin of Siemens & Halske type T 37 h No. 13508 page-printing teleprinter with error rate of 2 × 10–2 as a function of the circuit length*

Question 2/VIII — Start-stop apparatus for more than 50 bauds.

(interests Study Groups I and IX; see Question 16/IX)

What standards should be recommended for start-stop apparatus using alphabet No. 2 and operating at modulation rate of more than 50 bauds ?

Note. — The new modulation rates envisaged would be 75 and 100 bauds (so as to maintain a simple relationship with the modulation rate of 50 bauds).

Question 3/VIII — Reception on prepared forms.

(former Question 5/8 of Study Group 8, 1957-1960)
(interests Study Group I; see Question 4/I, Volume II bis*)*

Study of the reception of telegrams on prepared forms.

Note. — This question should not be studied until reply to Question 4/I has been prepared by Study Group I.

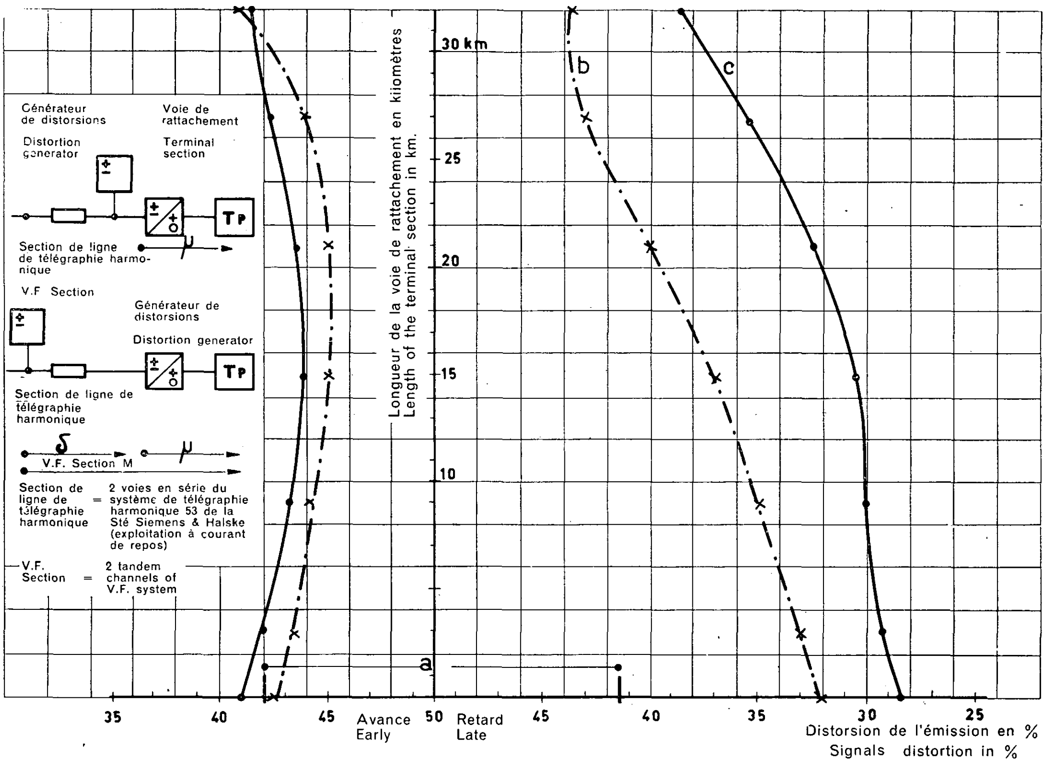


FIGURE 13. — *Margin of the receiving local end (with its termination) of the Lorenz Lo 15 No. 10593 page-printing teleprinter as a function of the terminal line section, measured through V. F. channels (Orientation range device symmetrical adjusted in service by short-circuiting the apparatus)*

Question 4/VIII — Answer-back signals for telex service.

(interests Study Group I)

Should C.C.I.T.T. Recommendations S.6 and F.60 be amended so that, in the telex service, the 4th signal sent by answer-back unit is made freely available to the Administrations ?

ANNEX TO QUESTION 4/VIII

(Contribution from the Netherlands: Contribution COM 8, No. 69, period 1957-1960)

According to Recommendation S.6 of the C.C.I.T.T. and Recommendation F.60 of the C.C.I.T.T., the answer-back must transmit 20 signals of which 15 may be chosen by each Administration.

In practice, the number of signals left to the choice of Administrations is often used up; the number of these signals should therefore be as large as possible. It would thus seem useful to give further consideration to the five obligatory signals. Under Recommendation S.6, the answer-back transmission must begin with the following four signals:

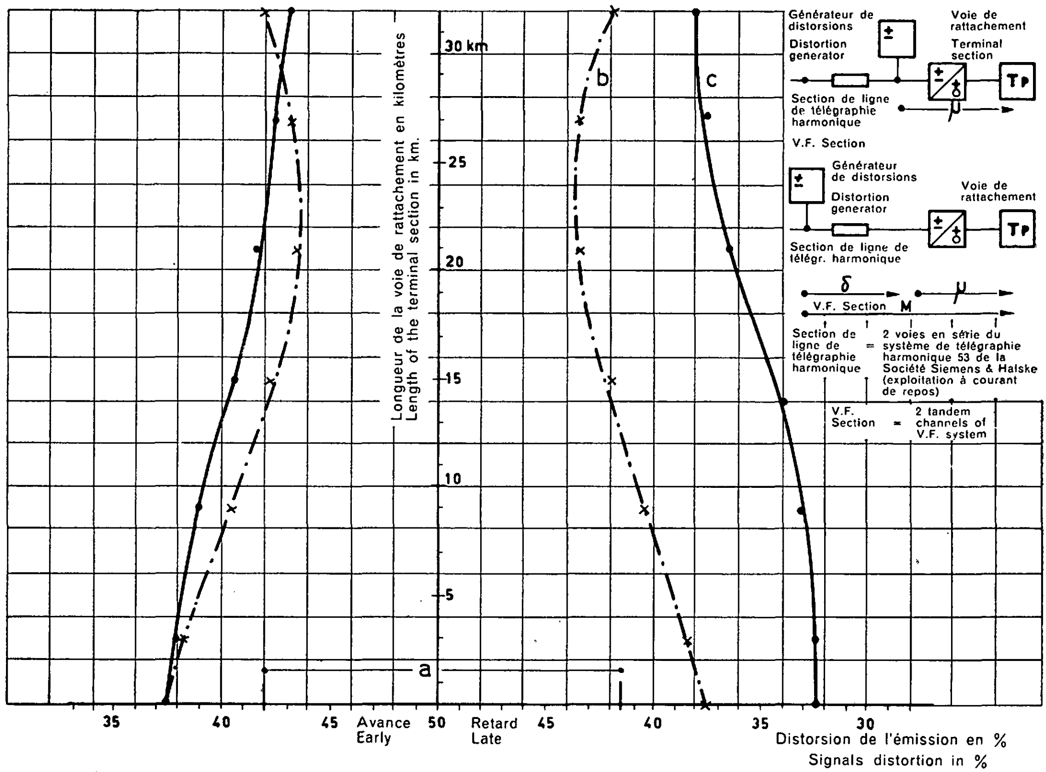


FIGURE 14. — *Margin of the receiving local end (with its termination) of the Lorenz Lo 15 No. 10593 page-printing teleprinter as a function of the terminal line section, measured through V. F. channels (Orientation range device symmetrically adjusted in service by short-circuiting the apparatus)*

1 signal " letters ",
1 carriage return,
1 line feed,
1 signal " letters " or " figures " (as appropriate).

The following remarks may be made in this connection:

The first signal " letters " cannot be omitted since there is an automatic switching system in which the charging or not of a call depends on whether the answer-back begins with the signal " letters " or with " carriage return ".

The " carriage return " and " line feed " signals cannot be omitted if one wishes to be sure that the full answer-back is printed under all circumstances.

On the other hand, the second signal " letters " or " figures " (as appropriate) may, in the view of the Netherlands Administration, be omitted when the text of the answer-back begins with letters.

When the text of the answer-back begins with figures, the signal " figures " should be used instead, but this signal may be left free for use at the choice of the Administrations concerned.

As far as we know, this signal originally has to be introduced as signal " letters " or " figures " because at that time telex traffic by means of single-frequency telegraphy over telephone-switching circuits was still used.

In such cases, the possible presence of echo suppressors on the telephone circuit might mean that the first signal " letters " would not be correctly received.

Also bearing in mind the Gentex Regulations (Recommendation F.22, Article 2), the Netherlands Administration considers that the other Administrations should now be asked to study whether it is still necessary to transmit the second signals " letters " or " figures " on an obligatory basis with teleprinters used in the telegraph subscribers' service.

Under Recommendation S.6, the last signal transmitted must also be the signal " letters ". This signal cannot be omitted because of the use of teleprinters where the mechanical construction of the answer-back transmitter makes this signal essential.

Furthermore, this last signal " letters " is useful with teleprinters where the signal last received is not immediately printed, preventing the complete answer-back from being read straight away.

Question 5/VIII — Synchronous telegraphy.

(interests Study Groups IX and X and the C.C.I.R.; study to be entrusted to a joint-working-group of Study Groups VIII, IX and X)
(see also Question 6/VIII)

Synchronous modulation enables a larger number of telegraph channels to be constituted by time sub-division of a standardized telegraph channels.

Such an increase is of particular interest in the case of submarine cables of the telephone type in view of the resulting economies.

Furthermore, the transmission of some of the telegraph switching signals defined in Recommendation E.1 is essential when incorporating the telegraph channels thus set up into the international switching network.

1. What switching signals is it essential to transmit ?

2. What characteristics should be recommended for telegraph modulation ?

3. What characteristics should be recommended for the transmission of this modulation ?

In the study of this question, it is suggested that consideration should be given, in particular, to standardizing the following aspects:

a) code,

b) method of manual and automatic phasing.

c) method of transmitting the full range of telex supervisory signals for type A and type B,

d) standards of performance,

e) method of multiplexing and sub-dividing,

f) transposition pattern.

ANNEX TO QUESTION 5/VIII

(Contribution of the United Kingdom: Contribution COM 8/66, of 1957-1960 period)

I. Synchronous radio-telegraph channels.

This part of the Question is answered by Recommendation S.12. The United Kingdom Administration would like to make the following comment:

Item 3 of the proposed Recommendation S.12 allows a tolerance of $\pm 10^{-4}$ on the interval between successive start elements.

If a synchronous radio-telegraph channel should be connected in tandem with a synchronous cable channel (see II below) having a single-character store, one channel being on the upper and the other being on the lower limit, the possibility exists that *two* characters in 10 000 will be lost owing to this cause.

The United Kingdom Administration proposes therefore that the tolerance should be improved to $\pm 10^{-6}$, which is not difficult to achieve.

II. Synchronous cable channels.

In recent years the United Kingdom Administration, in common with certain other Administrations and Operating Agencies, has embarked on a programme of laying long-distance submarine telephone cables for inter-connecting national networks. On these telephone cables, telegraph circuits are provided by means of voice-frequency multi-channel equipment. The voice-frequency telegraph equipment used by the United Kingdom Administration employs frequency-shift modulated channels spaced at 120 c/s in conformity with Recommendation R.35 of the C.C.I.T.T.

In view of the high cost of establishing such valuable and stable circuits, and of the great demands from potential users of such circuits, it becomes desirable from aspects both of utilization and economics to obtain the utmost speed from these telegraph circuits. The voice-frequency equipment used by the United Kingdom Administration provides telegraph channels of a high performance—(namely not greater than 10% distortion at 83 bauds)—which enables a telegraph channel to be operated at 83 bauds by synchronous technique in order to produce two 50-baud channels from a single standardized voice-frequency channel. A 6-unit code is used on the synchronous channel to provide the necessary supervisory signals for telex.

Such a voice-frequency circuit has been operated between London and Montreal since January, 1958, and several more similar circuits will shortly be brought into service. These synchronous channels also furnish half-rate and quarter-rate channels in the manner already standardized for synchronous ARQ radio-telegraph systems.

It is also proposed to operate such synchronous circuits on voice-frequency channels on cable circuits between London and New York in the near future.

The United Kingdom Administration proposes that in this study consideration should be given to the features outlined in the Appendix to this reply.

APPENDIX

A SYNCHRONOUS TIME-DIVISION MULTIPLEX TELEGRAPH SYSTEM FOR USE OVER 120 c/s SPACED F.M.V.F.T. CHANNELS

1. General.

The system is required to provide by synchronous time-division either two or three 5-unit 50-baud telegraph circuits over each of a group of similar F.M.V.F.T. channels spaced at 120 c/s; also to provide facilities for sub-dividing all or any of the channels, i.e. to provide a telegraph sub-channel which is either ¼ or ½ of the traffic capacity of the full channel, for use as a leased circuit. In addition to the transmission of all the signals in the international telegraph alphabet No. 2, provision shall be made for the transmission of the 5-unit start-stop idling conditions (i.e. continuous "start" polarity (A) and continuous "stop" polarity (Z) by utilizing additional combinations provided by the use of a 6-unit code on the synchronous channel.

Alternative start-stop input and output units shall enable the C.C.I.T.T. telex type A and type B signals of Recommendation U.5 to be recognized and reproduced at the receiving ends.

2. PHASING.

To facilitate automatic phasing and to economize in the use of common equipment, the timing for a group of up to six equipments shall be controlled from a common oscillator and common pulse generators. These equipments shall be locked together in time so that common phasing and synchronizing circuits may be used. However, apart from automatic phasing the points of compatibility would also apply to a single equipment.

3. RATE OF OPERATION.

The transmission cycle shall be $145^5/_6$ ms which for 6-unit 2-channel operation produces an aggregate modulation rate of $82^2/_7$ bauds and for 3-channel operation a modulation rate of $123^3/_7$ bauds, with an accuracy not worse than 1 part in 10^6. The channel input units shall be capable of receiving characters arriving at random, at a modulation rate of 50 bauds, at a minimum repetitive character duration of $145^5/_6$ ms. The channel outputs shall be at a modulation rate of 50 bauds start-stop only.

4. MULTIPLEXING.

The main channels A and B, or A, B and C shall be multiplexed on a character interleaved basis in the following sequence:

ABAB etc. for 2-channel operation;
ABCABC etc. for 3-channel operation.
The sub-channels 1, 2, 3 and 4 shall be operated in the following sequence:
A1 B1 A2 B2 A3 B3 A4 B4 A1 B1 etc. for 2-channel operation;
A1 B1 C1 A2 B2 C2 A3 B3 C3 A4 B4 C4 A1 B1 C1 etc. for 3-channel operation.

Combinations of sub-channels to provide multiples of ¼ character rate operation shall be in accordance with C.C.I.R. Report No. 108, extracts from which are given below. All characters of B channel shall be transmitted with their polarity inverted from that used on A (and C) channels.

5. PHASING AND GROUP CONTROL SIGNAL.

Phasing is herein defined as the action of altering the receiver operation in time until the particular elements of the incoming aggregate signal are associated with the respective receiver operation.

Provision shall be made for:

— automatic phasing, automatically initiated,
— automatic phasing, manually initiated, and
— manual phasing.

One quarter-rate sub-channel out of each group (as defined in paragraph 2) shall be permanently allocated for timing-control purposes and shall automatically send the character ZZAAZZ repeatedly. This shall be termed the " phasing character ".

Automatic phasing of the receiving equipments shall be in steps of one aggregate element per expected reception of the phasing character, i.e. every four transmission cycles ($583^1/_3$ ms). Phasing shall automatically cease when the phasing character is recognized on the correct sub-channel receiving unit, hence providing both automatic main channel phasing and sub-channel phasing.

Automatic initiation shall occur when three successive phasing characters have failed to be recognized. Automatic initiation shall be inhibited during those periods when the V. F. tone-fail alarm is operated.

The phasing signal shall be capable of being sent on sub-channel A1 of any one aggregate signal in a group, that aggregate signal being termed the " group control signal ".

6. Synchronization.

Synchronization is herein defined as the correction of the receiver timing to give optimum inspection times of the incoming aggregate signal elements.

Synchronization shall be derived from all transitions of one aggregate signal. An integrating device shall be included to reduce unnecessary synchronizing action. The maximum rate of correction (i.e. on aggregate reversals) shall be between 1/100 and 1/1000 of an element per element.

7. Code.

A 6-unit code shall be employed the combinations of which shall be utilized in the following manner. The 32 combinations of the C.C.I.T.T. 5-unit alphabet No. 2 shall be allocated to those 6-unit combinations which commence with an A element and have the remaining five elements as in the 5-unit code. Continuous "start" and continuous "stop" polarities shall utilize those 6-unit combinations which commence with a Z element and whose remaining five elements are AAAAA and ZZZZZ respectively. Thus the following code is obtained:

character	5-unit code	6-unit code
continuous " start " polarity	AAAAA	ZAAAAA
continuous " stop " polarity	ZZZZZ	ZZZZZZ
A	ZZAAA	AZZAAA
B	ZAAZZ	AZAAZZ

etc.

For transmission of telex signals see paragraph 10.

8. Transposition pattern.

In order to prevent characters being printed correctly on the wrong channel or sub-channel when the receiving equipment is out of phase, each of the twelve possible sub-channels shall be transmitted with a discreet element sequence. These element transpositions shall be allocated to the sub-channels according to the following pattern.

Channel	A	1 2 3 4 5 6	Sub-channel 1
,,	B	1 2 3 4 5 6	
,,	C	1 2 3 4 5 6	
,,	A	1 2 3 4 5 6	Sub-channel 2
,,	B	1 2 3 4 6 5	
,,	C	1 4 3 2 5 6	
,,	A	1 2 5 4 3 6	Sub-channel 3
,,	B	1 2 3 6 5 4	
,,	C	1 5 3 4 2 6	
,,	A	1 2 6 4 5 3	Sub-channel 4
,,	B	1 6 3 4 5 2	
,,	C	1 6 5 4 3 2	

Full character rate and ½ character rate channels shall take that sequence which is allocated to their lowest-numbered sub-channel, i.e. a full character rate channel shall take the sequence for its sub-channel 1, a ½ character rate sub-channel using sub-channels 1 and 3 shall take the sequence for its sub-channel 1, and a ½ character rate sub-channel using sub-channels 2 and 4 shall take the sequence for its sub-channel 2.

9. Performance.

The margin of the receiving equipments to the aggregate signals shall not be less than ± 45% when synchronization is taken from the test signal. The distortion of the aggregate outputs and start-stop outputs shall not exceed ± 3%.

10. Auto-telex unit.

An alternative start-stop input and output shall permit the C.C.I.T.T. type A and type B telex signals (except dialling pulses) to be recognized, and repeated at the distant end. Combinations in the 6-unit code shall be utilized to transmit the necessary information. For telex the V. F. tone-fail for over 0.5 sec. or loss of phase shall produce a " start " signal on the channel outputs.

The method of transmitting the full range of telex supervisory signals will require international agreement. The British Post Office proposes the following for consideration with a view to standardization:

By utilizing existing 6-unit combinations together with " continuous start " and " continuous stop " for multiples of character periods, it is possible to reproduce telex signals within the C.C.I.T.T. limits. Special coding equipment would be necessary at the transmit end only thus minimizing complexity and cost. The transmission of certain of these signals would be possible only during a known period previously set up by the commencement of continuous stop or continuous start.

The following codes would be used:

	Input telex signal	*6-unit character*	*Start-stop output*
	Continuous stop	Successive ZZZZZZ's	Continuous stop
	Continuous start	Successive ZAAAAA's	Continuous start
Type A	40 ms start	AAZZZZ (1 character " V ")	40 ms start
	150 ms start	ZAAAAA (1 character)	$145^{5}/_{6}$ ms start
Type B	25 ms stop	AAAAAA (1 " unpunched tape ")	$25^{5}/_{6}$ ms stop
	200 ms stop	ZZZZZZ once or twice	$145^{5}/_{6}$ or $291\frac{2}{3}$ ms stop

It will be seen that the output is substantially within the C.C.I.T.T. limits for the signals and no further " duration error " should occur during possible tandem transmissions over further multiplex links.

The above assumes that the " dialling " selection signals are converted to keyboard characters by common register equipment prior to access to the multiplex channels.

Consideration is being given to the possible advantage of extending the Type B-25 ms " stop " polarity signal to a duration of 145 ms. This would also require international agreement.

(5/VIII)

Extract from Report No. 108 of the C.C.I.R. (Los Angeles, 1959)

III. CHANNEL ARRANGEMENTS.

In each channel, one character per repetition-cycle is " marked " by inverting its polarity with respect to the other characters in this channel.

III.1 *Two channels.*

Channels A and B consecutive (A—normally direct keying, B—normally reversed keying).

Channel A:

— for 4-character repetition cycle (full-speed or sub-divided): one character keyed reversed followed by three characters keyed direct.
— for 5-character repetition cycle (full-speed only, where a 4-character cycle is not sufficient): One character keyed reversed followed by four characters keyed direct.
— for 8-character repetition cycle (for sub-divided operation where a 4-character repetition cycle is not sufficient): one character keyed reversed following by seven characters keyed direct.

Channel B:

— for 4-character repetition cycle (full-speed or sub-divided): one character keyed direct followed by three characters keyed reversed.
— for 5-character repetition cycle (full-speed only, where a 4-character cycle is not sufficient): one character keyed direct followed by four characters keyed reversed.
— for 8-character repetition cycle (for sub-divided operation where a 4-character cycle is not sufficient): one character keyed direct followed by seven characters keyed reversed.

III.2 *Four channels.*

Channels A and B consecutive,
channel C interleaved with channel A,
channel D interleaved with channel B.

(A and D—normally direct keying,
B and C—normally reversed keying).

channel A as channel A in III.1 above,
channel B as channel B in III.1 above,
channel C keyed as for channel B,
channel D keyed as for channel A.

III.3 " *Marked* " *characters.*

The relative positions of " marked " characters in each channel is
— the first direct character on A transmitted after the reversed character on A shall be followed by the direct character on B;
— the direct character on C shall be followed by the reversed character on D;
— the reversed character on A is element-interleaved with the direct character on C;

— in the aggregate, A elements precede those of C and B elements precede those of D.

IV. SUB-CHANNEL ARRANGEMENTS.

IV.1 The speed of operation of the fundamental sub-channel should be a quarter of the standard speed and multiples of quarter-speed channels may be used;

IV.2 Sub-channels should be numbered 1, 2, 3 and 4 consecutively.

In order to ensure the automatic phasing of the sub-channels, the polarity of the signalling of the sub-channels should be in accordance with paragraph III.3.

On each main channel, sub-channel number 1 should be that allocated to the " marked " character.

IV.3 In the case when sub-channels of half-speed or three-quarter speed are provided, combinations of the fundamental sub-channels should be arranged as shown in the Table below.

Proportion of channel operating speed	Combination of fundamental sub-channels
(1) quarter	No. 1
(2) quarter	No. 3
(3) half	Nos. 2 and 4
(1) half	Nos. 1 and 3
(2) half	Nos. 2 and 4
(1) quarter	No. 1
(2) three-quarters	Nos. 2, 3 and 4

Question 6/VIII — Synchronous systems for special codes.

(continuation of Question 7/8 of Study Group 8, 1957-1960)
(to be studied together with C.C.I.R.)
(see also Question 5/VIII)

What procedure and equipment should be used to permit interconnection of circuits worked by means of synchronous systems using special codes with circuits on which the international telegraph alphabet No. 2 is used ? (see Recommendation S.13).

Comments

1. The radiotelegraph channel is defined as being in conformity with figure 15 given below. (This definition does not in any way affect the distribution of the study between the C.C.I.R. and the C.C.I.T.T.).

In this diagram the radiotelegraph channel includes all the equipment contained between lines X and Y, that is to say the radio transmitter E and radio receiver R proper, as well as the repeaters T'_A and T'_B.

T_A and T_B are start-stop teleprinters linked to the radio channel by parts *a* and *b* of the network. These may include any number of channel sections, relays, repeaters or regenerative repeaters, etc.

In the study of this question it might be useful for the radio channel, as defined above, to be linked to a repeater (figure 16) comprising a receiving element R′ and a transmitting element E′.

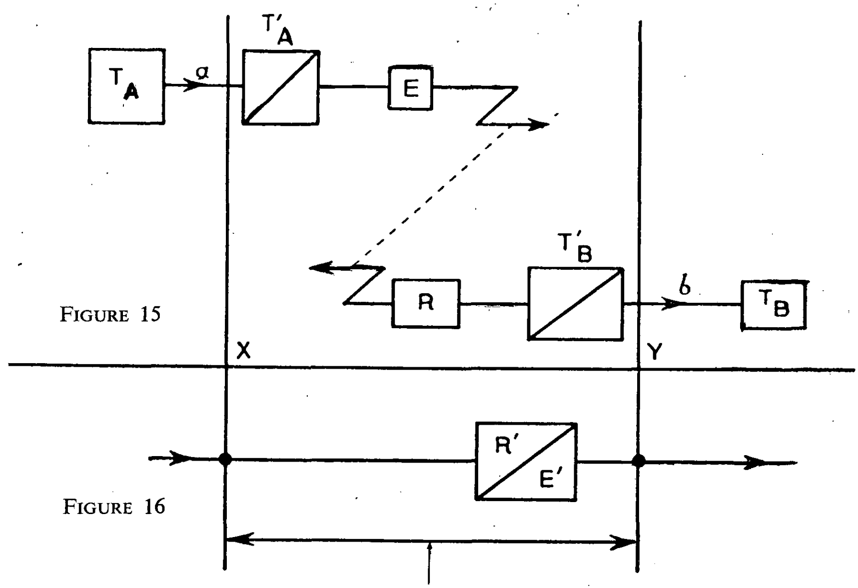


FIGURE 15

FIGURE 16

Radio channel

2. The study of the operating conditions to be imposed on the radio channel could be usefully carried out in accordance with the following:

a) Conditions to be imposed on the receiving element R′ of the repeater equivalent to the radio channel

b) Conditions to be imposed on the transmitting element E′

c) Conditions for the transmission of signals other than those of international telegraph alphabet No. 2, e.g., switching signals, control signals, etc.

d) In the case of systems using storage, the delay in the re-transmission of the signals.

e) What arrangements are to be recommended for the interconnection of two or more channels in tandem as may be required in international telex working ?

f) As there is some objection in certain circumstances to the use of perforated tape as a means of signal storage at the input to a synchronous telegraph system, what alternative arrangements can be recommended ?

3. Recommendation S.13 should be completed as regards the arrangement of channels and sub-channels once the C.C.I.R. has concluded the relevant study (see Los Angeles Recommendation No. 242 and Report No. 108 of the C.C.I.R., extract from which appears in Appendix to Question 5/VIII).

(6/VIII)

4. Certain long radio circuits, which may include long landline sections, and possibly relay stations also, may, however, have an overall propagation time for which the use of a four-character repetition cycle is insufficient. For this reason, some Administrations may use a repetition cycle comprising five characters (see Recommendation S.13).

As the cost of providing and operating such systems of great length is necessarily very high, Administrations find it convenient to sub-divide these channels and offer leased channels which are shared on a time basis by two or more renters, so that for example, the number of words per minute which can be sent by each renter is one-half or one-quarter of the standard rate, although each modulation rate remains at 50 bauds.

Although it is possible to use such sub-divided channels in association with the five-character repetition cycle, it is not a convenient arrangement and a preference has been expressed that when sub-divided channels are used on a circuit which has a propagation time requiring more than four characters in the repetition cycle, then a repetition cycle of eight characters shall be recommended.

There should also be a specification for inversion of the polarity of a sub-channel to facilitate the provision of a feature which ensures automatic phasing of the system.

It is however possible with such systems for printing errors to occur if automatic phasing operation is taking place while the system is open for traffic. It is also necessary for the sub-divided channels to be correctly phased after the main circuit has been brought into phase. The achievement of both those requirements can be realised by inverting the polarity of every *n*th character in such main channel where *n* is the number of characters in the repetition cycle, irrespective of whether these channels are sub-divided or not. By suitably relating this inversion in the main channels, a foolproof identity of phase may be recognized. The sub-divided channels, if present, are then locked in sequence and position relative to the main channel inversion. Automatic phasing is completely effective if the receiver is arranged to check all the characters in the repetition cycle.

Question 7/VIII — Error-detection via the return circuit.

(former Question 21/8 of period 1957-1960)
(interests also Special Study Group A)

Would it not be desirable in certain cases to make use of the return circuit of telegraph connections with a view to ensuring an immediate check at the transmitting end that the text transmitted has been correctly received ?

For this purpose the following system might be considered:

a) the connections in question would be established over 2-way simplex circuits;

b) teleprinters should be made available designed with a view to the immediate retransmission, over the return circuit, of the signals corresponding to the characters printed by the apparatus when operating as a receiver;

c) the possible use of devices associated with the teleprinters to stop and start retransmission; these devices would be controlled by means of the appropriate signals;

d) the possible use of an automatic device in the sending apparatus to check that the texts coincide.

ANNEX 1 TO QUESTION 7/VIII

Background of the Question, proposed by Belgium

In many cases it is important for the operator sending a message by telegraphy (whether in the case of telex, leased circuits, the public station-to-station service or the switched service) to be almost absolutely sure that the text received by his correspondent coincides with the text transmitted. This applies for example to financial transactions, price offers, orders, and the transmission of numerical data to accounting machines.

The same also applies in the case of circuits which are especially subject to disturbance, such as those including a radio path; this is particularly true when the latter is not provided with a repeater system, when it is important for the correspondents to be assured that reception is correct.

A similar requirement arises in the international public switched service, in which the problem of notification of receipt has not been solved entirely.

In none of the above-mentioned cases does correct reception of the answer-back afford sufficient guarantee.

A highly attractive solution to ensure efficient and immediate checking of good reception would be to make use of the return circuit, which is very badly utilized at present and which exists in the switching centres as well as in voice-frequency channels. Duplex is in fact practically non-existent in telex and relatively uncommon in station-to-station connections (except in radio connections of the public service). In other words the return circuit is really used only for receiving the answer-back.

The check in question could easily be made for apparatus connected by 4 wires (duplex) if teleprinters could be constructed in such a way that they could immediately retransmit signals corresponding to the characters they are receiving and printing. In this way the text returned would be printed by the sending equipment.

Another solution would be to design a device in the sending apparatus which would automatically check that the signals emitted and received are similar.

Supplementary arrangements should be made to ensure that the answer-back is released. One solution would be to operate the change to the " retransmission of check " position by remote control, using a sequence of signals.

ANNEX 2 TO QUESTION 7/VIII

(Contribution of the United Kingdom: contribution COM 8/67, 1957-1960)

Much attention is currently being given to freedom from undetected errors in reception of data over telegraph circuits, and various methods have been proposed for the detection and also for the automatic correction of errors in transmission.

Conventional methods rely upon the interpolation of additional elements, such as " parity bits ", or of " block totals " to carry checking information against which the receiving equipment can assess the accuracy or otherwise of the received information. With systems in which checking information is interpolated (the checking information itself being liable to mutilation in transmission), there is always a finite probability of undetected errors.

If, on the other hand, the received signals are retransmitted back over the normally-idle return path to the sending station the whole of the received information can be compared, element by element, with that originally transmitted. The results of such error detection can, if desired, be utilized to initiate automatic correction of the errors. Alternatively, the returned signals could be used to provide a printed copy on the transmitting teleprinter instead of the normal " local record " for visual check by the operator.

In achieving this approach to the ideal state of error detection by using the return path, a number of practical points have to be observed. For example the forward transmission may have been made over a tandem-linked circuit such that the received signals approach the limit of acceptable distortion: it may be necessary that the signals retransmitted back to the sending station should first be regenerated using for example a reperforator and automatic transmitter or a regenerative repeater. The regenerative device should ideally have a receiving margin no better than the receiving apparatus used for reconstituting the information. The quality of the retransmitted signals should be equivalent to that of the original transmission. In effecting comparison of the sent and retransmitted signals, due attention has to be paid to the total propagation time of the sending and receiving paths, which may vary from one switched connexion to another; and also to the physical limitations in the length of perforated tape which must be fed from reperforating machines at both the receiving and the sending stations before the tape is accessible for introduction to an automatic transmitter (at the receiving station) or a comparator at the sending station. In addition it is important to render ineffective the normal teleprinter transmitter at the receiving station during the transmission to prevent any interference.

The retransmitted signals will themselves be liable to errors during retransmission. The probability of an error in the original transmission being corrected by a neutralizing error in retransmission of any given element can no doubt be dismissed as negligible: the occurrence of errors introduced in the retransmission path and not present in the original forward transmission may be regarded as acceptable.

Question 8/VIII — New international telegraph alphabet.

(former Question 22/8-22/21 modified 1957-1960)

(this Question should be studied by a working group of Study Groups I and VIII)

(this is Question 6/I in the Series of Questions of Study Group I)

1. Study of the requirements which the telegraph service may be called upon to meet in future.

2. Study of a telegraph alphabet which would meet these needs.

ANNEX 1 TO QUESTION 8/VIII

The aim is to ascertain for what purpose or type of service a new alphabet is needed.

It will therefore be useful to know the ideas of operating services on the facilities which the general telegraph service and the telex service may be able to offer users in the distant future (10 to 15 years).

Thinking ahead should not be restricted to extensions to existing services, but they should be sufficiently extended to cover the possible requirements of new services for commerce and industry.

This problem can be simplified, however, if the range of possibilities could be restricted as far as possible by excluding features which could not be provided in any such service. Two of these possibilities which it will probably be impossible to include are:

— compatibility with existing alphabets
— the possibility of meeting the very diverse data-processing code requirements which are known to exist.

It appears that compatibility will be out of the question owing to technical difficulties, since, although an alphabet having more than five units can be so coded as to permit transmission to machines designed for international alphabet No. 2, transmission in the reverse direction is technically difficult because the transmission time occupied by each transmitted character in alphabet No. 2 is shorter than the character time of machines arranged to receive the longer alphabet.

As regards data transmission, it should be mentioned that the study of a standardized international alphabet for data transmission for use either by telex subscribers or telephone subscribers has been called for.

ANNEX 2 TO QUESTION 8/VIII

(Extract from Study Group's report; Warsaw meeting;
Document COM 8/35, period 1957-1960)

For the moment, the great majority of Administrations do not wish to abandon alphabet No. 2 for general service and for telex.

An extended alphabet is at present needed only for the special requirements of specialized networks. Administrations cannot now see clearly what their requirements might be in the distant future; it is not certain, but nor is it impossible, that new requirements such as having the same facilities as typewriters, the introduction of new control signals, transmission of data, etc. would make it necessary one day to choose an extended alphabet.

When such requirements begin to assume a definite form, it will be too late for the C.C.I.T.T. to begin the study of a new alphabet, which takes several years.

This is why the study of a new alphabet should be continued. This does not mean, of course, that Administrations have decided ultimately to apply the conclusions of this study, but that it seems that such a study would make it possible to reach conclusions more rapidly when new requirements become known.

The following represents the maximum possibilities to be expected of a new alphabet:

1. the use of both capitals and small letters
2. the addition of the following letters with diacritical signs:

á	à	â	ä	ą	å		æ
ć				ç			
é	è	ê	ë	ę			
		î	ï				
						ł	
ń							ñ
ó		ô	ö			ø	
ś							
	ù	û	ü				
ż						ż	

Among these letters, it should be possible to obtain the following as capitals or small letters:

ł	ż	
ø	æ	å
ä	ö	ü

3. The addition of the following signs:

%	°/oo			
Fr	£	$		
§	* (asterisk)	&	No.	@
H (underlined)				
1/	1/2	1/4	3/4	
² (squared index)		³ (cubed index)		

4. The addition of the following punctuation marks:

; ! « »

5. Allocation of signals for the following operations:

return to the preceding line
change of line spacing
back spacing
beginning of telegram
end of telegram
message separation
starting a perforator-receiver
stopping a perforator-receiver
disturbance signal
delay in synchronous service
error
tabulation (six signs).

There, with the signs already used in alphabet No. 2, need one hundred and seventy combinations.

Allowing for further requirements and the protection of certain signals would mean a total of two hundred combinations.

Without shift, an eight-unit code (two hundred and fifty-six combinations) is required.

With shift, a seven-unit code (twice one hundred and twenty-eight combinations) is necessary.

On this basis, the working party studied just how far it was possible to go with a six-unit code.

It was felt that one of the most attractive extensions of the telegraph facilities would be the use of capitals and small letters.

In many languages, small letters cannot be used without diacritical signs.

To keep within the limits of the six-unit code, diacritical signs can be used only with small letters, and not with capitals. There seems to be no great objection to this.

Diacritical signs would not cause the carriage to move on a space and would have to be in the same shift as the small letters.

The essential characteristics of the new six-unit code would therefore be as follows:

— use of small and capital letters, the same code combination going with the small and capital versions of a same letter;
— figures in the same shift as the small letters;
— diacritical signs which do not cause the carriage to advance and which are placed in the same shift as the small letters;
— no diacritical signs on capitals.

Question 9/VIII — Regional alphabets.

(this Question should be studied by a working group of Study Groups I and VIII)

(this is Question No. 19/I in the series of Questions of Study Group I)

Study of new regional alphabets for the exchange of information by start-stop apparatus in languages that are not based on roman characters.

The possibility of co-operation of these alphabets with international alphabet No. 2 will have to be considered.

QUESTIONS TO BE STUDIED BY STUDY GROUP IX: TELEGRAPH TRANSMISSION PERFORMANCE; EQUIPMENT SPECIFICATIONS AND DIRECTIVES FOR THE MAINTENANCE OF TELEGRAPH CHANNELS

Chairman: Mr. ROQUET (France)
Vice-Chairman: Mr. RENTON (United Kingdom)

Question 1/IX — Individual telegraph distortion.

(former Question 1 of Study Group 9, 1957 1960)

1. Since the degree of individual distortion of a significant instant depends on the choice of the corresponding ideal instant, is it necessary to recommend a particular method of choosing the ideal instant ?

If the answer is affirmative, what rules will permit the ideal instant to be determined ?

2. What use can be made of the definition of degree of individual distortion, so defined, to simplify the definitions pertaining to degree of distortion of a modulation or restitution ?

ANNEX TO QUESTION 1/IX

1. At the moment the definition of ideal instants of a modulation (or a restitution) is as follows:

(List of Definitions — Part I — No. 33.02)

Instants with which the significant instants would coincide under certain ideal conditions. In each particular case it will be necessary to indicate how one (or more) of these ideal instants is determined, all the others being placed in relation to it (or to them) at intervals equal to the corresponding theoretical significant interval.

C.C.I.T.T. Study Group 9 proposed to amend this definition as follows:

Definition No. 33.02 — Ideal instants of a modulation or a restitution

" Instants with which significant instants would coincide under certain conditions. It will be necessary to indicate, for each individual case, how a reference ideal instant is determined, on the basis of which all the other ideal instants will be fixed at intervals equal to the corresponding theoretical significant intervals."

In a start-stop modulation, the reference ideal instant for each signal coincides with the beginning of the start element of such a signal.

(1/IX)

In an isochronous modulation, the reference ideal instant can be chosed arbitrarily. In the absence of any other criterion, the instant can be chosen in which there is greatest condensation of significant instants in the displacement zone.

This proposal was the result of the following considerations:

a) *Start-stop modulation.*

The ideal instant of a start element is the instant at which this element begins.

The ideal instant of each of the other elements is n times the theoretical unit interval later than the ideal instant of the start element of the same signal, n being the rank of this element in the signal.

The standardized unit interval should be taken as the theoretical unit interval. The interval corresponding to the real mean speed can also be taken provided that it is specified.

The instant corresponding to the beginning of the start element should be known as the *reference ideal instant.*

b) *Isochronous modulation.*

It is difficult to define the ideal instant of an isochronous modulation without arbitrarily choosing a time origin.

The choice of origin should depend on the study undertaken, so as to facilitate such a study.

There are two main methods we can recommend:

1) That the instant of the beginning of a unit element, arbitrarily chosen in the isochronous modulation, be taken as the origin. A significant ideal instant of rank n (n being as large as is desired, positive or negative) is then situated at n times the mean unit interval from the ideal instant that has been taken as the origin.

   The ideal instant taken as the origin should be known as the reference ideal instant.

2) An isochronous modulation considered during a certain time interval has no natural, rational time origin. But we can choose well-defined instants which can be taken as a basis for the definition of the ideal instants of an isochronous modulation.

Thus, for example, synchronous apparatus, which maintain synchronism without recourse to special signals, have organs which are set back in relation to the corresponding organs on the other apparatus. The mean restitution delay suitably affects the movements of the organs thus directed, speeding them up or slowing them down. From this we can conclude that, without measuring the restitution delays, we can find the instants corresponding to the mean restitution delays. Pushing matters further, we can say that in observing a distorted isochronous modulation we can find a series of well-defined instants at intervals which are multiples of the mean unit interval of the modulation observed.

Let us, now, assume that we are observing an isochronous modulation given by the diagram *(a)* of figure 17.

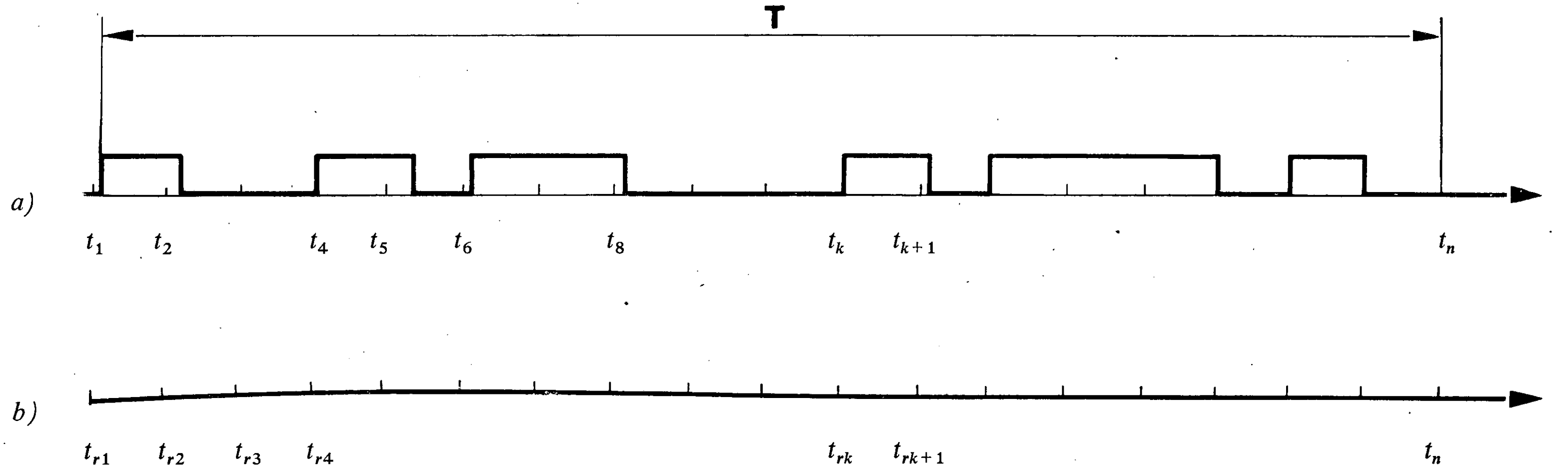
We can apply thereto a time scale with degrees equal to the unit interval, provisionally placed quite arbitrarily (diagram *(b)* of figure 17).

We can now define the function $F(t_{rk})$ as follows:

$$F(t_{rk}) = \sum_{k=1}^{k=n} (t_k - t_{rk})$$

The ideal instants will now be defined by the equation:

$$F(t_{ik}) = F(t_{rk})_{\min}$$



t_k = the significant instant of the modulation observed.
t_{rk} = the instant corresponding to the instant t_k in the arbitrary time scale.
T = time taken by the observation.
k = an index equal to the number of unit intervals which have elapsed during the observation.

FIGURE 17

The same result may be set forth in the following way:

The ideal instants of an isochronous modulation are the instants which, taken as the basis for the calculation of individual distortion, give the smallest sum of the absolute values of this distortion.

Be it noticed that, physically, the ideal instants thus defined coincide with the instant of maximum condensation of significant instants within the displacement zone.

One of these instants can be taken as the reference ideal instant. The other ideal instants will be deduced therefrom as in the first method. The ideal instant of rank *n* will be situated at *n* times the mean unit interval of the reference ideal instant.

2. The second purpose of Question 1/IX is to examine the simplification which the definition of the degree of individual distortion (thus specified by the choice of ideal instants) could bring into other definitions in connection with telegraph distortion.

Study Group 9 held that use of the definition of individual distortion would make it possible to abbreviate, and to clarify, certain definitions. However, the former definitions would perhaps be preferred by some people as they have become well known and widespread. It is therefore proposed to let the former definitions remain and to have the equivalent definitions, established on the notion of individual distortion, added.

With this in mind, Study Group 9 proposed:

Definition No. 33.04 — Telegraph distortion.

Add to the existing definition, which will be marked *(a)*, the following definition:

(b) a modulation (or restitution) is affected by telegraph distortion when significant instants do not coincide with the corresponding theoretical instants.

Definition No. 33.07 — Degree of isochronous distortion.

Add to the existing definition, which will be marked *(a)*, the following definition:

(b) Algebraical difference between the highest and lowest value of individual distortion affecting the significant instants of the isochronous modulation. (This difference is independent of the choice of the reference ideal instant.)

No change in the rest of the definition after:

" The degree of distortion . . . "

Definition No. 33.08 — Degree of start-stop distortion.

Add to the existing definition, which will be marked *(a)*, the following definition:

(b) The highest absolute value of individual distortion affecting the significant instants of a start-stop modulation.

At the end of this text, add a second note:

A distinction can be made between degree of *late* distortion (or degree of *positive* distortion) and the degree of *early* distortion (or degree of *negative* distortion).

Question 2/IX — Inherent distortion.

(former Question 2 of Study Group 9, 1957-1960)

What are the constituent elements of a channel to which the notion of inherent distortion can be applied ?

How can the inherent distortion of these elements be determined ?

ANNEX TO QUESTION 2/IX

The definition of inherent distortion is as follows:

(List of Definitions — Part I — No. 33.13)
Degree of distortion of the restitution when the modulation is effected without distortion.

Notes : 1) By inherent distortion is meant the combination of the different types of distortion caused by the channel (bias, characteristic, etc.).

2) This notion may be extended to the constituent elements of a channel.

3) It will be necessary to specify in what conditions the channel is used (type of apparatus, modulation rate, manual or automatic keying, etc.) and to effect the modulation under these conditions.

In particular should be defined:

— the point of entry at which the distortionless modulation is applied,
— the terminal point where the distortion is measured.

The inherent distortion of a transmission channel or of one of its elements cannot be measured without an outgoing and an incoming semator *, for distortion measurements can only be taken on modulation or restitution (i.e. rectangular-shaped signals).

A distinction should be made between:

— cases in which the telegraph signals both at the input and at the output of the element to be measured are in the form of a direct current modulation;
— cases in which the telegraph signals, at the input, or at the output, or at both ends of the element to be measured, are in the form of modulation (amplitude or frequency) of an alternating current.

1st case (fig. 18).

The element itself includes a semator at both ends.

For example : a channel section.

The measurement will be effected:

— by connecting a transmitter of undistorted signals to the input of the element; this will directly control the outgoing semator of the channel (normal operation current and voltage), and
— by connecting a distortion measuring set at the receiving end after the output semator.

The readings on the distortion measuring set will give the degree of inherent distortion.

* Semator = the appropriate device of a transmitter (or a receiver) which, assuming definite conditions in succession, forms a telegraph modulation (or restitution).

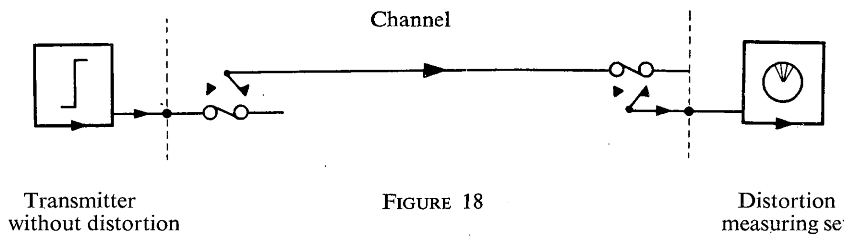


FIGURE 18

2nd case (fig. 18 *bis*).

The element includes an output semator and is fed at its input by (amplitude and frequency) modulated alternating currents.

For example: the receiving terminal equipment of a voice-frequency telegraph channel.

The measurement will be taken by placing a *perfect modulator (converter)* (PMC) at the origin of the element in the following manner:

— The element's input is disconnected from the section of the channel, and is connected to the output of the perfect modulator converter (PMC);

— the PMC is controlled by a transmitter without distortion which injects an undistorted modulation into it;

— the PMC restitutes the signals (with amplitude or frequency modulation) in such a way that their envelope (amplitude modulation) or their instantaneous frequency (frequency modulation) will reproduce exactly the modulation that has been injected;

— the signals thus emitted by the PMC should have their characteristics, frequency and mean level matched to the normal conditions at the element's input before it had been disconnected;

— the output impedance of the PMC is real and is equal to the nominal impedance of the part of the channel which has been disconnected.

The output semator is connected to a distortion measuring set, from which the inherent distortion of the element can be read.

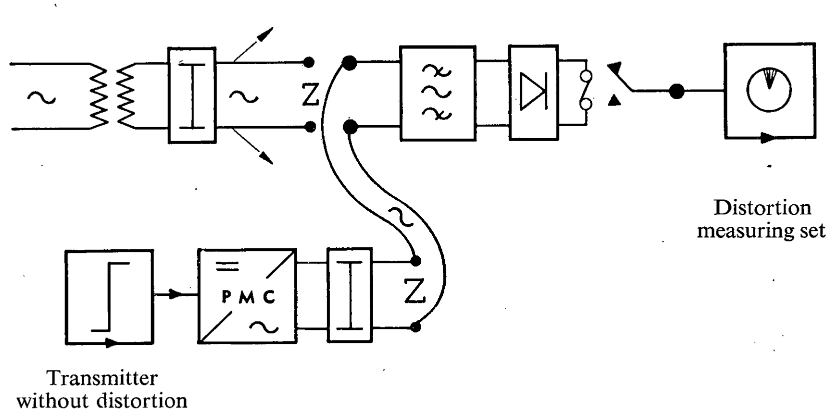


FIGURE 18 *bis*

3rd case (fig. 18 *ter*).

The element has an input semator but emits, at its output, signals in the form of the (amplitude or frequency) modulation of an alternating current.

For example: The transmitting terminal equipment of a voice-frequency telegraph channel.

The measurement will be taken by placing a *perfect demodulator (converter)* (PDC) at its output in the following manner:

— the element's output is disconnected from the channel section and is connected to the input of the perfect demodulator converter (PDC);
— the PDC is terminated by an output semator which controls a distortion measuring set;
— when fed by a frequency or amplitude modulated signal (of which the instantaneous frequency or envelope reproduces an undistorted modulation, and whose characteristics, frequency and mean level are matched to the normal conditions at the element's output before it was disconnected) the PDC supplies, at its output, an undistorted modulation identical with the modulation reproduced at the input;
— the input impedance of the PDC is real and is equal to the nominal impedance of the part of the channel which has been disconnected.

When the input semator of the element is directly connected to a transmitter of undistorted signals in normal conditions of use, the degree of inherent distortion of the element can be read from the distortion measuring set.

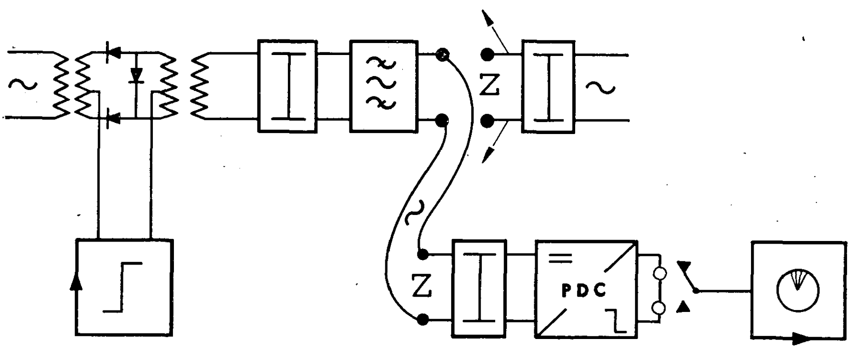


FIGURE 18 *ter*

The notion of inherent distortion is of interest only where channel elements are concerned which receive undistorted signals and normally restitute distorted signals.

When a single telegraph relay, which has been normally adjusted and fed by an undistorted semateme, restitutes a practically undistorted semateme, the only object of inherent distortion measurements would be to detect faulty adjustment. For this, however, there are much simpler methods than measurement of inherent distortion.

Question 3/IX — Effect of interference on telegraph distortion.

(Former Question 6 and item 1 of former Question 7 of Study Group 9, 1957-1960) (Question to be studied jointly with Special Committee C and Study Group IV).

1. Study of the quality, quantity and distribution in time of the causes of fortuitous distortion.

2. What part is played by disturbances to the reception of signals on voice-frequency telegraph channels in worsening the resulting distortion ?

ANNEX 1 TO QUESTION 3/IX

This question was studied by the " Noise " working party of C.C.I.T.T. Study Group 1 together with Question 7 of Study Group 1:

> " Is it possible to have a total-noise clause of common application to all systems of wideband carrier telephone transmission ? "

The conclusions of these studies have been recorded, as far as telegraphy is concerned, in Recommendation G.222 (General noise objectives for the design of carrier-transmission systems). (*Red Book*, Vol. III) and in Recommendation G.422 for telegraphy on line-of-sight radio relay links.

Extracts from Recommendation G.222 concerning telegraphy together with Recommendation G.422 are published in this Volume, page 246 et seq.

ANNEX II TO QUESTION 3/IX

Programme of measurements included under the study of the effect of noise on telegraph transmission using radio-relay links

(Extract from contribution COM 9/43, of Study Group 9, February 1959)

Study Group 9 considers that, for the time being, the immediate and most important aim is to eliminate interference due to human action or to defects in equipment.

Study Group 9 has observed that as regards short-term variations in equivalents on carrier circuits the situation is not satisfactory as far as telegraphy is concerned. The results given show an average of twenty-nine isolated short variations and 1.5 series of short variations (comprising series of more than one hour) per 1000 kilometres of circuit per week. This is far too many.

An error rate of three per one hundred thousand is impossible to obtain in these circumstances, and the International Telegraph and Telephone Consultative Committee cannot be too uncompromising as regards noise conditions to be imposed to get this standard. This standard, applicable to circuits carried on radio relay links, if we want to assimilate these circuits to circuits carried in cables, nevertheless remains an objective to be maintained for the benefit of all users of radio relay systems.

For the time being, then, Study Group 9 considers of quite extraordinary interest the following recommendation of the " Noise " working party.

The working party proposes to recommend that Administrations, in their designs of radio links, should do everything possible to avoid:

a) disturbances in power supplies,

b) a large number of short bursts of noise.

The measurement campaign called for by the " Noise " working party in connection with the effect of noise on voice-frequency telegraph systems should be undertaken on the following lines:

Measurement programme within the framework of the study of the effect of noise on telegraph transmission

Study Group 9 invites Administrations to furnish the results of measurements:

1) of the characteristics of the noise encountered on radio relay links,

2) of the effect of this noise on the operation of voice-frequency telegraph channels.

To this end, the recordings made by Administrations on radio-relay systems should be made use of. Exclusive attention should be given to those portions of these recordings in which noise power exceeds 10^5 pW and those portions of recordings in which the power exceeds 10^6 pW. These portions (which, so the International Radio Consultative Committee affirms, will generally last between 4 and 9 seconds) will be repeated so as to constitute sources of artificial noise. (The Administrations which have made these recordings will be asked to be so good as to supply copies to the Administrations anxious to undertake this investigation). It would be well to indicate the relationship between the time these recordings take and the total observation time during which they were made. Preferably, the observations should include a second track on which will be recorded a standard frequency at a given level with an eye to facilitating the reproduction of noise at the correct speed and level. It would be even better were provision made for two extra tracks giving two frequencies, for in this way we should get some indication of the stability of the characteristic of the recording frequencies.

1. *Measurement of characteristics.*

We should analyse the reproduction of the noise produced by the continuous repetition of these recordings, so as to obtain the following information:

a) the mean power;

b) the distribution in the specimen of the power of the noise in time, that is to say, a curve showing the proportion of the time in which the various powers are exceeded, these powers being measured with apparatus having a 5-ms time constant;

c) the distribution of noise power according to frequency. The frequency selector can be conveniently obtained in the form of a group of voice-frequency telegraph filters. At the output of every filter, an analysis should be made in accordance with *a)* and *b)* above. The corrections appropriate to the attenuation at the bottom of the band of each filter and to the width of the effective band should be made, and the mean power at the filter inputs should be shown (that is to say, the power measured according to *a)*.

2. *Measurement of the effect of noise on telegraph transmission.*

a) Two series of measurements are called for; one with the noise source furnished by the above-mentioned recordings, using the whole of the possible range of noise levels, and the other, with a white-noise generator having a gaussian amplitude distribution. Several different noise levels should be used, for example, 10^5, 10^6, and 2.10^6 pW. Useful additional data could be obtainted from tests carried out at the additional levels 5.10^5 and 5.10^6 pW.

A comparison between the two series of measurements would help us to determine just how far radio noise resembles white noise behaving in a gaussian way.

b) Measurements should be made of the performance of standardized telegraph systems used by Administrations. Additional measurements made on other systems (frequency-modulated, high-speed channels) would be useful too. It would be well to indicate certain characteristics of the systems under test, for example, the threshold of response to 2/2 signals at normal speed, expressed in relation to the normal level of the frequency transmitted to line. And when a channel uses frequency-modulation, the degree of distortion produced by a sine-wave interference of the variable frequency of a level, for example, of –20 db in relation to the telegraph signal, especially at the frequencies corresponding to the condition A and the condition Z.

c) Measurements will be undertaken to establish:

i) either the degree of inherent distortion with standard test, measured on a distortion meter of current type, the test signal transmitter having, for all practical purposes, zero distortion,

ii) or the distribution of the individual distortion measured by means of a distortion analyser. The results should be reproduced in the form of curves giving the signal-to-noise ratio and the probability of exceeding, in particular, distortion values equal to 8, 14 and 20%. Additional figures can be given according to the capacity of the instruments used. Each measurement should last about five minutes.

And it would be exceedingly valuable if measurements could be obtained of a similar kind, thanks to a signal source having a given degree of distortion, for example, 22%, corresponding to the probable figure at the output of the last section but one of a channel (this pre-distortion is most readily obtained, and most satisfactorily, too, by introducing an alternate bias distortion). The distortion figures in (ii) should be suitably increased.

3. Study Group 9 has asked whether it would be possible, when further observations are made, to introduce a further significant level of noise power, i.e. 2.10^6 pW and whether the two pilot tracks, mentioned in the introductory paragraphs above, can be provided on future recordings. It is appreciated that this higher level of noise may correspond to conditions which will also affect the transmission efficiency of the telephone channels. It would be desirable, where this possibility exists, that it should be noted and that the recordings should be accompanied by corresponding records of the received level of a pilot tone transmitted over the channel.

The attention of Administrations is drawn to the urgency of this programme of measurements.

ANNEX III TO QUESTION 3/IX

The following contributions published in Vol. VII refer to Question 3/IX.

France: Interference caused to telegraph transmission by white noise, page 251.

F. R. of Germany: Permissible maximum noise in a telephone channel with reference to voice -frequency telegraph disturbance, page 263.

C.C.I.R.: Measurements for the study of the effect of noise on telegraph transmission over radio-relay links, page 269.

Question 4/IX — Study of fortuitous distortion.

(items 2, 3 and 4 of former Question 7 of Study Group 9, 1957-1960)

1. Study of the possibility of making apparatus to generate a modulation having only fortuitous distortion; determination of the characteristics of such a generator.

2. Systematic study of the effect of fortuitous distortion on the total distortion of a channel link.

Question 5/IX — Law of distribution of degrees of telegraph distortion.

(former Question 3 amended, of Study Group 9, 1957-1960)

What method could be recommended for the determination of the law of distribution of the various values of degree of distortion pertaining to a prolonged modulation (or restitution) in the case:

a) of an isochronous modulation (or restitution) ?

b) of a start-stop modulation (or restitution) ?

c) when the distortion considered is individual distortion ?

Comments concerning start-stop modulation

It may be convenient to consider the curve giving the probability p of exceeding a given degree of individual distortion d. The shape of this curve Γ is shown in figure 19 below.

Distortion analysers make it possible to plot the curves showing how the degrees of positive and negative individual distortion are exceeded, by means of points. It is easy to deduce from them the curve showing the probability with which a degree of start-stop distortion is exceeded.

One interesting point of these curves is that they do not vary appreciably when the number of significant instants examined is increased, i.e., when the measuring time is increased.

It is thus possible to trace the curve Γ with a fairly short measuring time and then to extrapolate the results obtained without the risk of serious error.

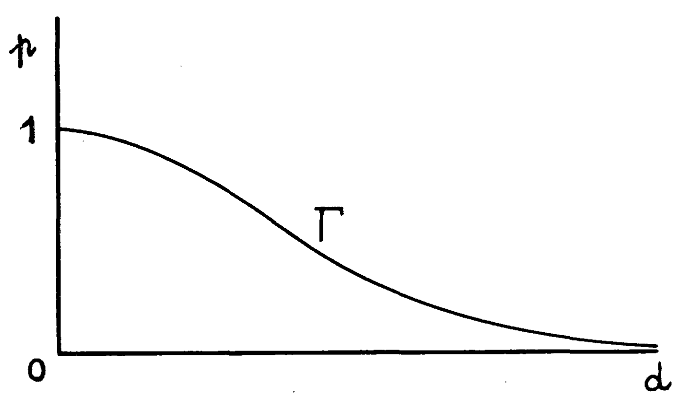


FIGURE 19

Note. — See the contribution of the United Kingdom on the statistical distribution of start-stop telegraph distortion in tandem-connected voice-frequency telegraph channels (Volume VII, page 226 et seq.).

Question 6/IX — Conventional degree of distortion.

Would it be useful to revise Recommendation R.54 which defines the conventional degree of distortion, with particular reference to the consideranda of this Recommendation ?

(6/IX)

Comments

In accordance with Recommendation R.54, and in particular its consideranda, the conventional degree of distortion is measured at the last point of the telegraph channel, that is, at the input to the teleprinter receiver.

Moreover, the idea of the conventional degree of distortion might be useful for measurements of the inherent degree of distortion in single circuits, in chains of circuits, and of the degree of teledistortion, measured at various points on the telegraph channel.

In the various measurements, there might in principle be recommended different values of probability of exceeding the conventional degrees of distortion, but the reasons in favour of such a solution are not sufficient to cancel out the advantage of unifying the value of probability to fix the conventional degrees.

Consequently, it is necessary to decide that for all measurements of the conventional degree of distortion, the value with a probability of being exceeded of 10^{-5} must be taken as the recommended value.

In theoretical and practical studies exceptions may be made to this rule when there are sufficient reasons for doing so but, in such cases the value of probability chosen must always be indicated.

Question 7/IX — Relation between the results of routine measurements of distortion and the conventional degree of distortion.

(former Question No. 5, amended, of Study Group 9, 1957-1960)

By how much should the measurement results obtained by the current distortion measurements carried out in accordance with Recommendation R. 5 be increased so that they may be considered as representing the conventional distortion degree ?

ANNEX TO QUESTION 7/IX

The following results obtained from previous studies by Study Group 9 are submitted for checking by Administrations:

1. When an isochronous distortion meter is used, if δ_t represents the degree of synchronous distortion measured on the text and δ_b the degree of bias distortion measured for balanced signals at the modulation speed used for adjustment, the conventional degree of distortion can be estimated as

$$1.15\ \delta_t - 0.15\ \delta_b$$

2. When a start-stop distortion set is used, the values of early and late distortion should be noted separately. The conventional degree of start-stop distortion can be estimated by adding 0.35 of the smaller of the two values to the larger value.

The derivation of the formula above is as follows:

The total distortion observed is δ_t and this represents the sum of bias distortion δ_b and the remaining forms of distortion δ_i

$$\delta_t = \delta_b + \delta_i \tag{1}$$

Assuming the bias to remain constant, but the value of δ_i to increase with the time of observation to a final value $k\ \delta_i$, the maximum value of total distortion is

$$\delta_{t\,\max} = \delta_b + k\ \delta_i \tag{2}$$

from (1) we get

$$\delta_i = \delta_t - \delta_b,$$

where

$$\delta_t \max = \delta_b + k (\delta_t - \delta_b) = k \delta_t - (k - 1) \delta_b$$

In the use of start-stop measurement the actual observation is effective only for a lower number of transitions and so a larger factor must be used. The smaller value of the two observations will be the one for which the transitions are uninfluenced by bias whilst the larger value will contain those with bias. Therefore, it is necessary to add to this latter value the proportion of the reading practically unaffected by bias.

To check these formulae, Administrations are requested to carry out several measurements in the conditions specified in Recommendation R.5 and to check the approximation of the formulae to the results of conventional degree measurements.

Question 8/IX — Error rates on unit elements.

Study of a definition for error rates on transitions or on unit elements.

ANNEX TO QUESTION 8/IX

The following extract from the report by C.C.I.R. Committee III to the IXth C.C.I.R. Plenary Assembly (1959), though it does not contain an exact definition of the error rate for elements, is of interest in the study of Question 8/IX and its usual extension: relation between error rate on characters and error rates on unit elements.

Extract from the report of C.C.I.R. Study Group III
submitted to the IXth Plenary Assembly of the C.C.I.R.

The performance of a circuit is usually expressed in terms of character-error rates. However, for calculation of the factors which determine the planning of circuits, it is more convenient to use element-error rates. With such a required element-error rate and the demodulation factor of a given receiver together with the performance charts for a reference receiver, it is possible to make plans based on the required performance under specified noise and propagation conditions.

Calculations from the probability functions involved give a simple conversion from an element-error rate to a character-error rate for various types of telegraph code, thus providing a simple relationship between the signal-to-noise ratio and the number of errors on the printed copy when the signal is steady. The conversion from an element-error rate to a character-error rate is more complex when the signal fades slowly relatively to the signalling speed. The particular case for noise having a gaussian distribution and for a steady signal represents a useful limiting condition which is approached closely when the error rate is low. If the error rate is known in terms of element-error rate rather than character-error rate, then the calculation of circuit performance is possible more directly.

Relationships between element and character error rates are shown in figures 20, 21 and 22.

In figure 20, curve (1) represents the upper limit of the character-error rate for a synchronous seven-unit code when the element errors are mutually independent. It should be noted here that the character-error rate is defined as being the number of characters subject to error at the output of the detector and thus an error in a shift character is counted only once and similarly for other characters such as carriage return and line feed. However, if the fading characteristics give rise to groups of errors, then the curve showing the relationship between element and character-error rates becomes asymptotic to curve (2). For element-error rates lower than 10^{-3} curve (1) is appropriate.

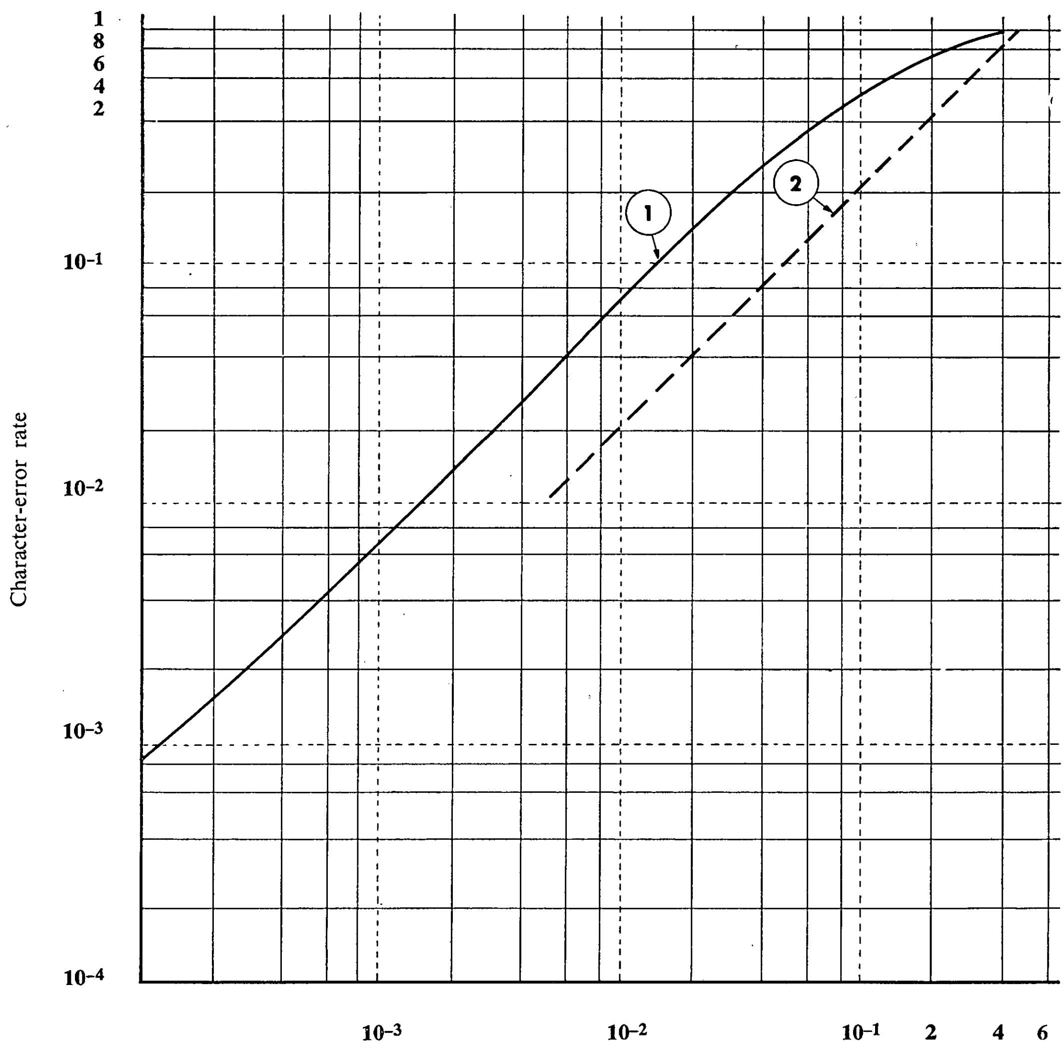


FIGURE 20

In figure 21, similar curves for the upper and lower limits applicable to a synchronous five-unit code are shown.

In figure 22, the upper limits are shown as follows:

Curve (1) — for a five-unit code as in curve (1) figure 21;

Cuve (2) — for a seven-unit code as in curve (1) figure 20;

Curve (3) — for a five-unit start-stop system with tape printing and allowing for errors due to loss of synchronism in addition to the simple character-errors;

Curve (4) — for a five-unit start-stop system with page printing, i.e. including an additional allowance for multiple errors due to carriage return and line-feed failures. Again, as for the previous curves, errors in shift signals are only counted once. It should be noted here that in any brief tests the results obtained might lie anywhere between curves (1) and (4) or even above (4) if the coincidence of failures abnormally affect the stop signals or carriage-return signals;

Curve (5) — one value of element-error rate corresponding approximately to a character-error rate (undetected) of 10^{-4} when using a ¾ code with ARQ is shown as one point only of curve (5).

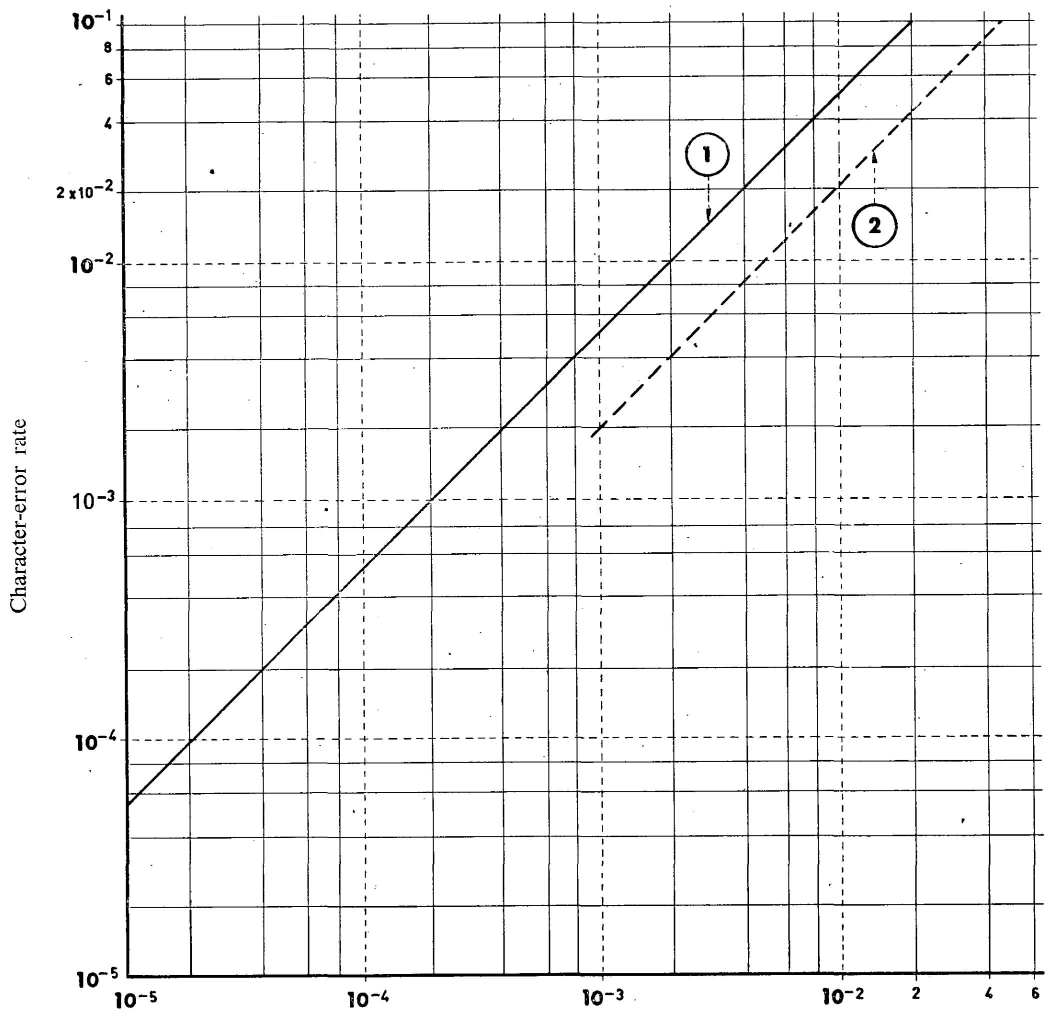


FIGURE 21

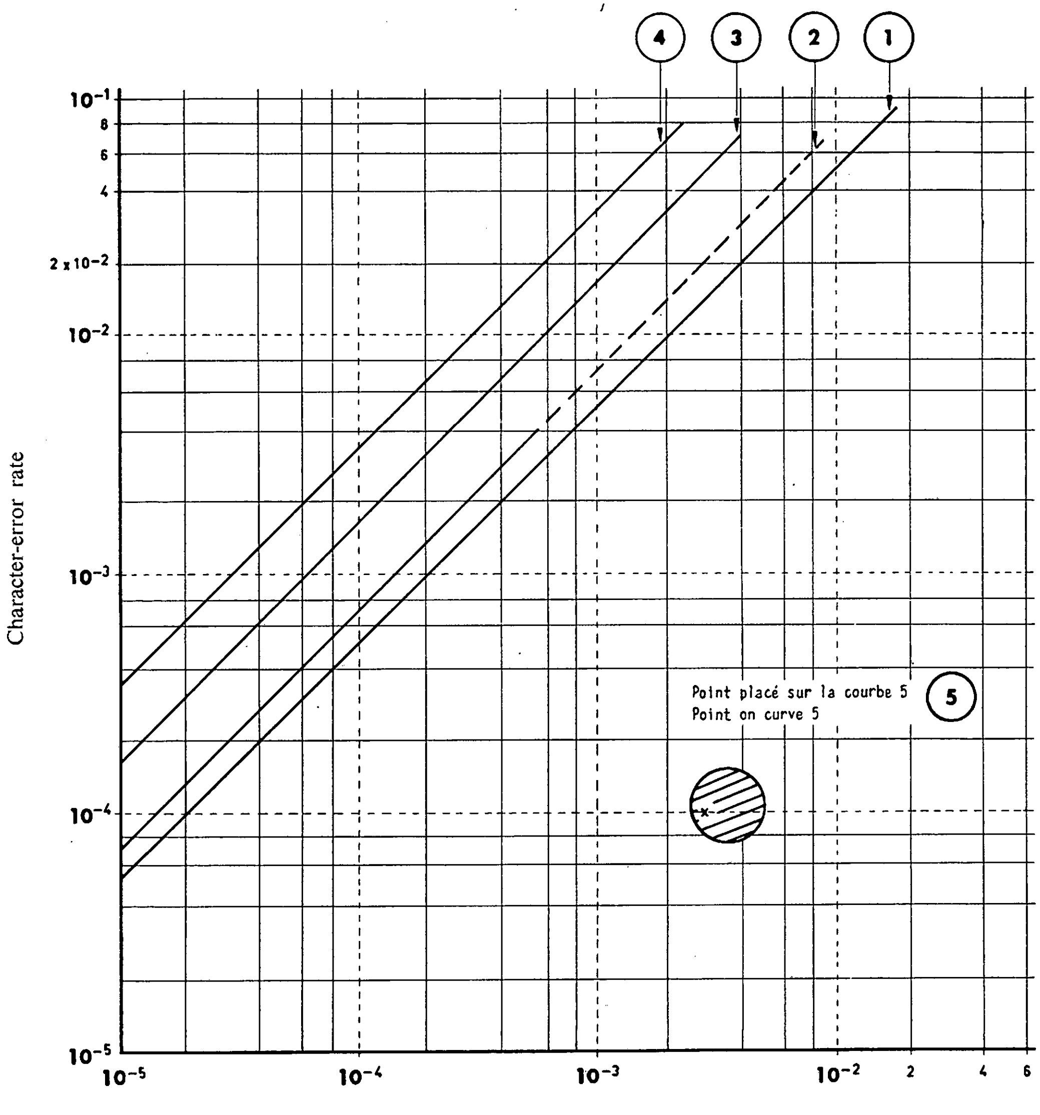


FIGURE 22

FRANCE

Statistical study of distortion and error rate on a long-distance radiotelegraph circuit

The aim of this study was to determine the relation between distortion, particularly when caused by propagation, and the performance of the circuit as indicated by the number of errors observed on a teleprinter.

a) *Test conditions.*

DAKAR-PARIS radiotelegraph circuit (4200 km).

Tests were made with frequency-shift telegraphy, the shift being 500 c/s. The transmission frequency was 15 735 kc/s. Both single and multiple reception were tested, using where necessary an antenna producing a circuit of barely commercial value.

b) *Apparatus used.*

For transmission: automatic, permanent modulation by a standard sentence.

For reception: a properly adjusted teleprinter capable of tolerating a distortion rate of the order of 37%, without automatic carriage return or automatic paper feed; such incidents as wrong paper inversion, a missed carriage return or paper jamming may lead to a considerable number of errors, and it is impossible on an ordinary circuit to tell whether the mistake lies in the character itself or elsewhere.

c) *Results obtained.*

In gauging the performance of the circuit, we did not count the number of erroneous signals reaching the equipment but rather—and this is more important from the performance point of view—the number of faults made by the teleprinter in the conditions mentioned above in paragraph (b).

As soon as the circuit suffers from fading, one can observe at regular intervals, during multiple reception, the total disappearance of one of the two frequencies, the other being received at a relatively high field strength. A great quantity of distorted elements are localized at these times—for example, during a test involving 20 000 characters, i.e. lasting about 50 minutes, ten such propagation accidents were noted, each affecting 20 to 100 characters at different times. Apart from these moments of fading, the field strength remains high on both frequencies and reception quality is excellent. The scattering of elements suffering from distortion around 0, remains low, about 99% of the elements having a distortion of between + and –10%.

Comparison of single and multiple reception.

On 18 December 1957, two consecutive tests were made on 20 000 characters:

— one with single reception, from 14h.17 to 15h.10 GMT,

— the other with multiple reception, from 15h.23 to 16h.14 GMT.

These showed, respectively, 368 and 7 errors, i.e. 184/10 000 and 3.5/10 000. Two other observations of the same kind, with different antennae, carried out on the following day and at almost the same times, showed an error rate of 2/10 000 with multiple reception against 20, 10 000 with single reception.

Relationship of the error rate to distortion.

The teleprinter is insensitive to any distortion below 37%. Errors can only occur, therefore, from distortion elements in excess of that percentage.

The error rate increases at first linearly in relation to the number of distorted elements: one error appears for each distorted element. But the corresponding curve departs quite soon from this rule and rises less rapidly. The noise periods due to propagation blanks are localized and cause the grouping of distorted elements in a small number of characters (fig. 23).

This curve is quite different from a theoretical curve showing a random distribution of distorted elements.

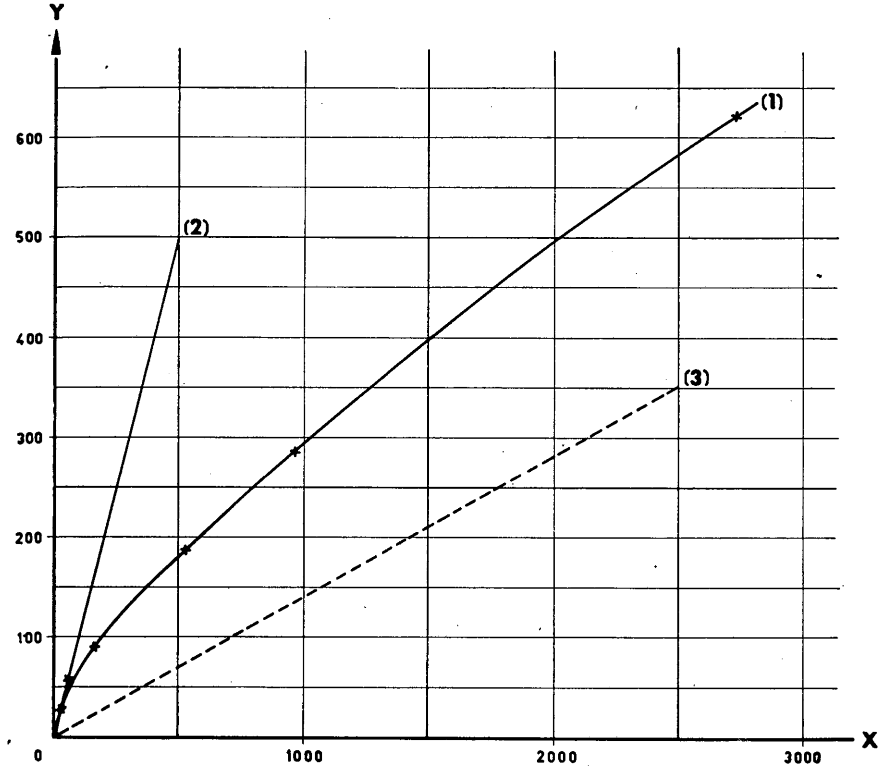


FIGURE 23. — *Number of errors in relation to the number of elements whose distortion exceeds 36% (for 10 000 characters).*

It would seem correct, therefore, to distinguish a radiotelegraph circuit by the error rate.

(1) Test curve.
(2) Straight line assimilable to the curve representing the random distribution of errors when these occur in small numbers.
(3) Asymptote.
x Number of elements whose distortion exceeds 36% per 10 000 characters.
y Number of errors per 10 000 characters.

Statistical distribution of distorted elements.

During these tests, it was observed that the statistical distribution of distortion was subject to different laws according to reception conditions.

When reception is good, the distortion is strictly concentrated around the value nil.

When fading occurs, the distortion rates are much more scattered although still centered round the value nil. Both laws result finally, on the distribution curves, in a highly localized maximum, which corresponds to good reception, as well as in a less rapid fall than that of the gaussian law for values which are far from zero (fig. 24).

If a diagram is made of these curves, in which the distortion rate is shown on the abscissae and the proportion of elements with distortion algebraically below that rate on the ordinates, the

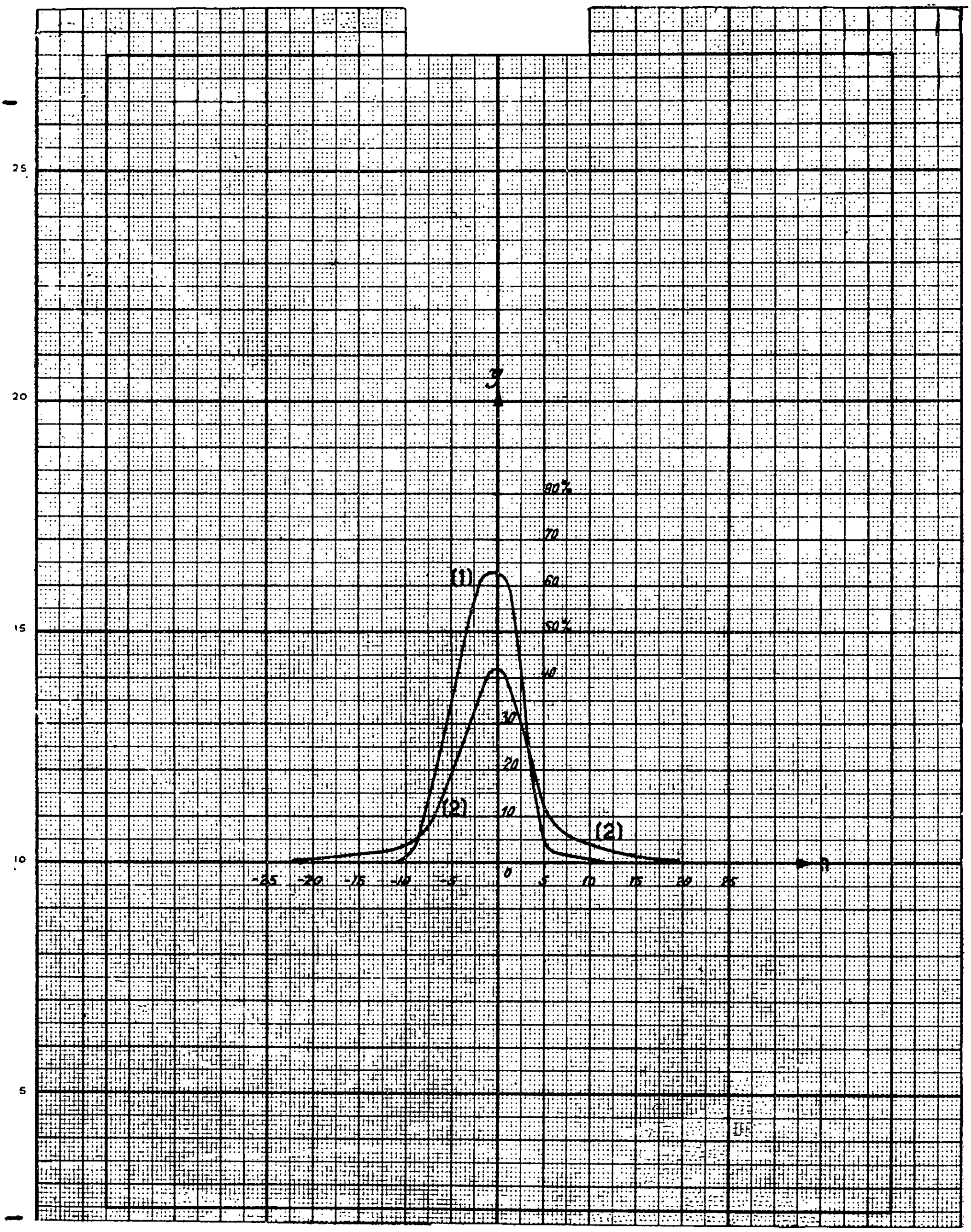


FIGURE 24. — *Percentage of the total number of elements whose distortion rate lies between* n — 5 *and* n %.

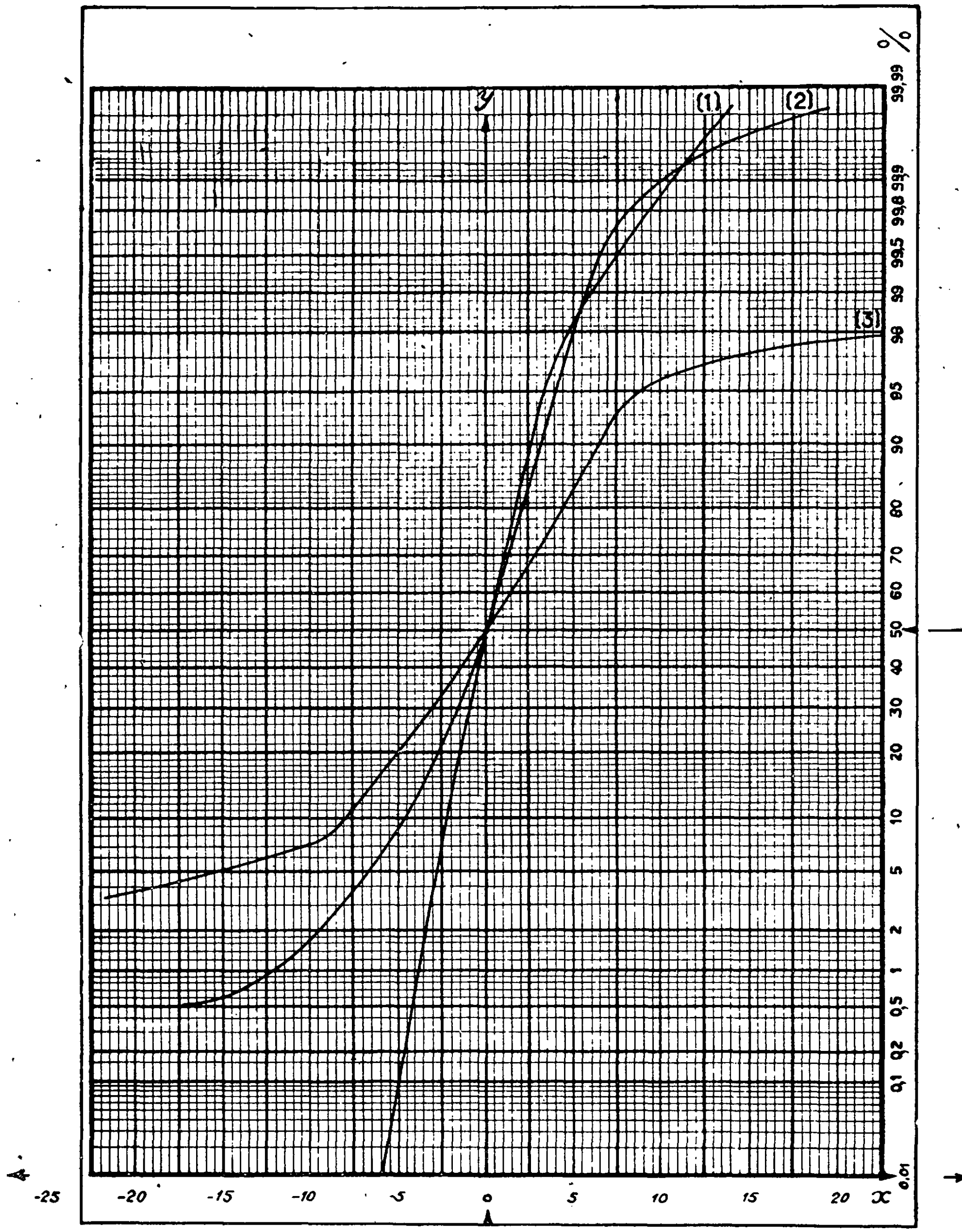


FIGURE 25. — *Curve showing the distribution of distorted elements.*

(1) and (2) Satisfactory propagation.

(3) Poor propagation.

x Distortion rate %.

y Percentage of the total number of elements with distortion algebraically less than the critical rate on the abscissae.

(8/IX)

ordinate scale being so selected that the normal distribution laws give straight lines, the result is not straight lines but curves, whose central parts are fairly straight, steep slopes, curving considerably at the ends where the slope is far less steep. This is explained by the superimposition upon the law of distribution during periods of satisfactory propagation of other laws with greater scattering corresponding to periods when fading occurs (fig. 25).

Question 9/IX — Efficiency factor and quality index.

(former Question 11 of Study Group 9, 1957-1960)
(is of interest for C.C.I.R. and Study Group I)

How can the ideas of " efficiency factor of a telegraph communication ", " quality index of telegraph operation " and " quality index of a modulation or restitution " be applied to assess the quality of a radio-telegraph communication ?

What method could be used to attain this result ?

Note. — The definitions of terms associated in the ideas concerned are given in the *List of Definitions* — Part I — under numbers:

33.23 and 33.22

Question 10/IX — Telegraph channel stability and quality coefficients.

1. Is it desirable to introduce new notions, expressed as channel stability and quality coefficients, to define the stability and quality of telegraph equipment ?

2. How could the following terms be defined:

a) channel stability coefficient,

b) channel quality coefficient ?

3. What limit values of these coefficients could be required of voice-frequency telegraph channels to ensure adequate conditions for co-operation between them ?

Comments

It seems useful to study the possibility of applying some new coefficients, e.g.:

a channel stability coefficient;

a channel quality coefficient.

The stability coefficient S could be defined as follows:

$$S = \frac{t}{T}$$

where t is the time elapsing between the moment when the channel is lined up and the moment when the degree of distortion is equal to its maximum permissible value δ_{max}, and
T is the period between one line-up and the next (at present $T = 3$ months).

Channels in which $S > 1$ can obviously be operated normally; where $S < 1$, special preventive means must be used if the channel is to fulfil its task satisfactorily.

If the channel is lined up and the measurement of δ_{max} is taken in normal operating conditions of a given channel and of other channels, the coefficient S can be designated as the stability coefficient of the channel in operation. If the measurements are carried out on the spot, the other channels being put out of operation, the coefficient S can be designated as the inherent stability of the channel equipment.

The channel stability should, as a general rule, be defined for each channel separately, especially in the period after it has been in operation, when the properties of the equipment have already been established.

When the best channel is chosen from those which are made available to us in a large number, it appears desirable to make use of the channel quality coefficient, which may be defined as follows:

$$Q = S \frac{1}{\delta_0 \, \delta_T}$$

where S — is the stability defined above,
δ_0 — is the degree of distortion of the channel just after it has been lined up, and
δ_T — is the degree of distortion of the channel at the end of the period T.

It should be added that the coefficients indicated in this way may also be applied to any telegraph apparatus, i.e. to amplitude-modulated as well as frequency-modulated voice-frequency telegraph channels.

Question 11/IX — Revision of definitions concerning telegraph transmission quality.

(results to be submitted to Study-Group VII and to Special Committee A)

Revision of definitions relating to telegraph transmission quality:

1. to make them clearer and more coherent;

2) to render them applicable to high-speed transmissions (such as data transmissions).

Question 12/IX — Effect on telegraph distortion of sudden changes of level

(former Question 13, amended, of Study Group 9, 1957-1960)
(item 1 to be studied jointly with Study Group IV and Special Committee C)

What maximum transitory distortion can be tolerated on signals when the transmission equivalent of circuits carrying voice-frequency telegraph channels suddenly varies ?

The further study of this question should be pursued in the following manner:

1. What are the duration, amplitude and frequency of occurrence of the level variations ?

2. Are the resulting distortions tolerable when their frequency of occurrence is taken into consideration ?

ANNEX TO QUESTION 12/IX

1. The observations made show a satisfactory state of affairs as far as telegraphy is concerned as regards long-term variations in equivalent (results probably obtained by use of automatic group regulators). It is observed that, for the circuits least favourably placed as regards slow variations in equivalent, the variation in equivalent corresponding to three standard deviations is less than 0.6 *N*, that is to say, is unlikely to entail a major disturbance in voice frequency telegraph systems.

2. On the other hand, as regards short-term variations, the situation is unsatisfactory as far as telegraphy is concerned. The figures show an average of 29 isolated abrupt variations per 1000 circuit-kilometres per week and 1.5 series of sudden changes (including series lasting more than an hour), which is too much.

3. Study Group IX urges that effective action be taken to counteract the excessive number of sudden changes on circuits used in V.F. telegraphy. The report by the working group of S.G. 4 shows from where the majority of these sudden changes comes. These causes had already been recognized before and form the subject of Recommendation M.15 (*Red Book*, Vol. IV).

It is desirable that the attention of Administrations should again be drawn to the appropriateness of these provisions.

4. Study Group 9 noted with interest the curve (fig. 26) showing the frequency of these sudden changes in relation to their duration. From this curve can be read off the percentage of interruptions which can give rise to false clearing signals. It was noted, however, that the lack of precision in the operating threshold of the various devices used by Administrations taking part in the tests is such that the curves cannot be guaranteed for durations shorter than 20 milliseconds.

Study Group IX desires that for any new measurements to be made by means of this equipment the operating threshold should be adjusted to the value recommended by the Swiss Administration in the Annex to Question 2 (page 434, Volume I of the *Red Book*), that is, approximately 4 milliseconds, be able to draw more accurate conclusions for the distribution curve with time of short-term variations.

5. Study Group IX believes that it would be desirable in future to record short reductions in level taking 0.6 neper instead of 1 neper as the operating threshold of the recording device. Falls in level of more than 0.6 neper are, in fact, liable to cause considerable distortion in amplitude-modulation systems.

6. It would also be interesting to observe the correlation between the frequency with which falls in level greater than or equal to the recommended value of 0.6 neper, on the one hand, and a fixed figure of 1.5 neper, on the other hand, appear on a given circuit.

These data would be particularly useful in showing the respective advantages of frequency-modulation voice-frequency telegraph systems and of amplitude-modulation voice-frequency telegraph systems of modern design which are unaffected by sudden changes in level. Administrations which participated in the tests might be able to carry out this correlation study fairly rapidly by using the devices mentioned on page 433 of the *Red Book* — Vol. I — to make simultaneous recordings of falls in level corresponding to thresholds of 0.6 and 1.5 neper.

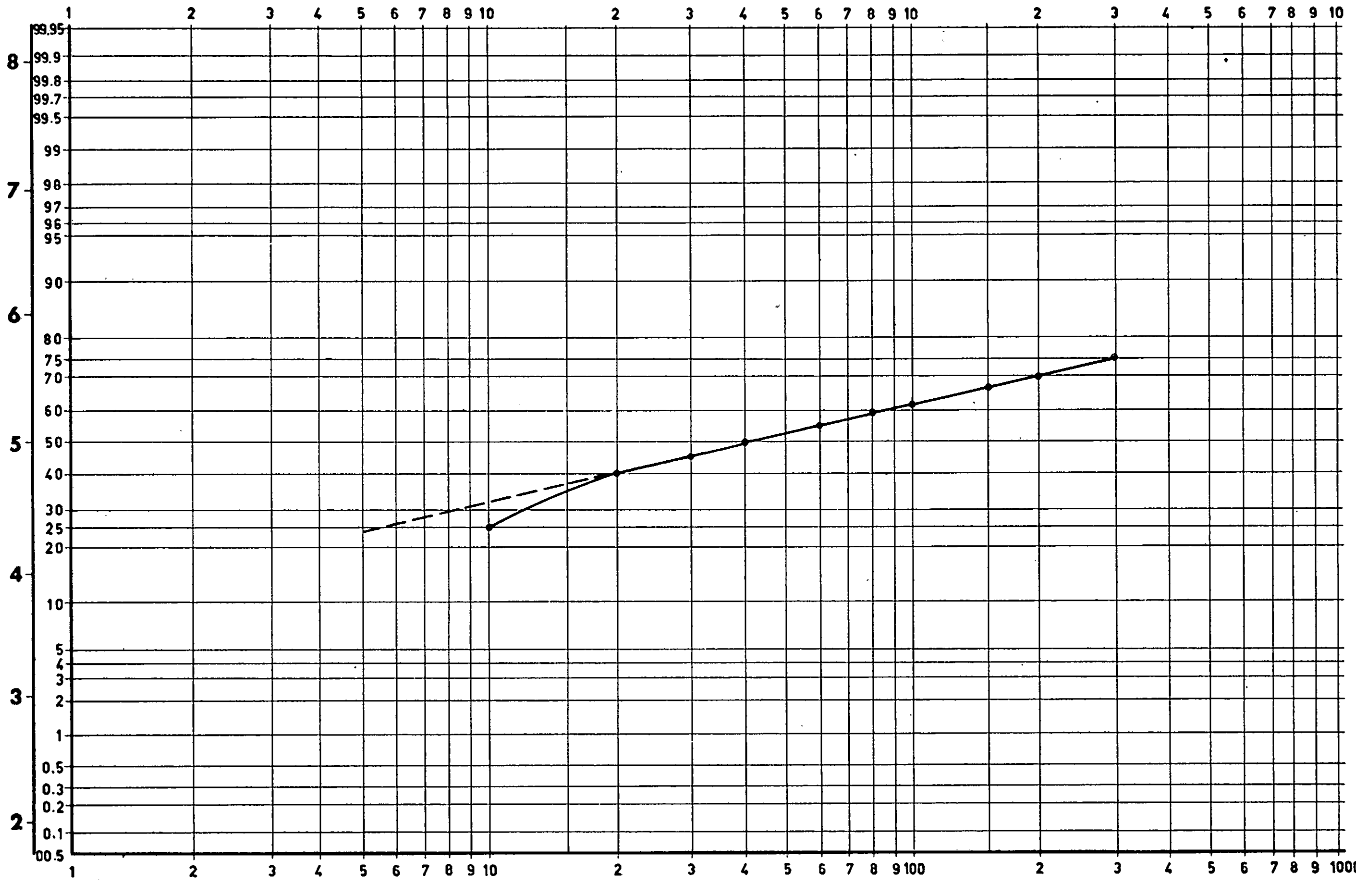


FIGURE 26. — *Integral curve showing the percentage frequency of sudden changes having a duration less than the values shown on the OX axis*

7. The telegraph services meanwhile will continue to record interruptions on the alarm channels of international voice-frequency telegraph networks. Study Group IX draws the attention of the telegraph services to the value of making periodic checks of the condition of telegraph channel equipment (bad contacts, dry joints, etc.).

8. Study Group IX proposes that, when a new series of tests is made, records should not be limited to falls in level of 0.6 neper below the nominal value, but should also include short variations (both falls and *increases* in level), the amplitude of which might be greater than 0.6 neper and the duration of which might be less than 1 second.

Such a count could be made on a small number of (V.F.T.) circuits to see whether there is a significant difference between the number of short variations defined in this way and the number of falls in level measured in accordance with paragraph 5 above.

Note. — See, in the Supplements to Series R Recommendations, the contribution from the United Kingdom entitled: Effect of sudden changes of level, on frequency-modulated voice-frequency telegraph systems, page 290.

Question 13/IX — Co-operation between different types of amplitude-modulated voice-frequency telegraph systems.

(former Question 15, amended, of Study Group 9, 1957-1960)

Study of co-operation between different types of amplitude-modulated V. F. telegraph systems (see Recommendation R.31).

Note. — This question will be examined particularly from the point of unbalance noted at the sending output filter and due, for example, to a duration of emission of the frequency during the elements " Z " differing from its normal value.

It will be necessary to find out:

a) the nature of the unbalance,

b) how to measure it,

c) its tolerable values.

Question 14/IX — 50-baud frequency-modulated voice-frequency telegraph systems.

(former Question 16, amended, of Study Group 9, 1957-1960)

Supplementary study of the standardization of 50-baud frequency-modulated voice-frequency telegraph systems (see Recommendation R.35).

Note. — This question should be studied especially from the following angles:

1. The frequency spectrum of the signals transmitted.
2. Fixing of the value for the factor Δ (maximum tolerable degree of bias distortion for output modulation).

3. Examination of the values indicated in point 12 of Recommendation R.35 to see whether they may be considered as final.

4. The unbalance at the output of the sending filter due, for example, to accidental variations in frequency for the elements A and Z.
It will be necessary to state:

a) the nature of the unbalance,

b) how to measure it,

c) its tolerable values.

ANNEX TO QUESTION 14/IX
(Item 1)

The determination of the spectrum of the signals transmitted (with limits) is a very difficult question. The detailed study of this question should be continued. In the course of discussion the following suggestions were put forward by way of example.

In systems in which, at the significant instants of modulation, the frequency of the oscillator changes suddenly (but without phase discontinuity) it will suffice, in order to define the frequency spectrum of the signals transmitted, to give the attenuation and phase characteristics of the sending filters in their pass bands and their attenuation characteristics in their attenuating ranges, because the spectrum of a wave whose frequency changes suddenly (with phase discontinuity) is well known.

For systems in which the transition from the " start " frequency to the " stop " frequency or vice versa takes an appreciable time, the spectrum of the signals transmitted should be defined, both in amplitude or in phase, either theoretically or empirically, in the band of frequencies $F_0 \pm 60$ c/s (where F_0 is the mean frequency) and should be defined only in amplitude in the remainder of the frequency band.

In the band of frequencies $F_0 \pm 60$ c/s one need consider only the discontinuous spectrum corresponding to 4 : 4 signals at 50 bauds; for the other frequencies the spectrum should be defined by the envelope of the maxima of the components of each frequency for signals whose modulation rate may vary from 0 to 50 bauds.

Note: See also the Supplement to the *Violet Book*, page 70.

Question 15/IX — 50-baud wide-band voice-frequency telegraphy.

(former Question 17, amended, of Study Group 9, 1957-1960)
(item 3 is of interest to Study Group XV)

1. For the transmission of signals with a modulation rate of 50 bauds, is it necessary to introduce for international traffic voice-frequency telegraph systems having a spacing between the mean frequencies exceeding 120 c/s ?

2. If so, what characteristics of these systems should be standardized ?

3. If a system with less than 12 channels is set up over a telephone circuit, what power limit per channel should be proposed ?

Note 1. — Would it be worth while, from the point of view of economy and maintenance, to use such systems for short links, for the transmission of telegraph signals at the normal modulation rate of 50 bauds ?

Note 2. — The study should cover amplitude-modulated channels and frequency-shift modulated channels.

Note 3. — In the Supplements to series R Recommendations, see the contribution from the F. R. of Germany entitled: Frequency-shift voice-frequency telegraph systems with channel separation of more than 120 c/s, page 287.

Question 16/IX — Telegraph channels for modulation rates of more than 50 bauds.

(former Question 17, amended, of Study Group 9, 1957-1960)
(is of interest for Study Group XV and Study Group VIII)

Standardization of telegraph channels for modulation rates of more than 50 bauds (see Recommendation R.36).

The study should deal with the use of amplitude modulation and frequency-shift modulation.

Question 17/IX — Frequency-modulated voice-frequency telegraphy using radio channels

(to be studied jointly with the C.C.I.R.)

Recommendation R.35 lays down the essential characteristics of frequency-shift voice-frequency telegraph systems; is it necessary to modify these characteristics, or to establish new ones so that these systems may be used on radio transmission paths, particularly on radio-relay links using forward scatter technique ?

Note. — See Report No. 135 by the C.C.I.R. IXth Plenary Assembly entitled: Radio-relay systems using tropospheric or ionospheric forward scatter (documents of the C.C.I.R. IXth Plenary Assembly, Volume III, page 206).

Question 18/IX — Extension of Recommendation R.75 to the case of frequency modulation.

Study of values to be inserted in Recommendation R.75 to make it apply also to links composed solely of frequency-modulated channels.

Question 19/IX — Limits of the degree of start-stop distortion.

(former Question 21 of Study Group 9, 1957-1960)

What limits to the degree of start-stop distortion can be set for standardized telegraph channels ?

Question 20/IX — Introduction of conventional degrees of distortion in Recommendations R.57 and R.58.

Revision of Recommendations R.57 and R.58 to ensure that the limits indicated in them also correspond to conventional distortion degrees.

Question 21/IX — Transmission standards in telegraph switching.

(former Question 22 of Study Group 9, 1957-1960)
(to be studied in co-operation with Study Groups VIII and X)

What telegraph transmission standards should be adopted for teleprinter switching networks:

a) between a user's station and an international terminal exchange ?

b) between international terminal exchanges ? (See Recommendation R.58).

Question 22/IX — Maintenance measurements for frequency modulation.

What maintenance measurements could be recommended for channels of international frequency-shift voice-frequency modulated systems ?
In the study of this question, the various routine measurements will be examined.

Note. — In particular, a study will be made of the tolerable increases in service with respect to the indications provisionally given in point 12 of Recommendation R.35.

Question 23/IX — Locating and clearing faults affecting switched telegraph connections.

(former Question 29, amended, of Study Group 9, 1957-1960)
(to be studied in co-operation with Study Groups I and X)

1. What measures should be taken to ensure that faults affecting telegraph switching connections are cleared as quickly as possible ?

2. What instructions should be given in the case of the telex service for international telex position ?

3. What provision should be made for a technical organization which would quickly take the necessary steps on telegraph switching corrections and what simple technical methods can be recommended for locating of faults ?

Note. — Systematic automatic tests might be recommended, but they can be envisaged only if mutually agreed upon between Administrations. If such tests should be generally recommended, a study of them should form the subject of a special question

Question 24/IX — Revision of Series R Recommendations.

(Question to be examined by a small drafting group)

Revision of Series R Recommendations — in particular — to specify whether they apply to a modulation rate of 50 bauds, to amplitude modulation or to frequency modulation (or to both).

QUESTIONS TO BE STUDIED BY STUDY GROUP X: TELEGRAPH SWITCHING

Chairman: Mr. JANSEN (Netherlands)
Vice-Chairman: Mr. FAUGERAS (France)

Question 1/X — Standardization of signalling in the telex service.

(continuation of Question 1 of Study Group 10, 1957-1960)

The points to be stressed in this study are the following:

— *charging for unsuccessful calls in fully automatic service* (see Annex 3);

— *waiting signals.*

Should a call reach a line on which waiting conditions prevail, for example in a call to a manual switchboard or test table, a waiting signal (MOM) could be sent back, without, of course, being followed by the clearing signal.

Separate consideration of continuously repeated signals and signal sequences providing a single code MOM seems necessary. In drawing up a recommendation covering continuous waiting signals, it is obvious that considerable latitude is possible in specifying the characteristics of the signals. The significant factors appear to be: the frequency of MOM codes, the frequency of carriage return and line feed functions and the inclusion of adequate continuous "stop" polarity to ensure that callers can clear.

Signal sequences providing a single code MOM are normally used in conjunction with access to manual switchboards. Draft Recommendation U.1 does not cover the signalling conditions governing access to manual switchboards and other service points and it seems necessary to add further tables to the recommendation to cover these cases. These tables could probably conveniently include the characteristics of the single sequence MOM signal.

— *re-test signal.*

The aim of this signal would be as follows:

Should the call-confirmation signal or the proceed-to-dial signal not be sent back over the switching channels within the time shown in paragraphs 3 and 4 *a)*, something should be done to ensure that a trunk circuit hold and re-test signal is sent on the forward signalling path.

This signal automatically ensures testing of the circuits, so that, if the fault disappears while the tests are going on, the international circuit is brought back into service.

See Annex 1.

Special attention will have to be given to the question of needless holding of recorders.

— *backward busying signal.*

This would be to facilitate the routine testing of the switching equipment connected at the incoming end of an international telex circuit. Arrangements should be made for the connection of a signal to the backward signalling path of the circuit concerned to show that the input to the circuit at the other end is busy.

See Annex 2.

ANNEX 1 TO QUESTION 1/X

Re-test signal

(Extract from contributions: COM 10 — No. 20, Netherlands, January 1959 and COM 10 — No. 25, United Kingdom, April 1959)

Netherlands.

The majority of interruptions of international V.F. telegraph circuits are of relative short duration. Therefore in fully-automatic working it is undesirable that a circuit should immediately be signalled as " out of order " when after a call the call-confirmation is not received. In many switching systems a circuit not returning the call-confirmation signal is busied out against subsequent seizure. A number of re-tests is made and only if after an interval of a few minutes the call-confirmation is still lacking, the fault signalling device is operated.

The same facility may be required in semi-automatic working if the operator has access to the international circuits via selectors.

In many step-by-step switching systems a trunk circuit re-test signal is used consisting of sequences of 60 seconds " stop " polarity and 1200 ms " start " polarity. In the case of both-way circuits and interruption of only the backward signalling path this re-test signal has the advantage of permanently busying out the equipment at the other end.

However, in the case of switching systems of type A or B using registers, trunk circuit re-test signals with long periods of " stop " polarity are undesirable. In the case of interruption of only the backward path of a V.F. system main line a fairly large number of channels could be brought in the re-test condition. This would cause the seizure at regular intervals of an equal number of registers at the incoming end for a period equal to the forced-release time of the registers (generally in the order of 5-10 seconds). Thus serious overloading of the group of registers serving international traffic is to be feared.

Therefore, when interworking with register systems, the period of " stop " polarity in the re-test signal should be as short as possible. Furthermore, termination of ineffective re-tests after an interval of a few minutes is desirable.

It is suggested to recommend for interworking a trunk circuit re-test signal with register systems consisting of sequences of 1 second " stop " polarity and 29 seconds " start " polarity during a maximum interval of 3 minutes. In case the circuit remains faulty, the free-line condition should be re-established after termination of the test cycle, the trunk relay set remaining of course in the busy condition.

Certain register switching systems may require a longer period of " stop " polarity to return the call-confirmation signal. In that case the Netherlands Administration would be willing to accept a slightly longer period of stop polarity for the sake of uniformity.

Probably a trunk circuit re-test facility is only required in the case of fully-automatic interworking. Since for fully-automatic interworking unidirectional circuits are generally used, the re-test signal suggested above might perhaps be recommended for step-by-step systems as well.

United Kingdom.

Recommendation U.1. provides for a call-confirmation signal so that international trunk circuits can be checked when taken into service for a call. It is customary to provide an alarm in the outgoing exchange whenever a fault is found. Some systems however, provide for the automatic re-test of trunk circuits for a period of about 2 minutes, or so, following the detection of a fault in order to avoid alarms being given for short duration faults. For inland trunks of the U.K. system, the automatic re-test is provided by connecting a signal of 29.5 seconds " stop " and 0.5 second " start ", continuously repeated, to the faulty circuit for a period of about 2½ minutes. This signal has the effect of clearing and recalling at ½ minute intervals, so that if the fault disappears during the testing period, the next recall is answered by the call confirmation signal and the trunk circuit can be restored to service. If at the end of the 2½ minute period the fault persists, permanent " stop " polarity is connected to the trunk circuit.

This facility has proved extremely useful in automatically switched teleprinter networks in the U.K. and it is considered desirable to standardize a similar facility for the international telex service. In standardizing such a facility it would also be necessary to agree on the form of re-test signal and the permanent " stop " polarity signal subsequently to be connected to the line when the fault persists at the conclusion of the test period.

Regarding the make up of the re-test signal, the following factors require to be borne in mind:

a) The effect of the alarm arrangements provided at the incoming end for indicating false calling signals. It is usual to provide a delay in the operation of alarms indicating false calling signals and it is desirable that the interval between the clearing signals of the re-test signal should be short enough to prevent the operation of the alarm at the incoming end whilst the trunk is being automatically tested.

b) The duration of the period of " start " polarity must be long enough to release the incoming equipment but short enough, in the case of bothway circuits, to allow the circuit to remain guarded and busied at the distant end during the re-test period.

c) The duration of the period of " stop " polarity must not be too long, otherwise, where the incoming exchange uses registers, failure of a MCVFT system could lead to congestion in the incoming exchange.

It is doubtful whether, in view of the conflicting requirements of register and non-register systems, a single signal could be standardized, but it may be possible to standardize signals for Types A and B signalling systems respectively.

Possible characteristics are:

Type A. " Stop " 2 secs. " Start " 28 secs. continuously repeated.

Type B. " Stop " 30.0 secs. " Start " 0.800 sec. continuously repeated.

Tolerances ± 30%

The signal should be connected to the circuit for a period of 2½ to 3 minutes so as to apply 5 tests to the trunk circuit.

As regards the signal to be connected to the line when the fault persists at the conclusion of the testing period, the choice appears to lie between permanent " stop " and permanent " start " polarity. Here again it is doubtful whether a single signal could be standardized because of the differing requirements of register and non-register systems, unidirectional and both-way trunk working, as well as the alarm arrangements at the incoming end. It would probably be necessary, therefore, to provide for the use of either signal according to the requirements of the incoming system. The U.K. system is designed to accept permanent " stop " polarity after an unsuccessful re-test.

ANNEX 2 TO QUESTION 1/X

Backward busying signal

(Extract from contributions: COM 10 — No. 20, Netherlands, January 1959, and COM 10 — No. 41, United Kingdom, September 1960)

Netherlands.

If switching equipment connected to an incoming or both-way international circuit has to be taken out of service (e.g. for maintenance), the other exchange should be informed. In actual practice, however, this information is often delayed or not given at all. Therefore an automatic trunk circuit hold facility is required as a supplementary measure.

If the return of the call-confirmation signal is suppressed when the switching equipment connected to an international circuit has been taken out of service, the outgoing equipment in the other exchange can be busied out against subsequent seizure after the first ineffective call. However, a disadvantage of this method is that there is no distinction between the out-of-order condition due to some fortuitous cause, which requires immediate attention, and the out-of-order condition due to the purposely taking out of service of the incoming equipment, which does not require action in the outgoing exchange.

Therefore a positive trunk circuit hold signal is to be preferred. It is suggested to recommend permanent " stop " polarity as trunk circuit hold signal.

A trunk circuit hold signal is not required and is even undesirable if the outgoing equipment of a unidirectional circuit is taken out of service.

The Netherlands Administration has an agreement with the Administrations of the countries with which the telex and gentex traffic is handled fully automatically to use permanent " stop " polarity as trunk circuit hold signal. This signal will seldom be returned by the Netherlands since incoming and both-way international circuits are connected to the exchange via line finders.

United Kingdom.

The primary purpose of the backward busy signal is to enable the equipment at the incoming end of a trunk to be removed from service for a short period without incurring the need to seek the co-operation of the maintenance staff at the outgoing end of the circuit. The need for this facility will become more pressing when, as a result of the growth of the telex service, testing techniques are made progressively more automatic.

Two cases require to be considered:

a) *Fully automatic working.*

It is proposed that for fully automatic working the backward busy signal returned from the incoming end of both unidirectional and bothway circuits should be permanent " stop " polarity for a period not longer than 5 minutes. The need to impose a limit of 5 minutes arises from the fact that it is usual in most switching systems to operate an alarm if a permanent stop condition persists on a trunk circuit, and, in order to avoid the operation of the alarm when the backward busy signal is applied, it will be necessary to arrange that the operation of the alarm has a delay period of 5 minutes. For tests requiring the busying of the circuits for periods longer than 5 minutes it will be necessary to seek the co-operation of the distant terminal.

b) *Semi-automatic working.*

For semi-automatic working, it is proposed that the signal to be returned should be either permanent " start " or permanent " stop " polarity for up to 5 minutes, the polarity to be as requested by the outgoing Administration. Where the outgoing equipment is arranged to busy the outgoing end of the circuit automatically on receipt of permanent " stop " polarity this signal is to be preferred. In certain circumstances, however, the use of " stop " polarity might produce difficulties, e.g. by causing a calling signal to appear on the outgoing manual switchboard. In such cases, permanent " start " polarity will have to be used.

As regards testing at the outgoing end of unidirectional circuits, there is no need to transmit to line a backward busy signal. It is proposed therefore that the outgoing Administration should maintain " start " polarity on the trunk circuit whenever the outgoing equipment is intercepted for maintenance purposes.

ANNEX 3 TO QUESTION 1/X

Charges for ineffective calls in the fully automatic service

(Extract from the report by Sub-Group 2/1, contribution COM 10 — No. 15, February 1958)

The question is to decide whether unsuccessful calls should be charged for in certain cases. Sub-Group 2/4, dealing with international telephony, did not accept the principle that an unsuccessfull call may be charged for.

In the opinion of Sub-Group 2/1, signal sequences sent on ineffective telex calls should not involve any tax.

Should this arrangement give rise to great technical difficulty, it would be necessary to keep the duration of these signal sequences to a minimum, and to follow them in the shortest possible time by a clearing signal.

Note from the C.C.I.T.T. Secretariat: At its meeting in Belgrade in January 1958, Sub-Group 2/2 confirmed the view of Sub-Group 2/4 that an unsuccessful call should not be charged for.

Extract from the contribution by the Netherlands
(contribution COM 10 — No. 20, January 1959)

Signalling conditions for semi-automatic or fully automatic working to service positions and manual switchboards.

The signalling conditions indicated in the tables 1*a* and 1*b* annexed to Recommendation U.1 are restricted to semi-automatic and fully automatic working to subscribers. In many telex networks different signalling conditions hold for calls to special services (e.g. enquiry and engineering positions, test message transmitters, etc.) and manual switchboards. An important question is whether subscribers should be allowed fully automatic access to service positions and manual switchboards in foreign networks. If such access is required it would certainly be very convenient if signalling conditions were the same as for calls to subscribers. As far as known subscribers are nowhere allowed to select fully-automatically service positions or manual switchboards in foreign networks. However, such access might be required in the future. For example, fully automatic access to foreign radio telex positions would certainly be in the interest of the intercontinental telex service.

It should be noted that fully automatic access to foreign manual switchboards entails a metering problem. Since in this case the charging will be done by a manual operator there should be no automatic metering of the call.

Suppression of the automatic metering is possible by examining the digits of the switchboard number. Similar arrangements as in Recommendation U.7 would be required for switchboard numbers.

In any case, additional tables covering signalling conditions for calls to service positions and manual switchboards are required. Administrations should supply the necessary information about their networks. In the Netherlands switching system the same signalling conditions are encountered for calls to service positions and manual switchboards as for calls to subscribers. However, for calls to manual switchboards the return of the answer-back code is delayed until the operator answers. Service positions have 2-digit numbers whose first digit is " 9 " or " 0 ". Manual switchboards have 2-digit numbers whose first digit is " 7 ".

Extract from the contribution by France
(contribution COM 10 — No. 28, May 1959)

A. For calls in the French internal telex system, the call-connected signal comprises only those teleprinter signals which are controlled by the outgoing switching equipment. These signals are, in order:

a) In the direction opposite to that of selection, the twenty signals of the called subscriber's answer-back.

b) At the same time, sent to both the called and calling stations, a sequence of twelve signals showing the day, the hour and the minute when the connection is made.

c) The " who are you ? " signal in the backward direction, which causes the caller's code to be transmitted and informs his correspondent as to the origin of the call. While these latter signals are being sent, the keyboard of the calling operator is normally blocked, which prevents any premature transmission.

Chargeable time is metered in the following manner:

At the first signal train *(a)*, after checking that the answer-back is indeed one of a telex subscriber, the time metering device in the outgoing exchange is connected to a cam providing a pulse every ten seconds.

If the called subscriber has mistaken the number, he immediately realizes he has done so when the first answer-back comes in, and the operator can clear down forthwith by giving the clearing signal. Even if it happens that the first charging pulse from the 10-second cam occurs at once, there will be no charge for the call.

Should the first code of the call-connected signal be in accordance with the operator's wishes, depending on the phase of the 10-second cam, the first charging pulse cannot be sent before the start of transmission of the time and date signals, and not later than some five seconds after transmission of the answer-back of the calling station, that is to say, after the end of the complete call-connected signal.

The possible inclusion in the chargeable duration of the last teleprinter signals of sequences *b)* and *c)* above — part of the call-connected signal — is justified by the service rendered. Such a call-connected signal can be considered as an automatically transmitted preliminary, which, in the long run, saves operators' time.

There has never been any objection to this on the part of subscribers who used sometimes, with the old manually-operated system, to time their calls with a stop-watch. Moreover, it represents a just compromise between a standard period of free transmission with a possibility of fraud, and excessive charging if there is a mistake in selection.

B. We expect to use the same call-connected signal, with three teleprinter signal sequences, for telex or gentex calls (fully automatic) outgoing from France.

But the time and date signals will be transmitted first, and to the French caller only, in the form of a sequence of twenty signals, like that of the answer-back of a telex subscriber, and only then will the " who are you ? " sequence operating the foreign subscriber's answer-back be transmitted on the international circuit.

Besides the advantages set forth under A, there are two others, as follows:

a) In international manual or semi-automatic operation, the international operator in the outgoing country already controls this complete exchange of answer-backs in both directions when the connection signal proper (or the DF sequence), arrives from the incoming network. Hence, so far as the subscriber is concerned, excluding time and date signals, the real international call-connected signal always has two answer-backs in all circumstances, whether selection be fully automatic or not.

b) The automatic charging devices used throughout the French network decide when the chargeable time begins by analysing the first answer-back received. Hence it is possible to use the charging devices existing in the outgoing switching equipment, to which the calling subscribers are directly connected, for automatic charging of international calls leaving France.

In this way, the international selection devices at the output of the inland network, that is to say, at the origin of the international circuit proper, merely have to add the effective communication times so that international accounts can be drawn up for each circuit or each kind of relation. As regards selection, it follows that the basic functions of these automatic devices are to carry out the selection in the distant network, correctly interpret the call-connected signal peculiar to the incoming network, and, if need be, replace it by the sequences of the full exchange of answer-backs between called and calling subscriber.

C. In the case of a foreign international position selecting a French telex subscriber, the present call-connected signal includes the three signal sequences *a)*, *b)* and *c)* shown in A above.

We could have invoked the basic principle of Recommendation E.1, whereby there is an obligation to adapt the equipment of the outgoing country to the signalling in the incoming network. Nevertheless, to facilitate interpretation of the call-connected signal in the outgoing country, we have agreed that the 150-millisecond pulse should be shown as obligatory in table I *b* for Type A signalling systems. Hence this pulse will be introduced in French automatic switching systems for calls coming from foreign telex networks. When the change is complete, the call-connected signal will accordingly comprise not only this pulse but, following 3 to 5 seconds of " stop " polarity after this pulse, the three sequences *a)*, *b)* and *c)* of teleprinter signals shown above.

Hence it will be possible, in the country of origin, depending on the usual habits of the subscribers and the preferences of the Administrations concerned:

— either to begin charging on receipt of the 150-millisecond pulse, so as to give the caller the benefit of this signal from the incoming network, in which case these signal sequences will be included in the charging period;

— or to block the caller's line until the end of the answer-back control signals, if it be desired that the chargeable period should begin only at the moment when the operator can actually transmit. In this case the caller must himself ensure, by manual control, who his correspondent is.

D. There is no plan to bar access to special information and assistance positions, which must be accessible from similar positions of other Administrations. When a telex subscriber from abroad calls such positions in France, the call will be treated as a normal telex one, and the call-connected signal, including the 150-millisecond pulse, will be transmitted to the switching equipment of the country of origin, as soon as the call is extended to the required position. Should the operator of the required position not be able to answer at once, the first part of the call-connected signal will be a fictitious waiting signal, ending with the sequence MOM. Since such calls are exceptional, nothing will be done to postpone the beginning of charging if in the country of origin this charging is started simply by reception of the 150-millisecond pulse of the call-connected signal.

For similar reasons, and to allow the setting-up of international transit calls, the international telex positions of a country must also be accessible to calls from the international positions of other countries. Now in most cases, these calls pass via automatic switching equipment in the transit country and arrive at the intermediate international positions in the same way as bookings by their national subscribers.

In France, outgoing international calls are charged for without recourse to the 150-millisecond pulse of the call-connected signal. When an international telex position (French) intervenes to put through a transit call, its intervention must have no effect on the charging system of the country of origin. In fact, in such cases, this operator has nothing to do with charging.

This rule remains inevitable, even if selection is fully automatic between two countries, for the international telex positions of the incoming country must also be accessible to calls from international positions in the outgoing country.

This being so, there is accordingly some danger that telex subscribers in the outgoing country will automatically call the international positions of the incoming automatic country, thus getting international transit calls free of charge. It seems difficult to cover this risk by laying down instructions for operators at the international positions, more especially because of the diversity of the answer-backs of the various international positions, which may on occasion lead to confusion with subscribers' answer-backs.

The best thing to do would perhaps be to bar access in the country of origin to international positions in other countries. This assumes that in every national telex dialling plan, numbers easily identifiable, for example, by means of their first figures, should be used uniformly to denote all international connections set up from that national network, no matter how.

E. Two types of service signals are to be considered: those which are given to a subscriber in response to a request for information, or requiring him to wait before giving him a call to a particular number (e.g., access to an information position); or those intended to show quickly why his call cannot be put through.

In the first case, the greatest possible freedom of action should be left to each Administration. The only problem that may arise is to know the exact instant at which the call-connected signal should be given to start the charging device. As was said in connection with the question of access to the information positions, the French Administration considers that charging should begin as soon as connection is made to the required line.

In the second case, it is desirable not to set the charging device in motion. If the technical difficulties mentioned in contribution COM 10 — No. 15 cannot be overcome, every effort should be made to reduce these signal sequences so far as possible and to follow them by an unbroken clearing signal until the international circuit is completely cleared.

The French Administration tries to shorten the signal sequences in three main cases of ineffective calls, i.e. busy " OCC ", barring " NA ", and subscriber temporarily out of service (sequence " ABS "). To ensure correct use of these signals, however, it considers that the sequences should be capable of including a maximum of 13 combinations.

Sequences given by other networks will be retransmitted to the French outgoing station in the form of the last combinations received, to prevent any confusion with a subscriber's code in the charging device.

Extract from contribution by Sweden
(contribution COM 10 — No. 35, September 1959)

Pending the issue of an international recommendation on the establishment of accounts for fully automatic international telex traffic, telecommunication Administrations have so far been reduced to solving this question of accounts as and when it has arisen, by means of bilateral agreements. As a contribution to the forthcoming meeting in Munich, we shall describe below the agreements concluded by Sweden with regard to the establishment of accounts for this type of traffic, and the charging system applied in Sweden for fully automatic telex traffic.

Outgoing telex traffic from Sweden to Belgium, Denmark, the Netherlands, and the Federal German Republic is at present operated fully automatically. For this traffic, a charge per minute is collected from subscribers, the change in question being the same, at present, as the charge per minute for semi-automatic traffic to the country in question. Hence, subscribers are slightly favoured by the abolition of the minimum three-minute charge applied to semi-automatic traffic. However, C.C.I.T.T. Recommendation F.66 will be adopted in the course of this year. It should be mentioned that in the fully automatic service, as in the manual and semi-automatic services, Swedish subscribers receive a check ticket for each telex call to another country (with the exception of a frontier service to Denmark which is fully automatic). For the charging of fully automatic traffic, a non-chargeable delay of 10 seconds is applied, as the meter begins to operate only at the end of this delay, after reception of the call-connected signal from the called station. This choice of a fairly long uncharged period was motivated by the desire to give subscribers sufficient time to cancel a call in case of a fault in the circuits or a wrong call, so that they are not subjected to a charge for such calls. The duration of the first *chargeable* minute, starting from the reception of the call-connected signal, may vary from 60 to 70 seconds.

Extract from contribution by the United Kingdom
(contribution COM 10 — No. 41, September 1960)

Charging on ineffective calls.

One of the principal problems in this connection arises from the fact that a number of Administrations employ dial selection systems which use Type B signalling and in which the teleprinter motors are arranged not to start until the backward signalling path reverts to " stop " polarity. For such systems it is necessary for the teleprinter characters in service signal texts to be preceded by two seconds (say) of " stop " polarity. If service signals having these characteristics are used, metering will occur on incoming international calls. As a means of overcoming this difficulty, it is proposed that on existing systems, where the use of printed service signals having a format in accordance with the current Recommendation U.1 is not practicable, a signal sequence format of the form shown in the attached sketch (fig. 27) should be permitted. The proposed signal sequence would provide for the correct reception of the printed service signal internally, (i.e. the initial 20 ms pulse of " start " polarity represents " letter shift " in the 5-unit alphabet, and would not produce a printed character even with the teleprinter motor running slowly), but would provide a means so that on international calls it would be possible to discriminate between ineffective calls and effective calls if the calling Administration so wishes. As far as the United Kingdom Administration is concerned, it intends to use in its internal system printed service signals conforming to the existing Recommendation U.1 but would be prepared to receive from other Administrations, Type B printed service signals of the format described above. The United Kingdom Administration proposes, therefore, that service signal sequences of the format described above should be admitted as an alternative in those cases where the present standards could not be adopted without significant modifications to the system. However, for new systems, the signal sequences shown in the current Recommendation U.1 should be used.

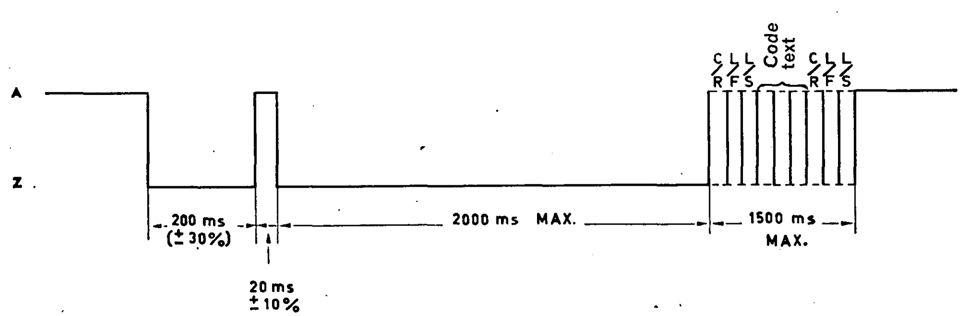


FIGURE 27. — *Proposed service signal sequence for use on existing systems which are unable to use existing standard printed service signals*

Question 2/X — Standardization of signalling for gentex network.

(continuation of Question 2 of Study Group 10, 1957-1960)

Note. — See Recommendation U.30.

(2/X)

Question 3/X — Service signal sequences on telex and gentex networks.

(continuation of Question 9 of Study Group 10, 1957-1960)
(interests Study Group I)

Consideration of the standardization of signal sequences and service texts transmitted by the switching equipment in the international telex and gentex networks when calls are being put through, especially when these calls cannot terminate in the ordinary way.

Note. — See Recommendation S.4.

Question 4/X — Telex signalling over radio circuits.

(continuation of Question 3 of Study Group 10, 1957-1960)

Further study of the standardization of switching signals to be used on the international telex service on calls involving radio circuits operated by means of synchronous 7-unit systems affording error correction by means of automatic repetition.

Study should stress signalling conditions with fully automatic switching.

Note. — See Recommendation U.20 and Supplements, page 340.

Question 5/X — Gentex signalling over radio circuits.

Gentex signalling over radio channels operated by synchronous 7-unit systems with error correction by means of automatic repetition for:

1) a fully automatic operation between two gentex networks directly connected.

2) a fully automatic operation between two gentex networks connected through a third transit exchange, connected by radio synchronous error-protected channels to an exchange of the first network and to an exchange of the second network.

Question 6/X — Operator recall on intercontinental circuits.

(interests Study Group I)

Study of the extension of Recommendation U.21 (operator recall on a telex call set up on a radiotelegraph circuit) to cover intercontinental telegraph circuits on modern submarine cables.

Question 7/X — Automatic service over intercontinental circuits.

Technique of fully automatic operation of intercontinental telex circuits.

Comments

1. Having regard to the need for minimizing the time required for establishing a call, as well as for simplification of the technical equipment on intercontinental lines, is it desirable or necessary that time and date, as well as possibly register numbers, be transmitted over the intercontinental circuits ?

2. Some of the present European systems automatically request the answer-back sequence either by equipment at the calling or called exchange locations. In view of such practice in some European systems, and not in others, is it desirable or necessary to provide such an automatic function over the intercontinental circuits ? If so, what should be the regulations governing this procedure ?

3. In establishing intercontinental connections on a fully automatic basis, it appears that a considerable amount of very valuable transatlantic trunk circuit time will be consumed by the waiting and operating time of one or more registers and especially so where in some cases an alternate route has to be selected. In order to keep the loss circuit time to a minimum, would it not be desirable to specify a maximum connection completion time immediately following the transmission of the last directory digit over intercontinental circuits ?

Question 8/X (Question 8/I of Study Group I) — Numbering scheme and routine plan for telex and gentex intercontinental services.

(Question of common interest for Study Groups I and X; to be studied by a joint working group I/X)

Is there a need to draw up an automatic switching plan for the intercontinental telex — and perhaps gentex — services? If so, what standards should be recommended in the light of problems of transit signalling, routing and switching in intercontinental traffic and the associated operating and financial questions ?

Comments

1. The rapid growth of intercontinental telex and gentex traffic and in particular the development of subscriber dialling in intercontinental relations which has been made possible by the provision of intercontinental coaxial cable systems, makes it desirable to consider the economics of telex traffic routing on a world-wide basis. The time differences between terminal countries in such relations and the consequent differences in the hours of peak traffic loading, may make it economic to employ tandem transit routing to a much greater extent than has been necessary in the purely European network. However, the development of a comprehensive plan for the economic employment of tandem routing depends, amongst other considerations, on agreement on numbering and routing plans. Moreover, even when a country is served by more than one telex network, the telex number of a subscriber should contain all the digits which must be dialled or passed by a correspondent or controlling operator in an overseas country to obtain connection, whatever itinerary may be employed for routing a call. It is also desirable to restrict the number of digits which must be examined by the equipment to determine the charging rate. It is therefore proposed that a question be put to the C.C.I.T.T. for study.

(8/X)

Question 9/X — Special circuits used in switched services.

(interests Study Groups, XI, XIV, Special A

Is it necessary to provide facilities in automatic switching centres for the selection of special circuits for data transmission, facsimile, high speed telegraphy, etc., by means of a code number, for example ?

If so, what are the possibilities and what arrangements should be made ?

Question 10/X. — Retransmission of messages.

(Question 10/I of Study Group I)
(question to be studied by a working group of Study Groups X, I and VIII)

What technical, operational and financial arrangements should be prescribed for international message telegraph systems using message relay techniques with automatic or semi-automatic switching of messages and tape or electrical storage?

Comments

In the study of this question account should be taken of the desirability that:

1. such relay systems should be fully capable of inter-working one with another, and

2. other systems using conventional techniques (e.g. point-to-point systems using manula transfer of messages between circuits) should be able to inter-work with such relay systems with only minimal changes in procedure, etc.

The study of this question should extend to all relevant aspects of the subject, including:

1. the transmission conditions appropriate to message relay operations;

2. collaboration between telegraph codes used at present, method of operation and speed of operation;

3. the message format, with particular reference to any functional signals, destination indicators *, priority indicators, etc., required for use at automatic or semi-automatic transit centres;

4. any other information (e.g. accounting information) for which provision should be made for automatic operation;

5. any special operational aspects (e.g. limitations on length of messages); and

6. general considerations relating to traffic control, emergency routings, etc., called for particularly by message relay operations.

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* *Note.* — The system of destination indicators recommended for use with international message telegraph systems using message relay techniques with automatic or semi-automatic switching of messages and tape or electrical storage, should if possible be also designed in such a way that it could also be used:

a) to provide short designations, of international validity, for the principal offices to which international telegrams may be sent;

b) in registered abbreviated telegraphic addresses to indicate more precisely the terminal office in the international system to which messages addressed to such addresses should be sent; and

c) to simplify the arrangements at international centres which handle traffic in transit between networks employing different techniques (e.g. between a message relay network and a through switched network such as the gentex system).

QUESTIONS TO BE STUDIED BY STUDY GROUP XIV: APPARATUS AND TRANSMISSIONS FOR FACSIMILE TELEGRAPHY

Principal Chairman: Mr. FIJAŁKOVSKY (Poland)
Vice-Chairman: Mr. BITTER (Federal German Republic)

Question 1/XIV — Use of the standardized test chart.

How can the quality of a received picture be gauged from the standardized test chart for facsimile transmissions ? What can be deduced regarding the overall quality of the transmission and of the apparatus ?

Note. — See Recommendation T.20.

Question 2/XIV — Correction of phase distortion for facsimile telegraphy.

(former Question 12 of Study Groups 1 and 8, 1957-1960)
(results to be submitted to Study Group XV)

Study of the possibility of increasing the speed of transmission for facsimile (including phototelegraph) systems in the international service by the use of equipment for correcting delay distortion on the carrier telephone circuits utilized.

Note 1. — Administrations should prepare a table giving the speeds and indexes standardized in C.C.I.T.T. Recommendation T.1 which, if exceeded, give rise to excessive group delay variations.

Note 2. — See Recommendation T.12.

ANNEX 1 TO QUESTION 2/XIV

In the case of circuits occasionally used for facsimile transmissions, the additional cost of inserting phase compensators would not be justified by the resulting advantages, especially since these circuits might have a complicated make-up which makes phase compensation difficult.

The use of phase compensators, therefore, is to be envisaged only for circuits permanently allocated or usually used for facsimile transmissions. The time is not yet come for proposing an international recommendation about the regular use of phase compensators. In fact, certain

Administrations consider that such compensators are too costly and that the preliminary adjustments which have to be made before each transmission result in the time gained due to the increase in transmission speed being lost. Administrations which wish to use phase compensators to increase transmission speed on certain circuits will make bilateral agreements about the method to be used. Administrations who do in fact use phase compensators are invited to supply detailed information with a view to subsequent standardization.

The above considerations apply to classical methods of facsimile transmission (including phototelegraphy) using frequency modulation or double sideband amplitude modulation. Vestigial sideband transmission is dealt with in Question 3/XIV.

ANNEX 2 TO QUESTION 2/XIV

Extract from the contribution of the Federal German Republic

(contribution COM 8 — No. 9 or COM 1 — No. 95, November 1957)

The delay distortion on the telephone channels of German long-distance traffic carrier systems (see page 332 ff.) are shown hereinafter in another diagrammatic form (fig. 28). The *b* curves show the distortions likely on *one* channel of a carrier system when amplitude-modulation is employed (carrier = 1900 c/s). At the same time, the *a* curves show what values of distortion can be considered admissible if index 352 or index 264 are used, with varying drum speeds. According to these indications, the limit for correct facsimile transmissions, in the most favourable instance, is 120 or 160 r.p.m. (352 or 264). These figures are confirmed by experience too.

The use of phase distortion correctors maintaining group propagation time in the band 450 to 3250 c/s within admissible limits would make it possible to increase the transmission speed to 150 or 200 r.p.m. Incidentally, amplitude modulation is no longer applicable at higher speeds, because the available bandwidth of 2800 c/s is then exceeded. For economic reasons, it is impossible to use phase distortion correctors for the individual correction of circuits designed for facsimile transmission. Since, contrary to audio-frequency circuits phase distortion on carrier channels remains within known limits the use of standardized phase distortion correctors in conjunction with phototelegraph equipment could well be envisaged. In such cases, these phase distortion correctors should correct the curve of average values of propagation time (see the dotted-line curve in figure 89, on page 333). Because of possible variations around this average value, there will inevitably be some residual distortion. The *c* curves in figure 28 show the values that may be attained by such residual distortion in conjunction with German carrier systems, assuming an accuracy in the correction of phase distortion of $\pm$ 0.08 millisecond. Whence it will be seen that by the use of standardized phase distortion correctors of the kind described, the transmission speed could be increased to about 140 r.p.m. with index 352 or to about 190 r.p.m. with index 264. The gain in relation to 120 or 160 r.p.m. is negligible.

In practice, connections between two phototelegraph stations are often made up of *several* carrier sections in tandem. In such circumstances, the outcome of phase distortion correction by standardized correctors is doubtful, because dispersions are added thereto statistically. And in international service, we have to reckon with a wider range of dispersion.

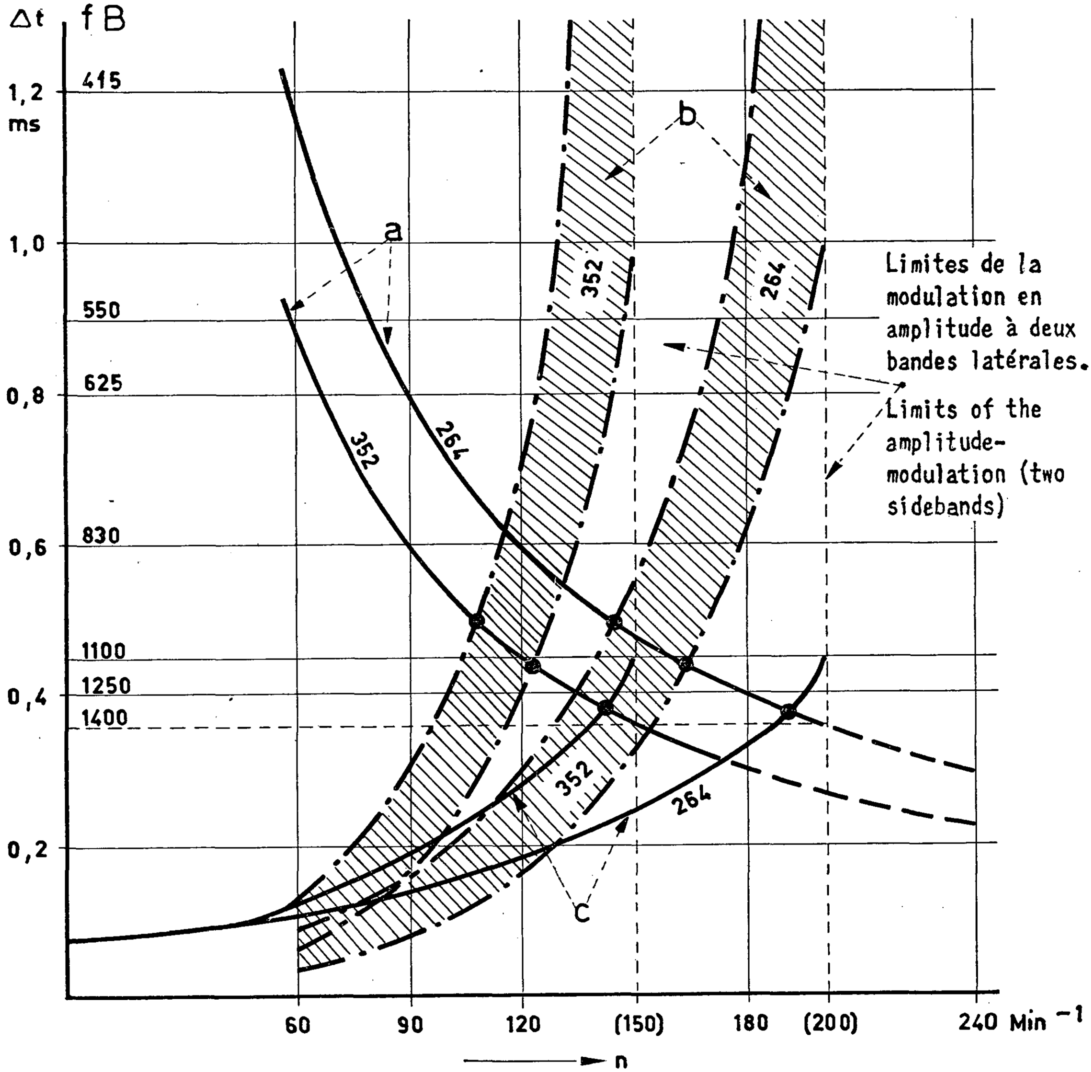

FIGURE 28

a = Delay distortion admissible in the band transmitted.

b = Residual delay distortion in a telephone channel of non-compensated V-60 systems.

c = Maximum delay distortion on a V-60 system telephone channel if a standard phase distortion corrector is inserted.

We hold that an adequate phase distortion correction is possible only if the phase distortion correctors, before each transmission, are adjusted to an optimum figure as staggered-action correctors. In this case, we shall also have to equip transmitting phototelegraph stations with a control signal generator, and the receiving ones with an oscillograph. It is doubtful, in our view, whether the almost negligible increase in transmission speed justifies such an outlay.

(2/XIV)

Besides which, we consider that the question of phase distortion correction is of importance for the transmission of half-tones only. For black-and-white transmissions, in which a perfect reproduction of the picture in all its details is less important than the intelligibility of the message transmitted, greater phase distortion is tolerable. There should be no increase in the cost of facsimile apparatus for the transmission of black and white (which will probably be used in greater numbers in the very near future) by mounting an additional phase distortion corrector. Equipment should be conceived for speedy, simple operation.

Question 3/XIV — Use of vestigial sideband modulation in facsimile telegraphy.

(former Question 16 of Study Groups 1 and 8, modified)
(concerns Study Group XV)

Is there a need to envisage the use of asymmetric sideband operation for permitting higher operating speeds on facsimile including phototelegraph apparatus working over international metallic telephone circuits ?

If so, what characteristics are to be recommended ?

Note. — Such transmissions are envisaged only over circuits set up specially for the purpose.

ANNEX TO QUESTION 3/XIV

The general expression " asymmetric sideband operation " in the wording of this question could apply to the two methods shown in figures 29 and 30. It should be clearly understood that it is the method shown in figure 29 which is concerned, and which in the C.C.I.F. has for many years been called " vestigial sideband transmission ", the method also being used for television transmissions on cables. The method shown in figure 30 is described under " transmission with partial sideband suppressed ", usually also called in English " vestigial sideband transmission ". Wherever the expression " asymmetric sideband " occurs in connection with this question it should be understood to mean the same thing as " vestigial sideband " as in the case of figure 29.

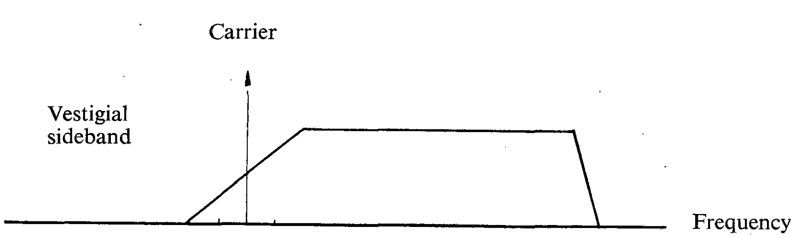

FIGURE 29

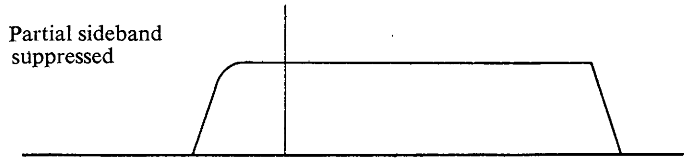

FIGURE 30

The results obtained in the U.S.S.R. with asymmetric sideband transmission (at speeds of 240 and 360 revolutions per minute) were examined.

It appears that such results are possible with standardized phase correctors only with circuit equipment having the same characteristics. It is feared that the existing diversity of certain equipment used in carrier circuits for international communications would be an obstacle to widespread use of such a method of phototelegraph transmission.

Administrations should study this question both for phototelegraphy and for facsimile with direct recording. Some sort of study should be made of the costs of the additional apparatus.

Attention is drawn to the effect, from a transmission point of view, resulting from the use of vestigial sideband transmission:

1. So as to reduce the effect of quadrature distortion on facsimile transmission, the ratio of white level to black level should be reduced. For example, it has been proposed to reduce this ratio to 12 or 14 db instead of 30 db in the case of double sideband amplitude modulation. Reduction of this ratio results in an increase in mean signal power. A detailed study of the permissible power for this type of modulation has been made. It is probable that the maximum permanent white signal level for the existing system could not be increased by comparison with double sideband amplitude modulation.

2. Partial suppression of the upper sideband in sending and receiving equipment must be achieved in such a way that the sum of the amplitudes at frequencies equally spaced on the two sides of the carrier frequency is equal to the total signal amplitude, and this may give rise to difficulties on a circuit on which there is attenuation distortion, when the carrier is at a relatively high frequency.

3. The carrier frequency and amplitude should be chosen with these considerations in mind. In particular, the higher the vestigial sideband reduction factor, the higher may be the carrier frequency. The following frequencies have been suggested:

   3100 c/s by the U.S.S.R.

   2850 and 2550 c/s by the Federal German Republic.

   See also : Contribution by U.S.S.R., Supplements of the C.C.I.T., *Violet Book*, page 158; Contribution by the Federal German Republic , page 336, Volume VII.

Question 4/XIV — Use of frequency-modulated carrier for facsimile telegraphy.

(former Question 15 of Study Groups 1 and 8, modified, 1957-1960)
(concerns Study Group XV)

Is there a need to envisage the use of frequency modulation for phototelegraphy apparatus working over international metallic telephone circuits ?

If so, what characteristics are to be recommended ?

ANNEX TO QUESTION 4/XIV

The difficulty of comparing the advantages of frequency modulation and amplitude modulation is due to the fact that the C.C.I.T.T. had no quantity with which to define the quality of phototelegraphy reception.

Standardization of the test charts should lead to obtaining an objective factor for defining the quality of a phototelegraph reception.

It seems that the majority of the characteristics specified by the C.C.I.T.T. for modern telephone circuits are sufficient to permit frequency-modulated phototelegraph transmissions on a circuit chosen at random in a group of circuits normally used for telephone working. However, it is not certain that such a circuit would have a sufficiently low phase distortion for such use, particularly channels 1 and 12 of a 12-circuit group, use of which is not advised. *Administrations should carry out measurements to determine the phase distortion* (change of group delay with frequency) on carrier telephone circuit equipments, which are the main sources of phase distortion in such circuits and in particular on telephone channel modulating equipment. It would be interesting, for example, to study the values to be expected on:

a) a telephone circuit set up on a single 12-channel group link,

b) a 2500 km hypothetical reference circuit.

The essential aim of the study will then be to decide if there are cases in which frequency modulation should be recommended rather than amplitude modulation or vice versa.

It is requested that frequency modulation tests be carried out and the relative merits of frequency modulation and amplitude modulation compared in respect of: quality of the picture received, effect of level and frequency variations, effect of the phase distortion.

Question 5/XIV — Extension of Recommendation T.11 (H.31).

(concerns Study Group XV)

Recommendation H.31 of Volume III (or Recommendation T.2 of Volume VII) of the *Red Book* defines the conditions to be observed, as far as transmission is concerned, when telephone-type circuits are used for phototelegraph transmissions.

Which of these conditions will also be applicable to the transmission of other types of facsimile telegraphy and what conditions should be laid down specially for these other types ?

Question 6/XIV — Alternate transmission of facsimile and telephony.

(concerns Study Group XVI)

What technical conditions should be laid down for private facsimile transmission (excluding phototelegraphy) alternating with calls over telephone circuits ?

The following cases should be distinguished:

a) a leased circuit operated alternately for telephony and facsimile telegraphy;

(6/XIV)

b) case in which a telephone subscriber, after having obtained a telephone call through the switching of circuits in the general network, substitutes facsimile telegraph apparatus in place of the telephone apparatus.

Note 1. — In these two cases, it should be examined whether it is possible to recommend the sending levels already recommended for data transmission.

Note 2. — Case *b)* is covered by Question 7/XIV, as regards the conditions for admitting such a service and the standards relative to facsimile telegraph apparatus.

Note 3. — In case *b)*, transmission could be disturbed by metering pulses or by the intervention of an operator in the call.

Question 7/XIV — Facsimile service for subscribers.

(continuation of Question 18 of Study Group 8, 1957-1960)
(concerns Study Groups I, XI and XVI)

a) Is there any need to introduce a new service into the international service to cater for the transmission by facsimile between subscribers of messages, business papers and similar documents ?

b) If so, what standards should be specified for such an international service ?

ANNEX 1 TO QUESTION 7/XIV

The following characteristics have already been agreed upon at New Delhi:

co-operation index = 264

speeds = normal speed of 120 revolutions per minute, with two other possible speeds:
60 revolutions per minute for difficult cases;
180 revolutions per minute for easy cases;

maximum dimensions of documents = 21 cm × 29.7 cm.

For the study of this question, Administrations should reply to the following questionnaire:

Dimensions.

1. What diameter do you propose for drum apparatus ?

2. What limits do you propose for the drum factor of the sending and receiving drums ?

Scanning speed.

Are the speed tolerances in C.C.I.T.T. Recommendation T.1 applicable to this service ? If not, what tolerances do you propose ?

Remote control.

Do you consider remote control of the receiving set by the transmitting set necessary or desirable ? If so, what signals should be used for:

— passage from telephony to facsimile and starting ?

— stop and return to " telephony " ?
— phasing and maintenance of synchronism ?
— choice of speed? etc.

Do you consider it useful to have a return signal:

— to announce that the receiver is ready ?
— to give the identity of the receiving station ?

If so, what signals do you propose ?

Modulation.

Do you recommend amplitude modulation or frequency modulation:

a) for communications by wire,
b) for communications by radio,
c) for communications by combined wire and radio.

Other characteristics which should be specified.

ANNEX 2 TO QUESTION 7/XIV

(Extract from the contribution of the Federal German Republic contribution COM 8/No. 44, January 1959, modified in accordance with decisions taken at New Delhi)

1. The Postal and Telecommunication Administration of the Federal German Republic considers that the use of facsimile apparatus for transmitting business papers, etc., between telephone subscribers will become fairly widespread in the near future, even in the international service. Even if such a need is not particularly felt at present, the apparatus which will be required for this service should be standardized now.

2. We have also made investigations to determine whether such apparatus should be considered for other purposes. It should be pointed out, in this connection, that the smaller ships and aircraft need facsimile apparatus for mobile services in order to receive weather reports (general barometric positions, wind forecasts, warnings of sea storms, etc.) from the meteorological services. These are simple documents which may be sent in the same way as business papers. The same type of facsimile apparatus, therefore, should be used for transmitting business papers and receiving small-size weather charts.

. . . .

5. To take account of the different sizes of business papers used in various countries, fascimile apparatus should have a drum diameter of D = 68.5 mm and a usable drum length of L = 33 cm.

6. The facsimile apparatus used by telephone subscribers will usually be (drum type) of a combined form which can serve for either transmission or reception. If both instruments have the same drum dimensions (see 5 above), no difficulty will arise in the international service. Accurate reproduction of dimensions would be ensured in the transmission of drawings. The only requirement would be for both subscribers to agree in advance on the length of the document to be transmitted.

7. We consider that subscribers' facsimile apparatus should also be adjustable to a scanning density half the normal value, without requiring any alteration either in the transmitting scanning beam or in the width of the receiving scanning line. In this way, it would be possible to cut the transmission time by half, provided the original to be transmitted was of such a kind as to permit a rough reproduction at the receiving end (e.g. certain drawings). Continuous lines thus would be reproduced as broken lines.

8. We believe that for the transmission of facsimile messages over telephone lines one should select an adjustable carrier frequency between 1300 and 1800 c/s (amplitude modulation) and a drum rotation speed of $n = 120$ r.p.m.

9. The following is a table showing the technical characteristics:

	Facsimile apparatus for business papers	Small-size facsimile receiver for weather charts
Drum diameter	68.5 mm	
Usable drum length	33 cm	
Paper width for page-printing reception	(about 21 cm)	about 21 cm
Index	(264)	?
Scanning density (lines per mm)		
normal (= scanning density)	(3.86)	?
switchable	(1.98)	?
Type of modulation	amplitude modulation	amplitude modulation
Carrier frequency adjustable within the limits of	1300 to 1800 c/s	1300 to 1800 c/s
Drum rotation speed (r.p.m.) or lines per minute in page-printing:		
normal	120	60
switchable		90 or 120

ANNEX 3 TO QUESTION 7/XIV

See Annex 2 to Question 8/XIV.

Question 8/XIV — Remote control for the transmission of weather-maps.

(continuation of Question 19 of Study Group 8, 1957-1960)
(to be studied together with W.M.O.)

Study of the characteristics to be recommended for apparatus for the facsimile transmission of meteorological charts. (This study is undertaken at the request of the World Meteorological Organization. It should be carried on in co-operation with this organization and the results communicated to it.)

Note. — This question will have to be examined from the point of view of remote control. The W.M.O. will be requested to describe its exact requirements.

ANNEX 1 TO QUESTION 8/XIV

The C.C.I.T. has already replied to Question 19/8 (see the Supplements to the documents of the VIIIth Plenary Assembly, page 151).

Only one point remained to be studied, in connection with phasing, to which the C.C.I.T. had already replied (Supplements to the documents of the VIIIth Plenary Assembly, page 153):

" 8. *Phasing.*

8.1. In view of the increasing use of automatic continuous roll recorders, it is considered that one standard should be adopted. The C.C.I.T. suggests that the initial phasing signals should be ' white ' pulses in all cases, to ensure the reliable remote control of the receiver and to enable the adjustment of the black recording level before the commencement of transmission of the subject-matter. In view of the fact that there is some existing receiving apparatus which requires phasing pulses throughout the transmission of the subject-matter, these latter pulses should be ' black '. It is therefore desirable that receiving equipment should be capable of accepting both ' phase-white ' and ' phase-black ' to ensure correct operation during the whole of transmission, and to permit a receiver to be phased correctly to a transmission which has already commenced. "

The W.M.O. wanted to know whether the C.C.I.T.T. advised that apparatus should be capable of adaptation both to phasing signals preceding a transmission and phasing signals sent during a transmission and, at the same time, to phase-white and phase-black.

The C.C.I.T.T. replied as follows:

" Phasing during transmission can be considered from three aspects:

1. apparatus for which it is necessary to maintain phase correspondence during transmission (a phase-black signal for each scanning line);
2. transmission of documents in series;
3. receiver connected when the transmission has already begun. "

This question has a general bearing for continuous roll facsimile receivers.

Although there are few machines at the moment which work with phasing or maintenance of synchronism during transmission, it seems that future development of such apparatus is possible and that it is advisable to look to the future.

Transmitters and receivers should therefore be designed for phase-white at the beginning of the transmission and phase-black during transmission.

The following reply is given to the W.M.O.:

" 8. *Phasing.*

8.1. In view of the increasing use of automatic continuous roll recorders, and the fact that phasing (or maintenance of synchronism) during transmission will be developed, it seems that transmitting apparatus should be designed for emission both of phasing signals at the start of transmission and phasing signals during transmission. "

The first phasing signals at the start of transmission will be " phase-white " signals and may allow remote control of the receiver and adjustment of the black recording level before transmission of the document is begun.

The phasing signals during transmission will be " phase-black " signals.

Of course, if the W.M.O. were to decide that its network should be operated with apparatus requiring only one phasing at the start of transmission, this double phasing facility would not be necessary, but the C.C.I.T.T. considers it desirable to provide for the double facility especially since the equipment necessary is simple and inexpensive.

ANNEX 2 TO QUESTION 8/XIV

(Contribution of the Federal German Republic, contribution COM 8 — No. 70, September 1960)

Telecontrol signals for the transmission of meteorological charts

1. So far as the German Administration knows, there is as yet no international convention dealing with a suitable procedure for automatic transmission of meteorological charts. All that has been done is to specify which operations are to be telecontrolled.

In view of the increasing use of facsimile transmission, and particularly the use of continuous recorders, the German Administration considers it necessary to have automatic recording of meteorological charts without staff having to be permanently on duty.

2. The same problem also arises in the case of facsimile apparatus used for transmitting telegrams and business papers. In its contribution to Question 18 of Study Group 8 (see Annex 2 to Question 7/XIV) the German Administration drew attention to the fact that facsimile apparatus for transmitting business papers will sometimes also be important for the reception of meteorological messages. It would thus be logical to align these two cases, not only in respect of the technical characteristics of the apparatus, but with regard to the sequence of automatic operations. The German Administration thinks that the C.C.I.T.T. should attempt to bring about the necessary co-ordination.

3. In principle, the automatization of operations should be so arranged that a manual service could also be carried on the whole time at the receiving end. Receiving stations will then be able, if necessary, to break in on a transmission already taking place.

4. The sequence of signals in automatic operation should be chosen in such a way that the transmitting station can operate both continuously (flat-bed transmitter or two coupled automatic drum transmitters) and consecutively (drum transmitter).

The following details (paragraphs 5 to 11) refer to automatic receivers (drum receivers). The conditions under which drum receivers would be used in automatic transmissions are dealt with in paragraphs 12 and 13.

5. The automatic control itself must fulfil the following conditions:

a) It must operate both on metallic circuits and on radio channels. The control signals must not lose their identity when converted from amplitude modulation to frequency modulation and vice versa.

b) When not in operation, the receiver must be kept ready for service. That is to say, the apparatus must be connected to the main supply and switched to automatic reception. The ready-for-service position may be switched in manually or automatically by means of a time switch.

c) In drum receivers, the following operations should be carried out:

1) choice of the index,

2) choice of the speed,

3) starting of the receiver,

4) adjustment of the level,

5) phasing,

6) stopping of the receiver.

At the same time, every attempt should be made to carry out several of these operations with a single signal.

d) When several charts have to be transmitted continuously (flat-bed transmitter or two coupled automatic transmitters), the stop signal (6) must be sent only after the last transmission, provided that neither the index nor the speed have been changed during the sequence of charts (see paragraph 10).

e) Care must be taken that, in a sequence of transmissions, the receivers do not move from the nominal phase position as a result of slight differences in speed (intermediate phase correction).

f) If the transmitting station uses consecutive scanning (with drum transmitter), care must be taken that, during the intervals between transmissions needed to change the document, the exact phase position is maintained at all the stations taking part in the transmission.

6. To ensure smooth running of the service, particularly in the case of the radio service, the start and stop signals should be such that before the beginning of the operation concerned their frequency and duration can be selectively checked at the receiving end.

7. With regard to the signals mentioned in 5 *(c)*, the German Administration makes the following detailed proposals:

As regards (1):

Recommendation 50 of the C.S.M. envisages two indices $\left(576 \text{ and } 288 = \frac{576}{2}\right)$ and three different speeds (60, 90 and 120) for the transmission of meteorological charts. In order that the index and the speed may be changed at will, it is necessary to have a special signal for the *choice of the index.*

It seems logical to choose a frequency of

300 c/s for the index 576

because it is already used or contemplated by various meteorological services in Europe and North America. The signal for the choice of the index 288 should be another audio frequency, which must not coincide with a harmonic of 300 c/s. The German Administration proposes

675 c/s for the index 288.

The carrier should, in each case, be modulated by these two frequencies for *5 seconds* in such a way that an approximately rectangular envelope is obtained with an amplitude difference of at least 25 db.

As regards (2) to (5):

For the choice of the speed and the adjustment of the receiver to the necessary level, the German Administration believes that use might be made at the same time of the *negative* *phasing signal* (black, interrupted by white pulses) envisaged for phasing in Recommendation 50. This signal should last at least 36 seconds, made up as follows:

1 second *for fixing the speed* (by spacing two successive phasing pulses, the speed is unmistakably indicated).

5 seconds *for starting the receiver and adjusting the level.*

$\geqq$ 30 seconds for the phasing (see Recommendation 50, para. 8.3).

A special signal for the beginning of the transmission itself (scanning start) is not considered necessary. The end of the phasing then also indicates to the receiver the start of the recording, while the transmitter begins the facsimile transmission only after the above time schedule expires.

As regards (6) :

After the end of the transmission, the receiver must be stopped by means of a special stopping frequency. As in American systems, the frequency 450 c/s should be chosen for this purpose. This frequency modulates the carrier frequency *for 5 seconds* in the same way as that described above in the case of the start signal.

8. *Positive phasing pulses* (black pulses during scanning in the dead sector) should always be transmitted *during the transmission.* Receiving stations which wish to take part in a transmission already taking place can then visually recognize the phase position and correct it by hand.

9. At the same time, these phasing pulses should be used to offset any possible speed differences between the receiving stations and the transmitting stations by *automatic phasing correction* at specified intervals.

10. Should the index or the speed be changed, the series of charts concerned must be terminated by transmitting the stop signal and a new series introduced by the appropriate start signal.

11. When the transmitting station is working with a simple drum transmitter, it must, if it is to be able to transmit several charts successively without a new start-stop (consecutive scanning) schedule, have at its disposal a special phasing signal generator which maintains the phase position during the changing of documents. *In the interval between two transmissions*, a positive phasing signal (white, interrupted by black pulses) which regulates the transmitter drum when phasing recommences should always be transmitted. This phasing signal also ensures a reliable automatic phasing correction in the intervals between the transmissions (see paragraph 9).

12. *Drum receivers* cannot receive automatic transmissions without losing part of the message unless the receiving station is equipped with two machines operating alternately. It is also necessary to have a special phasing signal generator which, precisely adjusted at the beginning of the transmission, brings the second machine into the exact phase position during the transmission of a chart. Care should also be taken to ensure that, at certain intervals, the generator can be corrected from the point of view of its phase position.

Otherwise, special measures must be taken so as to make it possible — and this also applies when drum receivers are being used — to carry out the phasing during a transmission which is already taking place. In this case, it is inevitable that some of the message will be lost.

13. When there is consecutive scanning (see paragraph 11 above), the positive phasing signal makes it possible for drum receivers to take part again in the transmission with an exact phase position after the paper has been changed, without any part of the message being lost.

(8/XIV)

14. Finally, attention should be drawn to the fact that, in radio transmission, the Radio Regulations (Chapter V, Article 19) require an identifying signal, which must be sent before transmission begins and during the intervals between transmissions.

In view of the fact that transmissions of meteorological charts are often carried out by different radio transmitters at the same time, the identifying signal should always indicate the facsimile transmitter station. Intervals between successive, individual transmissions of charts — provided that they do not last longer than 6 minutes — are not to be regarded as intervals in this sense.

15. The annexed table contains the sequence of signals proposed by the German Administration for the automatic transmission of meteorological charts.

ANNEX

Sequence of signals for the automatic transmission of meteorological charts

Signal	State	Remarks
1. Identification	Not in operation. The receivers are in the ready-for-service position 1.	The power supply is connected. The identifying apparatus is ready to recognize signal 2.
2. *Start signal* (5 seconds) . . . *a)* 300 c/s *b)* 675 c/s	Choice of the index. *a)* for 576 *b)* for 288 The receivers are in the ready-for-service position 2.	The identifying apparatus is ready to recognize signal 3.
3. *Negative phasing signal* (≧ 36 seconds)	1 second for the choice of the speed. 5 seconds for starting, and adjusting the level. ≧ 30 seconds for the phasing.	
4. *Positive phasing pulses*	Transmission No. 1.	Manual participation by receiving stations is possible.
5. *Positive phasing signal*	Interval between the transmissions: Changing of document and rephasing.	With consecutive scanning only: The transmitter station uses drum transmitter.
6. *Positive phasing pulses*	Transmission No. 2.	As for 4.
7. *Stop signal* (5 seconds) . . . 450 c/s	Stopping of the receivers. Return to the non-operating position.	See under 1.

Negative phasing signal = Black, interrupted by white pulses.
Positive phasing signal = White, interrupted by black pulses.
Positive phasing pulses = Black pulses during scanning in the dead sector.

ANNEX 3 TO QUESTION 8/XIV

Proposals and comments from the W.M.O.

(Extract from contribution COM 8, No. 36, June 1958)

8. PHASING (mise en phase).

8.1. Apparatus should be capable of operation using either phase-white or phase-black (mise en phase sur blanc ou sur noir).

Note: In view of the fact that in the case of automatic apparatus designed to operate on a single standard, the use of inverse phasing will probably necessitate manual adjustments at the recording terminal, it would be useful, therefore, to formulate a single standard for apparatus operating entirely by remote control.

8.2. *Length of phasing pulse* (durée de l'impulsion de mise en phase). The length (or duration) of the phasing pulse should be not less than 5% of the total transmission time of one scanning line (e.g. 50 milliseconds at 60 r.p.m.) and should also not exceed this value if the transmission of phasing pulses is continued throughout transmission of picture intelligence.

8.3. *Duration of transmission of phasing pulses* (durée de l'émission des impulsions de mise en phase). Phasing pulses should be transmitted *for not less than 30 seconds* before the transmission of picture intelligence, *regardless of the drum speed employed.* Phasing pulses may continue to be sent throughout the period of transmission of picture intelligence provided that the length of the pulse does not excess 5% of the total time taken to transmit one scanning line.

8.4. *Sequential or continuous transmission* (émission continue). If a sequence of charts is sent from automatically coupled transmitters, or if a flat bed (continuous scanning) transmitter is employed, the length of picture transmitted without re-phasing should not exceed a figure more than approximately three times the total length of the scanning line.

C.C.I.T. comments

8.1. In view of the increasing use of automatic continuous roll recorders, it is considered that one standard should be adopted. The C.C.I.T. suggests that the *initial* phasing signals should be " white " pulses in all cases, to ensure the reliable remote control of the receiver and to enable the adjustment of the black recording level before the commencement of transmission of the subject matter. In view of the fact that there is some existing receiving apparatus which requires phasing pulses throughout the transmission of the subject matter, these latter pulses should be " black ". It is therefore desirable that receiving equipment should be capable of accepting both " phase-white " and " phase-black " to ensure correct operation during the whole of transmission, and to permit a receiver to be phased correctly to a transmission which has already commenced.

8.2. *Length of phasing pulses.* The C.C.I.T. is of the opinion that the length of the phasing pulse should be within the limits 4% ± 1% of the total time taken to transmit one scanning line.

8.3. No comment.

8.4. No comment.

Remarks by C.S.M.

8.1. " Phase-white " should be adopted as the standard phasing signal to be transmitted prior to the transmission of picture intelligence. The C.C.I.T. reference to recorders which require phasing pulses throughout the transmission of picture intelligence is not fully understood. The black pulses sent during the transmission of picture intelligence are in most cases merely the transmissions of the image of the clip securing the subject-matter to the transmitter drum, and do not always appear.

8.2. It would appear to be necessary only to specify a minimum length for the phasing pulse, and the minimum of 3% permitted by the C.C.I.T. suggestion may be somewhat shorter than the optimum requirements (5% gives a 25 m/sec. pulse at 120 r.p.m. whereas 3% gives a pulse of only 15 m/sec.). The original suggestion by RA VI that the pulse should be of a duration not less than 5% of the total transmission time for scanning one line may be therefore a more desirable standard.

8.3. It is difficult to envisage the transmission of white phasing pulses throughout the transmission of picture intelligence because meteorological charts are predominantly white in character. Any pulses sent during the transmission of picture intelligence will therefore presumably be black ones and will usually result from a transmission of the clip image — see comment under 8.1. There are good reasons, particularly in the case of recorders employing electrolytic paper, for arranging the transmitter so that the image of the paper retaining clip is not sent during the transmission of picture intelligence.

8.4. No comment.

9. SYNCHRONIZATION.

The scanning speeds of apparatus used should be maintained within ± 5 parts in 10^6 of their nominal values.

Note : This tolerance admits a maximum skew of approximately 1:55 in the case where the transmitter and recorder operate at the maximum permitted deviation in opposite directions.

C.C.I.T. comment

" 9. SYNCHRONIZATION.

The view of the C.C.I.T., is that the amount of skew which can be tolerated is a matter for the user to decide. The imposition of a smaller speed tolerance than that quoted (± 5 parts in 10^6) would be likely to increase the cost and complexity of the equipment. The C.C.I.T. has observed that the maximum skew can be 1:55 for the speed tolerance quoted."

Remarks by C.S.M.

No comment.

10. SIGNALS FOR AUTOMATIC OPERATION (signaux prévus pour le fonctionnement par télécommande).

In the case of automatic equipment, standards have to be formulated for the following signals at least:

— for starting;
— for phasing;
— for stopping.

These signals must be acceptable for both land-line and radio transmissions; in the latter case, they should retain their identifying characteristics when subjected to AM/FM and FM/AM conversion.

C.C.I.T. comment

The C.C.I.T. took note of the contribution made by France and the United Kingdom (see Appendix).

Remarks by C.S.M.

The question of automatic control signals needs further study. It is considered that if the recorder is to be fully automatic it must be capable of carrying out the following operations:

1. recognize a starting signal,
2. select the correct speed (i.e. 60, 90 or 120 r.p.m.),
3. where necessary set recording levels,
4. phase correctly,
5. revert to a stand-by condition at the end of the transmission.

These functions need not necessarily be carried out in the above sequence nor is a separate and different controlling signal necessarily required for each operation.

APPENDIX

(Extracts from C.C.I.T. documents SG.IV/32 and SG.IV/34, 1953-1956)

UNITED KINGDOM (SG IV/32).

For land-line transmissions it is possible to operate satisfactorily with automatic recorders which start on the receipt of white phasing pulses and which close down when the picture carrier frequency is removed from the line. However, for radio transmissions it is considered that more positive signals are necessary if spurious operation is to be avoided. A preliminary study in the United Kingdom indicates that these stop/start signals:

a) must be acceptable for transmission over land-lines;

b) must be capable of transmission over radio links and, in particular, must not lose their identifying characteristics when subject to AM/FM and FM/AM conversion;

c) cannot conveniently be confined to the dead sector period of drum rotation, and therefore should be distinguishable from the facsimile signal.

It is tentatively proposed that the stop/start signals should be formed by substituting for the facsimile information before modulation either one or two tones having frequencies of the order of several hundred c/s.

Note. — If positive stop/start signals are employed for radio transmissions it will probably be convenient to employ the same procedure over land-lines.

FRANCE (SG IV/34).

It also appears that, apart from a few exceptions, meteorological services have adopted continuous automatic reception, as in France. This, incidentally, raises the special problem of remote control of definitions and speeds; as far as the French Administration is aware, only the French meteorological services have proposed solutions to this problem, it being understood that only two combinations are suggested, i.e., index 288/speed 120 r.p.m. and index 576/speed 60 r.p.m.

For automatic control of the facsimile receiver the following code is used:

Permanent black: condition of non-transmission.

White pulses on a black background: signals for starting, for remote control of the choice of speed/index combination, for phasing, for showing the presence of the facsimile sender (these last signals lasting 5% of the time taken by the transmitting drum to rotate).

The return to permanent black causes the receiver to stop automatically.

For transmission on radio channels, modulation converters ensure direct control of frequency modulation in transmitters which may be of the telegraph type: the automaticity of the receiver does not raise any problem in this respect.

Question 9/XIV — Half-tone pictures transmission over combined radio and metallic circuits.

(continuation of Question 11 of Study Group 8, 1957-1960)
(interests the C.C.I.R.)

Study of the transmission of half-tone pictures over combined radio and metallic circuits, when direct frequency modulation of the radio frequency carrier is used; revision, if necessary, of the limit values for frequency stability given in Recommendation T.15.

Comments

It may happen in practice that both systems are used in tandem: frequency modulation on the metallic circuit and direct frequency modulation on the radio circuit. If the deviation limits in the two systems are in the same direction, the resulting overall frequency deviation will no longer be tolerable for satisfactory transmission.

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SUPPLEMENTS TO SERIES R, S, T AND U RECOMMENDATIONS

Contributions received during 1957-1960 considered worth publishing owing to their interest

SUPPLEMENTS TO SERIES R RECOMMENDATIONS (TELEGRAPH TRANSMISSION)

SUPPLEMENTS TO SERIES S RECOMMENDATIONS (ALPHABETIC TELEGRAPH APPARATUS)

SUPPLEMENTS TO SERIES T RECOMMENDATIONS (EQUIPEMENT AND TRANSMISSION IN CASE OF FACSIMILE TELEGRAPHY)

SUPPLEMENTS TO SERIES U RECOMMENDATIONS (TELEGRAPH SWITCHING)

DISTORTION CAUSED BY A TELEGRAPH TRANSMISSION CHANNEL

(Extract from the contribution of France, contribution COM 9, No. 46, February 1959)

I. The different types of transitions of telegraphic modulation

A distinction should be made between:

1. space-mark transitions,
2. mark-space transitions other than the beginning of the start; they are generally distinguished from those mentioned before by a different restitution delay and a different distribution of this delay around its mean value. If the mean duration of the stop unit is the unit interval and if the case of automatic sending is considered, there is no need to distinguish the first start transition from other mark-space transitions; but in all other cases it is necessary to distinguish:
3. the first start transitions.

In the case of linear systems [1], the restitution delay may be deduced from the channel characteristics and from knowledge of the modulation which preceded the transition in question. The examination of given curves for information purposes in the article mentioned shows that, even in this case, it is very difficult to represent in a practical mathematical form, the mean restitution delay and its distribution around the mean value.

In the case of a real channel, account should be taken, apart from the distortion due to the " static " properties of the transmission channel, of distortion due to cross-talk, noises of various origins, non-linearity such as that which may be introduced by transformers, variations of voltage, resistances, etc.

Finally, as a first estimate for a theoretical examination, it will be assumed that, *for each type of transition,* the restitution delays on the channels be distributed around a mean value according to a normal law. Even if very rough, this estimate makes it possible to tackle the problem mathematically. It is also worth noting that, in practice, there is more interest in the degrees of distortion than in the restitution delays. The calculation and measurement of the distortions only brings in the difference between two restitution delays, that of the transition in question and that of the corresponding initial start. The different causes of distortion are thus combined, which makes the estimate more exact for calculation of distortion than for the calculation of restitution delay.

II. Theoretical consequences for the inherent distortion of a telegraph channel

Let us suppose that a perfect modulation is sent to the input of a telegraph channel and that the distortion of a space-mark transition at the output of the channel is watched.

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[1] MM. Bayard and Roquet: Mathematical characterization of messages and its use for the determination of correcting networks. *Ann. Telecom.*, February 1956.

This distortion is the relation to the unit interval, of the difference between the restitution delays of the space-mark transition in question and the corresponding initial start transition. Now, according to the preceding paragraph, each of these restitution delays is supposed to be distributed around a mean value t, according to a normal law, with a standard deviation s. A classical result of probability calculation shows that the difference between the two restitution delays is then distributed around a mean value T, according to a normal law, with a standard deviation S. In the formulae, the quantities relative to the space-mark transitions will be denoted by R, those relative to the initial start mark-space transitions by S and those relative to the other mark-space transitions by T; hence, using this notation:

$$T_{\mathrm{R}} = t_{\mathrm{R}} - t_{\mathrm{S}}$$

$$S_{\mathrm{R}}^2 = s_{\mathrm{R}}^2 + s_{\mathrm{S}}^2$$

A similar result will be obtained for the distortions relative to the mark-space transitions:

$$T_{\mathrm{T}} = t_{\mathrm{T}} - t_{\mathrm{S}}$$

$$S_{\mathrm{T}}^2 = s_{\mathrm{T}}^2 + s_{\mathrm{S}}^2$$

T_{T} and S_{T} are generally different from T_{R} and S_{R}, but may be equal to them.

If the statistical distribution of the distortions at the output of a telegraph channel (the incoming modulation being perfect) is examined, these distortions, which are proportional to the differences between two restitution delays, fall into two groups, one corresponding to the mark-space transitions and the other to the space-mark transitions, each group approximately obeying a normal law.

III. Note

The hypothesis that the initial start transitions allow of restitution delays which are distributed according to a normal law is subject to two reservations:

1. It assumes implicitly that the sending rate is constant. The distribution laws would in general be different when a modulation is transmitted at maximum speed and when the characters are transmitted one by one with an interval of one minute between two characters, for example.

This hypothesis does not cause difficulties in practice since the distortions on modulations sent at maximum speed (output from a margin measurer or an answer-back signal transmitter) are generally observed.

2. It also assumes that the modulation sent to line is as varied as possible so that the conditions taken by the line preceding the transitions under study vary as much as possible during the measurements. A measurement carried out with a character transmitted repeatedly might clearly give very different results.

IV. Joining of telegraph channels

The hypotheses and arguments put forward should be valid whatever the composition of the telegraph channel in question, in particular where it is formed by the joining of two or more channels with entirely different characteristics.

The arguments put forward in paragraph II with regard to the difference between two restitution delays apply to the sum of several restitution delays. Thus when several channels are joined, the distribution functions remain of the normal type; only the numerical values change.

By using T and S without subscripts to indicate the quantities previously defined for the composite channel and to indicate the same quantities for component channels $T_l \ldots$, T_n, $S_l \ldots$, S_n the following equations are immediately obtained:

$$T = T_l + \ldots + T_n$$

$$S^2 = S_l^2 + \ldots + S_n^2$$

THE STATISTICAL DISTRIBUTION OF START-STOP TELEGRAPH DISTORTION IN TANDEM-CONNECTED V.F. TELEGRAPH CHANNELS

(Extract from the contribution of the United Kingdom, contribution COM 9, No. 24, November, 1958)

For the purpose of assessing the overall quality of the voice-frequency telegraph channels in use in the United Kingdom telegraph automatic switching system, an analysis of distortion has been made on a considerable number of connections.

The total number of telegraph circuits examined was 728, each being composed of a number of tandem-connected channels ranging from two to six. The circuits were set up by dialling to provide a route through various switching centres to the centre at which the measurements were made. Two series of tests were conducted, one with the connections originating and terminating at a London switching centre and one with connections from London to Birmingham. In general, the V.F. telegraph apparatus in the U.K. is of a kind designated Type 3, but one London centre has Type 4 apparatus which is of a superior performance. Hence, in the first series of tests all connections included one link of Type 4 apparatus, whereas in the second series, a very small proportion of the connections included this apparatus. The effect of this is clearly shown in the measurements. Table I shows the number of tests of each size of circuit and the proportion of the tests that involved the various intermediate switching centres. An attempt was made to plan the routes for the tests according to random choice, but this was possible only in part, as some switching centres have a very limited number of routes available. Because the channels to be tested were selected automatically, they functioned as they would in ordinary service, without any possibility of being specially adjusted.

The measuring apparatus employed was the telegraph distortion analyser *. The modulation rate of the test signal was 50 bauds, the character length was 7.5 units and the

* WHEELER & FROST: "A telegraph distortion analyser". *P.O.E.E.J.*, Vol. 47, Pt. 1, Apr. 1954.

distortion of the test transmitter was less than 0.25%. The text of the test-message was:

THE QUICK BROWN FOX JUMPS OVER THE LAZY DOG 12345 67890
LINE X C/R L/F L/S

($X = 1, 2, 3, 4, 5, 6$ or 7).

The measurement made on each circuit was the distribution of individual start-stop distortion of 1000 space-to-mark transitions.

This restriction to one kind of transition must be borne in mind when reading the subsequent discussion, particularly where " distortion " or " distribution of distortion " is used without specific qualification.

Space-to-mark transitions were chosen because, being of opposite polarity to that of the commencement of the start element, they are directly affected by bias, which is found to be a dominant contribution to the limitation of circuit performance. The size of sample, 1000 transitions, has been found to be adequate for this particular type of study.

Analysis of the observations led to the following conclusions: that, for circuits comprising a given number of links, the mean values and the standard deviations of the distributions of distortion measured were both capable of being closely represented by normal distributions, and that there was negligible correlation between the mean and standard deviations.

An example of the distribution curves for the mean values and the standard deviations of distortion for one service of tests on five-link circuits is shown in figures 31 and 32. The statistics of the distributions of the mean and standard deviations for each magnitude of circuit are shown in figures 33, 34, 35 and 36.

From a more detailed analysis of a sample of distortion distributions from all lengths of circuit measured, it appears that these distributions have a common shape.

The empirically derived " fundamental distribution " curve is shown in figure 37. The values of the curve and an explanation of the scales are given in Table II. From this basis it is possible to calculate for each size-group of circuits the proportion of circuits expected to meet a given criterion of performance, e.g. producing an inherent start-stop distortion of less than 30% ($P = 0.0001$), but if this is done directly from the statistical data described above, there is some irregularity in the results produced by the wide variations in the original data which are undoubtedly due to the limited field of this investigation. To bring some consistency to the final predictions of the quality of the telegraph network an attempt is made in the following to relate the values of the statistics to the number of links in the circuits, on the foundation of the approximate theories of the addition of types of distortion in tandem-connected links that have previously been put forward. It is appreciated that these theories are by no means perfect and require more detailed investigation to improve them.

The distortion measured is the inherent distortion (of space-to-mark transitions) and therefore contains contributions of bias, characteristic and fortuitous distortion. For simplicity it will be assumed generally that there is no interdependence of these contributions.

The mean distortion of observations on a group of circuits of a given number of links will be largely decided by the average value of bias distortion of single links, but it is possible for the mean value of characteristic distortion to be other than zero and this will also affect the observed mean distortion. The variance of the mean distortion will be controlled by the variance of bias distortion. The mean of the standard deviations of distortion will naturally depend upon the fortuitous distortion, but it will also contain a component due to the dispersion of characteristic distortion.

The variance of the standard deviation of distortion will depend upon the distribution of the mean noise power in the circuits and probably on the interaction of the various types of distortion, but it is not readily predicted.

Let a = mean bias distortion of single links
b = standard deviation of bias distortion of single links
c = fortuitous component of the standard deviation of individual distortion of single links
d = characteristic component of the standard deviation of individual distortion of single links
e = characteristic component of the mean distortion of single links
m = mean distortion of a circuit
s = standard deviation of distortion of a circuit
$\bar{m}$ = mean of the means (m)
σ_1 = standard deviation of the means (m)
$\bar{s}$ = mean of the standard deviations (s)
σ_2 = standard deviation of the standard deviations (s)
N = number of links in circuit

Then

$$\bar{m} = (a+e)\,N \qquad \text{(i)}$$
$$\sigma_1 = b\sqrt{N} \qquad \text{(ii)}$$
$$\bar{s}^2 = c^2N^2+d^2N^2 \qquad \text{(iii)}$$

These expressions have been used to fit curves to the observed values as shown in figures 33, 34, 35 and 36. In the case of the tests of the first series, terminating at London, (iii) has been modified to the form

$$\bar{s}^2 = c^2\,N + [d\,(N - 1) + d_1]^2$$

to take into account the difference in the characteristic distortion produced by the final link from that in the other links.

Inspection of figures 33, 34, 35 and 36 leads to the following comments. Whilst, in general, the fitted curves pass within the 95% confidence limits of the statistics derived from the observations, there are several instances where they do not. This is because they have been selected to give a representation of the results of both tests and the tests terminating in London comprise the smaller number of observations.

In the case of the mean of the means ($\bar{m}$), figures 33*a* and 35*a*, a value of $(a+e) = -0.6$ gives a representation of the general trend, but a possible fit can be obtained only by the introduction of a constant term, different for the two tests. A possible explanation is that, since the measurements were made at two stations, there was possibly some circumstance individual to the station at the time of the test which influenced the bias on the channels terminated there.

The standard deviation of the means (σ_1), figures 33*b* and 35*b*, in both tests is fitted to a similar degree by a value of $b = 3.5$. This high value indicates the considerable variation of bias over the whole system and its serious effect upon the inherent distortion.

The relatively good representation which is achieved for the mean of the standard deviations (σ_2), figures 34*a* and 36*a*, may be regarded as justifying the notions of characteristic distortion being directly additive and fortuitous distortion being quadratically additive.

No attempt was made to substantiate from theory an expression relating the standard deviation of the standard deviations (σ_2) to the number N of links, but $\sigma_2 = 0.325.\sqrt{N}$ provides a possible fit, although agreement with the London tests is not very satisfactory. The relatively low value of the constant indicates a fair degree of uniformity of circuits comprising a given number of links from the aspect of fortuitous and characteristic distortion and may be largely due to the variations in noise level.

By the use of the derived statistics and the fundamental distribution curve, an estimate has been made of the proportion of circuits which will have a better performance than that signified by a degree of inherent distortion of 30% ($P = 0.0001$), assuming them to be composed entirely of Type 3 or Type 4 channel links. This is shown in figure 38. For this purpose it is assumed that the additional constant term in $\bar{m}$ is -2, i.e. that the influence of a particular terminal station will not be more adverse than this. The forecast is therefore slightly pessimistic as the majority of stations are probably better.

As stated earlier, this stage might have been achieved more directly from the original observations and a comparison is shown in Table III, but from the mathematical models derived, it is possible to study the influence upon the overall performance of the network of variation in the parameter.

This is illustrated in figures 39 and 40. One particular result shown is that if, in general, the bias distortion could be halved, one more link could be added for the same grade of performance.

Although the effort involved in conducting these tests and collating the results was considerable, it must be admitted that, in the statistical sense, the sample considered is very limited and that the conclusions must be applied with due caution. Nevertheless, it is felt that as an example of an attempt to measure the performance of a fairly large switching network this work should prove a good basis for further investigations. The procedure, to a large degree, circumvents the difficulties arising if one attempts to predict overall quality from consideration of the behaviour of single links alone.

TABLE I

The following table shows the comparative extent (as percentages) to which the various intermediate switching centres were used during the transmission tests. In referring to this table it should be recalled that the Birmingham tests were routed from JXN to JBM and the London tests from JTS back to JTS, e.g.

JXN-JMR-JLS-JBM (Test No. A 1730)
JTS-JMR-JLS-JTS (Test No. 3023)

TABLE I

Intermediate switching centre		Number of links in tandem N, Number of observations n									
		London tests					Birmingham tests				
		$N = 2$, $n = 20$	$N = 3$, $n = 100$	$N = 4$, $n = 40$	$N = 5$, $n = 100$	$N = 6$, $n = 60$	$N = 2$, $n = 11$	$N = 3$, $n = 49$	$N = 4$, $n = 100$	$N = 5$, $n = 200$	$N = 6$, $n = 98$
Aberdeen	JAB							2.0	1.3	1.3	1.8
Belfast	JBE							2.0	0.7	1.5	1.2
Birmingham	JBM	20.0	19.0	16.7	17.5	14.3				0.2	
Bournemouth	JBH							3.1	2.0	1.8	2.2
Brighton	JBR									0.7	0.2
Bristol	JBS					11.0	9.1	16.3	12.0	11.1	13.0
Cardiff	JCF						9.1	4.1	4.7	4.3	4.3
Edinburgh	JEH					6.0	9.1	4.1	4.7	4.5	4.5
Exeter	JEX	10.0		8.3	3.0	5.0		1.0	0.3	1.1	1.2
Glasgow	JGW	10.0	19.0	15.8	16.5	10.7		14.3	11.7	9.8	11.7
Grimsby	JGY							2.0	1.7	2.0	1.4
Hull	JHU						9.1	1.0	1.7	0.8	0.4
Leeds	JLS	20.0	20.0	15.0	16.0	13.0	9.1	22.5	17.6	16.7	16.2
Liverpool	JLV	10.0	16.0	12.5	12.5	9.3	9.1	8.2	8.0	6.4	8.2
London (Centre)	JTS								5.7	7.5	6.5
London (North)	JXN			10.8	11.0	9.7					
London (West)	JXW								9.6	11.3	11.2
Manchester	JMR	20.0	15.0	11.7	13.5	9.0	9.1	7.2	7.0	6.5	6.3
Newcastle	JNT	10.0	11.0	9.2	10.0	7.3	9.1	6.2	6.0	5.2	4.9
Nottingham	JNG						9.1	2.0	2.3	2.3	1.4
Sheffield	JSH						9.1	2.0	1.7	2.3	1.4
Southampton	JSO					4.7	9.0	2.0	1.3	2.7	2.0

TABLE II

The fundamental distribution curve

(see figure 37)

x_0	F
— 3.10	0.001
— 2.90	0.01
— 2.62	0.1
— 2.5	0.2
— 2.12	1.0
— 2.0	1.6
— 1.5	6.1
— 1.27	10.0
— 1.0	16.3
— 0.5	31.6
0.0	50.0

x_0	F
0.0	50.0
0.5	68.4
1.0	83.7
1.27	90.0
1.5	93.9
2.0	98.4
2.12	99.0
2.5	99.8
2.62	99.9
2.90	99.999
3.10	99.999

x_0 = normalized deviation of x
F = percentage of space-to-mark transitions which are earlier than x

$$x_0 = \frac{x - m}{s}$$

where x = given value of distortion
m = mean value of distortion
s = standard deviation of distortion.

TABLE III

Comparison of number (A) of circuits having a distortion of $< 30\%$ ($P = 0.0001$) deduced from:
i) the measured distributions directly,
ii) the final curves produced by statistical inferences.

Number of links		Number of tests	A (i)	A (ii)
JTS — JTS	2	20	20	20
	3	100	100	100
	4	40	40	39
	5	100	99	96
	6	60	54	55
JXN — JBM	2	11	11	11
	3	49	47	49
	4	100	99	98
	5	200	185	187
	6	98	82	84

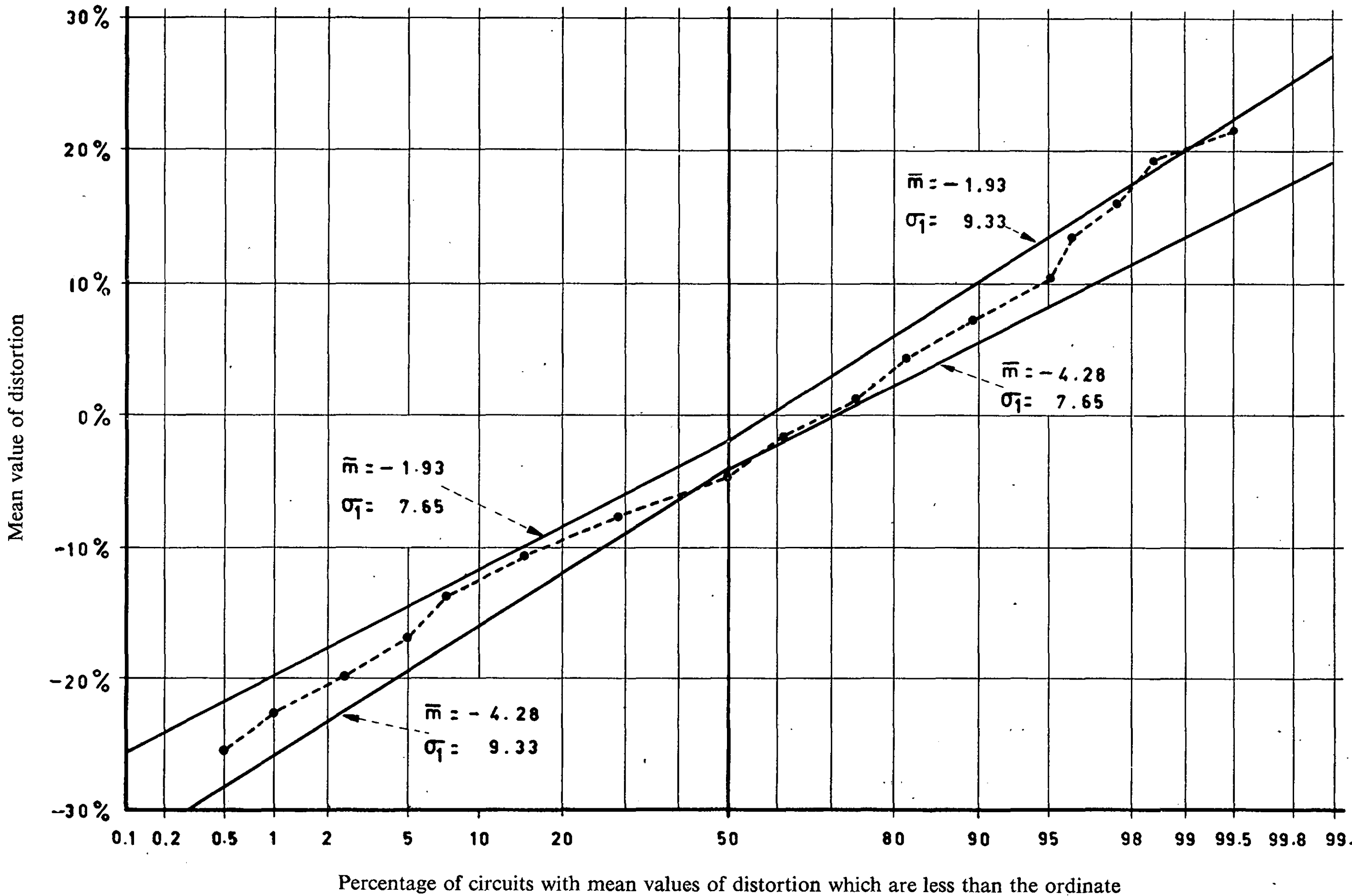


FIGURE 31. — *Distribution curve of means, 5-links circuits, Birmingham tests*

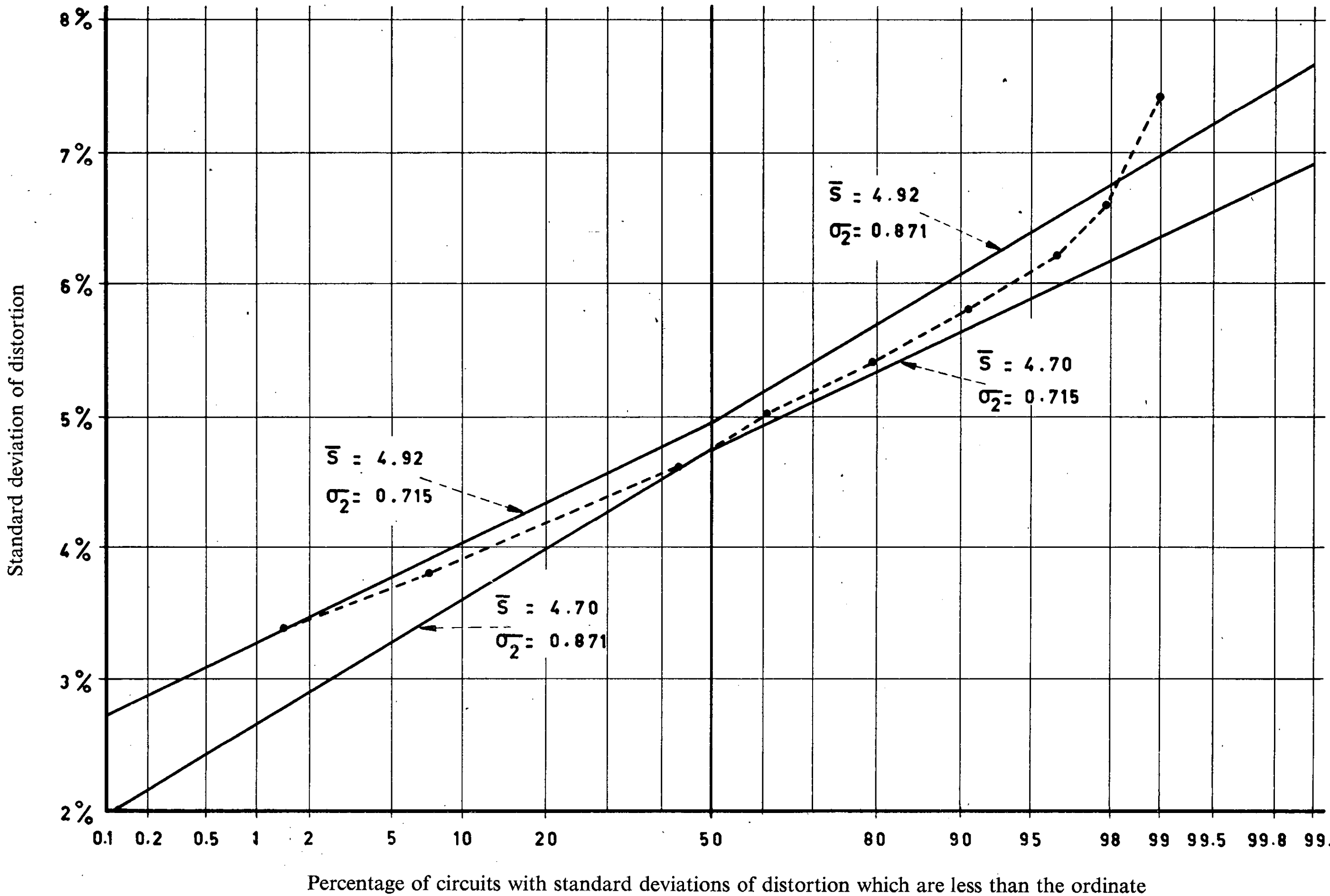


FIGURE 32. — *Distribution curve of standard deviations, 5-link circuits, Birmingham tests*

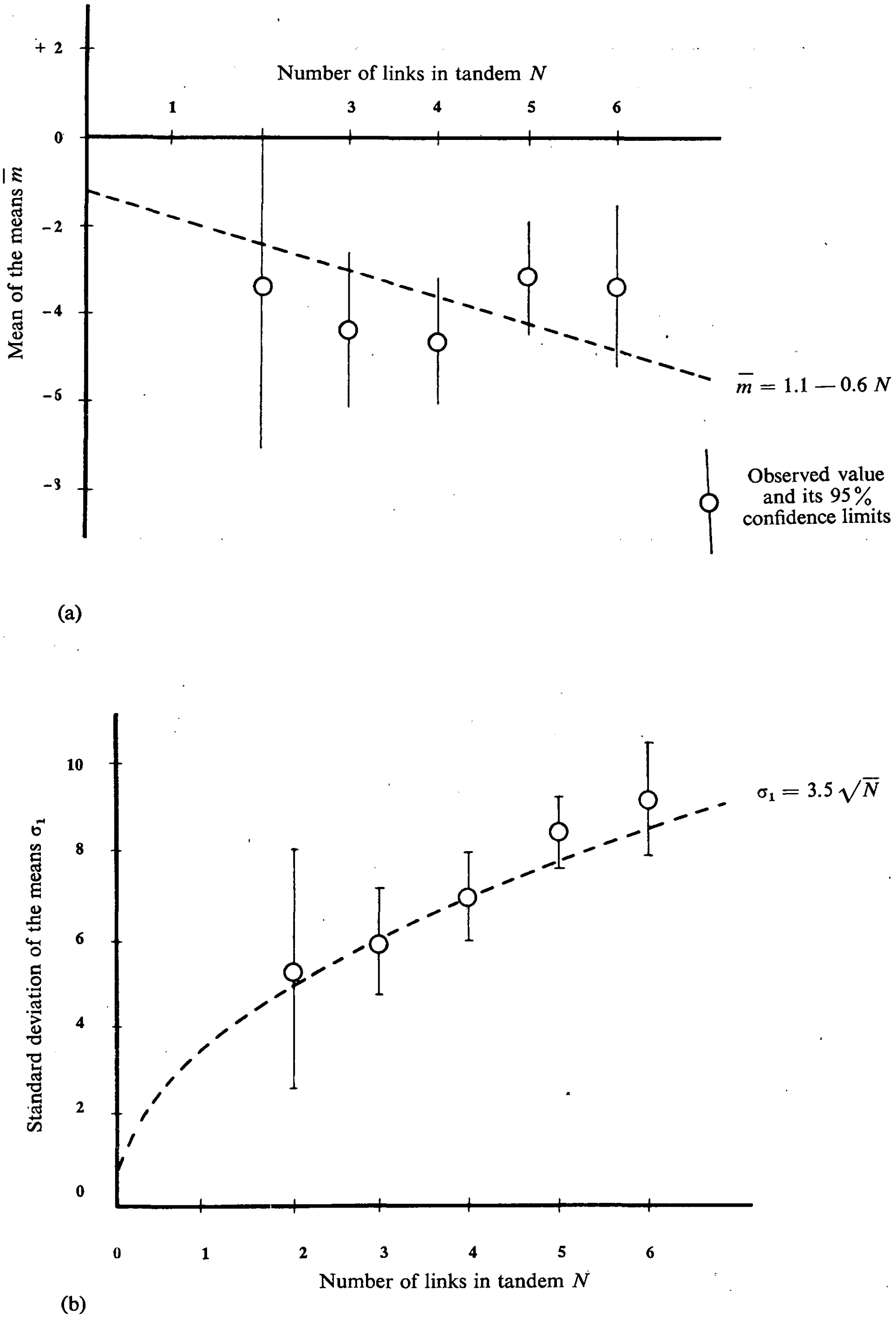


FIGURE 33. — *The mean of the means and the standard deviation of the means, Birmingham tests*

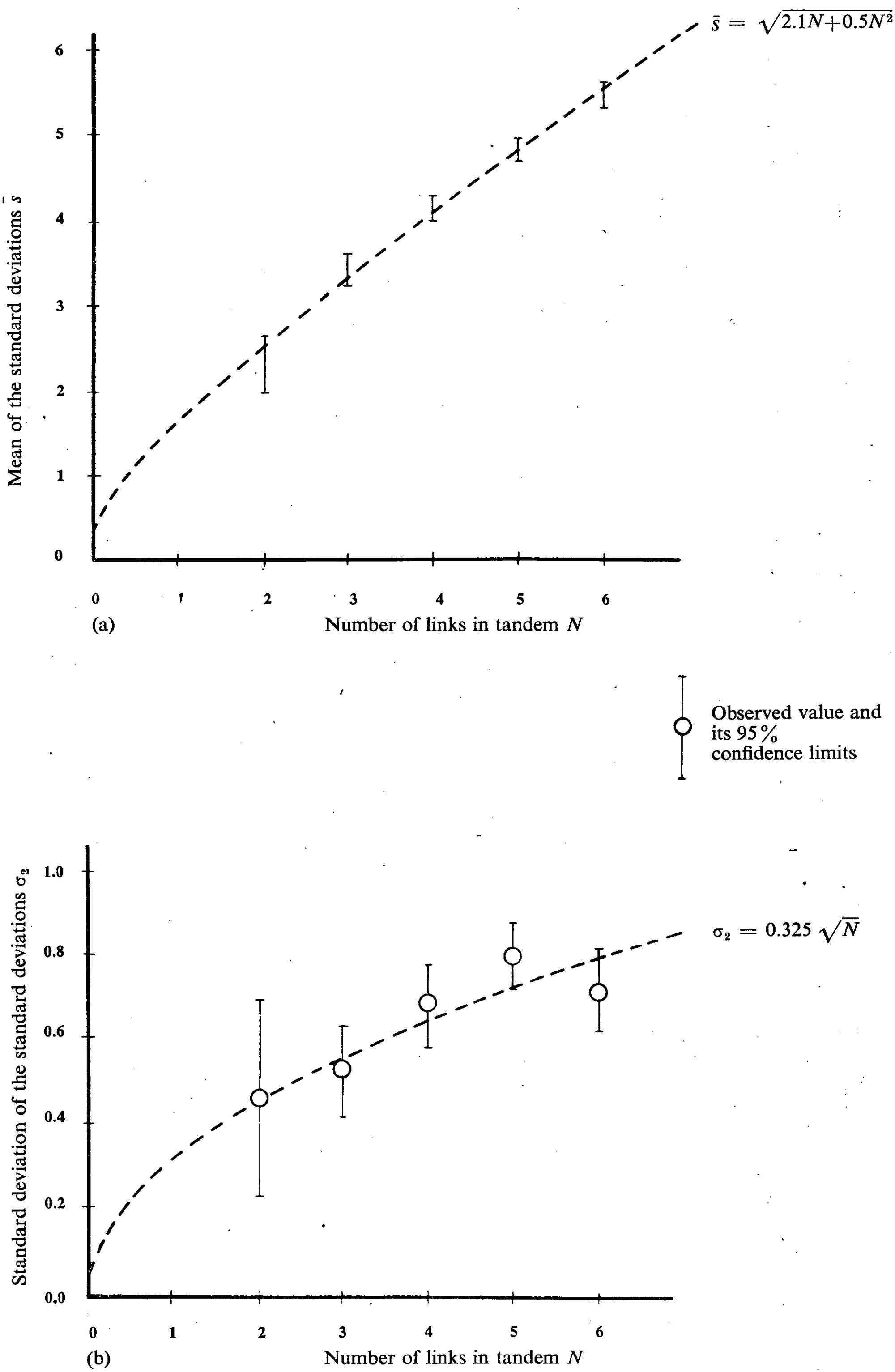
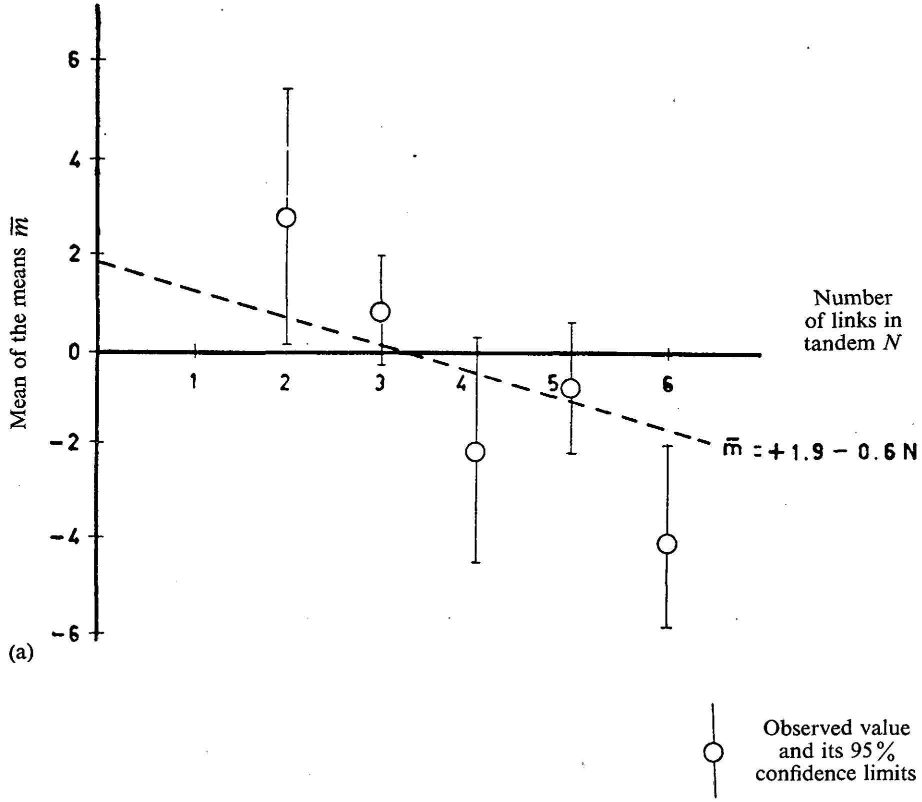


FIGURE 34. — *The mean of the standard deviations and the standard deviation of the standard deviations, Birmingham tests*



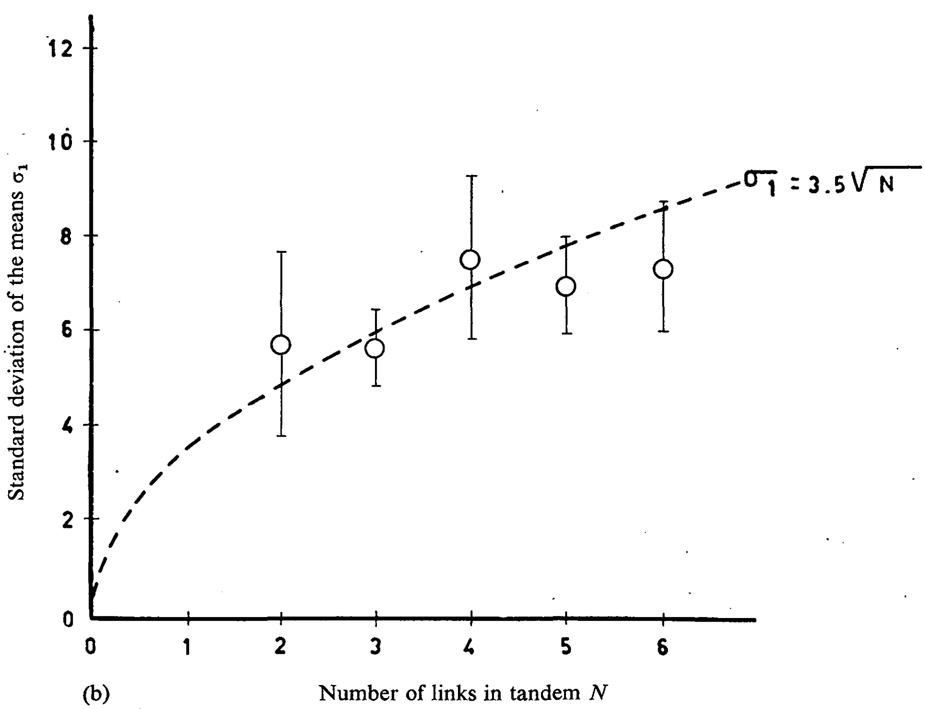


FIGURE 35. — *The mean of the means and the standard deviation of the means, London tests*

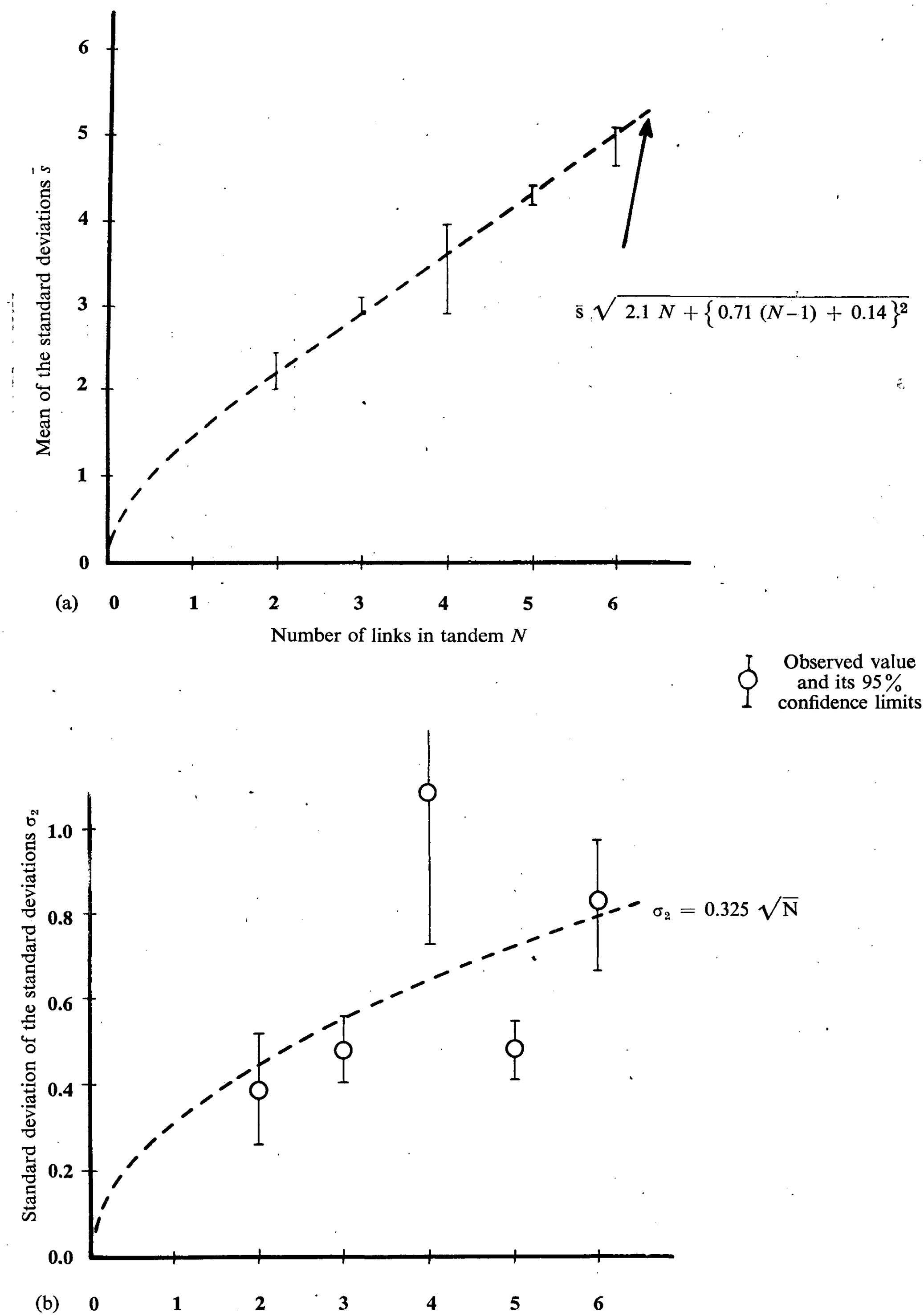


FIGURE 36. — *The mean of the standard deviations and the standard deviation of the standard deviations, London tests*

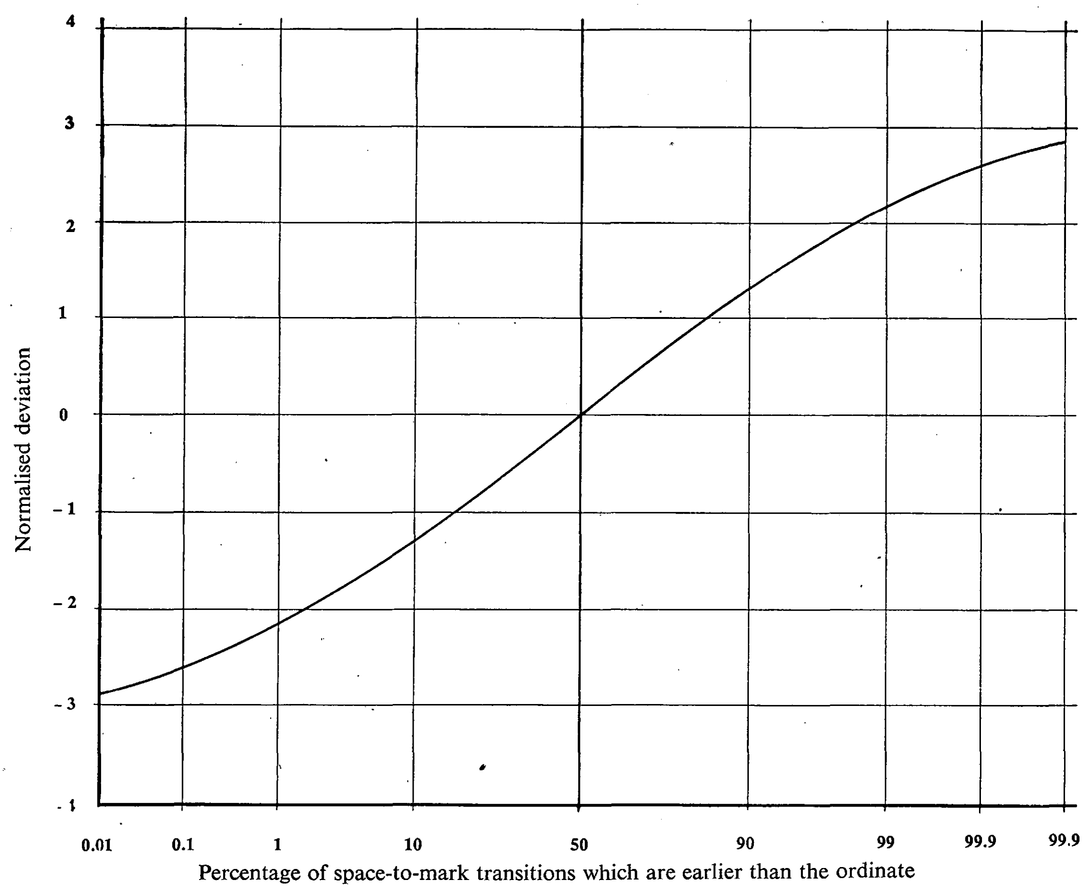


FIGURE 37. — *The fundamental distribution curve*

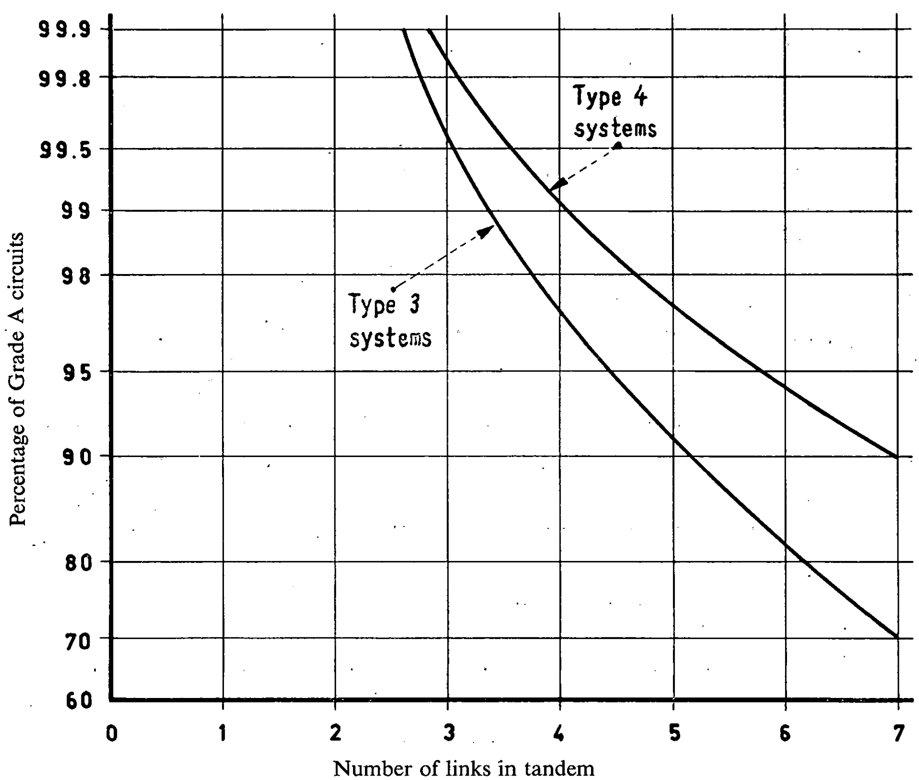
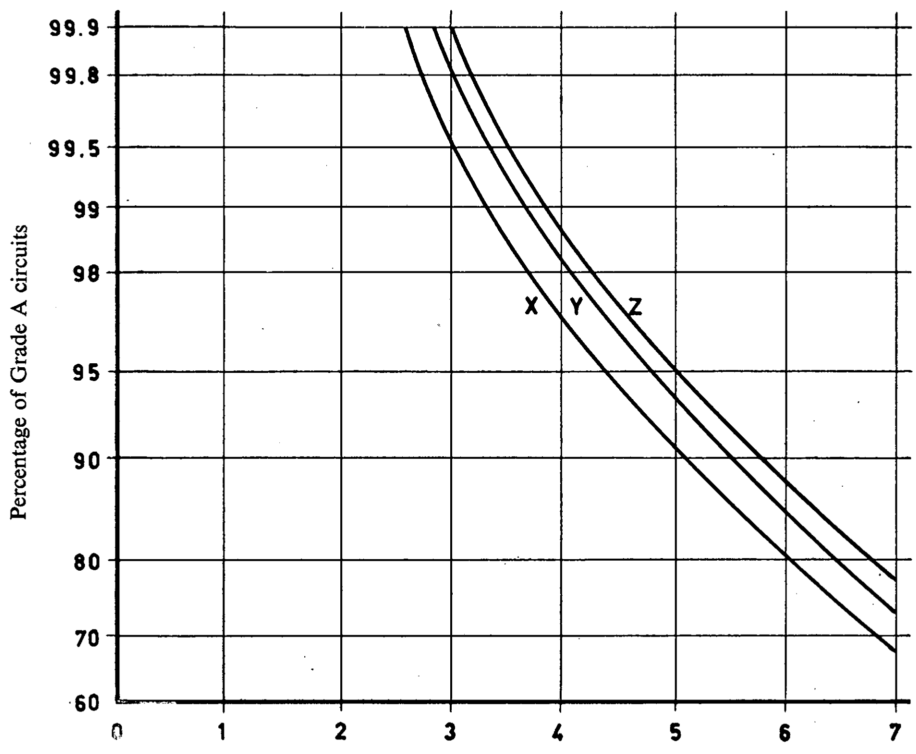
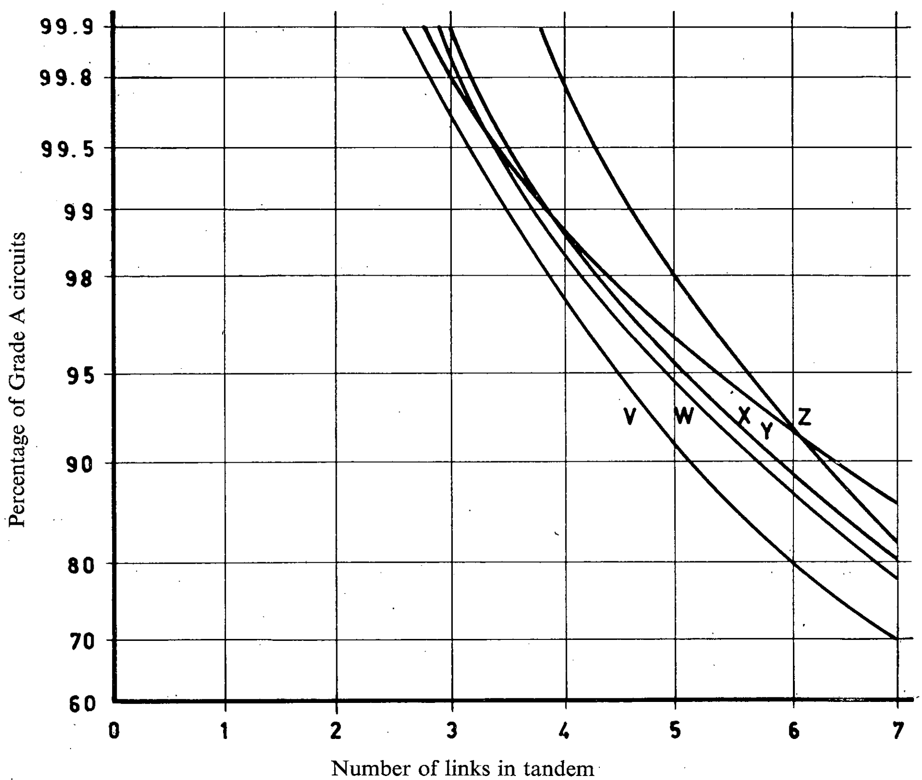


FIGURE 38. — *Comparison of Type 3 and Type 4 systems. "Grade A circuit" : inherent start-stop distortion < 30% (P = 0.0001)*



Curve X: Circuits terminated at a station at which the additional bias distortion is 2% marking.
Curve Y: Circuits terminated at a station at which there is no additional bias distortion.
Curve Z: Circuits terminated at a station at which the additional bias distortion is 2% spacing.

FIGURE 39. — *The effect of average bias distortion. Type 3 systems*



Hypothetical circuits

Curve V: Circuits as found during the transmission tests.
Curve W: Circuits in which the average value of bias distortion per link has been reduced from 0.6% marking to zero.
Curve X: Circuits in which the mean value of the fortuitous distortion component of the standard deviation of distortion has been reduced to half its present value.
Curve Y: Circuits in which the mean value of the characteristic distortion component of the standard deviation of distortion has been reduced to half its present value.
Curve Z: Circuits in which the standard deviation of bias distortion has been reduced to half its present value.

FIGURE 40. — *The effect of halving the value of the various forms of distortion. Type 3 systems*

EXTRACTS FROM RECOMMENDATIONS OF VOLUME III CONCERNING VOICE-FREQUENCY TELEGRAPHY

Extract from Recommendation H.11 — Conditions for setting up and changing over a voice-frequency telegraph circuit and its reserve circuit

a) *Make-up of circuit.*

Four-wire circuits should preferably be used for voice-frequency telegraphy. The make-up of a four-wire circuit for this purpose is different from that of a telephone circuit in that it has no terminating units, signalling equipment or echo suppressors.

1. *Use of a carrier telephone channel.* — When a 24-channel voice-frequency telegraph system has to be set up on a carrier telephone channel, the telephone channel should preferably use only one " group link " (see paragraph *a)* of Recommendation H.13).

2. *Use of an audio circuit.* — A four-wire circuit should preferably be used. The loading will depend on the number of carrier frequencies to be transmitted; for example, for systems having not more than 12 channels, medium loading may be satisfactory, even for long-distance transmission. On the other hand, for systems with 18 instead of 12 channels, circuits having something lighter than medium loading should be used.

Duplex working is not possible on two-wire circuits because the circuits cannot be balanced with sufficient accuracy to prevent mutual interference. However, a two-wire circuit can be used for voice-frequency telegraphy if low frequencies are used for transmission in one direction and high frequencies in the other.

b) *Relative levels.*

Points A and B (figure 41) where the changeover between the voice-frequency telegraph circuit and its reserve circuit takes place (and which are conventionally regarded as the origin and extremity of the four-wire circuit used for voice-frequency telegraphy) should be at the same relative level for the two circuits, the levels being determined from the level diagram of the telephone circuit.

The relative level at point A must not exceed — 0,4 neper.

The relative level at point B must be at least + 0.4 neper.

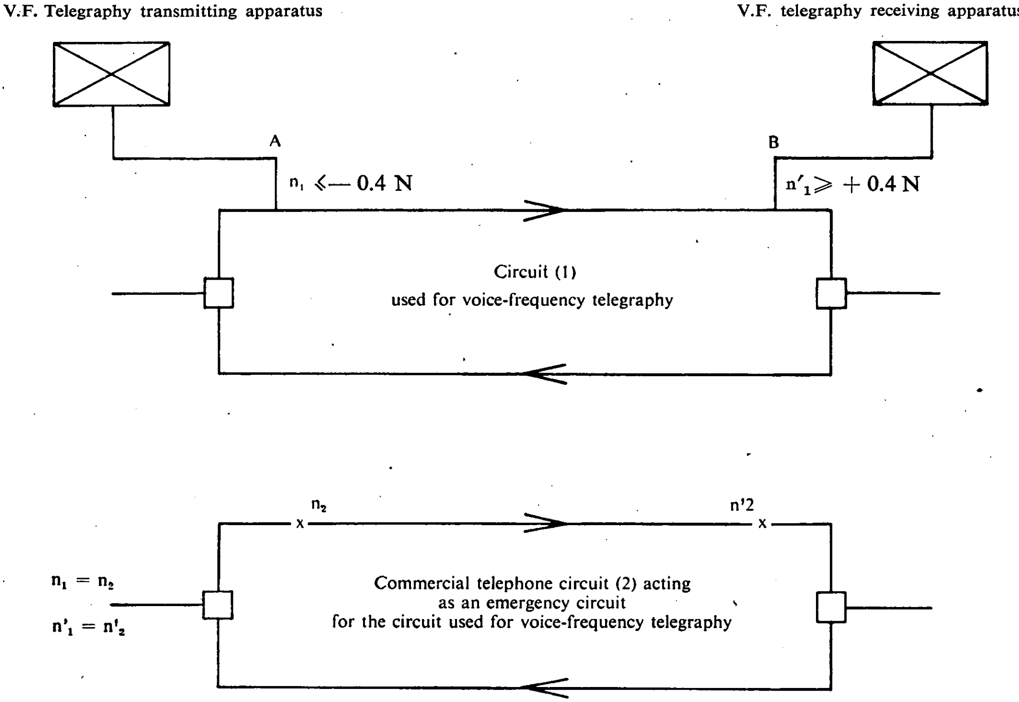


FIGURE 41. — *Diagram of a circuit used for V.F. telegraphy (1) and of its reserve circuit (2). A and B, Points 1. of connection between the telephone circuit used for V.F. telegraphy and the V.F. telegraphy equipments ; 2. of switching from the circuit used for V.F. telegraphy to its reserve circuit.*

Recommendation H.13 — Basic conditions applying to a carrier telephone channel required to provide 24 50-baud amplitude modulated voice-frequency telegraph channels

a) *Attenuation distortion.*

In the band 360 to 3240 c/s the variation of equivalent with frequency of a carrier telephone channel should in the worst case be within the limits of the graph of figure 42 which will be adopted for telephone working.

For the majority of carrier telephone channels used for voice-frequency telegraphy, it is recommended that in general the graph of figure 43 should be used in all cases where a circuit intended to provide 24 telegraph channels is set up on a single group link [1] for either a normal or reserve circuit for voice-frequency telegraphy.

Note. — Telephone channels 1 and 12 of a group may show greater attenuation distortion than the other channels of the group. It is recommended that the use of these channels 1 and 12 for voice-frequency telegraphy should be avoided.

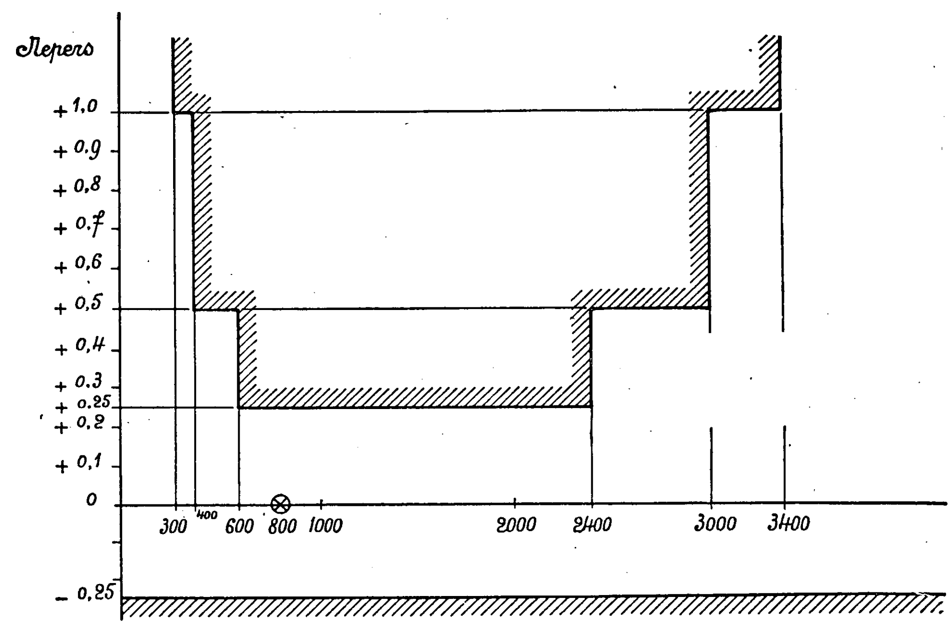
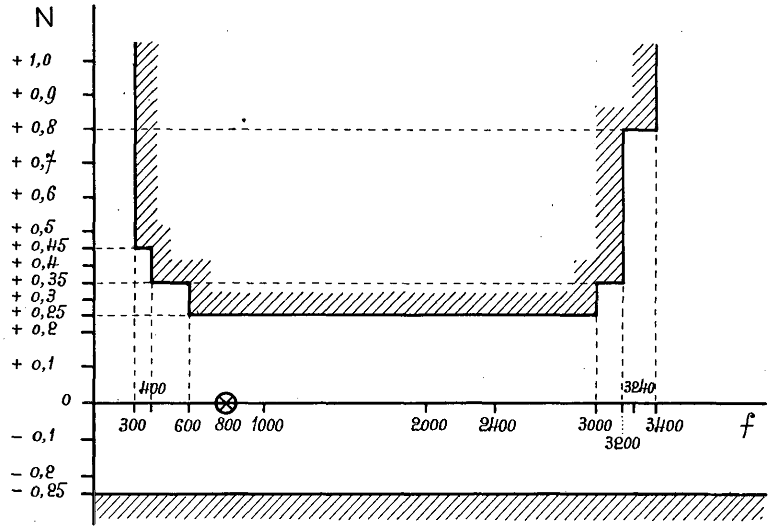


FIGURE 42. — *Variation with frequency of the equivalent in terminal service, relative to the value measured at 800 c/s (international circuit transmitting the band of frequencies 300 to 3400 c/s)*

[1] A group link is a transmission path of defined bandwidth (48 kc/s) connecting two group distribution frames or equivalent points. It extends from the point where the group is first assembled to the point where it is dispersed to channels. The term normally covers both directions of transmission.



Note. — The curve of the variations of the equivalent as a function of frequency should be inside the unshaded area. The measured 800 c/s value is, according to the maintenance instructions, brought as nearly as possible to its nominal value.

FIGURE 43. — *Variation with frequency of the equivalent in terminal service relative to the value measured at 800 c/s (circuit routed on a single group link to provide 24 voice-frequency telegraph channels)*

f = frequency c/s N = variation of equivalent (nepers)

b) *Phase distortion.*

Practical experience obtained up to the present shows that it is not necessary to introduce a supplementary clause relative to the slope of the " group delay-frequency " characteristic in the C.C.I.F. specifications for carrier systems, even considering the case where a telegraph link consists of telephone channels of several carrier systems connected in tandem. It may happen that under adverse conditions some telephone channels of such a connection are of insufficient quality to provide 24 telegraph channels. In such a case a better combination of telephone channels must be chosen for the telegraph service and this better combination will always be possible. By way of information, Annex 22 of the *Book of Annexes* of Volume III of the *Green Book* gives the result of a calculation made by the French Telephone Administration.

c) *Frequency stability.*

It has already been foreseen that in future carrier systems the virtual carrier frequencies will be stable to about ± 2 c/s based on the requirements of voice-frequency telegraphy.

So far as the stability of the frequencies provided by the carrier frequency generators for voice-frequency telegraphy is concerned, the C.C.I.T.T. has recommended that the frequencies should not differ by more than 3 c/s from the nominal value when the telegraph channels are routed on a telephone circuit which is not made up exclusively of ordinary audio-frequency telephone sections.

d) *Crosstalk.*

The near-end signal/crosstalk ratio between the two directions of transmission of a telephone circuit using a duplex voice-frequency telegraph system must be at least 43 decibels or 5 nepers.

Taking into consideration the crosstalk introduced by equipment, this value of near-end signal/crosstalk ratio can in general be guaranteed even in the case of the 2500 km hypothetical reference circuit on coaxial cable. It should therefore be possible to use any modern carrier telephone circuit on cable for duplex voice-frequency telegraphy.

Recommendation H.14 — Basic requirements for an audio telephone circuit to be used for an amplitude-modulated voice-frequency telegraph system

a) The graph in figure 44 shows for the different frequencies what are the variations, in relation to the nominal value of 800 c/s, of the difference in the relative power levels between the input and the output of the circuit (points A and B, figure 41 of Recommendation H.11).

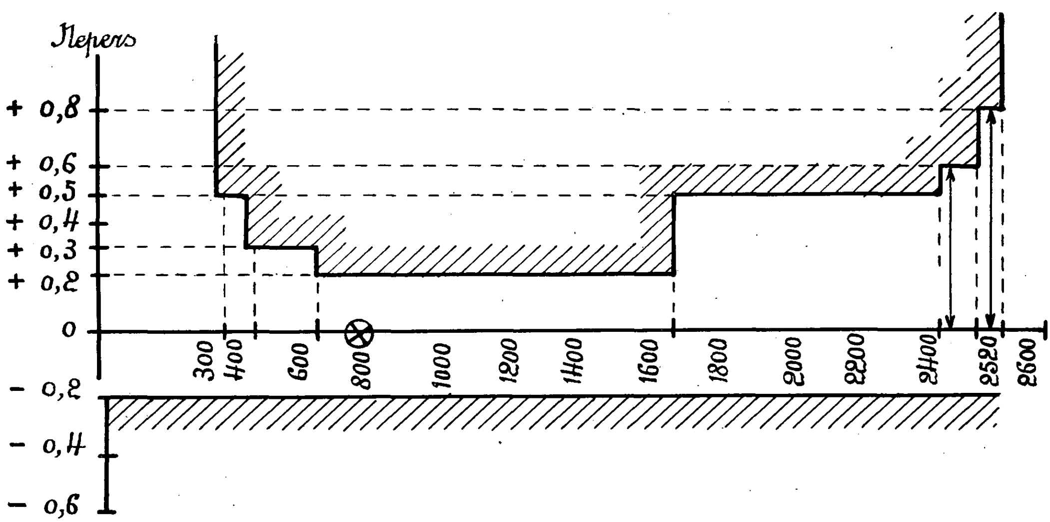


FIGURE 44. — *Limits for the variation, as a function of frequency, in relation to its nominal value at 800 c/s of the difference of relative power levels between the origin and the extremity of a circuit used for voice-frequency telegraphy (telephone circuit with passband of 300–2600 c/s)*

b) The permissible tolerances for the relative power level at the output of frontier repeaters correspond to those laid down for 4-wire telephone circuits, assuming that, in making maintenance measurements, a power equivalent to 1 milliwatt at the point of zero relative level deduced from the hypsogram of the telephone circuit is applied at the input of the circuit used for V.F. telegraphy.

These tolerances are shown in the graph given in figure 45.

It seems unnecessary to lay down special tolerances for the variations, in terms of the frequency, of the through level measured at the output of a frontier repeater since this figure can easily be calculated on the basis of the permissible tolerance for the relative power level.

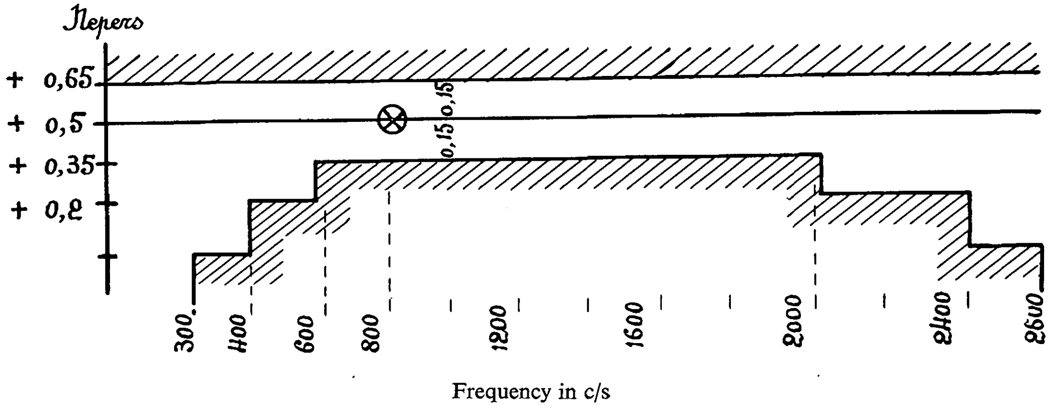


FIGURE 45. — *Limits for the absolute power level on the occasion of maintenance measurements at the output of a frontier-repeater (frontier side) of an international circuit with passband 300–2600 c/s used for voice-frequency telegraphy, a power corresponding to 1 milliwatt at the point of zero relative level (as deduced from the hypsogram of the telephone circuit) being applied at the origin of the voice-frequency telegraph circuit*

c) The relative power level at the point where the V.F. circuit, at the reception end, is switched to its reserve circuit must remain as constant as possible in time. Moreover, any interruption of the circuit, however short, is harmful to telegraph transmission. Great care should therefore be exercised when taking measurements on circuits and repeaters, when switching batteries, etc. To draw the attention of staff to this point, the circuits used for V.F. telegraphy should be specially marked in terminal offices and in repeater stations.

d) Special steps should be taken to ensure that no modulation is caused on circuits and in repeaters. Such modulation might be caused, *inter alia*, by fluctuations of battery voltages, or by the connection of sub-audio telegraphy equipments to the conductors of the cable.

Any interruption of such a circuit, even of very short duration, spoils the quality of the telegraph transmission. It is therefore desirable to take great care when making measurements on circuits used for voice-frequency telegraphy.

To draw the attention of staff to this matter, channel equipment for circuits used for voice-frequency telegraphy should be specially marked in the terminal exchanges and where necessary in repeater stations where the circuits are accessible.

EXTRACTS OF RECOMMENDATIONS DEALING WITH NOISE LEVEL WHICH CONCERN TELEGRAPHY

Extract of Recommendation G.222 (" Red Book ", Vol. III) — Hypothetical reference circuits and noise objectives for carrier telephone systems

a) *Design objectives in respect of noise produced by the line and the frequency division modulating equipment on hypothetical reference circuits for telephony*

In order to ensure that multi-channel carrier systems on cable and on line-of-sight radio 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 *,

1.2 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 integration 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. However, if use is foreseen of V.F. telegraph equipment conforming to Series R Recommendations of the C.C.I.T.T., in order to obtain telegraph connections with the quality indicated in C.C.I.T.T. Recommendation F.10, the mean unweighted noise power over 5 ms shall not exceed 10^6 pW for more than 0.001% (10^{-5}) of any month or for more than 0.1% of any hour.

Conditions in which the design objectives apply are given below under paragraph b).

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.223.

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 (Recommendations G.321 paragraphs A. b) and E. a),
- 4 Mc/s coaxial pair systems (Recommendation G.332 paragraph d) and 12 Mc/s coaxial pair systems (Recommendation G.333, paragraph e),
- systems on small diameter coaxial pairs (Recommendation G.341, paragraph d),
- line-of-sight radio relay links using frequency-division multiplex (C.C.I.R. Recommendation No. 287 repeated in Recommendation G.441) and time-division multiplex (C.C.I.R. Recommendation No. 301 summarized in Recommendation G.443).

Recommendation G.442 indicates the objectives when V.F. telegraphy is used on line-of-sight radio relay links.

* pW = picowatt (micro-microwatt).

The application of general noise objectives to radio relay links using forward scatter is still under study (see C.C.I.R. Report 135).

Other objectives are recommended for systems providing 12 carrier circuits on an open-wire pair (see Recommendation G.311, paragraph f)).

2. Designers are expected to fit their distribution curves to fall below both points given in sub-paragraphs 1.2 and 1.3 of paragraph a) of the 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 indicated.

4. . . . .

In a part of a hypothetical reference circuit consisting of one or more equal homogeneous sections, the mean noise power in any hour 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. The following Remark gives further recommended assumptions for use in calculating noise on hypothetical reference circuits for telephony.

. . . .

REMARK

Assumptions for the calculation of noise on hypothetical reference circuits for telephony cables (symmetric or coaxial pairs) *

1. *Nominal mean power during the busy hour.*

To simplify calculations when plans are being drawn up for 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 dbm (–1.73 nepers) (mean power –31.6 microwatts); this is the mean with time and the mean for a large batch of circuits.

* The assumptions for the calculation of noise on hypothetical reference circuits for radio relay links are indicated in C.C.I.R. Recommendations 287 and 301.

This total mean power (about 32 microwatts) is conventionally distributed as follows:

— a nominal mean power of 10 microwatts for all signalling and tones;

— a nominal mean power of 22 microwatts for other currents, namely:

- speech currents (including echoes),
- carrier leak,
- telegraph signals.

Note 1. — It is assumed that a few of the telephone channels of the system concerned will be used for voice-frequency telegraphy or for phototelegraphy; under these conditions, the power of the telegraph signals can be distributed over the whole of the telephone channels without changing the nominal mean power of 22 microwatts.

5. *Calculation of noise in modulating equipments.*

. . . .

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 equipments of the hypothetical reference circuit there are six exposures to adjacent-channel disturbance. Five of these disturbing channels will be assumed to carry speech-like loading signals each having a mean power of 32 μW, i.e. an absolute power level of – 15 db (– 1.73 *N*) per channel at a zero relative level point, while the sixth disturbing channel will be assumed to carry telegraphy, phototelegraphy or data transmission with a conventional loading of 135 μW applied at the zero relative level point, i.e. an absolute power of – 8.7 dbm (– 1.0 *N*), uniformly distributed over the frequency range 380 to 3220 c/s.

Recommendation G.442 (" Red Book ", Vol. III) — Radio relay system design objectives for noise at the far end of a hypothetical reference circuit with reference to telegraph transmission

As indicated in Recommendation G.222, if use on radio links is foreseen of V.F. telegraph equipment conforming to Series R Recommendations of the C.C.I.T.T., then in order to obtain telegraph connections with the quality indicated in C.C.I.T.T. Recommendation F.10, the design of these radio links should include the objectives recommended for telephone transmission and signalling, and, in addition, should include the objectives set out below:

On any telephone channel constituted in accordance with the hypothetical reference circuit for the type of radio link considered, the unweighted noise power, measured or calculated with a time-constant (integrating time) of 5 milliseconds and referred to a zero relative level point, should not exceed 10^6 pW during more than 10^{-5} (i.e. 0.001 %) of any month, nor more than 0.1 % of any hour.

Provided that short bursts of high level noise due to causes other than propagation have been reduced to negligible proportions, and assuming that the fine structure of the noise is the same as white noise, it is assumed that in designing line of sight radio links, the objective during any month is, in practice, equivalent to the following objective:

The unweighted noise power on a telephone channel at a zero relative level point, calculated from measurements made with an integration time of 1 second, should not exceed 2×10^5 pW for more than 10^{-4} (i.e. for more than 0.01 %) of any month.

With regard to the objective to be met during any hour, it may happen that on certain radio links, unforeseen exceptional propagation conditions may result in this objective not being met during certain most unfavourable hours. These hours, called " hours of interrupted telegraph traffic ", will be those during which a noise level of 10^6 pW is exceeded for more than 36 seconds.

Every effort should be made to reduce the number of such hours to a very small fraction of the total time. Since it follows from the recommended objective for telephone signalling, that the 5 millisecond unweighted noise power should not exceed 10^6 pW during more than 10^{-4} (i.e. 0.01 %) of any month, there should never be more than 7 " hours of interrupted telegraph traffic " during a month.

It may then be expected that satisfactory telegraph service will be given, the following additional conditions perhaps being applied in certain cases:

— use of telegraph systems that give good immunity to noise, e.g. frequency-modulation systems,

— choice of the channels for voice-frequency telegraphy from among those least subject to propagation noise.

These recommendations for noise power on telephone circuits used for voice-frequency telegraphy are provisional, for the following reasons:

a) in a number of countries, studies are in progress on time constants and methods of measurements,

b) although the C.C.I.R. has already given information (see C.C.I.R. Report No. 132, Los Angeles) on the number and the duration of noise bursts on radio links, more information on this subject is necessary;

c) more information is necessary on the results obtained on voice-frequency telegraph systems working on radio links.

Note.

a) 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 equivalent. 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.

b) 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.

DISTURBANCE OF TELEGRAPH TRANSMISSION BY A WHITE NOISE

(Contribution of France to Study Group 9, contribution COM 9, No. 48, August, 1959)

STUDY OF THE EFFECT OF A GIVEN LEVEL OF WHITE NOISE ON TELEGRAPH TRANSMISSION

Within the framework of the studies conducted by the joint C.C.I.T.T.-C.C.I.R. working group on Circuit Noise, the French Administration carried out a series of tests to show the effect of white noise on telegraph transmission operated by its standardized frequency modulation and amplitude modulation equipment.

I. *Test plan*

The test plan used, which shows how white noise is injected into the voice-frequency telegraph circuit, is shown in figure 46.

The selectivity curves for filters A and B are shown in figure 47.

An adjustable gain amplifier is used to control the noise power injected into the circuit. The level of telegraph transmission per channel, at the point where this injection is made, is shown in figure 46 for both amplitude modulation and frequency modulation equipment.

II. *Telegraph equipment used*

a) *Amplitude modulation.*

This equipment is the standard 44 (24-channel) type. It is fitted with vacuum tubes.

The tests were made on channels 2, 13 and 23, but the same transmitter-receiver was used, only the transmitting and receiving filters being changed to eliminate dispersion due to different adjustments.

b) *Frequency modulation.*

This equipment is the standard 51 *L* (24-channel) type. It is fitted with transistors and its sensitivity threshold conforms to the recent proposals by C.C.I.T.T. Study Group 9. The equipment is group-modulated, the basic channel used being channel 9, and the tests were made on channels 4, 9, 16 or 21 according to the group modulator used.

III. *Test conditions*

1) *Noise levels.*

To obtain degrees of distortion capable of being measured easily, and to reduce the number of tests required, three noise levels only were used: 5×10^5, 10^6 and 2×10^6 pW, at a point of zero relative level in the telephone circuit.

2) *Telegraph measuring apparatus.*

At the transmitting end: a calibrated telegraph signal transmitter (type 53); at the receiving end: a start-stop distortion measuring set (type 53), combined with a metering group.

The text sent by the calibrated signal transmitter is that mentioned in C.C.I.T.T. Recommendation R.52 (voyez le brick géant que j'examine près du wharf), and is either without distortion, or has a 22% distortion for all characters, obtained by providing the " start " signal with forward or backward distortion. At the receiving end, the degree of individual distortion of the significant instants was measured.

3) *Test conditions.*

To ensure that the test would last at least 5 minutes, in accordance with the programme set out by C.C.I.T.T. Study Group 9 (Annex II to Question 3/IX), the text was transmitted 20 times; this corresponds to the transmission of 1000 characters, including 3160 significant instants which might be affected by distortion.

The metering group shows directly the number of significant instants having a degree of individual distortion higher than the value mentioned on the start-stop distortion measuring set. The set is graded by steps of 2%. The probability that a given distortion rate will be exceeded is thus more or less equal to the ratio between the number of significant instants having a degree of distortion equal to or greater than the degree mentioned and the total number of significant instants in the text.

4) *Mode of operation.*

Once the telegraph channel is correctly adjusted, we obtain its degree of forward or backward inherent distortion for both degrees of distortion of the text transmitted (0 or 22%).

The noise level adjusted to the desired value, is injected into the voice-frequency telegraph circuit (figure 46) and a series of 20 texts is transmitted. The degree of distortion mentioned on the distortiometer is progressively increased by steps of 2% until the meter gives no further indication during the test.

5) *Presentation of the results.*

In accordance with Annex II to Question 3/IX, the curves annexed hereto (figures 48 to 54) show the probability of excess distortion as a function of the degree of individual distortion registered for the various noise powers used.

We have extracted from these curves the maximum distortion values observed which correspond to a probability of 0.5%. These values appear in Table I.

TABLE I. — *Maximum values of the degrees of distortion observed which correspond to a probability of 0.5%*

		Noise power in pW		
		5×10^5	10^6	2×10^6
Transmission at	0% AM	12	16	22
	0% FM	6	8	12
	22% AM	33	36	> 40
	22% FM	27	30	32

The results call for the following comments:

— These tests confirm the views of the " Noise " working party meeting in May 1958, i.e. in amplitude modulation the value of 10^6 pW at a point of zero relative level is a limit above which the noise peaks produce inadmissible degrees of distortion in telegraph transmission. When the radio relay link alone is used to bear a voice-frequency telegraph circuit (which corresponds to transmission at 0%), the power of 5×10^5 pW produces a tolerable distortion (12%); in frequency modulation the corresponding value is 2×10^6 pW.

— The position of the voice-frequency telegraph channel in the audio-frequency band has practically no influence; for the same noise level, the degrees of distortion observed are practically the same regardless of the telegraph carrier frequency used.

— The tests confirm that frequency-modulated systems have a distinct advantage over amplitude-modulated systems; on the basis of the foregoing results, which show a difference of 0.7 *N* in noise level for the same degree of distortion, and taking account of the difference in levels (indicated in figure 46), we see that this advantage is close to 1 *N*.

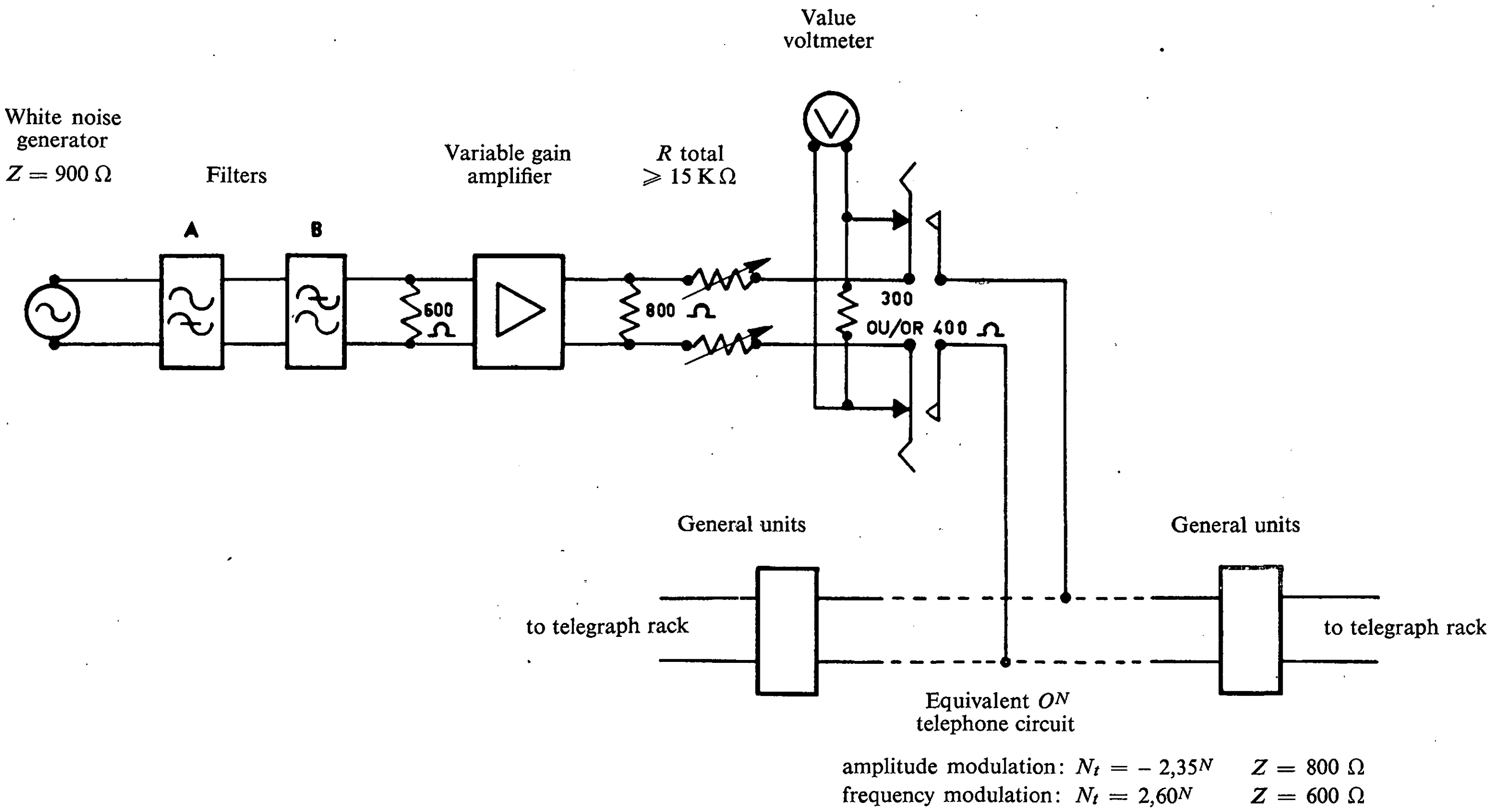


FIGURE 46. — *Device for injecting white noise into the voice-frequency telegraph circuit*

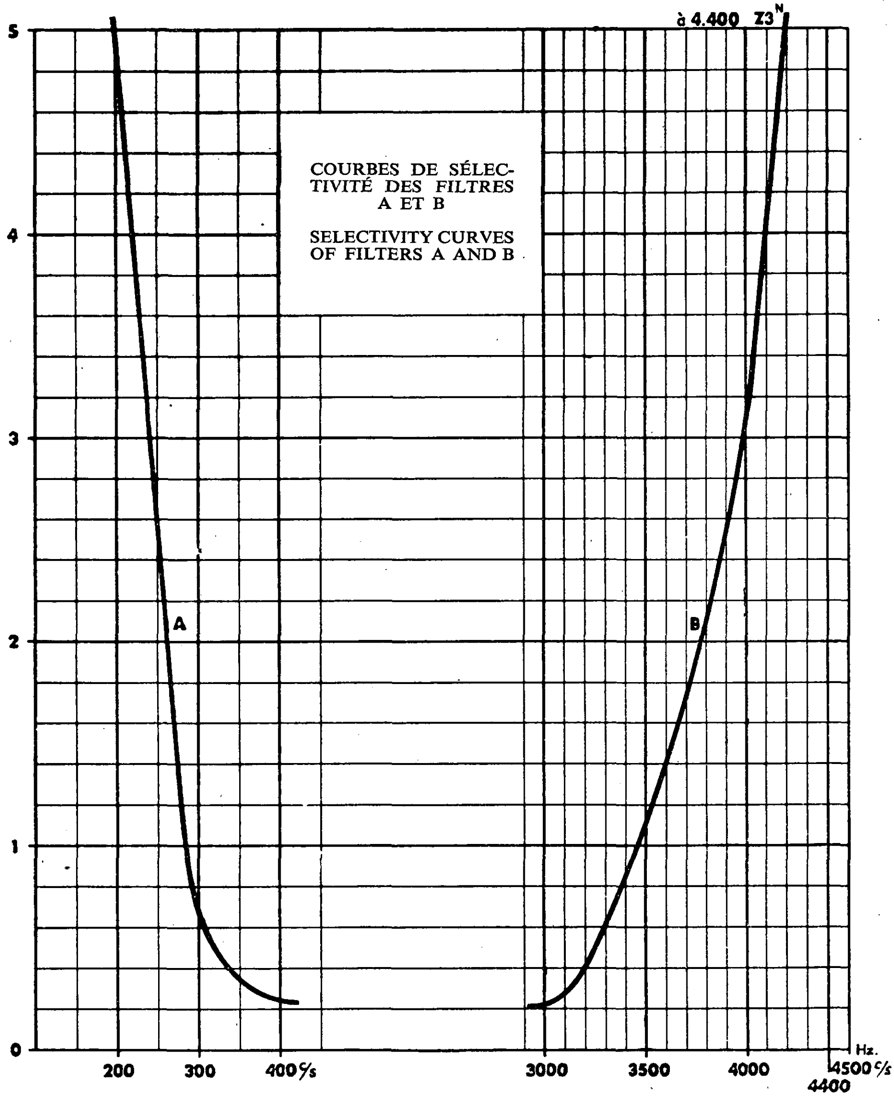

COURBES DE SÉLECTIVITÉ DES FILTRES A ET B
SELECTIVITY CURVES OF FILTERS A AND B
à 4.400 Z3 N
A
B
0
1
2
3
4
5
200
300
400 c/s
3000
3500
4000
4500 c/s
4400
Hz.

FIGURE 47

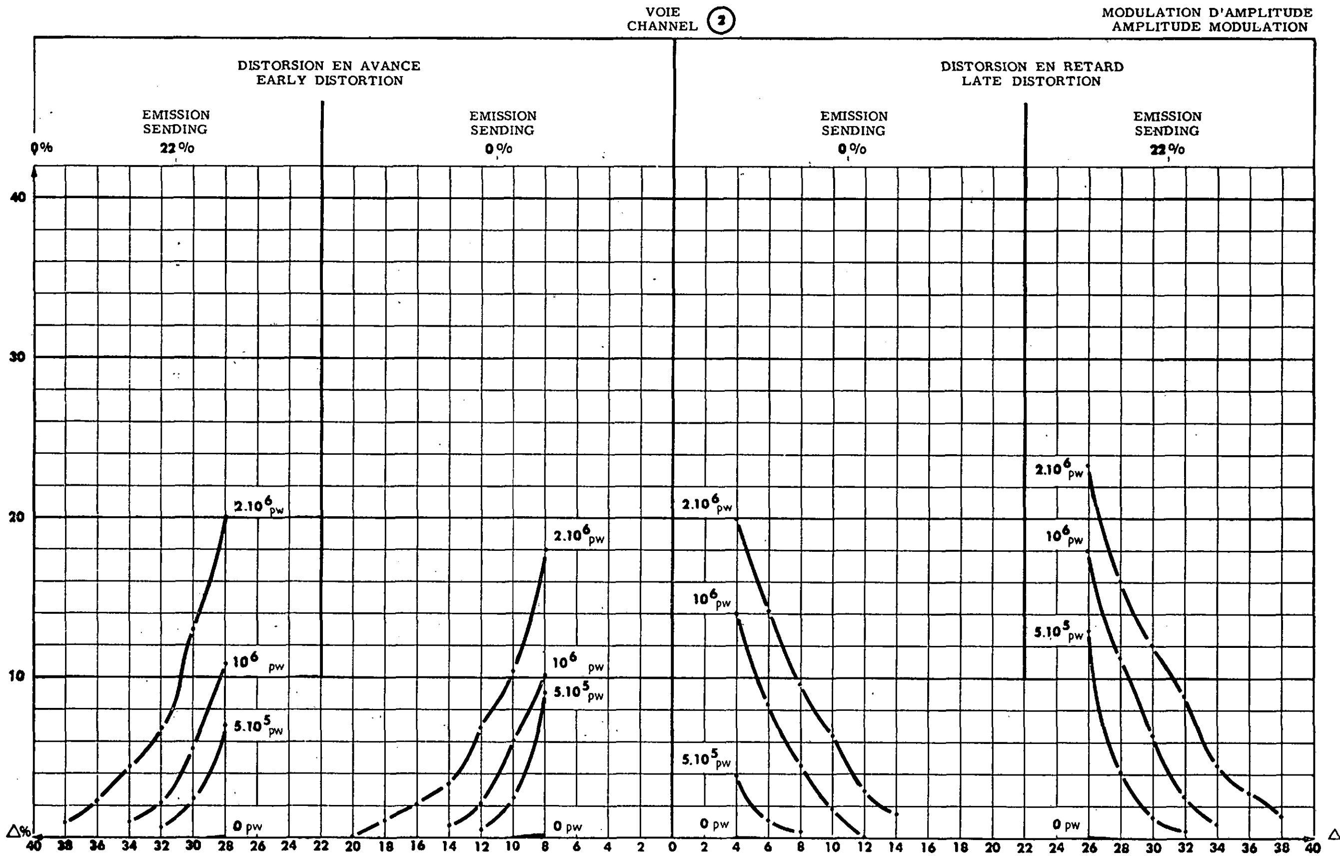

VOIE
CHANNEL
2
MODULATION D'AMPLITUDE
AMPLITUDE MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0%
40
30
20
10
Δ%
2.10⁶ pw
10⁶ pw
5.10⁵ pw
0 pw
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Δ%

FIGURE 48

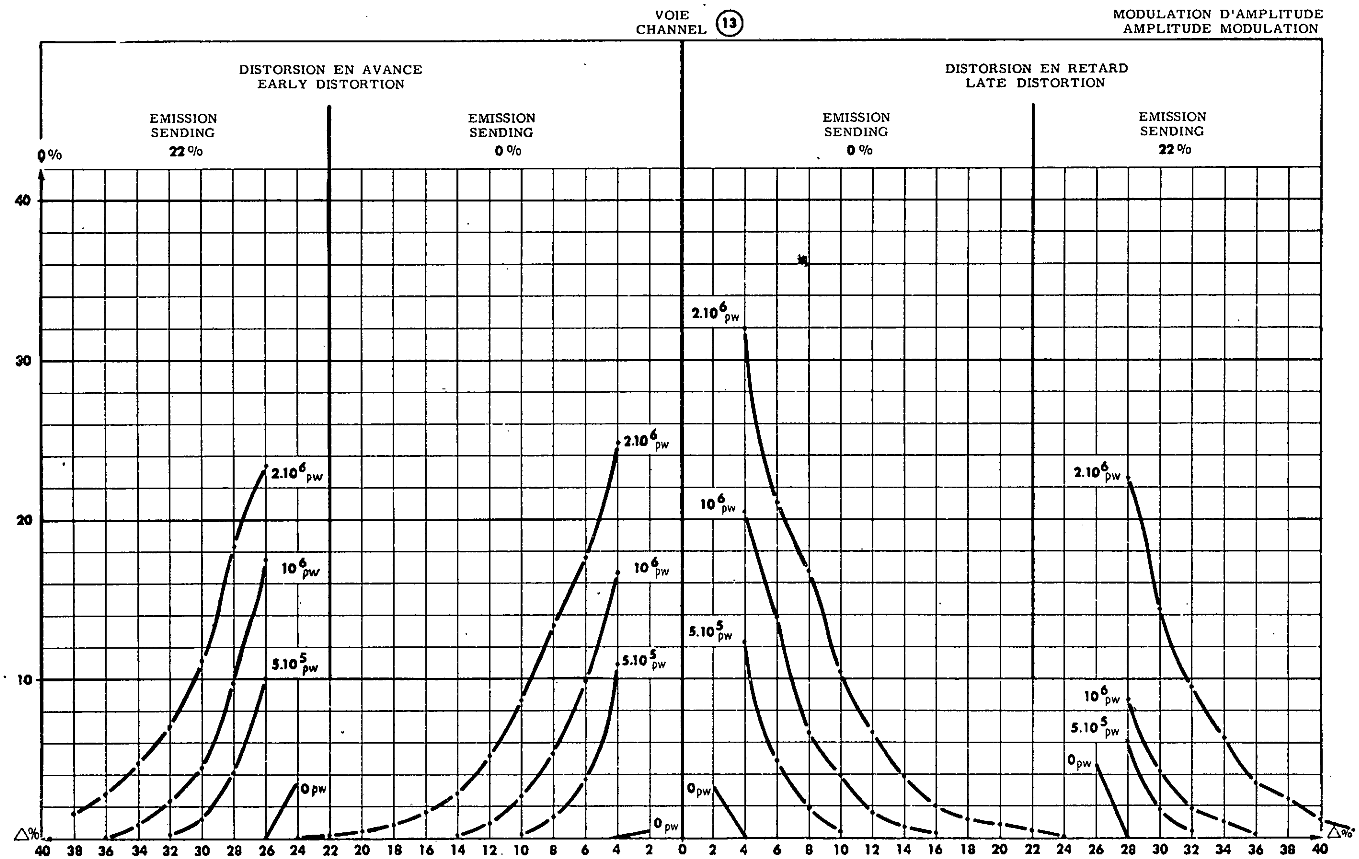

VOIE
CHANNEL
13
MODULATION D'AMPLITUDE
AMPLITUDE MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0 %
40
30
20
10
△%
△%
2.10⁶ pw
10⁶ pw
5.10⁵ pw
0 pw
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

FIGURE 49

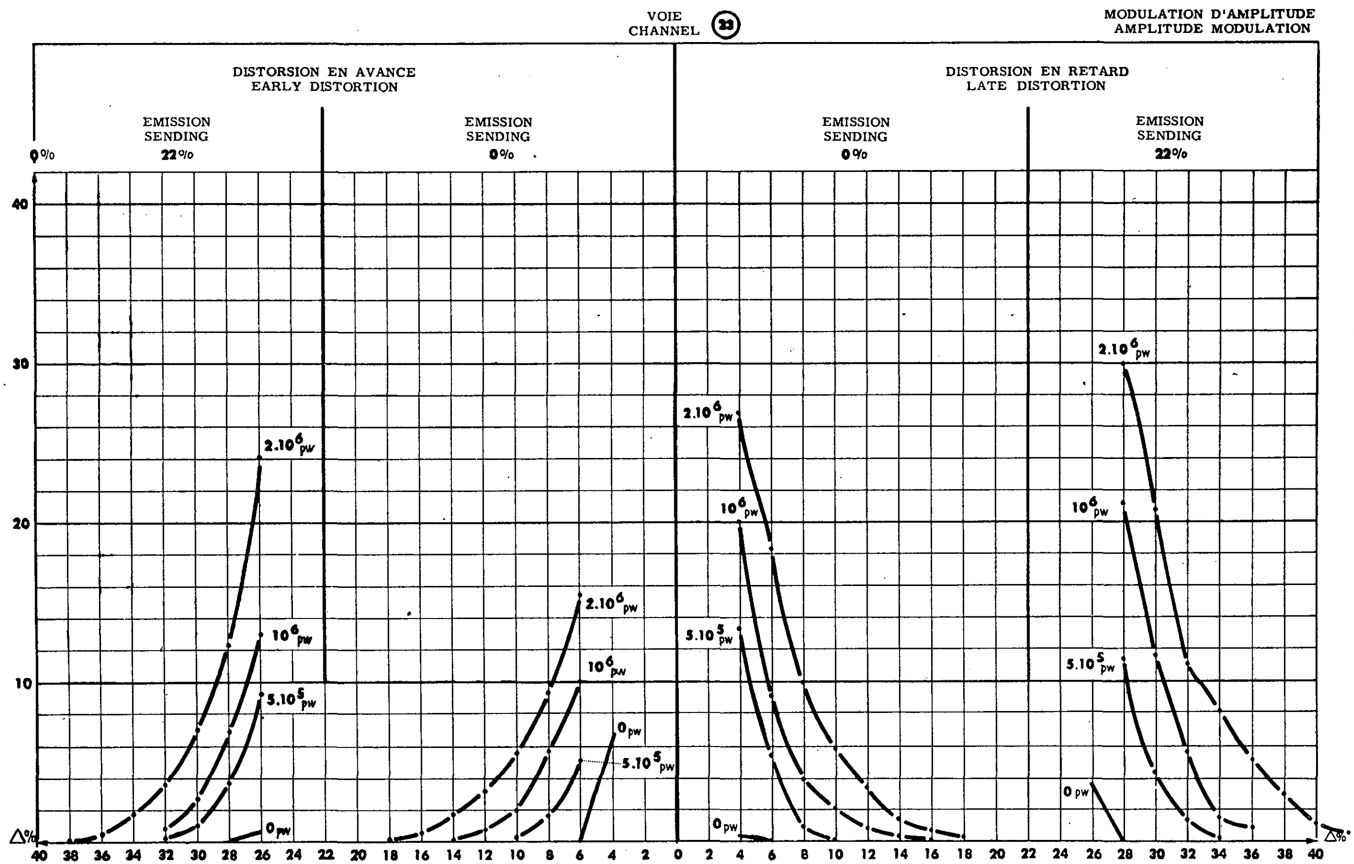

VOIE
CHANNEL
23
MODULATION D'AMPLITUDE
AMPLITUDE MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22%
EMISSION
SENDING
0%
EMISSION
SENDING
0%
EMISSION
SENDING
22%
0%
Δ%
2.10⁶ pw
10⁶ pw
5.10⁵ pw
0 pw
40 30 20 10
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

FIGURE 50

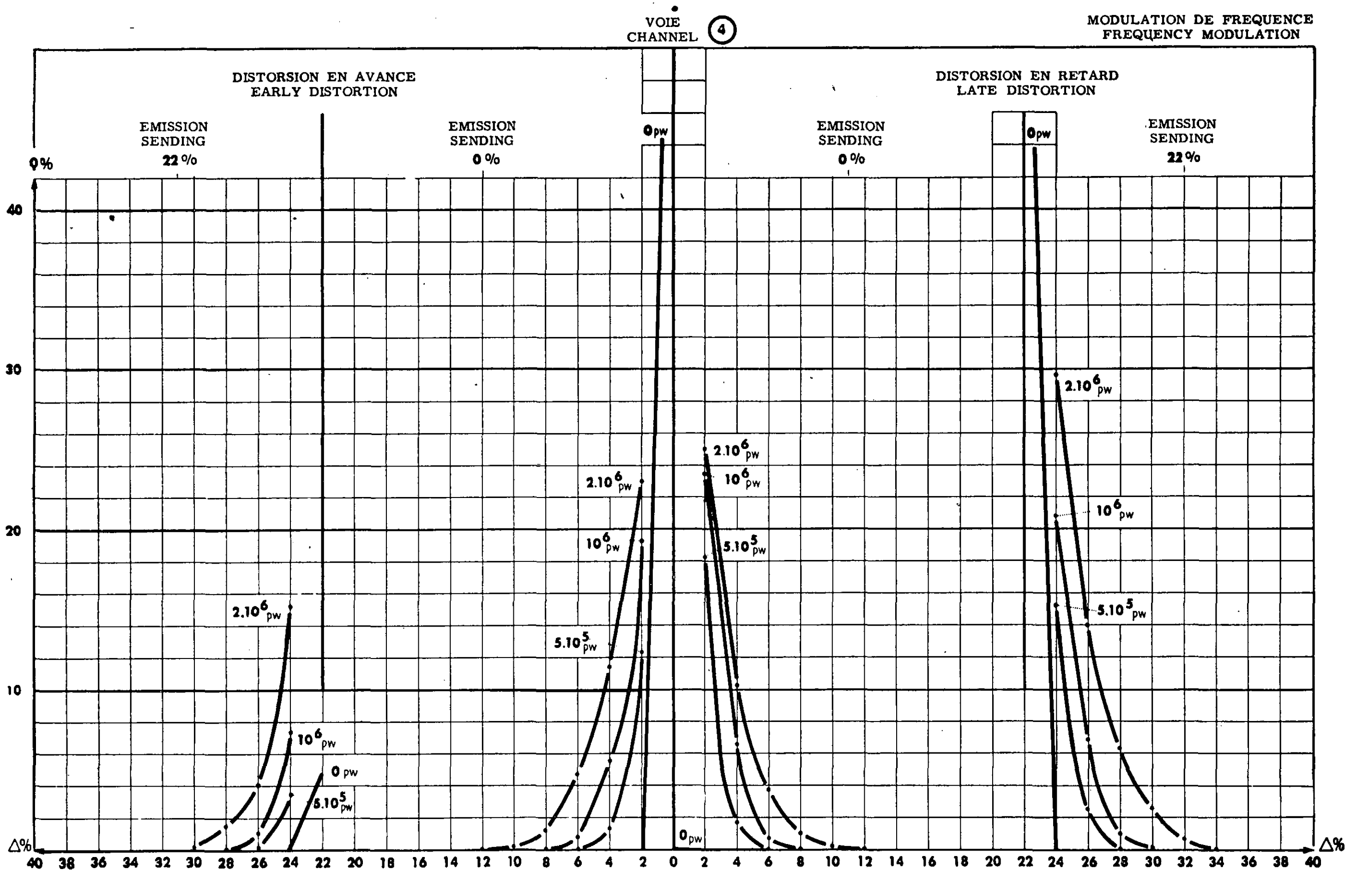

VOIE
CHANNEL
4
MODULATION DE FREQUENCE
FREQUENCY MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0 pw
2.10⁶ pw
10⁶ pw
5.10⁵ pw
0 pw
0%
Δ%
40 30 20 10
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

FIGURE 51

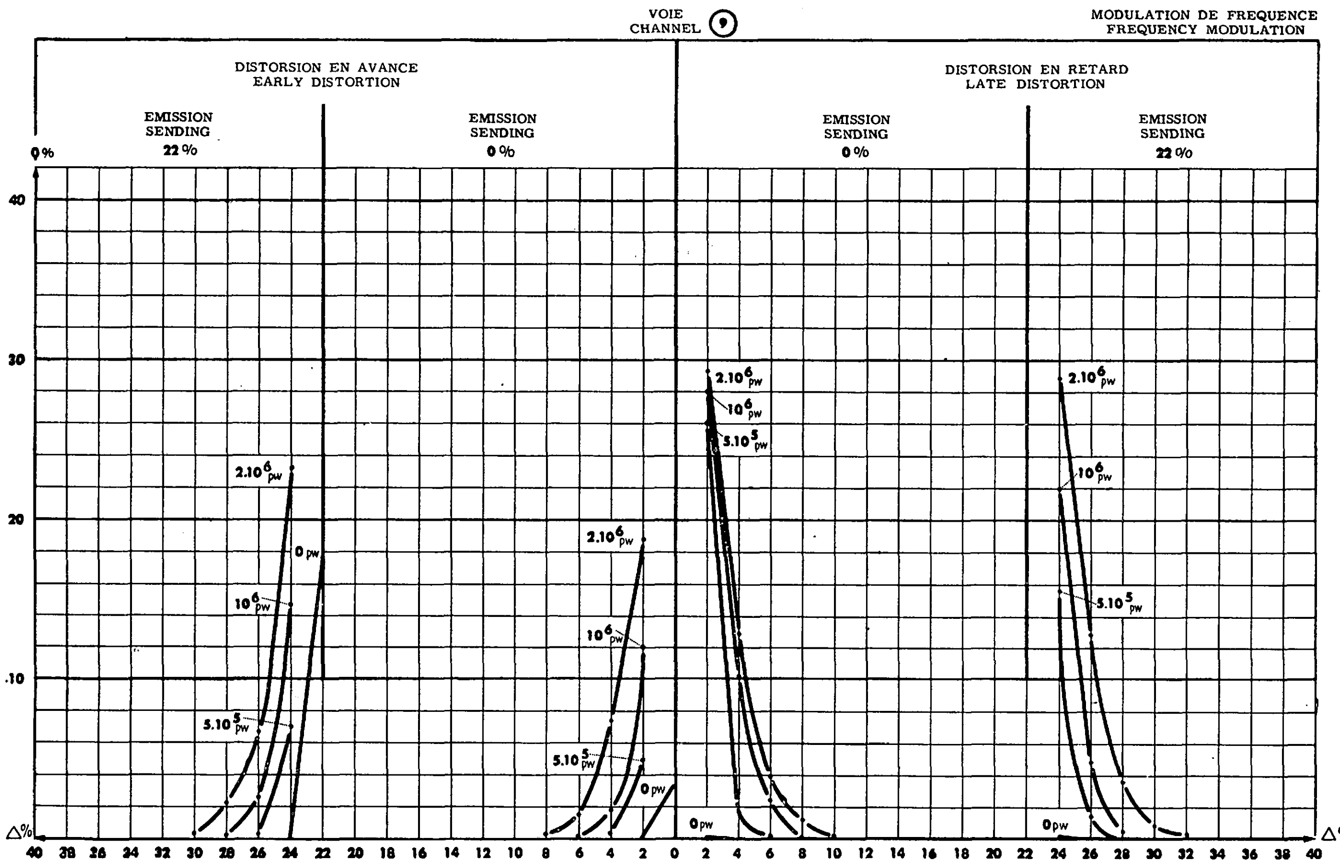

VOIE
CHANNEL 9
MODULATION DE FREQUENCE
FREQUENCY MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0 %
40
30
20
10
Δ%
2.10⁶ pw
10⁶ pw
5.10⁵ pw
0 pw
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
Δ%

FIGURE 52

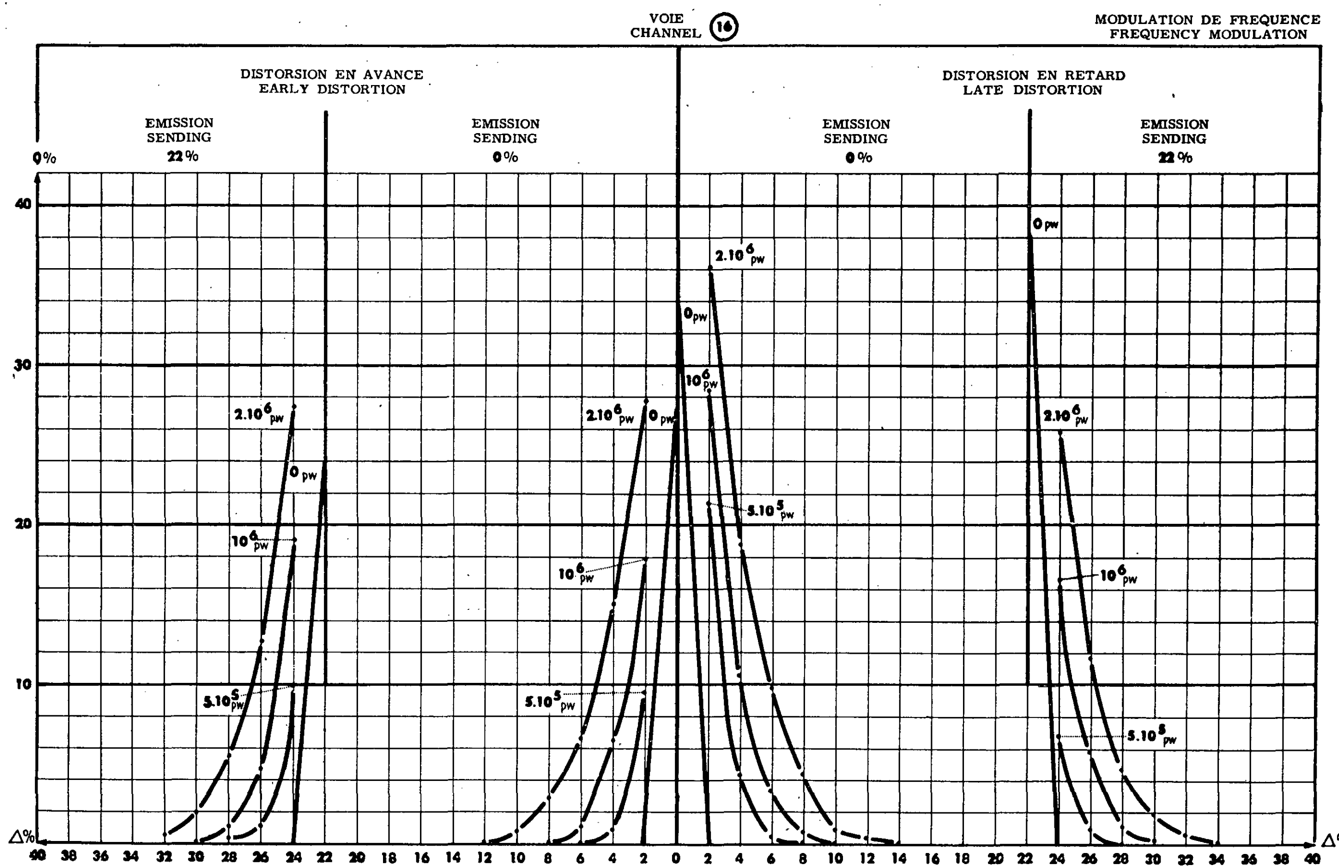

VOIE
CHANNEL 16
MODULATION DE FREQUENCE
FREQUENCY MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0 %
40
30
20
10
Δ%
Δ%
2.10⁶ pw
0 pw
10⁶ pw
5.10⁵ pw
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

FIGURE 53

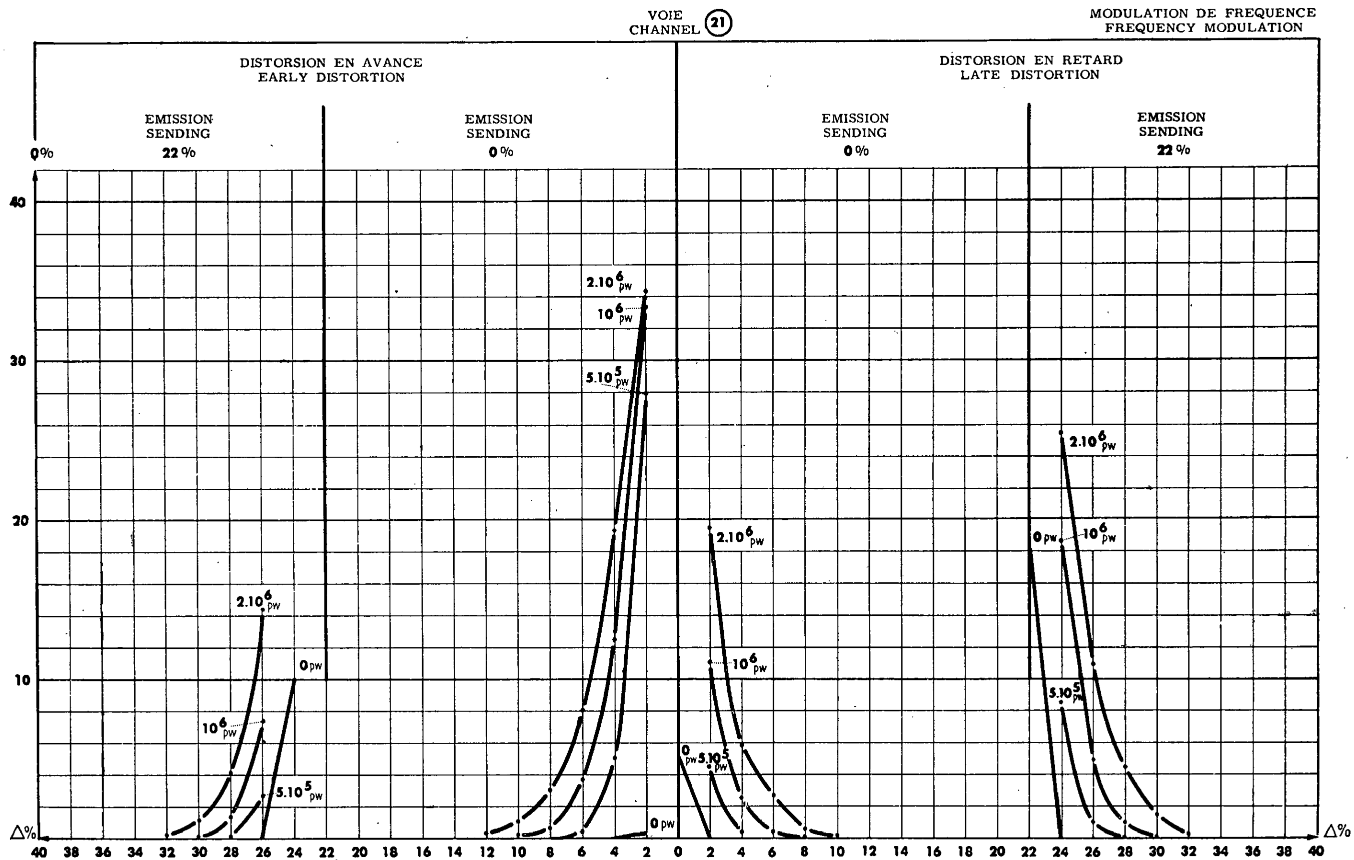

VOIE
CHANNEL 21
MODULATION DE FREQUENCE
FREQUENCY MODULATION
DISTORSION EN AVANCE
EARLY DISTORTION
DISTORSION EN RETARD
LATE DISTORTION
EMISSION
SENDING
22 %
EMISSION
SENDING
0 %
EMISSION
SENDING
0 %
EMISSION
SENDING
22 %
0%
40
30
20
10
Δ%
Δ%
40 38 36 34 32 30 28 26 24 22 20 18 16 14 12 10 8 6 4 2 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40
2.10^6 pw
10^6 pw
5.10^5 pw
0 pw

FIGURE 54

PERMISSIBLE MAXIMUM NOISE IN A TELEPHONE CHANNEL WITH REFERENCE TO VOICE-FREQUENCY TELEGRAPH DISTURBANCE

(Extract of the contribution by the Federal German Republic, contribution COM 9, No. 41, February, 1959)

Effect of white noise upon amplitude-modulated voice-frequency telegraphy (VFCT) systems having means for correcting the influence of level changes.

The measurements were obtained from two AM VFCT systems of Standard Elektrik Lorenz AG, namely the system WT 53 and the newly developed transistorized VFCT system.

The comments below briefly deal with the measuring method employed and the results obtained.

1. *Measuring method.*

1.1 *Fortuitous isochronous distortion.*

Reference is made to figure 55, block diagram of the measuring set-up.

The local transmitting branch of the VFCT channel was keyed with the C.C.I.T.T. standardized text at 50 bauds. A white-noise generator served as a noise source. The noise voltage of this generator was limited to 3.4 kc/s in a low-pass filter network and applied to the input terminals of the VFCT receiver through a decoupling network and a buffer amplifier (nominal gain = 1). The local circuit of the VFCT receiver was connected by switch $S2$ to the isochronous telegraph-distortion measuring set (TDMS). Measuring of the noise level R_0 across the receiver input was carried out, after disconnecting the carrier frequency, with the psophometer recommended by the C.C.I.T.T., but without the weighting network.

Similarly, the signal level S_0 was measured with a level meter by feeding to the line a continuous tone and switchingoff the noise generator during the measuring.

Both measurements were taken while the VFCT receiver was disconnected by switch $S1$ and while the buffer amplifier was terminated by the nominal resistance in order to preclude erroneous measuring results due to the frequency-dependent receiver-input impedance. The actual measurements of the fortuitous isochronous distortion were obtained by reading the maximum deflections of the stroboscopic TDMS within the observation periods of about 20 sec. each. The measuring procedure was repeated several times by different operators and the mean value so obtained was plotted. Very rarely occurring noise peaks can, of course, not be detected during the short observation period of 20 sec.; it can be assumed that the probability for exceeding was of the order of 5×10^{-3} approximately.

1.2 *Probability of error in a unit interval.*

The measuring set-up was the same as shown above except that the carrier-frequency generator of the VFCT channel was switched off and the electronic counter was connected to the set-up by switch $S2$. The response-threshold level A_0 (threshold of sen-

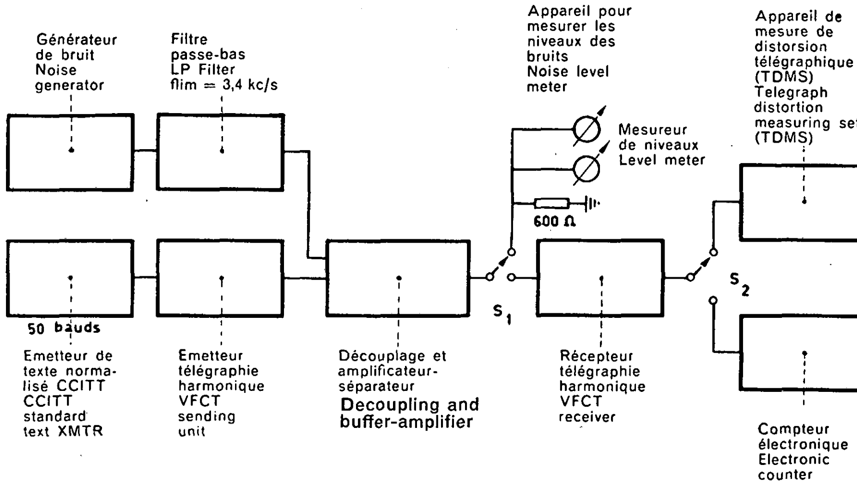


FIGURE 55. — *Block diagram of the measuring set-up*

sitivity) of the VFCT receiver was found by keying the VFCT channel with a test signal 2:2 (without applying the noise voltage) and observing on the TDMS at which level, referred to the centre of the level range, the receiving relay just failed to respond. (The real threshold value employed in calculation is by 3 db higher because the measured value of the threshold level was obtained with keyed sinusoidal voltages.)

To determine the error probability, the noise level R_0 was adjusted to a certain value referred to the threshold level A_0 and the electronic counter was employed to count the erroneous operations of the receiving relay within the observation periods of 5 min. and 10 min., respectively. The numerical value thus obtained was then divided by the number of the possible cases of exceeding the response threshold (which depends on the VFCT receiver bandwidth). The result was multiplied by the factor 0.5 because, in normal teleprinter messages, mark and space pulses usually occur in equal numbers and errors are nearly precluded as long as the tone is on the line.

2. *Results.*

The measurements so obtained are plotted in diagram 57 of the Annex. The upper curve shows the conventional isochronous distortion of a 24-channel VFCT system as a function of the psophometric noise, measured on the telephone circuit at a point of zero relative level. The associated unweighted noise level is 2.5 db higher. It will readily be seen that the isochronous distortion increases with the noise/signal ratio. The following approximate formula can be used: fortuitous distortion $df \approx \frac{2}{3}\,\rho$

$$\text{where } \rho = \frac{\text{noise voltage in telephone circuit, unweighted}}{\text{signal voltage}}$$

The curve below that just mentioned was calculated and corresponds to $2\,\sigma$ (where σ = r.m.s. deviation of the gaussian distribution of the individual distortion).

The steep solid curve gives the error probability in a unit interval for the 24-channel VFCT system Lorenz WT 53 whose response threshold A_0, referred to the mid-range level, is about 14 db (1.6 N) down. The hyphenated curve shows the same probability for the case where the response threshold is 18 db (2.1 N) down and in accordance with the

Recommendation R.34 of C.C.I.T.T. The curves coincide well with the threshold-exceeding probability P to be expected theoretically;

$$P = \frac{1}{2} \rho^{-\frac{1}{2}\left[\frac{\sqrt{2}\, a_0}{r_T}\right]^2}$$

where a_0 = voltage of the response-threshold level A_0,
r_0 = r.m.s. noise voltage in the VFCT channel.

The probability that a telegraph character (start signal, 5 mark/space elements, stop signal) is incorrectly reproduced in manual operation involving intervals is, for small error rates:

$$P_B = 1 - \left[(1-2P) \times (1-P)^5\right] \approx 7\,P$$

In the case of automatic operation with punched-tape feeding, the characters follow each other without interruption, and in this case an erroneous start signal causes about 2.7 faulty or lost characters due to loss of synchronism [1]. Hence, in this operation the probability of error is

$$P_B = 1 - \left[(1-2.7 \times 2P) \times (1-P)^5\right] \approx 10.4\,P$$

In these calculations the loss or erroneous production of a letter shift or a figure shift has been reckoned as a single error. If the series of misprints following these errors are taken into account, the number of character errors per element error is naturally increased. An even greater increase must be allowed in the case of page printing, where the loss of line-feed or carriage return or the erroneous production of carriage return can lead to a larger series of misprints.

The following values are obtained for the unweighted noise powers indicated:

		White noise power		
		10^6 *pW*	$3.4.10^5$ *pW*	10^5 *pW*
Signal-noise ratio on the telephone circuit; unweighted	$0—R_0$	30 db	34.5 db	40 db
Signal-noise ratio on the telephone circuit; weighted	$0—R_{0p}$	32.5 db	37 db	42.5 db
Noise level R_T in the *VFCT*-channel, referred to the signal level S_0, down by	$S_0—R_T$	25 db	29.5 db	35 db
Noise level R_T in the *VFCT*-channel, referred to the response threshold A_0 (when $S_0—A_0$ = 18 db), down by	$A_0—R_T$	7 db	11.5 db	17 db
Level difference between R_0 and A_0	$R_0—A_0$	9 db	4.5 db	—1 db
Conventional isochronous distortion		22%	13%	7%
Probability of error in a unit interval, when $S_0—A_0$ = 18 db		7.10^{-3}	10^{-6}	10^{-22}

[1] Kronjäger, Lenhart, Vogt, Die Gleichlaufkorrektur von Start-Stop-Fernschreib-Systemen bei Funkempfang. *N.T.Z.* (Avril 1957, p. 167.)

These level relations are illustrated in figure 56.

Since the measured curve follows relative closely the calculated curve, it is possible to make extrapolations. Therefore a simple method to find out at which level the probability of error in a unit interval has a value of approximately 10^{-6} consists in the following:

The gain of the buffer amplifier and therefore the level on the input of the VFCT-receiver is increased until the receiving relay responds with an average frequency of about 2....4 erroneous operations/s (which can be judged on the TDMS). Then 6 db (0.7 *N*) below this measured level lies the level for which a unit-error probability of about 10^{-6} exists.

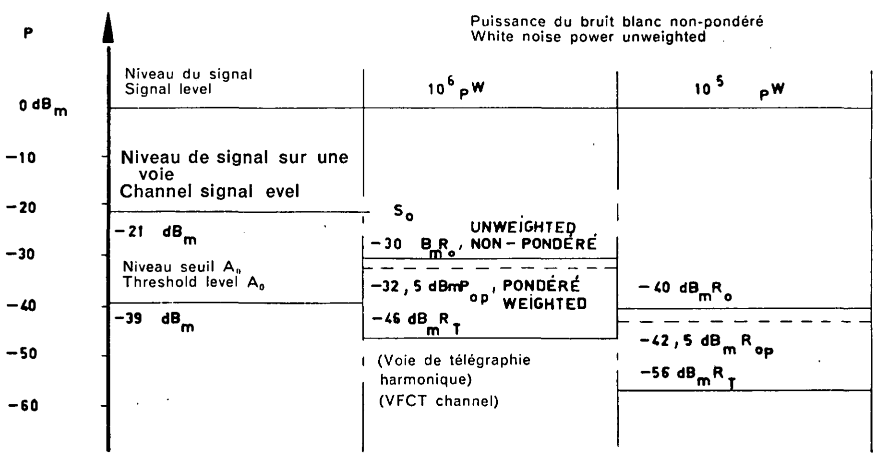


FIGURE 56. — *Level diagram of signal and noise levels*

ANNEX

Permissible maximum noise in a telephone channel with reference to voice-frequency telegraph disturbance

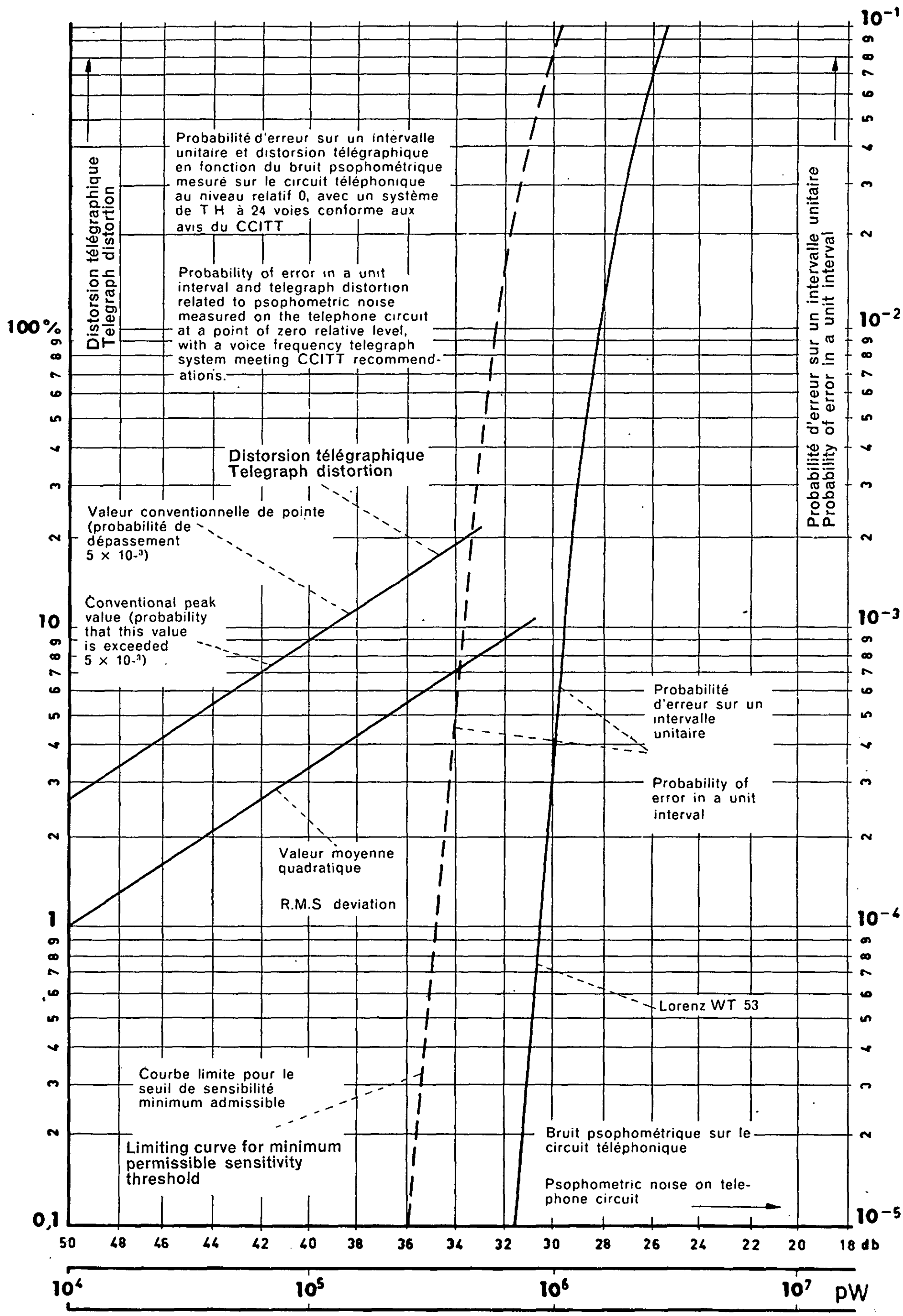
Short noise peaks should cause no serious disturbance in a telephone circuit, since a word misunderstood can be corrected by means of an inquiry back.

But with a voice-frequency telegraph connection a relatively short increase in noise (lasting, for example, a few seconds), such as might be caused by fading, can be a serious problem and can lead to the transmission of false signals. The probability of errors in telegraph signals can be assessed by two values which are relatively easy to measure, namely, the probability of errors on telegraph units and telegraph distortion. The former of these two factors is decisive for the appearance of errors inside a VF section. Telegraph distortion is decisive for the appearance of errors when several VF sections are joined in tandem with no telegraph distortion correctors inserted. Both values were measured and calculated in the presence of frequency-constant noise with gaussian distribution in the telephone channel (thermal noise). The diagram of figure 57 shows the probability of errors on units and the telegraph distortion as a function of psophometrically measured noise in the speech channel, at zero relative level in a 24-channel amplitude-modulation voice-frequency telegraph system meeting C.C.I.T.T. requirements (Lorenz WT 53).

The curve showing the probability of error on telegraph units is very steep. This gives a practical noise limit above which the probability of error increases very rapidly, so that a VF connection is seriously disturbed. This limiting value depends on the sensitivity threshold of the VF receiver and is the more critical the more sensitive the VF receiver is. The most critical case occurs with a 24-channel amplitude-modulation voice-frequency system which has the lowest sensitivity threshold allowed by the C.C.I.T.T., namely 2.1 *N* (below the VF-channel transmission level of –2.4 *N* at zero relative level) *. This limiting curve is shown dotted in the diagram and requires a noise margin of at least 36 db, corresponding to 250 000 pW. Most VF systems have in practice a higher sensitivity threshold (for example, 1.6 *N* instead of 2.1 *N*) and hence tolerate a noise margin of about 32 db, corresponding to about 600 000 pW, as the measured curve shows.

The telegraph distortion caused by noise is a value which varies statistically. Hence we must distinguish the conventional peak value (measurable, for example, with a distortion meter) from the r.m.s. value. This latter is decisive for the addition of telegraph distortion of VF sections in tandem. In considering these curves we can allow a 40-db limit, corresponding to 100 000 pW, for relatively short peak noises. Then, in any case, we shall have a negligible probability of error due to errors on units, an effective telegraph distortion of 3.5% and a peak telegraph distortion of about 9%, which can be considered as just tolerable.

* See C.C.I.T.T. Recommendation R.34.



Probabilité d'erreur sur un intervalle unitaire et distorsion télégraphique en fonction du bruit psophométrique mesuré sur le circuit téléphonique au niveau relatif 0, avec un système de T H à 24 voies conforme aux avis du CCITT
Probability of error in a unit interval and telegraph distortion related to psophometric noise measured on the telephone circuit at a point of zero relative level, with a voice frequency telegraph system meeting CCITT recommendations.
Distorsion télégraphique
Telegraph distortion
Probabilité d'erreur sur un intervalle unitaire
Probability of error in a unit interval
Distorsion télégraphique
Telegraph distortion
Valeur conventionnelle de pointe (probabilité de dépassement 5 × 10-3)
Conventional peak value (probability that this value is exceeded 5 × 10-3)
Probabilité d'erreur sur un intervalle unitaire
Probability of error in a unit interval
Valeur moyenne quadratique
R.M.S deviation
Lorenz WT 53
Courbe limite pour le seuil de sensibilité minimum admissible
Limiting curve for minimum permissible sensitivity threshold
Bruit psophométrique sur le circuit téléphonique
Psophometric noise on telephone circuit
100 %
10
1
0,1
10-1
10-2
10-3
10-4
10-5
50 48 46 44 42 40 38 36 34 32 30 28 26 24 22 20 18 db
10^4 10^5 10^6 10^7 pW

FIGURE 57

MEASUREMENTS FOR THE STUDY OF THE EFFECT OF NOISE ON TELEGRAPH TRANSMISSION OVER RADIO-RELAY LINKS

(Contribution of C.C.I.R., contribution COM 9, No. 47, June, 1959)

Note by the C.C.I.T.T. Secretariat.

At its meeting in Geneva from 2 to 11 February 1959, Study Group 9, at the request of the " Noise " working group, asked Administrations as a matter of urgency to make measurements

1. of the noise characteristics encountered on radio-relay links,

2. of the effect of noise on the operation of voice-frequency telegraph channels.

At its IXth Plenary Assembly (Los Angeles, 1959) the C.C.I.R. drew up a report on this subject, the following extracts from which may be helpful in carrying out the measurements requested.

Extracts of the Report on radio-relay systems using frequency division multiplex

3. *Typical noise-time distribution curves.*

The C.C.I.R. (Study Group 9) has constructed some distribution curves of noise with time in a 2500-kilometer hypothetical reference circuit for line of sight radio links with adequate clearance. The curves have been based on measured values of the received signal in the worst month in a two-year period in the various repeater sections of a 400-km radio-relay link having 8 repeater sections and operating on 4000 Mc/s in the United Kingdom. The curves are in broad agreement with the statements made in C.C.I.R. revised Document 230 regarding fading in the United States of America.

Two distribution curves, A and B in figure 58 attached, have been constructed. Curve A * is for the case of thermal noise in a hypothetical circuit consisting of 16 repeater sections with severe fading, 16 repeater sections with moderate fading, and 16 repeater sections with only slight fading. Curve B is for the same link and is the estimated performance assuming that diversity reception is used **. The measured data was in terms of a time constant of about one second; this is appropriate for the given circumstances, as pointed out below (section 5). The mean noise power per repeater section in the absence of fading has been taken as —78 dbm0.

4. *Numbers and durations of noise bursts.*

Attention is drawn to the Annex of Document 230 which gives information on the numbers and durations of noise surges due to fading in the United States of America. It appears likely that the envelope of a typical noise surge may be approximated by a rectan-

* It is not justifiable to extend curve A for shorter percentages of the time.

** In some cases a performance similar to that of curve B might be obtained without using diversity reception.

gular shape, with steep almost vertical sides and a rounded or nearly flat top. The duration of such noise surges is usually a few seconds (e.g. 4 seconds) at a height corresponding to a fade of about 40 db; the duration does not vary much over a considerable range of heights. This envelope is that of the noise power averaged over the fine fluctuations of the white noise; a more detailed " picture " would show standard white noise fluctuations modulated in amplitude by the nearly rectangular fades.

The total durations of such noise surges in various ranges of noise levels in the worst month, corresponding with the distribution curves A and B, are given in Table I.

The estimated numbers of noise surges of various levels are also given in Table I; the estimates are based on the surge durations of 4 to 9 seconds suggested by the Annex of C.C.I.R. Document 230.

There is insufficient information available to enable the table to be extended for higher noise powers. It is clear, however, that for noise powers of the order of – 30 dbm0 (10^6 pW) the total duration in the worst month would be appreciably smaller than the values 780 seconds for curve A and 78 seconds for curve B shown for – 38 dbm0. The average duration of surges would be somewhat smaller than the value of 4 seconds taken for – 38 dbm0; the number of surges of duration less than one second would be small.

5. *Time constant of the measuring instrument.*

If the " model " (in section 4 above) of a typical noise surge is accepted as a satisfactory one, then a suitable time constant of a measuring instrument could be about one second. Alternatively, if it were desired to take some account of the fluctuations of the fine structure

TABLE I

Numbers and durations of noise surges

(In agreement with curves A and B of figure 58)

Mean noise power in 3.1 kc/s band (dbm0)	Total duration T seconds and estimated numbers N of noise surges at the given noise power range in worst month			
	Curve A		Curve B	
	T	N	T	N
– 37 to – 39	780	195	78	19
– 39 to – 41	1040	216	104	21
– 41 to – 43	1560	280	156	28
– 43 to – 45	2050	320	205	32
– 45 to – 47	2820	392	282	39
– 47 to – 49	4160	520	416	52
– 49 to – 51	6500	738	650	73

Note. — The telegraph circuit may be imagined to be exposed to a steady white noise of mean power – 38 dbm0 (– 40 dbm0, etc.), of total duration 780 seconds (1040 sec. etc.), divided into 195 (216 etc.), occurrences each one lasting between 4 and 9 seconds, in the case of curve A.

of the white noise, then a time constant of about 5 milliseconds might be appropriate. However, the difference between the measurements obtained with time constants of about 1 second and with about 5 milliseconds is likely to be very small and it seems likely that the measurements of received signal strengths on various radio links already made with a time constant of about 1 second will give a very good indication of the noise performance as it affects telegraphy. These remarks apply only to line of sight radio links with adequate clearance.

If a noise surge is applied to a telegraph filter of bandwidth about 100 c/s, the effect will be to shape the rise and fall of the noise surge. The rise time and fall time will be of the same order of magnitude as the reciprocal of the bandwidth, e.g. about 10 milliseconds.

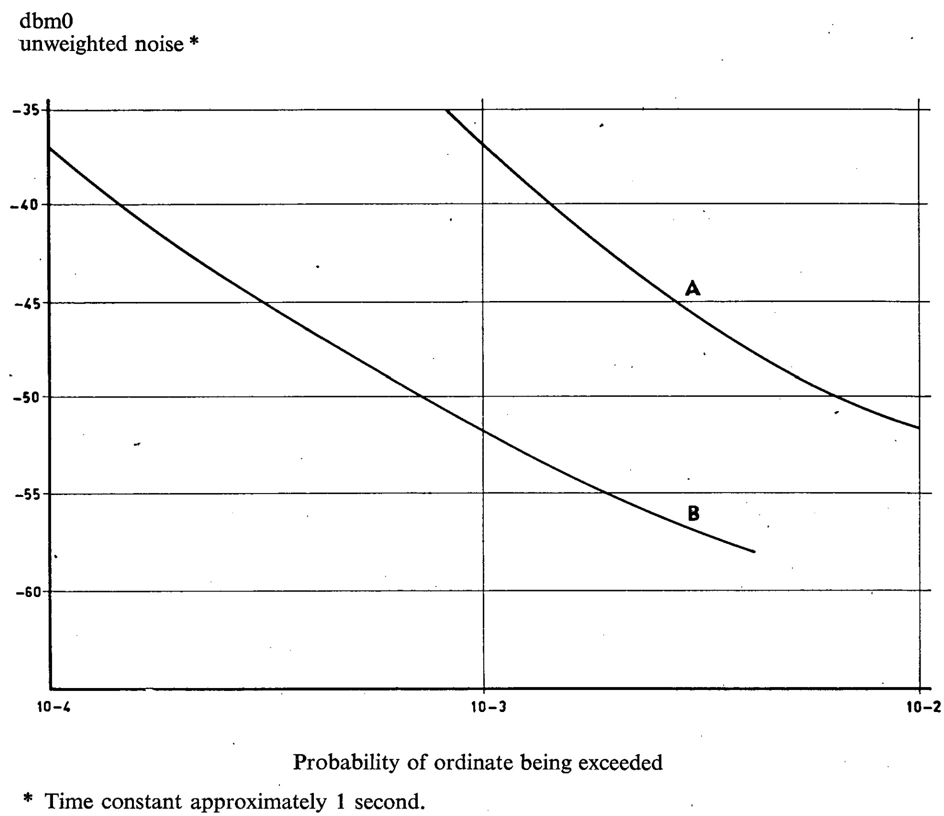


FIGURE 58. — *Noise distribution for 2500 km radio-relay link (worst month) assuming fading conditions to be as stated in paragraph 3*

Document 230 — Radio-relay systems for telephony

Noise tolerable during very short periods of time on line-of-sight systems (Study Programme No. 105)

1. *Method of specification.*

The maximum values of noise in telephone circuits on radio-relay systems should be specified in terms of:

a) the mean psophometric noise power in an hour;

b) the psophometrically-weighted noise powers which may be exceeded only for specified small percentages of a month when the fading is severe, measured with an instrument which indicates the mean value over one minute or a quantity approximately equivalent to this value.

2. *Time constant.*

Measurement in terms of the one-minute-mean power is favoured to facilitate the use of the opinion-rating method of assessing telephone conversations recommended by the C.C.I.T.T. Instruments having time constant of one minute are acceptable even though they do not precisely measure one-minute-mean values.

3. *Short noise bursts.*

Information on the performance of line-of-sight radio-relay links suggests that it is not necessary to specify a limit to the number of high noise bursts of duration exceeding a given value and occurring in a given time, provided that limits are placed on the noise which may be exceeded only for small percentages of a month, and that noise due to power supplies and switching operations is excluded. It is desirable to stipulate in addition that the link should incorporate some form of diversity reception on sections in which the fading is unusually severe, e.g. due to the use of exceptionally long sections or to reflections from a water surface. The Annex gives some information on noise bursts in one country (United States of America); the magnitude and duration of noise bursts in other regions may be somewhat different owing to the different meteorological conditions.

4. *Traffic loading.*

It is recognized that the period of worst fading usually occurs at night while the greatest traffic often occurs during the day. Whether advantage can be taken of this fact depends on the requirements that the system is intended to satisfy.

5. *Noise in parts of radio links.*

The noise power during substantial percentages of the time can without great error be considered proportional to the length of the circuit for lengths exceeding about 250 kilometres. There is some reason for assuming that intermodulation noise increases more rapidly with length than does basic noise; nevertheless, for lengths of circuit exceeding about 250 kilometres the error in assuming that noise for substantial percentages of time is proportional to length is small, and it is proposed, therefore, to make use of this law of proportionality in C.C.I.R. Recommendations.

When considering very small percentages of time for which high noise values may be exceeded, these percentages can, for lengths of circuit exceeding about 250 kilometres and for values below 0.1% or in some cases below 1%, be considered as proportional to circuit length.

The two working rules given above, i.e. linear-power-addition for large percentages of time and linear-percentage-addition for small percentages of time, are somewhat inaccurate between about 0.1% and 10% where the error may in extreme cases amount to 3 or 4 db. However, the rules are considered to be sufficiently accurate for most purposes. Greater accuracy can be obtained by detailed mathematical treatment which depends upon the particular monthly distribution curves involved. A method of approximation which can give useful accuracy in some cases has been discussed by B. B. Jacobsen (Proceedings of the Institution of Electrical Engineers, Part C, March, 1958).

ANNEX TO DOCUMENT 230

Relationship between short-term and long-term noise performance in radio-relay systems in the United States of America

1. The distribution of the duration of deep fades (and hence the resulting noise bursts) at the frequencies used in radio-relay systems appears to be log-normal. Such a distribution may be characterized by:

a) its slope or its standard deviation and

b) one point on the curve, such as the median or the average duration.

2. From several series of tests, the standard deviation is approximately $\log_{10} 2.7$ and appears to be substantially independent of frequency. This standard deviation has been observed in tests on individual paths and on systems comprising as many as 68 paths in tandem. It has been observed at different frequencies from 2000 to 6000 Mc/s. It has been observed in different regions which are subject to different fading influences, and on paths with both adequate and inadequate clearance. A somewhat higher standard deviation appears to be associated with inadequate clearance, possibly because of an increased tendency towards obstruction fading.

The average duration is not as closely defined, and appears to be approximately inversely proportional to frequency. That is to say, at a given depth of fade at 2000 Mc/s half as many fades twice as long as at 4000 Mc/s would be expected. The total time of fading would be nearly the same, although this is only approximately true over frequency ranges greater than 2 to 1.

At 4000 Mc/s an average duration in the order of 7 to 9 seconds has been observed for 30 db fades and in the order of 4 to 5 seconds for 40 db fades, in a limited series of tests on a 40 km path.

The duration of fades is approximately inversely proportional to the length of the radio frequency paths. The data quoted were observed on paths approximately 40 km long in the North-Eastern United States of America. In other tests on paths approximately 70 km long in the Western United States of America, durations approximately 40/70 as long were observed.

3. From these points it is possible to relate the number and duration of the fades to the total time that a given depth of fade is exceeded in a long period of time such as, for example, a month.

4. As a further example, consider a 4000-Mc/s system with parameters such that a 40-db fade in any one section will cause the noise to exceed a given maximum level. Consider further that each section may be expected to fade 40 db or more for n seconds during the worst month * and consider that there are N sections in tandem, without diversity, so that the total time that a 40-db fade will be exceeded somewhere in the system ** is nN seconds during the worst month.

5. From paragraphs 2 and 4, the system of the example might be expected to experience $\frac{nN}{4.5}$ or 0.22 nN fades exceeding 40 db during the worst month. The duration of these fades would be as outlined in paragraph 2.

6. Fading differs from day to day and from hour to hour. The worst day will have more fades than an average day by some variable factor, and the worst hour will have more fades than the average hour by some still more variable factor. In one series of tests on a system 450 km long including 8 paths, the first factor was 6 and the second factor was 60. There is no information for other lengths of system and for other numbers of paths.

7. Thus the system of the example might be expected to experience $\frac{1}{30} \times 6 \times 0.22\, nN$ or 0.044 nN fades during the worst day of the worst month, and $\frac{1}{30} \times \frac{1}{24} \times 60 \times 0.22\, nN$ or 0.018 nN fades during the worst hour of the worst month.

8. If the performance of a specified system is predicted using the methods of the example, it may be found that the performance does not meet the requirements. This demonstrates the need for avoiding the effects of fading by:

a) diversity operation;

b) reducing the length of path, or choosing more favourable sites; or

---

* For the North-Eastern United States and for paths about 40 km long, n may be taken as approximately 100. In other areas, and for other lengths of path, different values of n may be appropriate.

** The probability that 40 db fades will occur simultaneously in more than one of the N sections is very, very small. For shallower fades such as, for instance, 20 db, the probability of simultaneous fades is greater and may be appreciable.

c) improving the fading margin by the use of higher power or higher gain aerials where these factors are available to the system designer.

9. The effects of deep fades may be substantially reduced by the use of some form of diversity reception, such as frequency diversity or space diversity. A limited series of tests has shown that approximately 5% of the total fading time beyond 40 db cannot be counteracted by frequency diversity of 100 Mc/s or more or by vertical space diversity of 15 metres or more at 4000 Mc/s. The duration of the residual fades with diversity may be shorter than without diversity, by as much as 50%. No information is available on this point.

10. With the foregoing as guidance as to the probable performance of a system during the worst hour and worst day of the worst month, it is sufficient to define the system by the long-term performance, i.e. the statistical distribution of noise during the worst month.

EXPLANATION OF FORMULA $I_{F_0} < I . k . \Delta$ OF RECOMMENDATION R.35

Assumptions: The characteristic instants are given by:

$$F_0 = \frac{F_1 + F_2}{2}.$$

The bias distortion introduced by the modulators must be less than five per cent.

Let i be the telegraph current corresponding to F_0 and $\pm I$ the currents corresponding to the two frequencies F_1 and F_2.

If there be an exceedingly severe variation in frequency (relay or electronic flip-flop) the current i is defined as that at which there is abrupt passage from one frequency to the other.

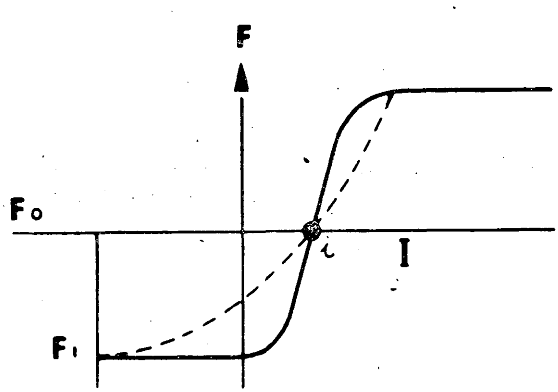


FIGURE 59

Let us now assume that the telegraph current varies trapezoidally

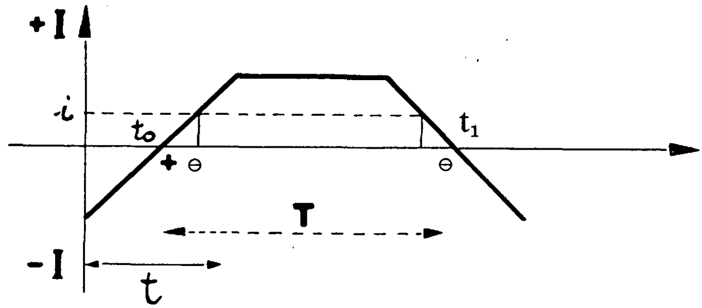


FIGURE 59 *bis*

Let T be the period (20 ms).
Let t be the rise time of the current.

If, now, we take t_0 and t_1 as ideal instants, we shall see that the current passes through i at a time Θ before or after t_1 or t_0 such that

$$\Theta = t \cdot \frac{i}{2I}$$

The bias distortion introduced by the modulator will then be:

$$\Delta = \frac{2\Theta}{T} = \frac{2i}{2I} \cdot \frac{t}{T} = \frac{i}{I} \cdot \frac{t}{T} = \frac{i}{I} \times k, \text{ where } k = \frac{t}{T}$$

If the bias distortion is required to be $\leqslant 5\%$, we get:

$$\frac{i}{I} \leqslant 0.05 \frac{T}{t}$$

$\frac{T}{t}$ is normally much greater than 4 ($t \leqslant 5$ ms).

This being so, it will suffice if $\frac{i}{I} \leqslant 0.20$.

STUDY OF DISTORTION IN A FREQUENCY-MODULATED VOICE-FREQUENCY TELEGRAPH CHANNEL

(Extract of contribution by U.S.S.R., contribution COM 9/9, November, 1957)

1. *Distortions due to harmonic disturbance.*

The study of transient phenomena (Bibl. 1) in a frequency-modulated voice-frequency telegraph channel gives the following expressions for the frequency variation and the amplitude of the frequency-modulated oscillation in the middle of the transient phenomenon front (figure 60):

$$y(t) = \frac{\Delta\omega(t)}{\Delta\omega} = \frac{A(\omega_1)[2g_1 - A(\omega_1)]}{\cos^2 \Delta\omega t\, [A^2(\omega_1) + \{[2g_1 - A(\omega_1)]\, \mathrm{tg}\, \Delta\omega t - 2g_2\}^2]} \tag{1}$$

$$U(0) = \sqrt{A^2(\omega_1) + \frac{1}{\pi^2}\left[\int_0^\infty \frac{A_2(\omega)}{\omega}\, d\omega\right]^2} \tag{2}$$

where

$$g_1 = \frac{1}{2} A(\omega_1) + \frac{1}{2\pi} \int_0^\infty A_1(\omega) \frac{\sin \omega t}{\omega}\, d\omega,$$

$$g_2 = \frac{1}{2\pi} \int_0^\infty A_2(\omega) \frac{\cos \omega t}{\omega}\, d\omega,$$

$$A_1(\omega) = A(\omega_1 - \omega) + A(\omega_1 + \omega),$$

$$A_2(\omega) = A(\omega_1 - \omega) - A(\omega_1 + \omega)$$

where $A(\omega)$ is the amplitude-frequency characteristic of a voice-frequency telegraph channel; it is symmetrical with respect to the average frequency of the channel ω_0. Similarly, the service frequencies ω_1 and ω_2 are situated symmetrically with respect to the frequency ω_0, at a distance of $\Delta\omega$, where $\Delta\omega = 2\pi\Delta f$ is the frequency deviation. The phase-frequency characteristic of a voice-frequency telegraph channel is assumed to be linear.

From equation (1) it is possible to find the expression for the slope of the increase of the frequency in the middle of the transient phenomenon front:

$$S = \frac{dy}{dt} = \frac{1}{\pi} \cdot \frac{A(\omega_1) \int_0^\infty A(\omega)\, d\omega}{A_2(\omega_1) + \frac{1}{\pi^2}\left[\int_0^\infty \frac{A_2(\omega)}{\omega}\, d\omega\right]^2} \tag{3}$$

In the special case of an ideal filter we have the following expressions:

$$S = \frac{2\Delta f\varphi}{1 + \frac{1}{\pi^2}\left(ln \frac{p+1}{p-1}\right)^2} = \frac{2\Delta f\varphi}{A}, \tag{4}$$

$$U(0) = \sqrt{1 + \frac{1}{\pi^2}\left(ln \frac{p+1}{p-1}\right)^2} = \sqrt{A} \tag{5}$$

where $\Delta f\varphi$ is the width of the filter $p = \dfrac{\Delta f\varphi}{2\Delta f}$,

$$A = 1 + \frac{1}{\pi^2}\left(ln \frac{p+1}{p-1}\right)^2 \tag{6}$$

The phase distortion in the voice-frequency telegraph channel does not have any effect on the frequency increase slope.

The frequency variation in the middle of the transient phenomenon front occurs roughly in accordance with the law of linear slope S; it can hence be written simply and with sufficient accuracy as follows:

$$\omega(t) = \omega_0 + S\Delta\omega t . \tag{7}$$

Let us write the expression for the frequency-modulated oscillation at the output of the receiving filter of the voice-frequency telegraph channel as follows (Bibl. 2):

$$u_c = U_c \sin\left[(\omega_0 + S\Delta\omega t)\, t + \varphi_c\right] ,$$

and for the harmonic disturbance:

$$u_n = U_n \sin(\omega_n t + \varphi_n) .$$

Let us add the signal and disturbance voltages, and then find the frequency variation of the oscillation obtained. By using the expression noted for the transient frequency, we arrive at the following formula for the maximum bilateral distortions of the telegraph pulse in the voice-frequency telegraph channel when harmonic disturbance occurs:

$$\delta_n = \frac{2e^{-\Delta p}\, e^{-\Delta b}}{\sqrt{A}} \left[\frac{1}{3} t_r + \frac{A}{2\Delta f\varphi}\left(\frac{1}{\alpha} + \frac{|\Delta fn|}{\Delta f}\right)\right] B \; 100\% , \tag{8}$$

where:

Δp is the difference in level between the signal and the disturbance, in nepers, at the output of the receiving filter;

Δb is the increase of the attenuation, in nepers, at the frequency of a disturbance introduced by the receiving filter and by the discriminator;

B is the telegraph speed, in bauds;

$\Delta f\varphi$ is the width of the voice-frequency telegraph channel filters, at a level of 0.7 neper;

Δf is the frequency shift;

$|\Delta fn|$ is the absolute difference between the disturbance frequency and the average frequency of a channel;

A is the coefficient which is a function of the relationship between the frequency shift and channel width; for an ideal filter it is determined by equation (6);

t_r is the transit time of the armature of the receiving relay.

Coefficient α determines the margin of sensitivity of the receiving relay:

$$\alpha = \frac{I_0}{i_r} ,$$

where I_0 is the permanent service current in the receiving relay, i_r is the relay's controlling current.

Equation (8) can be written in the following way:

$$\delta_n = \frac{e^{-\Delta p}\, e^{-\Delta b}\, \sqrt{AB}\, 100}{\Delta f \varphi} (\alpha + \gamma_1 + \gamma_2)\%, \tag{9}$$

where

$$\alpha = \frac{|\Delta f n|}{\Delta f}, \tag{10}$$

$$\gamma_1 = \frac{2}{3} \cdot \frac{\Delta f \varphi t_r}{A} = 0.58\, A^{1/3} \left(\frac{100 - K}{100B'}\right)^{2/3} \Delta f \varphi^{2/3}, \tag{11}$$

$$\gamma_2 = \frac{1}{\alpha} = \frac{i_r}{I_0} \tag{12}$$

Here, K is the efficiency of the relay (1) measured at the telegraph speed B'.

(1) $$1 - \frac{\text{transit time}}{\text{theoretical duration of the unit interval}}$$

Thus, the distortions due to harmonic disturbance are made up of three components:

a) a component which is directly proportional to the difference between the disturbance frequency and the average frequency of the channel;

b) a component which depends on the inertia of the receiving relay; it is directly proportional to the transit time of the relay armature;

c) a component which is a function of the final sensitivity of the receiving relay; it is directly proportional to the controlling current of the relay.

For $p \simeq 1.4$ used normally, formula (6) gives $A = 1.32$; therefore

$$\gamma_1 \simeq 0.64 \left(\frac{100 - K}{100B'}\right)^{2/3} \Delta f \varphi^{2/3} \tag{13}$$

Existing relays have $K \simeq 90\%$, hence we have approximately:

$$\gamma_1 \simeq 0.010\, \Delta f \varphi^{2/3} \tag{14}$$

Normally, relays function in case of $\alpha \simeq 10$, hence:

$$\gamma_2 \simeq 0.1 \tag{15}$$

Equations (14) and (15) show that the relay introduces an apparent increase in the distortions due to disturbance which cannot be overlooked in the calculation (figure 61).

Equation (9) shows that the relation between the distortions and the disturbance frequency is determined by the following function:

$$\varphi(\Delta f n) = e^{-\Delta b} \left(\frac{|\Delta f n|}{\Delta f} + \gamma_1 + \gamma_2\right).$$

Let us assume $\Delta fn = X$; $e^{-\Delta b} = f(X)$; $\gamma_1 + \gamma_2 = C$.

It can then be found that the position of the maximum distortions is determined by solving the following equation:

$$(|X| + C\Delta f) f'(X) \pm f(X) = 0 .$$

It can be seen that the solution does not depend on Δf in the case of absence of the mechanical relay (for $C = 0$). Considering that $C < 1$, it can be concluded that the position of the maximum distortions does not, in the first approximation, depend on the deviation (figure 62). Hence, the position of the maximum is determined solely by the frequency characteristic of the attenuation introduced, in principle, by the receiving filter or by the filter width, since the characteristics of real filters used in voice-frequency telegraphy have roughly the same form.

To determine the position of the distortion values, experience has yielded the following expression:

$$|\Delta f_{\max}| = \frac{\Delta f\varphi \text{ rec}}{2.9} . \tag{16}$$

By using equation (16), we obtain the expression:

$$\delta_{n\max} = \frac{e^{-\Delta p}\, e^{-\Delta b\max} \sqrt{AB}\, 100}{\Delta f\varphi} \left(\frac{\Delta f\varphi \text{ rec}}{2.9\,\Delta f} + \gamma_1 + \gamma_2 \right) \% \tag{17}$$

for the maximum distortion values.

If we leave aside γ_1 and γ_2 in formula (9), we have:

$$\delta_n = \frac{e^{-\Delta p}\, e^{-\Delta b} \sqrt{AB}\, 100}{\Delta f\varphi} \cdot \frac{|\Delta fn|}{\Delta f} \% \tag{18}$$

whence it is found that, taking into account equation (16), the value of distortions for $\Delta f\varphi =$ constant depends on the function $p\sqrt{A}$. For an ideal filter, this function has the minimum if $p \simeq 1.2$. A similar minimum can be expected for real filters. Experience confirms this (figure 63); the minimum of the distortions is around $p \simeq 1.4$ if there is harmonic disturbance.

2. *Distortions due to fortuitous disturbance.*

The momentary fortuitous disturbance voltage at the receiving filter's output can be represented as (Bibl. 2):

$$u = U_2 \sin(\omega_0 t + \Theta) , \tag{19}$$

where ω_0 is the average frequency of the channel, and
Θ the variable fortuitous value.

If it is admitted that the disturbance voltage is appreciably lower than the signal voltage, in the areas near the points where the instantaneous frequency intersects ω_0

(or, respectively, when the coil current passes through 0), the following expression is correct:

$$\Delta \varphi = \frac{U_2}{U_1} \sin \Theta \, , \tag{20}$$

where U_1 is the amplitude of the signal voltage,

$\Delta\varphi$ the variation in the signal phase due to the presence of a disturbance.

The derivate of $\Delta\varphi$ with respect to time gives the variation of the instantaneous frequency due to disturbance in these areas. With the aid of the law of the distribution of probabilities for the variation of the instantaneous frequency, it is possible to discover the distortion distribution.

If the disturbance (19) is normally distributed, the distortions will likewise be normally distributed, since the distribution parameters depend on the width of the channel and on the frequency shift.

For the purpose of measurements, it is convenient to compare the distortions due to fortuitous disturbance δ with the maximum distortions due to harmonic disturbance δ_0, should the standard mean value of the fortuitous disturbance be equal to the effective harmonic disturbance. This being so, if the effective width of the channel is related to a frequency shift of 2.8, we have the expression for the density of probabilities of the ratio δ/δ_0:

$$W\left(\frac{\delta}{\delta_0}\right) = \frac{1.24}{\sqrt{\pi}} e^{-1.53\left(\frac{\delta}{\delta_0}\right)^2} \tag{21}$$

Note. — The formula is obtained on the assumption that the relay has no inertia and functions at the moment when the instantaneous frequency passes through ω_0.

For amplitude modulation, if we compare the distortions with the same δ_0, we obtain:

$$W\left(\frac{\delta}{\delta_0}\right) = \frac{1}{2\sqrt{\pi}} e^{-\frac{1}{4}\left(\frac{\delta}{\delta_0}\right)^2} \tag{22}$$

Figure 64 gives the graphs of formulae (21) and (22). These graphs show that with AM (amplitude modulation) there is a much greater probability than with FM (frequency modulation) that the distortions will exceed δ_0. For instance, distortions greater than 2 δ_0 occur 10 times more often with AM than with FM over the same period of time.

Observations of distortions due to fortuitous distortion generally confirmed the relations given for AM and FM.

3. *Distortions in the case of sudden variations in the level of a signal.*

Results of distortion measurements taken in the channel of type TH-12/16 FM voice-frequency telegraph equipment, when there was a sudden variation in the signal level at the receiver's input are represented by curve 1 in Figure 65.

Figure 65 shows that, within the limits of variations of level $0 < \Delta p < 1.3$ néper, the distortions are not large and are approximately expressed by a linear law as a function of the level variation; for the values $\Delta p > 1.3$ N, the distortions increase rapidly. δ_{max} is the maximum distortion during the long period of observations, during which most of the pulses had distortions which were appreciably lower than δ_{max}.

The result obtained can be explained as follows (Bibl. 3).

The influence of the variation in the level of a signal obviously increases, the nearer the moment of the level variation is to the significant instant. Assuming that these moments coincide, we obtain the curves represented in figure 66 for the initial phase of the frequency-modulated oscillation

$$U = U \sin(\omega_0 t + \varphi) \tag{23}$$

at the filter output.

Figure 66 shows that, as the sudden level variation increases, the minimum of the curve φ shifts (to the right for $e^{\Delta p} < 1$ or to the left for $e^{\Delta p} > 1$); since the minimum of the curve corresponds to when the instantaneous frequency passes through ω_0, it is obvious that the presence of the sudden variation explains the appearance of distortions.

Within certain limits, the distortions are not large, and they grow slowly with an increase of Δp. After a certain value of Δp the curve φ changes shape and includes, in addition to the minimum in its lower part, the maximum and the second minimum in its upper part; in other words, the instantaneous value of the frequency passes through ω_0 three times instead of once, as had been the case with low values of Δp. This circumstance is the cause of the sudden increase in distortions for $\Delta p > 1.3$ N.

By introducing simplifications such as in section 2, and by considering the ideal filter, the following relation can be obtained for calculation of the distortions for the values of $\Delta p < 1.3$ N:

$$\delta_{max} = 0.25 \, \Delta p \, \frac{B}{\Delta f \varphi} \, 100\,\%\,, \tag{24}$$

where Δp is the variation in the level of the signal, in nepers,
and $\Delta f \varphi$ the effective width of the receiving filter's pass-band.

The straight line in figure 65 is dotted, in conformity with the formula. It passes slightly above the values measured due, obviously, to simplifications made while the formula was being deduced; for this reason, the coefficient in the formula should be specified exactly by experience. According to our observations it is desirable to give it a value of 0.2.

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2. V. Amarantov, " Distortions of telegraph pulses in AM and FM voice-frequency telegraph channels when there is harmonic or fluctuation disturbance ", *Electrosviaz*, No. 3, 1956.

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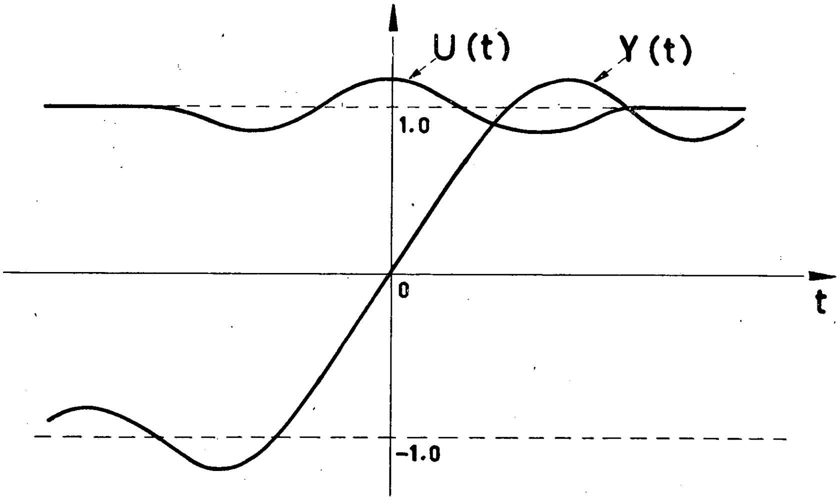


FIGURE 60. — *Transient state for frequency modulation*

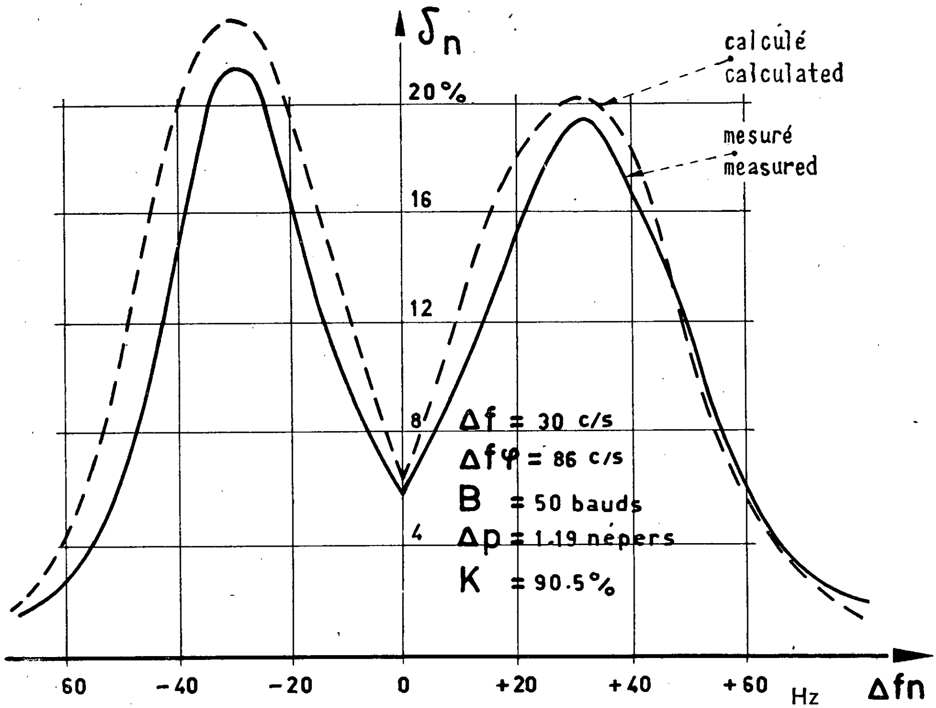


FIGURE 61. — *Distortion due to harmonic interference*

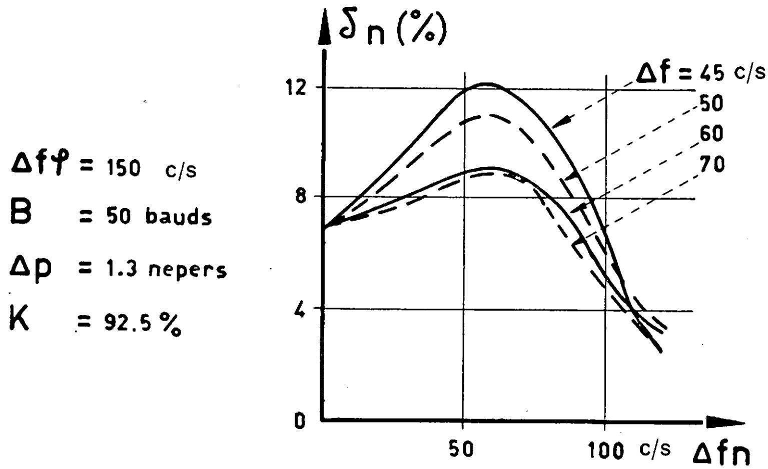


FIGURE 62. — *Effect of frequency deviation*

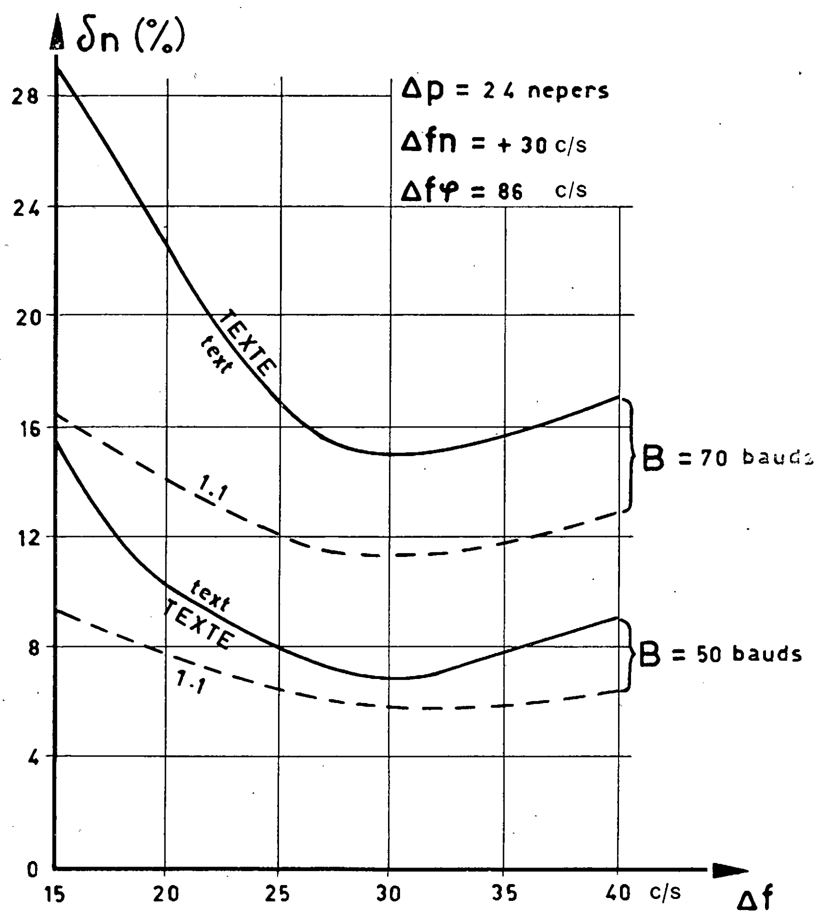


FIGURE 63. — *Distortion due to harmonic interference*

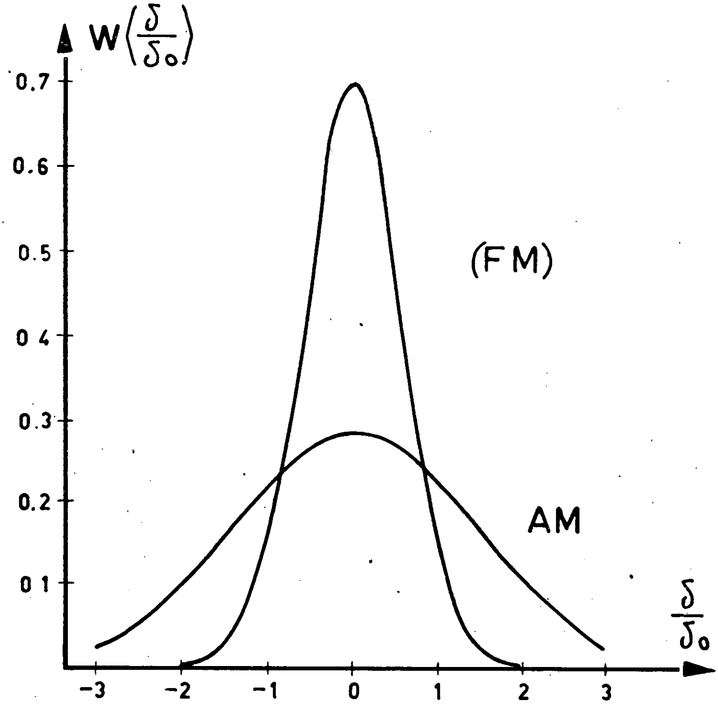


FIGURE 64. — *Probability density of distortion due to random harmonic interference*

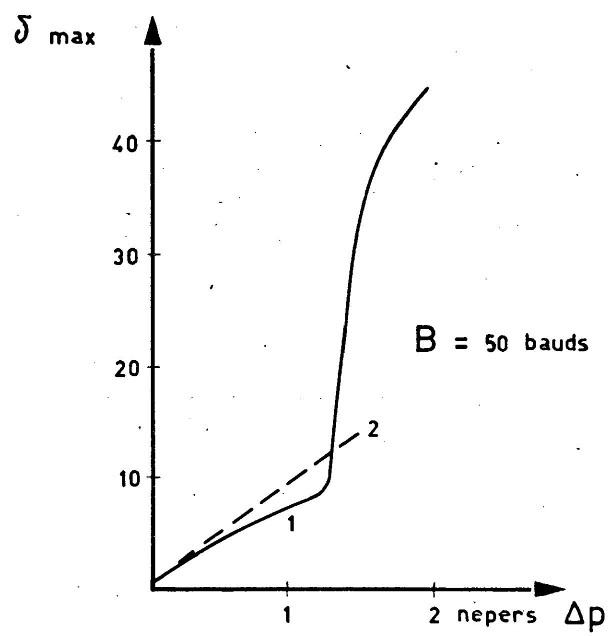


FIGURE 65. — *Distortions due to sudden increases in signal level*

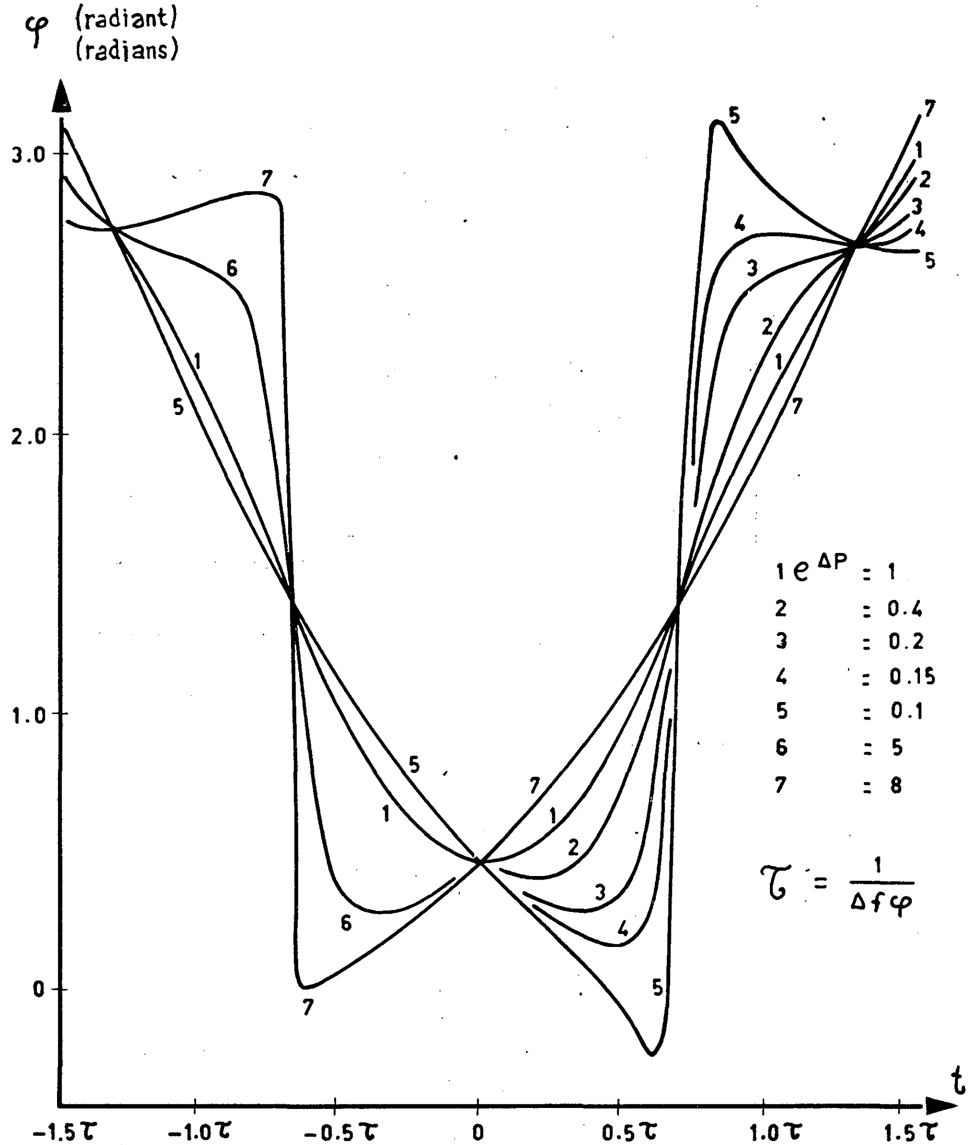


FIGURE 66. — *Phase variation of a signal for a sudden increase in level*

FREQUENCY-SHIFT VOICE-FREQUENCY TELEGRAPH SYSTEMS WITH CHANNEL SEPARATION OF MORE THAN 120 c/s

(Contribution of the Federal German Republic, contribution COM 9, No. 58, October, 1960)

1. *Frequency-shift voice-frequency telegraph systems with a separation of more than 120 c/s between the mean channel frequencies, for a modulation rate in excess of fifty bauds.*

According to C.C.I.T.T. Recommendation R.36 seventy-five bauds is the eligible modulation rate when frequency-shift voice-frequency telegraph systems are being introduced with a spacing of more than 120 c/s between the mean channel frequencies. This notwithstanding, it is our view that, for the future, agreement should be reached, too, on a frequency-shift voice-frequency system capable of transmitting telegraph signals at an even higher modulation rate (up to two hundred bauds, for example), because:

a) In the very near future, it is highly probable that equipment will be on the market offering a modulation rate of a hundred bauds or even more, quite apart from the equipment already in use, which affords a rate of seventy-five bauds.

b) In all likelihood, a rate of up to two hundred bauds would suffice to meet the requirements for data transmission over telegraph circuits.

c) As will be seen from the following Annex, the cost of a voice-frequency circuit with a rate of two hundred bauds (six telegraph circuits per basic audio circuit) should be by no means excessive, especially if the increase in data transmission capacity be borne in mind.

2. *Frequency-shift voice-frequency telegraph systems with a separation of more than 120 c/s between the mean channel frequencies, for a modulation rate of fifty bauds.*

We have worked out the annual cost of a telephone circuit and two voice-frequency telegraph terminal equipments and considered whether, for a rate of fifty bauds, voice-frequency telegraph circuits with more than 120 c/s between the mean frequencies can be economically used. In calculating annual costs, we counted all the factors involved, such as depreciation, interest on investments, staff costs, the cost of operation and upkeep, etc. The annual expense for a telephone circuit relates to a carrier system providing a hundred-and-twenty channels on symmetric pairs.

The result is shown in the following diagram (figure 67). In relation to the annual

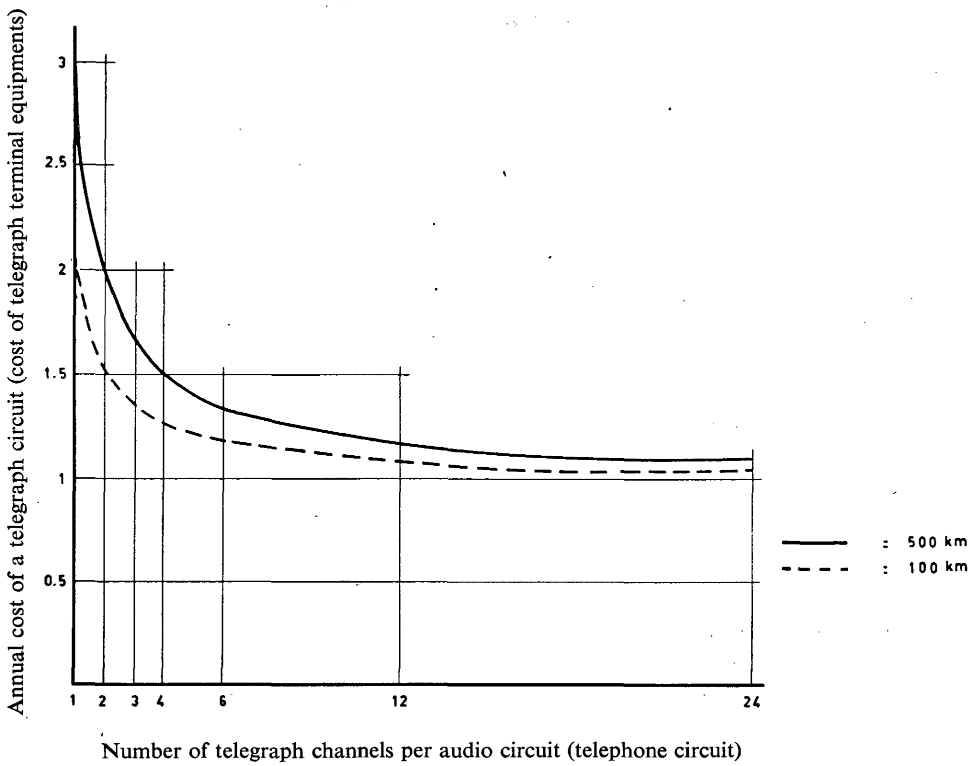


FIGURE 67. — *Cost of a voice-frequency telegraph circuit in relation to the number of telegraph circuits per audio circuit (telephone circuit)*

cost of two voice-frequency telegraph terminal equipments (= 1), the costs for an audio circuit (telephone circuit) are 2.10 if the circuit is 500 km long and 1.05 if the circuit is 100 km long. If these figures for the basic audio circuit (telephone circuit) are divided by the number of voice-frequency telegraph circuits, we get a figure giving the proportion of cost of the audio circuit per voice-frequency telegraph circuit. The total cost of the two voice-frequency telegraph terminal equipments (= 1) plus the proportion for the audio circuit, gives the figures shown by the curves in the Annex.

It will be readily observed that:

If an audio circuit carries only twelve telegraph channels instead of twenty-four, the annual costs per individual voice-frequency telegraph channel will be:

8 % greater when the circuit is 310 miles long;

4.5 % greater when the circuit is 62 miles long, always providing, of course, that the cost of maintenance per channel of a twelve-channel voice-frequency telegraph system is the same as for a channel in a twenty-four channel system. In fact, however, the channels in a twelve-channel voice-frequency telegraph system are less costly to maintain (since more time can be spent on measurements and upkeep), so that although there is an increase in annual costs from 4.5 % to 8 %, the money saved on maintenance will be about the same. Besides which, a twelve-channel voice-frequency telegraph system offers the following additional advantages:

1. The voice-frequency telegraph circuit can also be worked at a rate of a hundred bauds, if necessary.

2. With a rate of fifty bauds, the distortion is very slight. This is especially important when several voice-frequency telegraph sections are connected in tandem.

3. The channel transmission level can be higher, and the signal-to-noise ratio can be greater.

4. Because of the greater frequency change, a frequency-shift voice-frequency telegraph system is less sensitive to frequency variations.

Hence we take the line that frequency-shift voice-frequency telegraph systems with a mean channel separation of more than 120 c/s are economical on international circuits of up to 500 km in length, even when the modulation rate is fifty bauds, and that, because their transmission characteristics are so good, they should be used *, provided always that audio-frequency circuits (telephone circuits) are available in adequate numbers. We are at present installing a test network with the aid of frequency-shift voice-frequency telegraph systems with a spacing of 240 c/s between the mean channel frequencies and a frequency change of ± 60 c/s.

3. *Characteristics of a frequency-shift voice-frequency telegraph system with a spacing of more than 120 c/s between the mean channel frequencies.*

The following frequency allocation, we believe, could suitably be used for frequency-shift voice-frequency telegraph systems with more than 120 c/s between the mean channel frequencies:

The frequencies shown in Recommendation R.31 should appear in the frequencies used (odd multiples of 60 c/s; lowest frequency: 420 c/s). This is so when all multiples of 240 c/s are used for the mean frequencies, the lowest mean frequency used is 480 c/s, and the frequency change is ± 60 c/s.

* *N.B.* — Although transmission at up to 100 bauds using a bandwidth of 240 c/s can be made on voice-frequency telegraph circuits at no extra cost, the rates for rented circuits should, we feel, bear some relation to the modulation rate. This would be justified by the fact that a circuit so operated would be more useful.

Thus we get:

Channels	Mean frequency (c/s)	Stop frequency (c/s)	Start frequency (c/s)
1	480	420	540
2	720	660	780
3	960	900	1020
4	1200	1140	1260
5	1440	1380	1500
6	1680	1620	1740
7	1920	1860	1980
8	2160	2100	2220
9	2400	2340	2460
10	2640	2580	2700
11	2880	2820	2940
12	3120	3060	3180

We suggest that for twelve-channel frequency-shift voice-frequency telegraph systems used internationally, the power per channel be 11.25 microwatts (– 2.25 nepers), at a zero relative level point, in accordance with Table 1 in C.C.I.T.T. Recommendation R.35.

EFFECT OF SUDDEN CHANGES OF LEVEL ON FREQUENCY-SHIFT MODULATED VOICE-FREQUENCY TELEGRAPH SYSTEMS

(Contribution by the United Kingdom, contribution COM 9, No. 39, January, 1959)

The results obtained are given in figure 68. Except for the 5-6% early bias distortion introduced during the periods when the signal level was reduced by 2 N (this being approximately 2.4 db lower than the minimum designed operating level for the equipment), the distortion of 98% of the transitions was not affected by the changes in level. It would appear, therefore, that each abrupt level change affected only one transition, and hence that the time-constant of the limiter circuit of the receiver does not exceed the period of a signal element.

An attempt has been made in figure 69, which has been derived from the part of figure 68 outside the dotted ordinates, to plot only the increase in distortion of those transitions affected by an abrupt change of level; these curves have been extrapolated to indicate probabilities up to $P = 0.0001$.

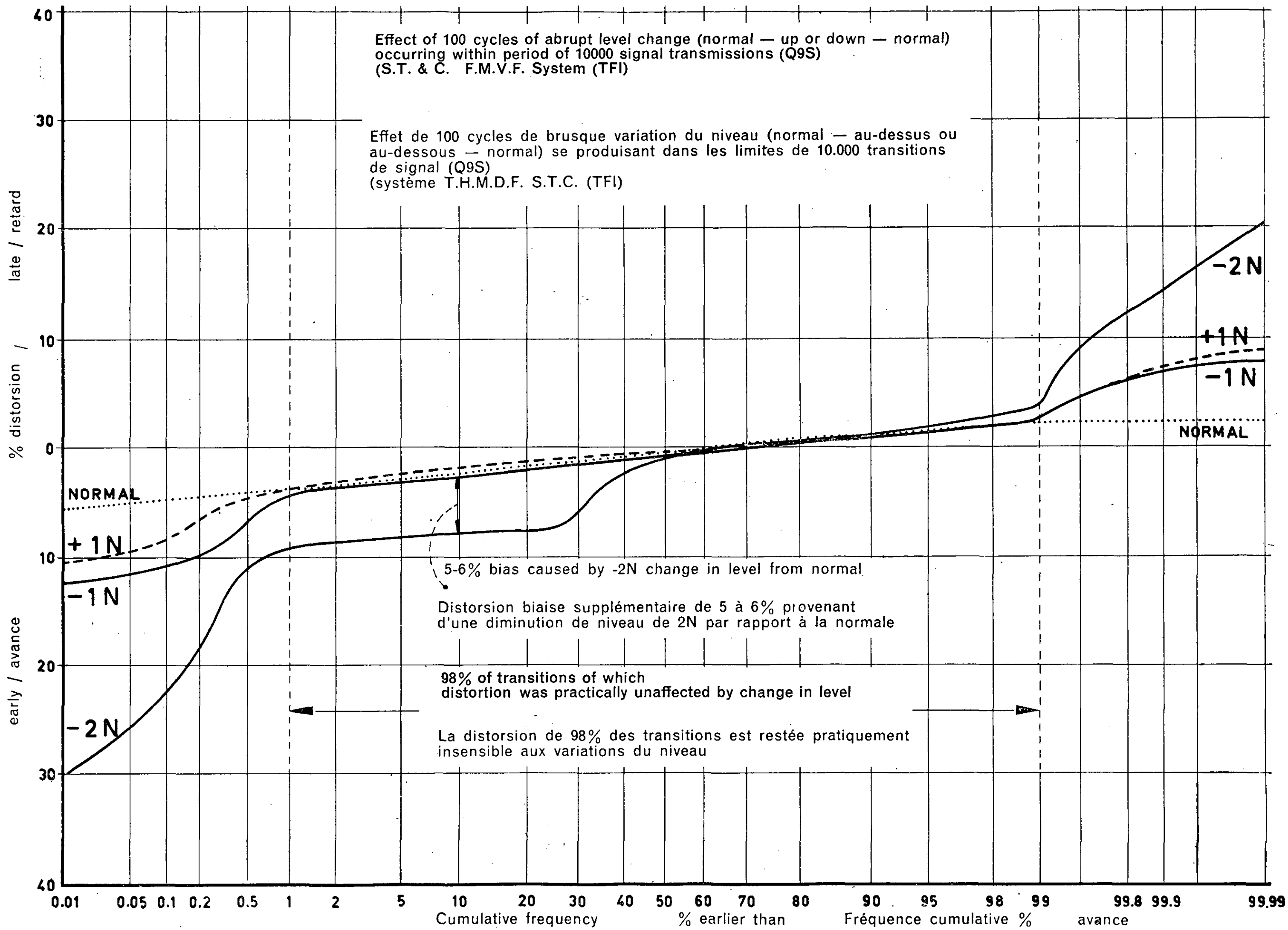
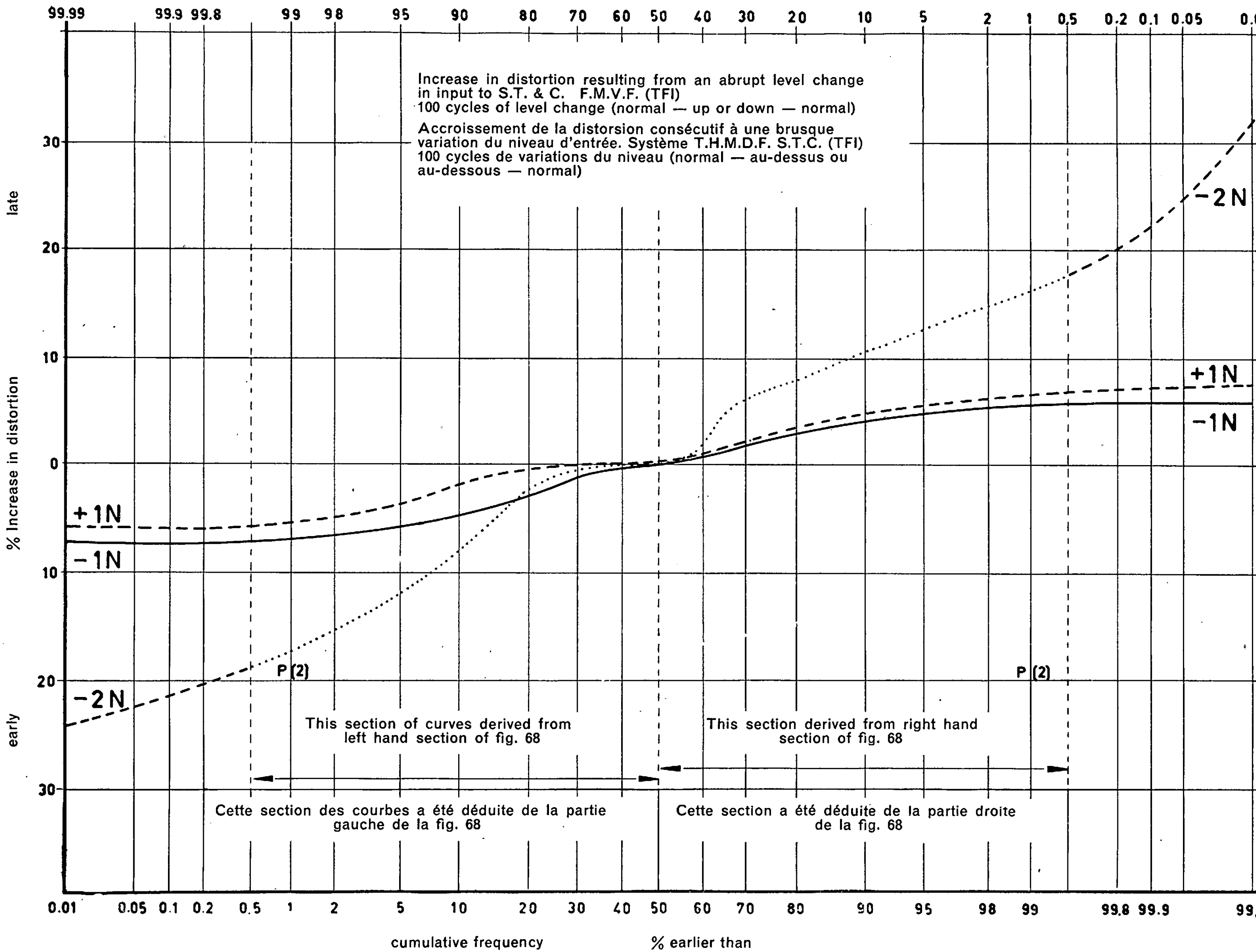

Effect of 100 cycles of abrupt level change (normal — up or down — normal)
occurring within period of 10000 signal transmissions (Q9S)
(S.T. & C. F.M.V.F. System (TFI)
Effet de 100 cycles de brusque variation du niveau (normal — au-dessus ou au-dessous — normal) se produisant dans les limites de 10.000 transitions de signal (Q9S)
(système T.H.M.D.F. S.T.C. (TFI)
late / retard
% distorsion /
early / avance
40
30
20
10
0
10
20
30
40
-2N
+1N
-1N
NORMAL
NORMAL
+1N
-1N
-2N
5-6% bias caused by -2N change in level from normal
Distorsion biaise supplémentaire de 5 à 6% provenant d'une diminution de niveau de 2N par rapport à la normale
98% of transitions of which
distortion was practically unaffected by change in level
La distorsion de 98% des transitions est restée pratiquement insensible aux variations du niveau
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
Cumulative frequency
% earlier than
Fréquence cumulative %
avance

FIGURE 68


Increase in distortion resulting from an abrupt level change in input to S.T. & C. F.M.V.F. (TFI)
100 cycles of level change (normal — up or down — normal)
Accroissement de la distorsion consécutif à une brusque variation du niveau d'entrée. Système T.H.M.D.F. S.T.C. (TFI)
100 cycles de variations du niveau (normal — au-dessus ou au-dessous — normal)
99.99
99.9
99.8
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
0.5
0.2
0.1
0.05
0.01
late
early
% Increase in distortion
30
20
10
0
10
20
30
+1N
−1N
−2N
P (2)
This section of curves derived from left hand section of fig. 68
This section derived from right hand section of fig. 68
Cette section des courbes a été déduite de la partie gauche de la fig. 68
Cette section a été déduite de la partie droite de la fig. 68
0.01
0.05
0.1
0.2
0.5
1
2
5
10
20
30
40
50
60
70
80
90
95
98
99
99.8
99.9
99.99
cumulative frequency
% earlier than

INFORMATION ON TRANSMITTER DISTORTION IN START-STOP TELEPRINTERS

(Extract of the Federal German Republic contribution; contribution COM 8, No. 7, November, 1957)

2.2. *Measurement of distortion.*

The Federal German Administration has undertaken detailed investigations to determine:

2.2.1. The suitability of the teleprinter answer-back device for determining transmitter distortion.

2.2.2. The effect of the way in which the teleprinter is operated.

2.2.3. The effect of the duration of transmitter on distortion.

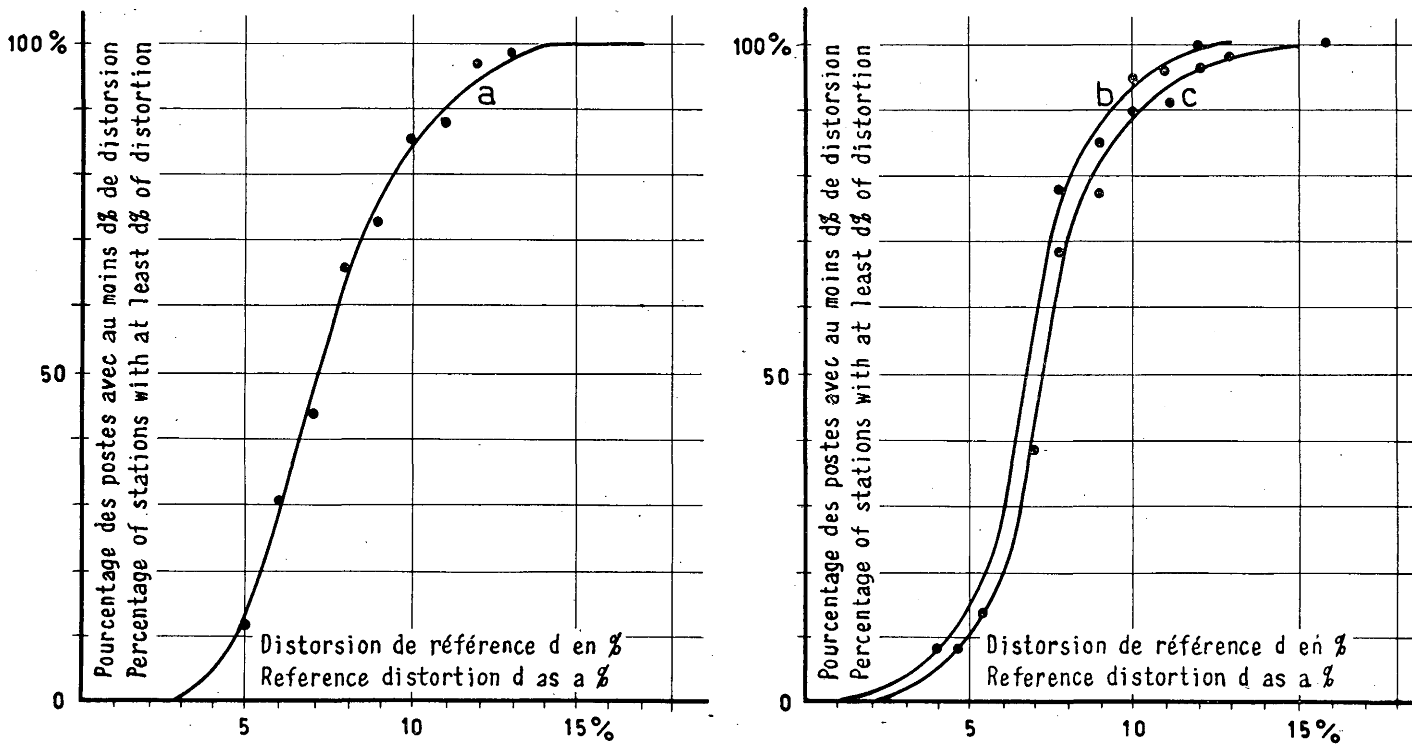
2.2.1. The measurements were made at the Munich telex centre with an electronic distortion measuring set. The values shown are maximum values for a triple transmission of the answer-back. Curve *a* in figure 70 shows the measurements made on 1200 stations of the Munich telex centre.

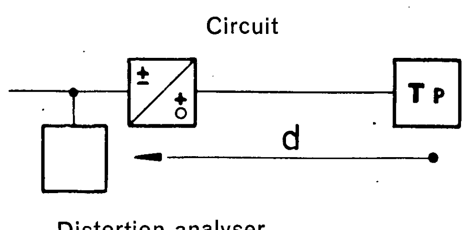
Only about 5% of all stations exceeded the 12% overall distortion proposed by the C.C.I.T. Curves *b* and *c* show the same measurements on 170 other telex stations, curve *b* showing distortion values for the answer-back signal, and curve *c* those for manual transmission (3 times the German test message of about 70 signals). It will be seen that with manual transmission, the figures are up to 1% worse. This percentage covers the influence of the longer duration and the greater irregularity of manual transmission. It appears from these results that measurements of the answer-back can be used to check the teleprinter transmitter.

2.2.2. The measurements were designed to show to what extent transmitter distortion varied in the terminal ensemble (teleprinter, including the circuit and repeater) in existing service conditions. The duplex service, with and without simultaneous transmission by the corresponding station, together with the simplex working in general use in the Federal Republic, were examined, both with manual transmission of the German test message or permanent transmission of the letter *r*. As a comparison, we show the results obtained with two Siemens and Halske teleprinters, one of an early type, and the other new. For the modern teleprinters, the variations occurring in the different operating methods are maintained within the limits of admissible distortion, ± 5% (fig. 71). For early type teleprinters, on the other hand, we must, as shown in figure 72, bear in mind the possibility of a widening of the distortion spectrum.

Hence, before admitting new kinds of teleprinter, it would seem necessary to undertake such research on specimen teleprinters in actual working conditions and to specify reception conditions in the light of the results.

The distortion figures given are for the synchronous distortion after the repeater, assuming the circuit is 6 km long on the average. The Federal German Administration of Posts and Telecommunications draws attention to the fact that the effect of the circuit can be offset by balancing, for any lengths, in the TW 39 type translations.





a: 1200 stations with triple answer-back emission

b: 170 stations with triple answer-back emission

c: the same 170 stations with emission of the German test message

FIGURE 70. — *Statistical study of subscribers' station reference distortion at the Munich telex exchange*

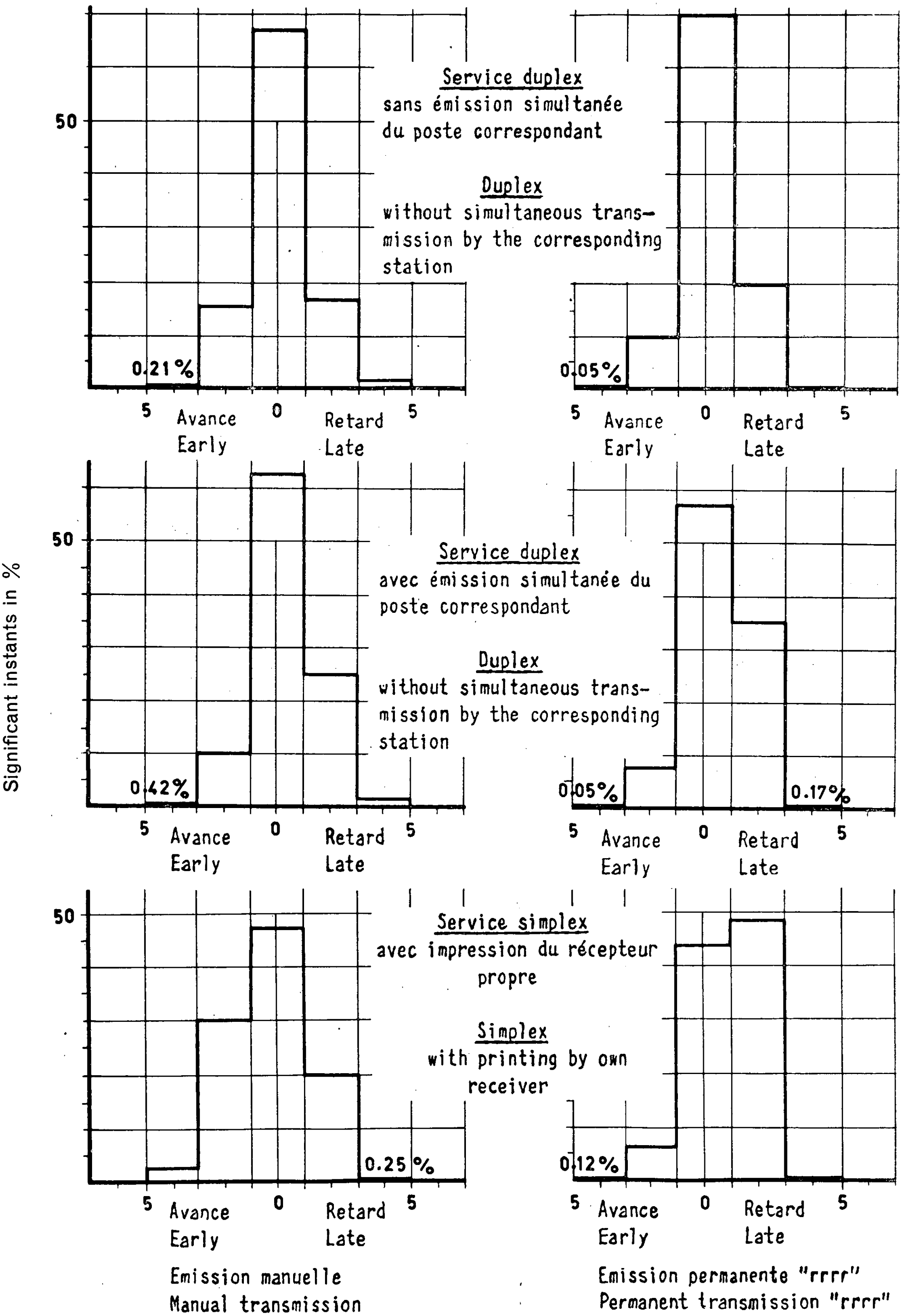


FIGURE 71. — *Statistical distribution of transmitter distortion of Siemens & Halske type 37 i No. 15141 page-printing teleprinter in various service conditions (single current with repeater)*

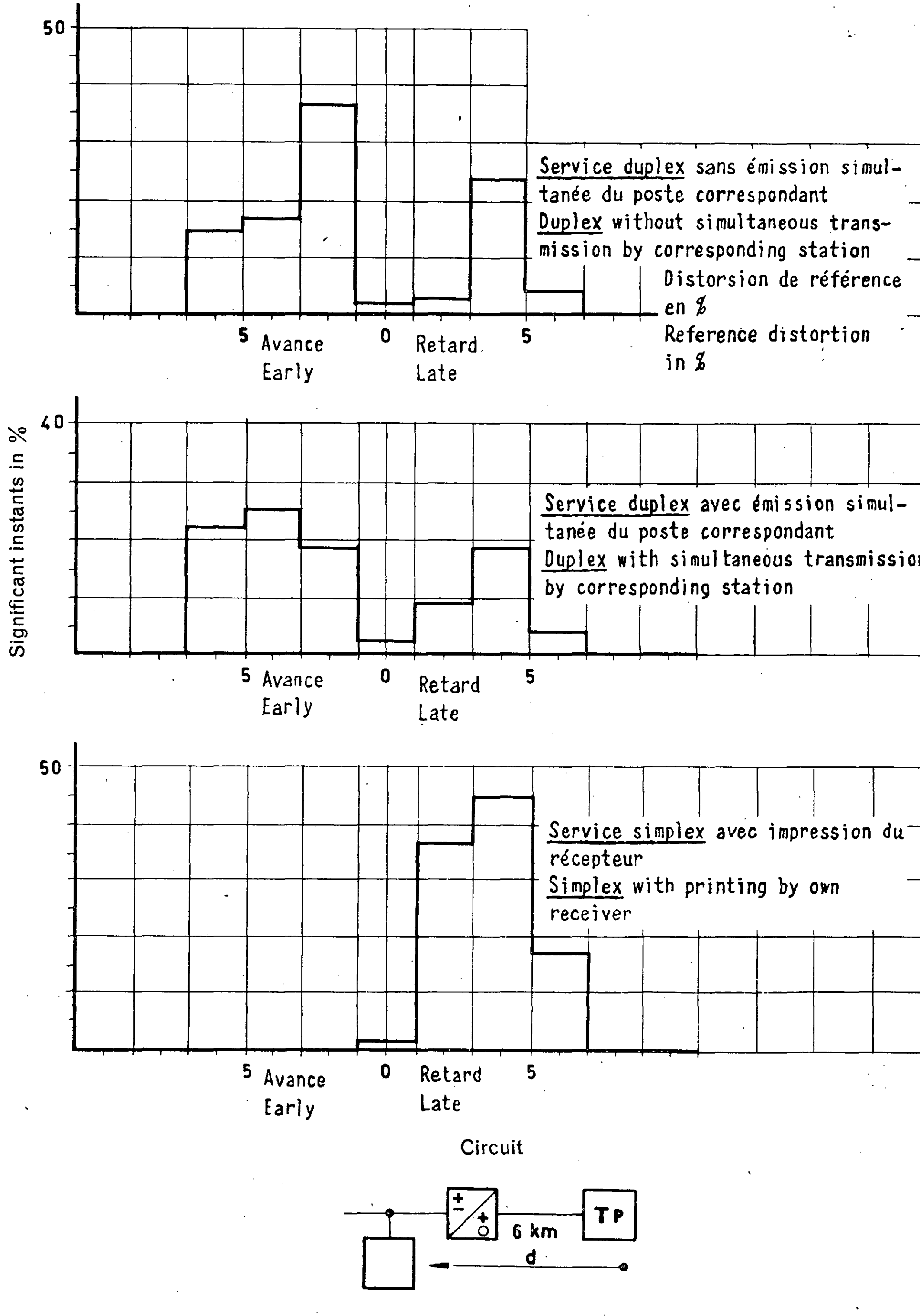


FIGURE 72. — *Statistical distribution of transmitter distortion of T type 37 h No. 13508 Siemens & Halske page-printing teleprinter, simplex and duplex (single current with repeater)*

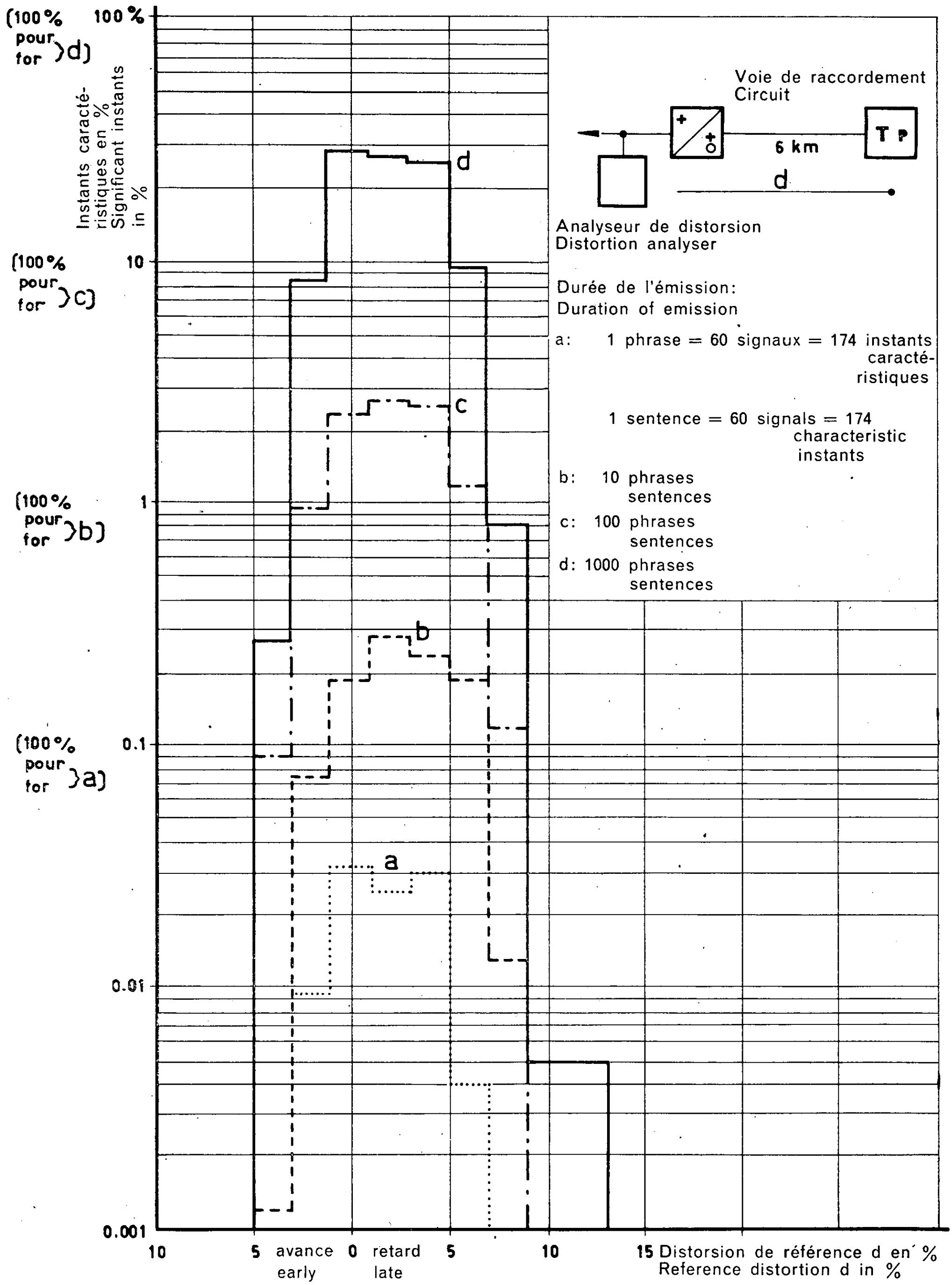


FIGURE 73. — *Statistical distribution of transmitter distortion of additional perforated tape T send 69 d transmitter associated with Siemens & Halske T type 37 i No. 15141 page-printing teleprinter*

2.2.3. The influence of the duration of transmission was also determined by means of the distortion analyser. The apparatus tested was an additional perforated tape transmitter, with the English test message of 60 lines or 174 significant instants.

The curves in figure 73 show that, as might be expected, the distortion spectrum widens as the transmission time increases. Under test, when one sentence or 1000 sentences were transmitted, early distortion increased from 3 to 7% and late distortion from 7 to even 13%. According to the diagram, less than 1% of the significant instants exceed the distortion spectrum for one sentence.

Tests on a broader basis show what probability of loss is likely in service with the various types of teleprinter, and what, in each case, is the relation with the results of a short measurement.

France (extracts from contributions COM 8, No. 51 and COM 8, No. 54, February, 1959)

2. *Speed check.*

The working speed was measured on 116 subscribers' stations. 96% of these stations were connected to the exchanges by lines less than 7 km long and the remainder by lines having a length of between 7 and 16 km. 71% used double-current working (relayed reception) and the remainder used single-current.

The results are shown in diagram 74 which indicates the number of machines whose speed deviation from nominal speed is comprised between 0 and +2 per thousand, +2 and + 4 per thousand, etc., between + 8 and + 10 per thousand, above + 10 per thousand, and the same for negative deviations. The measurement apparatus could not record speed deviations above 10 per thousand.

It was noted that 17 machines out of 116 exceeded a tolerance of ± 0.8%, and consequently the tolerance of ± 0.75% fixed by Recommendation S.3.

3. *Transmitter distortion check.*

Because of practical difficulties of access to subscribers' stations, measurements of sending distortion had to be made on fifteen consecutive transmissions of the answer-back code (approximately 1000 transitions).

The distortion rates obtained show a probability of exceeding the given value of $\frac{1}{1000}$.

The results of synchronous distortion measurements are shown in figure 75; it is seen that, for example 51 machines (i.e. 44%) have a synchronous distortion of over 4% and 21 machines (i.e. 18%) exceed 6%.

Figure 76 gives a similar curve concerning overall distortion for normal working alone: only 8.5% of machines have an overall distortion exceeding 10%, which is the maximum recommended in Recommendation S.3.

One main factor has to be noted: the limit for overall distortion is much better met than that for synchronous distortion. If n (in %) represents the start-stop speed deviation of the machine, the overall distortion measured in % is equal to the synchronous

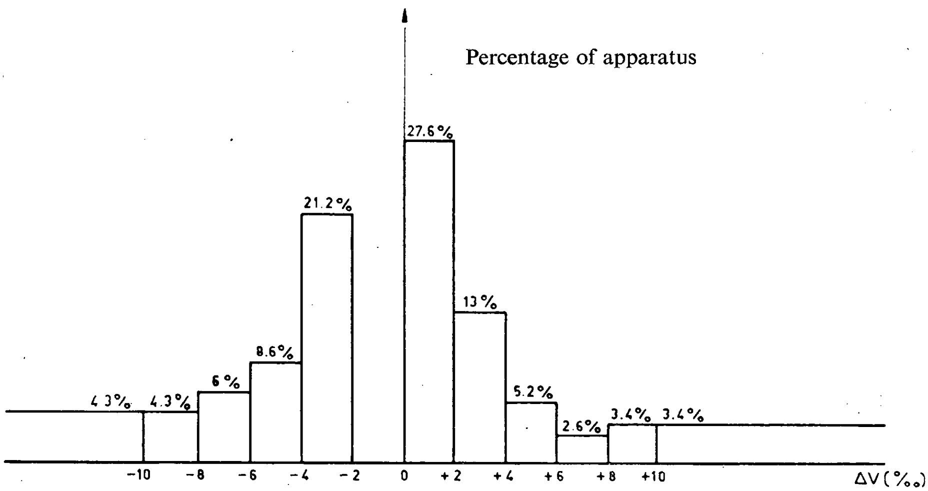


FIGURE 74

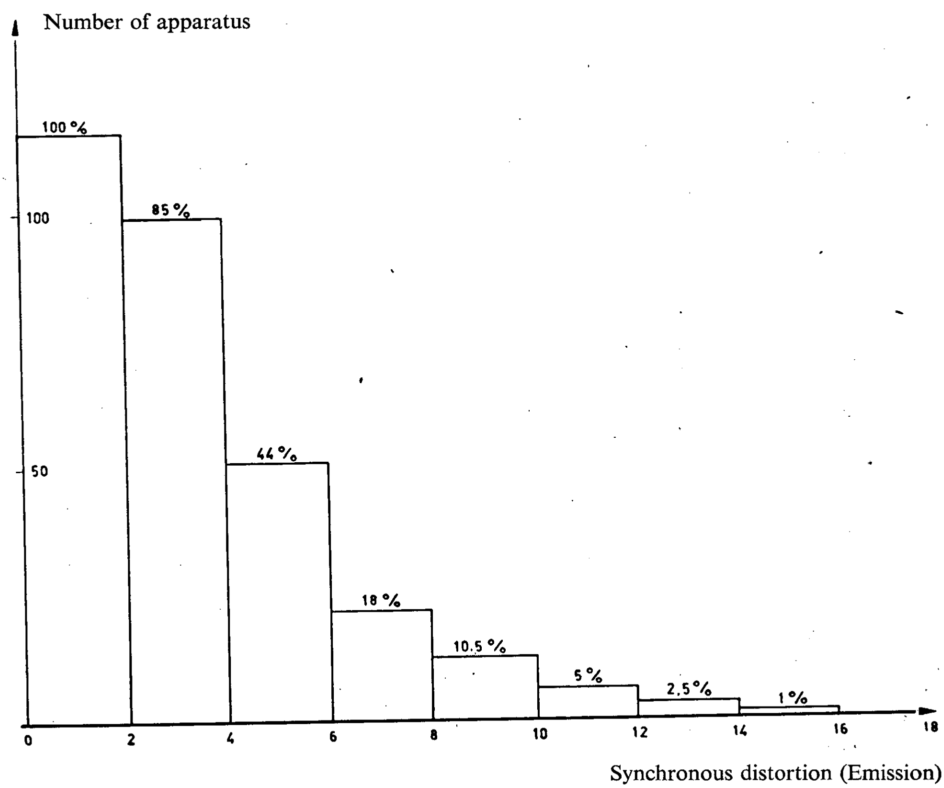


FIGURE 75

distortion increased by 6 n, in the most unfavourable condition (in certain cases, the speed deviation compensates in part the synchronous distortion). A synchronous distortion of 5% will only give an overall distortion of 10% if the speed deviation reaches 0.8% in the unfavourable direction. It is therefore obvious that the condition imposed on overall distortion is less rigid statistically than that imposed on synchronous distortion.

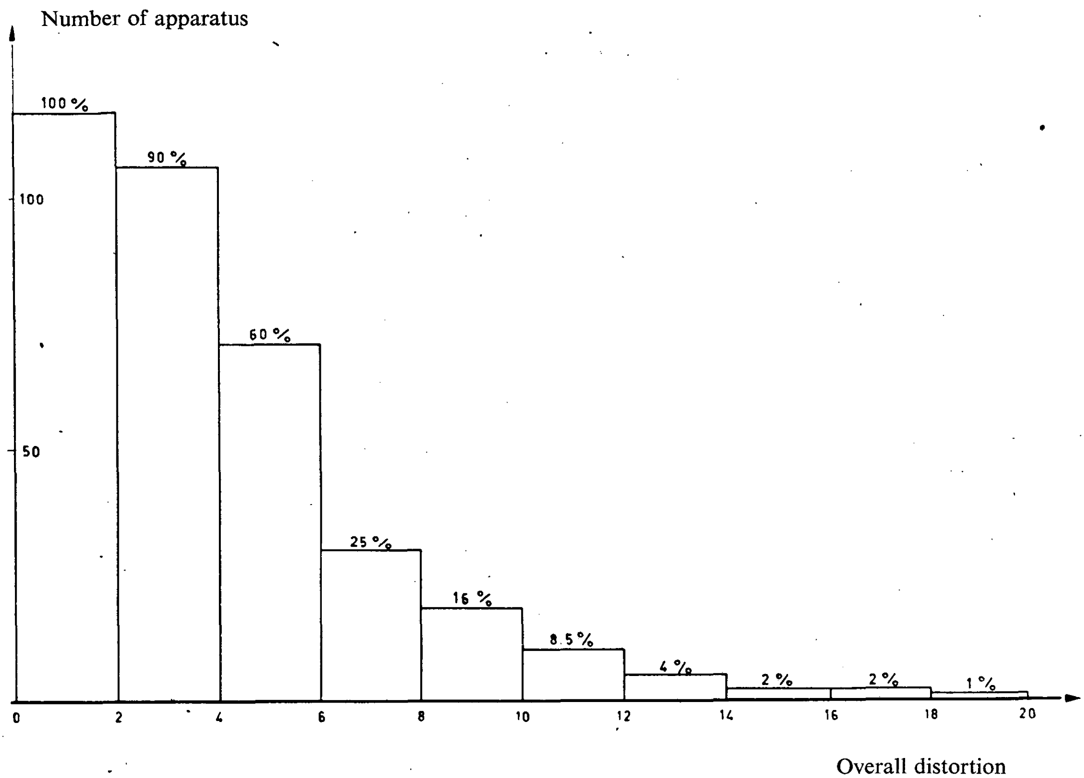


FIGURE 76

Distortion at teleprinter output

I. *General remarks.*

In a SAGEM type transmitter used by the French P.T.T. Administration sending is achieved by connecting the segments of a sending distributor in turn to the transmission channel; in addition these segments are previously connected to the appropriate polarities by a codifier. The sending distortion is thus independent of the direction of the transitions; there is thus no need to distinguish the mark-spaces from the space-marks. But it may be necessary to distinguish the beginnings of these different units from one another. If it is the beginning of the 1st unit, its sending distortion, in view of the mechanical operation of the machine, will, for a series of transmitted characters, have d values which will be distributed around an average value D with very low dispersion, due entirely to the slight variations in speed of the sending distributor. The average value depends primarily on the adjustment of the distributor contacts and of course on the average sending speed; it will thus differ from one unit to another.

The sending distortion of such a set will thus be distributed, to a first approximation, around 6 average values according to 6 normal laws with low standard deviations. If the set is very well adjusted, these 6 laws are practically superposed, since the average values are very close to one another, so that the sending distortions of the transitions are distributed around a low mean value according to a single normal law with a fairly low standard deviation.

II. *Practical tests.*

A series of very detailed tests was carried out on a SAGEM set to compare the dis tortions of *M—S* and *S—M* transitions having the same position (beginning of the third code unit for example) and to determine the effect of a deviation from the nominal speed.

By sending a given character with automatic repetition it was possible to be independent of the variations in speed due to jerks in operation and to isolate the transitions from one another: thus sending a repeated *E* makes it possible to study the distortion of the *M—S* transition of the 2nd unit of the code, and by sending a repeated *V* the corresponding *S—M* transition distortion can be studied. The start element being negative and the stop element being positive, the transitions at the beginning of the first element or of the stop element are always *S—M* transitions.

The results of the measurements carried out in this way are as follows:

1) for each unit studied, the transition distortions are distributed around a low mean value (lower than 2%) according to a normal law with a low standard deviation (0.5 to 1% maximum).

2) the *S—M* and *M—S* transitions which have the same position follow the same distribution law, with allowance for errors in experiments.

3) the mean value and the standard deviation for each of these laws depends on the position of the transitions studied.

The same measurements were carried out again on the same machine after the speed had been considerably misadjusted:

1) for each unit studied, the distortions are still distributed around a mean value according to a normal law with a low standard deviation, but the mean value is clearly greater where the transition studied is further away from the start unit.

2) the *S—M* and *M—S* transitions having the same position follow the same distribution law with the same mean value and standard deviation, allowance being made for errors in experiments.

The comparison between the two series of tests carried out shows the great importance of variations in speed. In particular, a single machine sending the same text more or less irregularly or by automatic transmission will not show the same distribution of distortions, since, in the first case, the instantaneous speed will be much less constant than in the second.

III. *Conclusion.*

In practice the measurement of sending distortion is carried out on the answer-back signals of the machine, that is to say on a text transmitted at a fairly constant speed; the measurement will then be fairly optimistic in general. In any case it is clear that the distortions of the whole of the sent transitions are not in general distributed according to a normal law around a mean value. The law of distribution is the sum of 6 elementary laws whose mean values are not equal. The distribution of distortions of the *S—M* and *M—S* units of the answer-back signals transmitted by automatic repetition, clearly show that they cannot be fitted to normal laws.

It may finally be noted that there are 6 different normal laws for the distribution of sending distortions. These laws relate to the initial transitions of the 1st, 2nd, 3rd, 4th and 5th unit and to that beginning the stop unit; they do not depend on the direction of the transitions; on the contrary they vary with the instantaneous speed of the transmitting shaft and consequently with the method of carrying out the measurement (manual sending, sending answer-back signals, automatic sending of one character). If the set is well adjusted, the mean values and the standard deviations of each of these laws are low and should not exceed a few percent; it is only where the 6 mean values are practically equal that the sending distortions of the whole of the transitions are distributed according to a normal law.

INFORMATION ON THE MARGIN OF START-STOP TELEPRINTERS

(See also Annex to Question I/VIII)

Siemens Halske (extract from contribution COM 8, No. 1, December, 1956)

A report by Siemens & Halske A.G.[1] treated of an electronic teleprinter signal distortion generator, capable of producing steadily or alternately distorted teleprinter signals of high accuracy.

Using said distortion generator, a Siemens page-printer T type 37 i was subjected to margin tests. To this end, the teleprinter was circuited for local-loop operation. One of the objectives of these measurements consisted in examining to what extent the test results are a function of whether the distortion has a steady or an alternating characteristic.

Test procedure.

All measurements apply to single current of 40 milliamps. (make-break operation).

An *RC* network, which functionally corresponds to the customary spark suppressor $C = 0.25\ \mu F$, $R = 150$ ohms, shapes the output signal of the electronic signal distortion generator in such a manner that the waveform closely resembles that produced by an idealized electric contact (deviations from the ideal waveform affect the accuracy of the distortion measurements in a considerable measure).

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[1] " Supplements to Documents of the VIIIth Plenary Assembly of the C.C.I.T. ", page 114 et seq.

In order to make the measurements readily reproducible, the page-printer was set up in a temperature-stabilized room and, prior to each test, was given a warming-up period of half-an-hour. Moreover, the orientation device (range finder) was inspected for symmetric adjustment between test series.

The various *types of distortion* applied in the course of the tests are given in the following table.

Code combination \ Start element	*uv* (no delay)	*kv* (steady delay)	*wv* (alternate delay)
uv no delay	undistorted	steady early	alternate early
kv steady delay	steady late	undistorted	alternate late
wv alternate delay	alternate late	alternate early	alternate early and late

With the types of distortion shown in the " start element *wv* " column, the *signal length* is varied, whereas with the types of distortion given in the horizontal " code combination *wv* " division the *element length* within the code combination is varied. Hence, with " alternate early and late " distortion both variations occur.

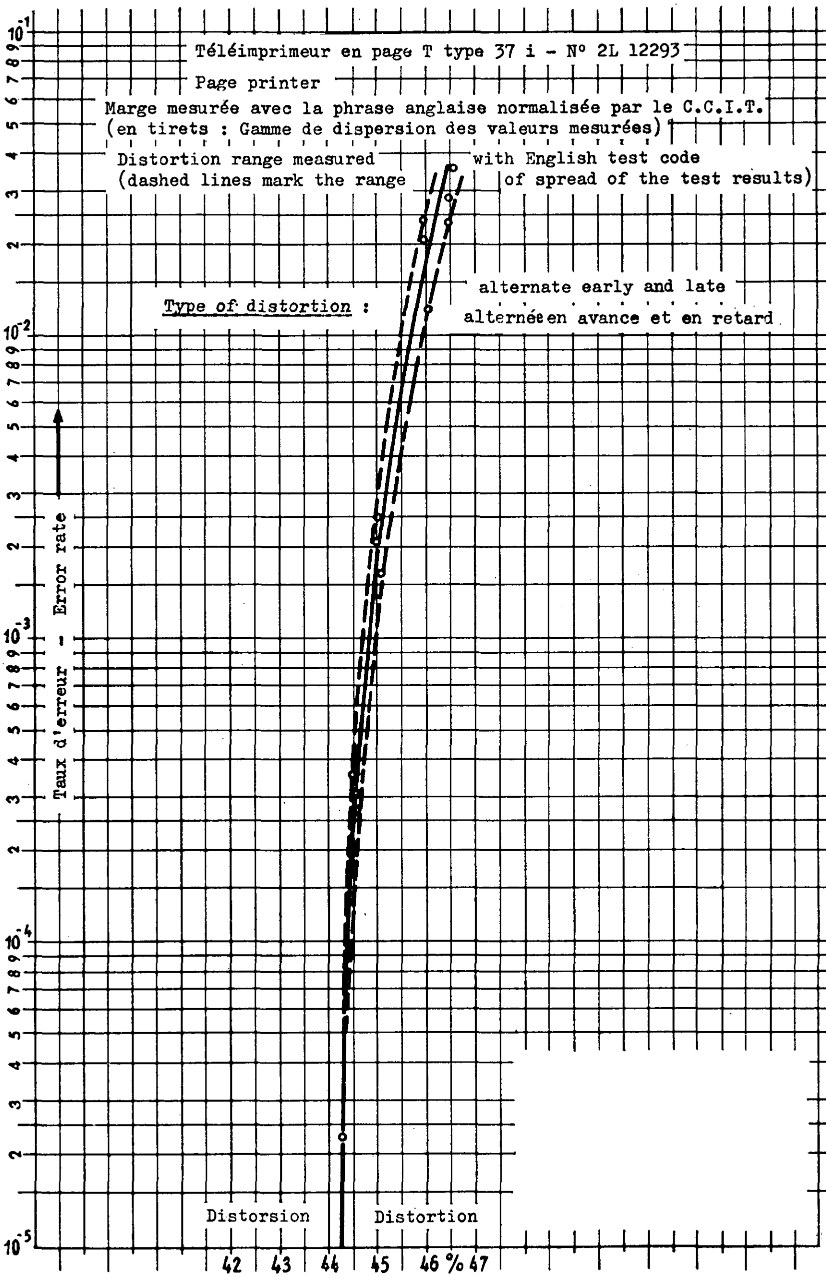
Test results.

Figure 77 shows the error rate, plotted as a function of the degree of distortion, with alternate early and late distortion. The distortion limit value, below which there are practically no errors, lies at approx. 44%. If the distortion is increased by less than 1%, the error rate will rise from 10^{-5} to 10^{-3}, i.e. by two orders of magnitude.

An advantage of the measurement employing alternate distortion lies in the fact that it permits the actually interesting error characteristics of the machine to be traced within *one* series of tests. With the previous test methods, which employed either purely early or purely late distortion, it was necessary to run two test series to obtain the same results (see figure 79 as an example). Moreover, the new type of distortion is a more faithful replica of actual service conditions, since it involves varying element and signal lengths.

Figure 78 shows a comparison of the various types of distortion. The measurements plotted here were taken in such a manner that, with the error rate kept on an approximately equal level, the individual types of distortion were applied in direct succession. In this way, comparison remained unaffected by such variations of the teleprinter characteristics as might have been introduced if the tests had been run at longer intervals.

It can be seen that all error curves on figure 78 are disposed within a strip of 1% width, i.e. relatively closely together.



Téléimprimeur en page T type 37 i - N° 2L 12293
Page printer
Marge mesurée avec la phrase anglaise normalisée par le C.C.I.T.
(en tirets : Gamme de dispersion des valeurs mesurées)
Distortion range measured with English test code
(dashed lines mark the range of spread of the test results)
Type of distortion :
alternate early and late
alternée en avance et en retard
Taux d'erreur - Error rate
Distorsion
Distortion
42
43
44
45
46 % 47

FIGURE 77

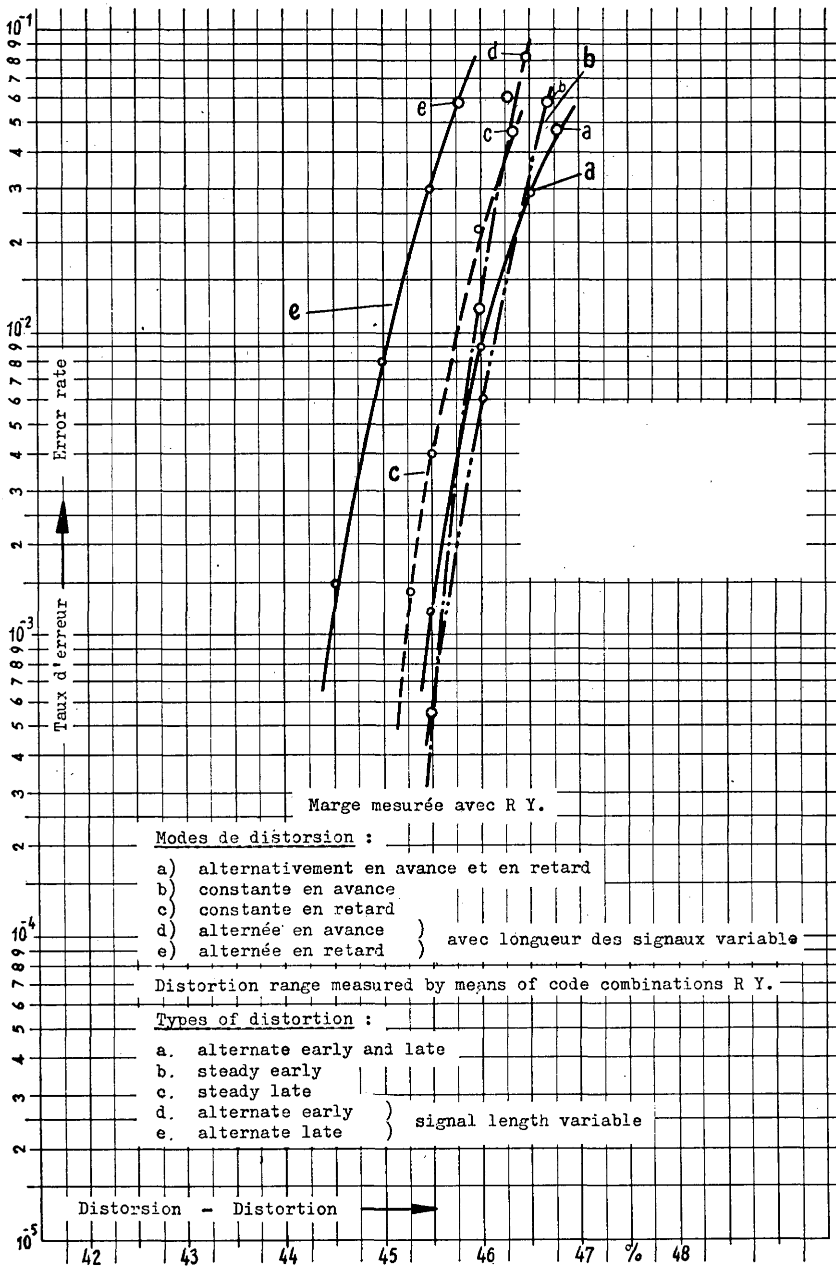

Error rate
Taux d'erreur
Marge mesurée avec R Y.
Modes de distorsion :
a) alternativement en avance et en retard
b) constante en avance
c) constante en retard
d) alternée en avance
e) alternée en retard
avec longueur des signaux variable
Distortion range measured by means of code combinations R Y.
Types of distortion :
a. alternate early and late
b. steady early
c. steady late
d. alternate early
e. alternate late
signal length variable
Distorsion - Distortion
42
43
44
45
46
47
%
48

FIGURE 78

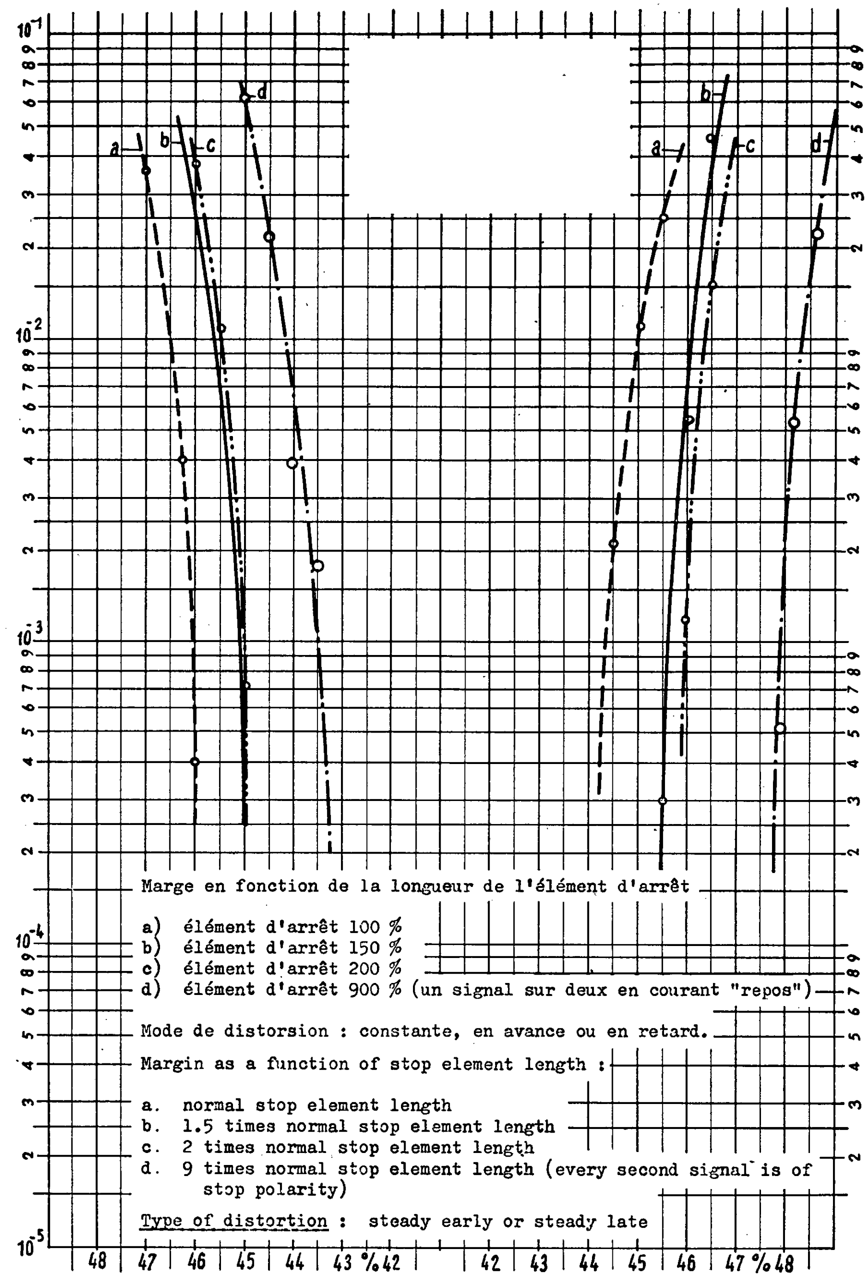

Marge en fonction de la longueur de l'élément d'arrêt
a) élément d'arrêt 100 %
b) élément d'arrêt 150 %
c) élément d'arrêt 200 %
d) élément d'arrêt 900 % (un signal sur deux en courant "repos")
Mode de distorsion : constante, en avance ou en retard.
Margin as a function of stop element length :
a. normal stop element length
b. 1.5 times normal stop element length
c. 2 times normal stop element length
d. 9 times normal stop element length (every second signal is of stop polarity)
Type of distortion : steady early or steady late
48 47 46 45 44 43 % 42 42 43 44 45 46 47 % 48
Distorsion - Distortion
Early - En avance
En retard - Late

FIGURE 79

Nevertheless, it is interesting to note that distortion types " e " and " d ", which differ from types " b " and " c " only in their varying signal length, are positively more error-prone.

In the case of distortion " a ", which also involves varying signal length, allowance must be made for the fact that, commensurate with the distortion programme, half of the characteristic instants are undistorted relative to the start element.

Figure 79 evidences that the various lengths of the stop element essentially signify a displacement of the centre of the orientation range. A detailed analysis to determine the causes of this phenomenon has not yet been conducted.

France (extracts from contributions COM 8, No. 51 and COM 8, No. 54, February, 1959)

Measurement of receiver margins.

Measurements were carried out on 23 machines. The apparatus received the French international sentence having start distortion only (non-alternate distortion) and with a 150 millisecond cycle. The margin was measured at a probability of one fault per sentence (i.e. one fault per 50 characters instead of one fault per 100 characters). Figure 80 shows that 22 machines out of 23 accepted a distortion that reached 34%; 20 machines accepted a distortion reaching 36%.

It appears therefore that working machines have a net effective margin which is never very far below the limit of 35% fixed by Recommendation S.3.

Teleprinter margin.

The idea of teleprinter margin should be made more specific by the measurement conditions (kind of text sent, transmission cadence, etc.). and by the error rate allowed (1 error in 100 000 characters, 1 error per sentence, etc.). The probability of transition error depends to a first approximation on the distortion of the received modulation in accordance with a normal law for fairly small rates of errors (less than about 10% of transition errors). The probability of a character error can be deduced from it when the kind of text used for the measurement of the margin and in particular the percentage of distorted transitions in this text are known.

Experience shows that in every case an increase by a few per cent of the distortion of the text makes the error rate increase rapidly (from 10^{-5} to 10^{-3} or from 10^{-3} to 10^{-2} for example).

All measurements, whether on machines or channels, involve questions of probabilities such as the probability of the distortion or of the margin being exceeded. For a measurement to have any point, it is thus necessary to specify the extent of probability of error at which the measurement has been carried out and it is also necessary to avoid the so-called " sampling " errors.

Let us suppose for example that the margin of a machine is defined as the distortion which must be applied to the incoming modulation so that there is an error in the machine in the first sentence thus distorted. In general, then, the probability of error is not one error per sentence. More precisely, if the incoming modulation is distorted so that the machine gives one error per sentence on the average over a large number of sentences, there is a 37% chance that the machine will give no error in the first sentence thus dis-

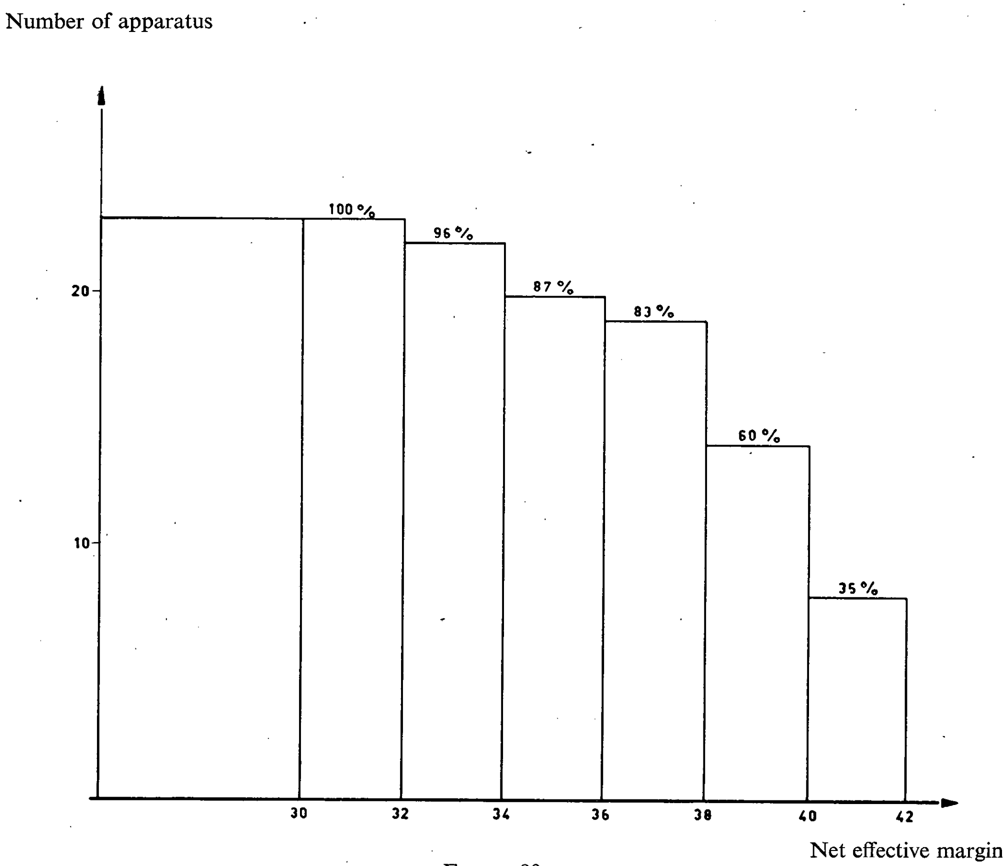


FIGURE 80

torted; there is still a 14% chance that it will give no error in the first two sentences; these probabilities cannot be considered as negligible. The sampling error is on the contrary very small if the probability error is larger (about 5 errors per sentence over a large number of sentences) the measurement being carried out in practice on a single sentence: in 96% of cases, for example, 2 errors at least will be observed in the first sentence; in 88% of cases at least 3 will be observed. The margin corresponding to a probability of one error per sentence will be obtained approximately by subtracting 2% of the calculated margin for a probability of 5 errors per sentence (in the case of distortion on start only).

Telegraph receiver margin

I. *Some general comments.*

The margin of a telegraph receiver is ordinarily defined as the maximum distortion of the incoming modulation for which the receiver produces a percentage of faults less than some given figure. This definition clearly is inadequate. Hence " early " and " late " margins are terms frequently used. That is to say, relative to modulations having early and late distortions to advance-distorted and delay-distorted modulation. The difference between the two figures is largely due to the adjustment of the gearing mechanism and the motor speed. Furthermore, we should distinguish between the margins relative to the mark-space transitions and the margins relative to the space-mark ones to make allowance, for example, for a bias in the receiving relay or a lag in setting. This makes, all in all, four figures for the margin of a receiver, each of them fluctuating around a mean value because of friction, inertia, and mechanical wear-and-tear.

II. *Experimental checks.*

The existence of bias at reception and of an inequality between the early and late margins is well enough known to require no experimental checking. On the other hand, experiments show how the percentage of errors varies with the distortion of the modulation received. The measurements made by the French and Federal German Administrations (Document SG III/22 of the International Telegraph Consultative Committee, *Violet Book*, Supplement, pages 95 and 96) show that the frequency of receiving errors increases with extreme speed when the distortion of the received modulation exceeds a certain figure. For example, the error frequency increases from 1% to about 10% for an increase of 1% in the modulation distortion.

The Federal German Contribution (page 304) is especially interesting, showing as it does that the error rate varies with the distortion in accordance with a normal law. In fact, it is rather the transition error rate which obeys such a law. When the rate is low (5% to 10% approximately), every transition error produces a mistake in a character. Hence the character error rate will be equal to the transition error rate multiplied by a factor which depends on the mean average of distorted transitions per character. This factor will, for example, be 3 if the received modulation has repeated start distortion.

III. *Conclusions.*

If this remark be borne in mind, it will be convenient, in network planning, to assume that the margin (early or otherwise) of a receiver for each kind of transition *M-S* or *S-M* assumes values which are distributed around a mean value according to a normal law. The number of errors in characters will be deducted from the number of errors in transitions by multiplying by a factor which will depend on the kind of modulation used for the measurement. The approximation so arrived at will hold good just as long as the error rate is not excessive (less than 5 to 10% of transition errors).

Like the measurements of sending distortion, measurements of margin will very largely depend on the instantaneous speed of the governor. Hence the margin will depend in particular on the rate of the incoming modulation.

Hence, too, we must not expect a degree of accuracy impossible to attain in measuring margins. And for every measurement, we must specify the circumstances: the test text, the speed, the kind of distortion, and the percentage of errors in the characters.

SPROCKET-FEED MECHANISMS USED ON PAGE-PRINTING START-STOP APPARATUS

(Extract from C.C.I.T. Violet Book, *page 109 et seq.)*

Note. — The following details relating to the operation of sprocket-feed page mechanisms used in the internal services of the Federal German Republic may be of interest to other Administrations:

The platen has eleven pins on each side (see figure 1 in drawing 81). These pins permanently engage in the holes on the two sides of the form. The spacing between pins is slightly less than half-an-inch. Hence seven copies can be used.

Figure 2 in drawing 81 shows the dimensions of the sprocket-punched paper.

Dimensions are as follows:

a) Spacing between lateral holes: 12.7 mm = half an inch.

b) Spacing between two rows of lateral holes: 203.2 mm = 8 inches.

These are identical to those normally used for this purpose in the United States and in the United Kingdom.

The forms are separated lengthwise by " *y* " score lines. The " *x* " lines determine the width of the form. The form itself measures 192 × 304.8 mm.

The carbon paper, 192 ± 1 mm wide, is not scored (see figure 2 of drawing 81).

With 3 layers of paper, all layers are perforated and can be provided by a spare reel.

If it is desired to print more copies, only the layer immediately against the platen is perforated (see figure 3 of drawing 81).

All the other layers of paper are narrower (196 ± 1 mm).

In this case, all the layers, including the carbon, have to be stapled close to the separation line " *y* ". Then it will be impossible for the forms to be provided by a reel. The various layers of paper so clipped are folded in zig-zag.

All paper tolerances are valid for 65% relative humidity of the atmosphere.

Figure 82 shows the printed part of the form for a spacing of 4.23 mm and of 6.35 mm between the printed lines. Space A is so chosen that the printed form last received can be torn off, while the next one is ready for printing. In the free space A, the heading of a commercial firm can be printed in advance.

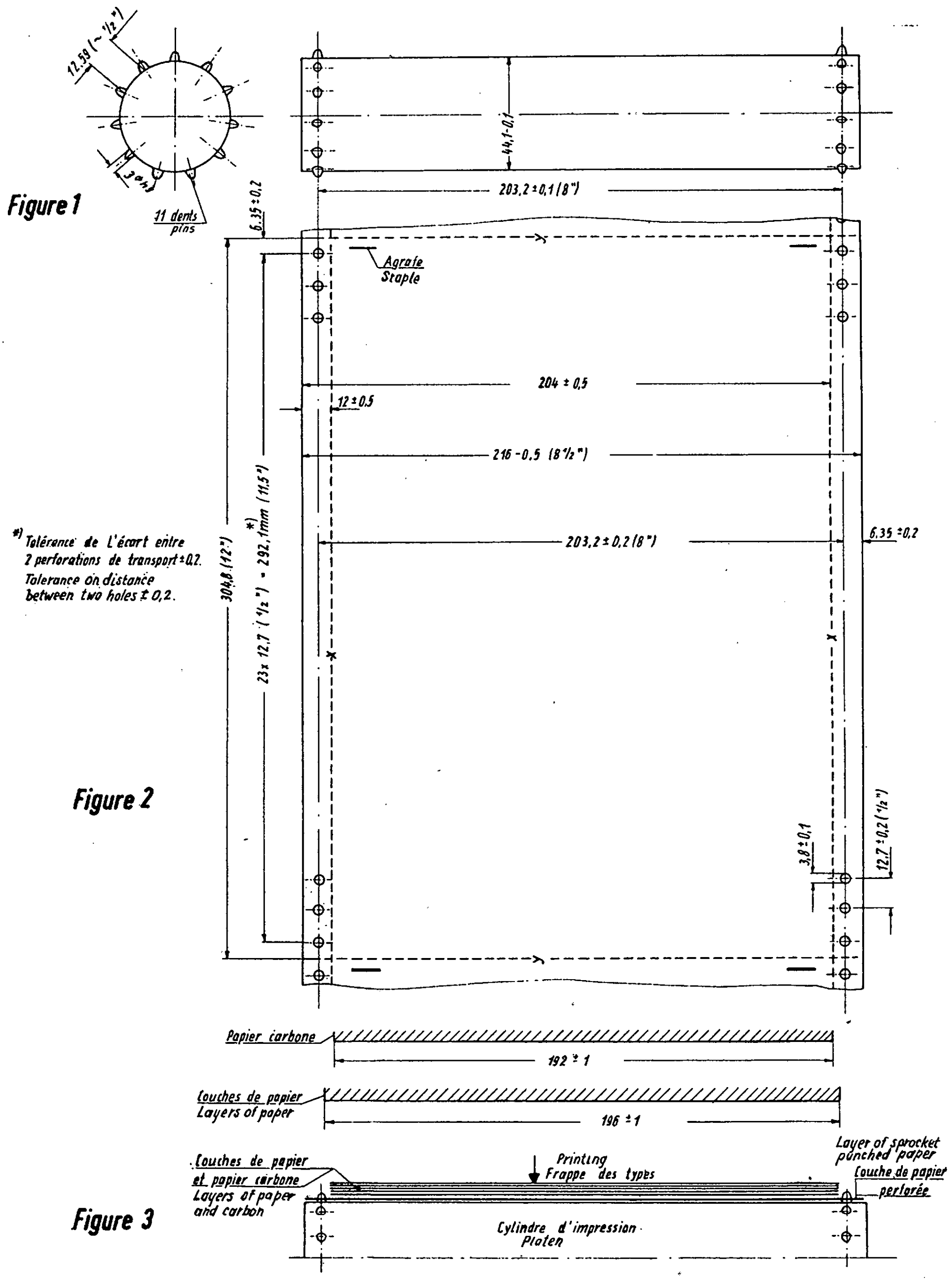


Figure 1
12,59 (~½")
3 a 4
11 dents
pins
Figure 2
203,2 ± 0,1 (8")
44,1-0,1
6,35 ± 0,2
Agrafe
Staple
204 ± 0,5
12 ± 0,5
216 - 0,5 (8½")
203,2 ± 0,2 (8")
6,35 ± 0,2
*) Tolérance de l'écart entre 2 perforations de transport ± 0,2.
Tolerance on distance between two holes ± 0,2.
304,8 (12")
23 x 12,7 (½") = 292,1 mm (11,5") *)
3,8 ± 0,1
12,7 ± 0,2 (½")
Papier carbone
192 ± 1
Couches de papier
Layers of paper
196 ± 1
Figure 3
Couches de papier et papier carbone
Layers of paper and carbon
Printing
Frappe des types
Layer of sprocket punched paper
Couche de papier perforée
Cylindre d'impression
Platen

FIGURE 81

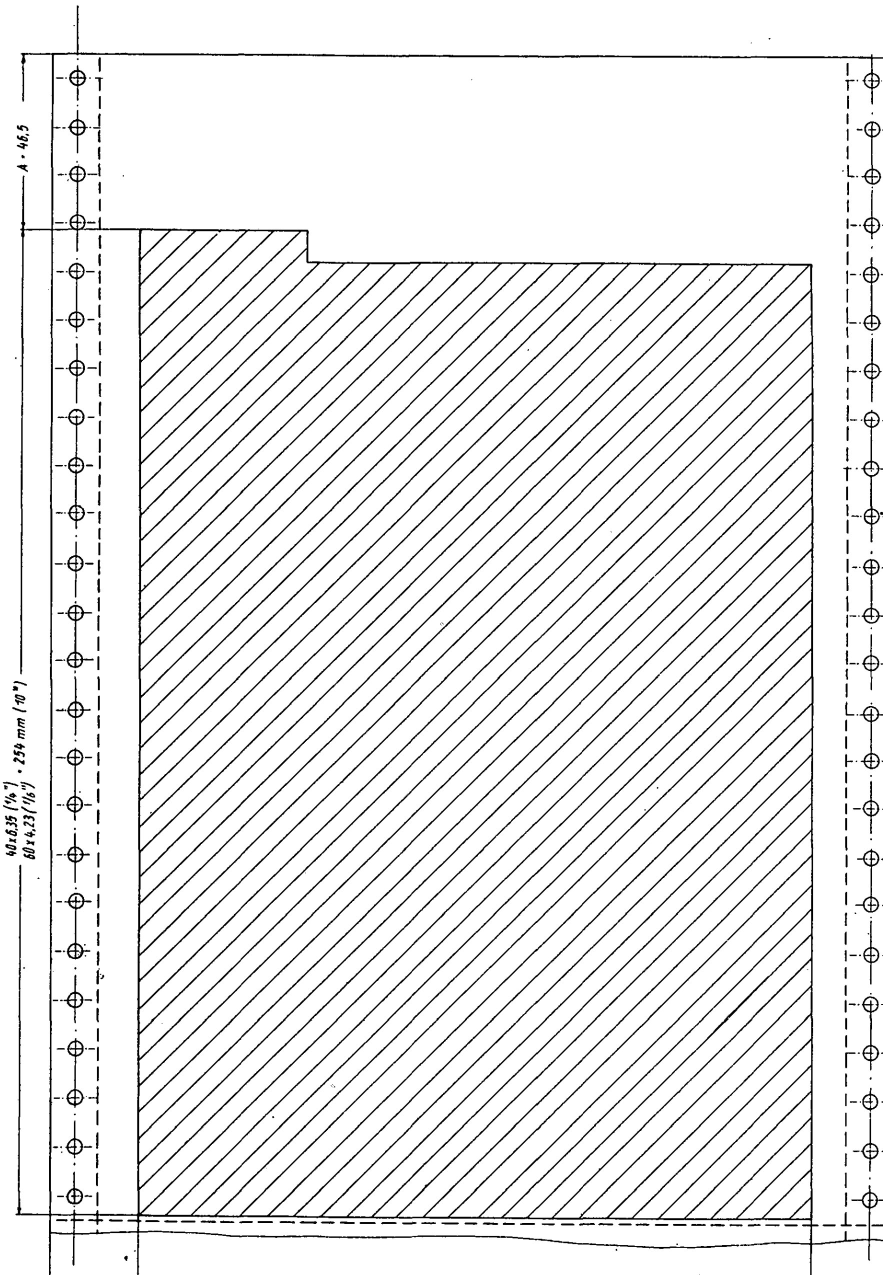


Figure 4

FIGURE 82

CONSIDERATIONS INVOLVED IN THE NEW TELEGRAPH ALPHABET

Poland (Extract from contribution COM 8, No. 5, October, 1957)

How the teleprinter facilities might be extended.

We can extend these up to fifty-nine signs at the very utmost, by using the five-unit code, the signs being divided into two groups. Quite clearly, this is not enough.

If, now, we increase the units in the code to six, and keep the signs divided into two groups, we shall multiply the facilities afforded by more than two. The machine will now meet all requirements, as regards faithful transmission of the text and operating simplicity, thanks to the introduction of switching signals and other auxiliary signs.

The six-unit code offers one hundred and twenty-eight combinations in two groups.

Apportionment of the signals into groups.

Since we have so many combinations now available, it will be easy to divide the signals into two groups, in such a fashion that the signals most used are in one group and the remainder in the other.

In certain circumstances, there would be no need to have each group preceded by a special signal. It might conceivably be more economical and practical if *every* signal in the second group were preceded by a special signal, transmitted by depressing, simultaneously, the key of the signal of the second group and that of the special signal, as is done on typewriters. This question requires meticulous scrutiny, in the light of statistics showing how frequently capital letters and certain auxiliary signals are used in various languages and various kinds of text.

Modulation speed and output.

This is closely bound up with the extension of teleprinter facilities.

The present teleprinter output—400 signals a minute—does not seem very great, and should certainly not be reduced.

With the same theoretical output, the modulation speed with a 6-unit code will be given by:

$$V_{11t} = V\frac{a_{11} + 2.5}{a_1 + 2.5} = 50\frac{8.5}{7.5} = 56.7 \text{ bauds}$$

where V_1 = modulation speed with the old code,
a_1 = number of units in the old code,
a_{11} = number of units in the new code.

It should be possible for existing transmission systems to cope with this rate of modulation.

For a comparison between the two codes, this calculation is incomplete, since we ought to take, as our basis, not the theoretical but the practical output (i.e., without the auxiliary signals which are not part of the text transmitted, for example, the inversion signals).

If, now, we define the output with the code η by the relation between the number of signals of the text transmitted (including spacings, line feeds, etc.) and the number of all the signals transmitted by the teleprinter and required for reproduction of the text at the reception end, we shall obtain:

$$N_{p\max} = \eta N_t$$

where $N_{p\max}$ = the practical output.

The output with a particular code is a statistical figure varying with the kind of text transmitted.

For any particular constant output, the modulation rate will be given by :

$$V_{11p} = V_1 \frac{(a_{11} + 2.5) \cdot \eta_1}{(a_1 + 2.5) \cdot \eta_{11}} = V_{11t} \frac{\eta_1}{\eta_{11}}$$

where η_1 = output with the old code,
η_{11} = output with the new one.

If we obtain a greater output with the new code with a better apportionment of the signals into groups, this modulation speed will be $\frac{\eta_{11}}{\eta_1}$ times smaller.

Independently of the calculated increase in modulation speed for the same output, some thought should be given to an increase in modulation speed and a simultaneous change in code. Thus we could obtain a greater teleprinter output. Evidence for this is provided by the ever more extensive use of automatic transmission and the fact that the existing teleprinter output limits the possibilities of a good typist.

The question of co-operation.

There are very many teleprinters in use, and they are expensive, so that the question of whether the new teleprinters could work with the old ones, supposing there were a change in the telegraph code, is an exceedingly important one.

If, with a change in alphabet, output changes appreciably, direct co-operation (of the conversation type) will be possible if the new teleprinter can adapt its output to that of the old one.

Whether this direct co-operation can be achieved can be shown only by a thorough technical and economic analysis. I should like here to draw attention to certain aspects of the problem.

In order that a transformation designed to make co-operation possible may be kept simple, the new alphabet must be arranged with an eye to this operation.

There is a danger, therefore, that the new alphabet will have to shoulder the burden of " original sin " from birth. In considering the problem of co-operation, we must take care to reduce difficulties of this kind to a minimum.

Let us, now, as an example, consider two of the numerous kinds of co-operation possible.

There would seem to be no special difficulty about a system in which the new 6-unit code would be so conceived that if the last unit has a " stop " polarity, the first five units would correspond to Alphabet No. 2.

To effect co-operation, it would suffice to block certain keys on the keyboard of the new machine (and perhaps to use a simplish sort of transformer to adapt the modulation rate). But adaptation of this system would impose the inclusion of the figures and auxiliary signs, fairly often used, of the second group, which would complicate operation of the teleprinter and reduce its output.

If we wish to keep a more effective apportionment into groups, we must insert all signals of Alphabet No. 2 in the first group of the new alphabet. For co-operation, the second group would have to be blocked in the new teleprinter. Quite apart from this, a fairly complicated transformation would be necessary, which would do away with one of the six units (for example, the sixth) in the direction towards the old teleprinter and would transmit an additional " figure " or " letter " signal if there were a change in the significant state of this unit.

For example:

Signal transmitted by the new teleprinter	N ——++—++	R ——+—+—++	2 —++——+—+	
Signal transmitted by the transformer	N ——++—+	R ——+—+—+	figures —++—+++	2 —++——++

In the direction towards the new teleprinter, the transformer would suppress the " figure " and " letter " signals, and, depending on the signals last transmitted, would supplement the combination transmitted by the sixth unit with appropriate significant condition.

It seems clear that our desire to arrange the new code conveniently runs to some extent counter to our anxiety to simplify co-operation.

An additional question for discussion.

Reform of the alphabet is exceedingly costly, and this is why the present alphabet has remained, despite the fact that it has become, with time, a considerable obstacle to technical progress.

A revision of the present alphabet would offer an excellent, and perhaps the only, opportunity for a radical modernization of telegraph apparatus.

As an example, let us consider two problems. Firstly, can we guard against wrong restitutions? On an actual circuit, the teleprinter is not very satisfactory in this respect, with the result that whole portions of telegrams (especially portions containing figures) have to be repeated. One way of substantially reducing the likelihood of false signals being received would be to print a special sign instead of the false one. This signalling of errors, based on the principle of a constant relation between marking and spacing signals, requires an increase in code units.

The second problem is how to ensure synchronism of the transmitter and receiver.

The present system is to check the phase before each signal is transmitted. This was all very well at a time when the technical possibilities of stabilizing the rotation were none too extensive, and when the problem of how the circuit should be operated was not felt with anything like its present acuity. It would be well to ascertain whether control by larger groups of signals would not be better, despite the complications involved, for example, for groups of ten signals. This would obviate the need for signal storage but would lead to no complications in automatic transmission. Since automatic transmission is becoming ever more widely used, the advantages to be derived from this procedure would outweigh the drawbacks of manual transmission.

Transition to such a system would increase the theoretical output of 400 signs a minute at 50 bauds (with the existing code) to 577 signs a minute, which would mean an increase in modulation rate in the present system to 72.2 bauds. On the other hand, since the 6-unit code has a modulation rate of 56.7 bauds, the changeover would increase the theoretical output of 400 signs a minute to 548. This would mean an increase in modulation rate to 77.5 bauds. In these circumstances, the accuracy of the synchronization of the receiver and transmitter is 10^{-3}, which should not exceed the capacities of modern engineering.

Federal German Republic (extract from contribution COM 8, No. 32, May 1958)

2.4. *Teletypesetting.*

Teletypesetting requires that the message be copied with absolute accuracy. Capital letters, small letters, figures and all punctuation signs must be transmitted. Furthermore, many new control signals are needed for the typesetting machine. The 5-unit International Telegraph Alphabet No. 2 cannot satisfy those requirements.

For this reason, the Linotype Company " Teletypesetter " equipment uses a 6-unit alphabet with 64 combinations, which consists of International Telegraph Alphabet No. 2 with the addition of a 6th unit at the beginning of the 5-unit group. When used with letters of the telegraph alphabet, the 6th unit has " start " polarity, and when used with figures, " stop " polarity. Some sequences of these elements are different from those of International Telegraph Alphabet No. 2.

From the point of view of safeguarding the transmission, teletypesetting may be more exacting than the telex service, depending on the type of message (newspaper, periodical, book) and whether or not verification is provided at the receiving station. The Linotype code does not permit of transmission safeguards, as all combinations are already in use. Adequate safeguarding of transmission could be obtained by verifying the message transmitted, as in the case of the 5-unit code, if additional equipment were included in the installations.

3.1. *Five-unit alphabet with 3rd shift.*

By the introduction of a 3rd shift, the number of signals can be increased by 25. Other characters and special functions not included in International Telegraph Alphabet

No. 2 also can be made available. In that case, certain inconveniences in transmission and manipulation must be accepted.

If the 3rd shift is to be put into effect by means of one signal, we can only contemplate the use of combination 32, which is not employed at present (5 times " start " polarity).

It would appear rather dangerous, however, to use this combination for the 3rd shift, as the latter may then be made by interrupting the communication channel. To obviate lengthy mutilation of the text, an automatic device to return the shift to normal would be necessary. Such a solution is feasible and even desirable when the 3rd signal group consists of one national letter. On the other hand, if a national alphabet (Greek letters, for example) has to be included in the 3rd signal group, the automatic device is not required. The number of errors caused by interruptions can be reduced by replacing combination 32 by a secondary combination which is unused or which could be made available. Change of alphabet in telegrams is such a rare occurrence that the use of 2 shift signals (figures shift and 3rd shift) would not complicate the work of the teleprinter.

Some export and import undertakings, for instance, like to exchange messages in the language of foreign undertakings and thus prefer to use teleprinters offering a 3rd row of signs. The German Administration, therefore, proposes that all teleprinters used in the European system should operate the 3rd shift by means of a common combination of secondary signals to be mutually determined. Combination 12, which is not used at present, might be made available for the purpose.

The fact that co-operation is possible between teleprinters equipped with International Telegraph Alphabet No. 2 is an argument in favour of a 3rd shift. This consideration is particularly important given the great number of 5-unit teleprinters which function in the telex networks of all countries.

Amplification of the telegraph alphabet to include the 3rd shift is sufficient when we are concerned only with providing a greater number of national letters or a national alphabet.

For teletypesetting (2.4) and data transmission an alphabet of more than 5-units is essential in view of the greater number of signs and special functions involved.

3.2. *Six-unit alphabet.*

In establishing a new alphabet, the paramount consideration is whether or not it can and should be combined with International Telegraph Alphabet No. 2 and, consequently, whether certain limitations in the choice of the alphabet must be accepted.

From the technical point of view, the best way of establishing a 6-unit alphabet to be operated in conjunction with International Telegraph Alphabet No. 2 is by adding a 6th " stop " polarity unit to existing teleprinter signals and a " start " polarity unit to the new signals, such as capital letters. Inter-working is then made possible—provided the signals are of equal duration—by inserting a regenerator to correct the duration of the signal units. This kind of alphabet is useless, however, when operations require that the keyboard of a 6-unit alphabet teleprinter should be the same as that of an ordinary typewriter.

On a typewriter, a shift is provided for changing from small letters to capitals. Figures and the more usual punctuation signs may be written without changing the shift. Capital letters and other signs, however, are written in the shift position. With a 6-unit alphabet, therefore, it is advisable to assign the various groups in such a way that only one combination is required for each letter. The 6th unit thus differentiates between the primary and secondary positions of the 5-unit alphabet. Combinations of figures come within the secondary group of the new alphabet. If punctuation signs also are included in the secondary combinations, other unit groups can be made available for special functions in both shift positions. This type of alphabet is used by the Linotype Company for their teletypesetter (figure 83).

If unit groups are assigned in this manner, the keyboard may be the same as that of a typewriter. A further advantage of such an alphabet is that the text remains legible even when the shift is wrongly operated.

A combination of this alphabet with International Telegraph Alphabet No. 2 is much more difficult than in the preceding case. Six-unit and 5-unit teleprinters can work together only by means of converters, which also are intended to correct the duration of the units.

In transmitting to a 5-unit teleprinter, the shift signal must be given each time either automatically or by the transmitting operator. In the former event, recording equipment (perforated tape) is required, while in the latter there is the risk of error in operation. The teleprinter, moreover, is fitted with devices which are unnecessary in operations between 6-unit teleprinters (blocking of keys, blocking of unused signs, etc.). On the contrary, when the 5-unit teleprinter sends, the polarity of the 6-unit must be added by the converter independently of the preceding inversion signal. Despite these technical difficulties, the only possible solution for a 6-unit code is to allocate capital letters and small letters to the same combination, as just described.

A six-unit alphabet provides, of course, sixty-four combinations, affording accommodation for twice sixty-four signs and functions. All these facilities are made use of in full for teletypesetting.

The alphabets hitherto described afford no safeguard against disturbance during transmission. Nevertheless, for the 6-unit code as well, there are ways and means of safeguarding the message transmitted to some extent.

3.3. *Six-unit code with increased transmission safeguards.*

With the Federal German teleprinter manufacturers, we have thoroughly investigated the various ways of solving the problems arising with a new 6-unit alphabet affording increased safeguarding of transmission. Figure 84 shows a proposal for an alphabet of this kind. This proposal is based on the following considerations:

The experience acquired in the gentex and telex services shows that mistakes occurring in a plain-language message as a result of short interruptions in the circuit are not felt to be disturbances because the text does not become unintelligible and because the meaning of the text is changed only rarely. But the data transmitted for computers or accounting machines, or numerical data transmitted in a text, must have greater safeguards, because it is not always possible to recognize changes in the signs brought about by a fault. It is quite sufficient if only the important parts of messages are safeguarded (numbers, special signs for calculations and a few special functions), and if the plain-language text is transmitted without safeguards.

The 6-unit alphabet has $\binom{6}{3} = 20$ combinations made up of three " start " polarity units and three " stop " polarity units (see figure 84). If these combinations be assigned to digits, punctuation marks and special functions, accounting data can be transmitted with safeguards when made up of such combinations. Breakdowns due to interruptions can thus be reliably recognized because at least two units of different polarity have to be mutilated in a signal for a false signal to be produced. Safeguarding in telegraph correspondence is thus about 10^{-9}.

Among the *20* signals to be safeguarded, made up, each of them, of three " start " and " stop " polarity units, combinations have been assigned to the *digits 1 to 0* which can be readily transformed into the " 3 excess " code of decimal computers.

The 10 tetrades of the " 3 excess " code each contain one, two or three " stop " polarity units. Hence they can be supplemented by binary groups corresponding to the six combinations each comprising three " start " or " stop " polarity units.

It is just and right to bear the " 3 excess " code in mind. It offers great advantages, especially in connection with the indication of lengthy breakdowns in computers, and is coming into ever-wider use with decimal-code computers.

For co-operation with International Telegraph Alphabet No. 2, we must bear in mind that, for several combinations, we shall have to transform the code. This, indeed, is simple enough if we have properly chosen our 6-unit code.

The proposed 6-unit code, by the temporary use of supervision device, makes it possible to transmit important parts of messages with a high degree of accuracy. Nevertheless, all the other code combinations can still be used. Our experience shows that the 20 protected signs are enough for teletypesetting requirements to be met with the least possible outlay.

If transmission is to be afforded for all sixty-four signals, we shall have to have an alphabet with at least eight units.

3.4. *An eight-unit telegraph alphabet.*

An 8-unit alphabet has $\binom{8}{4} = 70$ combinations, each having four " start " or four " stop " polarity units. The letters and digits and signs and special functions necessary for accounting operations, etc., must be assigned to these. The protection afforded is the same for all combinations, and is exceedingly great. Co-operation with the 5-unit alphabet calls for a transformation of the code for all combinations.

In the start-stop service, when the signals last for 150 milliseconds, the telegraph rate of 70 bauds is relatively high. Hence, a synchronous system is the only possible one to provide safeguarded transmission. The telegraph rate will then be reduced to 53.5 bauds. But a synchronous system requires so heavy an outlay for synchronization equipment and so much time for initial phase regulation that at present it can be used only for station-to-station calls.

3.5. *Summary.*

As regards the need for, and the possibility of, a new alphabet, the following conclusions can, we think, be drawn:

International Telegraph Alphabet No. 2 suffices (with slight modification, if need be) for gentex and telex services. For national letters not accommodated in this Alphabet, and for supplementary national alphabets, a third shift is indicated. This is recommended

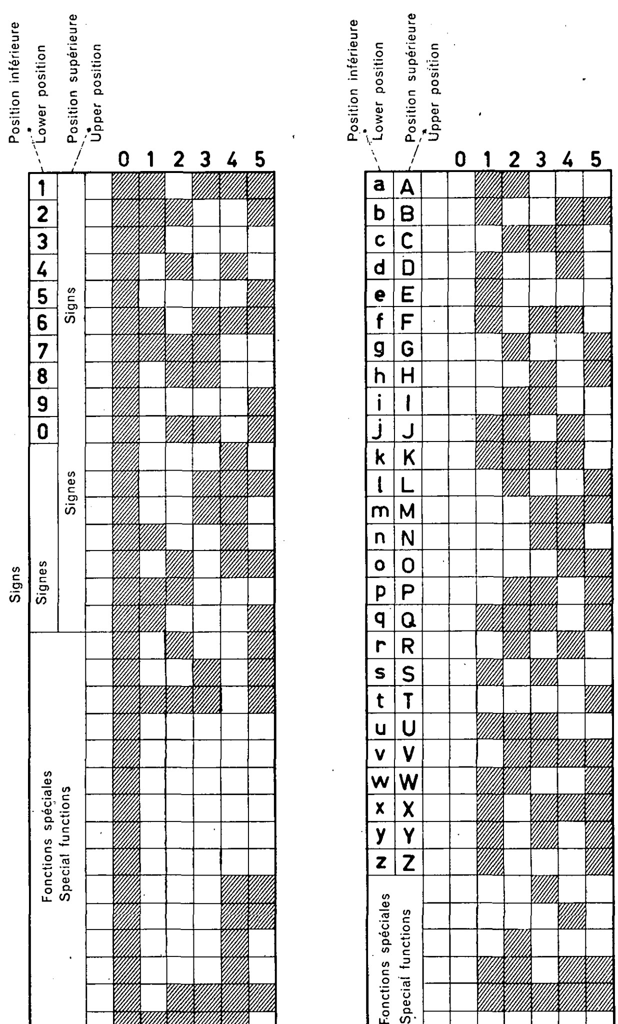


FIGURE 83. — *Principle of the teletypesetter alphabet*

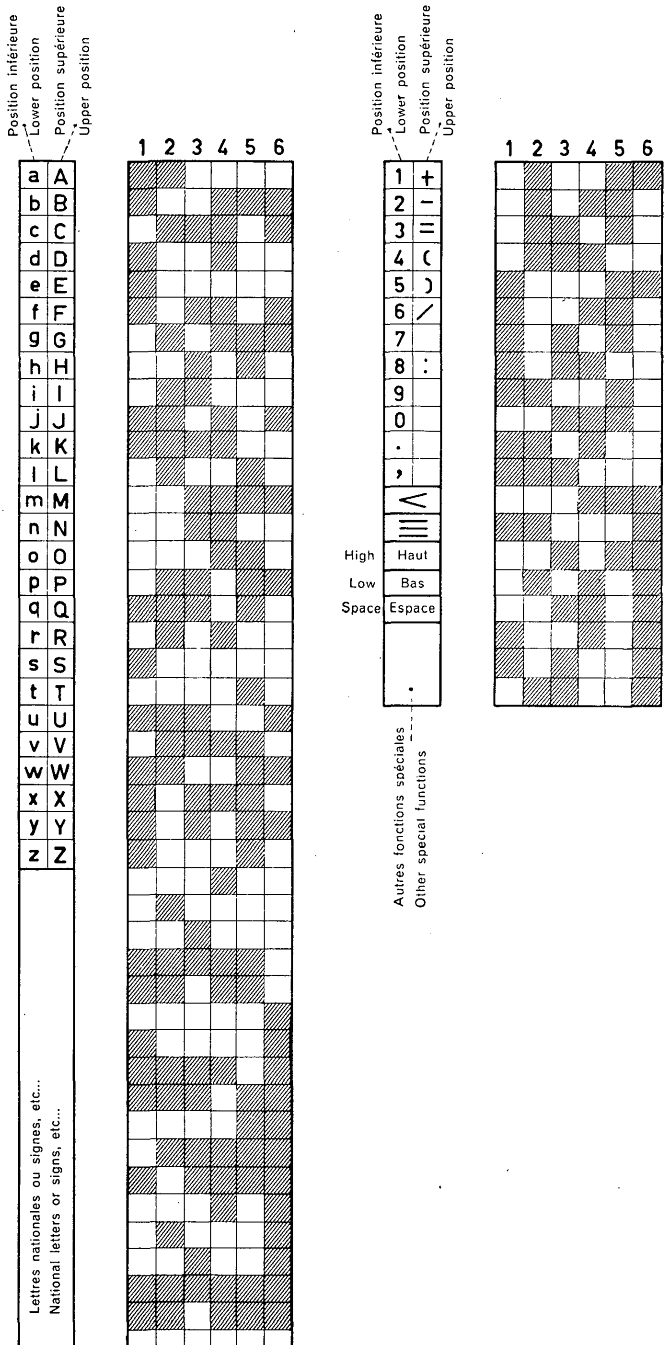


FIGURE 84. — *Example of a 6-unit code offering the protected transmission of digits*

because inter-working between the very numerous 5-unit code teleprinters already in service can be simply effected.

Severe requirements as regards the number of signals or the safeguarding of transmission (teletypesetting, transmission of data for computers, etc.) call for an alphabet with at least 6 units. Inter-working between all 6-unit codes, however well chosen, and International Telegraph Alphabet No. 2 is possible only with extensive code-converting equipment.

Since the teletypesetter alphabet affords no message safeguards, we have suggested (see figure 84) a 6-unit code for teletypesetting and computers and for machines dealing with statistical data. This code, although all combinations are used, affords safeguards for another 20 signals. This protection seems enough for present needs. Only an 8-unit code will provide greater safeguards.

U.S.S.R. (extract from contribution COM 8, No. 34, May 1958)

Constitution of the new code.

The most important problem connected with the introduction of a new code is the problem of inter-working with teleprinters using the International Telegraph Alphabet No. 2.

The constitution of the new code must be such as to facilitate the solution of this problem. The only version satisfying this requirement is the version proposed in Supplements to C.C.I.T. *Violet Book*, page 136; according to this version the arrangement of the characters of the International Telegraph Alphabet No. 2 should be maintained with the addition of the 6th element with a " stop " polarity, and a new group of characters should be formed as a result of the introduction of the additional 6th element with a " start " polarity.

It should be pointed out, however, that even in this case the problem of inter-working is not completely solved. In fact, if a 6-unit teleprinter can work to a 5-unit apparatus without any trouble, then the transmission in the opposite direction will inevitably disturb the correction procedure (figure 85). As a result the automatic working of a 5-unit teleprinter to a 6-unit one will be impossible while manual operation will be possible only at a reduced speed.

Some technical solutions must be therefore found to provide for reliable working in both directions.

Any other version chosen for the constitution of the 6-unit code will necessarily imply the use of code conversion devices. However, these devices appear to be quite unacceptable due to their considerable complexity.

It seems to us that the group of combinations resulting from the addition of the 6th unit with a " start " polarity should be disposed of as follows:

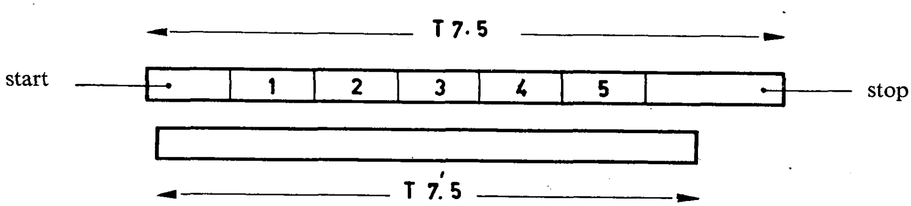
a) Functions should be set apart which should be preferably carried out by the apparatus. To each function a special combination should be assigned.

b) Several combinations should be reserved for special national needs which should not be specified.

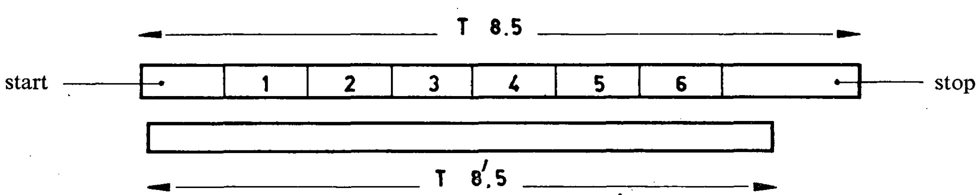
c) The rest of combinations should be set at the disposal of the Administrations.

This decision is based on the following considerations:

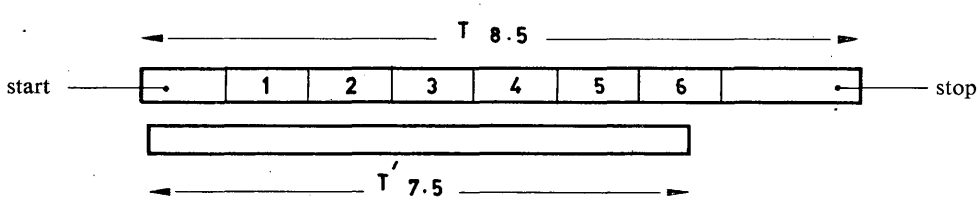
1. It is desirable to assign combinations to single functions because, if this principle is not observed, the inter-working of teleprinters operated by various Administrations may become impossible.



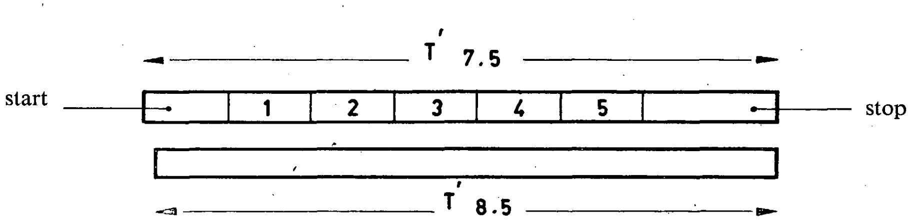
1. 5-unit teleprinter cycle



2. 6-unit teleprinter cycle



3. Cycle of a 6-unit sender inter-working with a 5-unit receiver



4. Cycle of a 5-unit sender inter-working with a 6-unit receiver

FIGURE 85. — *Inter-working of 5-unit and 6-unit teleprinters*

$T_{7.5}$ Duration of a single cycle of a 7.5-unit teleprinter sender.
$T'_{7.5}$ Duration of a single cycle of a 7.5-unit teleprinter receiver.
$T_{8.5}$ Duration of a single cycle of a 8.5-unit teleprinter sender.
$T'_{8.5}$ Duration of a single cycle of a 8.5-unit teleprinter receiver.

2. A group of combinations should be set apart for national use as many nations have to accommodate a greater number of diacritical signs than that provided for by the international code No. 2. As these signs will not be used in international service, they need not be specified.

Poland (extract from contribution COM 8, No. 50, February 1959)

Proposed telegraph alphabet with 6-units and 2 shifts

No.	Series I	Series II		No.	Series I	Series II	
1	A	a		33	&	1	
2	B	b		34	§	2	
3	C	c		35	!	3	
4	D	d		36	;	4	
5	E	e		37	—	5	
6	F	f		38	?	6	
7	G	g		39	:	7	
8	H	h		40	(	8	
9	I	i		41	)	9	
10	J	j		42	.	0	
11	K	k		43	.		for international diacritical signs
12	L	l		44	=		
13	M	m		45	,		
14	N	n		46	/		
15	O	o		47	+		
16	P	p		48	———	backspace	
17	Q	q					
18	R	r		49	*	change in line-space	
19	S	s					
20	T	t		50	%	— » —	
21	U	u		51	°/oo	— » —	
22	V	v		52	»	return to preceding line	
23	W	w					
24	X	x					
25	Y	y		53	who is there	ring	
26	Z	z	available to Administrations for their inland services	54	carriage return		
27				55	change of line		
28				56	shift I		
29				57	shift II		
30				58	space		
31				59	reserve		
32				60	”		
				61	”		
				62	”		
				63	”		
				64	”		

United Kingdom (extract from contribution COM 8, No. 57, June 1959)

1. In view of the very heavy investment throughout the world in 5-unit equipment in the general service and in telex, and the problems which may be expected to arise

should a change from 5 to 6 unit working be contemplated, it is considered that 6-unit apparatus must be expected to come into use gradually. The most important requirement would thus be the facility of inter-working between the two types of teleprinter, that using 5-unit and that using 6-unit codes. The constitution of the 6-unit code should therefore be such as to facilitate as much as possible inter-working but since this paper is concerned mainly with the operational rather than the technical approach to a new alphabet no opinion is offered as to what extent inter-working is practicable and, if so, at what cost in terms of additional terminal equipment.

2. In an alphabet using a 6-unit code with 2 inversions the number of characters or signs available in the two groups is 128 but because it is difficult at present to see clearly the full requirements of the more distant future, say ten to fifteen years hence as suggested by Sub-Group 8, generally only the more obvious requirements have been considered in the possible assignment of combinations of the code.

3. The availability of 128 combinations in upper and lower case would permit the provision on teleprinters of capital and small letters of the Latin alphabet. Any urge for this facility would probably stem from telex subscribers rather than from the needs of the general public service. The use of capital and small letters in the latter service does little, if anything, to clarify the contents of telegrams and the United Kingdom Administration does not regard the provision of both capital and small letters on teleprinters on the public service as of major importance. Nevertheless, if they are to be provided, the capital and small prints of each letter should appear on the same combination as they do on the ordinary commercial typewriter. By this means the consequences of printing in the wrong shift are very largely minimized. It should be pointed out that in the United Kingdom teleprinters print letters in capitals whereas the normal commercial typewriter prints small letters in the lower case and capitals in the upper case.

4. It is desirable that the figures or digits 1 to 0 should appear in the more commonly used lower case but after some consideration of the expressed needs of other Administrations, the United Kingdom Administration would not expect fractional numbers to appear in the same case also although it is recognized that fractions are generally closely associated with whole numbers. It is considered that a stronger case exists for the provision in the lower case of as many accented letters and other letters with diacritical signs as practicable. Yet all letters with diacritical signs and fractional numbers cannot be accommodated in the same case along with the 26 letters of the Latin alphabet, whole numbers and the essential functional signals. The present method of signalling fractional numbers is not considered unduly onerous, but if each of a number of such fractions is to be printed by the operation of a single key, the assignment of such fractions should be in the upper case.

5. Consideration has been given to what special use, if any, might be made of the presence of a number of constant-relation signals in a code of 6 units, of which there are 20, each made up of three " start " polarity and three " stop " polarity units or elements. The number of such signals is too small, however, to be of significant advantage to the public general service or to telex. The problems of discrimination between characters which should have a constant-relation signal and those which do not have such a signal would outweigh any advantage in their use, excepting perhaps in the transmission of data-processing intelligence where that intelligence might consist of characters having three " start " polarity and three " stop " polarity units only.

6. The full extent of the demands that may be made of the public telegraph service, including telex, for the transmission of data processing intelligence is not yet clear. It may be that Study Group 8 has not made sufficient allowance for the needs of firms using computers and accounting machines in its proposed code, and 10 signs might be left unassigned in order to meet unforeseen requirements in this particular field.

7. At least six combinations will be required for the essential functions of line feed, carriage return, space, shift and unshift, bell and WRU. Complete combinations should be assigned to each of these excepting the last two which can be accommodated on the lower and upper case of one combination. An erasure signal should be provided, but the all-space combination 64 should not be assigned to any particular function at this stage.

No provision appears to be necessary for other functions such as underline, line-return, back-space or variation of line-feed either for the general service or for telex.

8. There are a number of countries where the provision of the 26 letters of the Latin alphabet only is inadequate for the essential requirements of the national service. A number of Administrations have therefore indicated characters which might be accommodated in the new alphabet, mainly letters with diacritical signs, in some cases with the capital and small print of the same letter. The full list of these characters considerably exceeds the number which can be accommodated in any 6-unit code. Not all Administrations have the same requirements, however, and if five combinations, in both upper and lower cases, were reserved to Administrations for use on their internal services it is probable that difficulties in meeting requirements in this field would be minimized.

9. All the punctuation signs of the Alphabet No. 2 should be provided for and provision should be made also for the signs of percentage (%), per thousand (‰) and seconds (″).

10. In meeting the foregoing requirements use would be made of 110 signals with 18 signals unassigned. Consideration has been given to the provision of signals for tabulation, signals for the requirements of semi- and fully-automatic switching systems such as start-of-message signal, perforator-insertion and removal signals, a signal to call in the operator on a telex connection, but the assigning of a 6-unit code signal for any of these functions at this stage is not favoured. There is an operational need for such signals but the choice of signals for these requirements is being actively pursued in other studies. It would be preferable to await the outcome of such studies, and leave the assignment of the 18 signals for further consideration.

11. To summarize, the following facilities should be provided by a 6-unit code on teleprinters with 2 inversions:

(i)	Latin alphabet—capital letters	26	signs
(ii)	Latin alphabet—small letters	26	”
(iii)	Digits	10	”
(iv)	Functional signals	12	”
(v)	Reserved for use of Administrations for their internal service	10	”
(vi)	Punctuation and miscellaneous signs, including the all-space combination	16	”
(vii)	Data-processing possible needs	10	”
		110	”
	Unassigned . . .	18	”

12. The proposed new alphabet is tabulated in the Annex attached to this paper.

a) Series II of combinations 27-36 inclusive reserved for the special requirements in the field of the transmission of data-processing intelligence.

b) Complete combinations 53-57 inclusive to be placed at the disposal of Administrations for their internal service.

c) Complete combinations 50-51-52 and series II of combinations 38-49 inclusive available for the possible requirements of tabulation, switching signals for semi- and fully-automatic systems, the special requirements of telex, miscellaneous characters, etc. not otherwise provided for.

ANNEX

Proposed telegraph alphabet with 6-units and 2 shifts

No.	Series I	Series II	No.	Series I	Series II
1	a	A	33	7	
2	b	B	34	8	(a)
3	c	C	35	9	
4	d	D	36	0	
5	e	E	37	%	‰
6	f	F	38	(	
7	g	G	39	)	
8	h	H	40	.	
9	i	I	41	—	
10	j	J	42	/	
11	k	K	43	=	
12	l	L	44	?	
13	m	M	45	,	
14	n	N	46	:	(c)
15	o	O	47	’	
16	p	P	48	»	
17	q	Q	49	+	
18	r	R	50		
19	s	S	51		
20	t	T	52		
21	u	U	53		
22	v	V	54	(b)	
23	w	W	55		
24	x	X	56	Bell: Sonnerie	
25	y	Y	57	WRU: « Qui est là ? »	
26	z	Z	58	Carriage return: Retour de chariot	
27	1		59	Line feed: Avance ligne	
28	2	(a)	60	Shift: Inversion	
29	3		61	Unshift: Suppression d’inversion	
30	4		62	Space: Espacement	
31	5		63	Not assigned all-space: Signal composé exclusivement avec des moments de travail	
32	6		64		

DOCUMENTATION ABOUT PHASE DISTORTION ON CARRIER CHANNELS

Phase distortion on telephone channels of coaxial carrier systems in the United States of America.

The curve of figure 86 shows typical values for the variation with frequency of the group delay, relative to the value at 2000 c/s, for telephone channels in the type L coaxial system. They are applicable in practice to any length of circuit on a single carrier system.

It should be realized that phase distortion is not an important characteristic for telephone circuits and that the attached curve will not necessarily be met for future types of carrier systems.

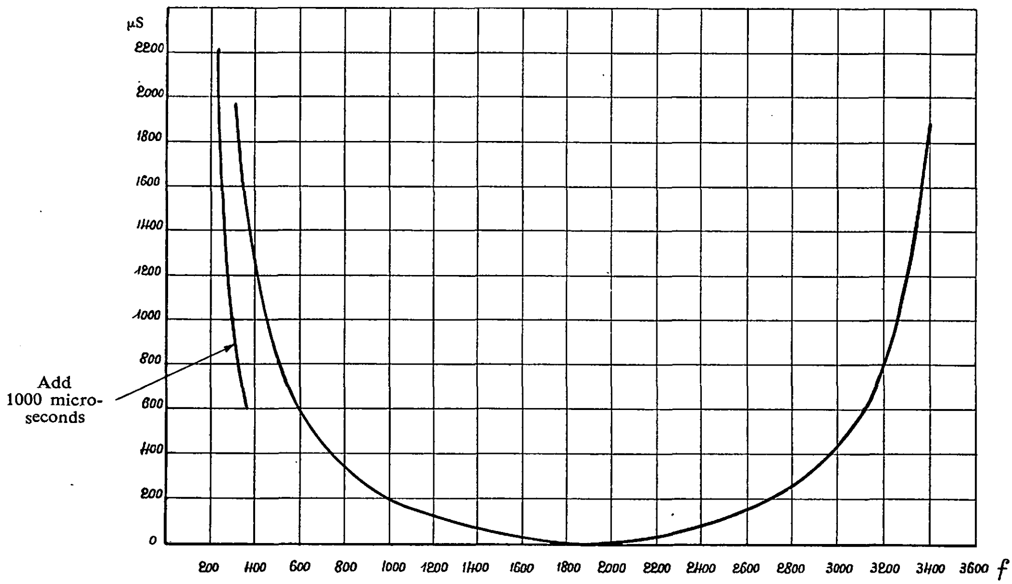


FIGURE 86. — *Variation with frequency, relative to the value at 2000 c/s, of the group delay of a typical telephone channel on a type L carrier system (corresponding to the mean of channels 1—12 for type A2 channel banks)*

f = frequency (c/s) μs = group delay (microseconds)

Phase distortion introduced by various carrier equipment used in Great Britain.

1. The group delay-frequency characteristic of a telephone channel routed on a modern type of carrier system, which effectively transmits the audio-frequency band 300-3400 c/s, is determined mainly by the group delay characteristics of the channel translating equipment (which translates the audio-frequency band to basic group and vice versa). Table 1 which follows gives the characteristic obtained on a channel translating equipment of the type used by the British Administration.

TABLE I

" Group delay frequency " characteristic of a channel translating equipment of the type used by the British Administration

Frequency (c/s)	300	500	800	1200	1800	2400	2800	3100	3400
Group delay (milliseconds) .	3.5	2.1	1.4	1.1	1.0	1.1	1.3	1.7	2.8

Note 1. — The equipment translates from the audio-frequency band to basic group B (60-108 kc/s) and vice versa.

Note 2. — The characteristic is that actually measured on an equipment and is given to show the order of values obtained. The characteristic does not represent a mean value neither does it give the maximum values that would be obtained, nor a specification limit.

2. The characteristic of the circuit, as determined by the number of channel translating equipments through which it passes may be modified to an appreciable extent by other equipment in the circuit and particularly by the frequency band occupied by the circuit in passing through these equipments.

3. A typical installation of equipment used by the British Administration showed the general characteristics given in paragraphs 3.1 to 3.5. The more important differences in group delay usually had the characteristic of a positive or negative slope over the frequency band corresponding to 300-3400 c/s on the channel.

3.1. Equipments which translate from one basic group of 12 circuits to another (e.g. basic group B to A or group A to B) or from basic group to the line frequency range (e.g. the case of carrier systems on symmetric pairs) and equipments which translate from basic group to basic supergroup and from basic supergroup to the line frequency range, may introduce a difference in group delay of the order of 50 microseconds in the worst channels and 10 microseconds in the majority of channels for each pair of modulations or demodulations.

3.2. Each filter passing a group of 12 circuits and having a sharp cut-off (e.g. 24-channel filter for symmetric pairs or through group filter) may introduce a difference in group delay of the order of 1 millisecond on the worst channel and 20 microseconds on most channels.

3.3. Each filter selecting a supergroup of 60 circuits and having a sharp cut-off may introduce a difference in group delay of the order of 50 microseconds for the worst channel and 10 microseconds on most channels.

3.4. 24-channel line links on symmetric pairs comprising cable, amplifiers and equalizers may introduce a difference in group delay of the order of 60 microseconds per 100 miles (about 160 km) for the worst channels and 10 microseconds in most other channels.

3.5. Coaxial line links comprising cable, amplifiers and equalizers introduce a relatively small difference in group delay (less than 10 microseconds per 100 miles) except in supergroup 1 (60-300 kc/s) where a difference of up to about 500 microseconds per 100 miles may occur.

3.6. The difference in group delay on a complete circuit will be determined by the translating equipment, the filters and lines over which it is routed and no standard characteristics can be predicted. Thus for the coaxial cable hypothetical reference circuit the group delay-frequency characteristic will be similar to the characteristic of Table I above but could have approximately three times the magnitude (e.g. if all three pairs of modulations had the characteristics of Table I the overall group delay relative to the minimum value which occurs at about 1800 c/s would rise to about 7.5 milliseconds at 300 c/s and 5.5 milliseconds at 3400 c/s) and this may be modified by a positive or negative " slope " or a combination of both, of up to possibly a few milliseconds. In addition there may be a random variation of the order of a few hundred milliseconds.

Phase distortion on channels of carrier systems in the Netherlands.

This distortion is shown in the curves of figures 87 and 88. Figure 87 refers to the group delay with equipment provided by constructor A. Curve " *a* " refers to channel 1 and curve " *b* " to channel 12 of a basic group. Figure 88 refers to the group delay with equipment provided by constructor B. In the latter case all the channels of the group are about the same.

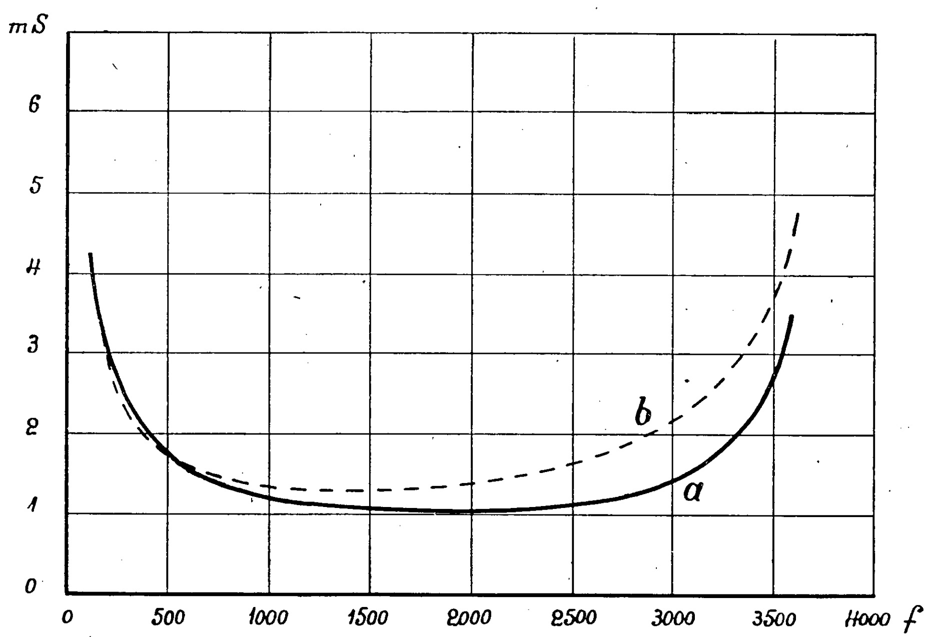


FIGURE 87 (Netherlands — Constructor A)

Curve *a* = channel No. 1 Curve *b* = channel No. 12

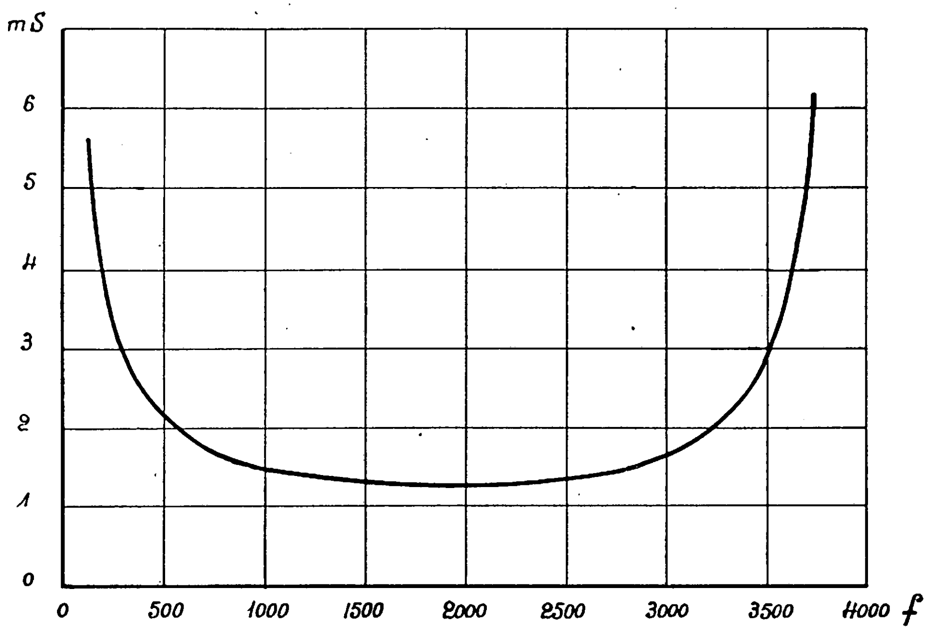


FIGURE 88 (Netherlands — Constructor B). — *Curve applicable to all channels of a group*

f = frequency c/s

ms = group delay (milliseconds)

Phase distortion in telephone channels of symmetric pair cable carrier systems (with 5 basic groups or 12 + 12 type) used by the Federal German Administration.

Figure 89 shows the variation of group delay on a telephone channel of the new German carrier systems for long-distance traffic (the V 60 system providing 60 telephone circuits on symmetric pairs), relative to the minimum group delay. The curves of propagation time (valid also for the edge channels) measured on terminal equipment of different types are contained within the shaded area; for the mean curve shown by the dotted line the variation of group delay is 2.4 milliseconds at the lower end and 1.25 millisecond at the upper end of the transmitted frequency band of 300-3400 c/s.

Case of a hypothetical reference circuit. — If the arrangement of the hypothetical reference circuit on coaxial pairs is applied to symmetric pair carrier circuits, phase distortion on channels 2 to 10 of a group is produced only by the filters of the channel modulating equipment. The phase distortions produced by the triple modulation and demodulation of the channel amount to about three-quarters of the permissible tolerance given by the former C.C.I.F. Recommendations. The difference between the group delay at the frequency under consideration and the minimum group delay must not exceed 10 milliseconds at 300 c/s and 5 milliseconds at 3400 c/s.

Case where groups or supergroups are transferred from one system to another. — The Federal German Administration does not consider that it would be useful further to reduce the limits fixed up to the present by the C.C.I.F., because for the edge channels 1 and 12 of a group, additional phase distortion can be produced by group or supergroup modulating equipment or by the transfer of groups without modulation or demodulation. In the same way for carrier systems on two-wire lines with different frequency bands in the two directions of transmission (for example the German Z 12 N system), additional phase distortion is produced in the edge channel adjacent to the frequency band eliminated by the directional filters which in the case of a large number of intermediate repeaters can result in the permissible tolerance for the propagation time being exceeded.

The phase distortion shown in figure 89 which follows refers to telephone channels which have only one receive channel modulation equipment. Several group and supergroup modulations are permissible. However with filter having a large rise in attenuation in the stop band of frequencies (for example through group filters for the 60 to 108 kc/s band) a small increase can occur in the phase distortion of the edge channels 1 and 12 of the group.

Case of circuits permanently used for phototelegraphy. — If it is ensured that telephone circuits used for phototelegraphy include only one channel transmitting and receiving

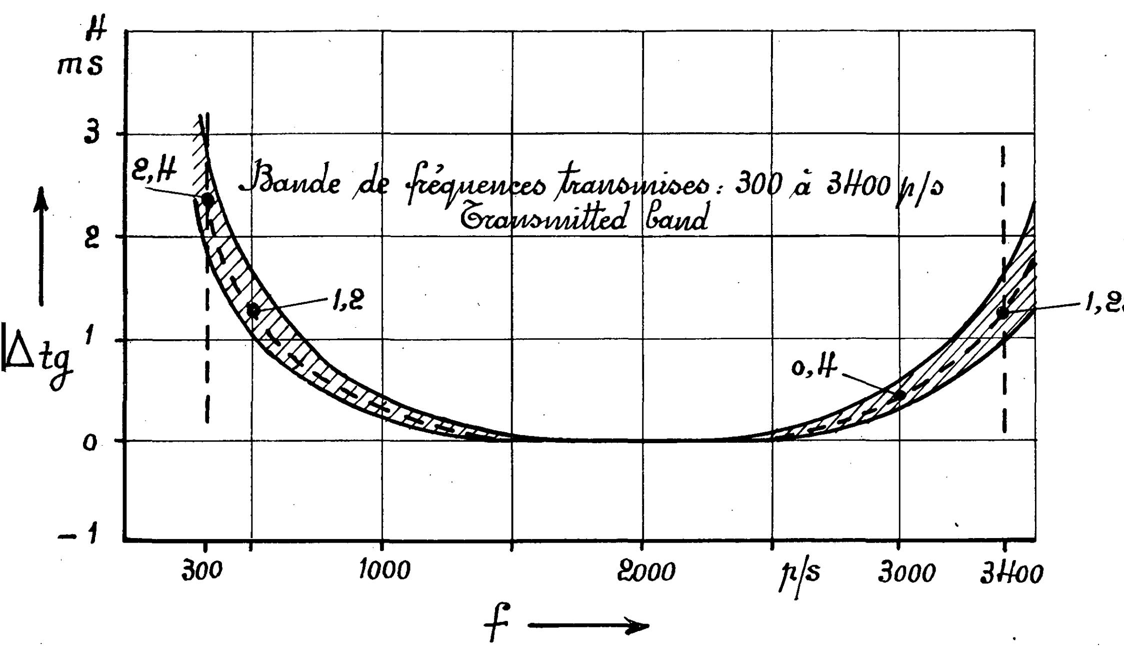


FIGURE 89 (Federal German Republic). — *Variation of group delay on a telephone channel of V 60 systems, relative to the minimum group delay*

f = frequency (c/s)
ms = group delay (milliseconds)
band of frequencies transmitted 300-3400 c/s

equipment and are not edge channels of a group, a very small phase distortion can be obtained, all the more so since the phototelegraphy uses only a part of the carrier channel where the phase distortion is proportionately smaller (much less than 1 millisecond). It is therefore not necessary to fix tolerances. In the case of permanent phototelegraph links it will be possible to meet this arrangement in the majority of cases.

Phase distortion on channels of carrier telephone systems in France.

The French Administration has undertaken propagation time measurements on unloaded symmetric-pair carrier systems (quads specified 9/10).

Paris-Limoges	802 A + 803 A channel 1
	802 M + 503 M channel 12

The measurements made were loop measurements.

On the curves given in the attached figure 90, it will be seen that the group delay distortion does not exceed:

In the band 1000-3000 c/s	± 0.35 ms	for channel 1
	± 0.40 ms	for channel 2
In the band 1000-2350 c/s	± 0.15 ms	for channel 1
	± 0.20 ms	for channel 2.

The minimum distortion appears in the band around 1800 to 2000 c/s.

These figures, which refer to two circuits in tandem, are very liberal. Theory indicates and practice confirms that the transmission of a picture is still satisfactory when the group delay distortion is equal to the duration of the elementary spot.

In the present case let us recall the figures:

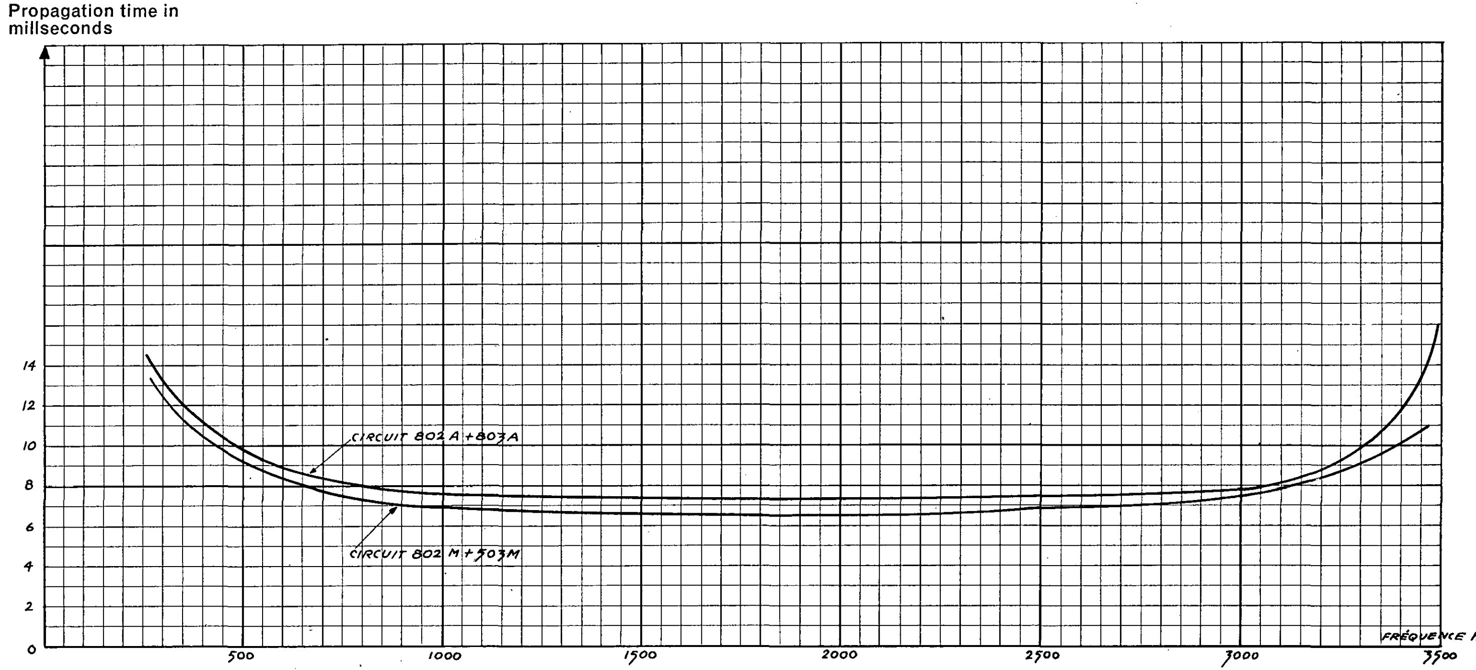
— at index 352, speed 60 r.p.m., the duration of the scanning spot is about 0.9 ms and the band occupied is 1100 c/s.

— at index 352, speed 120 r.p.m., the duration of the scanning spot is about 0.45 ms and the band occupied 2200 c/s.

It therefore seems that by centring the carrier around 1800 to 2200 c/s—for example at 1900 c/s—it should be possible in most cases to operate at 120 r.p.m. with satisfactory results.

These figures should nevertheless be given a reasonable test, and it would be advisable to check that the noise level of the carrier circuits permits correct transmission in every case, bearing in mind the desire of the C.C.I.F. to lower the transmission levels.

Note. — If it is desired to increase the transmission speed, the solution would seem to be to use index 264 at a speed of 180 r.p.m. The French Administration has carried out successful tests in this direction.



TEMPS DE PROPAGATION EN FONCTION DE LA FRÉQUENCE SUR DES CIRCUITS A COURANTS PORTEURS 12 VOIES

PROPAGATION TIMES IN RELATION TO FREQUENCY OF CIRCUITS ON 12 CHANNELS CARRIER SYSTEMS

FIGURE 90 (France)

USE OF ASYMMETRIC SIDEBAND OPERATION FOR PHOTOTELEGRAPHY

Federal German Republic (contribution COM 8, No. 6, November 1957)

1. *Telefax apparatus* [1].

As is well known, asymmetrical transmission occupying the same total bandwidth as modulation with two normal sidebands reproduces details better than the latter, even when transmission speed is greater. This fact would support its use for facsimile transmission with rapid black-white changes as, for instance, in the transmission of telegrams. Nevertheless, it should be ensured that these advantages are not destroyed by phase distortions on the transmission channel, to which asymmetrical transmission is much more sensitive.

The Federal German Administration has already stated why telefax apparatus should always be used without additional phase distortion correctors. The advantages of asymmetrical transmission can thus only be utilized when the transmission channel characteristics make this possible. The curves *a* in figure 91 show admissible propagation time distortions in the case of normal amplitude modulation and the curves *a'* the corresponding values in the case of 1:6 reduction of the upper sideband. The curves *b* show the distortions to be expected with facsimile transmission over *one* channel of the German V 60 carrier systems using respectively form 352 or 264. A comparison of the curves shows that asymmetrical transmission enables the speed to be increased from 1.4 to 1.5 time with respect to symmetrical transmission.

The advantage of asymmetrical transmission would be obvious, were it not that in practice there are communications in which *several* carrier circuit sections are connected in tandem. Hence, with asymmetrical transmission, it would be necessary to bring the filter and the carrier to a lower frequency position, in addition to reducing the speed.

The asymmetrical transmission of facsimile telegraph signals requires that the attenuation of the Nyquist filter should follow a relative complementary curve to the central frequency and that the carrier frequency should be placed as accurately as possible on the centre of the filter slope. It thus imposes stricter conditions than does normal amplitude modulation on the correction of the attenuation distortion of the transmission channel, particularly in the neighbourhood of the carrier, and the stability of the carrier frequency itself.

The Federal German Administration considers that telefax apparatus should be as simple as possible both as regards handling and technical installation, so that subscribers may use them and so that they may be capable of entering into the telephone

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[1] The term telefax, as opposed to phototelegraphy, is taken to mean facsimile telegraph systems limited to the reproduction of black and white pictures without half-tones.

network without supplementary correction of their transmission characteristics. These conditions do not allow asymmetrical transmission to be introduced for the telefax service.

2. *Phototelegraphy.*

From the phototelegraphy point of view, asymmetrical facsimile transmission has the accompanying drawback that black values tend to become grey. This means that the contrast near details is reduced, elimination of which requires special attention in subsequent phototelegraph operations. Photographs often have sudden tone changes between parts differing in density, which are flattened by transient phenemena at the Nyquist filter and appear in a blurred reproduction at the places in question. For this reason the attenuation curve of the Nyquist filter should not have too steep a slope. It is useful to lower the modulation rate simultaneously, which is the same as raising the black level. The Federal German Administration considers that a 1:6 reduction of the upper sideband and a black level less than 12:14 db at the white level would be suitable values.

In carrier current phototelegraphy with a frequency band between 300 and 3400 c/s, a modulation frequency of $f_B = 2400$ c/s (bandwidth = 2800 c/s) will, in these conditions, be the upper limit that can be reached (see figure 92). Such transmission requires, in the 450 to 3250 c/s transmission band, phase balance with an accuracy of $\Delta\tau = \pm\ 0.1$ millisecond in order to ensure that no additional echo-balance will be necessary) see figure 91). Furthermore, an accuracy of $\Delta\tau = \pm\ 0.15$ millisecond on a bandwidth of $F = 1900$ c/s ($f_B = 1650$ c/s) will be the lower limit from which asymmetrical transmission could be contemplated. The technical characteristics which could be recommended for an asymmetrical transmission should hence fall within the limits shown in figure 92. There would then be, with respect to the maximum speed at present feasible, an increase to roughly twice as much in case (*a*) and to 1.5 time in case (*b*).

In asymmetrical transmission, moreover, it must be remembered that the filter slope is in a position where it may already be influenced by the attenuation distortion of the transmission channel. Supplementary compensation of the attenuation distortion (in addition to the phase distortion compensation) will probably be necessary, starting at 2300 c/s.

The Federal German Administration thinks that the question of further study should depend essentially on whether, or to what extent, phase compensation can be obtained by means of a calibrated phase distortion corrector with a control signal permitting rapid adjustment to an optimum value. However, the loss of time involved in adjusting the phase compensation would straightaway cancel out the advantages of faster phototelegraph transmission.

Nor does asymmetrical picture transmission *without* phase distortion correction enter into consideration for phototelegraphy, for the reasons given under section 1.

The Federal German Administration has not so far carried out experimental research on this subject. It first wishes to await the opinion in principle of other administrations. Despite the possible increase in speed, the Federal German Administration, bearing in mind experiments in television transmission over metallic lines, does not tend to use asymmetrical transmission for phototelegraphy. Reasons against such use are:

1. Asymmetrical transmission would entail fundamental changes in all apparatus connected to the European phototelegraph network.

2. All phototelegraph transmitting stations would have to be additionally equipped with a control signal generator and all receiving stations with an oscillograph at least.

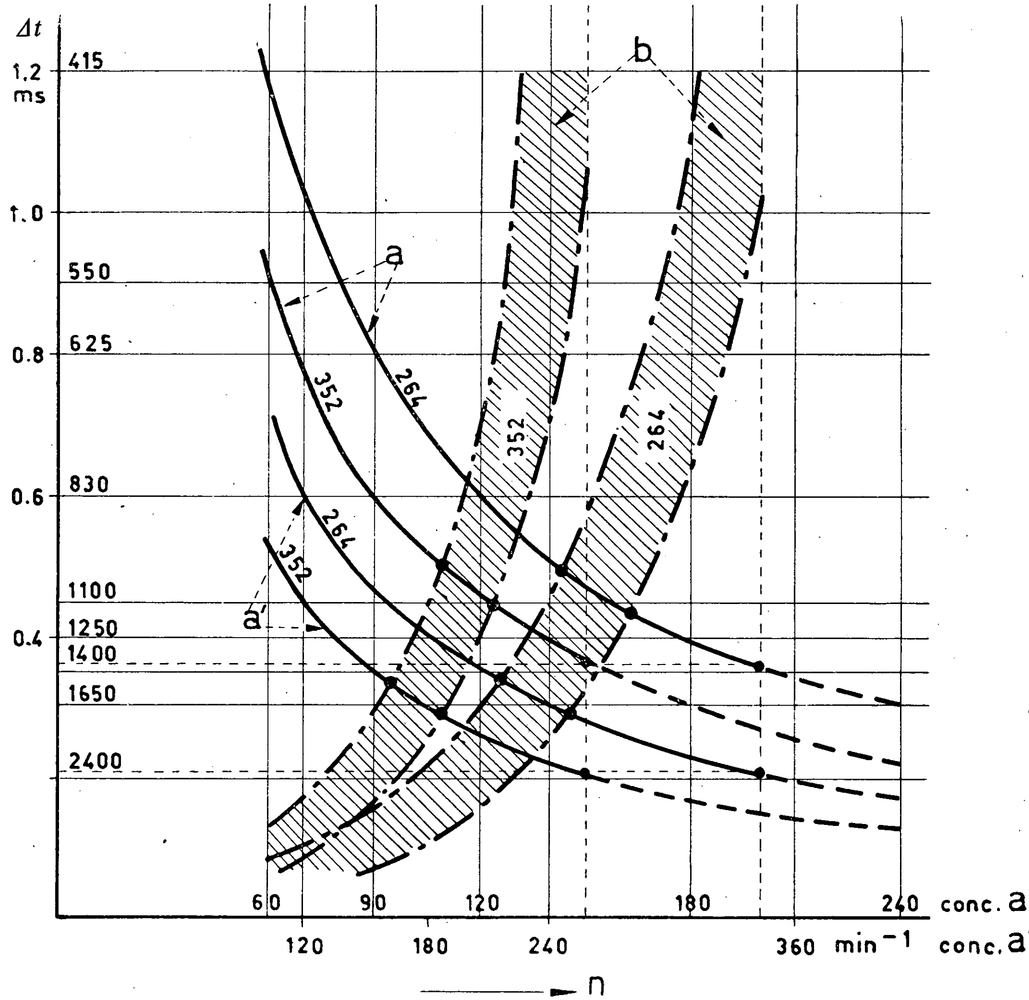

FIGURE 91

a = Distortion of group propagation time admissible with transmission by two symmetrical sidebands.

a′ = The same, but transmission with asymmetric sidebands 1 : 6.

b = Residual dispersion of distortion of group propagation time on a telephone channel on V 60 asymmetric system.

3. For this reason the use of portable phototelegraph transmitting apparatus would become more difficult.

4. The gain in transmission speed is partly lost through the distortion compensation of the transmission channel which precedes transmission of the picture.

5. A reduction in the modulation rate increases the sensitivity to disturbing noise.

6. Should there be a decision in favour of asymmetrical transmission, it would no longer be possible to enjoy the advantages of frequency modulation.

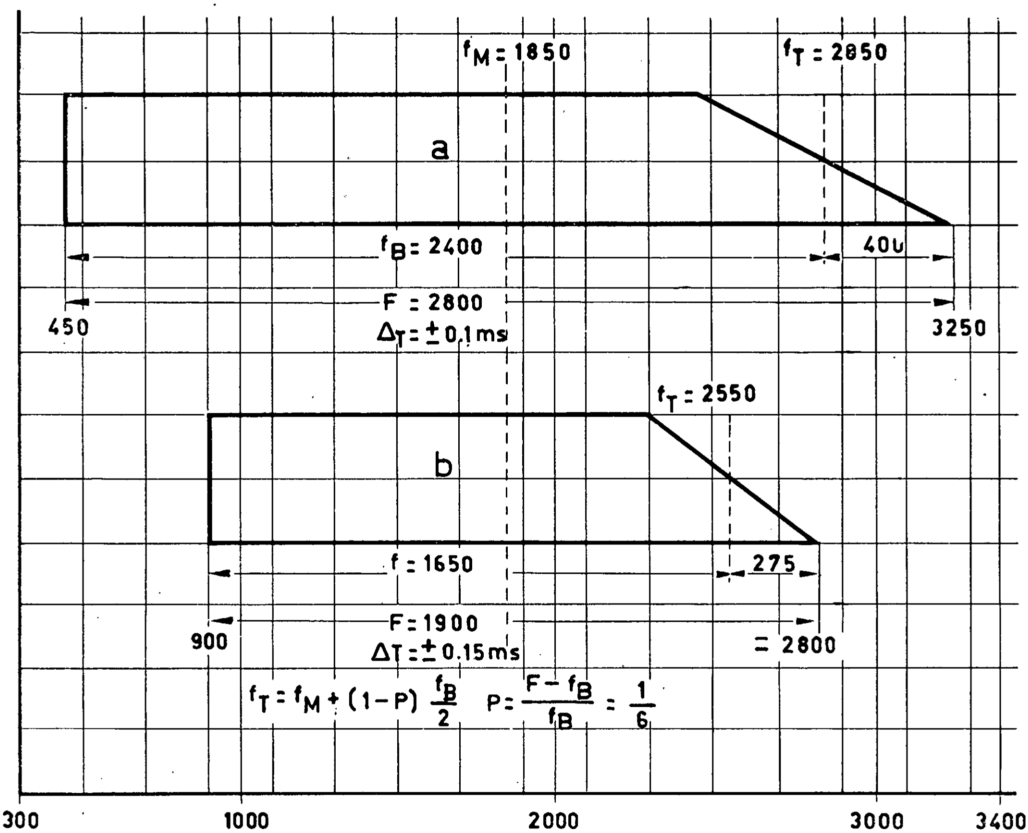

FIGURE 92

a = Characteristics in the most favourable conditions.

b = Characteristics from which the use of asymmetric sideband modulation could be envisaged.

3. *Station-to-station traffic.*

However, the Federal German Administration considers that asymmetrical transmission can be used to advantage and without limitations in the case of links for fixed station-to-station traffic.

TELEX SIGNALLING ON RADIO CHANNELS

(extract from contribution by the Netherlands, contribution COM 10, No. 23, April 1959)
(see Recommendation U.20)

1. *Introduction.*

The fundamentals of telex signalling on radio channels operated by means of synchronous 7-unit systems affording error correction by means of automatic repetition, are laid down in C.C.I.T. Recommendation E.6 *. However, this recommendation should be read in conjunction with C.C.I.T. Recommendation E.1 **, stipulating the signalling conditions on land-line telex circuits. Since the time interval between signals sent on the land-line part of a connection may be shortened or lengthened on the radio part (due to repetitions), special signalling conditions may be expected to arise. Hence a new recommendation covering both the radio and land-line aspect of signalling seems to be desirable. Moreover, detailed information by the C.C.I.T.T. may be very helpful to certain Administrations and Private Operating Agencies taking part in the radio telex service but perhaps having little experience of land-line switching networks. Furthermore, with the gradual introduction of semi-automatic and perhaps in a not too distant future even fully-automatic working, adequate signalling provisions are becoming more and more important.

In the document are considered the signalling conditions on a radio telex circuit terminated at both ends on a type A switching network. In the case of a type B switching network some supplementary provisions will of course be required. However, it is thought that the basic principles will be the same.

It is a question of appreciation and of practical considerations where the actual boundary line between the switching and the radio equipment is drawn. However, for the present contribution the boundary line is of no consequence. In the diagram, " switching equipment " stands for equipment using start-stop 5-unit transmission and " radio equipment " stands for equipment using synchronous 7-unit transmission with error correction.

2. *Call.*

In the case of both-way circuits a call originating in A should be transmitted as quickly as possible to B in order to prevent simultaneous seizure at both ends. Therefore the inversion from " start " to " stop " polarity should initiate the transmission of β signals on the radio path without undue delay.

* C.C.I.T.T. Recommendation U.20.
** C.C.I.T.T. Recommendation U.1.

The fully automatic reperforator transmitter distributor (*FRXD*) in A should be started forthwith in order to enable it to accept subsequent selection signals.

On the radio path disturbances may occur which cause one A-element of a character to be changed into a Z-element and one Z-element of the same character to be changed into an A-element. Such transpositions (which have a small probability of occurrence) cannot be detected by the error-correcting equipment. In order to have a guard against false β signals due to transpositions, only the reception of 2 consecutive β signals in B should be interpreted as a call. This guard against false calling signals was found to be a necessity in actual practice.

The circuit should be busied immediately against outgoing seizure in B after reception of 2 consecutive β signals. Furthermore the *FRXD* in B should be started. Since the *FRXD* should be able to accept the proceed-to-select signal which may follow the call-confirmation signal with a small delay, the inversion from " start " to " stop " polarity on the forward path in B should be delayed until the motor has gained speed.

3. *Call-confirmation signal.*

The switching equipment in B should return permanent " stop " polarity to confirm the receipt of the call. Since the radio equipment contains a guard against false calls it is not necessary in this case to recommend a minimum delay between the receipt of the call and the return of the call-confirmation signal. The maximum delay may be the same as that recommended for land-lines. In the case of manual switching the return of the call-confirmation signal should be independent of the operator answering.

The inversion from " start " to " stop " polarity should initiate the transmission of β signals on the backward radio path without undue delay.

For reasons analogous to those mentioned under 2 only the reception of 2 consecutive β signals in A should cause the inversion from " start " to " stop " polarity on the backward path.

4. *Proceed-to-select or proceed-to-transmit signal.*

In the case of a radio telex circuit terminated on distant automatic switching equipment which cannot accept the selecting information immediately after a calling signal is received, a proceed-to-select signal will be required.

In the case of a radio telex circuit terminated on a distant manual switchboard a proceed-to-transmit signal will be required.

The proceed-to-select or proceed-to-transmit signal should consist of one or more teleprinter signals. For semi-automatic working to the Netherlands the proceed-to-select signal is: figure shift, carriage return, line feed, a 2-digit register number and space. For possible fully-automatic working to the Netherlands the proceed-to-select signal will be: combination 22.

The proceed-to-select or proceed-to-transmit signal sent by the switching equipment in B may follow the call-confirmation signal after a very short delay. Measures should be taken to ensure that at least 2 consecutive β signals precede the proceed-to-select (or transmit) signal received in A. If allowance is made for one transposition in the series of received β signals, 4 β signals should be transmitted to ensure the correct reception of at least 2 consecutive β signals. Hence after 4 β signals have been offered to the storage of the error correcting equipment in B it can be presumed that at least 2 consecutive β signals have been or will be received in A. Thus the transmission of the proceed-to-select (or transmit) signal on the radio path should be delayed until 4 β signals have been transmitted. The period of "stop" polarity preceding the proceed-to-select (or transmit) signal in A will be at least equal to 1 cycle of the synchronous equipment or 145 $^5/_6$ msec.

5. *Selection signals.*

The selection signals should be teleprinter signals on the forward signalling path. It seems to be desirable to recommend figure shift as "prepare for digits" signal and combination 26 as "end-of-selection" signal.

Since the interval between the initiation of the call and the receipt of the proceed-to-select (or transmit) signal will be at least equal to $2 + 4 + 1 = 7$ cycles of the synchronous equipment or $7 \times 145\,^5/_6$ msec. = 1020 $^5/_6$ msec., it is unlikely that a delay in the transmission of the selection signals by the switching equipment in A will be required to allow the motor of the *FRXD* to gain speed. However, a delay may be required in the case where the call-confirmation signal also indicates the proceed-to-select condition. In that case the minimum interval between the initiation of the call and the receipt of the call-confirmation/proceed-to-select signal is equal to $2 + 2 = 4$ cycles of the synchronous equipment or $4 \times 145\,^5/_6$ msec. = 583 $^1/_3$ msec., which may be insufficient for the *FRXD*-motor to gain speed.

6. *Call-connected signal.*

The call-connected signal should be teleprinter signals on the backward signalling path. The following cases should be considered:

a) *Manual working.*

The call-connected signal "*DF*" should be used.

b) *Semi-automatic working.*

The signals "*DF*" could also be used in this case. However, the automatic return of the answer-back code of the called subscriber seems to recommend itself.

c) *Fully-automatic working.*

In addition to the indication that the call has been extended to a called subscriber, the call-connected signal should in this case start the equipment for determining the charge of the call. To this end this signal should preferably have characteristics which can be readily detected.

It is current practice to determine the chargeable time by counting the number of effectively transmitted (i.e. without request for repetition) cycles of the synchronous system. Hence the necessary information for the automatic charging equipment should be furnished by the radio equipment. This requirement cannot be met by the normal equipment for determining the charge of calls over land-line circuits since this equipment may be at a long distance from the radio equipment. It seems that the only possible solution will be the use of ticket printers placed close by the radio equipment. Since the number of these ticket printers will be comparatively small, the requirement for the call-connected signal to be identifiable in a simple way is not as stringent as it is for calls over land-lines.

At first sight it seems desirable to choose a signal outside the teleprinter alphabet. This would lead to the use of a pre-determined number of α signals for the call-connected signal. However, the difficulty is that in order to be sure of the correct reception of a certain number of α signals a larger number of α signals has to be transmitted. At the transmitting end the exact number of correctly received α signals cannot be known. Hence the advantage of using α signals instead of teleprinter signals does not seem to be very important. Moreover, it should be noted that the use of a pre-determined number of α signals has already been excluded in the comments annexed to Question 3/10.

The call-connected signal used in type A land-line switching networks (150 msec. pulse of "start" polarity) would be translated on a radio channel into combination 32 and letter shift. A sequence of these 2 characters, which can be detected fairly simply, could be used as call-connected signal. However, taking into account the possible mutilation of these characters due to transpositions, the best solution will perhaps be the counting of the number of characters in the answer-back code.

The standardization of the call-connected signal for fully-automatic working does not seem to be an urgent matter. However, the problem has been elaborated here in order to verify that in this respect no special requirements will have to be met by the radio equipment. From the above, the provisional conclusion may be drawn that the ticket printing equipment will be able to determine the beginning of the chargeable time by discrimination of a sequence and/or counting a number of teleprinter signals.

7. *Clearing signal.*

A period of at least 130 msec. (6 elements + allowance for maximum distortion) " start " polarity sent by the switching equipment in A could be translated into one or more α signals on the radio path. However, if after the receipt of one α signal in B " start " polarity should be sent to the switching equipment and following signals (not necessarily α signals) should be mutilated, " start " polarity would be maintained until the termination of the error correction. Thus an interruption not effecting the release in the switching network A could cause a clearing signal to be sent to the switching equipment in B. Hence special measures should be taken to prevent false clearing signals from appearing on the radio path.

Therefore the first requirement is that a period of " start " polarity not likely to effect the release in the switching network should not cause the transmission of α signals over the radio path. In general an average period of about 600 msec. " start " polarity will be interpreted as a clearing signal in land-line switching networks. A period of $3 \times 130 + 120 = 510$ msec. " start " polarity will cause the punching of 4 combinations 32 by the *FRXD*. Combinations 32 do not cause teleprinters to print. Thus a good solution seems to be to terminate the punching of the *FRXD* upon receipt of permanent " start " polarity after this signal has caused the punching of 4 combinations 32. After transmission over the radio path of the text which may be stored in the *FRXD* and the 4 combinations 32, α signals should be sent continuously until the complete release of the radio channel. It seems undesirable to extend the period of " start " polarity interpreted by the radio equipment as a clearing signal in order to cover the maximum period of " start " polarity which might be required by the switching equipment as a clearing signal (in the order of 1000 msec.), since it would then become difficult to prevent the punching of an extra character (letter shift, *v*, *m*, *o*, or *t*) after the series of combinations 32.

The second requirement is that only the receipt in B of 2 consecutive α signals should be translated into permanent " start " polarity. This is to prevent the appearance of a false α signal due to transpositions from initiating the transmission of a clearing signal to the switching equipment in B.

8. *Confirmation of the clearing signal.*

The switching equipment in B should return permanent " start " polarity over the backward path after the receipt of a clearing signal over the forward path. Preferably the return of permanent " start " polarity should confirm the complete release of the switching equipment in B.

In general, a minimum interval of 350 msec. between the start of the clearing signal and the return of permanent " start " polarity (prescribed in the third line of paragraph 8 of Recommendation E.1) will be provided by the switching equipment in B. In this case, however, this is not an essential requirement as a sufficiently long interval for the switching equipment in A is already ensured by the delayed transmission of signals over the forward path.

The maximum interval between the start of the clearing signal and the return of " start " polarity provided by the switching equipment in B should be equal to that recommended for land-line circuits. Since the release of automatic switching equipment in A may depend on the return of permanent " start " polarity, a manual switchboard in B should return permanent " start " polarity upon receipt of a clearing signal independent of the disconnection by the operator. The manual switchboard should, of course, meet the requirement stipulated in para. 3 of Article 24 of Recommendation H.1; furthermore, a follow-on call should be confirmed by the return of the call-confirmation signal even in the case where the cord is still plugged.

It is unnecessary to have the α signals over the backward radio path preceded by combinations 32. Therefore the receiving magnet of the *FRXD* in B should be blocked when the α signals over the forward path have been interpreted as a clearing signal.

In the normal case where there is no untransmitted perforated tape in the *FRXD* in B, α signals should be sent over the backward radio path as soon as the permanent " start " polarity returned by the switching equipment in B has been interpreted as a clearing signal.

For obvious reasons the supervisory equipment used to interpret a clearing signal originating in B will also be used in this case. Hence the interval between the inversion from " stop " to " start " polarity and the return of α signals will be at least 510 msec.

A peculiar situation arises if the *FRXD* in B contains perforated tape which has not yet been transmitted. This situation might arise in the case of an interruption (false clearing) in the switching network A or the untimely clearing by the subscriber in A. In any case the return of α signals over the backward radio path (initiating the release of the radio channel) should be delayed until the perforated tape in B has been fed out. The information stored in the perforated tape could be transmitted over the radio path. However, since the aforementioned peculiar situation is most likely to arise in the case of bad radio transmission conditions leading to many repetitions, the feeding out of the tape in this way might take a very long time. Moreover, it is most unlikely that the text transmitted over the radio path will be received by the subscriber in A. Hence it seems better to expedite the release of the radio channel by feeding out the perforated tape at full speed without paying attention to requests for repetition. During the feeding out of the tape the backward radio path should be blocked with β signals.

For the reason mentioned in section 7, the reception in A of 2 consecutive α signals should cause permanent " start " polarity to be sent to the switching equipment in A.

9. *Guard arrangements.*

The condition with α signals on both radio signalling paths should be maintained until the complete release of the switching equipment at both ends.

Until the guard period has elapsed the radio channel should be busied against seizure by a follow-on call from either A or B.

At the terminal where the clearing originated (A) the guard time should be measured from the moment when permanent " start " polarity is transmitted on both signalling paths. Since the α signals on the backward path might be due to a false clearing (interruption) in the network B, an additional requirement for the beginning of the guard period is that, at the moment when 2 α signals have been received in A, a sufficient number of α signals has already been sent by A to have been interpreted as a clearing signal in B. With error-correcting equipment in accordance with the Annex of C.C.I.R. Recommendation No. 167 (Warsaw 1956) it is known after the transmission of 3 α signals whether or not the first α signal has been received correctly. If allowance is made for one transposition in the series of received α signals, 4 α signals should be transmitted to ensure the correct reception of at least 2 consecutive α signals. Hence, after the transmission in A of $3 + 4 = 7$ α signals without request for repetition being made, at least 2 consecutive α signals can be presumed to have been received in B.

At the other terminal (B) the release of the radio channel cannot be deduced from the appearance of permanent " start " polarity on both signalling paths (cf. section 8 above). Here the guard time should be measured from the moment when both permanent " start " polarities are transmitted over the forward signalling path in B and 2 consecutive α signals have been received in A (i.e. after the transmission in B of 7 α signals without request for repetition).

The length of the guard period depends on the release conditions in the switching networks concerned. However, a uniform guard time of about 2 seconds will probably cover the requirements of all existing switching networks.

From the above it might be concluded that a separate wire is required to signal the busy condition of the radio channel to the switching equipment. Such a requirement would be rather onerous in the case where there is a great distance between the switching and the radio equipment. However, it is possible to measure the guard time in B from the moment when " start " polarity has appeared on both signalling paths. In that case the radio equipment should delay the transmission of the calling signal over the radio path until the guard period has elapsed. Thus an extra delay in the return of the call-confirmation signal may be expected. Therefore the previously described method is to be preferred wherever possible.

PART II

DATA TRANSMISSION

SERIES V RECOMMENDATIONS

RECOMMENDATIONS CONCERNING DATA TRANSMISSION

RECOMMENDATION V.1.

EQUIVALENCE BETWEEN BINARY NOTATION SYMBOLS AND THE SIGNIFICANT CONDITIONS OF A TWO-CONDITION CODE

(New Delhi, 1960)

Binary numbering expresses numbers by means of two digits normally represented by the symbols 0 and 1. Transmission channels are especially well suited to the transmission of signals by a modulation (or a semation) having two significant conditions (two-condition modulation). These two significant conditions are sometimes called " space " and " mark " or " start " and " stop ", or they may be called condition A or condition Z *.

It is very useful to make the two conditions of a two-condition modulation correspond to the binary digits 0 and 1. Such equivalence will facilitate the transmission of numbers resulting from binary calculation, the conversion of codes for binary numbers and of codes for decimal numbers, maintenance operations and relations between transmission personnel and the personnel in charge of data-processing machines.

At first sight, it does not seem to matter whether the symbol 0 corresponds in transmission to condition A or condition Z, the symbol 1 then corresponding to condition Z or condition A or vice versa.

In telegraphy however, when a telegraphic communication is set up and the sending of signals is stopped (called the idle condition of the line), the signal sent over the line consists of condition Z throughout the suspension of transmission.

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* Definitions of condition A and condition Z: *List of Definitions* — Part I — No. 31.38.

It is logical (and for certain V.F. telegraph systems also essential) to use the same rule in data transmission. During the " idle periods " of transmission, condition Z should be applied to the circuit input.

Data transmission on a circuit is often controlled by perforated tape. On perforated tapes used for telegraphy, condition Z is represented by perforation. When binary numbers are represented by means of perforations, it is customary to represent the symbol 1 by a perforation. It is therefore logical to make this symbol 1 correspond to condition Z.

For these reasons, the C.C.I.T.T.,

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

1. In transmitting data by two-condition code, in which the digits are formed using binary notation, the symbol 1 of the binary notation will be equivalent to condition Z of the modulation, and the symbol 0 of the binary notation will be equivalent to condition A of the modulation.

2. During periods when there is no signal sent to the input of the circuit, the circuit input condition is condition Z.

3. If perforation is used, one perforation corresponds to one unit interval under condition Z.

4. In accordance with C.C.I.T.T. Recommendation R.31, the sending of symbol 1 (condition Z) corresponds to the tone being sent on a channel using amplitude modulation.

5. In accordance with C.C.I.T.T. Recommendation R.35, when frequency modulation is used, the sending of symbol 0 corresponds to the higher frequency, while the sending of symbol 1 corresponds to the lower frequency.

Summary table of equivalence

	Digit 0 " Start " signal in start-stop code Line available condition in telex switching " Space " element of start-stop code Condition A	Digit 1 " Stop " signal in start-stop code Line idle condition in telex switching " Mark " element of start-stop code Condition Z
Modulation by interruption of direct current	No current	Positive current
Double-current modulation	Negative current	Positive current
Amplitude modulation	Tone-off	Tone-on
Frequency modulation	High frequency	Low frequency
Perforations	No perforation	Perforation

(V.1)

RECOMMENDATION V.2.

POWER LEVELS FOR DATA TRANSMISSION OVER TELEPHONE LINES

(New Delhi, 1960, Recommendation H.41, Volume III of the Red Book)

The choice of power levels recommended for data transmission has been influenced by the following considerations, mainly based on the load on carrier systems:

i) When introducing a new mode of working into the telephone system, it is essential to avoid disturbances to widely established practices.

ii) Power levels should be kept low to avoid overloading on carrier telephone systems, and crosstalk.

iii) On the other hand, a relatively high level will assist designers of data-processing and data-transmission systems in establishing this new service, particularly with respect to the important requirement of reducing errors.

iv) The difference between maximum and mean signal levels will be smaller for data transmission than for speech.

v) Data-transmission traffic is unlikely for some years to exceed a small proportion of general traffic, and therefore its contribution to the summation of power on any carrier-telephone system is expected to be small.

vi) The attention of designers of data-transmission systems should be drawn to the need for reducing the load on carrier-telephone systems; this reduction may be assisted in the following ways, for example:

  a) When data is not being transmitted (apart from temporary idling) the data signal might be turned off or reduced in power.

  b) In those systems, probably the majority, where at any one time the main flow of data is in one direction, it might be possible to use reduced power for control or checking signals flowing in the reverse direction.

For these reasons, the C.C.I.T.T.

UNANIMOUSLY DECLARES THE FOLLOWING VIEW:

A. *Data transmission over leased telephone circuits (private wires) set up on carrier systems*

1. The maximum power output of the subscriber's apparatus into the line shall not exceed 1 mW.

2. For systems transmitting tones continuously, for example frequency modulation systems, the maximum power level at the zero relative level point shall be – 10 db. When transmission of data is discontinued for any appreciable time, the power level should preferably be reduced to – 20 db or lower.

3. For systems not transmitting tones continuously, for example amplitude-modulation systems, higher levels, up to – 6 db at the zero relative level point may be used provided that the mean power during the busy hour on both directions of transmission added does not exceed 64 microwatts (corresponding to a mean level of – 15 dbm0 on each direction of transmission simultaneously). Further, the level of any tones above 2400 c/s should not be so high as to cause interference on adjacent channels on carrier-telephone systems.

Notes.

i) In suggesting these limits, the C.C.I.T.T. has in mind that the recommended maximum level of – 5 db referred to the zero relative level point for private circuits for alternate telephony and telegraphy may no longer be acceptable having regard to the recommendation that " To avoid overloading carrier systems, the mean power should be limited to 32 μW if such systems are subject to considerable extension ".

ii) The proposed limit of – 10 db for continuous tone systems is in line with the existing Recommendation T.11 of the C.C.I.T.T. for frequency-modulation-phototelegraph transmissions.

iii) It is not possible to give any firm estimate of the proportion of international circuits which will at any time be carrying data transmissions. If the proportion should reach a high level, the provisional limits now proposed would need to be reconsidered.

B. *Data transmission over the switched telephone network*

1. The maximum power output of the subscriber's apparatus into the line shall not exceed 1 mW.

2. For all types of system, e.g. frequency modulation, amplitude modulation, etc., the maximum power level at the zero relative level point on the first trunk-carrier system, in the chain of national and international circuits, shall not exceed – 6 db. Further, the level of any tones above 2400 c/s should not be so high as to cause interference on adjacent channels on carrier-telephone systems.

Notes.

i) On switched calls the loss between subscribers will sometimes be high, e.g. 30 to 40 db; the received signals will then be at a very low level and liable to interference from dialling impulses etc. on other circuits. It is therefore important that the transmitter level shall be as high as possible.

ii) With the output from the terminal equipment limited to 1 mW the level at the input to the first trunk-carrier system will often be lower than the proposed maximum figure of – 6 db. The subscriber's line alone may reduce the signal level to about – 8 db.

iii) The international telephone network will include circuits fitted with echo suppressors, and systems intended for unrestricted use will not be able to transmit in both directions simultaneously; the circuit activity cannot then exceed 50 % and may be as low as 25 %. The level of −6 db proposed above is therefore not out of line with the limit of −10 db proposed for frequency-modulation, etc., systems on private wires as these can have a higher activity.

iv) If the demand for switched, data transmission, international calls should become very high, some Administrations may wish to provide special four-wire subscriber's lines. The levels used might be those proposed for leased circuits.

QUESTION ENTRUSTED TO SPECIAL STUDY GROUP A: DATA TRANSMISSION

Chairman: Mr. J. RHODES (United Kingdom)

Vice-Chairman: Mr. H. E. VAUGHAN (United States of America — American Telephone and Telegraph Co.)

Question 1/A — Data transmission.

(continuation of question 43 of S.G. 1 and 8, 1957-1960)

What general characteristics should be standardized to permit international data transmission?

ANNEX TO QUESTION 1/A

Study programme for further study of the Question:
Points for special study and recommendations on the tests to be made

General studies

A. For transmitting data over international telephone or telegraph circuits what are the basic aspects which should be standardized?

B. (Background information.)

For general information, what types of data transmission facilities are available for national use over:

a) private circuits?

b) switched networks?

C. To enable telex subscribers to exchange data and to ensure that such a facility is available without distinction to the greatest possible number of subscribers, is it desirable to recommend:

a) a standardized international telegraph alphabet for data?

b) an international error-detection or error-correction code?

If so, what should be the code and the alphabet, and what general characteristics should be recommended for the error-correction system?

D. To enable telephone subscribers to exchange data and to ensure that such a facility is available without distinction to the greatest possible number of subscribers, is it desirable to recommend:

a) a standardized international telegraph alphabet for data?

b) an international error-detection or error-correction code?

If so, what should be the code and the alphabet, and what general characteristics should be recommended for the error-correction system?

E. Considering that the presence of noise and interruptions will result in errors in transmission which will need to be corrected by repetition and that the repetition process will need to be initiated by supervisory signals:

> Is it necessary, from the user's point of view, that an immediate indication should be provided at the transmitting station if the reception of data is interrupted due to a disconnection, or a faulty condition? If so, how should this be done?

F. How should the quality of circuits for data transmission (excluding terminal modulator/demodulator equipment) be assessed, and what agreement is necessary on the measuring techniques involved for:

a) putting circuits into service for data transmission?

b) carrying out routine maintenance measurements?

This study should include both telegraph and telephone circuits. Switched and point-to-point circuits should be stuided. The quality should be defined in the same terms in all cases though the terms may be given different values according to the system (point-to-point telegraph circuit, switched telegraph circuit, point-to-point telephone circuit, switched telephone circuit).

To enable Administrations to check and maintain the standards of quality mentioned above, there should be a standard type of modulation and one or two standard speeds.

(1/A)

What type of modulation and what speeds should be recommended?

What standards should be met by the modulating and demodulating equipment?

If necessary, the transmission system to be used on the repetition control circuit should be specified.

Note. — In other telecommunication services, it has been found convenient to subdivide responsibility for different aspects of the service: this may be expected to be the case for the data service, separating the line from the terminal equipment. The study of the question of how to assess the quality of lines for data transmission and of what agreement is necessary on the measuring techniques involved will facilitate the division of responsibility.

Studies applying to the telegraph network

G. For the purpose of data transmission, it is useful for it to be known what quality of service can be expected from a 50-baud telegraph circuit standardized in accordance with C.C.I.T.T. recommendations.

For the purpose of working out suitable error-detection methods for data transmission systems, it would be useful for Administrations to make measurements of the error rate on elements.

To this end, they could use either (or both, if feasible) of the following methods:

First method:

Send standard start-stop code signals using an automatic telegraph transmitting apparatus, and receive these signals on a reperforator.

(The apparatus should send signals with gross output distortion of less than 10% with continuous repetition; the margin of the receiver should be greater than 35%.)

Deduce, from an examination of the perforations, the number of errors in the elements, their distribution as single, double, triple errors, etc., and the distribution of the intervals between consecutive errors.

Second method:

Send long series of unit elements (bits) by means of synchronous telegraphy. At the output, compute the wrong elements in terms of single, double and triple wrong elements, and the intervals (in number of units) between consecutive errors.

Deduce therefrom the mean number of errors

per group of 5 elements,
per group of 10 elements,
per group of 100 elements,
per group of 1000 elements.

This latter method requires special apparatus which is not necessary for the first method. It has the advantage however that the same apparatus could easily be used for measurements with modulation speeds other than 50 bauds, such as 100, 200, 600, 1000 bauds, etc.

With both methods, the results should be grouped in terms of circuits having the same structure, i.e. circuits with the same number of voice-frequency telegraph channels and using the same sort of modulation (amplitude of frequency).

Periods in which the circuit may be considered to be " out of service " should be ignored when the test results are evaluated. Such periods would be indicated in the test report (duration, time of occurrence, and, if possible, the cause).

It was agreed that time intervals in which a " start " polarity is received for more than 300 milliseconds should be considered as " out of service ".

To establish an error-detection system well suited to requirements, it is necessary to know the " fine structure " of errors, i.e. their probability of being grouped as a single error (one mutilated elementary interval), a double error (2 consecutive mutilated elementary intervals), a triple error (3 consecutive mutilated elementary intervals), etc., as well as the probability distribution of the correctly transmitted numbers of elements separating the mutilated elements.

H. Similar measurements to those requested under G for 50-baud circuits should be undertaken by Administrations on 75, 100, or 200-baud telegraph circuits.

The second method described under G should be easier to apply in these cases.

I. The question of using the telex network for data transmission should be studied according to the following programme:

1. A telex call will be set up between the calling and called subscribers in accordance with the procedure recommended by the C.C.I.T.T. for setting-up and checking a telex call by the interchange of answer-back signals (C.C.I.T.T. Recommendations E.1 and F.60).

2. If one of the subscribers wishes to introduce data-transmission equipment on the connection, he will send an Alphabet No. 2 signal sequence to cause the transmitting or receiving-data equipment to be brought into circuit at either the receiving or the sending end.

   This sequence has to be decided.

   If the connection involves the use of a radio channel with an automatic error-detection device transmitting delay signals (see C.C.I.T.T. Recommendation U.22), the sending of the waiting signals should be suppressed by sending the HHHH sequence (in start-stop code No. 2). This sequence should be sent before the sequence that brings the data transmission equipment into circuit.

3. For some international communications, the possibility of the telex connection being routed over radio channels employing ARQ, time division synchronous system, or over regenerative repeaters, makes it essential to restrict the transmission to 7½-unit start-stop signals.

   Due to this limitation, data transmission should be restricted either:

   a) to Alphabet No. 2 or

   b) provisionally to any other 5-unit start-stop alphabet which is arranged so as not to conflict with established practice in the telex network (and especially with that described in para. 5 below). For the benefit of users of the international service a standardized 5-unit start-stop data alphabet seems to be desirable. The corresponding code would be drawn up by agreement between Administrations and data-processing machine manufacturers; error detection should be included.

4. At the end of the data transmission, the return to the normal telex connection would be controlled by sending combination 6 of Alphabet No. 2 repeated 4 times (FFFF).

   The connection between the telegraph apparatus could then be renewed using Alphabet No. 2.
   *

5. Users of a special alphabet as described under 3 *b)* may make up their alphabet as they wish, provided that its composition respects the conditions outlined under 3, and that the following code combinations of Alphabet No. 2 are not used for data transmission:

   Combination 6, repeated 4 times (FFFF),

* The question of a special signal for the change of code should be examined.

Combination 8, repeated 4 times (HHHH),

Combination 28, followed by 4 combinations 27,

Combination 32, repeated 3 or more times.

6. Before the end of the call, the subscriber who has sent the data will cause the answer-back of the station of the other subscriber to be sent; the clearing signal will be given as in the telex service.

7. Equipment for the transmission and reception of data must satisfy the conditions set out in C.C.I.T.T. Recommendation S.3 relating to start-stop apparatus.

8. The possibility should be studied of using, with certain limitations, codes falling outside Alphabet No. 2 (6, 7 and 8-unit codes), (study to be considered in conjunction with manufacturers of data-processing equipment).

J. Is it considered that there is a need for a slow speed (i.e. rate of transmission up to 200 bauds) duplex data-transmission system for operating alternately with speech over a telephone type circuit on the normal international switched network? If so, what characteristics should be specified for the modulating and demodulating equipment (i.e. the terminal equipment which at the subscriber's premises accepts serial data signals and modulates the carrier for transmission over the line and vice versa)? In this respect consideration should be given to the following:

a) Rate of transmission,

b) Type of modulation,

c) Frequencies to be employed taking into consideration existing telephone signalling systems,

d) Level of signal tone,

e) Arrangements required to permit duplex working whichever station originates the call,

f) Procedure for initiation of commencement of transmission of data signals,

g) An alarm for indicating loss or failure of transmission path.

Note. — A suitable system might have the following characteristics:

a) 50 to 200 bauds,

b) Frequency modulated with deviation of ± 100 c/s or ± 120 c/s, shift convention to be consistent with V.1 Recommendation,

c) To be chosen from the frequency band 900–1900 c/s. The bandwidth of each unidirectional channel might be 480 c/s,

d) As proposed by Recommendation V.2,

e) It will be apparent that for both-way communication frequencies will be required for:

subscriber A to signal to subscriber B—say f_1,
subscriber B to signal (reply) to subscriber A—say f_2.

For free choice of interconnection therefore each equipment must provide for both f_1 and f_2 to be used in either direction. The convention must therefore be established that, say, the

caller uses the lower frequency f_1 and the
called subscriber the higher frequency f_2,

f) The telephone call might be set up initially in the normal manner, the data-transmission equipment being then manually or automatically switched into circuit, *g)* An alarm might be given on the failure of the incoming tone (i.e. circuit interrupted).

Studies applying to the telephone network

K. What are the relative advantages and disadvantages of the various forms of modulation for the transmission of data over:

a) leased telephone-type circuits?

b) telephone-type circuits in a switched network?

Test programme for data-transmission systems on telephone-type circuits

L. It would be difficult and probably undesirable to establish a rigid test specification but nevertheless some guiding principles can be given for future tests.

1. *Preliminary laboratory tests.*

The recommendations given below apply to systems which have already been subjected to the normal laboratory tests applied to new transmission systems.

2. *Arrangement of the test connection.*

It is possible to set up the test connection on a point-to-point basis or in the form of a loop. The former arrangement most closely resembles the practical case but there are serious difficulties involved in transporting equipment and personnel.

A satisfactory form of loop testing can be achieved by connecting the transmitting apparatus to a distant point by means of a high quality circuit producing no noise or attenuation in the test conditions. The return circuit to the receiving apparatus can be set up in a variety of ways as detailed later.

3. *Modulation rate.*

It is recommended that proposed transmission systems should be tested in one or more of the following ranges:

500- 750 bauds
1000-1500 bauds
2000-2500 bauds.

Speeds higher than 2500 bauds may be required, but it is too early to suggest ranges over which tests at such higher speeds might be carried out.

4. *Signal level.*

It is recommended that the tests should be made at the signal level of Recommendation V.2. Additional tests should be carried out at levels 6 db above and below the level proposed. In the event that no particular value of signal level is recommended, systems should be tested on the basis of a signal level of – 10 dbm0 with auxiliary tests at levels 6 db above and below this value. Tests at 6 db above the recommended levels should be made only if they do not cause interference with other circuits.

5. *Sampling of test circuits.*

The system performance tests should be carried out on a selection of samples totalling not less than the quantities shown in the following table:

Range	Rented circuits	Switched circuits
500 - 750 bauds	2×10^7 bits	4×10^7 bits
1000 - 1500 bauds	4×10^7 bits	8×10^7 bits
2000 - 2500 bauds	8×10^7 bits	2×10^8 bits

For the rented circuits the samples chosen should be representative of the facilities likely to be frequently used in practice.

For the switched circuits the tests should include at least 25 different connections which are representative of the facilities likely to be experienced in practice.

The tests should be restricted to the business hours of normal working days and the samples should be representative both of the working day and the different attenuation conditions which may be experienced in practice.

Tests should also be made on long and complicated circuits.

No special maintenance should be carried out on circuits.

6. *Test message.*

It is recognized that there would be some advantage in using a standard message, but in view of the fact that those who have undertaken the most testing hitherto considered that it was of value to be able to change the message from time to time, it was decided to state, for information, the three methods for which preference has been shown, namely:

i) A short message (e.g. 8 bits) which is continually repeated but which is capable of rearrangement manually.

ii) A short message (e.g. 8 bits) which is continually changing and is essentially a random character generator.

iii) A longer message (e.g. 64 bits) made up of several different sections each containing a different characteristic. This message is repeated unchanged but is capable of being changed manually.

7. *Error record.*

It was agreed that there are two possible forms in which the error statistics might be recorded:

i) A complete fault statement including the exact position of all faults. Such raw material could be used for a variety of statistical studies necessary for the overall design of a data-transmission system.

ii) A simplified fault record indicating totals for a number of predetermined parameters which could be easily obtained during the testing process.

It was agreed that the complete fault statement was preferable for general assessment and essential for the evaluation of the error-detection part of the system. The simplified record will be valuable for the comparison of different data-transmission systems and line facilities.

8. *Block size.*

For comparison of results, it is recommended that a block of about 250 bits should be used for the ranges 500-750 bauds and 1000-1500 bauds, and a block of about 500 bits for the range 2000-2500 bauds. In many instances, it may be of interest to test and report on the basis of a smaller block (about 64 bits).

9. *Presentation of results.*

It is recommended that for all tests the following statistics should be recorded:

i) the total number of bits and blocks transmitted,

ii) the total number of bits in error,

iii) the total number of blocks in error.

10. *Information concerning connections used for test.*

It is desirable that characteristics of the connections used for data tests should be obtained by monitoring and by measurement. For example, if the transmission of data causes any unwanted operation of signalling equipment with a consequential adverse effect on the stability of the connection, this should be recorded. Similarly it should be recorded if the reception of the test message is adversely influenced by warning tones, metering signals, etc. The presence and extent of switch noise, dial impulses and random impulse noise should be noted. The level of the signals at the receiving apparatus, the level of white noise and, if possible, noise bursts, attenuation distortion and phase distortion, should also be recorded.

11. *Interruption of the connection used for the test.*

It was agreed that in the event of the connection used for the test being interrupted for a period exceeding 300 milliseconds, it should be considered that the connection was " out of service " during such an interval.

12. *System description.*

It is recommended that the performance results should be accompanied by a brief description of the basic characteristics of the data-transmission system undergoing test. In addition, a short explanation of the method of testing used would be advisable.

M. Study of the compatibility of transmission methods and telephone signalling.

N. Study of the problem raised by transmission time and echo suppressors.

Vocabulary

O. Preparation of an international vocabulary for data transmission.

SUPPLEMENTS TO RECOMMENDATIONS AND QUESTIONS CONCERNING DATA TRANSMISSION

(Contributions received during 1957-1960 which are published on account of their special interest)

SWEDEN: DESCRIPTION OF PHASE MODULATION EQUIPMENT USED FOR DATA-TRANSMISSION TESTS

(Extracts from contribution GT.43 — No. 9, February 1960)

General.

Information is transmitted in serial binary code by phase modulation of a carrier. Modulation is by 180° phase reversal so that some means is required at the receiver of distinguishing between a " 0 " and a " 1 ". This can be provided either by transmitting a known " start character " at the beginning of each block of data or by using the convention that a phase reversal represents a " 1 " and the absence of a phase reversal represents a " 0 ". The latter method was used in the tests.

The carrier is preferably synchronized with the bit frequency so that a bit period corresponds to an integral number of half-cycles of the carrier. This synchronization is desirable because it reduces modulation jitter, a factor which becomes increasingly serious as the bit rate approaches the carrier frequency. In all the tests the synchronized mode of operation was used and the phase reversals occurred at the zero crossings of the carrier.

Equipment.

The equipment used for the tests could be operated at the following carrier frequencies: 1000 c/s, 1500 c/s, 1800 c/s and 2000 c/s. Any bit rate could be used provided that a bit period corresponded to an integral number of half-cycles of the carrier. Thus, for example, with a carrier of 2000 c/s, the bit rate could be 2000, 1333, 1000, 800, . . . bits/sec. While all the speeds could be used to determine the effect of distortion caused by the lines, the test equipment restricted tests involving error counting to the two bit rates, 500 and 1000 bits/sec.

Transmitter.

The transmitter comprises a carrier oscillator synchronized to the clock used for reading the binary information, and a balanced modulator. The data input, which for the tests was from an 8-bit character generator, is a two-level signal (+12 and 0 volts); a transition from one level to the other represents a " 1 " and the absence of a transition represents a " 0 ". The modulator produces a 180° phase change in the carrier for each transition of the input. The output to the line is through an isolating transformer, the output impedance being 600 ohms.

Receiver.

In the receiver the signal is amplified, and phase detected with a synchronous carrier. The phase detected output is filtered and squared to yield the data output which is in the same form as the input to the transmitter. The synchronous carrier is reconstructed from the delayed input signal, by reversing the phase of that signal at each binary transition of the output data, in a phase modulator. The delay is chosen to correspond with the delay inherent in the low-pass filter and shaping circuits.

The data output of the receiver requires a timing output to provide a means of sampling the data at intervals equal to the bit rate. This timing waveform, or clock, is derived in the receiver directly from the output data and is independent of the telephone line delay.

In the receiver used in the tests there was no filtering or clipping at the input, nor was an automatic gain control provided. It is envisaged that these features will be incorporated in future designs.

NIPPON TELEGRAPH AND TELEPHONE PUBLIC CORPORATION: VIEWS ON THE STUDY OF THE DATA-TRANSMISSION SYSTEM

(Contribution GT.43, No. 10, February 1960)

Introduction

The necessity for the data-transmission system was early recognized by various nations and since 1957 a more active study in regard to this matter has also been carried out in Japan. The processing machine of the punch-card system has hitherto been mainly and adequately utilized at a transmission speed of 50 bauds, but as there is a tendency to substitute the recently very improved electronic computer for the conventional system, there is need to develop a high-speed transmission system parallel with it in the future.

1. *General.*

We agree with the opinion that the data-transmission technique should not be strictly standardized yet, because it is still under development. Accordingly, the scope of its standardization by the C.C.I.T.T. should be minimized as far as possible. Problems to be discussed for decisions on the data-transmission system may be broadly divided into two categories as follows:

1. transmission circuits,
2. signals to be transmitted.

2. *How would the modulation rate be fixed?*

The system to divide a voice-frequency band for high-speed data transmission has been presented by the Federal German Republic, but another modulation speed to occupy the whole voice-frequency band should also be considered besides the 500 baud operation.

In this case a modulation speed which could easily attain steady transmission without a special network for compensation of delay distortion should be considered and it might very well be about 1000-1500 bauds.

Were a data transmission of super high speed exceeding the voice-frequency band to be contemplated, a frequency band for one group of telephone circuits (48 kc/s) would have to be considered.

3. *How would a telephone circuit be utilized for data transmission?*

In a toll telephone line which satisfies C.C.I.T.T. recommendations it may be possible to accommodate a modulation rate up to 1800 bauds and in case of approximate 1000-baud operation any inferiority as regards telegraph distortion could hardly be perceptible compared with the transmission quality on a 50-baud channel.

We can affirm this from the conclusion of study activities we have undertaken three times since 1958.

The study data concerned will be presented separately but an extract of the data is shown in the table below.

The study on a local line is under way now. A 4-wire circuit is generally preferable for data transmission and in the case of the 2-wire system the deterioration of frequency response caused by echo is of course inevitable, therefore the modulation speed should be considerably decreased compared with the 4-wire system. But here we cannot make any reference to the problem as to what the most suitable modulation rate is, because the relevant study has not yet been made.

If the errors shown above are analysed, the proportion of errors converted from the "stop" polarity to the "start" polarity is much higher than that of errors from the "start" to the "stop" because of an instantaneous break of the circuit, but in this case the errors consisting of a change from the "start" to the "stop" polarity sometimes occur before or after the occurrence of the other.

TABLE

1. Error rate on the high-speed transmission test

1.1. *Test on carrier telephone circuit (cable)*

Modulation speed	Number of unit pulses transmitted	Number of error pulses	Error rate
500 bauds	2×10^6	5	2.5×10^{-6}
1000 bauds	11×10^6	2	1.8×10^{-7}
1500 bauds	13×10^6	30	2.3×10^{-6}
1750 bauds	22×10^6	start polarity → stop polarity 255 stop polarity → start polarity 600	3.9×10^{-5}

1.2. *Test on SHF telephone circuit*

Modulation speed	Number of unit pulses transmitted	Number of error pulses	Error rate
1000 bauds	95×10^6	start polarity → stop polarity 46 stop polarity → start polarity 578	6.6×10^{-6}
1500 bauds	24×10^6	start polarity → stop polarity 38 stop polarity → start polarity 78	4.9×10^{-6}

Note. — The data of high-speed transmission tests shown here were taken from the experiments tried between Tokyo and Fukuoka (1336 km), Tokyo and Sendai (365 km) and Tokyo and Okayama (765 km) in February 1958, January 1959 and October 1959 respectively.

4. *What modulation system would be preferable?*

As to the modulation system for high-speed data transmission, various systems such as Double Side Band (D.S.B.), Vestigial Side Band (V.S.B.), Frequency Shift (F.S.) Phase

Shift (P.S.) and their modified systems can be considered, but the D.S.B. system is the most recommendable.

Besides this system, the F.S. system is also being eagerly studied; therefore, it would be wise to leave the way open for the adoption of other systems.

We present below the result of our study concerning the D.S.B. system.

(a) Suppression of telegraph distortion caused by phase difference between carrier and signal waves.

In the case of high-speed modulation, the signal frequency is close to the carrier frequency and the number of cycles of carrier frequency contained in a unit pulse of signal frequency is only one or less.

Therefore the telegraph distortion may occur according to the relative phase difference between the two frequencies but it can be suppressed by letting the signal frequency pass through an adequate low-pass filter before it is fed to the modulator. For instance, if 300 c/s-3400 c/s for the signal frequency band and 1850 c/s for carrier frequency are taken respectively, a filter which gives the flat amplitude response with linear phase at its pass band of 0-1550 c/s and the attenuation for over 25 db at the transmission band over 2150 c/s would be inserted. The data to go upon are explained in Supplement I.

(b) Limitation of modulation rate caused by frequency response of transmission circuit.

The conventional carrier channel of narrow frequency band (300-2700 c/s), apart from the standard one (300-3400 c/s), is still partly used and similarly to other nations this system accommodates both carrier and voice circuits together in the same line and as a filter for the separation of both circuits is located at every repeater station, the delay distortion by phase non-linearity of the first channel of carrier circuit becomes worse. This channel would be omitted for data transmission but the others are capable of high-speed data transmission without compensation of the distortion. The data to go upon are explained in Supplement II.

. . . .

6. *How would the maximum acceptable limit for the duration of interruption of transmission circuit be considered?*

To attain a highly reliable data-transmission circuit special consideration must be given to the instantaneous break of the circuit. For telegraph circuit the break for below 5 ms may be allowable but for high-speed data transmission the duration of even 0.5 ms must be considered. And as for the treatment of the trouble, some standard should be established. The high-speed data transmission is more easily affected by peak noise than in the case of low-speed telegraph transmission and then the noise regulation thereafter would be carefully established with due regard to the characteristics of the data-transmission circuit. In this matter we have not yet reached the final conclusion and the promotion of international co-operative studies is advisable.

SUPPLEMENT I

Influence of phase difference between carrier and signal waves on telegraph distortion and the method to suppress it

The result of the study of the waveform transmission characteristic where the binary code is transmitted by the D.S.B. system on telephone circuits is explained below.

In case that signal frequency $f(t)$, carrier frequency ω_0 and transmission line response $T(\omega)\, e^{j\theta(\omega)}$ (in this transmission line the frequency band outside of $\omega_0 - \omega_1 < \omega < \omega_0 + \omega_1$, is considered to have an infinite attenuation) are given respectively, the waveform $R(t)$ after the modulated wave is sent through this transmission line is discussed here.

Signal frequency spectrum $F(\omega) = \int_{-\infty}^{\infty} f(t)\, e^{-j\omega t}\, dt$

Modulated wave $= f(t) \cos(\omega_0 t + \alpha)$

$$R(t) = \frac{1}{2\pi}\left(R_e \int_{-\omega_1}^{\omega_1} F(\omega)\, T(\omega + \omega_0)\, e^{j\{\omega t + \theta(\omega+\omega_0) - \theta(\omega_0)\}}\, d\omega\right.$$

$$\left. + R_e \int_{-\omega_1}^{\omega_1} F(2\omega_0 + \omega)\, T(\omega + \omega_0)\, e^{j\{\omega t + \theta(\omega+\omega_0) - \theta(\omega_0) - 2\alpha\}}\, d\omega\right) \times \cos\{\omega_0 t + \theta(\omega_0) + \alpha\} -$$

$$\frac{1}{2\pi}\left(lm \int_{-\omega_1}^{\omega_1} F(\omega)\, T(\omega + \omega_0)\, e^{j\{\omega t + \theta(\omega+\omega_0) - \theta(\omega_0)\}}\, d\omega\right.$$

$$\left. + lm \int_{-\omega_1}^{\omega_1} F(2\omega_0 + \omega)\, T(\omega + \omega_0)\, e^{j\{\omega t + \theta(\omega+\omega_0) - \theta(\omega_0) - 2\alpha\}}\, d\omega\right) \times \sin\{\omega_0 t + \theta(\omega_0) + \alpha\}\,.$$

In this equation $R(t)$ indicates the response when $f(t) \cos(\omega_0 t + \alpha)$ is sent through the transmission line which has a response of $T(\omega) e^{j\theta(\omega)}$ and the second term of both components of right angle and same phases means the echoing component of the zero frequency.

As the phase difference α between signal and carrier waves is contained only in both terms, if these components are taken away prior to the modulation process, the distortion caused by the phase difference can be eliminated. Then if 1850 c/s for ω_0 and 1550 c/s for ω_1 (300 — 3400 c/s for frequency band) are taken, it may be possible to reduce the telegraph distortion by inserting a low-pass filter which gives linear phase characteristic and flat amplitude response within the range of $0 - \omega_1$ and enough attenuation above $(2\,\omega_0 - \omega_1)$, namely 2150 c/s.

SUPPLEMENT II

Frequency response of transmission line and limitation of maximum modulation speed

For the study of the limitation of maximum modulation speed the response in case the signal input of unit function is modulated after passing through the ideal low-pass filter to eliminate the echoing component of zero frequency is sought here. In this case the amplitude response of the transmission line is divided into the even symmetrical component $Te(\omega)$ and the odd one $To(\omega)$ to the centre frequency ω_0 and the phase characteristic similarly into the odd symmetrical component $\theta_0(\omega)$ and the even one $\theta_e(\omega)$ respectively.

The response $Ru(t)$ here is—

$$Ru(t) = \left(\frac{T(\omega_0)}{2} + \frac{1}{\pi}\int_0^{\omega_1} \frac{Te(\omega)\sin\{\omega t + \theta_0(\omega)\}\cos\theta_e(\omega)}{\omega}\,d\omega + \frac{1}{\pi}\int_0^{\omega_1} \frac{To(\omega)\cos\{\omega t + \theta_0(\omega)\}\sin\theta_e(\omega)}{\omega}\,d\omega\right)$$
$$\times \cos\{\omega_0 t + \theta(\omega_0) + \alpha\}$$
$$+ \left(\frac{1}{\pi}\int_0^{\omega_1} \frac{To(\omega)\cos\{\omega t + \theta_0(\omega)\}\cos\theta_e(\omega)}{\omega}\,d\omega - \frac{1}{\pi}\int_0^{\omega_1} Te(\omega)\cos\{\omega t + \theta_0(\omega)\}\sin\theta_e(\omega)\,d\omega \times \sin\{\omega_0 t + \theta(\omega_0) + \alpha\} \quad \ldots.(1)\right)$$

If the amplitude characteristic is even symmetrical to ω_0 and the phase characteristic is odd symmetrical to ω_0, $Ru(t)$ is as shown below:

$$Ru(t) = \left(\frac{T(\omega_0)}{z} + \int_0^{\omega_1} T(\omega)\sin\{\omega t + \theta(\omega)\}\,d\omega\right)$$
$$\times \cos\{\omega_0 t + \theta(\omega_0) + \alpha\} \quad \ldots.(2)$$

On the narrow band system, setting the carrier frequency at 1500 c/s, the integral in the equation (2) is calculated with M-1 computer (developed in Electrical Communication Laboratory, NTTPC) and from that result the relation between the modulation speed and its acquirable margin can be gained as shown in the following table. From this table it is clear that the existing telephone circuit is very capable of high-speed transmission.

TABLE

Modulation rate and its acquirable margin

Modulation rate (bauds)	Margin
1260	40%
1360	33%
1480	26%
1640	20%
1820	20%
2050	17%

FEDERAL GERMAN REPUBLIC: SYSTEMS FOR DATA TRANSMISSION ON TELEPHONE LINES

(Extract from contribution GT.43, No. 19, March 1960)

The existing world-wide communication networks suggest their use for data transmission. These networks comprise:

(a) teleprinter lines,

(b) telephone lines,

(c) radio links; broadcasting, group, supergroup, television and other wideband transmission paths.

(a) and *(b)* may be either permanent channels or connections established when a need arises *. The transmission paths under *(c)* are generally of the permanent type.

Teleprinter lines are operated at the rather low telegraph speed of 50 bauds and are suitable for the transmission of relatively small quantities of information. This speed can be increased 10 to 20 times using telephone lines.

If normal switched connections are taken into consideration, then existing local networks, especially subscribers' lines, together with the trunk network for direct long-distance dialling may be used. Such a data-transmission system would have a remarkable flexibility because subscribers would be interconnected regardless of locality and no additional transmission lines would be required. It is of the greatest interest to provide a data-transmission system suitable for such an arrangement. Hence, the discussion that follows deals with this case alone.

The following specifications would appear adequate for such a system:

A. Transmission medium: conventional telephone channel.

B. Faulty-character probability $p_{ch} \doteq 10^{-7}$ to 10^{-8}.

C. Telegraph speed: 500 to 1000 bauds.

Ref. A. — This specification means that the system should be able to cope with noise caused by rotary selectors as well as with short-time interruptions not uncommon in carrier channels.

Ref. B. — The faulty-character probability $p_{ch} = 10^{-7}$ (errors occurring at a rate of 1 faulty character in 10 million) means that not more than one character should be incorrect in 24 hours of transmission at a speed of 1000 bauds. This specification seems rather high, but would adequately meet the application alluded to in the Introduction.

Ref. C. — Any telephone channel would permit a telegraph speed of 1000 bauds. To make use of this speed, the redundancy of the code used should not reduce the speed by a factor greater than 2.

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* Also termed " stand-by " and " switched " connections, respectively.

Figure 93 shows the block diagram of a data-transmission system comprising input memory, encoder, modulator, transmission channel, demodulator, decoder and output memory. The return path of the (basically duplex) telephone line can be used for decision signals (" proceed to send " or " repeat "). The number of possible systems is rather high: with 5 memory types (paper tape, punched card, ferrite cores, magnetic drum, magnetic tape), 4 coding methods, 4 modulation methods and 3×2 transmission methods, the problem is to select the most suitable from $5 \times 4 \times 4 \times 3 \times 2 = 480$ possible systems. Some of the transmission, modulation, coding and error-correction methods will be discussed, neglecting details for the sake of a general synopsis.

2. *Transmission methods.*

The transmission methods may be subdivided into two groups: The first subdivision includes simplex, duplex and half-duplex operations, i.e. use of only one direction of transmission, both directions, or both directions alternately. Table 1 shows the important properties of these three types:

TABLE 1

	Technical properties	Operating properties
Simplex	No decision signal	One-way operation
Duplex	Decision without delay	No echo suppressors permissible
Half-duplex	Decision with delay	Echo suppressors permissible

In the simplex case, no backward decision signal can be transmitted; on the other hand, a one-way connection may be used in special cases. In the duplex case, the decision signal can be returned without delay as both directions are in operation at any time; however, the 2-wire channels of the two directions would have to be separated by filters which might reduce the speed of transmission. In half-duplex operation, the decision signal in the backward direction invariably causes a loss of time equal to at least twice the line delay plus switching time. Echo suppressors, permissible in half-duplex operation, have to be disconnected in duplex operation, thus causing additional inconveniences. As will be seen below, decision signals in the backward direction are indispensable; this eliminates the simplex method. The duplex method appears to be the most suitable, as decision signals are possible without loss of time. Echo suppressors are rarely encountered in the European network; hence, this problem is not too serious.

Another possible subdivision of transmission methods is into sequential and parallel transmission (time division and frequency division multiplex systems, respectively). The two methods differ in respect of noise and distortion as shown roughly in Table 2.

TABLE 2

	Pulse-shaped noise	Random noise	Periodic interference	Linear distortion	Non-linear distortion	System properties
Sequential	—	Same	Better ($\sqrt{n}$)	—	Better	Any code
Parallel	Better ($\sqrt{n}$)	Same	—	Better ($\sqrt{n}$)	—	Inflexible code

The signal power is assumed to be the same in both cases (as limited to avoid overloading the carrier system). Under these conditions, both the sequential and the parallel systems have the same sensitivity to random noise; the parallel system has a better performance with respect to pulse-shaped noise, the sequential with respect to periodic interference. In the case of n parallel channels, the peak amplitude of a noise peak will be n times less than in the sequential systems because the channels of the parallel system are narrower by that factor. Since, however, the signal amplitude in one parallel channel is by $1/\sqrt{n}$ less than in the sequential method, the overall improvement for the parallel operation is only $\sqrt{n}$. As to linear distortion, for instance, delay distortion at the corners of the frequency band, the parallel system is more favourable owing to its longer pulse durations which have to be compared with the delay distortion. Non-linear distortion, however (as produced, for instance, by a compandor), affects the parallel system more. Of particular importance is the fact that the parallel-system code is fixed for all practical purposes while there are no restrictions in choosing the code for the sequential system. This is of particular advantage for a building-block type data-transmission system that can be adapted to various applications, and it induced the author to favour the sequential system.

3. *Modulation methods.*

Some of the most important modulation systems for binary codes are presented in Table 3, where VF (1st column) means direct voice-frequency transmission; VF bipolar = voice-frequency transmission in which every binary digit is represented by two bits of opposite polarity to avoid the DC component; PM = phase modulation; FM = frequency modulation; VSB = vestigial sideband amplitude modulation.

Column 2 shows the telegraph speeds, referred to the speed for VF transmission. The third column indicates the signal/noise ratio under random-noise conditions, referred to the same faulty-bit probability (see also (1)), so that positive figures mean improvement and negative figures deterioration.

TABLE 3

	Telegraph speed	S/N ratio for random noise	Miscellaneous	System properties
VF	1	0 db	Direct current asynchronism	
VF bipolar	1/2	+ 3 db	Asynchronism	
AM	1/2	- 1 db	— —	
PM	1/2	+ 3 db	Synchronization	Independent of level changes
FM	1/2	- 1 db	— —	Independent of level changes
VSB	1/1.5	- 6 db	Square-law distortion	

The difference is only few db for each method except for the vestigial sideband method which must have the carrier transmitted to avoid square-law distortion. Column 4 shows that both voice-frequency methods must be eliminated because of the effect of asynchronism in which the received frequency may deviate by a maximum of 2 c/s from the transmitted frequency in a carrier system. For phase modulation which is most favourable as regards the signal-to-noise ratio, synchronization would be required involving higher cost and greater complexity. Phase modulation and frequency modulation are insensitive to level variations. This point of independency of any carrier synchronization leads the author to prefer frequency modulation to phase modulation, putting up with the small disadvantage of the signal-to-noise ratio being 4 db less than in phase modulation. There are no compelling necessities pointing to the use of a certain transmission method or a certain modulation method. Nevertheless, a choice ought to be made, in view of inter-working between future data-transmission systems.

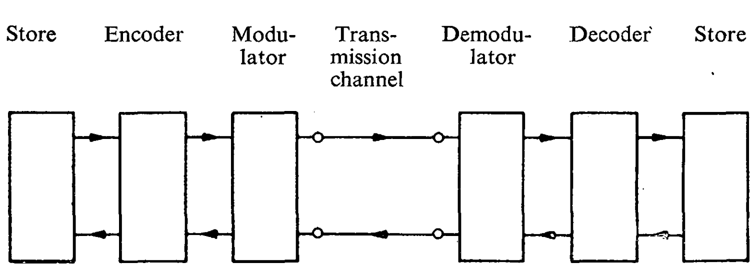


FIGURE 93. — *Block diagram of a data-transmission system*

AMERICAN TELEGRAPH AND TELEPHONE Co.: PARALLEL TRANSMISSION DATA-PHONE SUBSET

(Contribution GT.43, No. 22, April 1960)

Introduction.

Recently, there has been considerable interest in high-speed data-transmission with rates of thousands of bits per second contemplated for telephone message circuits. High-speed equipments are too complex and expensive to meet the needs of the low-volume-data customer who transmits thousands of bits per day rather than hundreds of thousands. The small savings in toll bills cannot justify expensive equipments which stand idle most of the day.

The parallel transmission data-phone subsets described here are directed toward fulfilling the requirements of the low-volume-data customers. Multifrequency parallel transmission leads to extremely simple transmitter circuitry and results in a system especially attractive in the frequently encountered communication pattern of a multiplicity of transmitters feeding a single receiver. The parallel transmission data-phone subsets are designed to be directly connected to business machines. The input required for the transmitting subset is contact closures on several leads in parallel. The output of the receiving subset is also contact closures on several leads in parallel. These subsets will operate at any rate up to twenty characters per second. The transmission is asynchronous using a return to normal state to separate characters. In the normal state all inputs are open. Thus, neither the character timing nor character rate need be closely controlled.

Inasmuch as these data-phone subsets use the switched telephone network, they must be tolerant to thermal and impulse noise, delay distortion and carrier shift.

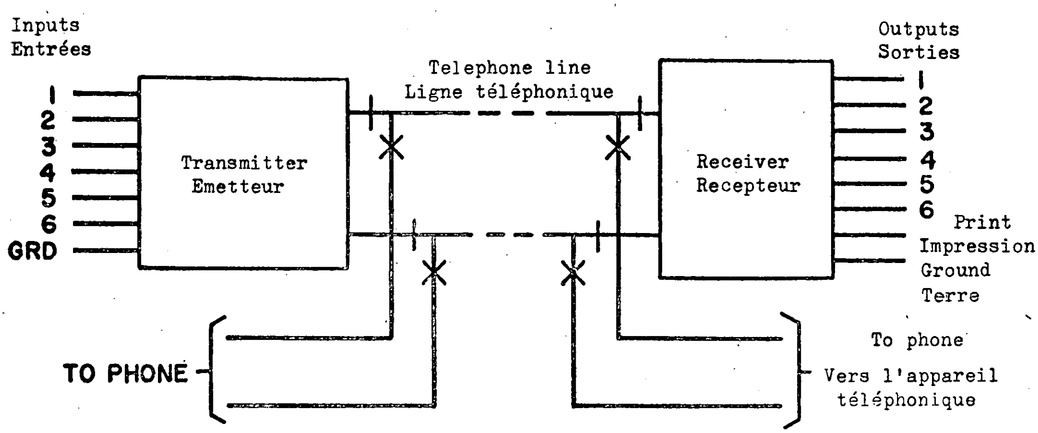
Two types of parallel transmission systems are described which fulfil different requirements. However, the multifrequency techniques used in both are similar. The group arrangements of the multifrequency signals, and a number of circuits features, are adaptations from the development of push-button signalling from the customer's telephone set.

The three-out-of-twelve system (figure 94).

One such type of parallel transmission system has been called the three-out-of-twelve system (3/12). Only one direction of transmission is provided. There is no digital acknowledgment of validity of the data reception. This system can handle any number of parallel binary inputs up to six. Thus, the inputs are six contacts which may be opened or closed. This system is capable of operating up to 20 characters per second. Since there are six binary inputs, this is equivalent to 120 bits per second, and if the characters are English text, this is equivalent to 200 words per minute.

In the 3/12 system the condition of a pair of leads is translated into one of four frequencies. Each of the three pairs of leads controls a quaternary frequency-shift channel. In the normal condition when all inputs are open the three normal frequencies are generated. Hence, signal is always present on the telephone line.

At the receiver the three frequency-shift channels are separated by filters. Each channel is individually limited. Each limiter drives a discriminator which determines which of the four frequencies was transmitted and operates the appropriate relay through a simple logic circuit. A straight parallel arrangement of six binary frequency-shift channels would not require translation but would require complex filtering and six limiters. Furthermore, the transmitter would have to generate six frequencies simultaneously. Use of one high-speed binary channel with parallel to serial conversion would require complex translation at the transmitter and receiver but the filtering would be simple. Binary to quaternary translation can be accomplished with very few components and results in a great reduction in receiver complexity. Furthermore, three frequencies can be generated in a single transistor oscillator. Three-out-of-twelve operation results in a very simple transmitting terminal equipment.



Input Entrée 1	2	Frequency Fréquence	Input Entrée 3	4	Frequency Fréquence	Input Entrée 5	6	Frequency Fréquence
1	0	515	1	0	1208	1	0	1950
0	0	630	0	0	1336	0	0	2090
1	1	770	1	1	1477	1	1	2240
0	1	914	0	1	1637	0	1	2400

Where 1 represents input grounded
and 0 represents input open

Le chiffre 1 représente un contact relié à la terre
le chiffre 0 représente un contact ouvert

FIGURE 94. — *Block diagram of the three-out-of-twelve system*

Frequency-shift is used in the 3/12 system because it is more tolerant to noise and system imperfections than amplitude modulation. Quaternary frequency-shift is slightly less tolerant to noise than binary. However, its use is justified by the much greater simplicity of the terminals with quaternary channels.

Timing for this system is simplified by the return-to-normal operation. The beginning of the character is detected when a channel goes off normal and the end is detected when the channel returns to the normal. This is a form of start-stop synchronization with a start pulse preceding each message character. The reduction in speed due to return to normal operation is justified by the simplicity of the timing. Moreover, most input equipments (business machines) generate return to normal signals. Another dividend of return-to-normal operation is tolerance to delay distortion. When any one of the data relays at the receiver goes off normal it actuates an extra relay called the print relay. The print relay can be used to enable the outputs. The print relay is delayed on operate. This delay can be made long enough to span the difference in delay between the fastest and slowest channels. Thus, although the transmission medium has delay distortion and relay operate times vary, the outputs can be enabled simultaneously when the print relay operates.

Three-out-of-twelve transmitter.

The 3/12 transmitter shown in figure 95 is a single transistor three-frequency oscillator which is powered by the central office battery over the local telephone loop. The transistor acts a linear amplifier. The limiting is provided by diodes CR. 1, 2 and 3 for each frequency separately.

The simplicity of translation from binary to quaternary is illustrated in figure 94. When inputs 1 and 2 are open the tank composed of L10 and C10 has a resonant frequency of 630 cycles per second. When input 1 alone is grounded, C1 is across the tank, and the resonant frequency is lowered to 515 cycles per second. If input 2 alone is grounded, the resonant frequency is 941 cycles. When both 1 and 2 are grounded the resonant frequency is 770 cycles per second. A combination of capacitor and inductor is switched rather than two capacitors to provide more equal spacing between frequencies. The coils and transformers used are ferrite cup core coils. Tuning is accomplished by adjustment of the cores.

The transmitter is arranged to put out a total of less than one-half milliwatt of signals into 900 ohms.

Three-out-of-twelve receiver.

The three-frequency-shift channels are separated at the receiver (fig. 96) by a single input, three output cut-apart filter. Each channel is limited individually. The limiters provide a fundamental component which is constant to one db for a range of inputs from 0 to -50 dbm. Since signal is always present in each channel the limiters are always saturated and tend to suppress the noise.

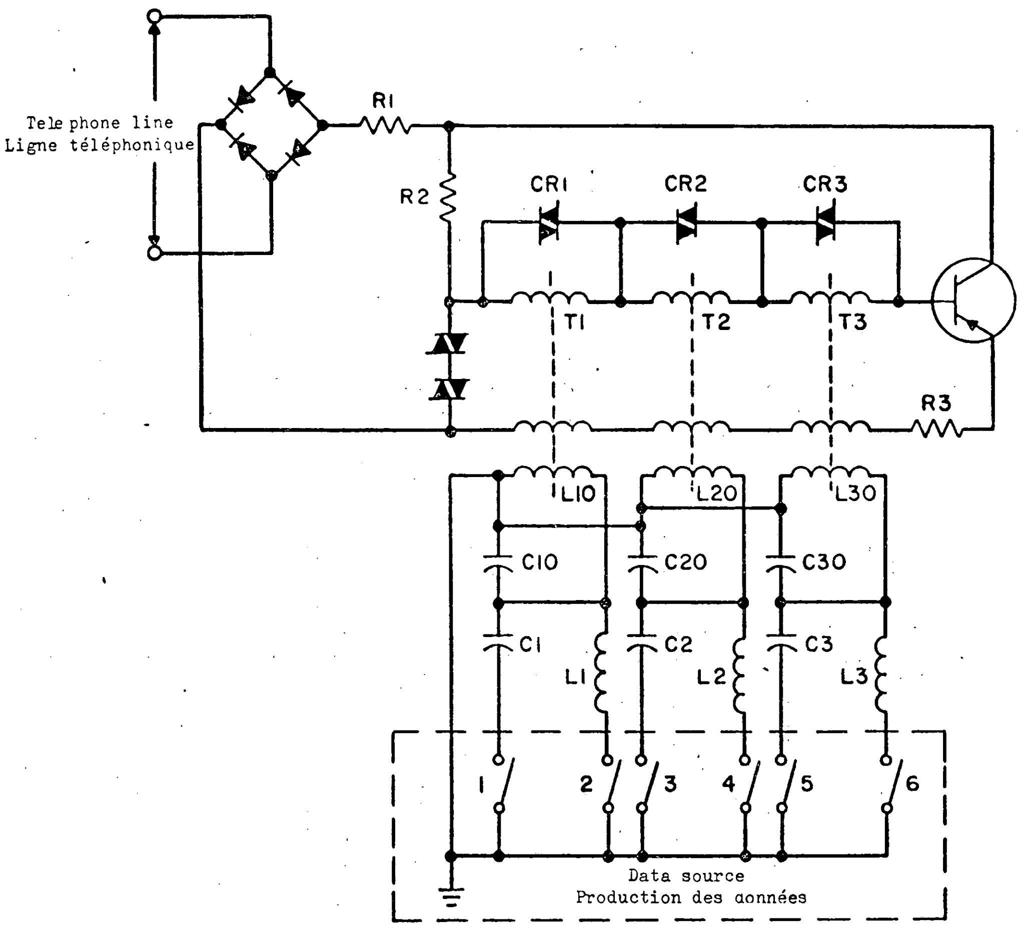


FIGURE 95. — *Three-out-of-twelve transmitter.*

The limiters drive a set of four tuned circuits. The tuned circuits are part of a four-level frequency discriminator. If the limiter has a fundamental component at one of the tuned frequencies the voltage builds up on the tuned circuit until it exceeds the back bias on a detector transistor. The detector transistor conducts on the peaks of the tuned circuit voltage. The filter in the detector collector smoothes the wave. One of the tuned circuits in each channel is tuned to the rest frequency. The output of its detector is used only for checking. The other detectors drive relays through a simple logic circuit.

If, at the transmitter, input 1 is closed across the basic tank circuit, the low frequency is generated. At the receiver (fig. 96) the tuned circuit tuned to 515 c/s operates the associated detector. The smoothed output of the detector drives a relay driver which operates data relay 1. If, instead, input 2 is closed, the transmitter generates 941 c/s which energizes the 941 c/s tuned circuit. This tuned circuit drives the associated detector which drives the relay driver and operates data relay 2. Closing both inputs 1 and 2 causes

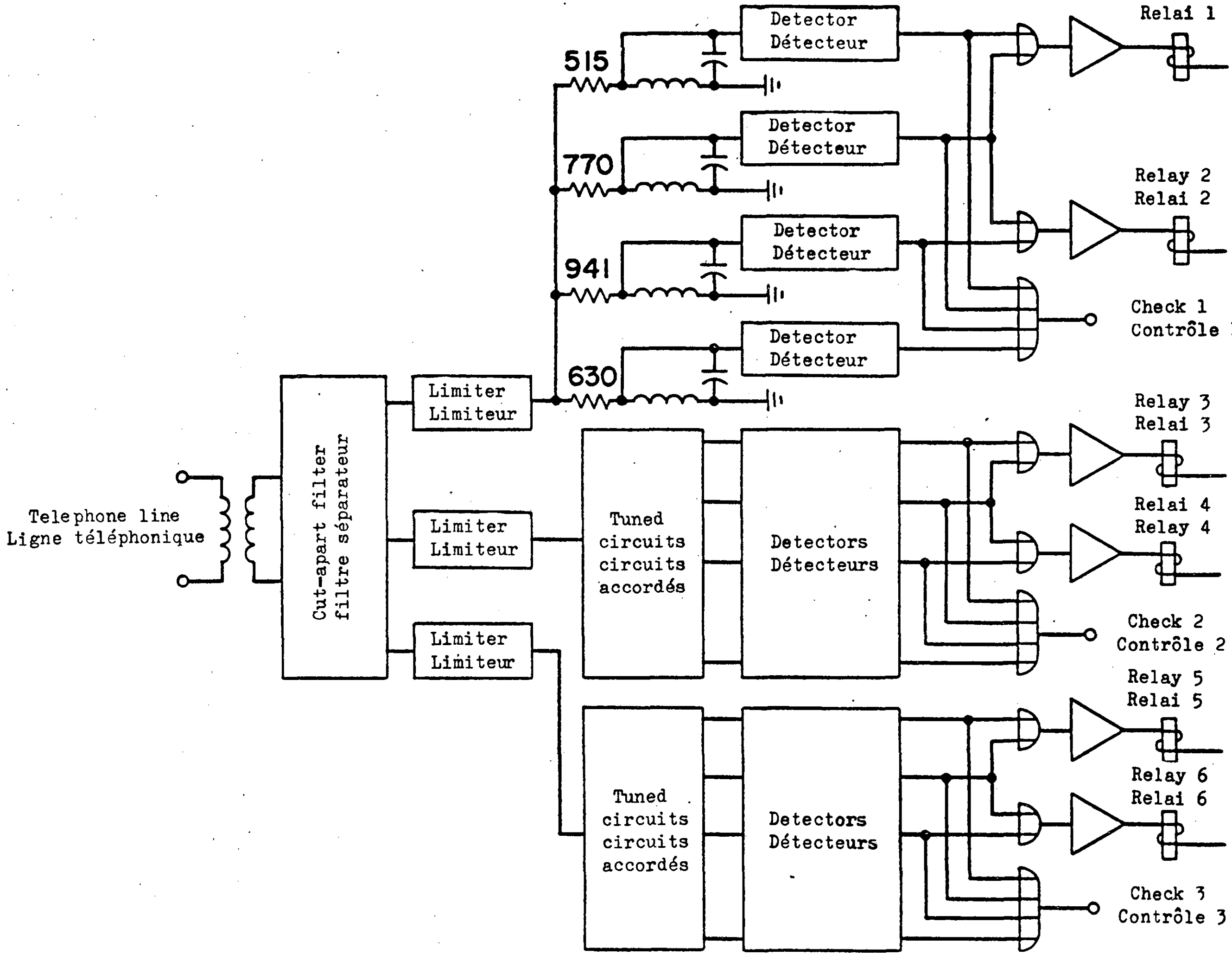


FIGURE 96. — *Three-out-of-twelve receiver*

the transmitter to generate 770 c/s. At the receiver the 770 tank is energized which operates the associated detector and drives both relays 1 and 2 through the " or " gate. The other channels are similarly arranged. Thus, a one-to-one correspondence exists between the transmitter inputs (fig. 95) and the receiver outputs (fig. 97).

An adjustment is provided between the limiters and tank circuits so that the frequency range over which the relays operate is ± 35 cycles from the nominal frequencies. This bandwidth is to allow for carrier offset and variation in tuning.

When any data relay operates it activates the print relay (PRT of fig. 97). The operate time of the print relay is increased by the associated network.

The 3/12 system has some inherent redundancy in that only one frequency should occur in each channel. Thus a check circuit could determine that one and only one frequency occurs in a channel. In the 3/12 system a simple check circuit is arranged to detect that a frequency is missing in a channel. The limiter output is designed to be low enough so that the operation of more than one detector in a channel is unlikely.

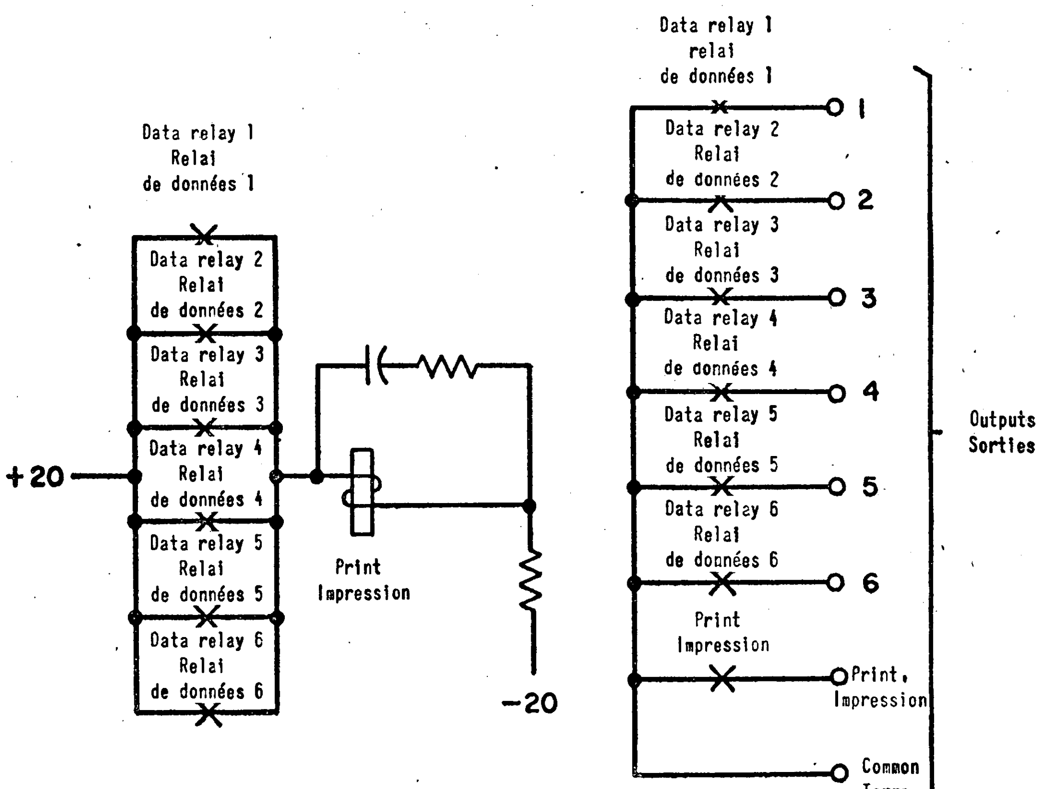


FIGURE 97. — *Relay circuit*

The two-out-of-eight system.

The two-out-of-eight system (2/8) is a parallel transmission data-phone system for the transmission of numerical information from punched cards or a manual key set. The output of the card reader or key set is 8 leads in two groups of four with no more than one lead closed in each group. In this system the receiver is able to acknowledge receipt of a message by returning a signal which can be heard on a loud speaker at the transmitter *. Otherwise the requirements of the 2/8 system are similar to those of the 3/12 system. It is capable of handling up to 20 characters per second with a return to normal between characters. It is intended for operation over telephone lines and so must be tolerant to noise, delay distortion and carrier shift.

Since two directions of transmission are required, on-off amplitude modulation is indicated. The oscillator at the transmitter runs only during the characters and is off, ready to receive signals, between characters. The oscillator must start up quickly when the inputs are closed to avoid excessive pulse shortening. There are basically two methods of ensuring quick start-up. First, direct energy can be stored in one of the oscillator reactors so that no build-up is required at starting. Alternatively, fast start-up can be insured by high oscillator loop again. The difficulty with the storing of direct energy in a reactor is the time required. For instance, if the oscillator has been running and is interrupted momentarily, the storage will not be complete, and the oscillation will build up again slowly. If the oscillator is provided with high loop gain, the same build-up rate will occur for long or short interruptions. With the simple type of card reader ** likely to be used with this system, short interruptions of the contact closures are possible. For this reason, the high loop gain method was chosen.

The problem of frequency pulling is aggravated by high loop gain. In the 3/12 transmitter (fig. 95) the frequency generated when switch 2 is closed depends upon whether switches 3 and 4 are closed. Closing switch 2 generates a nominal 941 c/s. Closing switch 3 changes the phase angle of the impedance of the tank involving T2, thus the frequency of oscillation (nominally 941 c/s) must change slightly (pull) to make the phase around the loop remain equal to zero. In the 3/12 system the circuit is arranged so that pulling is negligible. However, as loop gain increases so does pulling. The limiter CR1 provides damping at 941 c/s to hold the oscillator amplitude constant. As loop gain increases the limiting and damping must increase. This results in a reduction in the effective Q and impedance at T1. At T2 there is no limiting at 941 c/s. Hence, this impedance to 941 c/s remains the same. Since the impedance at T1 is lower, the same impedance change at T2 will result in a greater frequency change (that is, more pulling) than with lower loop gain.

* L. L. Sevebeck, P. G. Grunfelder, A.I.E.E., Conference Paper No. 59-1278.

** L. L. Sevebeck, *op. cit.*

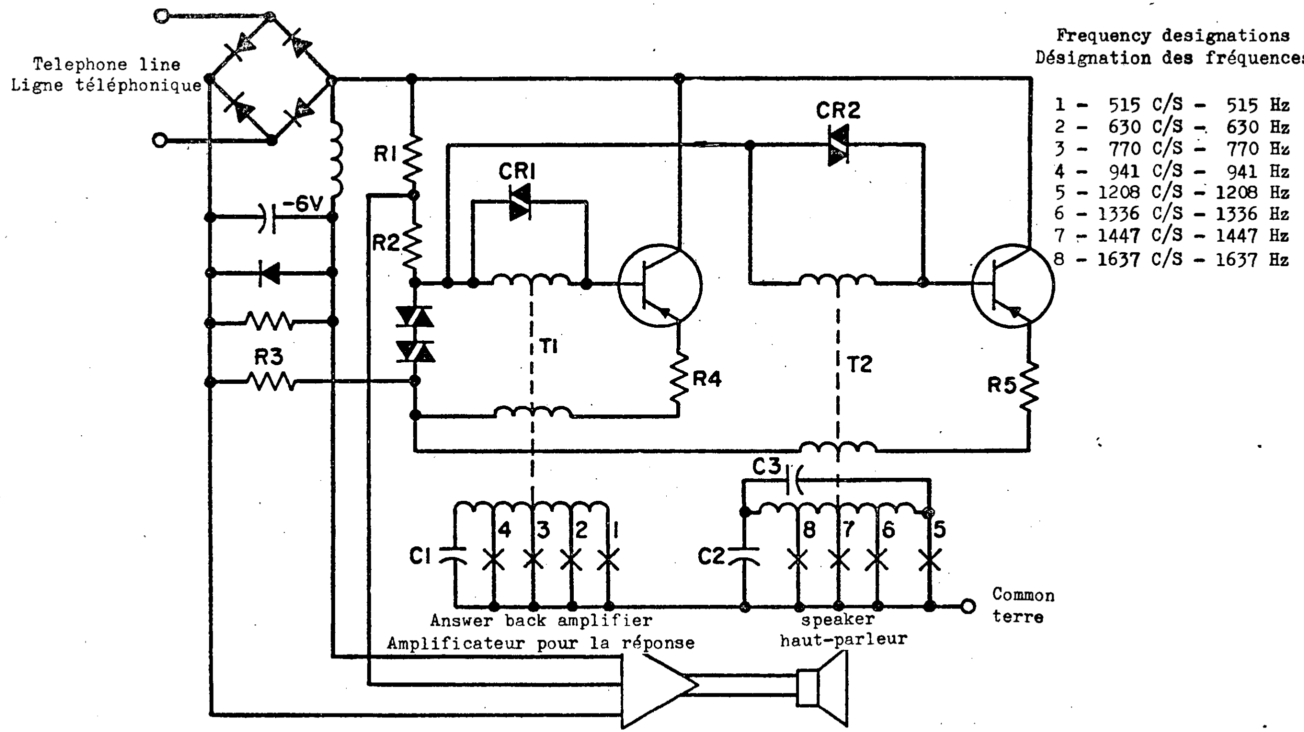


FIGURE 98. — *Two-out-of-eight transmitter*

Since high loop gain and low pulling are required for the 2/8 transmitter, it has been necessary to isolate the tank circuits by providing two separate oscillators which couple to the telephone line.

The two-out-of-eight transmitter.

The two-out-of-eight transmitter involves two frequency-shift oscillators and a two-transistor answer-back amplifier (fig. 98). The transmitter is still powered from the telephone line. Since the output of the associated card reader is already in one-out-of-four code, the closures of the switches can connect a capacitor to one of four taps on the oscillator coil. Since high gain is required for fast build-up, even with the coil open the oscillator will run at a high frequency which is outside the telephone transmission band.

The output of the 2/8 transmitter is 0.5 milliwatt at 900 ohms.

The audible answer-back amplifier is tuned to receive 1780 c/s. The amplifier drives a telephone speaker at constant output where the telephone line has 0 to 30 db loss. The amplifier has a threshold which prevents low level spurious noise from reaching the speaker.

The two-out-of-eight receiver.

The two-out-of-eight receiver is similar to the 3/12 receiver except that only two channels instead of three are used. Also, since the transmission is AM, the receiver sensitivity cannot be as high as in the 3/12 receiver. Each of the 8 input frequencies causes a relay to be operated. Because of the redundancy in the 2/8 code these outputs can be used for checking. The 2/8 receiver is also equipped with an answer-back oscillator which can be keyed by the customer.

Control.

In both parallel transmission data-phone subsets which have been described, the connection is set up by initially dialling a voice connection. When this connection has been established the data transmitter and receiver can be connected by pulling up a specially wired exclusion key on the associated telephone set.

Conclusion.

Experimental models of transmitting and receiving subsets for both the 3/12 and the 2/8 systems have been built. They have been tested with paper-tape readers operating at 200 words per minute and with simple card readers. The results of these tests indicate that error rates considerably better than one error in 10^4 characters are to be expected over the majority of telephone circuits. The tests to date have demonstrated the practicality of the parallel transmission data-phone subsets described above. Further work is continuing on several variations of these subsets.

LENKURT ELECTRIC Co.: A HIGH-SPEED QUATERNARY FM DATA-TRANSMISSION SYSTEM

(Contribution GT.43, No. 23, April 1960)

Digital data transmission involves the coding of various forms of information into characteristic groups of pulses. The most typical form of coding utilizes binary pulses, where each pulse can take either of two possible states: on or off, plus or minus, mark or space. The information contained in such a pulse is often referred to as a bit. Telegraph signals are a familiar example of coded binary data pulses.

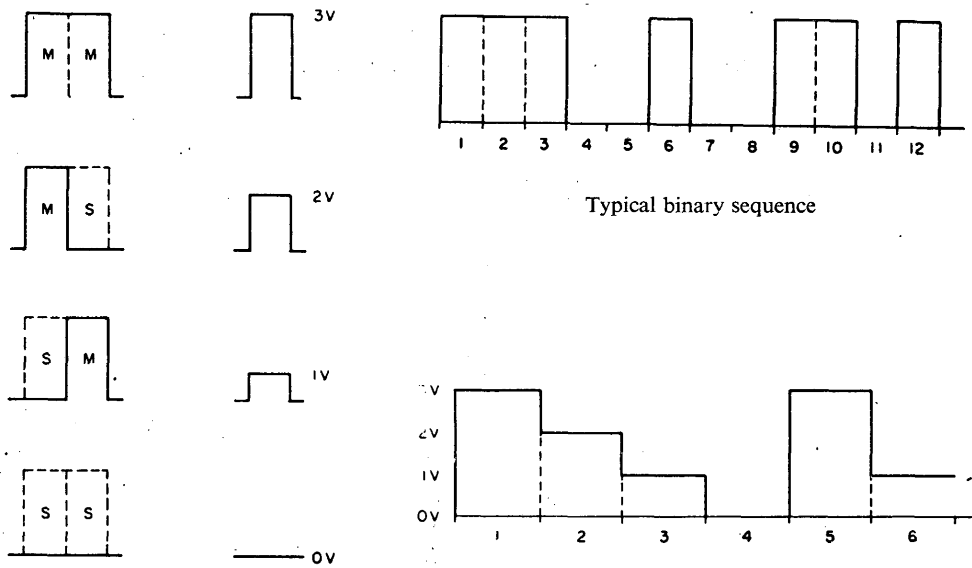
By increasing the number of possible states for a pulse from two to four, the information content of the pulse can be doubled. A typical coding scheme to accomplish this is shown in figure 99. Ideally, this conversion from a two-level code to a four-level code halves the fundamental pulse rate for the same rate of information transfer. Conversely, the rate the information is transmitted can be doubled if the pulse rate is held constant. It is to be expected that the increase in the information rate made possible by quaternary transmission is accomplished at the expense of some of the desirable features of a binary system. This paper will discuss one approach to providing a quaternary data-transmission system, and will compare its characteristics with that of a similar binary system.

Description of the experimental system.

Most data originate and are processed in the form of binary pulses. A sequence of such pulses can be directly transmitted over physical wire circuits for short distances. However, it is not practical at present to apply them directly to single sideband multiplex facilities because of the d-c components involved, and the extreme distortions introduced by frequency error in the multiplex system. It is therefore necessary to modulate a carrier frequency with the data to be transmitted. This modulated carrier can then be passed over a single sideband voice channel using conventional techniques.

The type of carrier transmission to be described in this paper involves frequency modulation because of its well-known high degree of immunity to interference and to level changes in the propagation path. In a quaternary system, the modulation consists of shifting the carrier to any of four possible frequencies instead of two as in a binary system.

A block diagram of the experimental system used for the comparison of binary and quaternary transmission is shown in figure 100. The input data pulses, after shaping by a modified cosine filter, frequency-modulate a 10.2 kc/s carrier. This frequency-modulation is accomplished in a Royer oscillator which has a frequency of oscillation directly proportional to the applied voltage. When binary pulses at 1000 pulses per second are applied,



Conversion code

Typical binary sequence

Quaternary code for above sequence (pulse rate is one-half that of binary)

FIGURE 99. — *A typical binary to quaternary conversion operation*

the carrier is shifted from 9.7 kc/s to 10.7 kc/s producing a deviation ratio of unity. For quaternary pulses at the same pulse rate, the same extremes of frequency are used so that the deviation remains unity when shifting between levels 0 and 3. However, the deviation ratio is only one-third when shifting between adjacent levels.

The frequency-modulation is done at a frequency range above the voice band to reduce " keying loss ". To translate the frequency-shifted tones into the voice channel, a modulation stage is used. A double-balanced transistor modulator is used in both the transmitter and receiver to provide this frequency translation of the signal. This modulator produces sidebands in which the signal-to-distortion ratio is greater than 50 db. The carrier leak, signal leak, and the unwanted sideband resulting from this modulation stage are eliminated by a low-pass filter in the transmitter and by a band-pass filter in the receiver.

In the receiving direction the frequency-shifted signals are delay-corrected in a time-delay equalizer to remove most of the envelope distortion caused by the transmission through a band-limited channel. After this correction these signals are modulated to a higher frequency range to simplify and improve detection. The signal is then amplified and limited to remove amplitude variations. The limiter-amplifier consists of a two-stage class B amplifier with limiting being performed by the forward characteristics of silicon diodes. The output of the limiter-amplifier is a square wave of constant amplitude over a 40-db change in the level of the input signal.

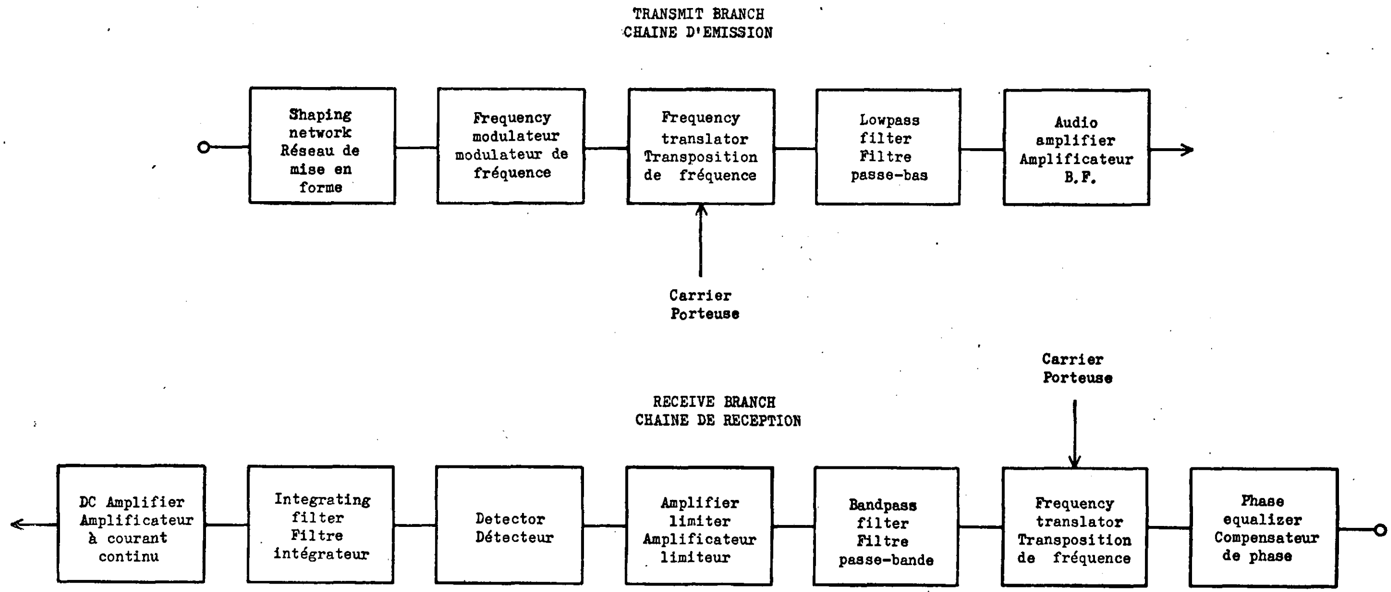


FIGURE 100. — *Block diagram of a high-speed quaternary data-transmission system*

In the experimental system a saturable core magnetic detector was used to detect the FM signals. This type of FM detector converts the amplitude limited input signals (which are approximately square waves) into a sequence of pulses whose repetition rate depends on the applied frequency. This output can then be integrated in a low-pass filter to provide a DC signal which has an amplitude dependent on the repetition rate of the pulses.

A test set was also constructed to aid in the comparison of quaternary transmission and binary transmission. A ten-pulse word is generated by the test set, with the words either in binary or quaternary form. The particular pattern which is generated is arbitrarily selected by switches. The pulse rate is variable from 500 to 8000 pulses per second. This output, in either binary or quaternary form, is applied to the transmitter portion of the data-transmission system to frequency-modulate the carrier.

The receiving portion of the test set detects only errors. This is done by comparing the waveform produced by the data receiver to that which was transmitted. A variable time delay is provided in the test set to synchronize the generated waveform with the received waveform. The comparison is made by a linear differential amplifier, with an output proportional to the difference between the amplitudes of the generated and received waveforms. When the output exceeds a pre-set reference during sampling time an error pulse is generated. These error pulses can be counted to give an indication of the number of errors. For the tests reported the reference was adjusted so that an amplitude difference greater than one-half the voltage difference between two levels indicated an error.

Channel characteristics for data transmission.

There are several characteristics of a channel which significantly influence the transmission of digital data through that channel. The most important are:

1. Bandwidth,
2. Time delay (envelope distortion),
3. Interference,
4. Synchronization.

To provide a common basis for conducting the comparison described in this paper, certain arbitrary constants have been assigned to each of these characteristics. The available bandwidth was specified by the characteristics of the voice channel which was used in this case. The pass-band of this channel is flat within ± 0.5 db between 400 and 3400 cycles per second.

The time delay encountered in the transmission medium was also specified by the characteristics of this particular voice channel. For purposes of this evaluation, phase equalization was provided only for the centre portion of the channel from 1000 to 2500 cycles per second. The time delay variation across this band contributed by both the data-transmission equipment and the voice channel was held to ± 150 microseconds. Because equalization was not utilized across a wider band, the maximum pulse rate through the experimental system was limited to 1000 pulses per second.

Interference can take many forms, but this study was confined to analysing only the effects of white noise, impulse noise, and interfering tones on binary and quaternary systems. To determine the effect of white noise on these data systems, various levels of noise were introduced in the transmission path and the resulting error rates measured. In a similar fashion the effects of impulse noise and interfering tones were measured. The noise figures used throughout this paper are not weighted and represent the total of all interfering components in the entire voice-frequency spectrum.

Synchronization of a data transmitter and receiver is necessary in order to detect and correctly identify the data pulses at the receiver. The purpose of synchronization is to permit sampling of each received pulse at its time centre where the amplitude is most likely to be of the correct value. In the experimental system described the synchronization was performed by the test set. It was possible to vary the sampling position along the time base of the pulse so that varying degrees of synchronizing efficiency could be simulated. Data was acquired for perfect synchronism, which is the case when the pulses are sampled at their time centre, and for samples taken off centre which represents imperfect synchronism.

Experimental results.

The experimental system was constructed to provide data for a comparison of the performance of binary and quaternary transmission under identical conditions. This comparison was obtained by transmitting binary pulses at a rate of 1000 pulses per second and determining the error rate for various conditions in the channel. Then quaternary pulses at the same rate were transmitted, doubling the information rate, and again the pulse error rate determined. In this manner a comparison of sensitivity to interference was determined for white noise, impulse, and tone interference.

Figure 101 shows the relationship of error rate to signal-to-noise ratio when the interference is white noise. The quaternary system required approximately 9 db better signal-to-noise ratio than a binary system when the pulse error rate is less than one per million. For a signal-to-noise ratio of 26 db the error rate of the quaternary system is better than 1 part per million.

For pulse-type interference the results are shown in figure 102. The pulses used were of 1 millisecond duration with a repetition rate of 100 pulses per second. Although the duration of the data and noise pulses was the same, the two repetition rates were different and there was no synchronization between them. In this test, the binary system was less sensitive than the quaternary system by approximately 6 db.

The frequency selected for the interfering tone test was determined experimentally by choosing an interfering tone which caused the highest error rate. In this case (figure 103) the worst interfering frequency was 2500 cycles per second. The quaternary system was approximately 10 db more sensitive to this type of interference than a binary system.

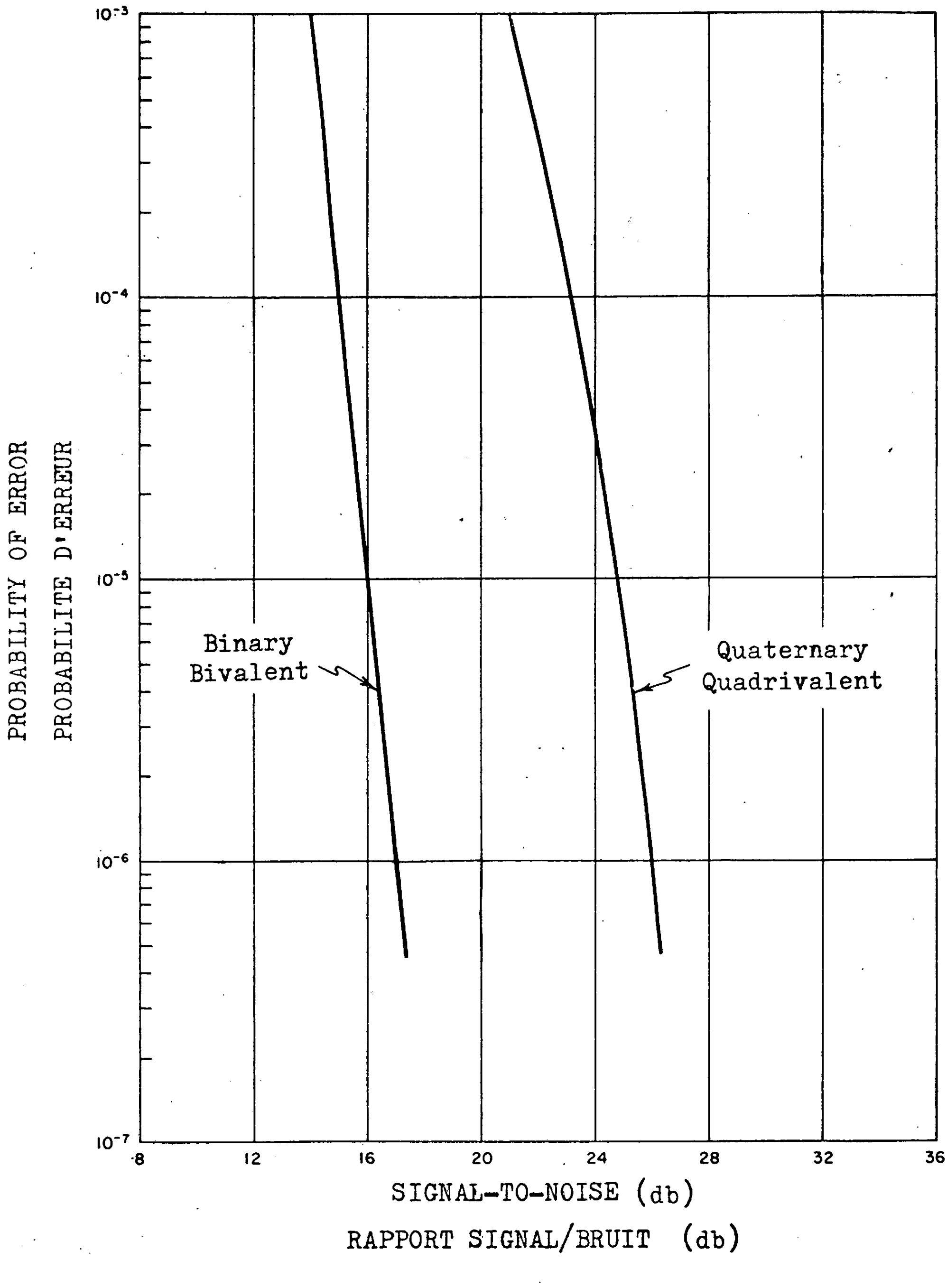


FIGURE 101. — *Probability of error for white noise interference*

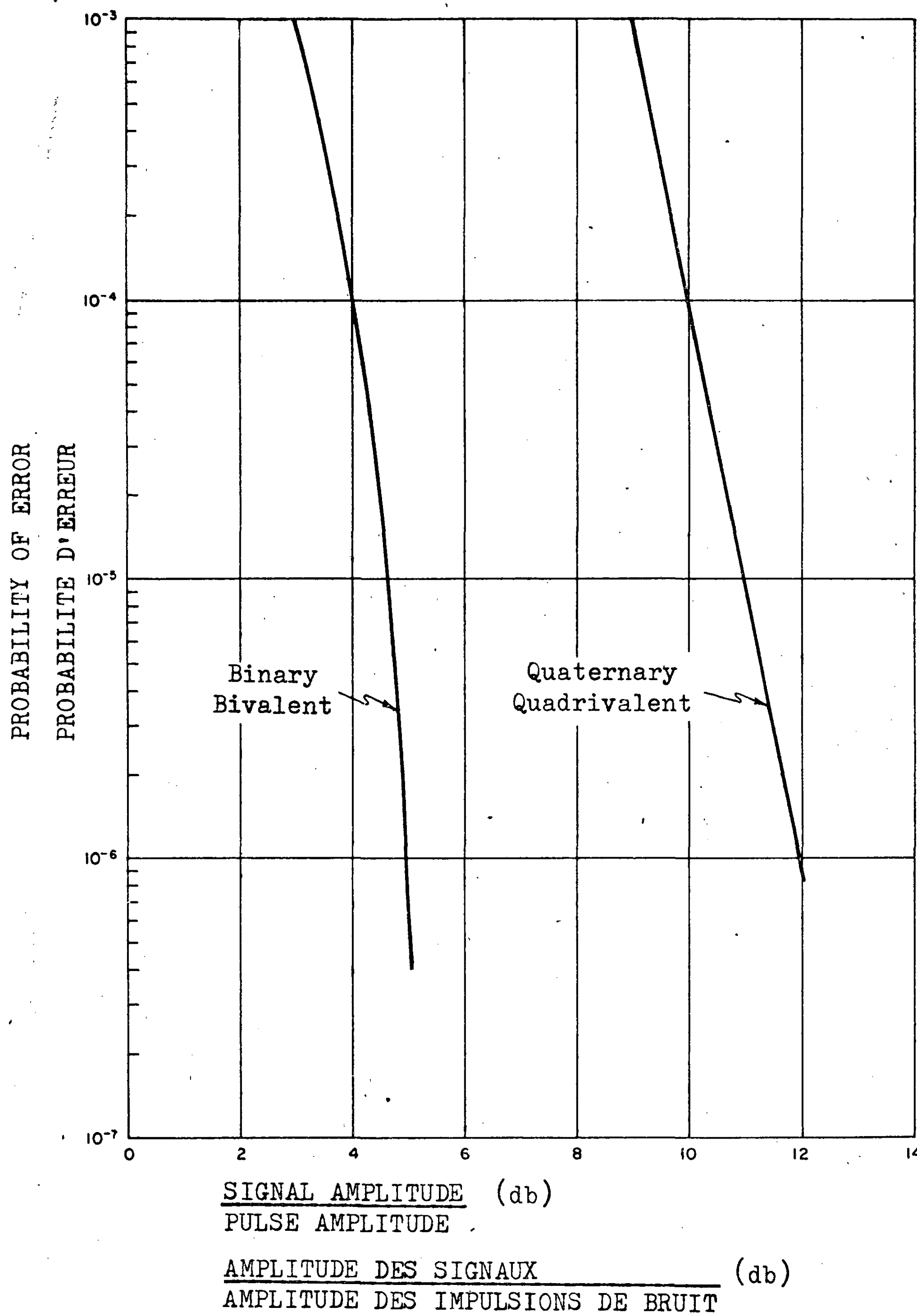


FIGURE 102. — *Probability of error for pulse type interference (1 millisecond pulse, 10% duty factor)*

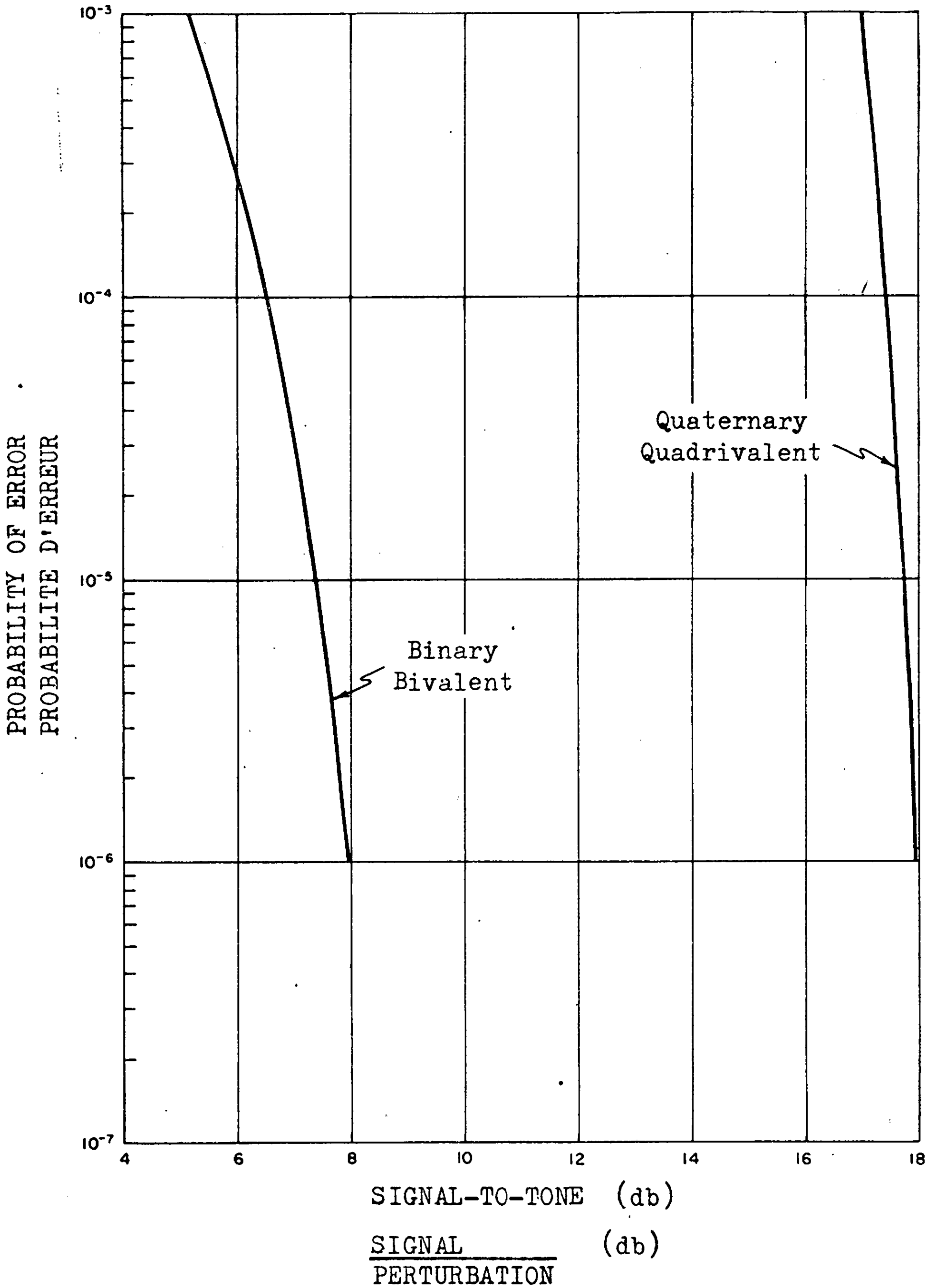


FIGURE 103. — *Probability of error for 2500 c/s sine wave tone interference*

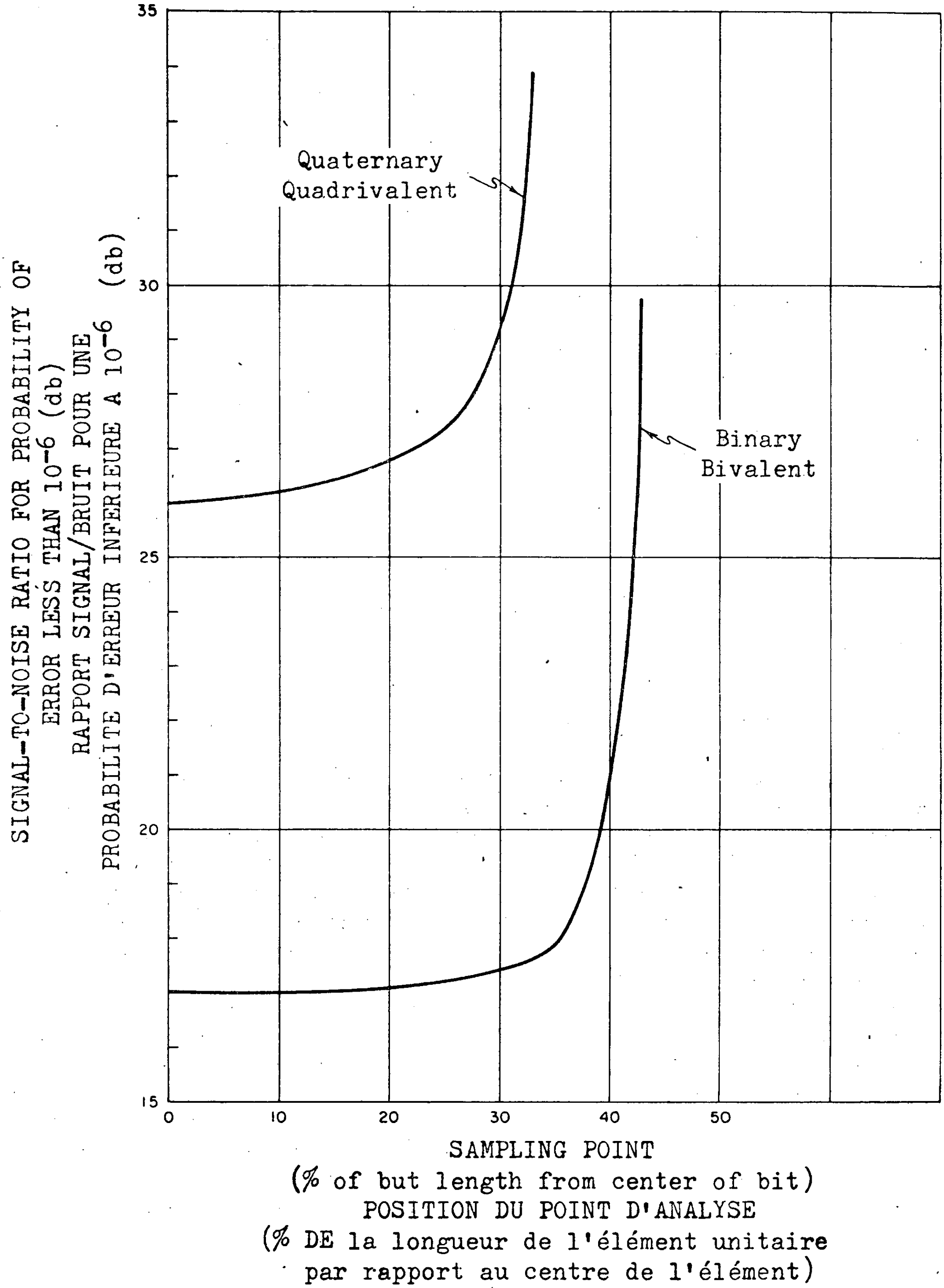


FIGURE 104. — *Effect of synchronization error on data-error rates*

Figure 104 shows a curve of signal-to-noise ratio for an error probability of less than one per million versus the position of the sampling point with respect to the centre of the pulse (synchronization error). The 20-microsecond-sampling pulse used in these tests has a time duration of 2 per cent of the data pulse, and for practical purposes the sampling can be considered instantaneous. The permissible synchronization error for practical data systems, corresponding to a signal-to-noise ratio change of 3 db, is 38 per cent of the data-pulse length for binary and 30 per cent for quaternary transmission. Thus quaternary pulses have to be sampled more closely to their centre to provide optimum operation than is necessary for binary pulses.

As a result of these measurements, it can be seen that doubling the rate of transmission of information by utilizing a quaternary system involves sacrificing some of the binary system's inherent insensitivity to interference. At signal-to-noise ratios normally encountered in wire line and microwave-carrier channels, however, the adverse effects of quaternary's higher sensitivity are not apparent. Thus quaternary transmission can be efficiently used to increase the information transmission rate over toll-quality channels without noticeably affecting the error rate. This is accomplished using relatively simple and economical techniques.

An application of the quaternary technique.

The experimental quaternary data-transmission technique explained has been used as a basis for the development of a complete data-transmission system. This system operates at a basic rate of 3360 bits per second with 3000 bits per second of data information and 360 bits per second of timing information. The data-transmission terminal equipment consisted of circuitry to accept and temporarily store a digital data sample consisting of four 36 bit words received over 144 parallel input lines. Timing information is added to the data sample and the combination is serialized for transmission over a voice using the quaternary technique. The serialized quaternary pulses modulate an 8.8 kc/s carrier to a maximum deviation of ± 800 c/s. This frequency-modulated tone is then translated to the voice-frequency range for transmission over a communications facility. The transmitting rate of the equipment is fixed at 3360 bauds but can be changed quite readily for other applications by retuning the transmit clock oscillator. Data-handling equipment is of modular construction which allows the data-sample format to be changed in word size and number by essentially adding or subtracting plug-in units.

The data receiver first converts the frequency-modulated tone received from the communications facility into serialized four-level pulses. It then changes these pulses to their binary equivalents and stores the data until a complete sample is received. The data receiver then rapidly transfers the stored sample on 36 lines into a computer in a four-word sequence before the next data sample commences to arrive. The detection, timing, and sequencing circuitry to perform these functions are contained in the data receiver. As in the transmitter, flexibility is inherent in the modular design to allow for convenient change of data format if other applications become desirable in the future.

There are no operating adjustments or controls in either the transmitter or the receiver. Variable components are provided for adjusting oscillator frequencies, and these frequencies are normally checked and adjusted, if necessary, only during infrequent " line-up " procedures.

The performance of this system has generally followed that expected from analysis of the experimental results described. Tests were conducted using untreated video pairs and 19-gauge non-loaded cable pairs as the transmission media. Also, some operational experience was gained using delay-corrected carrier voice channels as the communications link. Transmission at the rate of 3360 bauds has been essentially error-free over cable pairs. Carrier voice-channels error rates occurred between one error in 10^6 bits and one in 10^7 bits.

Additional series of transmission tests were performed. For purposes of these tests the FM output tone from a data transmitter was recorded on magnetic tape for subsequent application to various communications circuits which were considered to be a representative cross-section of the transmission facilities encountered in the telephone plant. Each test signal received after transmission through these circuits was recorded and at a later date " re-run " into a data receiver for error-rate measurements. The amount of signal degradation and consequent additional measured errors introduced by the multiple use of this record-reproduce technique remains an unknown variable.

An analysis of the data available from all sources indicates that satisfactory performance at 3000 bauds can be assured under the following minimum transmission conditions:

(a) received signal-to-noise ratio of 30 db,

(b) 3 db attenuation points at 700 and 3000 c/s,

(c) envelope delay corrected to 500 microseconds between 700-3000 c/s.

On 2000 bauds operation, these conditions can be relaxed significantly with regard to envelope delay correction so that 1 millisecond delay between 700 and 3000 c/s is tolerable.

UNITED KINGDOM: MEASUREMENT OF ERROR RATE ON VOICE-FREQUENCY TELEGRAPH CHANNELS AT 50 BAUDS

(Extract from contribution GT.43, No. 6, December, 1959)

A series of tests have been made in the United Kingdom to determine the error rate on 50-baud telegraph channels. Three groups of tests were made and are described below.

PART III*a* describes tests taken on the United Kingdom automatically switched telegraph network.

PART III*b* describes tests over an international private telegraph circuit.

PART III*c* describes tests taken on the United Kingdom telex network.

PART III*a*.

Tests taken on the United Kingdom automatically switched telegraph network

General.

1. The object of the tests was to measure the synchronous element error-rate and the start-stop character error rate on switched 3 and 4 link V.F. telegraph circuits. For data transmission the results of the element error-rate test are of most interest but the character error rate was also measured and the results are given.

Method of test.

2. A series of dialled loop connections were set up and measurements taken of the element error rate in one direction of transmission and the character error rate in the opposite direction of transmission simultaneously. The signals used for the element error-rate measurements were 50 bauds, 7-unit start-stop signals with random code elements, but as they were transmitted without inter-character pauses they were suitable for synchronous reception. The element errors were detected and counted on a synchronous comparator which was supplied with the incoming signal and a locally delayed version of the transmitted signal. Each test connection was subjected to 5 consecutive tests each of 10 000 elements (200 seconds).

3. The signals used for the character error-rate measurements were generated by a 7½ unit auto-transmitter from a tape containing a block of 1000 random characters and at the receiving end operated a reperforator. Each connection was subjected to 5-11 blocks of 1000 characters. The errors were counted by feeding the transmitting and receiving tapes into a tape comparator.

4. A total of 199 test connections were set up over 61 different 4-link circuits and 6 different 3-link circuits. Although a route was used several times, it is unlikely that the same combination of V.F. channels was encountered on each occasion.

5. *Results of the tests.*

(a) *Element error-rate measurements:*

Total number of tests made	376
Tests with at least one element error	58

Number of blocks of 10 000 elements transmitted	1880
Blocks with at least one element error	71
Total number of elements transmitted	18.8 million
Total number of elements incorrectly received	212

It was noticed from casual observation of the comparator that errors tended to occur in bursts and that there was considerable variation in the error rate of different connections.

The average error rate is 1 per 90 000 elements.

Using a synchronous receiver over the selection of 3 and 4-link connections, the following performance was obtained.

200-sec. calls free from error	96.2%
,, ,, with 1 element error	1.2%
,, ,, ,, 2 ,, errors	0.8%
,, ,, ,, 3 ,, ,,	0.6%
,, ,, ,, 4 ,, ,,	0.4%
,, ,, ,, 5 or more element errors	0.8%

(b) *Character error-rate measurement:*

Total number of tests made	302
Tests with at least one character error	14
Number of blocks of 1000 characters transmitted	2280
Number of blocks with at least one character error	19
Total number of characters transmitted	2.28 million
Characters incorrectly received	98

Examination of the receiving tapes showed that the character errors occurred in groups, the most frequent cause being loss of synchronism by the start-stop receiver.

The average error rate is 1 in 23 000 characters

The following performance was obtained:

200-sec. calls free from error	99.2%
,, ,, with 1 character error	0.16%
,, ,, ,, 2 ,, errors	0.14%
,, ,, ,, 3 ,, ,,	0.10%
,, ,, ,, 4 ,, ,,	0.08%
,, ,, ,, 5 or more character errors	0.32%

PART III*b*.

Tests over an international private telegraph circuit

General.

1. The object of the tests was to ascertain the element and character error rate on a 50-baud private circuit over two European international V.F. telegraph channels in tandem with either two or four national channels.

Method of test.

2. The start-stop 50-baud signals from an auto-transmitter were transmitted from an office in the United Kingdom over two international telegraph channels and then extended first over two national telegraph channels and later four national telegraph channels in tandem back to the office of transmission. The signals were received on a receiving perforator (or reperforator) and the ' received ' tape was continuously compared with the ' sent ' tape, due allowance being made for propagation time. The character errors were recorded and by examination of the tapes the element errors were counted.

3. The test message of 1704 characters was divided into four identical blocks, i.e. 426 characters (2987 elements) per block. The tests were conducted between the hours of 8 a.m. and 4 p.m. daily.

Results.

4. *Two international and 2 national V.F. telegraph channels in tandem—1080 miles:*

Number of blocks transmitted	1668
,, ,, ,, with 0 element error	1660
,, ,, ,, ,, 1 ,, ,,	1
,, ,, ,, ,, 2 ,, errors	0
,, ,, ,, ,, 14 ,, ,,	1
,, ,, ,, ,, 32 ,, ,,	1
,, ,, ,, ,, 35 ,, ,,	2
,, ,, ,, ,, 56 ,, ,,	2
,, ,, ,, ,, 126 ,, ,,	1

Error rate 1 in 114 500 characters
,, ,, ,, 122 000 elements.

5. *Two international and 4 national V.F. telegraph channels in tandem—1360 miles:*

Number of blocks transmitted	1459
,, ,, ,, with 0 element error	1412
,, ,, ,, ,, 1 ,, ,,	13
,, ,, ,, ,, 2 ,, errors	6
,, ,, ,, ,, 3 ,, ,,	5
,, ,, ,, ,, 4 ,, ,,	0
,, ,, ,, ,, 5 ,, ,,	1
,, ,, ,, ,, 6 ,, ,,	3
,, ,, ,, ,, 7 ,, ,,	1
,, ,, ,, ,, 8 ,, ,,	1
,, ,, ,, ,, 9 ,, ,,	1
,, ,, ,, ,, 11 ,, ,,	1
,, ,, ,, ,, 15 ,, ,,	2
,, ,, ,, ,, 16 ,, ,,	1
,, ,, ,, ,, 30 ,, ,,	1

There were also 11 blocks having 56, 66, 77, 147, 168, 225, 300, 370, 400, 1500 and 1974 errors respectively.

Error rate 1 in 16 000 characters
,, ,, 1 ,, 32 000 elements.

PART IIIc.

Character error tests over the United Kingdom telex network

1. The tests were made to measure the character error-rate of 7½-unit telegraph signals transmitted over connections comprising 2, 3 or 4 voice-frequency telegraph links. The signals were transmitted from an automatic tape transmitter and one of the subscribers' circuits included one V.F. link in addition to the above. The connections were set up by dialling in the normal way and the received signals were recorded on a reperforator.

For analysis the transmitting and receiving tapes were fed into a tape comparator.

2. The results are given in Table 6.

TABLE 6

Character error tests over the United Kingdom telex network

Trunk connections Number of V.F. links	Number of characters transmitted	Number of character errors	Characters per error
	Thousands		Thousands
2	464	7	67
3	1040	74	14 (includes one burst of 40 errors)
4	1800	79	23
Total	3304	160	20.6

An analysis showed that

54% of the bursts comprised more than 1 error
18% ,, ,, ,, ,, ,, ,, 5 errors
10% ,, ,, ,, ,, ,, ,, 10 ,,

3. The tests are continuing and the element errors will be recorded in future as being more applicable for determining the performance of the circuit for data transmission.

SWEDEN: DATA TRANSMISSION OVER TELEGRAPH CIRCUITS

(Extracts from contribution GT.43—No. 9, February 1960)

Certain investigations have been made for the purpose of ascertaining the susceptibility to interference of different types of telecommunication circuits at a transmission speed of 50 bauds. In the type of tests referred to here, a certain text perforated on a tape is sent by an automatic transmitter over a loop circuit. After passing the loop the text is perforated into a new tape by means of a reperforator. The occurrence of a failure or an interference on the circuit will make itself apparent by causing the reperforator to make a misperforation. The reperforated tape will again be introduced into the auto-transmitter and the text with possible alterations will again be retransmitted over the loop. Thus alterations occurring during a prolonged test will be accumulated, and upon termination of the test the alterations can be summed up and will provide a measure of the reliability of the loop.

Such tests were carried out during altogether 152 days on physical and carrier frequency circuits, 52 days being spent on physical circuits and 100 days on carrier circuits. The tests were pursued each time during a continuous period of 6 hours in the daytime, when according to experience the reliability of service is at a minimum. The measuring results obtained refer to circuits of a length of about 1000 km. A typical pattern of distribution of faults is shown in the Appendix. During 6 hours, transmission is effected of about 140 000 telecommunication signs, each requiring 7-unit pulses, thus of altogether about 1 000 000 pulses.

2.1 *Parallel and series modulations.*

Parallel and series modulations both have their advantages and inconveniences. A parallel system can profitably be used in connection with data apparatus designed to provide as well as to receive information in parallel form. For commercial lines connected to an automatic switching system a series system seems to be preferable. It therefore appears advisable to standardize a parallel as well as a series system, in any case for the present, awaiting the future development of data-transmission techniques as regards transmission speeds wanted and other requirements.

A parallel system should be based on frequency distribution in the present voice-frequency telegraph service, so that the frequency bands can be arranged in multiples of 120 c/s and the channels be located in the normal voice-frequency telegraph systems. The frequency division 480 c/s, for instance, would provide a speed of 300 bauds and that of 720 c/s about 500 bauds, and there are other divisions and speeds that could easily be accommodated in the present V.F. systems.

APPENDIX

Number of misprints in 6 daytime hours	Number of tests on	
	physical circuit	carrier frequency circuit
0	38	37
1	10	5
2	2	5
3	2	4
4		5
5		2
6		5
7		0
8		1
9		2
10		1
11 — 15		1
16 — 20		3
21 — 30		2
31 — 40		9
41 — 60		3
61 — 80		1
81 — 100		3
101 — 200		3
201 — 400		4
401 — 800		4
	52	100

Length of circuit: about 1000 km.

WORKING GROUP 43: REPORT

(Extract from contribution GT.43, No. 20, March 1960)

3. *Consideration of transmission characteristics of telegraph circuits for data transmission.*

3.1. *Standardized circuits.*

These circuits conform to C.C.I.T.T. Recommendations.

For data-transmission purposes it is useful to know the performance that can be expected from a 50-baud telegraph circuit standardized in accordance with C.C.I.T.T. recommendations.

The performance is expressed by:

(a) the maximum degree of distortion that such a circuit may introduce into a 50-baud telegraph communication, and

(b) the mean error rate introduced by " mutilating " disturbances, i.e. disturbances causing a change in the significant condition of the modulation during one or more elementary intervals.

As regards *(a)*, it can be said that if the gross start-stop distortion at the input to the telegraph circuit is less than 10%, the gross start-stop distortion at the circuit output will be less than 35%.

With respect to *(b)*, many measurements have been made for telegraphy, but the recordings of these measurements are not all of use for data transmission.

For data transmission it is useful to know the error rate per element rather than per character, since the composition of a character depends on the code chosen for the data, and this code depends, in part, on the degree of protection against undetected errors.

To establish an error-detection system well suited to requirements, it is essential to know the " fine structure " of the errors, i.e. the relative number of errors per element, the probability of their being grouped as single errors (one mutilated elementary interval), double errors (2 consecutive mutilated elementary intervals), triple errors (3 consecutive mutilated elementary intervals) etc., together with the probability distribution of the number of correctly transmitted elements separating the mutilated elements.

The following results, taken from contribution GT.43—No. 6 (United Kingdom) and from the supplementary results given during the meeting, give an idea of the quality of 50-baud standardized telegraph circuits:

circuit composed of 1 (national) voice-frequency telegraph channel: error rate on characters = 1/49 000;

circuit composed of 3 (national) voice-frequency telegraph channels: error rate on character = 1/100 000;

circuit composed of 2 (international) and 2 (national) voice-frequency telegraph channels (length: 1080 miles); error rate on elements = 1/122 000; error rate on characters = 1/114 500;

circuit composed of 2 (international) and 4 (national) voice-frequency telegraph channels (length: 1360 miles); error rate on elements = 1/32 000; error rate on characters = 1/16 000.

Not too much significance should be attached to these results as they are not derived from a sufficient number of tests; they merely give an idea of the approximate error rate on point-to-point circuits.

It may however be foreseen that in practically every case data transmission will call for protection against errors.

It would be desirable for Administrations to take measurements on the element-error rate, so as to enable appropriate error-detecting methods to be devised for data-transmission systems. To this end, a programme of measurements to be carried out by Administrations has been drawn up (point G of the Annex to Question 1/A).

3.2 *Non-standard telegraph circuits.*

It is possible that the use of circuits for modulation rates higher than 50 bauds will be considered, particularly as there is quite a lot of telegraph apparatus in service with a higher modulation rate than 50 bauds and since the question is being studied by the C.C.I.T.T.

Although it is too early to indicate what modulation rates should be contemplated, it may be mentioned to Administrations that it would be of interest to consider 75, 100 and 200 bauds.

4. *Considerations on the use of switched telegraph networks for data transmission.*

The results of tests carried out on either the telex network or the gentex network are to be found in contribution GT.43—No. 6 (United Kingdom).

The following error rates may be quoted from these results:

gentex network:	mean error rate on elements:	1/90 000,
	mean error rate on characters:	1/23 000,
telex network:	mean error rate on characters:	1/20 600.

The error rate varies considerably from one connection to another.

The telex network provides means for rapid telecommunications by reason of its automatic switching which is developing more and more; it is well suited to the transmission of two-condition code signals, although with a low modulation rate (50 bauds).

5. *Restrictions to be recommended when telegraph channels are used for data transmission.*

For the use of standard circuits and for the use of the telex network, it can be specified that signals sent for data transmission should have the same quality as is required for telegraph signals, i.e., their gross telegraph distortion should be less than 10%.

Data-receiving apparatus has to be capable of correctly recording the transmitted signals with a (telegraph) distortion of less than 35%; in other words, the net margin of such apparatus has to be 35%.

UNITED KINGDOM: SERIAL BINARY DIGITAL TRANSMISSION OVER TELEPHONE-TYPE CIRCUITS

(Extracts from contribution GT.43, No. 6, December 1959)

Introduction.

1. Some of the makers and users of computers and automatic data-processing equipment need to know what facilities can be offered by Administrations for the transmission of serial binary digital signals at rates much higher than can be carried by nominally 50-baud telegraph circuits. At present, interest is mainly in the use of telephone-type circuits for rates ranging from a few hundred to a few thousand bits per second.

2. It is recognized that it would be quite impracticable for Administrations to make fully comprehensive surveys of all types of telephone transmission and switching plant and to compile performance specifications covering such impairments as attenuation/frequency and phase/frequency distortion, non-linearity distortion, frequency error, random and impulsive noise, crosstalk and short interruptions.

3. The United Kingdom Administration therefore suggests that the Working Party might consider an alternative approach to the problem. The proposal is that Administrations, through the C.C.I.T.T., shall offer guidance to the data-equipment manufacturers by stating the main features of each of several " recommended data-transmission systems " which may be expected to give satisfactory results on certain defined classes of private circuit and switched connection. This proposal is based on the assumption that it may often be desirable, for reasons of economy and convenience, to incorporate the necessary sub-carrier modulating and demodulating units in the data-processing equipment.

4. The experimental work needed to determine the systems to be recommended may be carried out by Administrations alone or by Administrations in co-operation with data-equipment manufacturers.

5. The proposal may be illustrated by considering its application to one particular class of private circuit, namely the kind which is suitable for carrying 18-channel voice-frequency telegraph systems (420-2460 c/s). This class of circuit is provided on a 4-wire basis throughout to meet well-established transmission standards which do not call for the use of delay equalizers. Attention will be restricted to " bit-synchronous " data systems, i.e. those which are synchronous in the telegraph sense, as distinct from " start-stop " systems. For such an application it may perhaps be desirable to consider two alternative " recommended data-transmission systems ", the first using relatively simple sub-carrier modulating and demodulating units and the second using more complex units designed to yield a higher signalling rate or lower error rate. After a full assessment of both systems has been made, it may happen that the data-equipment manufacturers will unanimously prefer one of them; if so, the other could be abandoned.

6. In the following sections are given brief details of two experimental data-transmission systems, and in Part II *(a)-(d)* are given summaries of some preliminary tests made recently over private circuits and switched connections in the United Kingdom.

Data System A.

7. For tests over private circuits of the class mentioned in para. 5 the United Kingdom Administration has first considered one possible version of the simpler data-transmission system, the main features being as follows:

Data system:	bit-synchronous; 1000 bits/sec.
Method of modulation:	on-off amplitude modulation; double sideband.
Sub-carrier frequency:	1600 c/s.
Nominal bandwidth of main channel:	800-2400 c/s.
Line signal amplitude:	1 volt peak-to-peak at a point of zero relative level.

Sending-end units:	input shaping network; single-stage modulator.
Receiving-end units:	band-pass line filter; auto-gain-control amplifier; envelope detector; output shaping network; pulse regenerator.
Auxiliary channel:	600 c/s sub-carrier, narrow-band, for auxiliary signals or pilot.

8. For the purpose of the tests, the auto-gain-control amplifier and the auxiliary channel were omitted. Because the sending and receiving units were at the same location, bit-synchronizing arrangements were also omitted.

9. It may be mentioned that the sub-carrier frequency, 1600 c/s, was chosen as a compromise between opposing delay-distortion requirements. A higher frequency would be preferable for a circuit routed wholly on modern microwave or cable carrier systems, and a lower frequency for a loaded-cable audio circuit.

10. In addition to the main tests over private circuits, the opportunity was taken to make a few tests over switched connections with this system, although it would not, of course, be recommended for such an application.

Data System B.

11. Tests were also made with a second type of data-transmission system the main features of which are:

Data system:	Carrier synchronous: adjustable bit rate; bit period corresponds to an integral number of half-cycles of the carrier.
Method of modulation:	Phase reversal at zero crossings of the carrier.
Sub-carrier frequency:	Adjustable, 1000 c/s, 1500 c/s, 1800 c/s, 2000 c/s.
Sending-end unit:	Single-stage balanced modulator.
Receiving-end unit:	Phase detector with a synchronous carrier. The phase-detected output is filtered and squared to yield the data output. The synchronous carrier is obtained from the delayed input signal by reversing the phase of this signal at each binary transition in a phase modulator. The timing waveform, or clock, is derived in the receiver directly from the output data.

12. No filtering or clipping was employed at the input of the receiver used for the tests. Automatic gain control was not provided. These may be incorporated in the final design. For the tests an eight-bit character generator was used.

PART II*a*.

Tests for data system " A " over private circuits

1. The tests were made over three types of circuit, constituted as follows:

Circuit 1: Three links, interconnected at audio-frequency points, on coaxial-cable systems totalling 500 miles in length; the two directions of transmission, designated 1*a* and 1*b*, were tested separately. Uniform-spectrum continuous random noise having a psophometric power (telephone-type weighting) of 10^6 picowatts at a point of zero relative level was added to the existing circuit noise to provide a more stringent test.

Circuit 2: Three links, interconnected at audio-frequency points, on 24-channel balanced-pair cable systems totalling 430 miles in length. The two directions of transmission, designated 2*a* and 2*b*, were tested separately. Random noise of 10^6 picowatts psophometric power was added as for circuit 1:

Circuit 3: A unidirectional audio link, 100 miles in length, on 20-lb./mile conductors loaded with 88 -mH coils at 2000-yd spacing. Random noise of 10^5 or 10^6 picowatts psophometric power was added as for circuit 1.

2. Most of the tests were made with random data-test signals at 1000 bits/sec; the remainder were made with various recurrent patterns chosen to provide particularly stringent conditions. Generally, each test consisted of the continuous transmission of 10^7 bits, occupying approximately 167 minutes and covering either the morning or afternoon busy hours. The received signals, after regeneration, were compared continuously with a delayed replica of the transmitted signals. Every incorrect bit caused a unit to be added to the total of an error counter. The approximate time of occurrence of each burst of errors was noted, together with the number of errors in the burst. It may be remarked that the term " burst " is not precisely defined, but merely means a relatively isolated group of errors which are not necessarily in consecutive bits.

3. The results of these preliminary tests are given in Table 1, and the main conclusions are summarized in the following paragraphs 4-7.

4. The frequency of occurrence of bursts of N errors tends to decrease rapidly as N increases from 1 upwards.

5. The larger bursts of error are attributed to " brief interruptions " of the kinds which have been studied by the C.C.I.T.T., namely, those caused by imperfectly soldered

TABLE 1

Tests with data system " A " over private circuits

Circuit No.	Added noise pW	Duration of test minutes	Percentage of error-free minutes	Number of bursts containing the following number of errors: 1	2	3	4	>4
1*a*	10^6	167	96.4	1	2	0	0	1 of 6 1 of 100 1 of 525
	,,	167	99.4	1	0	0	0	0
	,,	167	95.8	3	1	0	1	1 of 6 1 of 7
	,,	167	100	0	0	0	0	0
1*b*	10^6	167	98.8	1	0	0	0	1 of 4348
	,,	167	97.6	1	0	0	0	1 of 9 1 of 419 1 of 519
	,,	167	100	0	0	0	0	0
	,,	167	100	0	0	0	0	0
2*a*	10^6	167	95.2	6	2	0	0	0
	,,	167	100	0	0	0	0	0
	,,	270	97.0	4	0	1	1	2 of 9 1 of 189
	,,	167	98.2	2	0	0	1	0
	,,	167	94.0	4	2	2	0	2 totalling 823
2*b*	10^6	167	96.4	3	1	2	0	0
	,,	167	99.4	1	0	0	0	0
	,,	167	99.4	0	0	1	0	0
3	0	167	100	0	0	0	0	0
	10^5	167	100	0	0	0	0	0
	10^6	167	88.0	12	7	0	1	0

joints and by defective contacts in switches, jacks, valve-holders and the like. It should be mentioned that none of the circuits used in the tests had received special treatment designed to reduce the frequency of brief interruptions. The smaller bursts of errors may have been caused either by brief interruptions or, more likely, by impulsive noise arising from component defects or external interference.

6. Because errors tend to occur in bursts, the usual description of performance in terms of " mean error rate" would be inadequate and misleading. Instead, each test period is divided into 1-minute intervals and the percentage of these intervals which are free from errors is taken as the primary figure-of-merit. It is suggested that the Working Party might consider standardizing this " percentage of error-free minutes " as one of the

statistics to be recorded in future tests. It is also suggested that particular attention should be given to *(a)* the statistical distribution of the time intervals between successive bursts, and *(b)* the detailed structure of the bursts.

7. As expected, waveform distortion was the dominant impairment in the case of the audio circuit (No. 3), indicating the importance of keeping to a minimum the length of loaded audio sections in data-transmission circuits intended for high signalling rates.

PART II*b*.

Tests with data system " A " over switched connections

1. Although not intended for such an application, data system A was tested over some switched connections in the experimental " subscriber trunk dialling " network in the

TABLE 2

Tests with data system " A " over switched connections

Signal amplitude	Connection No.	Duration of test minutes	Percentage of error-free minutes	Number of bursts containing the following number of errors: 1	2	3	4	>4	Mean interval between bursts seconds
2V p-p.	1	25	48	15	5	0	0	10	75
,,	2	30	57	4	4	5	2	4	95
,,	3	30	50	15	2	1	0	2	90
,,	4	30	63	10	1	2	2	1	112
,,	5	15	67	3	0	0	1	1	180
,,	6	30	70	5	4	0	1	2	150
,,	7	30	47	9	4	4	1	5	78
,,	8	30	50	12	3	1	2	1	95
		Total	Mean	Totals					Mean
2V p-p.	1-8	220	56	73	23	13	9	16	99
4V p-p.	1-8	220	71	58	16	3	2	3	161
1V p-p.	1-8	225	32	211	65	52	18	61	33

United Kingdom. Several connections were set up over one route, i.e. London-Birmingham-Swansea-London, involving two local and five trunk automatic exchanges. A different combination of circuits was probably encountered for each connection.

2. The main tests were made with a signal amplitude of 2V peak-to-peak applied to the subscriber's line, but tests were also taken with amplitudes of 4V and 1V peak-to-peak. No additional noise was injected into the received signal. The method of test was similar to that described in paragraph 2 of Part II*a*, except that the duration of most of the tests was 30 minutes.

3. The results of the test are given in Table 2.

PART II*c*.

Tests with data system "B" over private circuits

TABLE 3

Sub-carrier frequency 2000 c/s — Signalling rate 1000 bits/sec.

Type of circuit	Duration of test in minutes	Percentage of error-free minutes	Errors
Audio, 100 miles 20 lb./mile conductors, loaded 88-mH coils at 2000-yd. spacing	15	100	Nil
Three 24-channel carrier systems interconnected at audio-frequency points, totalling 430 miles	15	93	One burst of 3 errors
Three coaxial systems interconnected at audio-frequency points, totalling 500 miles	15	100	Nil

PART II*d*.

Tests with data system " B " over switched connections

TABLE 4

Signalling rate 1000 bits/sec.

Route	Sub-carrier frequency	Duration of test	Percentage of error-free min.	Number of bursts containing the following number of errors													Total errors
	c/s	minutes	%	1	2	3	4	5	6	7	8	9	11	12	20	91	
London-Birmingham-Swansea-London	2000	15	0	17	13	7		4	2	2		3	1	1	1	1	271
London-Birmingham-Swansea-London	"	"	80	1	2												5
London-Carlisle-London	"	"	60	3	2		1	1									16
London-Chester-Birmingham-London	"	"	27	9	4		4				1						41
London-Swansea-London	"	"	47	5	3	4											23
London-Birmingham-Chester-Swansea-London	"	"	33	15	1		1										21
London to a Chandlers Ford Exchange subscriber	1500	"	0	146	25	2		1									207
"	"	"	80	2	1		1				1		1				27

TABLE 5

Connections across London which are known to be approaching limiting attenuation

Sub-carrier frequency 2000 c/s — Signalling rate 1000 bits/sec.

Test No.	Duration of test	Percentage of error-free min.	Number of bursts containing the following number of errors													Total errors
	min.	%	1	2	3	4	5	6	7	8	9	10	17	25	39	
1	15	40	6	4	4	3	1	1								58
2	15	20	7	7	2	2		2	1	1						62
3	15	87	1			1										5
4	15	13	11	7	3	9	5	4		2	1	22	2	1	1	262

TELEFONOS DE MÉXICO: HIGH-SPEED DATA TRANSMISSION

(Contribution GT.43, No. 7, January, 1960)

1. *Scope.*

At least four classes of data traffic can be envisaged, for which there is every reason to expect interest to be shown in the future. These are namely:

I. via a telegraph channel,

II. via a telephone channel in the general network,

III. via a specialized telephone channel.

IV. via a 48 kc/s band corresponding to the whole band occupied by a 12-channel telephone group.

This contribution is primarily concerned with the transmission requirements for classes II, III and IV. We suppose the distinction whereby one imagines a class II channel to be obtained by dialling and class III to refer to private lines will disappear; we understand that in America it is already possible in certain cases to obtain special quality lines by dialling an appropriate prefix before the wanted subscriber's number.

2. *Class III traffic.*

2.1. *Objectives.*

In order that this (or indeed any) service shall prove worth while, it has to be made economically attractive to the subscriber. We therefore consider that the first limited objective should be to keep the transmission equipment rather simple and inexpensive, even though this may render it impossible to exploit to the full the capabilities of the channel for information transmission. Later, when the service has grown, there may be justification for diverse types of equipment, in the same way as today for telephony we have normal, short-haul and " high-efficiency " terminal equipment, according as line costs justify expenditure on terminal equipment for better exploitation of the line.

2.2 *Sub-channels.*

The first question which seems to arise is whether a sub-division of the telephone channel is of value. For comparison we can consider the sub-division made for telegraphy. There are 24 sub-channels each having a transmission rate of 50 bauds (= 50 bits/second with the bivalent code used), giving a total transmission rate of 1200 bits/second. Each element lasts 20 milliseconds and each sub-channel is some 120 c/s wide, so that the requirements imposed on the bearer telephone channel concerning delay distortion are that this shall be somewhat less than 20 milliseconds in any band of 120 c/s. This is very easily met without any special precautions. Now a single high-speed channel using the same modulation principle and with the same transmission rate must have an element duration of $20/24 = 0.87$ millisecond and a bandwidth of very roughly $120 \times 24 = 2880$ c/s. Thus a delay distortion of somewhat less than 870 microseconds (actually about ± 0.4 times the signal element—see bibl. 1) over a band of upwards of about 2000 c/s is needed.

We conclude from such studies that for a class III channel over a carrier system undergoing only one pair of channel modulation/demodulations up to about 1000 to 1200 bauds could be transmitted without delay equalization. (A system of the kind which might be envisaged is described in bibl. 2). For longer, more complex circuits which may consist of several tandem links with demodulation to voice frequencies (compare the nominal maximum circuits of the various systems) some kind of delay equalization would be desirable to allow economic exploitation of the channel capacity. Feasible objectives for such equalization have been discussed, for instance, in the C.C.I.T.T. *Red Book*, Vol. I, page 123, in conjunction with phototelegraphy. These might permit of speeds even up to 2000 bauds or so. Better can hardly be achieved by sub-channelling, which may have certain disadvantages, as discussed in paragraph 4 below.

In the passive part of the network, loaded phantom circuits offer fairly good possibilities of equalization to the required degrees.

To keep the system of transmission for class III traffic as simple as possible, we should therefore be inclined to use delay equalization and thereby to dispense with channel subdivision, i.e. to use a single-channel data system. This will mean the designation of certain circuits in advance so that the necessary equalization can be carried out. It may also be desirable to designate stand-by circuits, as is now the practice for circuits used for voice-frequency telegraphy.

2.3. *Type of modulation.*

Practical methods of utilization of a transmission band involve modulation of a sub-carrier. Methods which appear worth considering are:

(a) amplitude modulation, double sideband,

(b) amplitude modulation, vestigial sideband,

(c) frequency modulation,

(d) phase modulation.

The first three are methods whose practicability has been proved in conjunction with phototelegraphy. The last method appears to have certain theoretical advantages (bibl. 3). The maximum advantage, however, is achieved only when phase-locked carrier systems are used. A form which has been tried out on a limited scale in practice is " Kineplex " (bibl. 4, 5).

As in the case of phototelegraphy, it may be that different types of modulation could be preferable in different circumstances. We think this point may be left open for the moment, but if a standardization is desired later, it might be based on the results of actual trials. Certain further aspects are dealt with below in conjunction with errors and noise.

2.4. *Code valency.*

The type of data we have in mind here needing to be transmitted is in digital and not analogic form. By well-known methods, such digital information may be transformed into a scale of any desired notation. Information theory indicates (bibl. 6) that there would be some advantage to be gained in normal circumstances by using codes of higher valency that the two-condition code used in, for instance, voice-frequency telegraphy. Nevertheless, we consider that this would involve unnecessary complication: in fact, apart from cable code, polyvalent codes have never found favour technically in the past and we have consequently restricted ourselves to the consideration of bivalent codes for the actual information transmission. A third condition may, however, be desirable for " start " signals in order not to restrict the form of the information signal. This third condition might, for instance, take the form of a specially high level in the case of amplitude modulation (this is used in the American SAGE system), or of a third frequency in an f.m. system.

We do not consider a special code condition is necessitated by phasing requirements. The choice of method is admittedly restricted because of lack of synchronism between carrier terminals. However, a method which appears to have the possibility of a very general application is to exploit the transitions between the " 0 " and " 1 " conditions in the actual information transmission. Phasing can then be accomplished using the known " flywheel " or " spongy lock " technique.

2.5. *Distortion limits for the demodulated signal.*

Given that digital data are to be transmitted in the form of a bivalent code, the distortion which is significant is the transient (waveform) distortion when an abrupt transition from one state to the other is sent. An analogous problem arises in television transmission, and we think there is a lesson to be learned from experience in this field. This is that, for checking overall performance from sub-carrier modulator input to demodulator output, it is best to specify a distortion limit directly in the form of a waveform response, rather than trying to arrive at it indirectly by specifying the steady-state frequency and delay distortions. But for line maintenance personnel who need to check the performance of the telephone bearer channel, limits of steady-state frequency and delay distortion are needed. As a corollary, correction of small amounts of distortion is most rapidly and conveniently carried out where necessary by waveform correction at the terminal equipment rather than by equalization of the steady-state response. Line sections are, however, best maintained with the aid of steady-state measurements.

2.6. *Distortion limits for the code elements.*

The modulated signal is passed to some form of receiving relay, i.e. a two-state trigger device. The resulting output has thus no longer any waveform errors but (in case of envelope demodulation) only timing distortion. This is of the same nature as telegraph distortion, and analogous limits could perhaps be applied. Equipment for this type of distortion measurement at high speed is already available commercially. The use of so-called synchronous demodulation corresponds to the use of regeneration in telegraphy, in that no timing distortion but only errors can occur.

It would appear that keying loss (bibl. 7) can be more likely to cause distortion in data systems, and this point should be watched. One possible approach is to synchronize modulation and sub-carrier, but this can lead to difficulties with frequency errors in carrier systems.

2.7. *Error rate.*

It ought to be possible to keep errors arising from accumulation of distortion at quite a low level for class III traffic. Most errors will then probably arise owing to short interruptions in transmission or sudden variations in equivalent. (The possibility of errors due to noise is dealt with below.) The recent investigations of Study Group 4 are of value in this connection, and also the results published in the C.C.I.T. *Violet Book* Supplements, pages 41-50.

We may deduce that with shorter elements the error rate will be higher than that achieved for telegraphy, whereas the performance expected by the subscriber will almost certainly involve lower error rates. Some kind of error detection and correction will thus be necessary. This can of course be achieved, though not in a very simple manner, by introducing redundancy into the coding. A difficulty arises because errors do not occur randomly distributed in time. Available results have not been analysed to determine what the law of distribution is, but it is fairly clear that errors tend to occur grouped together. This means that full advantages cannot be taken of redundancy within groups of elements only covering a short time, because of the correlation of error risk. Furthermore, the addition of redundant elements inevitably reduces the effective transmission speed.

However, it should not be lost sight of that a telephone circuit assigned to data transmission will be four-wire over the greater part of its length, with separate go and return channels, and with class III traffic, to extend the four-wire circuit all the way to the subscriber *. We then have available the rather simple technique of checking the transmission via the return channel, as already suggested for telegraphy (Question 7/VIII). Even if there is a correlation between the time of occurrence of certain breaks in the go and return channels, e.g. due to change over to common stand-by power, the delay introduced by re-transmission would be sufficient to eliminate correlation of this type. Hence the

* This is even a tendency of development for the general telephone network.

probability of an undetected error is quite simply the probability of simultaneous cancelling of errors in the forward transmission and checking paths. For an unchecked error rate of 1 in 10^4 for instance, the checked error rate should be 1 in 10^8.

If further improvement is required, redundancy or double transmission (either successive or in diversity by different routes) would be necessary. It may be worth considering reversing the mark and space conditions for the check path if a.m. is used. It may also be noted in this connection that a frequency-modulated or phase-modulated signal allows a rather simple direct check on transmission interruptions or sudden level variations, since a signal of constant amplitude is always present. This may prove an advantage. Furthermore there is the noise advantage obtainable from f.m. or p.m.

It is also necessary to take into account the relative effect of frequency errors (arising from lack of synchronism in carrier systems) with different systems of demodulation.

From the subscriber's point of view it would no doubt be highly desirable to have a fixed maximum error rate introduced by the transmission. However, there are obvious difficulties in trying to work to a common standard irrespective of the circuit constitution; on the other hand the hypothetical reference circuit is not of much help to us here as the laws of addition of errors are not very clear — the same difficulty is already recognized with telegraphy. Furthermore it is doubtful whether an Administration can guarantee that a certain value is not exceeded; at best only a long-time average could be given with considerable statistical uncertainty in its determination. A comprehensive programme of tests and subsequent statistical analysis would be necessary, and this is probably beyond the resources of smaller Administrations.

2.8. *Noise.*

The amount of distortion or number of errors due to noise should remain within acceptable limits, even if radio links are used for transmission. The recent report of the Noise Working Party provides us with typical curves of noise distribution which can help to form a basis for system design. It may be noted that the noise limits are for 5 milliseconds integration time, while for the type of transmission envisaged here the element length would be much shorter. A further point is that the noise level variations within a period of a second are considered to be negligible. Hence there will be difficulties in exploiting redundancy in the case of radio link transmission, because the error rate due to noise for signal elements not widely separated in time is not uncorrelated and earlier remarks regarding errors due to interruptions. This results in the improvements obtainable with practical redundant codes being rather small (bibl. 8) and being actually negative unless a certain threshold is exceeded. It therefore seems best to us:

(a) to choose the method of modulation which is least sensitive to noise,

(b) to use return-channel checking, with the inclusion of redundancy left to the user according to his particular requirements.

3. *Class IV traffic.*

An extension of the argument concerning sub-channels given above in 2.2 leads us to believe that there is little future to be expected for class IV transmission, at least for digital data, because of the phase characteristics of through-group filters. These could lead to subdivision most probably being required, and in that case normal telephone channelling appears highly suitable for the purpose.

4. *Class II traffic.*

For class II traffic, adjustment of equalization before transmission is probably just as undesirable as in the case of phototelegraphy. But the delay distortion will be a very variable quantity according to the constitution and complexity of any particular connection set up: in the general network, loaded audio cables without delay equalization may often be met with. Hence a subdivision, perhaps about 300 bauds per sub-channel, seems preferable if higher speeds are to be aimed at. Such a subdivision can also give a somewhat increased flexibility in the network. On the other hand, distortion in the telephone channel amplifiers etc. will give rise to intermodulation products between sub-channel carriers which may interfere with other sub-channels. Furthermore, if we are content with not more than 800 bauds, probably no subdivision would be needed and the terminal equipment ought to be much cheaper. The effects of circuit interruptions would presumably be about the same on either system. In this connection it may be of interest to note the results of experience in the U.S.A. (bibl. 9). In a new version of the " Dataphone " the original design has been changed to six sub-channels instead of one, and this is also said to simplify the input-output arrangements for the data-handling equipment.

An analogous solution of a data-transmission problem is used in TASI (bibl. 10), where some 6.2 bits of information (identifying one of 72 equally likely conversations) have to be transmitted over any arbitrary channel in a time not exceeding 10 milliseconds, i.e. upwards of 600 bits/second. Here multi-frequency pulsing has been chosen by the designers, doubtless having in mind the reliable performance of multi-frequency inter-register signalling. This reliability is provided by redundancy, the inherent system capacity being 1500 bits/second.

There seems to be already a fair number of commercially available types of class II transmission equipment developed by the manufacturers of data-handling equipment, (see especially bibl. 11), and we are therefore inclined not to standardize or recommend any particular form of equipment for class II traffic at present, but only to place the minimum necessary restrictions on the transmission, e.g. maximum power, and to give the necessary indications to the subscriber of the normal transmission quality of a telephone connection. In many cases this information is already available in the form of C.C.I.T.T. recommendations.

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CHILE TELEPHONE COMPANY: DATA TRANSMISSION OVER SWITCHED TELEPHONE CONNECTIONS

(Extracts from contributions GT.43, No. 8, February 1960 and GT.43, No. 17, March, 1960)

A series of tests is being carried out to examine the error distribution when data are transmitted at medium speed over telephone connections switched by two-motion, step-by-step, selectors. The transmission is substantially a continuous stream of data, but for analysis purposes the stream is considered to be divided into blocks of 50, 100, 200 and 500 bits. The tests have been arranged in such a way that the identity may be established of the individual bits which have been received incorrectly. This facility enables statistics to be collected regarding the amount of retransmission necessary to correct the errors and also regarding the probability of errors remaining undetected.

The following table lists the tests which have so far been carried out and shows, for each test, the date, the time of day, the transmission level at the output from the last switch, the number of blocks of 50 bits transmitted, the error data and the case of the test.

NOTES ON SCHEDULE OF TESTS

Key to case numbers

Case No.	Data speed	Sampling	Channel bandwidth
1	250 bits/sec.	central	250 bits/sec.
2	250 ,,	,,	1000 ,,
3	250 ,,	1/4 from 1.edge	1000 ,,
4	500 ,,	central	1000 ,,
5	250 ,,	1/8 from 1.edge	1000 ,,
6	500 ,,	1/4 from 1.edge	1000 ,,
7	1000 ,,	central	1000 ,,

Each test is designated with a serial letter and a serial number, tests with the same serial letter being carried out over exactly the same circuits. Tests A1 to D4 and GC1-JC1 were carried out over long-distance connections, and the remainder over local connections. All the tests were carried out during normal working hours, i.e. between 9 a.m. and 5.30 p.m.

The four tests YB1, YB2, ZB1 and ZB2, were not carried out on switched connections and the signal level quoted in the Schedule is the sending level.

Although the tests are not specifically designed to determine the influence on the error rate of the time of day and of the transmission level in the switched network, it has been observed:

(i) that errors occurring between 12.30 p.m. and 2 p.m. are approximately one order lower than during the busier morning and afternoon periods, and

(ii) that with a transmission level higher than –10 dbm, the error rate is only about 1/200th of that obtained with a level between –30 and –40 dbm.

Schedule of tests

Date	Test No.	Start time	Finish time	Level at last switch	Blocks of 50 bits	Number of errors	Case No.
16.11.59	A1	4.25	4.58	— 19.0 dbm	8 140	0	1
16.11.59	A2	5.05	5.40	— 25.5	8 085	7	1
17.11.59	B1	12.11	12.57	— 14.0	11 440	0	1
17.11.59	B2	1.00	1.54	— 20.0	13 640	9	1
17.11.59	B3	1.58	2.32	— 26.0	8 800	8	1
17.11.59	B4	2.37	3.09	— 32.0	8 250	25	1
18.11.59	C1	11.08	11.54	— 15.7	11 302	2	1
18.11.59	D1	2.35	3.13	— 11.7	9 625	0	1
18.11.59	D2	3.15	3.55	— 17.7	9 817	0	1
18.11.59	D3	3.58	4.35	— 23.7	9 680	0	1
18.11.59	D4	4.44	5.18	— 29.7	8 800	19	1
19.11.59	E1	10.52	11.50	— 17.6	14 740	322	1
19.11.59	E2	12.13	4.07	— 17.6	58 957	290	1
19.11.59	E3	4.11	5.33	— 23.6	19 800	0	1
20.11.59	E4	10.35	11.55	— 29.7	20 295	740	1
20.11.59	E5	1.10	2.35	— 29.7	20 157	553	1
20.11.59	E6	2.40	4.25	— 35.8	26 895	419	1
23.11.59	F	2.55	5.33	— 35.9	38 582	9	1
24.11.59	G1	12.32	2.30	— 2.0	31 047	0	1
24.11.59	H1	3.55	5.30	— 8.0	24 420	3	1
25.11.59	H2	10.10	11.16	— 2.0	21 725	0	1
25.11.59	J1	2.15	3.55	— 8.0	24 942	0	1
26.11.59	J2	10.10	10.45	— 19.8	9 212	44	1
26.11.59	J4	11.46	12.22	— 13.8	9 157	0	1
26.11.59	J5	1.00	2.10	— 19.8	17 737	0	1
26.11.59	K	3.47	5.35	— 35.8	27 747	0	1
27.11.59	L	9.42	11.00	— 19.5	19 085	4	1
27.11.59	M1	11.11	11.54	— 19.5	10 230	16	1
27.11.59	M2	12.00	12.55	— 19.5	14 740	3	1
27.11.59	M3	1.00	2.05	— 13.8	14 875	2	1
27.11.59	N1	2.16	3.09	— 19.5	13 475	138	1
27.11.59	N2	3.19	5.00	— 19.5	26 317	22	1
1.12.59	O1	10.18 1.30	12.00 3.40	— 19.8	55 000	29	1
2.12.59	P1	10.50	12.00	— 17.5	16 582	0	1
2.12.59	P2	12.00	1.00	— 23.5	14 575	0	1

Date	Test No.	Start time	Finish time	Level at last switch	Blocks of 50 Bits	Number of errors	Case No.
2.12.59	P3	1.05	2.05	— 29.5 dbm	15 207	0	1
2.12.59	P4	2.08	2.45	— 32.5	8 992	632	1
2.12.59	Q1	3.05	5.33	— 34.5	37 537	1	1
3.12.59	Q2	9.13	10.37	— 33.8	21 037	2	1
3.12.59	R1	11.00	2.08	— 34.3	46 062	0	1
3.12.59	S1	2.32	3.23	— 34.4	12 760	4	1
3.12.59	S2	3.58	5.33	— 34.3	23 732	4	1
4.12.59	S3	12.08	1.35	— 35.0	22 275	0	1
4.12.59	S4	1.37	2.34	— 35.0	19 112	0	1
4.12.59	T1	3.40	5.00	— 27.0	20 240	23	1
7.12.59	T2	9.15	11.20	— 26.8	31 102	17	1
7.12.59	U1	11.40	12.50	— 36.8	17 435	85	1
7.12.59	U2	12.55	2.10	— 36.8	18 947	41	1
7.12.59	U3	3.00	5.30	— 36.8	36 465	50	1
8.12.59	V1	9.38	11.10	— 26.9	23 237	16	1
8.12.59	V2	11.37	2.10	— 33.9	36 630	21	1
8.12.59	V3	2.23	5.30	— 51.9	47 740	77	1
9.12.59	W1	10.25	10.35	— 52.9	2 035	86	1
9.12.59	W2	10.35 4.00	12.30 5.20	— 46.9	48 757	415	1
10.12.59	X1	10.45	12.33	— 52.8	27 307	—	1
10.12.59	Y1	2.33	3.36	— 52.8	15 867	283	1
10.12.59	Y2	3.57	5.05	— 52.8	16 000	198	1
11.12.59	Z1	9.55	11.55	— 52.6	30 772	207	1
11.12.59	Z2	11.58	3.00	— 52.6	45 872	189	1
11.12.59	Z3	4.11	4.55	— 52.6	11 137	86	1
14.12.59	AB1	9.50	10.02	— 39.6	2 475	103	1
14.12.59	AB2	10.04	10.31	— 39.6	6 792	77	1
14.12.59	AB3	10.40	12.00	— 39.6	19 525	298	1
14.12.59	AB4	12.00	2.00	— 39.6	29 947	119	1
15.12.59	BB1	11.17	12.22	— 38.5	16 082	65	1
15.12.59	BB2	12.23	1.45	— 38.5	20 515	86	1
15.12.59	BB3	1.45	3.48	— 41.5	30 936	112	1
15.12.59	BB4	3.50	5.30	— 41.5	24 692	637	1
16.12.59	BB5	9.00	9.50	— 41.5	12 375	24	1
16.12.59	CB1	10.05	11.58	— 51.5	28 187	285	1
16.12.59	CB2	12.00	2.04	— 51.5	31 432	106	1
16.12.59	CB3	2.05	5.30	— 51.5	52 882	282	1
17.12.59	CB4	9.37	12.00	— 27.5	36 025	35	1
17.12.59	CB5	12.00	3.40	— 27.5	55 000	21	1
17.12.59	CB6	3.45	5.33	— 27.5	28 105	27	1
18.12.59	CB7	9.10 12.05 3.45	12.00 3.40 4.25	— 27.5	108 350	116	1
22.12.59	DB1	9.15	12.55	— 27.5	55 000	15	1
22.12.59	DB2	12.58	4.37	— 27.5	55 000	14	1
22.12.59	DB3	4.41	5.33	—	13 090	1	1
23.12.59	DB4	8.58	9.25	—	6 490	0	1
23.12.59	EB1	9.58	12.00	—	30 085	333	1
30.12.59	FB1	11.53	4.52	—	55 000	118	1
31.12.59	FB2	9.39	11.35	—	21 330	244	1
31.12.59	FB3	11.44	2.15	— 29.0	42 800	117 (+6200)	2
31.12.59	FB4	2.54	5.26	— 29.0	41 720	443	2
1. 1.60	FB5	12.38	4.37	— 30.5	64 120	20	2
4. 1.60	GB1	9.43	12.30	— 40.0	44 720	308	3
4. 1.60	GB2	12 35	3.20	— 40.0	43 880	141	5
4. 1.60	GB3	3.22	5.28	— 40.0	33 680	106	3
5. 1.60	HB1	9.16	11.18	— 40.0	33 120	399	5
5. 1.60	HB2	11.29	1.43	— 40.0	35 680	36	3

Date	Test No.	Start time	Finish time	Level at last switch	Blocks of 50 Bits	Number of errors	Case No.
5. 1.60	HB3	2.00	3.45	— 40.0 dbm	26 320	94	5
5. 1.60	HB4	3.45	5.15	— 40.0	23 440	113	3
6. 1.60	HB5	9.00	9.58	— 28.0	15 080	49	3
6. 1.60	JB1	10.30	11.07	— 26.0	9 760	34	3
6. 1.60	JB2	11.10	12.45	— 26.0	25 640	12	3
6. 1.60	JB3	12.47	2.18	— 26.0	24 280	26	5
6. 1.60	JB4	2.22	2.43	— 30.0	5 720	1	3
6. 1.60	JB5	2.45	4.07	— 40.0	21 960	89	3
6. 1.60	JB6	4.27	5.03	— 40.0	9 320	625	5
6. 1.60	JB7	5.04	5.30	— 40.0	7 080	74	3
7. 1.60	KB1	9.38	10.13	— 32.0	10 760	839	3
7. 1.60	KB2	11.50	4.49	— 19.0	80 000	1	5
18. 1.60	LB1	3.20	4.15	— 20.0	14 000	5	4
18. 1.60	LB2	4.32	5.30	— 20.0	15 040	9	4
19. 1.60	MB1	10.20	10.45	— 40.0	5 960	105	4
19. 1.60	MB2	10.45	11.35	— 40.0	12 680	243	4
20. 1.60	MB3	12.00	1.05	— 28.0	16 200	8	4
20. 1.60	MB4	1.47	3.12	— 28.0	22 400	15	4
20. 1.60	MB5	3.49	4.10	— 28.0	4 720	7	4
20. 1.60	MB6	4.22	5.30	— 28.0	18 680	3	4
21. 1.60	MB7	9.05	12.00	— 28.0	46 440	170	4
21. 1.60	MB8	12.05	4.30	— 28.0	80 000	344	4
22. 1.60	NB1	11.00	11.41	— 32.0	10 480	208	4
22. 1.60	NB2	11.43	12.49	— 28.0	17 080	77	4
22. 1.60	NB3	3.53	5.00	— 28.0	16 960	131	4
25. 1.60	OB1	9.15	10.23	— 30.0	17 120	34	4
25. 1.60	PB1	10.58	1.43	— 32.0	43 480	32	4
25. 1.60	PB2	1.45	5.30	— 35.0	59 000	45	4
26. 1.60	QB1	9.15	10.51	— 35.0	24 960	229	4
29. 1.60	RB1	11.30	12.05	— 35.0	8.000	265	4
29. 1.60	RB2	12.05	12.47	— 35.0	10 720	495	4
29. 1.60	RB3	12.48	4.00	— 29.0	48 000	49	4
1. 2.60	SB1	9.43	11.49	— 35.0	31 240	202	4
1. 2.60	SB2	11.51	5.12	— 27.0	80 000	99	4
2. 2.60	TB1	9.23	10.13	— 35.0	11 560	219	4
2. 2.60	TB2	10.18	11.05	— 28.0	10 280	18	4
2. 2.60	TB3	11.09	1.42	— 28.0	34 000	185	4
2. 2.60	TB4	1.44	4.08	— 24.0	34 680	5	4
3. 2.60	UB1.	9.10	12.00	— 28.0	42 840	187	4
3. 2.60	UB2	12.00	3.48	— 24.0	56 680	36	4
3. 2.60	UB3	4.07	5.30	— 28.0	23 600	39	4
5. 2.60	VB1	9.13	9.50	— 35.0	9 400	139	4
5. 2.60	VB2	9.52	3.21	— 28.0	80 000	47	4
5. 2.60	VB3	3.23	5.00	— 24.0	25 200	8	4
8. 2.60	WB1	11.35	2.15	— 28.0	40 600	83	4
9. 2.60	XB1	9.20	2.30	— 28.0	80 000	93	4
9. 2.60	XB2	2.40	5.15	— 28.0	40 000	516	4
10. 2.60	YB1	10.30	3.00	(— 8)	70 720	0	4
10. 2.60	YB2	3.20	5.45	(— 12)	40 000	0	4
11. 2.60	ZB1	9.30	2.30	(— 12)	80 000	0	6
12. 2.60	ZB2	10.00	4.40	(— 40)	105 480	9	6
24. 2.60	AC1	2.38	4.00	— 10.5	72 320	9	7
24. 2.60	AC2	4.00	5.30	— 10.5	83 680	18	7
25. 2.60	BC1	11.15	4.30	— 10.5	320 000	70	7
26. 2.60	CC1	11.30	12.10	— 10.5	12 800	8	7
26. 2.60	CC2	12.15	1.45	— 28.0	4 960	137	7
26. 2.60	CC3	1.50	3.30	— 28.0	78 600	675	7
26. 2.60	CC4	5.00	6.00	— 28.0	29 480	736	7
29. 2.60	DC1	10.30	11.30	— 28.0	40 120	31	7
29. 2.60	DC2	12.00	1.00	— 28.0	80 000	2	7

Date	Test No.	Start time	Finish time	Level at last switch	Blocks of 50 bits	Number of errors	Case No.
1. 3.60	EC1	9.57	12.00	— 28.0	80 000	62	7
1. 3.60	EC2	12 00	1.15	— 28.0	80 000	36	7
3. 3.60	GC1	12 00	2.10	— 31.5	20 000	532	5
3. 3.60	GC2	3.00	4.00	— 31.5	13 640	52	2
3. 3.60	GC3	4.00	5.30	— 31.5	13 320	48	5
4. 3.60	HC1	10.50	12.05	— 31.5	12 850	1074	5
4. 3.60	HC2	12.05	1.10	— 31.5	8 550	978	5
4. 3.60	JC1	2.30	3.45	— 31.5	9 450	55	2
9. 3.60	KC1	4.00	5.30	— 28.0	63 640	39	7
10. 3.60	LC1	10.30	12.15	— 28.0	72 680	31	7
10. 3.60	LC2	12.45	2.20	— 28.0	66 680	45	7
10. 3.60	LC3	3.15	5.00	— 28.0	80 000	76	7

Statistics measured in respect of the retransmission of data after the detection of errors

Speed of transmission : 250, 500 and 1000 bits per second

Block size	Number of blocks			% Retransmitted
	Total transmitted	Requiring retransmission	Not requiring retransmission	
50	1 735 050	6937	1 728 113	0.4
100	867 525	6148	861 377	0.71
200	433 763	5578	428 185	1.32
500	173 505	4591	168 914	2.75

Schedule comparing percentage of blocks received correctly with different speeds and levels of transmission

Gross speed in bits per second	Signal level at first switching stage	No. of blocks of 50 bits	No. of blocks containing errors	% of blocks transmitted correctly
250	— 16 dbm	923 343	623	99.93
500	— 16 dbm	634 760	770	99.88
500	— 23 dbm	208 840	998	99.52
1000	— 16 dbm	835 160	1965	99.76

Distribution of errors in blocks of 50 bits

Test	Number of blocks with the following numbers of errors																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
B2	2	2	1																											
B4	7	6	2																											
D4	8	4	1																											
E1	4	3	4	5	3	5	8	6	1	5		2		1		1		1												
E2	4	2	5	3	4	4	2	4	3	2	1	4	2		1			1												
E4	9	7	6	7	4	6	4	9	7	6	6	3	4	2	2	3	3	1	1			2								
E5	2	10	3	3	3	5	5	2	2	5	2	6	3	2	2			2			1		1	1	1	1				1
E6	5	4	3	4	3	1	4	2	3	4	3	2	1	2	3	2	2	1				1								
J2	1			2			1				1						1													
L		2																												
M2	1	1																												
M3	2																													
N1	9	4	3	1	2	1	1		2	2	1							2												
N2	4	6	2																											
O1	13	6		1																										
T1	7	8																												
T2	10	2	1																											
U1	20	10	3	3	2		2																							
U2	6	9	2	1			1																							
U3	11	7	7	1																										
V1	6	5																												
V2	6	6	1																											
V3	30	17	2				1																							
W1	20	15	4	4				1																						
W2	83	63	12	9	5	5	1	1			2	1	1				1													
Y1	93	55	6	3	2	2	4																							
Y2	98	34	8	2																										
Z1	64	30	6	6	1	1	3		1																					
Z2	48	22	7	3	5		1	1				2																		
Z3	23	14	6	1		1	1																							
AB1	39	14	6	2	2																									
AB2	34	20	1																											
AB3	147	49	9	5		1																								
AB4	66	17	5	1																										

Test	Number of blocks with the following numbers of errors																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
BB1	48	9	3	3	1		1																							
BB2	68	9																												
BB3	79	8	3	2																										
BB4	198	23	13	8	7	5		6	6	2	4	2	4		1															
BB5	10	2		1		1																								
CB1	143	23	16	7	4																									
CB2	82	8	2																											
CB3	182	27	6	2	1	1	1																							
CB4	28	2	1																											
CB5	17	2																												
CB6	16	4	1																											
CB7	66	12	5	1			1																							
EB1	81	2	1		1		1						1																	
FB2	27	12	7	5	2	2	1	—	2	1	—	2	3	1	—	—	—	1												
FB3	52	4	2	—	1	2	2	—	1	—	—	2																		
FB4	66	32	24	12	9	6	1	3	2	—	2	—	1	2																
FB5	12	1	1	1																										
GB1	205	18	3	4	1	—	1	—	—	1																				
GB3	91	6	1																											
HB5	16	2	1	1	2	2																								
JB1	5	4	1	1	—	1	—	1																						
LB1	5																													
LB2	7	1																												
MB3	3	1	1																											
MB4	13	1																												
MB5	5	1																												
MB6	3																													
MB7	40	18	10	5	3	—	—	—	2	—	1																			
MB8	53	4	1	4	1	2	—	1	1	2	1	4	—	1	—	—	1	—	—	1	—	1	1	—	—	—	1	1		
NB2	51	5	4	1																										
NB3	73	18	4	1	—	1																								
OB1	27	2	1																											
PB1	26	3																												
PB2	38	2	1																											
RB3	40	13	1																											

Test	Number of blocks with the following numbers of errors																												
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SB2	54	1	4	5	1	—	1	—	1																					
TB1	96	16	9	5	3	—	1	—	1	—	—	—	1																	
TB3	126	21	3	2																										
UB2	32	1																												
UB3	39																													
VB2	43	2																												
VB3	8																													
WB1	71	4	—	1																										
XB1	69	8	—	2																										
CC1	—	—	1	1																										
CC2	58	17	8	3	—	—	—	—	1																					
CC3	261	104	33	17	3	4																								
CC4	102	10	6	5	2	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	1						see note *			
DC1	6	3	1	—	—	—	1	—	1																					
GC1	153	30	10	4	2	3	3	2	4	2	1	—	—	1	2	—	2	1	—	—	1	—	—	1						
GC2	40	1	2	1																										
GC3	36	—	—	1	—	—	—	1																						
HC1	413	92	38	17	21	11	6	3	4	1	1																			
HC2	233	67	40	24	19	11	9	6	3	2	1	2	2	—	1															
JC	26	7	2	1	1																									
KC	23	4	1	—	1																									
LC1	13	5	1	—	1																									
LC2	20	9	1	1																										
LC3	46	12	2																											

* *Note.* — CC4 also contained 1 block with 30 errors, 1 block with 38 errors, 9 blocks with 50 errors, and several periods during which the connection was interrupted.

SWEDEN: DATA TRANSMISSION OVER TELEPHONE CIRCUITS

(Extracts from contribution GT.43, No. 9, February 1960)

Tests at higher speed than 50 bauds

In data transmission at higher speed, short breaks and pulse interferences will essentially affect reliability. Short disturbances of less duration than 10 ms do not normally influence the transmission of speech but may have a destructive effect on data transmission. The frequency of short breaks on coaxial cable circuits involving break durations of more than 0.5 ms has been investigated during 383 days on a loop circuit of 304 km length. The distribution of breaks appears from Appendix 2.

Pulse interferences have not been examined to the same extent as breaks, but it has been found that the Swedish network breaks are many times more frequent than pulse disturbances.

A great portion of the breaks occurring in the night-time are due to interventions to be made during the night service. Also in the daytime a great number of faults are caused by staff interventions for maintenance measurements, etc., and in cases of breakdowns of the mains supply, replacement of oscillators, etc. Failures due to " unknown causes " are very few.

For the purpose of investigating also the effect of pulse interference on data transmission, a special measuring equipment has been designed. The speed of transmission can be varied between 50 and 2000 bauds, and a unit code of 5 or 8 elements with start and stop can be used. This equipment will count the number of wrong signs and also distinguish between signs having 1, 2, 3, etc., wrong unit pulses. It may be assumed that such a measuring device will be valuable in determining the suitable design of error-correcting apparatus. The equipment in question having only recently been brought into use no data concerning results obtained are yet available but will be provided later.

In co-operation with the Swedish Telecommunications Administration the IBM has made certain tests on Swedish telephone circuits. Measurements of a corresponding nature have been undertaken also in other countries, on the initiative of the IBM. The measurements were made chiefly on circuits connected to the commercial network and in most cases engaged several automatic exchanges. A brief summary of the results of the measurements is given in Appendix 5. Similar measurements in a frequency-modulated system will be carried out later. It may be said that, on the whole, disturbing pulses or breaks originating in the selector equipments of automatic exchanges are not very frequent, either in cross bar or in 500-line systems. On the other hand, disturbing pulses are produced by the tariff-control units, which will have to be eliminated in order to enable the network to be used for data transmission.

APPENDIX 2

Distribution of current breaks in a 304-km coaxial cable circuit

Number of breaks	0006 — 2300 h.			2300 — 0006 h.		
	1/2 — 3 ms	3 — 20 ms	> 20 ms	1/2 — 3 ms	3 — 20 ms	> 20 ms
0	268	313	295	348	354	299
1	16	16	22	10	5	49
2	27	17	10	1	2	5
3	10	8	10	1	1	2
4	12	4	3	4	0	1
5	10	1	3	3	0	3
6	3	6	3	2	1	4
7	3	4	5	2	2	1
8	4	2	5	0	0	0
9	1	0	1	1	1	1
10	1	1	4	2	10	0
11 — 15	3	4	2	2	1	1
16 — 20	4	0	4	1	1	3
21 — 30	7	3	8	2	1	2
31 — 40	0	1	2	0	0	2
41 — 60	3	0	3	0	1	6
61 — 80	2	0	2	2	1	1
81 — 100	2	1	0	1	0	1
101 — 200	4	0	1	1	2	1
201 — 400	3	2	0	0	0	1
401 — 800	0	0	0	0	0	0
	383	383	383	383	383	383 days

APPENDIX 5

Summary of tests with data transmission on the Swedish public telephone network

The tests were carried out by IBM in October 1959. Test duration generally 15 minutes. All tests during office-time

Tests over dialled lines in Stockholm.

Test No.	Distance km	Exchanges		Metering interval	Data transmission					Errors		Remarks
		Type	Number		Bit rate Bits/sec.	Carrier c/s	Output level N	Discr. 1) %	Bias dist. 1) %	Number	Possible cause 2)	
1	13	500—p. sel.	3	No metering	1000	2000	0	Well	—	7		
2	,,	,,	4	,,	1000	2000	0	—	—	1		
3	,,	,,	,,	,,	2000	2000	0	100	<10	0		Test duration only 3 minutes
4	,,	,,	,,	,,	1000	2000	0	—	—	0		
5	30	,,	6	,,	1000	2000	0	50	20	2		
Tests over dialled trunk circuits, loaded circuits.												
6	26 ($f_0 = 3500$ c/s)	Crossbar	4	6 minutes	1000	2000	0	Well	—	40	Metering	
7	,,	,,	4	,,	1000	2000	0	—	—	46	Metering	
8	,,	,,	4	,,	1000	2000	0	50	<10	11	Metering	Test duration 16 minutes 30 sec.
9	,,	,,	4	,,	1000	2000	-2	—	—	40	Metering	Two metering clocks on the circuit. Test duration 16 minutes
10	,,	,,	4	,,	1000	2000	0	—	—	53	Metering	
11	123 ($f_0 = 3000$ c/s)	1500—p. sel. 3 Crossbar	4	90 sec.	1000	2000	0	Well	—	27	Metering	

Tests over dialled trunk circuits, carrier system.

Test No.	Distance km	Exchanges		Metering interval	Data transmission					Errors		Remarks
		Type	Number		Bit rate Bits/sec.	Carrier c/s	Output level N	Discr. 1) %	Bias dist. 1) %	Number	Possible cause 2)	
12	1000	500—p. sel.	4	10 sec.	2000	2000	0	Marginal	—	0		
13	1000	,,	,,	,,	1300	2000	0	Well	—	0		
14	,,	,,	,,	,,	1000	2000	0	50	10	769	Metering and short breaks	
15	,,	,,	,,	,,	1000	2000	0	20	20	8	Metering	
16	,,	,,	,,	,,	1000	2000	0	—	—	17	Metering	
17	1200	2500—p. sel. 2 Crossbar	4	8 sec.	2000	2000	0	Marginal	—	0		
18	,,	,,	,,	,,	1000	2000	0	50	10	30	Metering	
19	,,	,,	,,	,,	1000	2000	0	40	10	16	Metering	
20	,,	,,	,,	,,	1000	2000	– 2	—	—	184	Metering	
21	2213	500—p. sel.	2	No metering	1000	2000	0	30	10	0		
22	,,	,,	,,	,,	1000	2000	– 0.7	—	—	0		
23	,,	,,	,,	,,	1000	2000	– 2	—	—	3		

Tests over dialled trunk circuits, mixed circuits.

Total distance 768 km, 332 km radio link (2 m band), 432 km carrier system.

Test No.	Distance km	Exchanges		Metering interval	Data transmission					Errors		Remarks
		Type	Number		Bit rate Bits/sec.	Carrier c/s	Output level N	Discr. 1) %	Bias dist. 1) %	Number	Possible cause 2)	
24	768	500—p. sel.	2	No metering	2000	2000	0	Unworkable		—		
25	,,	,,	,,	,,	1000	2000	0	20	20	0		
26	,,	,,	,,	,,	1000	2000	0	60	10	4		
27	,,	,,	,,	,,	1000	2000	–1	—	—	11		
28	,,	,,	,,	,,	1000	2000	–2	—	—	22		
Total distance 1611 km, 1414 km carrier system (including 268 km carrier system on open wires) 192 km cable (2-wire circuit).												
29	1611	500—p. sel.	2	No metering	1000	2000	0	Unworkable		0		
30	,,	,,	,,	,,	1000	1500	0	5	20	0		
31	,,	,,	,,	,,	1000	1500	0	70	<10	0		

[1] Definitions of discrimination and bias distortion are given by IBM on the following page.

[2] To decrease the influence of metering pulses a high-pass filter (500 c/s) was connected to the input of the receiver.

Explanation of terms " discrimination " and " bias distortion "

Discrimination.

This is measured at the output of the low-pass filter in the receiver. The procedure is as follows:

(a) The character generator at the transmitting end is set to give the pattern 1.1.1.1.1.1.1.1. The amplitude and mean d. c. level of the output of the low-pass filter are measured on the oscilloscope (figure 105).

(b) Another pattern is set up on the character generator and the waveform at the low-pass filter output is examined. The effect of the line is to distort the ideal waveform at this point in the way indicated in figure 106.

(c) The measurement is repeated until the pattern is found which gives the smallest values of V_M. Then this value is used to calculate the discrimination using the expression

$$\text{discrimination} = 100 \frac{V_M}{V_R} \%.$$

Bias distortion.

The squared output from the receiver is displayed on the oscilloscope and the extent to which the transitions are displaced from the correct relative timing is observed. This displacement is expressed quantitatively as follows:

The time between any two transitions should be an integral number of bit periods. Let " t " be the departure from the ideal interval. The transmitted character is varied until the pattern which gives the maximum value of " t " is found. This value of " t " is used to calculate the bias distortion using the expression

$$\text{bias distortion} = \frac{t}{T} \%$$

where T = the bit period.

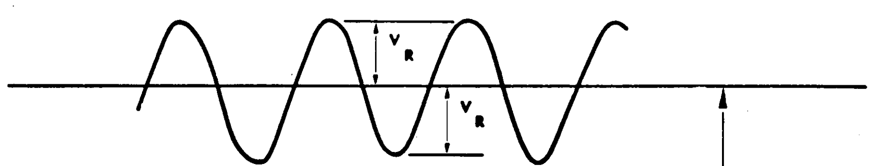


FIGURE 105

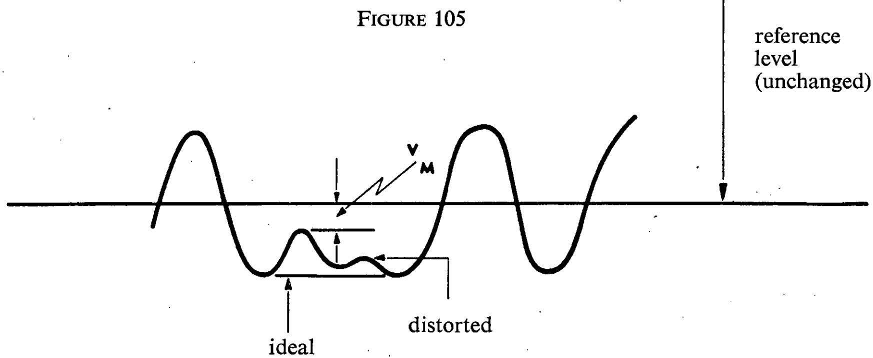


FIGURE 106

AUTOMATIC TELEPHONE AND ELECTRIC Co.: CONTRIBUTION ON DATA TRANSMISSION

(Contribution GT.43, No. 11, February, 1960)

1. *Introduction.*

It is considered that high-speed data-transmission requirements can best be met by the use of broadband bit-synchronous signalling systems utilizing the whole of the available bandwidth of normal telephone channels. This approach is favoured on the grounds of the increased complexity and reduced bandwidth-efficiency of multi-frequency systems. It seems probable that the maximum possible bit rate compatible with channel bandwidth will in general be required by users.

We believe that it is too early to arrive at a standardized design for a high-speed data-transmission system and favour the independent development and trial of various systems by manufacturers in co-operation with Administrations. An important aspect of these trials would be a determination of the principal factors responsible for producing errors. Carefully conducted tests at various signal levels can throw much light on these factors. From trials so far conducted it is considered that the major type of interference over private lines is modulation noise of one form or another while over switched lines impulsive noise of error bursts appears to be the information of greatest value to the designers of data-handling equipment.

It seems probable that continuously variable bit rate systems will be less tolerant to bad line conditions than systems designed for one or more particular bit rates.

2. *Types of data-transmission systems.*

Two transistorized high speed data-transmission systems have been considered for trials over telephone circuits. System A (see Reference 1) is a 750-baud system, using an amplitude-modulated signal with a 1500 c/s sine wave carrier, both sidebands being transmitted. The information is transmitted in binary form such that a " 1 " is transmitted as a pulse and a " 0 " as no signal. Each pulse contains two cycles of the 1500 c/s carrier and its envelope corresponds to the appropriate portion of a 750 c/s sine wave.

System B is a 1500-baud system. It uses a phase modulation signal with a 1500 c/s sine wave carrier. The information is transmitted in binary form such that a "1" is transmitted as a 180° change in phase and a " 0 " is transmitted as no change in phase between the signal carriers in adjacent signal elements. Each signal element contains one cycle of the carrier.

Both systems A and B are essentially synchronous systems and will therefore be operating continuously during the whole period in which messages are being transmitted.

Each signalling channel contains one pulse transmitter and one pulse receiver whose connections to the associated equipment are shown in figure 107. The pulse transmitter converts the information which is fed to it in the form of a square wave (waveform A), into a form most suitable for transmission over the line, and the pulse receiver reconverts the received information back into its original form (waveform B). Associated with the pulse transmitted are the transmitter logical circuits, whose waveforms and operations are synchronized with those in the pulse transmitter by means of the timing waveform *ts* 1, and associated with the pulse receiver are the receiver logical circuits, whose waveforms and operations are synchronized with those in the pulse receiver by means of the timing waveform *ts* 2. The speed of signalling is therefore determined entirely by the frequency of an oscillator in the pulse transmitter.

3. *System and channel characteristics.*

The signal waveform for System A — amplitude modulation — was chosen to give a reasonably high-speed data-transmission system, providing at the same time the maximum possible reliability and tolerance to the types of interference and distortion normally experienced over telephone circuits.

The signal waveform for system B — phase modulation — was chosen as that promising to give the fastest signalling speed for a given bandwidth consistent with a good tolerance to noise and distortion.

A phase-modulated system has definite advantages under conditions of sudden and severe level changes in the received signal, such as sometimes occur over short-wave radio links. The system would probably also give a better performance over channels using compandors. Moreover, when the delay distortion in the transmission path is small, the phase-modulated system should for the same signalling speed tolerate more severe impulsive noise and white noise than an amplitude-modulated signalling system. On the other hand, the amplitude-modulated system should give more reliable operation under conditions of frequency drift or sudden frequency fluctuations in the received signal, such as occur over carrier telephone circuits. The sudden level changes which sometimes occur over these circuits are also not normally of sufficient amplitude to cause errors in a binary coded amplitude-modulated system. This system should, moreover, tolerate larger values of delay distortion, and should therefore probably have a greater tolerance to interference over telephone circuits with severe delay distortion.

Tests over different telephone circuits have indicated that over private lines the majority of the interference occurs in the form of amplitude or frequency modulation of the transmitted signal by some noise source. A transient interruption can for instance be regarded as 100% amplitude modulation of the transmitted signal by a square-wave interference signal.

In the case of a phase-modulated system, as used for instance in System B, interference comprising either frequency or amplitude modulation of the right form and intensity can

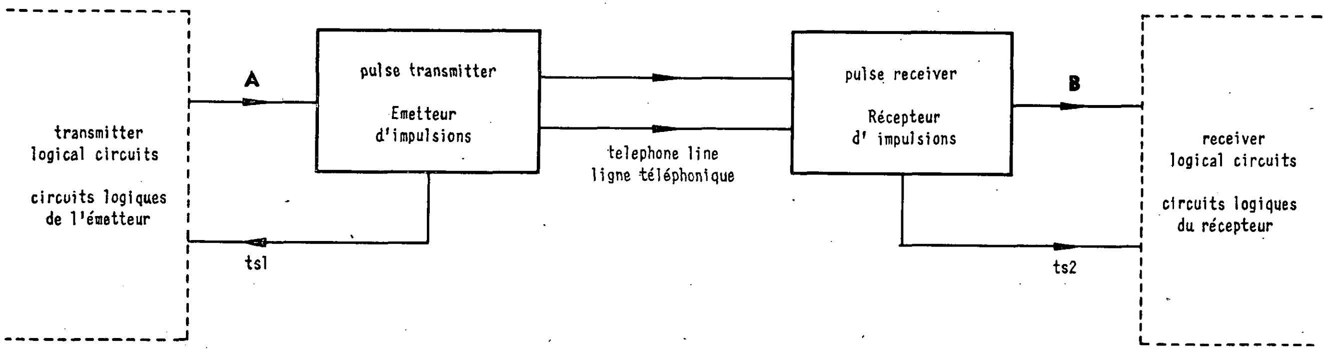


FIGURE 107. — *A single signalling channel*

in practice produce errors which may be " 1's " converted to " 0's " or " 0's " converted to " 1's " or a combination of these.

In the case of an amplitude-modulated system, as used for instance in System A, frequency modulation of the type likely to be encountered over carrier telephone circuits will not produce errors or impair the performance, provided only that the normal form of detection is used as in System A, and not a phase sensitive detector or product demodulator. Amplitude modulation of the transmitted signal in System A can only convert " 1's " to " 0's ", since neither amplitude nor frequency modulation of this signal can affect the " 0's " which are transmitted as no signal. The tolerance of an amplitude-modulated system to modulation interference should therefore be at least as good as that of a phase modulated system, and it has the great advantage in that all the errors caused by these types of interference will be " 1's " converted to " 0's ". This means that with quite a simple error-detecting code employing the minimum of redundant information, all these errors can be detected. This property, together with the previous considerations, should give an amplitude-modulated data system such as System A a definite advantage over phase-modulated systems when used over private lines. Over switched lines, particularly those involving only audio links, the majority of the interference is usually impulsive noise and under these conditions a phase-modulated data system would probably give a lower error rate than that obtained with an amplitude-modulated system.

4. *Laboratory tests and field trials.*

4.1. *System A.*

The results of the laboratory tests and field trials over various types of telephone circuits are contained in Appendix 1 to this contribution.

4.2. *System B.*

A similar set of laboratory tests and field trials over telephone circuits are about to commence on signalling system B, and the corresponding results will be the subject of a separate contribution at a later date.

Reference 1.

A.T.E. Journal, Vol. 15, No. 2, April 1959, describes a system similar in principle to System A.

APPENDIX 1

Results of tests carried out on signalling system A

1. *General.*

All the laboratory tests and field trials were carried out at a speed of 600 bauds using a 1200 c/s signal carrier, and the basic arrangement of the equipment used for these tests is shown in figure 108. For all the tests, only one pulse transmitter and one pulse receiver were used.

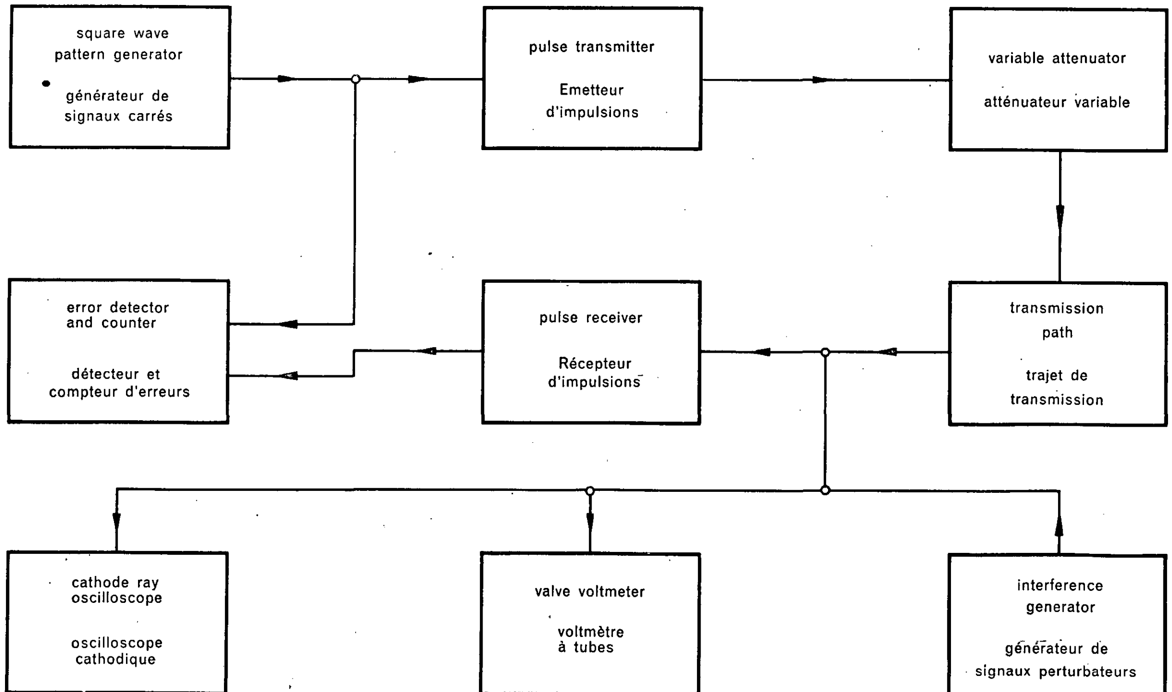


FIGURE 108. — *Outline of the equipment used in the tests*

Instead of sending messages, the equipment transmitted a continuous pulse pattern, the form of which was determined by the square waveform produced by the square wave pattern generator. This generator was designed to give a choice of nine different waveforms to simulate some of the possible arrangements of " 1's " and " 0's " obtained with a five-element code. Errors were detected by comparing the input waveform to the pulse transmitter, waveform A, with the output waveform from the pulse receiver, waveform B, after suitably phasing these waveforms. Each bit at which the waveforms disagreed was recorded as an error and the total number of errors obtained was noted on a counter. A separate part of the equipment analysed the errors and counted the number of single, double, treble and quadruple errors (a double error, for example, being composed of two consecutive errors, that is, two adjacent incorrect bits in waveform B).

2. *Results of laboratory tests.*

The frequency spectrum of the transmitted signal was measured for a number of different pulse patterns and it was found that, with any combination of pulses likely to be used in a normal signal, at least 90% of the total transmitted energy is contained in the frequency band 600 to 1800 c/s. The band 600 to 1800 c/s was thus the effective transmitted frequency band of the signal. Further experiments also showed that the signalling system was not seriously affected by distortion and interference outside this frequency band.

Tests carried out over one type of compandor have shown that satisfactory operation is obtainable when working with this type of equipment although attenuation of the signal over the compandor is about 5 db more than that experienced by a sine wave of similar level and frequency.

Laboratory tests with band-limited white noise have shown that a signal-to-noise ratio of 12 db gives an error rate of less than 1 bit in 10^5 while a signal-to-noise ratio of 11 db gives an error rate less than 1 bit in 10^4. Signal-to-noise ratio is here defined as the ratio of the mean power level over the duration of a signalling pulse (the signal level) to the r.m.s. value of the noise, band-limited white noise being random noise confined to and evenly distributed over the frequency band 600 to 1800 c/s.

Tests with various single frequency tones have shown that the equipment will tolerate a continuous sine wave of any frequency within the signal frequency band, with no resultant errors, provided its level is a little more than 6 db below the signal level. The tolerance to single frequency tones increases rapidly at frequencies extending beyond the limits of the signal-frequency band, becoming very large at frequencies sufficiently removed. This is due, of course, to the increasing attenuation of the input filter at these frequencies.

A number of tests were made to measure the effects of different degrees of signal distortion, on the tolerance of the signalling system to band-limited white noise. The different degrees of signal distortion were produced by passing the transmitted signal through various networks which were designed to give different values of attenuation and delay distortions in the signal frequency band. Perhaps the most significant of these tests was one carried out over a network whose attenuation and delay characteristics were approximately equivalent to the worst permissible under the C.C.I.T.T. requirements for a modern type telephone circuit. The group delay introduced by this network at 600 c/s is 4.6 milliseconds greater than the minimum group delay in the frequency band of the signal. This corresponds to a delay distortion of 4.6 ms in the signal-frequency band, there being negligible attenuation distortion in the band. This distortion reduces the tolerance of the signalling system to white noise by 5.5 db, in other words to maintain the same error when this network is included in the transmission path, the signal-to-noise ratio must be increased by 5.5 db. Delay distortions of 2.0 ms and 1.2 ms in the signal-frequency band were found to reduce the tolerance to white noise by 2 db and 0.5 db respectively. Delay distortions of less than 1 millisecond in this band were found to have only a negligible effect on the tolerance of the signalling system to white noise.

An experiment simulating the effect of transmitting the signal over a hypothetical carrier telephone circuit, in which the modulating and demodulating carrier supplies might differ in frequency, showed that the frequency band of the received signal can be shifted by order of $\pm$ 200 c/s with negligible change in the tolerance to white noise. The small variable frequency shifts of one or two c/s produced in the received signal after transmission over a carrier telephone circuit, or the sudden phase shifts sometimes experienced over these circuits, should therefore produce no errors in the signalling system and have a negligible effect on the tolerance to noise.

Measurements on the equipment have shown that the oscillator frequency can drift over a range of $\pm$ 6 c/s about 1200 c/s, for example $\pm$ 0.5 % of the correct frequency, without at any time reducing the tolerance of the system to white noise by more than 1 db. The maximum frequency drift which can be tolerated in the oscillator before errors result in any of the nine pulse patterns in the absence of noise, is $\pm$ 18.7 c/s or just over $\pm$1.5 %.

3. *Results of field trials.*

Field trials were carried out with the kind co-operation of the Engineering Department of the B.P.O. over several different telephone circuits. The basic circuit arrangement shown in figure 108 was used, but the noise generator and valve voltmeter were omitted. The transmission path in every case included a telephone circuit, and signals were transmitted over that circuit in one direction. The pulse transmitter was adjusted to give a standard output signal level of – 8 dbm and the signal was attenuated to the various lower levels used in the tests by the variable attenuator. In a practical application of the system a transmitted signal level of the order of – 8 dbm would probably be used.

A total of nine different transmission paths including seven different telephone circuits were used. The two additional paths were produced by connecting a line simulator at the input to the two noisiest private line telephone circuits, in order to raise their delay distortion within the frequency band of the signal to about 5 milliseconds. Each telephone circuit was connected in a loop with both the transmit and receive terminals at the place where the signalling equipment was housed. The results of the trials are summarized in the table. The telephone circuits 1 to 8 were set up as private lines, but circuit 9 contained a length of line set up as in an ordinary switched connection through automatic telephone exchanges.

Circuit 1 contained two audio links in tandem. Circuits 2 to 8 each contained the two audio links of circuit 1 in tandem with two carrier links, the carrier links in the different circuits having various lengths or being contained in different carrier systems. Circuit 5 was the longest of these, being 939 miles long, and it was specially selected as a circuit likely to give severe interference conditions. It was by far the noisiest of the six private lines tested. Circuit 6 was produced by connecting the line simulator at the input to circuit 5. This circuit has a combination of noise and delay distortion about as severe as would normally be encountered over any private line. In practice the conditions over the large majority of private line telephone circuits would almost certainly be very much less severe. Circuit 7 was noisier than any of the circuits 1 to 4 and circuit 8 was produced by connecting the line simulator at the input to this circuit.

Circuit 9 contained, in tandem with the two audio links of circuit 1, a length of switched line set up through 14 two-motion step-by-step switches and 4 transmission bridges, these being contained in two automatic telephone exchanges. This line was set up by ringing up one exchange from two different telephones in another exchange and linking the two calls together at the first exchange.

The figures for delay distortion quoted for the circuits 1 to 9 represent the variation of group delay in the frequency band 600 to 1800 c/s for each of these circuits.

In the telephone circuits 3, 5 and 7 the signal level at the input of each carrier link was about 6 db below the transmitted signal level, and in circuits 2, 4, 6 and 8 the signal level was about 7.5 db below. In all tests the received signal levels are quoted to the nearest db above the values actually measured.

In every test each of several different pulse patterns was transmitted over the telephone circuit for a given period to give in most cases a total signalling time of several hours. Different signal levels were used to determine very approximately the minimum signal level at which the error rate did not exceed 1 bit in 10^5.

The tests over the private line telephone circuits 1 to 8 showed that an error rate of about 1 bit in 10^5 or less was obtainable in each case when using a transmitted signal level of – 8 dbm. (In the circuits 6 and 8 the signal level actually fed to the transmit terminals of the telephone circuit was always 1.5 db lower than the transmitted signal level, due to the attenuation in the line simulator.) Over circuits 1, 2, 3, 4 and 7 an error rate of less than 1 in 10^5 was obtained with a transmitted signal level of – 30 bdm, the received signal level having nearly the same or a somewhat lower value. The good performance over circuits 6 and 8, these being the two noisiest private line circuits with considerable additional delay distortion added, indicates that satisfactory operation with a total error rate of less than 1 bit in 10^5 should be obtained under normal conditions over any private line telephone circuit.

The received signal was monitored by means of a pair of earphones at regular intervals during the field trials. It was shown that whenever the error rate was higher than 1 bit in 10^5 (as was the case for instance at the lowest transmitted signal levels), the audible level of the noise was at times high enough to have constituted a real nuisance in the reception of speech where this had the same level as that of the signal.

Four tests were carried out over circuit 9 which included a switched line, the switched line used in tests 22 and 23 being different from that used in tests 20 and 21. Test 20 was carried out in the evening after 6 p.m., whereas the other three were carried out during the normal working hours and each covered a busy period.

The signal level at the input to the switched line was 4 db below the transmitted level, and the signal level at the output of the switched line was the same as that reaching the pulse receiver. The majority of errors occurring during tests 20 to 23 were due to the effects of impulse interference in relation to the comparatively low signal level attaining, particularly at the last main group of switches where the signal level was only approximately 5 db above the received signal level.

The general indications from these tests are that an error rate of the order of 1 bit in 10^5 or less should be obtained over a switched line connected through busy automatic telephone exchanges, provided that the signal level at any of the switches does not fall much below – 15 or often – 20 dbm. When the error rate is appreciably higher than 1 bit in 10^5, the interference would in any case begin to cause a nuisance to the reception of speech over that circuit.

Consideration of the characteristics of the poorer types of telephone circuits in the light of the results obtained in the tests shows that the signalling speed can be raised to 750 bauds with satisfactory operation over these circuits and with no serious reduction in tolerance to the interference present. This is particularly so, since over many circuits the more serious delay distortion occurs at the extreme low frequency end of the transmitted frequency band. In raising the signalling speed from 600 to 750 bauds, the lower limit of the transmitted frequency band is also raised from 600 c/s to 750 c/s, thus in many circuits escaping the more serious delay distortion.

4. *Types of interference observed over the telephone circuits.*

During the field trials many hours were spent observing the cathode ray oscilloscope on which the received signal was monitored, in order to detect the various types of interference present and to estimate their relative importance in producing errors in the pulse receiver.

The types of interference observed can be classified into two groups: those in which a waveform is added to the transmitted signal and those in which the transmitted signal is changed or distorted without affecting the spaces between the pulses. The latter group corresponds to a modulation of the signal by the interference. The types of interference in the second group are modulation noise, transient interruptions, sudden level changes, sudden frequency fluctuations and gradual frequency drift. In each group the types of interference listed above have been placed in order of their importance as measured by their effect in producing errors in the pulse receiver. This does not by any means correspond to their importance as measured by the magnitude and frequency of their occurrence. The types of interference in the first group become less effective in producing errors, as the signal level is increased, while those in the second group have the same effect on the signal regardless of its amplitude.

Over the two audio circuits, and particularly that containing the switched line, the large majority of the errors were produced by impulsive noise. This was also responsible for a number of the errors obtained when signalling over the carrier circuits, more particularly at the lower signal levels.

Speech crosstalk was responsible for a number of the errors at the lower signal levels and at normal signal levels under line fault conditions; however, it was not observed to produce errors at the higher signal levels under normal line conditions.

White noise was not effective in producing errors except at extremely low signal levels.

Over the telephone carrier circuits connected as private lines, a large proportion of the errors occurring when using the normal transmitted signal level of – 8 dbm, were caused by modulation noise. This appeared as a modulation of the signal by band-limited white noise and it usually occurred in short severe bursts. No modulation noise was observed on the two audio circuits.

Four or five transient interruptions were observed on the two carrier circuits 5 and 7. Each of these interruptions appeared as a sudden and clean break in transmission, lasting on the average for three or four characters, that is about 30 milliseconds. Only a small number of errors were caused by these transient interruptions and they did not contribute appreciably to the total number of errors counted on the circuits on which they were observed. If a single error-detecting code is used for the transmitted characters, such that each character always has an odd number of " 1's ", the errors caused by any interruption removes at least one complete character, which will usually be the case in practice. Transient interruptions cannot therefore be considered as a significant obstacle to the successful operation of a high-speed signalling system of this type.

Except under line fault conditions, sudden level changes did not appear to produce errors in the pulse receiver, providing this was used with the correct slicing level.

Sudden frequency fluctuations and gradual frequency drift may perhaps more correctly be regarded as forms of distortion, but they have been included in the list for the sake of completeness. Although they occurred quite frequently over the carrier circuits, no errors attributable to these effects were observed.

5. *Characteristics of the distribution of errors observed when working over telephone circuits.*

On the private line audio circuit 1, which was common to all the other telephone circuits, the error rate was very low and the errors, although occasionally occurring in groups at the lower signal levels, were generally fairly evenly distributed.

On the private line carrier circuits 2 to 8, it was observed that the more serious modulation noise which was responsible for the majority of the errors at higher signal levels, tended to occur in short bursts, each of which lasted up to about a second and caused some ten or twenty errors in the pulse receiver. When the transmitted signal level was low enough for the speech crosstalk to cause errors, these also tended to occur in bursts, although not as concentrated perhaps as in the case of modulation noise. The transient interruptions when they occurred of course always produced a very close succession of errors. One general characteristic of the error distribution observed over the private line carrier circuits was in fact this very marked tendency for the errors to be concentrated into short isolated bursts.

On circuit 9 containing the length of switched line, the large majority of the errors were produced by impulsive noise and were in general fairly evenly distributed.

In many of the tests over the carrier circuits there were some periods of half-an-hour with no errors and others with up to seventy. For this reason the tests were whenever possible made over two or more hours, the average time spent over each test being a little over 4½ hours. With these precautions it was found that fairly consistent results were obtained.

All the tests except test 20 were carried out sometime between 9 a.m. and 5 p.m. Where possible the tests were arranged to include the morning or the afternoon busy hour and if possible both. The private line telephone circuits showed on the average no significant variation in error rate over the day. The switched lines, however, showed a reduction in error rate at the lunch hour and towards the evening.

Over the private line circuits the ratio of single to double errors was on the average about 11 to 1 and the ratio of single to treble errors was about 60 to 1. Over the switched lines the ratio of single to double errors was on the average about 15 to 1 and the ratio of single to treble errors was about 80 to 1. Quadruple and higher multiple errors were negligible. In the tests over private line circuits, where there was severe delay distortion over the line or where the received signal levels were of the order of − 8 dbm, the ratio of single to multiple errors was somewhat below the average, and in the tests at low signal levels the ratio was correspondingly higher than the average.

Another interesting result obtained was the almost negligible occurrence of a double error involving a change of a " 1 " to a " 0 " and an adjacent " 0 " to a " 1 ".

A brief theoretical study has been made into the effects of various distributions of the different multiple errors, on a simple automatic error detection and correction system in which errors are corrected by retransmission. In this system it is assumed that a two-way signalling system is available and the information in either channel is transmitted in the form of separate messages, where each message is subdivided into characters each of which contains say 5 bits. One of these bits in each character is a parity check bit which is made a " 1 " or a " 0 " so that the sum of the " 1's " in that character is always odd. A fixed message length of about 10 characters is assumed. Errors are corrected by causing the whole of the message which contains a detected error in one of its characters to be retransmitted.

When the errors are widely dispersed, with not more than one error per message, the number of messages containing detected errors and consequently retransmitted will be slightly greater than the total number of single and treble errors. The number of messages containing undetected errors and therefore mutilated but accepted as correct will be slightly less than the number of double errors.

When the errors are closely packed together, with several errors in each message affected, the number of messages retransmitted will be much smaller than the total number of single and treble errors in these messages, and the number of messages mutilated but accepted as correct will be very much smaller than the number of double errors occurring during the same time.

There is in general an increase in the proportion of the errors detected and corrected as the errors become more closely bunched. This improvement in error detection and correction is due of course partly to the fact that in any message a detected error takes precedence over other undetected errors, causing all the errors in that message to be automatically corrected.

Over the private line carrier circuits, where the bunching of errors was very marked, the effect of these errors on a practical signalling system would therefore be appreciably less significant than that anticipated solely from the measured error rates.

Conclusions.

The results obtained from extensive laboratory tests and field trials show that, when an amplitude-modulated system of the type described is used over any main line telephone circuit of the standard used in Great Britain, an error rate of less than 1 bit in 10^5 should be obtained provided the circuit is free from specific faults and would be acceptable for speech. The telephone circuit can be set up either as a private line or as in a normal switched call.

The nature and the distribution of the errors obtained when working over the various telephone circuits have shown that under the most severe conditions considered as acceptable, giving an error rate of 1 bit in 10^5, it is most unlikely that the number of messages mutilated but still accepted as correct would exceed one in every 30 000 and the number would usually be much smaller. The accompanying reduction in the rate of transmission of information, due to the retransmission of messages containing detected errors, should also be well below 0.1 %. The values estimated here are based on a message length of about 50 bits and assume the simple error detection and correction system mentioned.

Test No.	1	2	3	5	6	7	8	9	10	11	12
Circuit No.	1	1	1	2	2	2	3	3	3	4	4
Total length of circuit (miles)	75	75	75	315	315	315	315	315	315	589	589
Delay distortion (milliseconds)	1.9	1.9	1.9	0.5	0.5	0.5	0.9	0.9	0.9	0.8	0.8
Transmitted signal level (dbm)	— 8	— 30	— 40	— 8	— 30	— 40	— 10	— 30	— 40	— 8	— 30
Received signal level (dbm)	— 12	— 34	— 44	— 13	— 34	— 44	— 8	— 28	— 38	— 13	— 35
Total error rate (bits per 100 000) ($x\ 10^{-5}$)	0.00	0.07	2.41	0.05	0.02	1.45	0.02	0.58	2.73	0.05	0.57

Test No.	13	14	15	16	17	18	19	20	21	22	23
Circuit No.	5	5	6	7	7	8	8	9	9	9	9
Total length of circuit (miles)	939	939	939	315	315	315	315	83.5	83.5	83.5	83.5
Delay distortion (milliseconds)	0.5	0.5	4.9	0.7	0.7	5.1	5.1	0.5	0.5	0.5	0.5
Transmitted signal level (dbm)	— 8	— 20	— 8	— 8	— 30	— 8	— 20	— 8	— 8	+ 2	— 8
Received signal level (dbm)	— 10	— 23	— 12	— 9	— 30	— 10	— 22	— 30	— 30	— 20	— 30
Total error rate (bits per 100 000) ($x\ 10^{-5}$)	0.13	1.25	1.21	0.00	0.95	0.14	0.77	0.44	30.30	0.43	3.35

Summary of results obtained in the field trials

AMERICAN TELEPHONE AND TELEGRAPH COMPANY: DATA TRANSMISSION POSSIBILITIES OF THE TELEPHONE NETWORK WITH SWITCHING

(Extracts from contribution GT.43, No. 13, February 1960)

In the programme about 1100 test calls were made. About 25% of these were local calls, not involved with the long-distance switching plan. About 25% were short-haul long-distance calls, up to about 500 miles airline distance. The remaining 50% were long haul, 400 to 3000 miles long.

In order to keep the testing programme within manageable size, a single data-transmitting system known as the FM digital subset was used for the higher speed data-performance tests. In this system the modulator accepts base band binary information in serial form and provides a frequency-modulated output. The marking condition is one frequency, the spacing condition another. A single oscillator swings between the two frequencies and transmits the binary information to the demodulator.

The demodulator is a zero crossing detector, pulse generator and integrator which provides serial binary base band signals at its output. The output signals are reproductions of the modulator input signals modified by distortion effects of the telephone facility and mod-demod process.

For the tests a level of –6 dbm at the transmitting terminal was selected in order to meet established criteria for interference and overloading. Means were provided to reduce the output level in discrete steps so that relationships between error rate and transmitting level might be determined.

Based upon previous studies and experience it was determined that the most satisfactory operating region was likely to be centred somewhere between 1200 and 1800 cycles and that, at least initially, a speed of 600 bits per sec. should be used for these tests. Provision was made to operate the data terminals at three pairs of mark-space frequencies: 900 (M)—1400 (S), 1400 (M)—1900 (S) and 1100 (M)—1900 (S).

Information gathered during the early part of the programme indicated that sufficient margin was available to permit increasing the speed if the effect of amplitude and delay distortion could be reduced. Compromise amplitude and delay equalizers were designed and the latter part of the programme was carried out using a speed of 1200 bits per sec. with mark-space frequency pairs of 1100 (M)—2100 (S), 1200 (M)—2200 (S), and 1300 (M)—2300 (S).

In order to accommodate the increased frequency spectrum the digital subject was modified with a more optimum band-pass filter and integrating filter.

Error-rate information was taken at 600 bits per sec. using the 900 (M)—1400 (S) frequency pair. At 1200 bits per sec. the 1100 (M)—2100 (S) pair was used. The three frequency pairs at each speed were used to determine the best operating region for each connection. This was done by measuring maximum repetitive jitter in the transitions of the 30-bit word binary signal as received at the output of the demodulator. Jitter is the total variation in time of the binary transitions from what they should be. The timing standard is supplied by the receiving clock. The peak jitter may be expressed in terms of per cent peak distortion in accordance with the following:

$$\text{Per cent distortion} = \frac{\text{Max variation in transition time}}{\text{time of two bits}} \times 100$$

(The maximum possible distortion is 50%.)

The per cent peak distortion (repetitive jitter) was used as the criterion for determining the best pair of operating frequencies.

The following paragraphs discuss the effect of present telephone facility transmission characteristics on binary data signals and summarizes the results of some of the basic transmission measurements that were made during the field testing programme.

IV. *Basic transmission characteristics*

A. *General.*

Nyquist theorizes that a channel should be capable of transmitting binary digital information at a rate numerically equal to twice the channel bandwidth, e.g., 6000 bits per second, assuming a bandwidth of 3000 c/s. This requires a channel having flat loss and no delay distortion within the pass-band and infinite loss outside — conditions not met by the switched telephone network. Telephone bandwidths have been designed to accommodate speech frequencies from about 300 c/s to about 3300 c/s. It is therefore necessary to translate the data signal spectrum into this nominal pass-band by such means as the FM digital subset. If the resulting sidebands are transmitted symmetrically, the allowable bit speed is reduced by one-half.

Another factor limiting data speeds involves an effect of non-linear distortion. It is frequently called " Kendall effect " because its occurrence was first predicted by B. W. Kendall in connection with studies of telephoto transmission. Non-linear distortion results in second-order modulation products which may fall within the baseband spectrum of the data signal. If this overlaps the line signal, distortion will result. Therefore the lower portions of the telephone band cannot always be used efficiently and the frequency space available for the data signal is reduced.

Practically speaking, then, data speeds of binary signals on the switched telephone network are certainly less than 3000 bits/sec. Higher speeds may be achieved by other than binary systems. For a given speed the rate at which errors occur will depend on the method of modulation and transmission characteristics of the channel. The basic transmission phenomena of interest are:

1. *Effective channel bandwidth* characterized by the attenuation and delay distortion parameters of the telephone network — imposes an upper bound on transmission speed and reduces the noise margin to error generation.

2. *Circuit net loss* affects signal-to-noise margins and hence margin to error.

3. *Noise.*

B. *Transmission characteristics of telephone plant.*

The characteristics described herein represent the cumulative effects of the different transmission systems and switching equipment required to complete each particular connection. Consider initially the effects of individual transmission and switching facilities.

The attenuation of typical non-loaded wire pairs is proportional to the square root of frequency within the voice band and only for short lengths is this distortion across

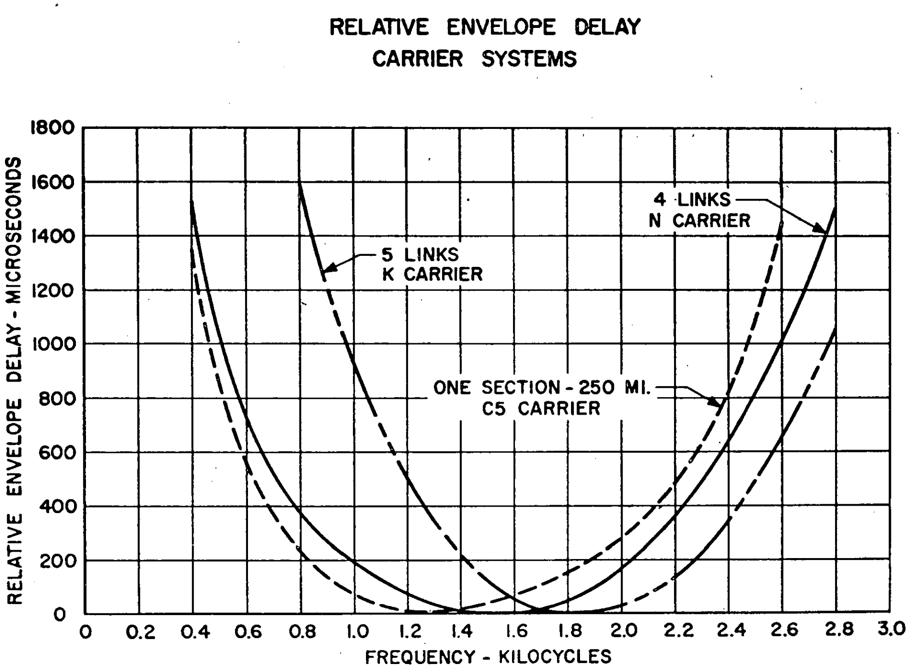


FIGURE 109

the band tolerable. Cable pairs longer than about 3 miles are loaded at uniform intervals with inductance to reduce attenuation frequency distortion and the overall loss. With this added inductance the line looks like a low-pass filter and exhibits a cut-off. The cut-off of the loaded facility also introduces additional phase or delay distortion over the non-loaded pair.

Carrier systems exhibit cut-offs both at high and low frequencies. Typical delay distortion characteristics for these systems are shown in Figure 109.

Because of multiple connections and cabling runs within switching offices, shunt capacitance is added to a switched connection. This of course has the greatest effect at the upper end of the voice band on both attenuation and delay characteristics. Associated with switching points are repeating coils, series capacitors and shunt inductors used for signalling and supervisory purposes. These have their greatest effect at low frequencies. Therefore, even if the transmission facilities are voice-frequency wire lines, switched connections will show lower end cut-offs.

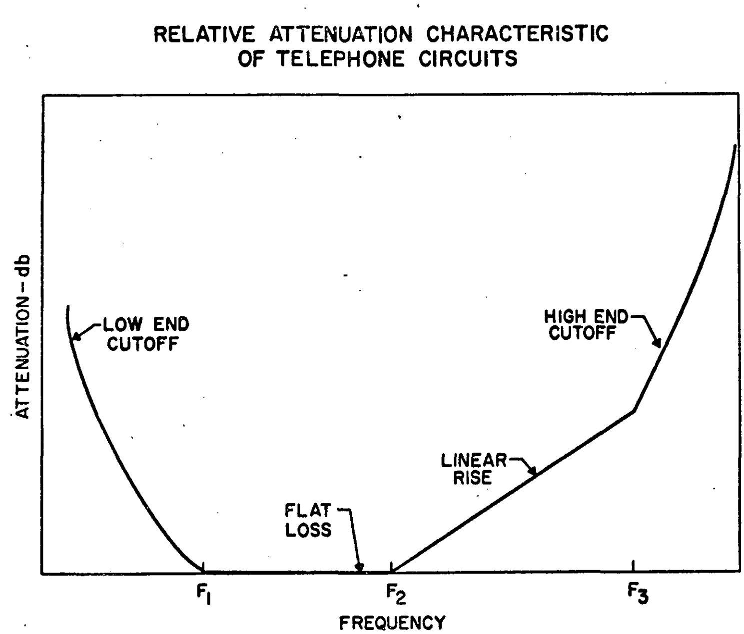


FIGURE 110

At switching points a considerable amount of impulse noise is generated due to the switches themselves, relays, dialling pulses and the like. This noise is coupled in varying degrees, either directly or as cable crosstalk between pairs, to all channels switched by office.

1. *Effective channel bandwidth.*

It is convenient to consider attenuation and envelope delay distortions as occurring between two cut-off frequencies at which signal frequency components will be so severely attenuated by the transmission medium as to be relatively insignificant. For the purpose of this presentation, a 20 db bandwidth is defined as the interval between those frequencies at which the circuit loss is 20 db greater than the minimum loss of the circuit. The average 20 db bandwidth is of the order of 3000 c/s. However, distortions to be described within this band are such that considerably less than 3000 c/s may be usable for data-transmission purposes.

2. *Attenuation distortion.*

A careful examination of all the characteristics taken during the field measurement programme has revealed that, in general, the relative attenuation characteristics assume the form shown in Figure 110. That is, the circuit loss rises rapidly below f_1 c/s and above f_3 c/s, is relatively flat from f_1 c/s to f_2 c/s and rises linearly with frequency from f_2 c/s to f_3 c/s. These average frequencies and loss roll-offs are described below.

TABLE 1

	Roll-off below f_1	f_1	f_2	f_3	Roll-off above f_3
	db/octave	c/s	c/s	c/s	db/octave
Exchange	15	240	1100	3000	80
Long distance					
Short haul	24	300	1075	2950	90
Long haul	27	280	1150	2850	80

For exchange calls sharp lower roll-offs are not to be expected on the average since many such connections are short, use voice facilities and cut-off only because of the signalling and supervisory networks. Some longer calls use carrier facilities showing a sharper cut-off. Long-distance calls, in particular, use single carrier systems extensively so that the average lower roll-off is fairly sharp.

The upper end roll-offs are much sharper for all classes of calls because of the combined effects of carrier systems and inductively loaded cable pairs.

Since data signals in most cases tend to be placed in the band from 1000 c/s to 2600 c/s, it is particularly desirable to describe the linear portion of the relative loss curve between these two frequencies. Figure 111 is a plot of cumulative distributions for the loss differences between 1000 c/s and 2600 c/s for the three classes of calls. Note that, on the average, this difference is about 8 db but that, in about 5% of the cases, 15 db is exceeded. In general, long-distance connections show greater slopes as a result, in part, of the shunt capacitance added by the switching points. Exchange calls usually are switched only twice whereas long-distance calls may be switched at four or more points.

When transmitting at 1200 bits per second with the FM digital subset it was found advantageous to use an attenuation equalizer designed to compensate for a 4 db slope between 1100 c/s and 2100 c/s, the mark and space data frequencies respectively. Between 1000 c/s and 2600 c/s this network equalized a loss slope of about 7 db.

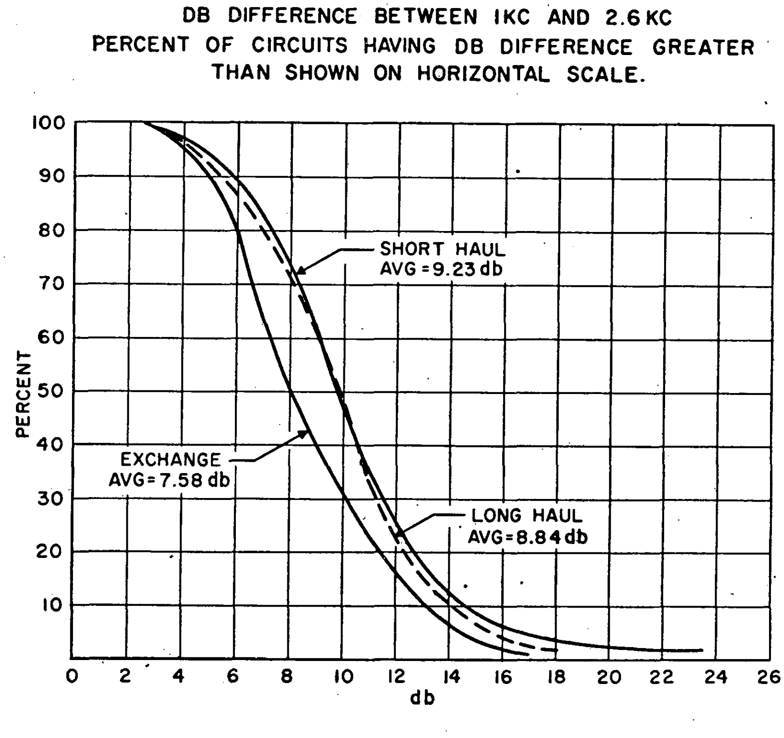


FIGURE 111

3. *Envelope delay distortion.*

The ear is relatively insensitive to minor phase distortions so that the telephone message plant, designed for speech transmission, has not required the extremely low distortions demanded by data transmission. Since there is no reason to assume that the telephone network is minimum phase, knowledge of attenuation characteristics must be supplemented by a characterization of the phase variations. It is most practical to measure the derivative of the phase with respect to frequency, $\frac{d(\theta)}{d\omega}$, which has the dimension of time and is referred to as envelope delay.

AVERAGE ENVELOPE DELAY CHARACTERISTICS

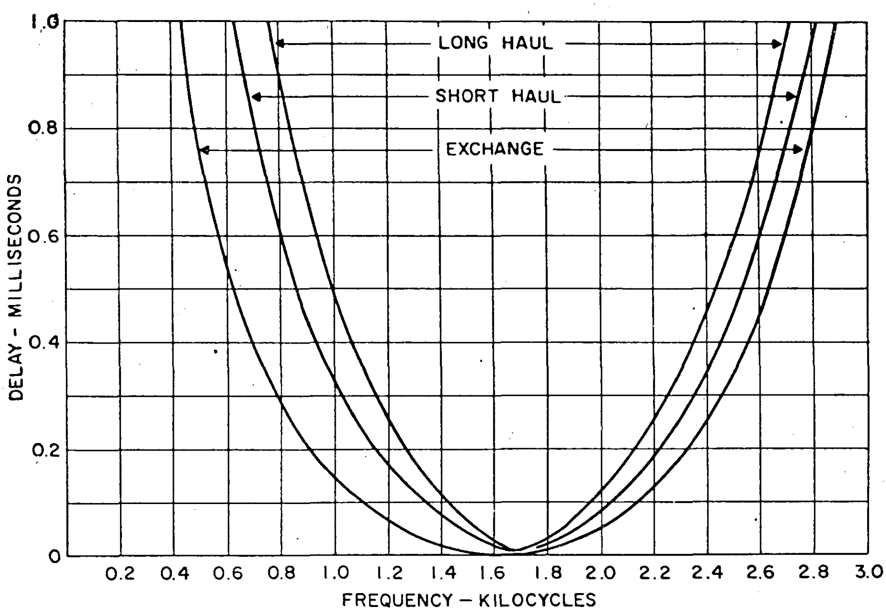


FIGURE 112

Curves of envelope delay versus frequency tend to be concave upward as a result of the upper and lower cut-offs of the telephone network. Average envelope delay characteristics are plotted in Figure 112 for the three classes of calls with the minimum envelope delays normalized to zero. They were derived by drawing smooth curves through the following five points: the average frequency of minimum delay (FMD), the average upper and lower frequencies at which the envelope delay is 1.0 millisecond greater that the minimum, and the average upper and lower 0.5 millisecond frequencies.

Three facts are noteworthy: (1) the average FMD is of the order of 1700 c/s, (2) distortion for exchange calls is less than for long-distance calls, and (3) all the curves appear to be fairly symmetrical about their respective FMD's.

It is mildly surprising that the exchange delay characteristics do not show more dissymmetry around an FMD somewhat lower than measured. Such a result is to be expected if the lower cut-off is determined by signalling and supervisory circuits. The explanation lies in the fact that almost 50% of the exchange connections measured used carrier facilities with typically symmetrical delay curves. Deleting the data from calls using exchange carrier systems gives rise to the curves shown on Figure 113 which is somewhat more representative of wire line characteristics.

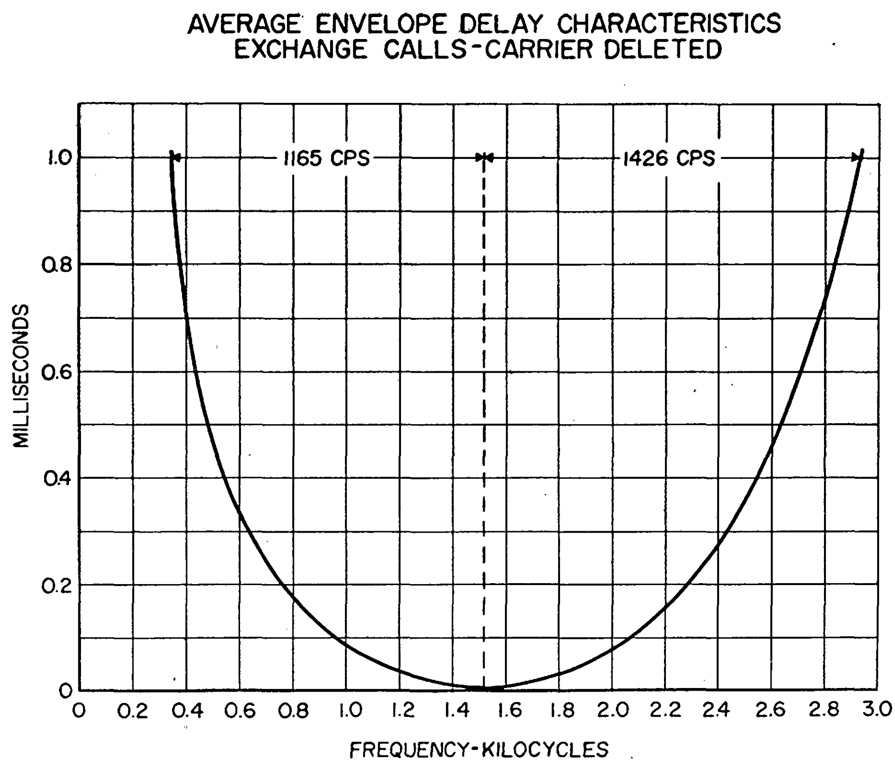


FIGURE 113

Of interest are the variations from these average curves which are shown in Figures 114 to 116. For each point used to draw the average characteristics described above, limits were found so that about 90% of the measured points fell within these limits. By systematically joining respective limit points, the plots in Figure 114 were derived. Careful sampling of the actual data confirms that indeed approximately 90% of the measured curves fall within the shaded areas of the diagram even though the limit points were determined independently. Dotted lines indicate typical measured curves.

Note that all curves are tangent to the abscissa representing minimum delay (zero microsecond) at frequencies varying from 1200 c/s to 2000 c/s. More detailed information on the variations of this frequency of minimum delay is shown in Figure 115.

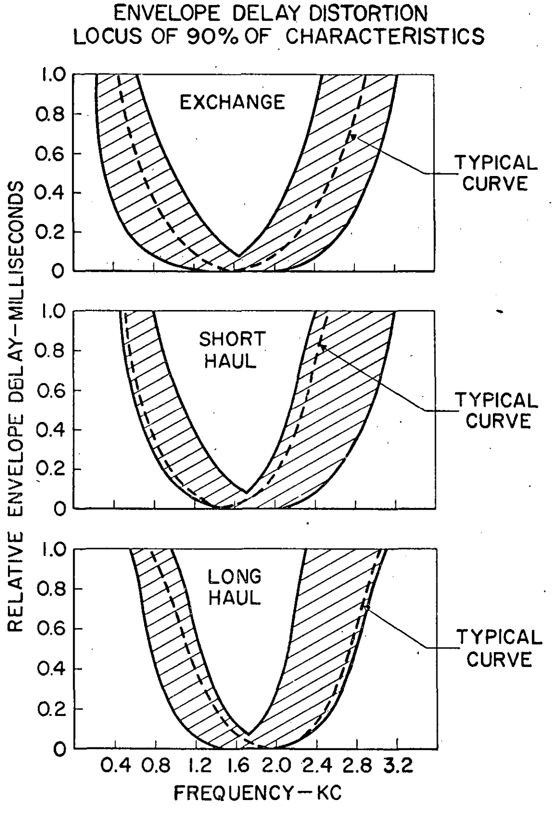


FIGURE 114

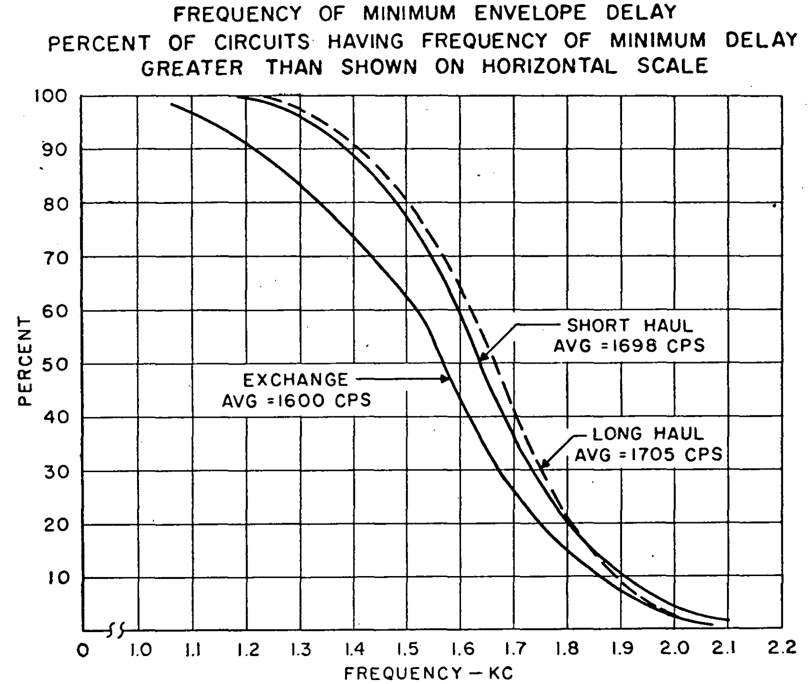


FIGURE 115

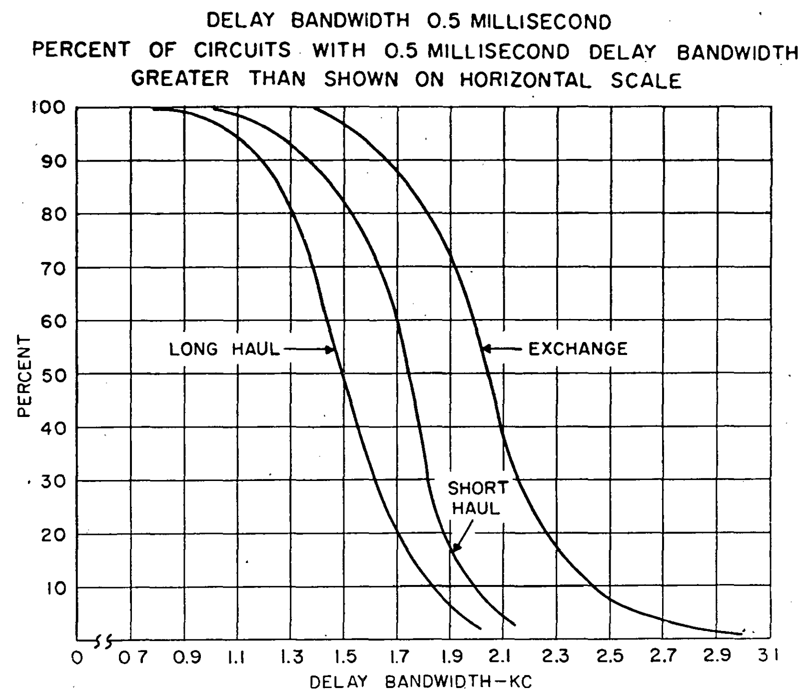


FIGURE 116

Statistics on the delay distortion at the band edges is presented in Figures 116 and 117 in terms of 0.5 millisecond and 1.0 millisecond " bandwidths ". Delay bandwidth is here defined as the difference between those frequencies at which the envelope delay distortion is 0.5 ms or 1.0 ms.

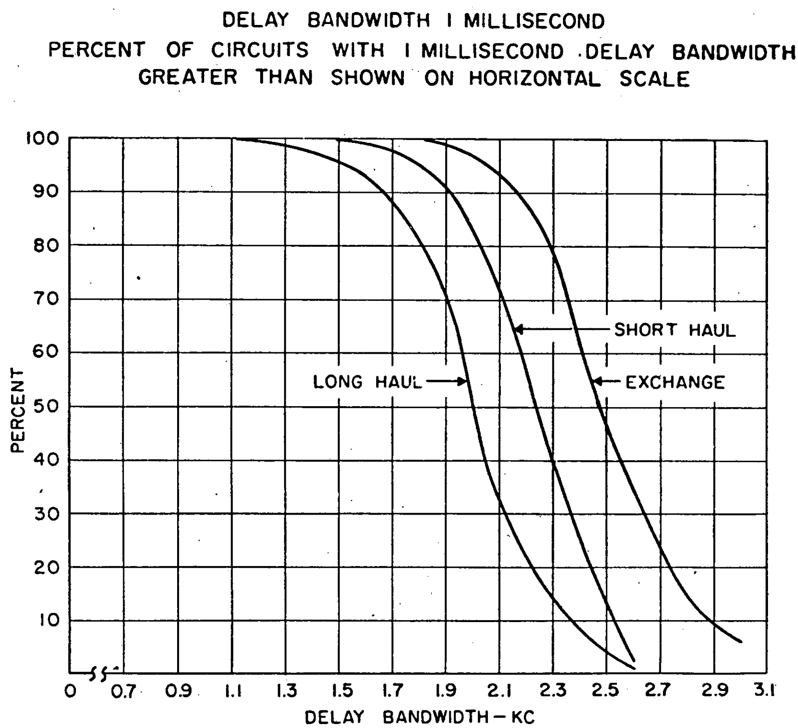


FIGURE 117

A comparison of the measured delay characteristics with the compromise delay equalizer used during the tests while transmitting at 1200 bits is made in Figure 118. The inverse of the equalizer characteristic is shown superposed on a diagram indicating the locus of 90% of the delay curves including all three classes of calls. Hindsight indicates that lower frequencies probably would have been better equalized on the average had the compromise favoured those circuits utilizing carrier facilities.

The combined effect of amplitude and delay distortion on the FM digital subset shows up as jitter on the transitions of the demodulated signal and can be described in term of peak distortion (repetitive jitter). Peak distortions of less than 20% are considered quite acceptable. More than 99% of the calls met this 20% limit while transmitting at 600 bits at mark-space frequencies of 1400-1900 cycles. Although the percentage of calls exceeding the limit did not vary widely for the three frequency pairs used the overall distribution for the 1400-1900 cycles was considerably better. This was probably due to a better match of the resultant data spectrum to the average envelope delay characteristic. A correlation of peak distortion and error performance showed that the error statistics would not have been significantly changed if the 1400-1900 cycle frequency pair had been used in this test.

Upon changing to a speed of 1200 bits per second the measured peak distortion, without either attenuation or delay equalization, was beyond practical limits. After inserting the compromise equalizer, the jitter was considerably improved. Note that for pair (1100-2100 c/s) over 20% of all calls exceeded the 20% limit whereas for pairs (1200-2200 c/s) and (1300-2300 c/s) less than 10% of the calls exceeded the limit. Pair (1300-2300) shows the lowest distortion for two possible reasons: (1) these frequencies best match the average compromise equalized connection and (2) the number of carrier cycles per signal element is greatest for this pair.

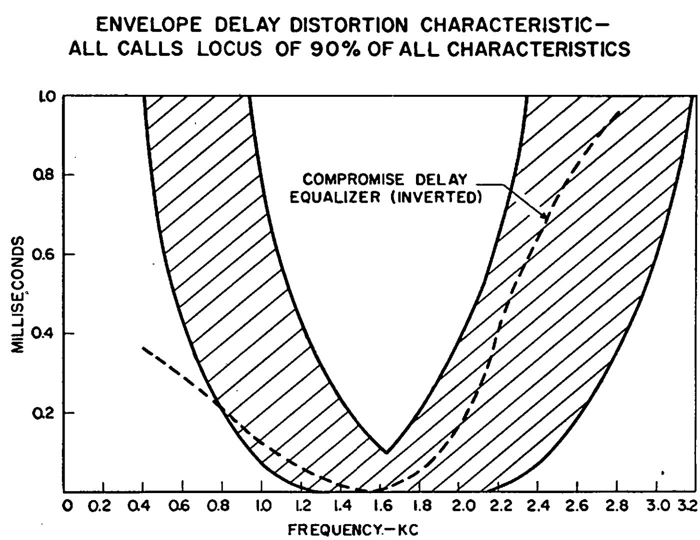


FIGURE 118

4. *Ripples in distortion characteristics.*

The attenuation and delay characteristics described herein were derived by discounting ripples in the raw measured data. These ripples, mainly the result of echos (reflected energy), can be appreciable and must not be ignored. The source of echoes is varied and includes all points of impedance mismatch in bilateral circuits, and hybrid unbalance at the junction of 2-wire and 4-wire circuits. If multiple echoes exist, ripples in the attenuation and delay characteristics of the same circuit are not necessarily correlated. However, for each characteristic, the ripple period on a frequency scale tends to be inversely proportional to the electrical length of the path from the observer to the source of echo. That is, close-in echoes give rise to long sweeping ripples while remote echoes cause fine structure ripples.

Owing to increased reflected energy at the band edges, where impedances deteriorate, the ripple amplitudes tend to increase in these areas. In the main, the ripple in the amplitude characteristic is significant (i.e., greater than one to two db) only above about 2000 c/s. For the most part the maximum ripple occurs in the frequency range of 2000-3000 cycles.

Both the amplitude and period of the ripples varies across the band, probably due to the existence of multiple echo points. Such variations are difficult if not impossible to describe statistically.

It has been pointed out that close-in echoes result in ripples in the transmission characteristics which can be equalized whereas remote echoes cannot. The reason for this is that an individual transmitted pulse will be affected mainly by its own echo if the source of the echo is close-in, and can be equalized to eliminate this distortion. Remote echoes tend to affect subsequent transmitted pulses, and the effect is random for an information bearing train. Hence ripple equalization will not be effective in general.

. . . .

6. *Noise.*

Two types of noise are of interest in the telephone plant:

1) steady line noise, and

2) impulse noise.

Steady noise is important for its interfering effect on speech transmission. Impulse noise, characterized by relatively high peaks of short duration pulses, has the greatest effect on the transmission of pulses.

In general, steady noise is not of great importance in pulse transmission. Only about 1% of all the calls exceed noise values of 40 dba. This is equivalent to an average of about -42 dbm of white noise in a 3 kc/s band. In only about 5% of the calls did the

– 6 dbm data signal exceed losses of 26 db for a received level of – 32 dbm. Very few calls exhibited less than a 10 db average signal-to-noise ratio.

Impulse noise, on the other hand, frequently has peaks comparable to the received data signal level. The incidence of impulse noise tends to follow the traffic fluctuations in the switched network. That is, busy periods generate considerably more impulse bits than quiet periods. In fact, in the field test about 40% of the calls failed to show any impulse counts regardless of the measured level. This is to be expected in that calls were placed at random during both the busy and the quiet periods of the day.

The average number of impulse noise counts above given slice levels for 15 minutes measurement periods is plotted in Figure 119. This data gives a general indication of impulse noise conditions within the message plant even though it does not correlate well with error rates on the same calls. In many instances in which errors occurred, no impulse

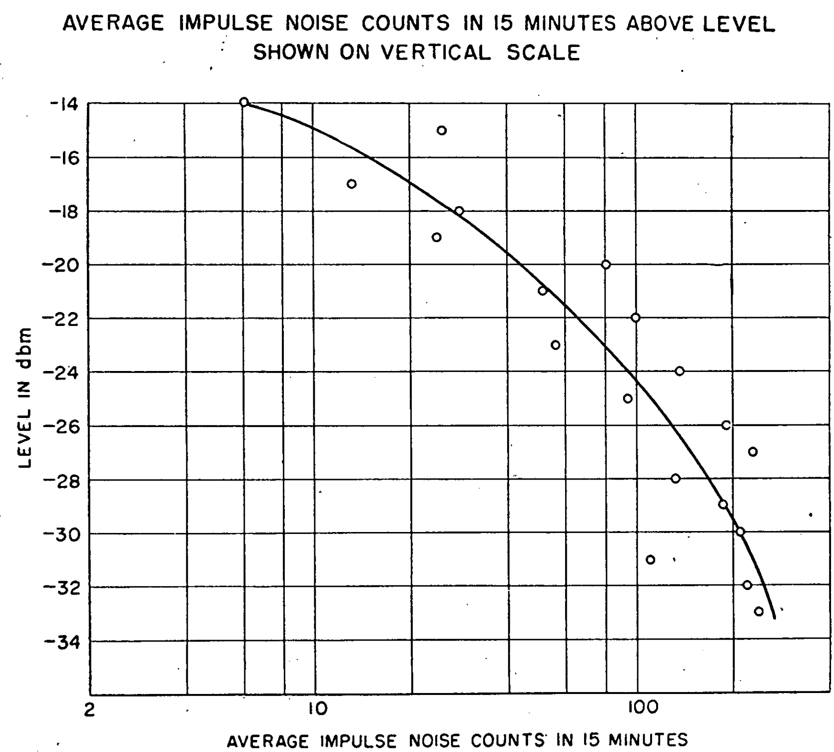


FIGURE 119

noise was measured and vice versa. As a result the correlation of impulse noise and error generation was poor. Drop-outs and interruptions that do not show up as impulse noise counts limit the usefulness of noise measurements in predicting error performance on the switched message network.

The error performance actually experienced during the field testing programme is described and discussed in the following paragraphs.

V. *Error rates*

The primary purpose of the investigation described herein was to provide statistics of the error rate and the time distribution of errors at bit rates which have a *high probability of success for transmission over any facility between any two telephone stations in the United States.* There would be little value in designing data systems which have such high bit rates that they would work on only half of the circuits encountered. We are interested in the performance at data rates where satisfactory transmission can be achieved on practically all of the connections.

In order to obtain a better understanding of error rate as a function of transmitting level, some measurements were made at a number of levels. The bulk of the data, which includes the distribution of errors as a function of time, was collected with a transmission level of — 6 dbm at the sending station.

The method permits a computer to count the number of good bits between error bits and present the distribution of errors. This distribution is obtained in a printed output similar to that shown below, and is also available on cards and on magnetic tape which can then be used for later evaluation of various types of error control schemes or for more detailed analysis of error bursts.

Zeros	Ones
25 226	1
222 866	1
14 692	6
8 971	1

The first column designated " zeros " is the number of good bits between errors. The second column designated " ones " is the number of errors. Thus, this printed output is interpreted as follows: 25 226 good bits were transmitted and then one error was encountered; then 222 866 good bits were transmitted and another error was encountered, then 14 692 good bits were transmitted and six consecutive errors were encountered, etc. This is the basic information from which various types of analysis have been made.

The particular distributions and relations presented herein have been selected on the basis of what is thought to be most significant in the planning of data-communication systems. The first statistic essential in the planning or evaluation of a data system is the cumulative distribution of average error rates.

A. *Average error rates at 600 bits per second.*

Figures 120 to 123 indicate the probability of obtaining a circuit which produces an average error rate better than shown on the abscissae. These probabilities are shown for the three types of calls. It is at the receiving central office where the introduction of switching noise is most critical due to the lower level of the signal. Figure 120 indicates that 85% of the exchange calls can handle 600 bits per second with an error rate of one bit in error for every 10^5 bits or more transmitted. A slightly lower percentage, 82%, of the short-haul calls performed as well, and 75% of the long-haul circuits met this accuracy figure. On the average, exchange calls have less attenuation than short-haul or long-haul calls. Since all stations are transmitting at the same levels, this means that the signal-to-noise ratio at the receiving station is greater for the exchange calls.

In order to eliminate the effect of the higher losses on the longer connections, Figure 122 compares error rates at a common receive level of −25 dbm. The transmitting levels were adjusted so that at the receiving station line signals of −25 dbm were received. Here the exchange calls and the short-haul calls are virtually the same, but on the long-haul calls, at the same receive level, the performance is somewhat inferior. This should be expected since on long circuits there is a greater probability of exposure to noise and interference.

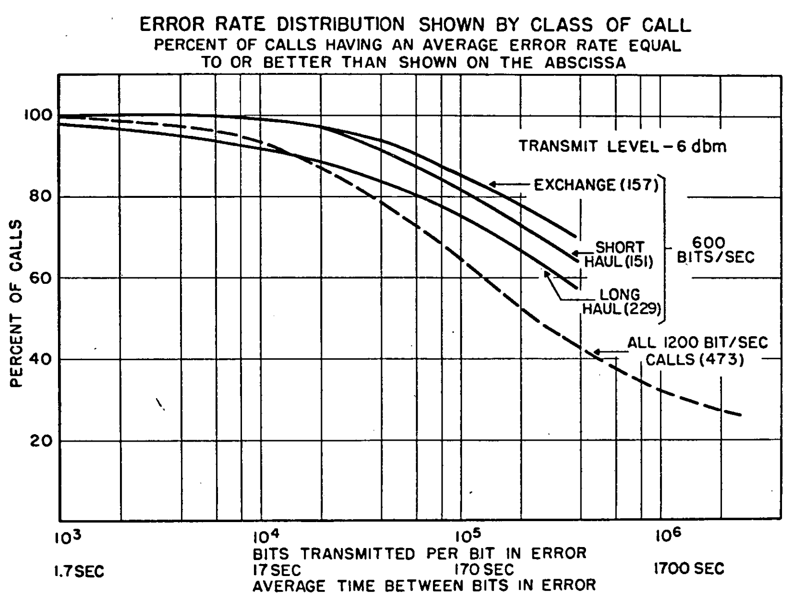


FIGURE 120

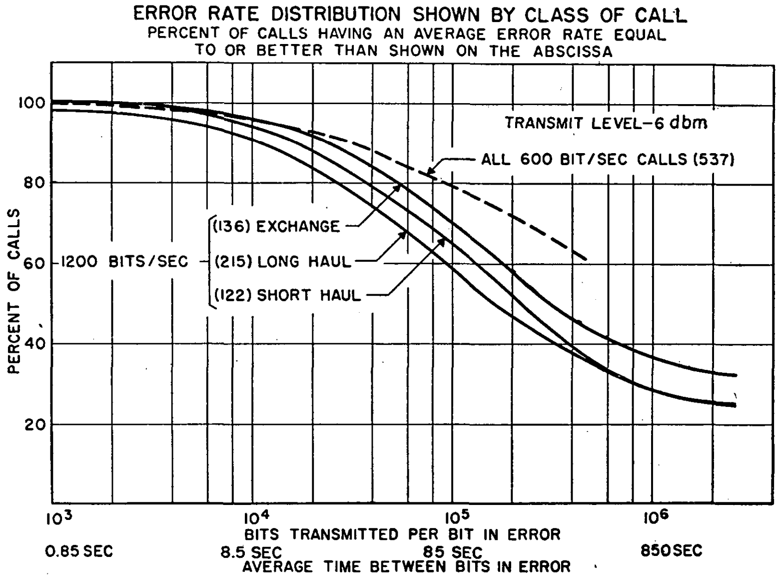


FIGURE 121

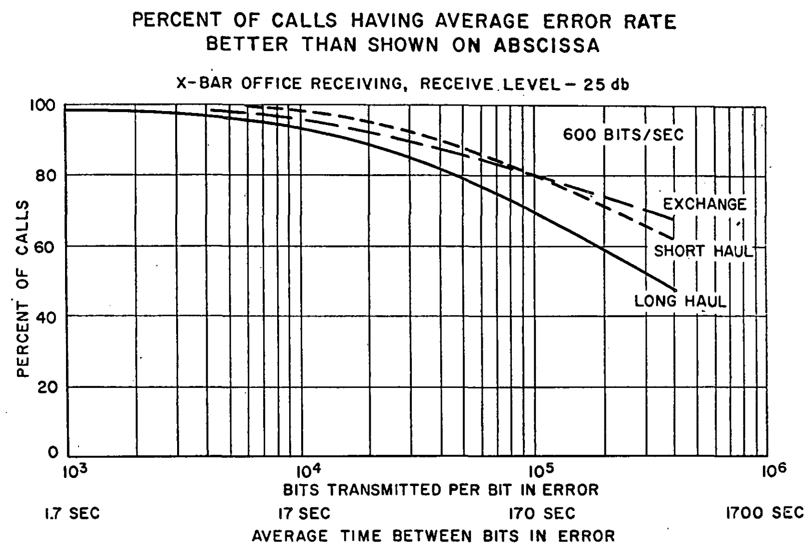


FIGURE 122

Figure 123 indicates the change in error rate distribution as the transmitting level is reduced in 5-db steps. Note that if the transmitting level is lowered from — 6 dbm to — 11 dbm the error rate is approximately doubled.

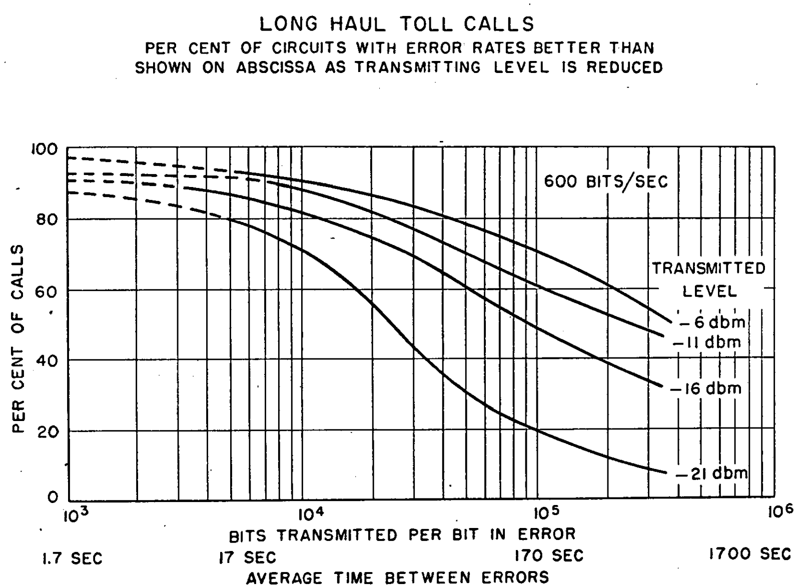


FIGURE 123

B. *Average error rate at 1200 bits per second.*

The curves on Figure 121 are plots of the results at 1200 bits per second for the various types of calls. They are shown on the same axis with the curve of all calls at 600 bits per second. Note that for a given per cent of the circuits the error rate at 1200 bits per second is two or three times greater than that for 600 bits per second. In other words, 70% of the calls at 600 bits per second will produce an error rate better than about one error in 200 000 bits, but at 1200 bits per second 70% of the calls will produce an error rate better than one in 70 000 bits.

VII. *Conclusion*

The evaluation programme has demonstrated that speeds as high as 1200 bits per second with an FM mod-demod using a zero crossing detection system is entirely practicable on the regular switched telephone network. The error performance on the connections is variable depending upon a number of factors. In many cases, the probability of error in transmission may be so much lower than the probability of error from other sources that error control may not be necessary. When very high accuracy is required error control techniques can be used effectively.

Error detection and block retransmission methods appear necessary in order to obtain a high degree of accuracy on the long-distance transmission. Forward acting error-correcting codes may be used to improve the line efficiency when such methods are used.

It is possible to design around many of the data limiting characteristics of the network the compandors and echo suppressors, for example. The variability in circuit characteristics can also be compensated for somewhat by corrective devices associated with either the data terminal equipment or in some cases the telephone channel itself. The compromise equalizers used for the 1200 bit per second tests are typical examples of what can be done in this direction.

For some applications, arrangements may be made to bypass certain facilities that limit the transmission of data signals. These may take the form of controlled access to the long-distance switching network or perhaps the use of only certain telephone facilities and offices in the data service offering. In any case, the final decision as to the engineering design will be determined by the overall economies.

WORKING GROUP 43: REPORT

(Extracts from contribution GT.43, No. 20, March 1960)

7. *Consideration relating to the transmission characteristics of connections set up over telephone-type circuits by switching.*

7.1. For data transmission the telephone subscriber will generally want to use the same equipment for local, trunk and international connections, so that local conditions will have to be taken into account as well as C.C.I.F. conditions for the international telephone service.

Useful data for designers will be, primarily:

— the usable bandwidth in difficult cases, and

— the maximum attenuation to be considered.

It will no doubt be the local conditions that impose the limits. Since the use of 4-wire connections throughout would tend to a considerable improvement in data transmission over telephone networks, the question arose of whether it might not be desirable to recommend the use of such connections. This raises the question of 4-wire switching systems which are being considered at present, but it does not seem that there will be a general practical solution of this question for a fairly long time.

TABLE 1

Information received on the subject of national voice-frequency signalling systems

European countries

	Germany (Federal Republic)		Austria	Belgium	Denmark	Spain	France	Great Britain		Irish Republic				Italy	Netherlands	Norway	Sweden	Switzerland	U.S.S.R.	
Frequency (c/s)	3000	(2280)	2280	2280	3000	2500	2000	600-750 separate		2040/ 2400 compound	600-750 separate		600/ 750 compound	2040/ 2400 compound	2400/ 2500 separate	2400	2400 (for 2 wires: 2200 and 2400)	3000	1200-1600 separate	2100
Tolerance at the generator terminal (c/s)	± 7.5	± 7.5	± 3	± 5	± 6	± 3	± 6	± 3		± 6	± 3		± 3	± 6	± 2	± 2	± 10	± 3	—	—
Frequency variation possible at the input to the international circuits (c/s)	± 15	± 15	± 7	—	± 8	± 6	± 12	± 5		—	—		—	—	± 7	—	± 15	—	± 8	± 8
Splitting time (milliseconds)	30	30	30	8	35	10	15 then 35 with attenuated 18 db	140 or 320	400	60	140 or 320	400	110	40-60	55	25	35	70	25	25

TABLE 2

Information received on the subject of national voice-frequency signalling systems

Extra-European countries

	Argentina	Australia	Canada (British Columbia Telephone Co.)	United States of America (U.S.A.) (A.T.T. Co.)		Japan
Frequency (c/s)	2040/2400 compound	600-750 separate	2600 (for 2 wires: 2400-2600)	1600-2000	2400-2600	1900-2300 separate
Tolerance at the generator terminals (c/s)	± 6	± 2.5	± 3	± 5		
Frequency variation possible at the input to the international circuit (c/s)	± 15	—	± 10	± 15		
Splitting time (milliseconds) .	60	160/210	25 then attenuated 30 db	20—30 then attenuated 30 db		500

In the meantime, therefore, it can only be recommended that the existing 2-wire networks should be used, though this will mean a lower modulation rate.

The question of the compatibility of data transmission and signalling for switching purposes (particularly the signalling which is used once the call has been set up) will have to be examined very thoroughly; in Europe, at least in the international service conforming to C.C.I.F. Recommendations, 2040 and 2400 c/s are used for supervisory signals in 2-frequency signalling systems, and 2280 c/s in 1-frequency signalling systems.

In their national services, however, Administrations use other frequencies. Tables I and II above (taken from the C.C.I.F. *Green Book*, Volume V) give some information on this subject. It should be noted further that other signals are sometimes used in inland services, for example, metering pulses.

The problem is thus rather complex. It has in fact two aspects: there is the question of the frequencies which, when they are used during data transmission may cause wrong signals and there is the question of possible interference to data transmission resulting from signalling or operation.

Administrations should therefore examine whether existing or projected signalling systems are compatible with the procedures expected for data transmissions.

7.4. *Echo suppressors.*

Echo suppressors present a problem on switched connections, though in the absence of echo suppressors, echoes may become a nuisance.

Companies which have already instituted a data-transmission service over the general telephone network in countries where echo suppressors are fairly common have chosen a signal to switch the echo suppressors before a data transmission begins. Echoes must obviously be taken into account in this case, but when they come back over the return channel, which is used only for acknowledging the receipt of blocks, they need not be a nuisance if the frequency spectrum of the wanted signals is markedly different from that of the echoes, or if an appropriate modulation system is used.

The attention of Administrations should be drawn to this point with respect to circuits equipped with echo suppressors and long circuits which are not equipped with suppressors. Information on the characteristics recommended by the C.C.I.F. for echo suppressors is to be found on pages 33 to 38 of the *Green Book*, Volume III *bis*.

7.5. *Transmission time.*

Transmission time is limited to 250 milliseconds in one direction by C.C.I.F. Recommendations. Studies have already been made in connection with phototelegraph transmissions and informations can be found in the contribution of the A.T.T. (See pages 445 to 450.)

6. *Consideration on the data-transmission characteristics of point-to-point telephone circuits (not set up by switching).*

6.1. Tests have been carried out on telephone circuits not set up by switching. The results of these tests are given in the contributions published in the Supplements.

On telephone type circuits that meet C.C.I.F. Recommendations a general modulation rate of 1000 bauds is to be expected.

It appears that, with correction of the phase distortion, up to 2000 bauds is feasible. With specially designed circuits, which are far more expensive, 3000 bauds and over can be expected.

No general value has been given for the error rate when there is no protection against errors. In the most difficult cases, it seems to rise to as much as one in 10^3.

The method of electric modulation, the output level and the noise level have a very great effect on this error rate.

After a long discussion, it emerged that the possibilities of telephone type circuits for data transmission have not been studied as thoroughly as their possibilities for speech transmission.

It is essential to assemble data on this subject, which should enable a choice to be made of modulation speeds, electric modulation methods and the composition of channels, establishment of codes with error detection, length of blocks, etc.

SIEMENS & HALSKE: STATISTICS AND DETECTION OF ERRORS FOR PURPOSE OF DATA TRANSMISSION

(Extracts from contribution GT.43, No. 3, September 1959)

The essential improvement of the transmission reliability on telegraph lines required for data-transmission purposes depends on the employment of apparatus designed to detect or correct errors. The basis for achieving an appropriate design of such apparatus is provided by measurements of the nature and rate of errors occurring on the lines. This contribution presents provisional results of such a measurement conducted by Siemens & Halske A.G.

It must be assumed that data transmission will proceed partly over conventional 50-baud channels, and partly over channels operating at higher telegraph speeds, e.g. 500 bauds. In its Recommendation F.7 (Geneva, 1956), the C.C.I.T. recommended, for land-line communication circuits operated by 5-unit code start-stop apparatus, a maximum error rate of $3:10^5$ equalling a minimum transmission reliability of $10^5: 3 = 3.3 \cdot 10^4$, at the same time declaring that these figures merely represent a provisional standard. It is expected that a transmission reliability in the order of between 10^7 and 10^9 will have to be set as a standard for data transmission.

Measurement of errors on lines.

With this in mind, Siemens & Halske have started a series of systematic error measurements. One of these involves the transmission of a 1000-signal test code on a point-to-point circuit between Berlin and Munich for approximately 4 hours per day. The perforated tape generated at the receiving location is evaluated in a special perforated-tape comparator in the following respects:

3.1. Counting the total number of signals;

3.2. Counting the number of errors produced by unilateral (unipolar) errors within a signal group, at the same time ascertaining the falsified signal elements having stop and start polarities;

3.3. Counting the number of transposition errors within a signal group;

3.4. Counting the number of interruptions of more than 300 milliseconds' duration.

The differentiation between errors as per 3.2 and 3.3 is an important concern, because many error-detection systems operating on simple principles are capable merely to detect the errors coming under 3.2 while other more complex systems are able to detect or correct a smaller or larger percentage of the errors of category 3.3.

In the period from July 27 to September 11, 1959, with a total of 2.6 million signals transmitted, the following errors occurred:

— 56 errors of category 3.2, totalling 58 falsified start-polarity elements and 9 falsified stop-polarity elements;

— 2 errors coming under category 3.3;

— 6 extended line interruptions.

A certain model of error-detecting apparatus, which was to be tested in conjunction with these measurements, clearly detected all of the 56 errors as per category 3.2 and corrected them by way of repetition request signals. Also, one of the two errors coming under category 3.3. could be corrected in response to a repetition request signal, because the signal group affected contained further errors as per 3.2 which initiated the repetition process.

The only error not recognized was the second one of category 3.3.

Thus the insertion of an error detector enhanced the transmission reliability on this circuit from $2.6 \cdot 10^6 : 58 = 4.5 \cdot 10^4$ to the substantially higher value of $2.4 \cdot 10^6$. (The extended line interruptions have been disregarded in this example).

CHILE TELEPHONE COMPANY: CONSIDERATION OF VARIOUS REDUNDANCY ARRANGEMENTS

(Extracts from contributions GT.43, No. 8, February 1960 and GT.43, No.17, March 1960)

Redundancy can be employed to allow errors to be detected and corrected by one means or another.

The efficiency of a redundancy arrangement is judged on three qualities: firstly, the liability for errors to remain undetected; secondly, the amount of hardware necessary; and, thirdly, the delays which may be produced in the processing or transmission of the data and redundancy.

Five different arrangements, A-E, have been considered, and these may be described as follows:

A *(row parity)*

If it is considered that a block of 100 bits is transmitted in the order 1, 2, 3 ..... 100, then a typical row parity arrangement is achieved by making:

bit 10 dependent on bits 1—9,
bit 20 dependent on bits 11—19, etc.

B *(two-column parity)*

Considering a block of 100 bits as before, then a typical two-column parity arrangement is given by making:

bit 96 dependent on bits 1, 11, 21, 31, 41, 51, 61, 71, 81, 91; and 6, 16, 26, 36, 46, 56, 66, 76, 86;
bit 97 dependent on bits 2 ..... 92; and 7 ..... 87;
bit 98 dependent on bits 3 ..... 93; and 8 ..... 88;
bit 99 dependent on bits 4 ..... 94; and 9 ..... 89;
and bit 100 dependent on bits 5 .. 95; and 10 ..... 90.

C *(one-column parity)*

This arrangement is similar to B, except that the columns are not paired, bit 91 being dependent on bits 1, 11 ..... 81, and bits 92—100 likewise on the remaining columns.

D *(two-co-ordinate parity)*

The first co-ordinate is taken as in B or C. The second co-ordinate is provided by taking, for example, a diagonal parity word. In such a case bit 10 might be the parity bit for the parity word comprising bits 19, 28, 37, 46, 55, 64, 73, 82, 91. Bit 9 would serve the parity word 18, 27, 36, 45, 54, 63, 72, 81, 100; and bits 1—8 would serve corresponding parity words.

E *(binary digit parity)*

Bits 1—100 can be expressed in binary code, using not more than seven digits. Bits 1, 2, 4, 8, 16, 32 and 64 are used for these digits and are each dependent on the parity words with which they are associated:

The parity word for bit 1 is 3, 5, 7, 9, 11, 13 ... 99.
,, ,, ,, ,, ,, 2 is 3, 6, 7, 10, 11, 14, 15, 18, 19 ... 98, 99.
,, ,, ,, ,, ,, 4 is 5, 6, 7, 12, 13, 14, 15, 20, 21, 22, 23 ... etc.
,, ,, ,, ,, ,, 8 is 9, 10, 11, 12, 13, 14, 15, 24, 25, 26, 27, 28, 29, 30, 31 ... etc.
,, ,, ,, ,, ,, 16 is 17—31, 48—63, 80—95.
,, ,, ,, ,, ,, 32 is 33—63, 96—100.
,, ,, ,, ,, ,, 64 is 65—100.

It will be seen that, as in D, each data bit influences more than one parity bit (for example 0001101 (13) influences the parity words 8, 4 and 1). Unlike D, the number of parity bits influenced is not constant.

Redundancy percentages for the above arrangements, with different block sizes, are shown below. For the sake of simplicity, the redundancy percentage is quoted with reference to the complete block:

Block size	Arrangement	Bits of redundancy	% of block
50	A	5	10
100	A	10	10
200	A	20	10
500	A	50	10
50	B	5	10
100	B	5	5
200	B	5	2.5
500	B	5	1
50	C	10	20
100	C	10	10
200	C	10	5
500	C	10	2
50	D (incl. B)	5 + 5	20
100	D (incl. B)	5 + 5	10
200	D (incl. B)	5 + 5	5
500	D (incl. B)	5 + 5	2
50	D (incl. C)	10 + 10	40
100	D (incl. C)	10 + 10	20
200	D (incl. C)	10 + 10	10
500	D (incl. C)	10 + 10	4
50	E	6	12
100	E	7	7
200	E	8	4
500	E	9	1.8

The equipment needed for processing the redundancy is dependent on the number of redundant bits per block, whereas the time needed to transmit the redundancy is related to the redundancy percentage.

In considering the results quoted in the summary which follows, it should be observed that as regards redundancy arrangement A the number of undetected errors decreases as the block size increases. This is due to the fact that with the larger blocks there are more likely to be other errors which are detected and cause retransmission of the whole block including the undetected errors. Reference to the summary will show that the A arrangement is not acceptable for data transmission. It may be added that a constant-ratio code would introduce at least a 50% reduction in undetected errors but would cause the redundancy percentage to become much larger.

The B arrangement is interesting as it offers a very low redundancy percentage with fewer undetected errors. As with the A arrangement, the undetected errors may be covered by errors detected elsewhere. On the other hand, the larger the block the greater will be the chance of an even number of errors in a column.

The C arrangement, having more redundancy, should always show fewer undetected errors than the B arrangement. If the bits received erroneously are randomly distributed, it will be expected that the C arrangement will have rather less than half the undetected errors of the B arrangement. The B arrangement, and to a lesser extent the C arrangement, is liable to miss a group of errors in a block.

The D arrangement is very much safer than A, B and C because the two-co-ordinate check greatly reduces the probability of an even number of errors within a block forming an undetectable combination.

No statistics have been collected for the E arrangement as this would necessitate recording all the errors in 7-digit binary numbers and carrying out parity checks which are cumbersome when the number of errors in a block is excessive.

Both the D and E arrangements are able to indicate which bit is wrong if only one error exists. However, the nature of switched telephone connections is such that in many cases the chance of having more than one error in a block is considerable, and there appears to be little justification for relying on correction without retransmission.

A schedule is included comparing the percentage of blocks received correctly with different levels and speeds of transmission.

In the schedule the undetected errors are shown in three columns. Those in the first column relate to tests at various speeds with a signal level of – 16 dbm at the first switching stage. Column 2 includes only case 7 tests having a full record at 1000 bits per second and these figures are also included in the totals in column 1. Column 3 shows results of tests with a signal level of — 23 dbm at the first switching stage and a speed of 500 bits per second. These figures are not included in column 1. The programme used for collecting the statistics in column 3 did not include the calculation of results for Arrangement D.

Summary of statistics measured in respect to undetected errors

Speed of transmission: 250, 500, 1000 bits per second.
Block sizes measured: 50, 100, 200, 500 bits.

	1	*2*	*3*
Total number of blocks of 50 bits transmitted . . .	536 222	219 360	523 610
Total number of errors	4 284	152	2 310

Arrangement A.

Number of undetected errors in blocks of 50 bits . .	418	36	302
,, ,, ,, ,, ,, ,, ,, 100 ,, . .	278	36	244
,, ,, ,, ,, ,, ,, ,, 200 ,, . .	184	36	216
,, ,, ,, ,, ,, ,, ,, 500 ,, . .	106	36	170

Arrangement B.	*1*	*2*	*3*
Number of undetected errors in blocks of 50 bits	172	4	106
,, ,, ,, ,, ,, ,, ,, 100 ,,	146	4	100
,, ,, ,, ,, ,, ,, ,, 200 ,,	136	4	86
,, ,, ,, ,, ,, ,, ,, 500 ,,	144	4	52

Arrangement C.

Number of undetected errors in blocks of 50 bits	78	0	34
,, ,, ,, ,, ,, ,, ,, 100 ,,	74	0	36
,, ,, ,, ,, ,, ,, ,, 200 ,,	80	0	34
,, ,, ,, ,, ,, ,, ,, 500 ,,	80	0	18

Arrangement D (incl. B).

Number of undetected errors in blocks of 50 bits	6	0
,, ,, ,, ,, ,, ,, ,, 100 ,,	8	0
,, ,, ,, ,, ,, ,, ,, 200 ,,	14	0
,, ,, ,, ,, ,, ,, ,, 500 ,,	12	0

Arrangement D (incl. C).

Number of undetected errors in blocks of 50 bits	0	0
,, ,, ,, ,, ,, ,, ,, 100 ,,	0	0
,, ,, ,, ,, ,, ,, ,, 200 ,,	4	0
,, ,, ,, ,, ,, ,, ,, 500 ,,	6	0

AMERICAN TELEPHONE AND TELEGRAPH COMPANY: ERROR DISTRIBUTION AND ERROR CONTROL EVALUATION

(Extracts from contribution GT.43, No. 13, February 1960)

A data-transmission system should be designed to provide for the optimum useful bits of information with the minimum cost. Cost includes the cost of data equipment such as the data-originating equipment, data-receiving equipment, cost of providing a communication channel, as well as the modulators and the demodulators. In many cases this resolves into the design for optimum line efficiency for a specified accuracy objective. Many studies have been made to relate this efficiency in terms of various error-correcting and error-detecting methods. Wood derives optimum block lengths for retransmission methods, and Brown and Meyers describe the efficiency of various error-control systems including forward acting codes as well as retransmission methods. However, in all these evaluations the probability of errors and the distribution of errors in time are fundamental in arriving at the proper solution. The selection of optimum codes and optimum block lengths in error-control schemes is a complex subject. The information contained in the statistics herein are provided to aid in the derivation of better control systems. However, the overall system concept for data transmission, including error control, should be cognizant of the following considerations:

1) How serious is an error that is produced? Is error control necessary in view of the accuracy of the origin of the data or the final disposition of the data?

2) Is the relationship of the line transmission cost to equipment cost including error control such that optimum line efficiency may not result in the most economical solution for the system?

3) Is the format of the data such that optimum blocking must be in terms of lines of characters, or numbers of cards where mechanical limitations are an important factor in the optimum arrangement?

4) Is there storage and logic circuitry already provided in the system, such as in a computer or in buffer storage or other data machines, which can also be used for error-control purposes?

The above factors are functions of the data machinery and how it is employed. In addition, the functions of the transmission medium such as error probability, propagation time and turn-around time of echo suppressors must be considered to resolve the optimum data-transmission system. If it were not necessary to consider all these factors, then the error-control function could become a basic feature of the transmission medium. Therefore, it is not the purpose of this paper to make an evaluation of the many specific error-control methods which have been proposed, but it is desired to provide the fundamental error distribution and indicate the relative orders of magnitude improvement that might be expected from the error-control schemes. The following curves are arranged to facilitate evaluation of optimum block lengths for retransmission methods, to evaluate error-detection schemes, and to evaluate forward acting single error and multiple error correction codes which include burst-correcting codes.

The error-rate distribution curves (Figures 120 to 123) describe the probability of getting an error per number of bits transmitted. An important statistic is the probability of getting succeeding errors within various time intervals after the first error, for it is the dependency of one error on another which must be considered in error detection or correction codes. If a cumulative distribution is made of the good bits between errors, a curve is obtained which shows the probability of getting an error as a function of time since the previous error. Figures 124 and 125 show these distributions for 600 bits per second and 1200 bits per second, respectively. The results have been analysed and plotted for exchange type of calls, short-haul calls, long-haul calls, and another curve for all calls together.

These curves provide statistics which are useful in the planning and evaluation of error-control schemes. For example, having experienced an error, the probability of having one or more good bits following that error before getting another error is 0.70 considering all types of calls. This means that the probability of having zero good bits which

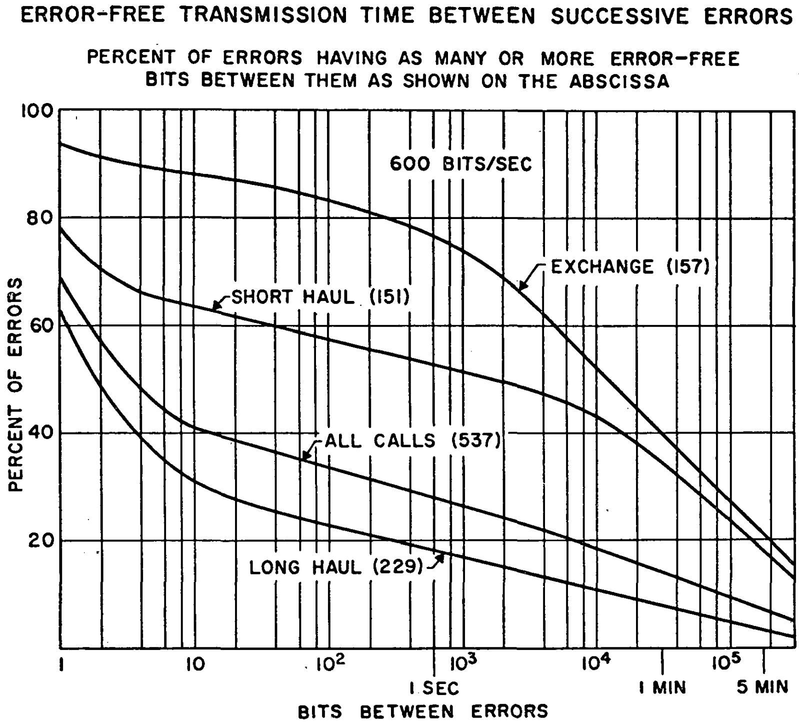


FIGURE 124

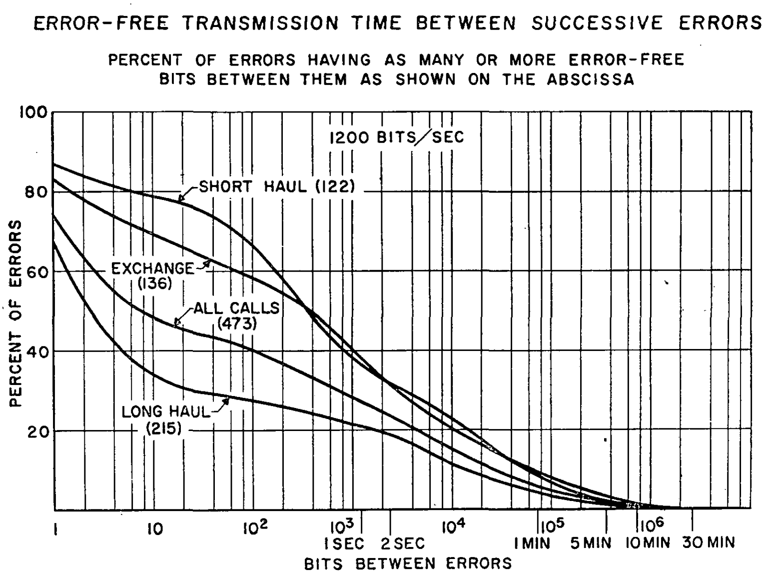


FIGURE 125

is the same as having two or more consecutive errors is 0.30. In other words, 30% of all errors are immediately followed by one or more errors. For 1200 bits per second the comparable figure is 0.74 which is approximately the same as the 0.70 for 600 bits per second. If there is particular interest in eight-bit characters, for example, on long-distance calls at 600 bits per second the curve shows that approximately 40% of the erroneous characters are likely to contain single bit errors because 4 or more good bits will follow the erroneous bit. This assumes that on the average the erroneous bit is in the middle of the character. However, this means that 60% of the erroneous characters will have more than one bit in error.

Each forward acting correction code, whether it be a Hamming code, a Hagelbarger code, or a square matrix code, is limited in the number of errors it can correct within a given number of total bits. Also some require that a period of error-free transmission exist for specific lengths of time between errors or bursts of errors in order to clear out the memory and logic of the circuitry and be ready for the next burst of errors. The number of correctible errors in a burst and the clear-out period required is a function of the redundancy of the code and the amount of storage and logic provided in the system.

To define these bursts let us assume the sequence of good bits and error bits shown by zeros and ones below.

00001010000000001101010000001000100000

| ↔ | | ↔ || ↔ | | ↔ | ↔ | burst of 4

A burst is defined as a sequence of bits which starts with an error bit and extends for $N - 1$ additional bits whether they be error bits or not, where N is the length of the burst. For example, assume we are interested in burst sizes of length 4. The first bit in error and the next three bits following are considered as the burst. The succeeding burst of size 4 starts at the next error that occurs after the first burst and so on until the entire message is analysed by bursts of size 4, and the quantity of good bits between errors. Thus, in the illustration above, there are nine good bits between the first two bursts of 4, one good bit between the second and third bursts, six good bits between the third and fourth bursts, and three good bits between the fourth and fifth bursts. The number of good bits between bursts as illustrated, is counted from the last error in one burst to the beginning of the next burst. The density of the burst is the ratio of error bits in a burst to total bits. For example in the illustration, out of a total of four bits in the first burst, two of them are in error, and the density is 50%. Whereas, in the second burst three bits are in error, and the density is 75%.

An analysis of the 600-bit-per-second transmission and the 1200-bit-per-second transmission on this basis is described in Figures 126 to 133. A range of burst sizes from bursts of 1 which facilitate the evaluation of single-error-correction codes to bursts of 20 are shown. This range is provided because it is felt that burst-correcting codes for larger bursts than 20 become quite complex and would be of such high cost that there would be little application for such systems. The curves are shown for all calls, and for only the exchange calls. This shows how the effectiveness of error-correcting schemes may vary for different types of calls. To illustrate the improvement that can be expected from a Hagelbarger code which is designed for correcting bursts of 8 bits in duration, and which requires a clear-out interval of 26 bits between bursts, an approximation is made. Such a code would have a redundancy of 50%. In Figure 126, 69% of the bursts for bursts length 8 have 26 or more good bits between them. This means these are correctible bursts. If it is assumed that the uncorrected bursts have the same error density as the corrected bursts,

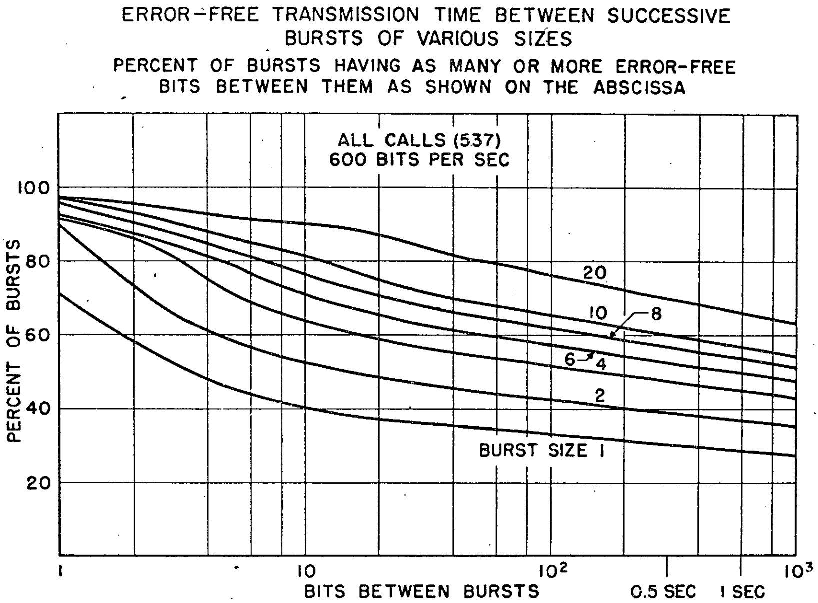


FIGURE 126

namely that shown by Figure 127, then an improvement or reduction in average error rate of about 3.2 to 1 can be expected. The only reason why this is an approximation rather than an exact evaluation is because of the previous stated assumption regarding density of uncorrectible bursts and also because the coding scheme may introduce additional errors when the bursts are too close. For exchange calls, based on the information shown in Figure 128 approximately 96.5% of the bursts are correctible by an 8-bit-burst correcting code with 50% redundancy which should result in an improvement of about 28 to 1. This is because on exchange calls there are fewer uncorrectible bursts, since there are fewer bursts which extent beyond 8 bits and fewer bursts which are closer together than 26 bits. It is interesting to note that if an evaluation is made of a single-error-correcting code which requires, say, 10 good bits between errors (a Hamming code would accomplish this), then it is found that on these exchange calls the single-bit errors predominate to such an extent that a substantial amount of the improvement made with a 8-bit-burst-correcting code could have been made with a single-error-correcting code.

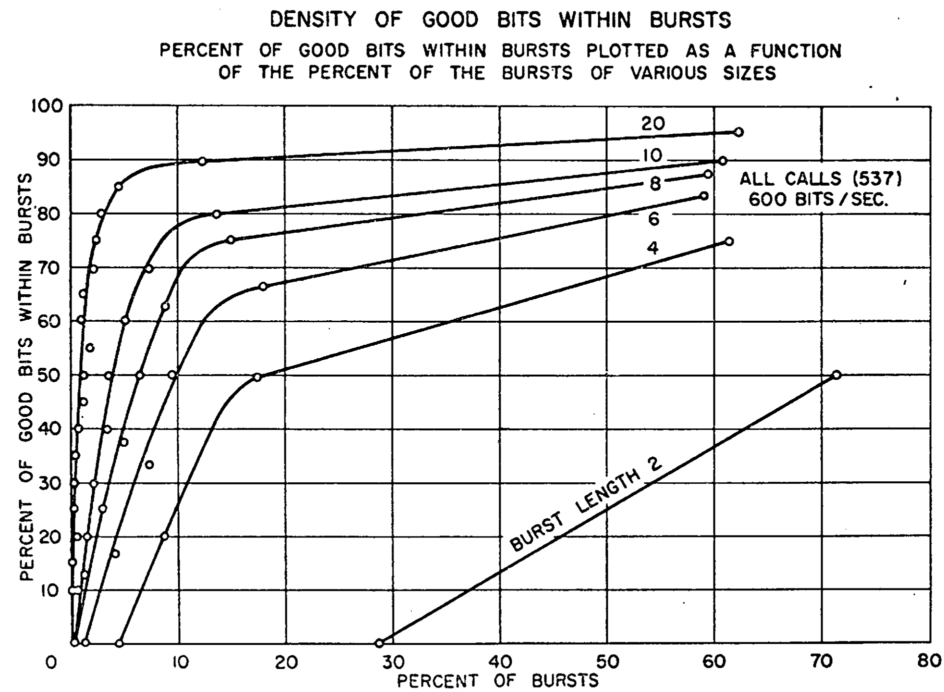


FIGURE 127

Now examine all calls to explore the amount of improvement that may be expected by increasing the error-correcting capabilities from 8 bits to 20 bits. This means that for the same redundancy that clear-out interval must be extended from 26 bits to 62 bits. The curves indicate that there is very little additional improvement. Figure 126 shows that the 20-bit bursts with a clear-out interval of 62 bits represent 79% of the total burst instead of 69%. Therefore, very little advantage is obtained compared with the increased circuit complexity that must be provided. These bursts may seem long for data transmission since they may affect many bits, but for speech the circuits are very satisfactory and such interruptions are rarely noticeable.

Information is provided for determining the effectiveness of these codes for different types of calls. However, the relative value of these coding schemes can better be illustrated on cumulative error-rate distribution curves. A computer was programmed to correct

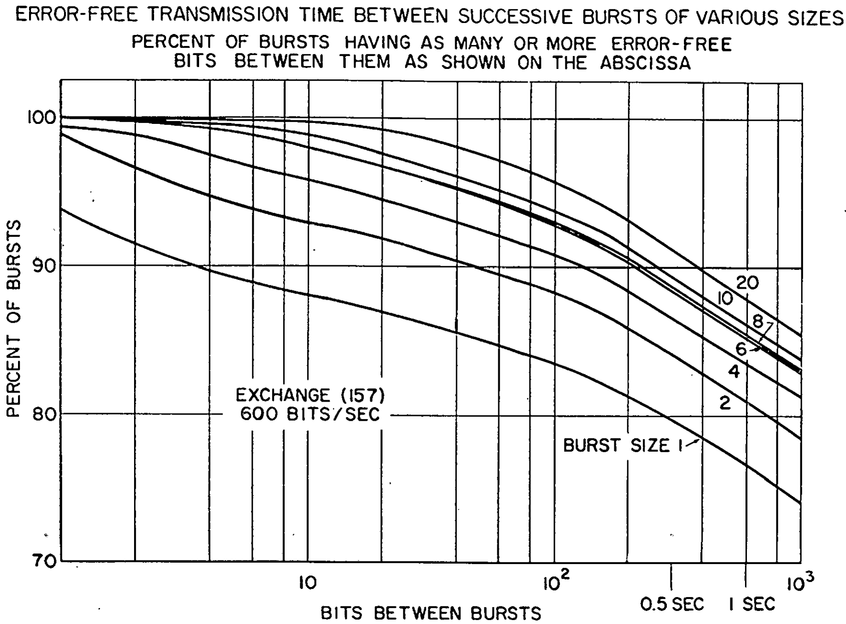


FIGURE 128

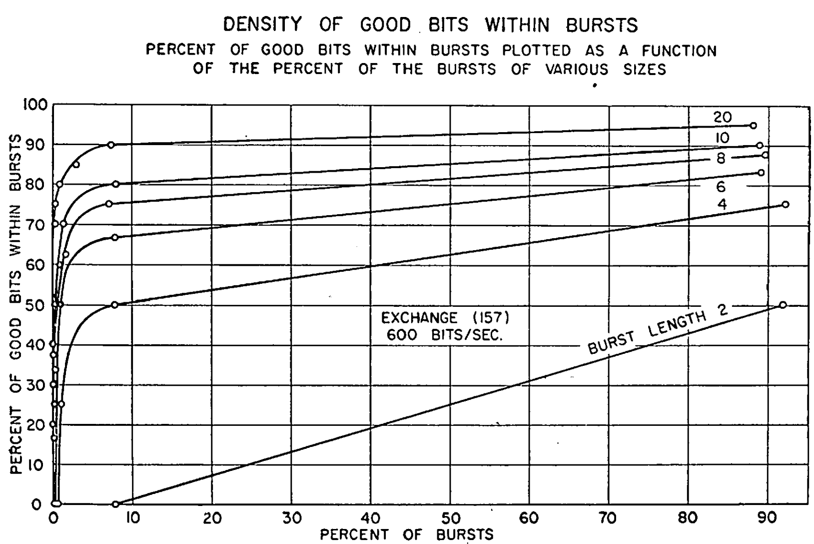


FIGURE 129

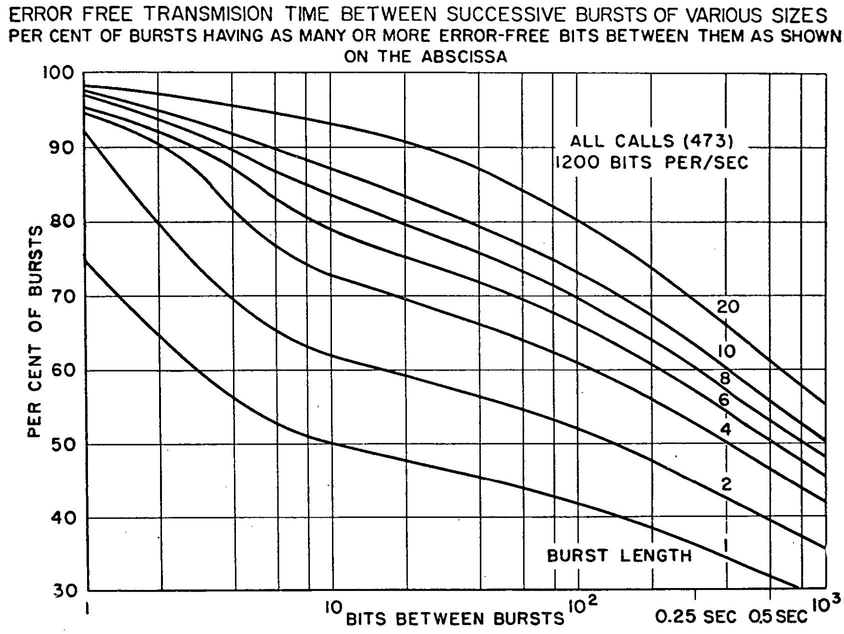


FIGURE 130

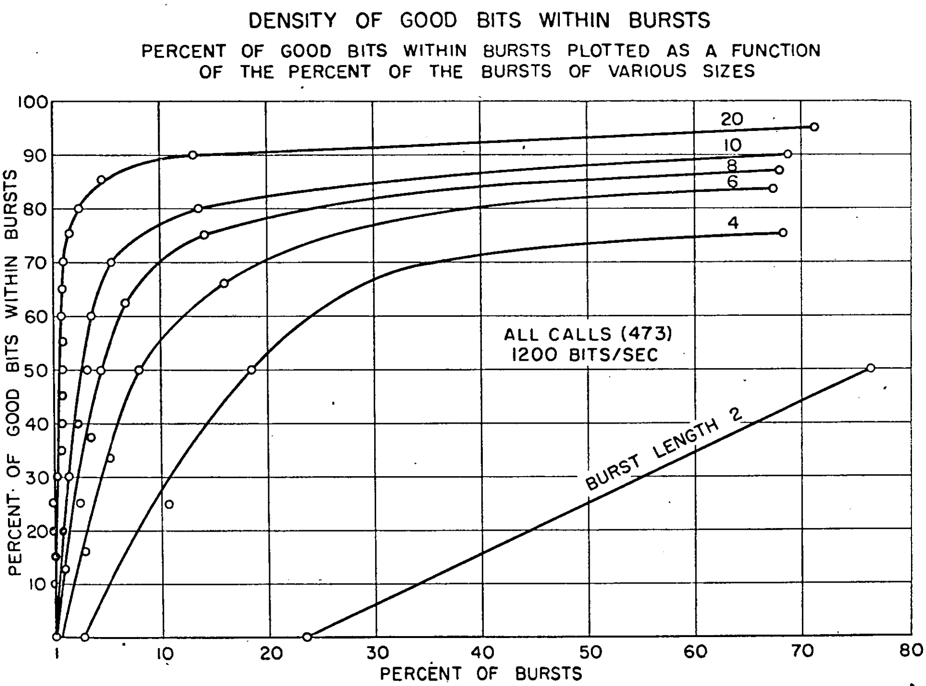


FIGURE 131

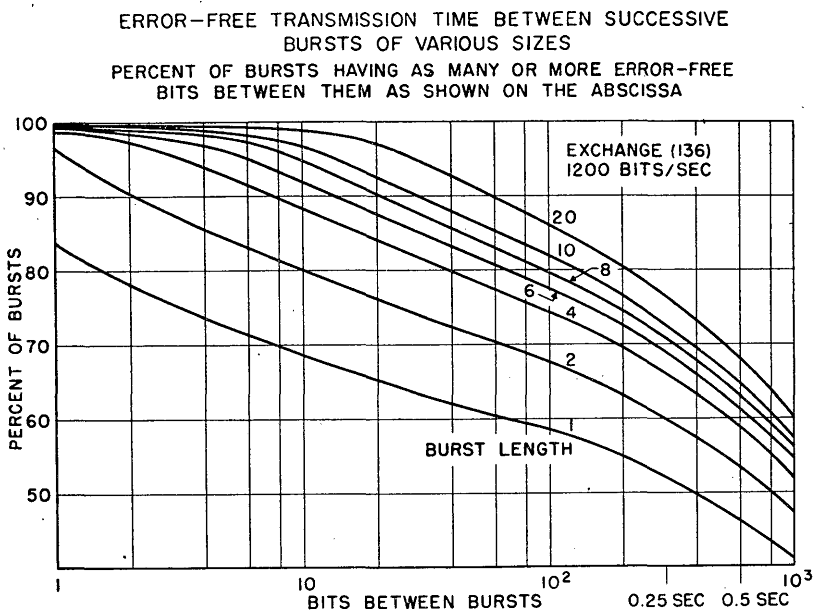


FIGURE 132

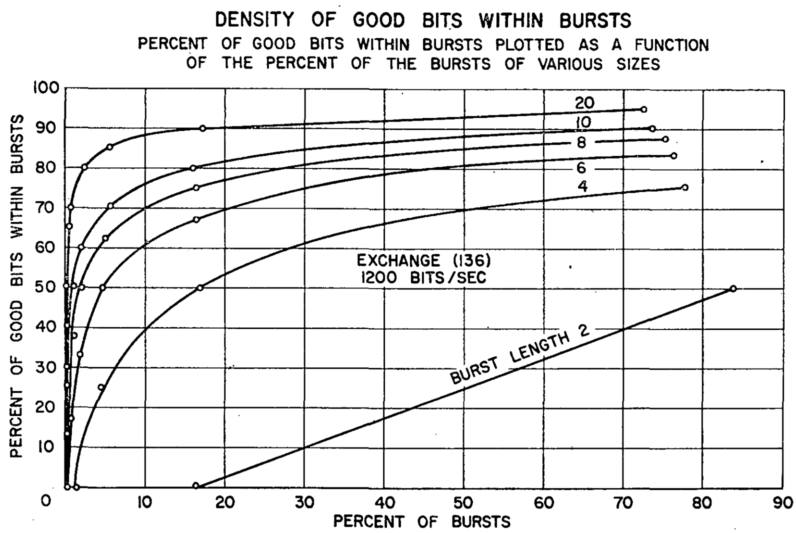


FIGURE 133

those errors which were single errors with more than 10 good bits between them and also was programmed to correct those bursts which did not exceed 8 bits in duration and which had at least 26 good bits between them. These values were chosen since they are thought

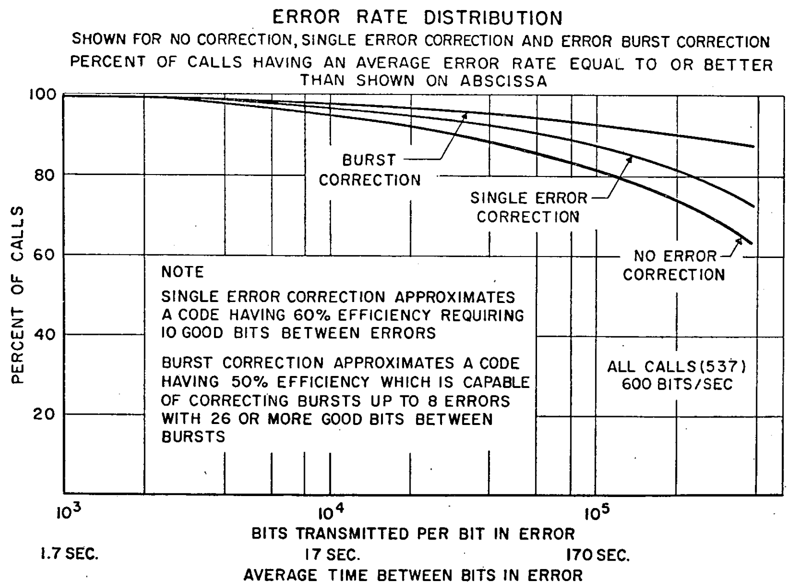


FIGURE 134

to represent coding systems which can be implemented with relative ease and illustrate order of magnitude improvements that might be expected. The cumulative distributions of uncorrectible errors are shown in Figures 134 and 135 for speeds of 600 bits per second, and 1200 bits per second, respectively. Also, plotted on the same axes are the identical curves which are distributions for these calls without error correction of any type. Thus, it is shown that at 600 bits per second 80% of the circuits achieve an error rate better than 1 error in more than 100 000 bits without any error correction. With single-error-correction, 85% of the circuits perform this well, and with burst correction the percentage is increased to 91%. It is necessary to keep in mind that, with error correction, redundancy is added and in the case of burst correction 50% of the bits are check bits. Therefore, a comparison is made of 1 in 10^5 bits with no correction, to 1 in 1.7×10^5 bits with single error correction, and 1 in 2×10^5 bits with burst correction.

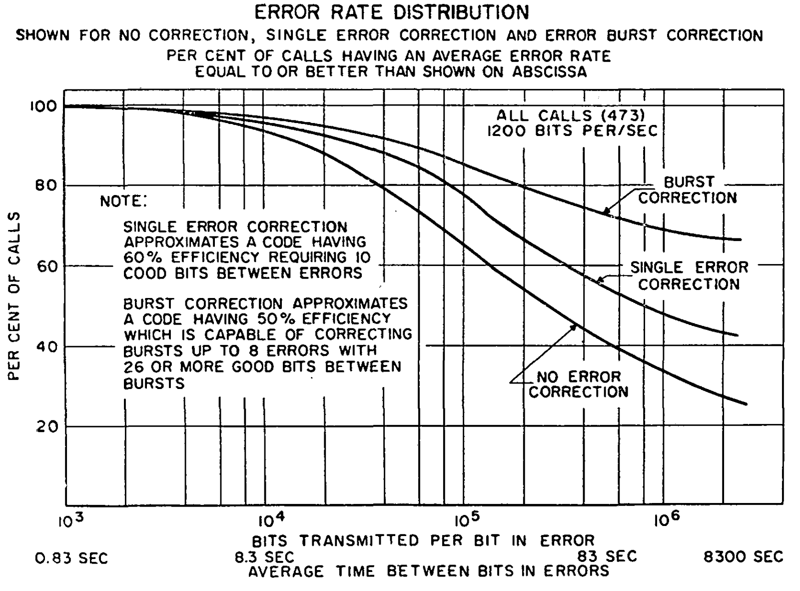


FIGURE 135

At 1200 bits per second, the improvement in performance with single-error correction and burst correction is somewhat better than at 600 bits per second. Actually, the addition of error control tends to make the performance at 600 and 1200 bits per second very close. For example, at 600 bits per second with burst correction, 94% of the circuits produce an error rate better than 1 bit per 50 000 transmitted. At 1200 bits with the same error control, 90% of the circuits gave the same performance. These two sets of curves on Figures 134 and 135 are for all calls made in the investigation, and therefore included exchange, short-haul and long-haul connections. It is emphasized that if such curves were shown for only exchange calls the improvement would be greater, whereas if they were shown for only long-haul calls the improvement would be less.

These error statistics indicate that where a high degree of accuracy is required, retransmission of data is also required. Forward-acting error-correcting codes by themselves do not at present appear to be the complete solution. Undoubtedly, progress will be made in the direction of achieving large volumes of storage at low cost which will facilitate more economical design of forward-acting error-control schemes. Also, as new transmission systems are developed and improvements are made to existing systems, the probability of large bursts of errors will be reduced.

The previous curves have provided the information necessary to aid in making decisions as to whether error control is necessary and what type is most effective. If retransmission is necessary the question then arises as to the optimum block length. An important factor

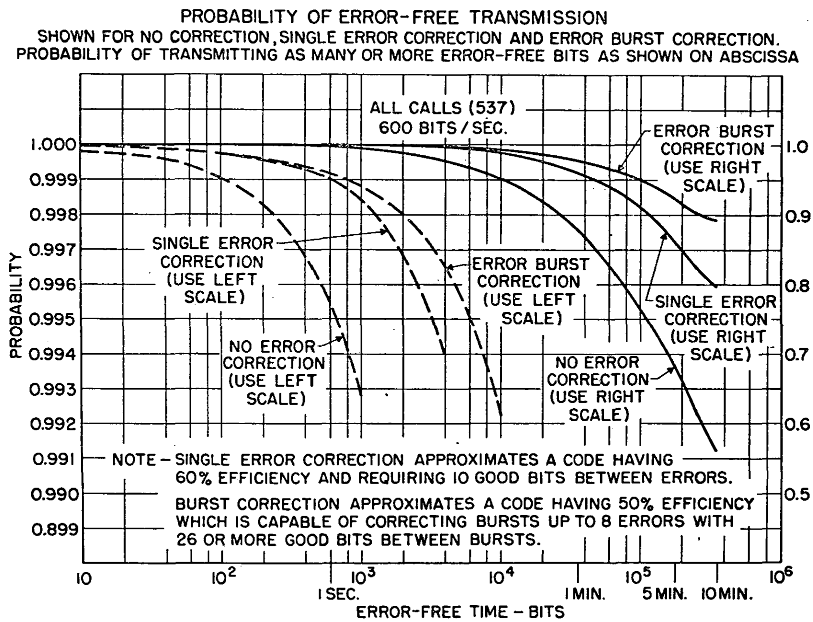


FIGURE 136

adding to the complexity of this problem is the turn-around of the echo suppressors, the propagation time, and the physical and electrical design of the data input and output machinery. Retransmission methods can cover a vast range of possibilities. For example, one method might be to send blocks of data of just a few bits in duration three times consecutively and to take the best two out of three. Another scheme which might represent the opposite extreme would be to transmit entire messages, say 10 minutes duration, and when an error is encountered to retransmit the whole message over again. To evaluate the effectiveness of these schemes it is necessary to know the probability of error-free transmission as a function of message length. Also, if this latter scheme were used with single-error correction so that retransmission was not required on the single errors, but was only required on the long bursts, this method of error control might be considerably more promising.

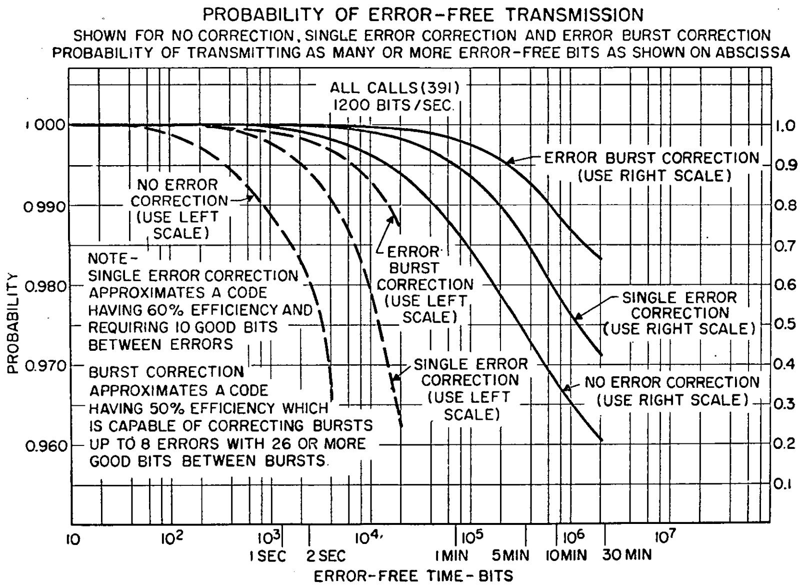


FIGURE 137

Figures 136 and 137 describe the probability of error-free transmission for no-error correction, single-error correction, and 8-bit burst correction. Because of the vast time scales which may be of interest for error control purposes the curves are plotted on two different scales. The probability scale on the left permits accurate evaluation for message lengths of less than 1000 bits and the scale on the right is used for longer message lengths. These curves are shown for both 600 bits per second tests and 1200 bits per second tests.

For example, Figure 136 indicates that with 1000 bit blocks at 600 bits per second with no error connection the probability of error-free transmission is 0.993. With single-error correction this probability increases to 0.9984 and with burst correction this probability further increases to 0.9988. Thus, it is quite obvious that in this application there is very little advantage in forward-acting error-correction codes. A forward-acting error-control scheme may not by itself appear very promising when it provides for a reduction in error rate by a factor, say, of 5 to 1. But if this error-correction scheme is used along with a retransmission method and the forward-acting code reduces the number of retransmissions, then this code may have proved itself by increasing the efficiency in the use of the telephone circuit. Many more interesting examples of error control could be discussed on the basis of these curves, but the objective herein is to illustrate the engineering value of the statistics and to let individual ingenuity go to work.

N. V. PHILIPS TELECOMMUNICATION INDUSTRY: SOME REFLECTIONS ON OPTIMUM BLOCK LENGTH, TRANSMISSION EFFICIENCY, NON-DETECTABLE ERRORS AND ERROR BURSTS IN CONNECTION WITH THE USE OF PARITY CHECK CODES

(Contribution GT.43, No. 15, March 1960)

1. *Introduction*

The application of data transmission to telephone lines requires *a protecting code* against *disturbances*.

Such a protecting code may be designed either to detect or to correct errors. An *error-correcting code* has the advantage that transmission has to take place only once, but the disadvantage is that the correction of a few errors necessitates a high redundancy in the number of bits to be transmitted as well as complicated coding and decoding equipment.

As the maximum number of errors to be corrected has to be determined beforehand, there will naturally remain a small probability of non-corrigible errors. Therefore a compromise must be found between this probability and the *bit redundancy* which reduces the effective transmission rate. The drawbacks of this theoretically attractive code will carry full weight in practice, and an *error-detecting code* will usually be preferred for data transmission. Such a code requires less complicated equipment and permits a much lower bit redundancy. On the other hand it involves a certain *time redundancy*, which is necessary for detecting and *asking for repeat* of wrong characters or blocks. The possibility of asking for repeat implies furthermore that characters or blocks have to be temporarily stored in *memories*.

The error-correcting codes are on the principle of *parity checking*. This is usually done in the form of parity checking in a character, known as *vertical parity check*. When a number of characters are combined into a *block* (also called matrix), one may add to such a block one or more parity check characters which, individually or in combination, check all the corresponding bits of the characters in the block for parity. This is known as *horizontal* (single or multiple) parity checking.

Also well known is a combination of *vertical and single horizontal parity checks*. The use of this detection code in data transmission will be considered in the following paragraphs.

Table of figure 138 lists a number of parity check codes.

TABLE I

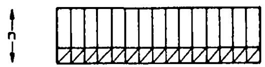
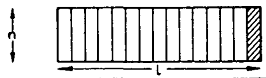
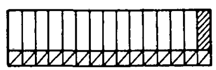
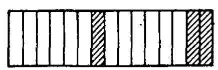
	Catégorie	Class	Exemples	Examples	Nombre Number	Observations	Notes
I	Contrôle par parité intrinsèque	Intrinsical parity check	code "2(3) sur 5" code "3 sur 6" code "3(4) sur 7" code "4 sur 8" code "tous les pairs (ou impairs) sur n"	"2(3) out of 5" code "3 out of 6" code "3(4) out of 7" code "4 out of 8" code "All even (odd) out of n" code	10 20 35 70 2^{n-1}	Contrôle de la parité de chaque caractère assuré automatiquement par le choix du code.	Parity per character automatically ensured by choice of code
II	a) contrôle par parité vertical	a) Vertical parity check			2^{n-1}	Correspond à "tous les pairs (ou impairs) sur n"	Corresponds to "all even (odd) out of n"
	b) contrôle par parité horizontal	b) Horizontal parity check			2^n		
III	a) contrôle par parité mixte vertical et horizontal	a) Combined vertical and horizontal parity check				Combinaison de IIa et de IIb	Combination of IIa and IIb
	b) contrôle par parité horizontal multiple	b) Multiple horizontal parity check				Par exemple, un caractère servant au contrôle de tous les caractères pairs, et un autre pour tous les caractères impairs	E.g. one parity check character for all even characters and one for all odd ones
	c) contrôle par parité horizontal multiple scindé	c) Split-up multiple horizontal parity check				Peut remplacer IIIa	"Substitute" for IIIa

FIGURE 138

Since the number of bits per character is completely dependent on the number of different characters to be transmitted, the dimensions of a block are determined only by the number of characters one wants to transmit successively. The " length " of the block can thus be matched to the disturbance pattern of the transmission line; the most favourable value will be called *optimum block length.* Let M be the number of different characters needed for data transmission. Each character may then be represented in the binary system by m bits, with the condition that:

$$2^m \geqq M$$

It is evident that *coding redundancy* will occur if M deviates from a whole power of 2, as the information content of M (equally probable) different characters is $\log_2 M$. This coding redundancy:

$$R_c = \frac{m}{\log M}$$

will be left out of the discussion, as the transmission aspect has nothing to do with it. (The coding is an *a priori* condition.) It may be interesting to note, however, that in the class " Intrinsical parity check " the coding redundancy R_c absorbs the bit redundancy R_b. When all possible characters are indeed used the values of R_c for the examples given will be successively:

$$1.50;\ 1.39;\ 1.36;\ 1.30;\ \frac{n}{n-1}$$

Let us now restrict the discussion again to class III*a* and forget about R_c. For an optimum block length of l, we have a *bit redundancy* R_b:

$$\boxed{R_b = \frac{(m+1) \times l}{m\ (l-1)} = \frac{n \times l}{(n-1)(l-1)}}$$

where the factor

$$\frac{m+1}{m} = \frac{n}{n-1}$$

predominates.

For $n = 8$ and $l = 30$ to 200, we have R_b included between

1.18 to 1.15.

The parity check code has a *transmission efficiency* which is inversely proportional to the product of bit and time redundancy, viz.

$$\boxed{E = \frac{100}{R_b \cdot R_t}\ \%.}$$

If R_t is of the same order as R_b, E will vary from about 50% to a maximum of 80%.

Finally we have to consider that a parity check code will not afford complete protection from errors, for the disturbed bits may be distributed through the block in such a manner that the detection device will approve the block on the grounds of the parity check while at least two characters are absolutely wrong. It is necessary, therefore, to determine the error probability of *non-detectable combinations.* While this is desirable for a disturbance pattern consisting of mutually independent errors, it becomes a necessity in the case of *error bursts* prolonged disturbances involving several successive bits (even up to 20 bits at a transmission rate of 1000 bauds).

When quantities have to be numerically calculated for illustration in the following paragraphs, calculations will be based on a transmission rate of *1000 bauds.*

2. *Optimum block length and time redundancy.*

The average transmission time for a block of $N = nl'$ bits at a transmission rate of C bauds, a delay of t_w sec. and a mean error probability p_b is

$$t_b = \left(\frac{nl'}{C} + t_w\right)(1 + p_b \cdot n \cdot l') \text{ for } p_b nl' \ll 1.$$

Although p_b and t_w are not entirely independent of l', it will be permissible to make this assumption for a first approximation. In addition, we see that

$$t_w \ll \frac{nl'}{C},$$

so that we may approximate the minimum value of t_b as a function of l' with the aid of the expression

$$t_b = \frac{nl'}{C}(1 + p_b nl') + t_w,$$

from which it follows that the *optimum block length* l is defined by:

$$\boxed{l = l' = \frac{1}{n}\sqrt{\frac{C\, t_w}{p_b}}}$$

For t_b we may thus write:

$$t_b = \frac{nl}{C}\{1 + 2\sqrt{p_b\, C\, t_w}\}$$

For error-free transmission we may postulate:

$$t'_b = \frac{nl}{C}$$

The *time redundancy is*:

$$\boxed{R_t = 1 + 2\sqrt{p_b\, C\, t_w}}$$

The term Ct_w expresses the *delay* in bits.

Consequently, both the total number of bits per optimum block $N = nl$ and R_t are functions of p_b and Ct_w. A simple graphical representation is obtained if log Ct_w is plotted against log p_b, with N and R_t being used as parameters (Fig. 139).

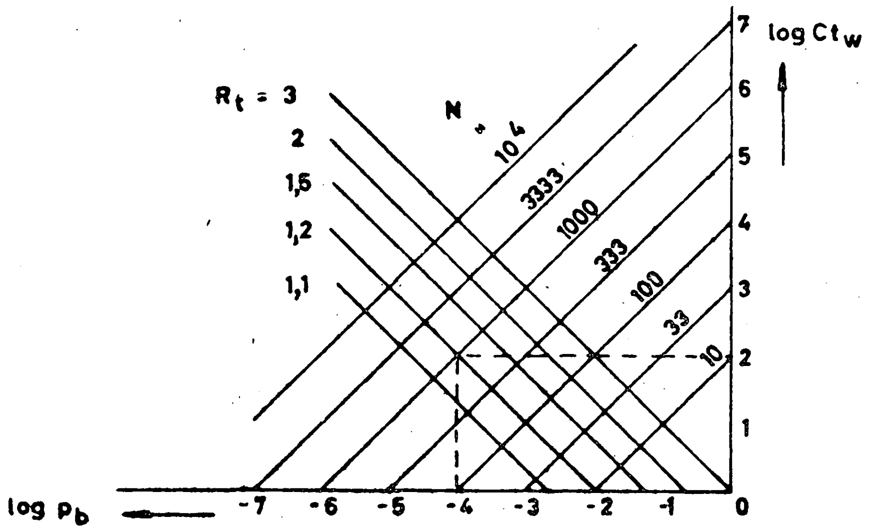


FIGURE 139

If, for instance, an optimum block length of 1000 bits (transmission time = 1 sec.) is required, p_b will directly determine the value of R_t. Thus $p_b = 10^{-4}$ gives a value of $R_t = 1.2$ and a consequent delay of $Ct_w = 100$ bits.

Since $R_b = 1.15$ for a block of 1000 bits, the efficiency under such conditions will be $E = 72.5\%$.

Whereas the variations of R_b are only small, those of R_t may be considerably greater. However, a lower limit for E of, say, 50% will restrict R_t to a maximum of 1.7.

3. *Independent errors.*

If p is the average probability of an error, the probability of x errors occurring in a block of N bits will be:

$$p_x = C_x^N \cdot p^x \cdot (1-p)^{N-x} .$$

When combined vertical and horizontal parity checking is employed the probability of *detected errors* in the block will be:

$$P = p_1 + p_2 + p_3 + p_4\,(1 - p_4') + p_5 + p_6\,(1 - p_6') + \dots$$

and the probability of *non-detectable error combinations*:

$$P' = p_4 \cdot p'_4 + p_6 \cdot p'_6 + \dots$$

where

$$p'_4 = \frac{C_2^n \cdot C_2^1}{C_4^N} \text{ and } p'_6 = \frac{C_2^n \cdot C_1^2 \cdot C_1^{n-2} \cdot C_3^1}{C_6^N}$$

The terms p'_8, p'_{10}, etc., may be neglected; even the term $p_6\, p'_6$ contributes hardly anything to P'.

For $n = 8$ and $N = 1000$ (which means $1 = 125$) we have:

$$p'_4 = 5.25 \times 10^{-6} \text{ et } p'_6 = 5.85 \times 10^{-8}$$

Both p'_4 and p'_6 are very much less than 1, so that P can be calculated from:

$$P = 1 - p_0 = 1 - (1 - p)^N$$

Table II gives some values of P as a function of p for $N = 1000$.

TABLE II

p	P
0.001	0.63272
0.0005	0.39326
0.0001	0.09427
0.00005	0.04830
0.00001	0.00985

P directly determines the value of p_b from paragraph 2, for $P = p_b nl = P_b N$.
The smaller the value of p and the higher the value of N, the more p^b will approach p.
For $p = 10^{-4}$ and $N = 1000$ we have $p_b = 0.94 \times 10^{-4}$, the deviation being only 6%.

Some values of P' are given in Table III.

TABLE III

p	p_4	p_6	P'
0.001	1.53×10^{-2}	5.0×10^{-4}	8.0×10^{-8}
0.0005	1.57×10^{-3}	1.3×10^{-5}	8.3×10^{-9}

It is seen that P' is already very small for relatively high values of p; the order of 10^{-7} to 10^{-8} is acceptable for data transmission.

4. *Error bursts (dependent errors).*

The term " error burst " is used for a prolonged disturbance extending over several successive bits. An error burst has a *length of* e if bits $i + 1$ and $i + e$ as well as any number of the intermediate bits ($i + 2$ to $i + e -$) are wrong. The combined vertical and horizontal parity check will fully detect any error burst having a length of $e \leqq n + 1$. *Non-detectable* combinations will occur only for $e > n + 1$; under these conditions the detection device may completely fail to recognize considerable disturbances covering 2 to 4 characters. For $n = 8$, all error bursts with $e > 9$ are therefore dangerous. If p_e is the probability of an error burst having a length of e, and P'_e is the corresponding probability of non-detectable errors, we have for $n = 8$:

$$
\begin{aligned}
P'_{10} &= 34.2 \times 10^{-4} \times p_{10} & P'_{15} &= 9.8 \times 10^{-4} \times p_{15} \\
P'_{11} &= 13.3 \times 10^{-4} \times p_{11} & P'_{16} &= 8.5 \times 10^{-4} \times p_{16} \\
P'_{12} &= 13.4 \times 10^{-4} \times p_{12} & P'_{17} &= 7.3 \times 10^{-4} \times p_{17} \\
P'_{13} &= 12.2 \times 10^{-4} \times p_{13} & P'_{18} &= 7.0 \times 10^{-4} \times p_{18} \\
P'_{14} &= 11.0 \times 10^{-4} \times p_{14} & P'_{19} &= 4.6 \times 10^{-4} \times p_{19}
\end{aligned}
$$

In the above, we have assumed that all error patterns with a length of e are equally probable, which is a perfectly reasonable assumption. The assumption that error bursts of different lengths are equally probable is less obvious and may even be wrong.

Disturbances of 10 to 20 ms duration, such as may be caused by selectors in switching centres, will lead to error bursts of $e = 10$ to 20 for a transmission rate of 1000 bauds. The assumption of equal probability will hold fairly well under these conditions, so that we may write:

$$
\begin{aligned}
\Sigma P'_e &= P'_{10} + P'_{11} + P'_{12} + \ldots\ldots \\
&= p_e \times 10^{-4} \{34.2 + 13.3 + 13.4 + \ldots\}
\end{aligned}
$$

From $e = 11$ upwards, the graphical representation of $P'_e = f(p_e)$ may be approximated by a straight line:

$$P'_e = \frac{14.5}{12}(23 - e) \times 10^{-4} \times p_e$$

so that

$$
\begin{aligned}
\Sigma P'_e &= p_e \times 10^{-4} \left\{34.2 + \frac{14.5}{12} \sum_{11}^{23} (23 - e)\right\} \\
&= 124 \times 10^{-4} \times p_e
\end{aligned}
$$

or put in a different form:

$$\boxed{\Sigma P'_e = \frac{pe}{80}\,.}$$

The probability of an error burst, divided by a *reduction factor* of 80, gives the probability of non-detectable errors.

If the order of magnitude is to be 10^{-7} to 10^{-8}, p_e must not exceed 8×10^{-6}. The ratio of p (paragraph 3) to p_e for $P' = \Sigma P_e' = 10^{-7}$ is about 150.

A more general expression for $\Sigma P_e'$: if $n = 8$ and $C = 1000$ bauds is:

$$\Sigma P_e' = \frac{p_e}{5 \times 2^{n-4}}$$

Thus it is seen that the reduction factor increases with a factor 2^n.

5. *A more effective detection code against error bursts.*

A more effective code against error bursts, based on the same principle as the code discussed in the preceding paragraphs, is obtained with a combination of II*a* and III*b* from Table I. At only slightly higher cost, this gives much better protection against non-detectable error combinations. Although this applies to independent as well as dependent errors, we shall restrict ourselves to the discussion of dangerous error bursts. The reduction factor in this case proves to increase with 2^{2n}, so that the gain is a factor 2^n,

The general expression for $P' = \Sigma P_e'$ is now:

$$\Sigma P_e' = \frac{p_e}{5 \times 2^{2n-4}}$$

Another important advantage is that error bursts start to be dangerous only for $e > 2n + 1$.

For $n = 8$ and $C = 1000$ bauds, this means that the duration of the disturbance has to exceed 17 ms.

Although not much is known about disturbance patterns in telephone connections, it will be understood that the concept of equal probability is hard to support for $e > 17$. Thus, the reduction factor will increase even more pronouncedly; for $n = 8$ it will be at least 20 000 when this detection code is employed.

6. *Detection codes without vertical parity check.*

One may consider the possibility of using only horizontal parity checking, which would considerably reduce bit redundancy, while the characters could be handled directly in parallel without the need of first removing the parity check bit. The latter advantage applies, of course, only in those instances of data transmission where this check bit has to be added in the transmitting equipment; in many cases the parity bit is integrated with the code (e.g. the code of the flexowriter), so that the advantage does not exist. Another, more important, advantage is the protection against error bursts because, as we have seen in the previous paragraphs, the vertical parity check pays no great contribution in this respect. A major disadvantage, however, is the poor protection from independent errors, and it will be demonstrated that this disadvantage weighs quite heavily in the balance.

To illustrate this we take code III*b* from Table I, i.e. the code with *twofold horizontal parity check.*

The bit redundancy of this code is:

$$R_b = \frac{l}{l-2}$$

which means that the deviation from the ideal value $R_b = 1$ is very small.

6.1. *Independent errors.*

Since combination of 2 errors may also figure among the non-detectable errors in this case, P' is defined by

$$P' = p_2 p_2' + p_4 p_4' + p_6 p_6' + \ldots$$

In order to make a comparison with the values given in paragraph 3, we take again $N \approx 1000$, for which $n = 7$. By choosing $l = 142$ we have $N = 994$.

For these values of n, l and N we obtain:

$$p_2' = 7.04 \times 10^{-2} \qquad p_4' = 1.39 \times 10^{-2}$$

$$p_6' = 3.59 \times 10^{-3}$$

P′ has been calculated for the same values of p as given in Table III and the results are listed in Table IV.

TABLE IV

p	p_2	p_4	p_6	P'
0.001	1.84×10^{-1}	1.53×10^{-2}	5.0×10^{-4}	1.317×10^{-2}
0.0005	0.76×10^{-1}	1.57×10^{-3}	1.3×10^{-5}	0.537×10^{-2}

Such figures for P′ are absolutely *unacceptable* for data transmission.

6.2. *Error bursts.*

The error bursts start to be dangerous at $e > 2n$.

It will easily be seen that the total probability of non-detectable error combinations is defined by:

$$P_e' = \frac{1}{2^{2n}} \{ 2p_{2n+1} + p_{2n+2} + p_{2n+3} + \ldots \}$$

A remarkable aspect is that the *coefficients* of p_e are not convergent now. The convergence of the series has to be found in the monotonic decreasing probability of p_e for increasing e.

In order to permit at least a rough comparison with the result of paragraph 4, where the reduction factor was 80, we assume a rectangular distribution for p_e up to $l = 23$, remembering that $n = 7$ in the present case.

$$\Sigma P_e' = \frac{p_e}{2^{14}} \{2 + 8 \times l\} = \frac{10}{2^{14}} \times p_e$$

or:

$$\boxed{\Sigma P_e' = \frac{p_e}{1640}}$$

Although the comparison cannot be perfectly objective, owing to lack of knowledge about the distribution of p_e, it will be evident that the protection against error bursts is definitely better.

N. V. PHILIPS TELECOMMUNICATIE INDUSTRIE: COMPARISON OF VARIOUS CODES FOR DATA TRANSMISSION ON A BASIS OF REDUNDANCY AND NON-DETECTABLE ERRORS

(Contribution GT.43, No. 16, March 1960)

1. *Introduction.*

At present, message transmission in many countries is practised on either public or private telegraph networks or on public telex networks, often with the possibility of leasing a private line.

The telegraph networks are almost exclusively used for one-way transmission of relatively short messages consisting mainly of text. The *telex network, a subscriber network with calling facilities*, on the other hand, is more widely used for two-way transmission (question and answer) of alpha-numerical messages, the numerical data being often repeated to improve reliability. Use is made in both cases of the *international 5-unit code* (teleprinter code), which does not provide any intrinsical protection against errors. Data transmission, which is mainly concerned with numerical messages, requires at any rate a network similar to the telex network. With a view to the reliability required, however, it is very much to be doubted whether the present telex network with the associated code is suitable for this purpose, quite apart from the low transmission speed of 50 bauds or $33\frac{1}{3}$ bits/sec. (start-stop system).

2. *Possibilities.*

From S.E.L. in Germany comes the suggestion to equip the *teleprinter* with a *third shift*, which gives the 10 numerals in the " *3-out-of-5* " *code*, so that an intrinsical protection (odd-number parity) is obtained for figures.

The number of permutations for a normal teleprinter is 57, of which 54 are used. The suggestion of S.E.L. raises the number of permutations to 83, and the number of combinations used to 65. Another suggestion from Germany (addressed to C.C.I.T.T.) concerns the introduction of a *new 6-unit code for teleprinters*, such that 20 characters, and amongst these the 10 numerals, are protected by the " *3-out-of-6* " *code.*

Although the new teleprinter is to have two shifts, resulting in about 120 possible combinations, we shall restrict ourselves to a machine with one shift giving $2^6 - 1 = 63$ combinations.

Further possibilities of reproducing about 60 characters are offered by the *7-unit odd-parity code* (64 characters) and the " *4-out-of-8* " *code* (70 characters).

In the U.S.A. Friden has constructed a *flexowriter* using an *8-unit code with odd-number parity* (128 characters) and offering more facilities than the teleprinter. The FPC 8 code (one shift) uses only 60 characters of the 128 possible ones. The flexowriter may also be provided with two shifts.

3. *Concepts and conventions.*

The various codes can be compared on a basis of redundancy and non-detectable errors. Before doing this we shall first define these concepts and introduce some additional conventions.

Although data transmission may be predominantly numerical in character, it will be desirable to have a code that is also suitable for *alpha-numerical and message tranmission.* The international telegraph alphabet for normal teleprinters (two shifts) meets this requirement. This *5-unit code* will therefore be used as a basis. Even in those cases where the information to be transmitted is purely numerical, we therefore accept the 5-unit code as the minimum code although we know that the coding of 10 numerals and a few operators requires only a 4-unit code.

By definition, the 5-unit code for numerical data has a redundancy of 1. If the 5-unit code in the sense of a teleprinter code is used for alpha-numerical data, we may assume that 1 shift character will be used on an average of 6 characters, so that in principle we have a redundancy of 1.2.

This assumption also holds good for a modified teleprinter with three shifts.

The codes mentioned in section 2 will thus have redundancies of 1.2 (6-unit code), 1.4 (7-unit code) and 1.6 (8-unit code).

It is known that any alpha-numerical message has a certain amount of *built-in redundancy*, which causes a given percentage of errors to be " *detected* ". Even in purely numerical data such detection may still be possible (code numbers etc.). It will be clear that this degree of detectability has to be left out of consideration here. We therefore make the convention: *every undetected error in alpha-numerical data transmission is non-detectable.* If it is known in advance that numerical data only will be transmitted, each undetected error received as non-numerical information will still be detectable; if a numeral changes into another numeral, the error will be non-detectable in numerical data transmission. Transmission problems such as method of modulation, serial or parallel transmission, transmission speed, synchronization, start-stop systems, line outages, etc. will be left out of discussion. The assumption is made that the *disturbances* causing errors in a message are *mutually independent*.

For protection against " error burst " please refer to the notes on this subject in Contribution GT.43 No. 15.

The probability of non-detectable errors will be determined for a *block length* $L = 80$ (equal to the number of columns on a punched card and about equal to the number of characters per line, including spaces, on a page printer).

4. *Comparison of the various codes.*

The probability of non-detectable errors P' is determined by:

$$P' = \sum_{i=l}^{\infty} p_i p_i'$$

p_i is defined for all codes as:

$$p_i = C_i^{nL} \cdot p^i \cdot q^{nL-i}$$

where p is the average probability of an error and $q = 1 - p$.

According to the code employed, n may be 5, 6, 7 or 8.

Table I gives the values of p_1, p_2 and p_4 as functions of p for the different values of n ($L = 80$).

TABLE I

$n =$	5	6	7	8
$p_1 =$	$0.40.10^3.p.q^{399}$	$0.48.10^3.p.q^{479}$	$0.56.10^3.p.q^{559}$	$0.64.10^3.p.q^{639}$
$p_2 =$	$0.80.10^5.p^2.q^{398}$	$1.15.10^5.p^2.q^{478}$	$1.57.10^5.p^2.q^{558}$	$2.05.10^5.p^2.q^{638}$
$p_4 =$	$1.05.10^7.p^4.q^{396}$	$2.18.10^7.p^4.q^{476}$	$4.05.10^7.p^4.q^{556}$	$6.93.10^7.p^4.q^{636}$

The values of p_1', p_2' and p_4' are obtained from exact expressions with binomial coefficients and/or from the average of a number of counts. Table II gives p_1', p_2' and P' for eight different cases without extra checking character, where P' has been calculated for $p = 10^{-4}$ and $p = 10^{-5}$.

The modified teleprinter, which can naturally be used for low transmission speeds only (telex network), has the lowest P'; the flexowriter, having completely different facilities, combines an R_b of 1.6 with an error probability which is 4.6 times higher.

TABLE II

	International 5-unit code			6-unit code		7-unit code	8-unit code	
	no protection		" 3-out-of-5 " code for figures	" 3-out-of-6 " code for figures		" odd-out-of-7 " code	" 4-out-of-8 " code	" odd-out-of-8 " code
	alpha-numerical	figures in 2nd shift	figures in 3rd shift	alpha-numerical	figures	alpha-numerical	alpha-numerical	alpha-numerical
$R_b =$	~ 1.2	1	1	1.2	1.2	1.4	1.6	1.6
$P'_1 =$	1	~ 0.55	0	1	0	0	0	0
$P'_2 =$	1	~ 0.30	$0.60.10^{-2}$	1	$0.63.10^{-2}$	$1.07.10^{-2}$	$0.63.10^{-2}$	$1.10.10^{-2}$
$P' =$	$0.39.10^{-1}$	$0.21.10^{-1}$	$0.46.10^{-5}$	$0.47.10^{-1}$	$0.69.10^{-5}$	$1.59.10^{-5}$	$1.20.10^{-5}$	$2.12.10^{-5}$
	$0.40.10^{-2}$	$0.22.10^{-2}$	$0.48.10^{-7}$	$0.48.10^{-2}$	$0.71.10^{-7}$	$1.67.10^{-7}$	$1.27.10^{-7}$	$2.24.10^{-7}$

The error probability of suitable codes is roughly from (0.5 to 2.3)$\cdot 10^3 \cdot p^2$ for $L = 80$.
For good transmission circuits, with $p \leqslant 10^{-5}$, the value of P' will be acceptable.

5. *Comparison of the various codes protected by extra checking characters.*

The discussion of Table II suggests that extra measures will usually have to be taken for data transmission to obtain a reliability of $P' = 10^{-7}$ to 10^{-8}. For those *codes in which* $p_1' = 0$ it is possible to make $p_2' = 0$ by means of one *additional checking character* (horizontal parity check). The reliability is then expressed by $P' = p_4 p_4'$, where $p_4 \ll p_2$ and $p_4' \ll p_2'$, so that the requirements of reliability can even be met by less good transmission circuits with $p = 10^{-3}$ to 10^{-4}. The codes for which $p_1' \neq 0$ will always be inferior to those discussed above. By means of horizontal parity checks it will be possible to make $p_1' = 0$, but $p_2' \neq 0$ even with multiple horizontal parity check. Furthermore, p_2' in these cases will always be larger than the p_2' from Table II for the codes discussed earlier.

The conclusion we have to draw is that *codes without intrinsical (vertical) protection cannot be considered for data transmission.*

Although this conclusion rules out the use of the normal teleprinter code, it will be useful to discuss the protection method of Western Union known as " *EDIT* ".

Western Union have used the following protection:

The binary sum, modulus $2^8 = 256$, is determined of all characters up to and including " carriage return " on a line (say $L = 80$). The supplement of this sum, $0 \leqslant S \leqslant 255$, is punched in two characters of four units each (numbers 1, 2, 4, 5 of the 5-unit code). At the receiving end, the sum for modulus 256 is again determined with the aid of eight binary counters. If no errors have occurred in transmission, the complement received will cause all the counters to be reset to zero; if they do not all return to zero, there will be errors. The idea is highly attractive and the method seems reliable at first sight. A more detailed study of it, however, shows that this method of protection is *worse, or at least not better*, than the simple method of double horizontal parity checking.

The figures listed in Table III for " EDIT " have been calculated on the assumption that 40 out of the 80 corresponding bits have a value of 1 while the other 40 have a value of 0. This assumption, which is necessary for a simple calculation, leads to maximum values for p_1'.

TABLE III

	International 5-unit code	
	EDIT	Double horizontal parity checking
$p_1' =$	0	0
$p_2' =$	102.10^{-3}	98.10^{-3}
$p_3' =$	24.10^{-3}	0
$p_4' =$	10.10^{-3}	27.10^{-3}
$p_5' =$	4.10^{-3}	0

The suitable codes are finally compared on a basis of redundancy and p'_4. For the figures listed in the columns of the 5-unit and 6-unit codes the condition applies that it should be known in advance that figures only are transmitted.

P' has been calculated for $p = 10^{-3}$.

TABLE IV

	5-unit code 3rd shift	6-unit code	7-unit code	8-unit code	8-unit code
	" 3-out-of-5 " code for figures	" 3-out-of-6 " code for figures	" odd-out-of-7 " code	" 4-out-of-8 " code	" odd-out-of-8 " code
	figures	figures	alpha-numerical	alpha-numerical	alpha-numerical
R_b =	1	1.2	1.4	1.6	1.6
p'_4 =	$1.08.10^{-5}$	$0.39.10^{-5}$	$1.65.10^{-5}$	$0.41.10^{-5}$	$1.25.10^{-5}$
P' =	$0.76.10^{-10}$	$0.53.10^{-10}$	$3.82.10^{-10}$	$1.50.10^{-10}$	$4.46.10^{-10}$

If, for instance, the 7-unit code is permitted the same redundancy $R_b = 1.6$ as the 8-unit codes, this means that the 7-unit code may be checked by 10 horizontal parity characters; in other words: each checking character checks 7 information characters. This reduces the error probability p'_4 to 1.45×10^{-6}, of course at the expense of more elaborate checking equipment.

6. *Conclusion.*

It is extremely difficult to draw strict conclusions, because various related but nevertheless important questions are still undecided. Quite apart from specific transmission problems, such as nature of lines and transmission speed, the following questions remain to be answered:

— to which extent is data transmission numerical?

— how many characters in addition to the roughly 60 already in use are required for control?

— to what extent must the codes be adapted to the codes of computers and input and output equipment?

— is it always preferable to make machines with several shifts, in order to keep the number of bits per character low?

The following conclusions can be drawn from Tables II and IV:

(a) Intrinsically protected codes have a probability of non-detectable errors of $p'_2 = (0.6$ to $1.1) \cdot 10^{-3}$; the order of magnitude is the same for all codes.

(b) The codes mentioned in *(a)*, when provided with extra protection by one horizontal parity character, have a probability of non-detectable errors of $p'_4 = (0.4 \text{ to } 1.7) \cdot 10^{-5}$; the order of magnitude is the same for all codes.

(c) Non-intrinsically protected codes, even with extra horizontal protection, are unsuitable for data transmission.

(d) The codes mentioned in *(a)* can be used on very good transmission lines ($p < 10^{-5}$); the codes mentioned in *(b)* will already be satisfactory on transmission lines with $p \leqq 10^{-3}$.

FEDERAL GERMAN REPUBLIC: CODING AND ERROR-DETECTION METHODS

(Extracts from contribution GT.43, No. 19, March 1960)

Coding and error correction are the main problems of data transmission at a low error rate. Hence, these problems will have to be treated in greater detail. Referring to Figure 140, the coding system provides code combinations consisting of m binary digits carrying the information, the total number of possible combinations being 2^m. The additional k binary digits form the results of k parity checks of the m information bits. Obviously, the error rate will decrease, but the redundancy of this code will increase with increasing k. A code of this structure may be used for both error detection or error correction with various efficiencies.

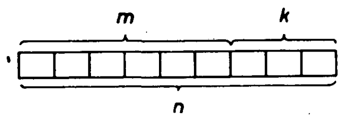


FIGURE 140. — *Code of* n *bits of which* m *information and* k *check bits*

Figure 141 presents four error-correction methods conceivable for such codes. In the case " without repetition ", the $n = m + k$ bits of each combination are transmitted in one direction only; hence, a simplex channel can be used. Owing to the absence of a backward path, only an error-correcting code could be used. The other three methods " with repetition " may employ error-detecting codes. Any disturbances will provoke a repetition of the information, the number of repetitions depending on the quantity and duration of the disturbances. For these reasons, the flow of information is discontinuous in all duplex or half-duplex systems employing repetition; this has a certain disadvantage compared with the simplex system without repetition where the information flows continuously. The systems "with repetition" can be subdivided into the following three groups:

(a) error detection in the receiver, involving decision feedback through the return channel. (The decision-taking station is shaded in Figure 141.) An error-detecting code is employed, and it is the receiver that decides whether the returned decision signal q is "proceed to send" (when no error is detected) or "repeat";

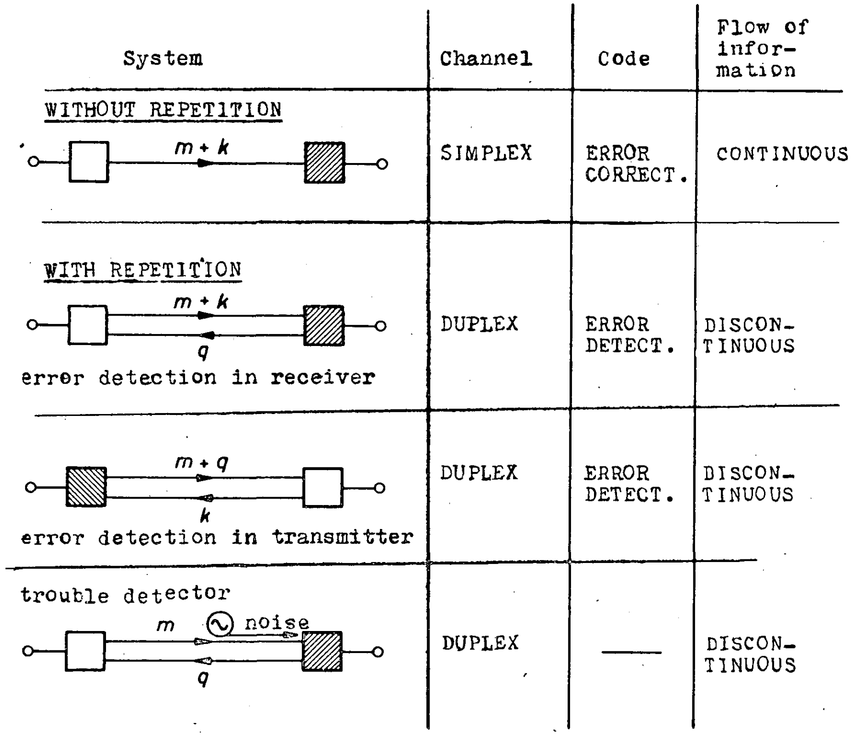


FIGURE 141. — *Comparison of error correction systems*

(b) error detection in the transmitter is provided by an operation where only the m information bits are transmitted to the receiver. The k check bits are derived in both stations and transmitted from the receiver back to the transmitter where they are compared with the k check bits there stored. This operation is also called redundancy feedback. The decision signal is now sent by the transmitter and prepares the receiver for either a repetition or for the continuation;

(c) to these two well-known methods, another one may be added which permits the abolition of the k check bits altogether. The receiver is here equipped with a "trouble detector" circuit that will indicate the presence of any trouble, interference or noise.

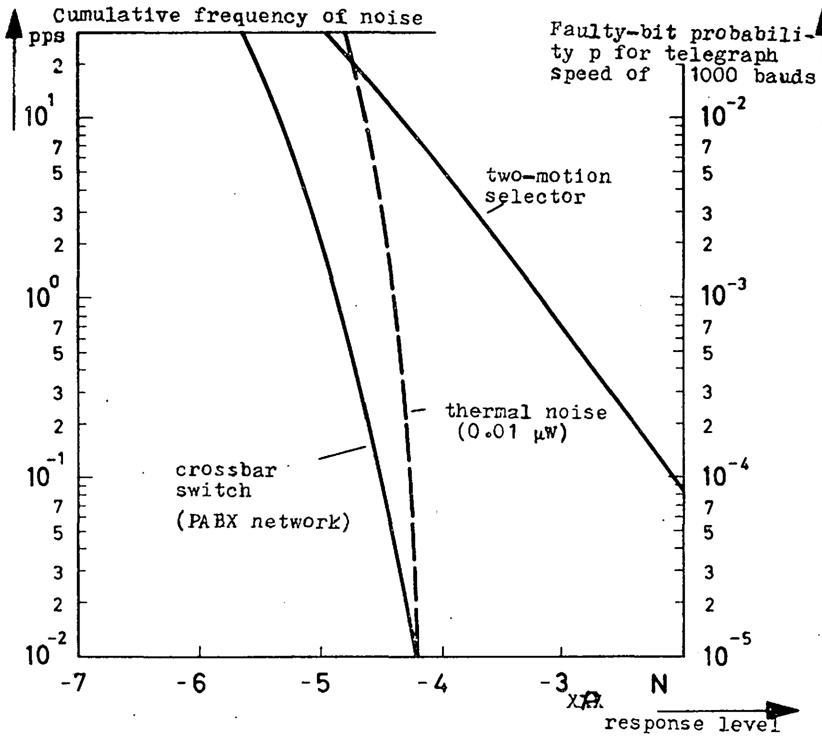


FIGURE 142. — *Frequency of noise pulses on a telephone line*

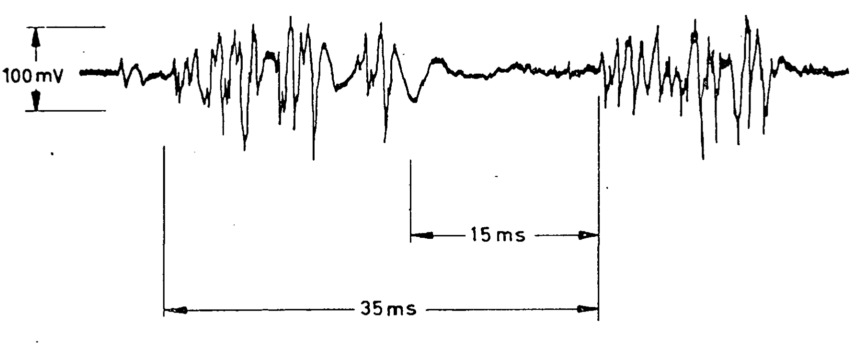


FIGURE 143. — *Typical selector noise on a telephone line*

This trouble detector may be an additional parallel channel conveying no transmitter signals; or, in a frequency modulation system, utilization of carrier amplitude modulation for trouble indication; or a circuit measuring the character distortion of the signal received; or a circuit with some other mode of operation. In each case, repetition of the message is provoked by the decision signal q (Figure 141) as soon as the output of the trouble detector reaches a pre-adjusted value, regardless of whether the character just received has become incorrect because of the trouble or not. This method can also be combined with the first method " without repetition " so that a repetition is provoked whenever the decision is initiated either by the error-correcting code or by the trouble detector.

The selection of the most suitable of the above four error-correcting methods must necessarily be influenced by the statistics of the noise affecting the transmission. This requires a brief discussion of typical noise on telephone lines and its statistical evaluation. Figure 142 shows the cumulative frequency distribution of such noise pulses against receiver-response level. This was measured as follows: a telephone connection was established by dialling; both subscriber's stations were then disconnected from their lines and replaced by proper terminating resistors. At one end of the line, an electronic counter was inserted which counted all noise peaks exceeding the response level. The two solid curves are representative for measurements on the public network of the Stuttgart area (two-motion selectors) and on the PABX plant of Standard Elektrik Lorenz AG (crossbar switches). Assuming a telegraph speed of 1000 bauds, the noise-peak frequency (left-hand ordinate of Figure 142) can be converted into the faulty-bit probability p (right-hand ordinate) denoting the probability of the occurrence of incorrect bits.

It should be noted that p can be somewhat improved by limiting the receiver bandwidth.

For comparison purposes, Figure 142 shows also the p caused by thermal noise of 0.01 microwatt as obtained by calculation. The local network noise curve is remarkably less steep than the theoretical thermal-noise curve corresponding to the Gaussian distribution, i.e. it does not give the chance of improving p by several orders by increasing the transmitter level (and receiver-response level). In the response-level range of interest (-3 to -4 N), a faulty-bit probability p of 10^{-2} to 10^{-3} will have to be expected.

The most important source of these noise peaks is the modulation of the selector-contact current by vibration due to the step-by-step motion of adjacent selectors. (This source is absent in crossbar switches.) Figure 143 shows the typical variation of this noise voltage with time. The clearly visible periodicity is caused by the horizontal homing motion of selectors. Such disturbances may have amplitudes up to 50 or 100 mV and last up to several hundred milliseconds.

The statistical evaluation may be facilitated by conceiving blocks of information being transmitted in a sequence as shown in Figure 144, each block having the same duration (of, say, 100 ms). Those blocks disturbed by one or more noise pulses are counted as " noisy blocks " (shaded in Fig. 144). Referring now to a noisy block, it is interesting to know the number of noise pulses is a block and the optimum duration of such a block. Figure 145 gives the probability distribution of the numbers of noise pulses in a noisy block, with block

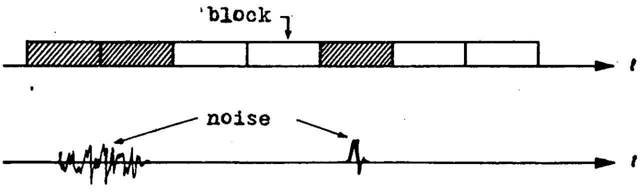


FIGURE 144. — *Schematic distribution of noisy blocks in time*

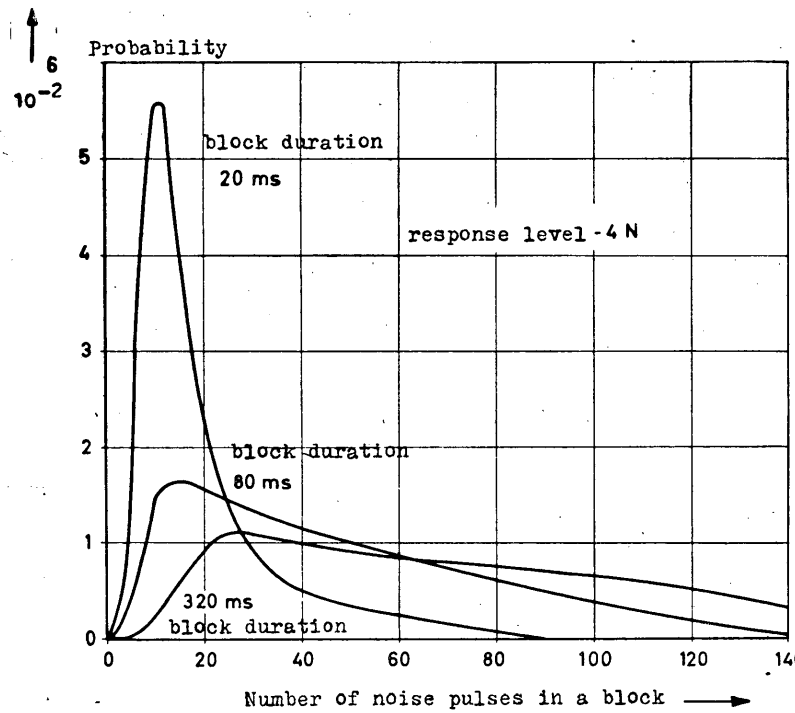


FIGURE 145. — *Probability of occurrence of noise pulses in blocks*

durations as parameters. As will be noted, the cases of only one, or only a few noise pulses appearing in a block, are relatively very rare. All curves are rather flat, that is, the probability of 10 noise pulses is not much different from the probabilities of 20 or 30 noise pulses appearing in a block. This shows the uselessness of an error-correction code (for instance, the Hamming code) which operates only as long as a given number of faulty bits is not exceeded. Large numbers of noise pulses should be very rare in this mode of operation, but measurements show that this is not the case.

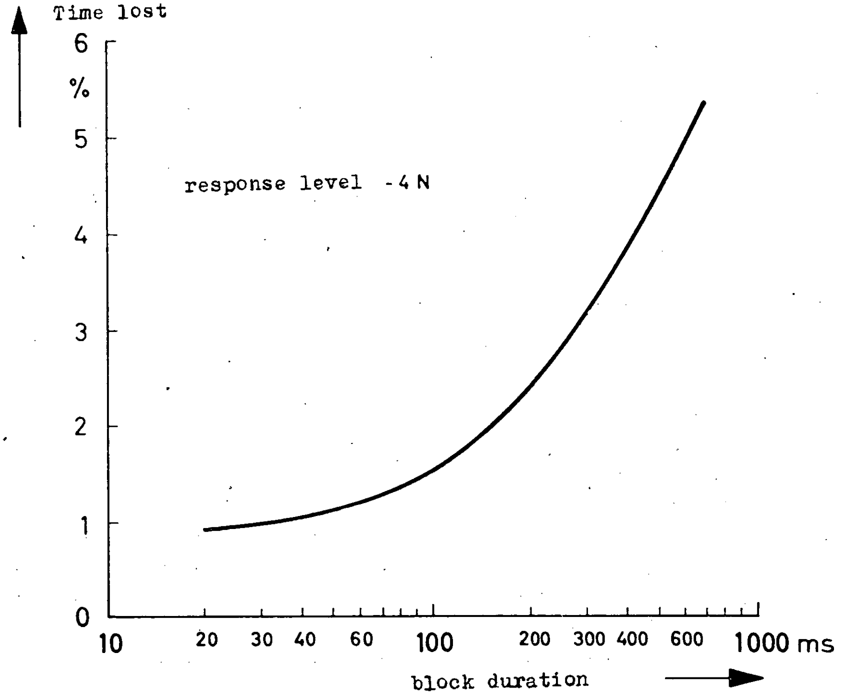


FIGURE 146. — *Loss of transmission time vs. block duration*

Another point of interest is the number of noisy blocks referred to the total number of blocks. This ratio governs the loss of time in a system where noisy blocks require repetition. The resulting time-loss (i.e. the shaded blocks in Figure 144 as a percentage of the total time) was plotted as a function of block duration in Figure 146. When the block duration is increased, it becomes more probable that it will coincide with a disturbance, and the time lost will necessarily increase. Figure 146 shows, however, that block durations may be increased to several hundred milliseconds without substantially increasing the loss of time; the latter will then not exceed a few per cent, and it will be negligible in a system where noisy blocks are repeated as correct blocks.

The result of the statistical evaluation of noise measurements is that considerable disturbances may occur; fortunately, however, the intervals between such disturbances are large enough to permit transmission. From this it follows that the data-transmission system should provide block-by-block transmission of information. Figure 147 indicates two possible modes of operation; in 147*a*, the transmitter is stopped after the sending of a block, to await the decision signal q from the receiver. The waiting time equals at least twice the delay caused by the transmission path plus the delay of transmitter and receiver equipments. Depending on the decision signal q (" proceed to send " or " repeat "), the transmitter either sends the next block of information or repeats the block just trans-

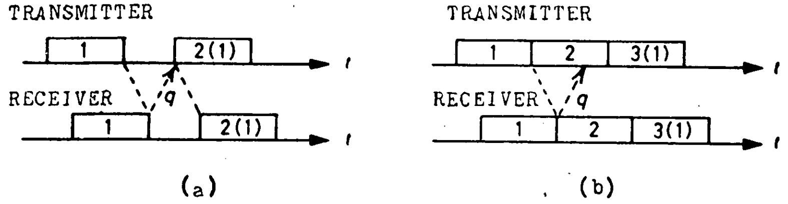


FIGURE 147. — *Method employing block repetition*

(a) with waiting time *(b)* without waiting time

mitted. In the case of Figure 147*b*, the second block is transmitted immediately after the first, the only requirement being that the decision signal related to the first block shall arrive at the transmitter before the transmission of the second block is complete. When the decision signal is " proceed to send ", the third block is transmitted immediately after the second. In the case of a " repeat " signal, the first block takes the place of the third. In this system (Fig. 147*b*), the minimum block duration is determined by twice the line delay plus equipment delay. Of course, this system is more favourable as the time loss due to the waiting time is eliminated and the only time-loss results from the frequency of a repeated block which does not exceed a few per cent (see Fig. 146).

Considering a maximum transmission-time delay of 20 ms (say, 8 carrier-system sections in series) and a telephone speed of 1000 bauds, the following reasonable limits would be attained:

Block duration: 50 ms $< t_b <$ 200 ms.
Block capacity: 50 bits $< n_b <$ 200 bits.

This data transmission system should have, it will be remembered, an error rate not exceeding $p_{ch} = 10^{-7}$ to 10^{-8}. Since only a few per cent of the blocks are disturbed, these should be detected when incorrect bits are to be expected at a fault probability $p_{ch} = 10^{-6}$ to fulfil the above high requirement. However, the noise amplitude may assume any value; hence, a faulty-bit probability covering the whole range $0 < p < 0.5$ has to be taken into account.

Compliance with this specification appears feasible when an error-detecting code is used in connection with a trouble detector as discussed in connection with Figure 141. On the other hand, it is desirable to base the error detection on the code alone. Such a code should then meet the specification

$$p_{ch} = 10^{-6} \text{ when } 0 < p \lessdot 0.5.$$

In general, computation of p_{ch} is cumbersome and calls for the use of an electronic computer. In the special case $p = 0.5$, however,

$$p_{ch} = 0.5^k - 0.5^n.$$

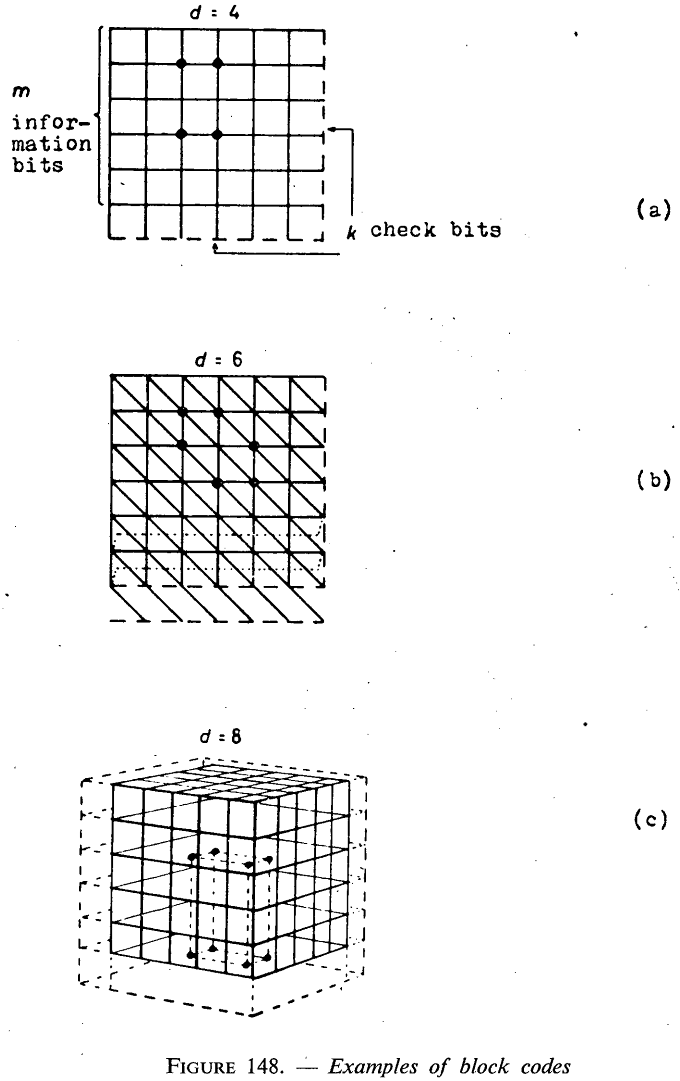


FIGURE 148. — *Examples of block codes*

(a) Plane matrix with line and column checks

(b) Plane matrix with line, column and diagonal checks

(c) Cube with checks in three dimensions

In this case, for instance, the probability is 0.5 that any one of the parity checks results in a 1. Hence, the probability is 0.5^k that each of the k parity checks results in 1's and, hence, is an undetected error. The minor probability 0.5^n that the character comprising

n bits is transmitted correctly should be subtracted from 0.5^k; however, this may be neglected. For $p_{ch} = 10^{-6}$ it is thus required that

$$k = 20$$

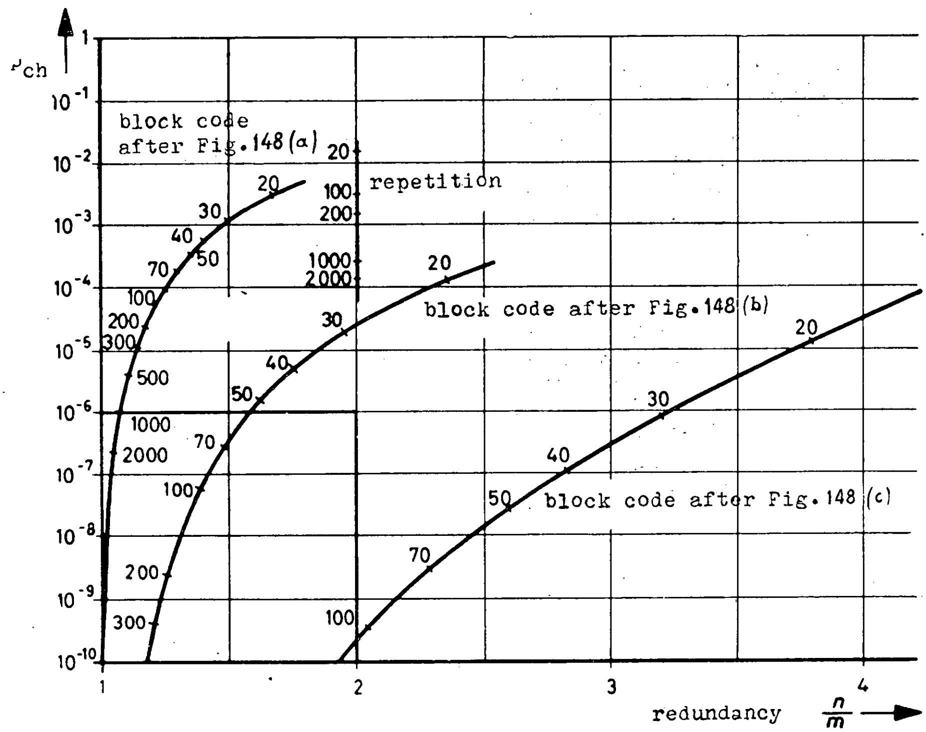


FIGURE 149. — *Maxima of faulty character probability* p_{ch} *of various block codes*

in other words: 20 parity checks and the transmission of 20 redundant check bits would be necessary. Compared with the 6 information bits of a character code, this means substantial redundance; that is why the " character code " should be replaced by a " block code " where each block-code combination comprises many more information bits.

Examples of block codes are shown in Figure 148. Figure 148*a* shows a two-dimensional matrix (for instance, of ferrite cores) into which a block of information may be written line by line, complemented by a check line and a check column. The check line and column contain the results of parity checks of all lines and columns. The k check bits of check line and check column can be so provided as to complete all line and column parity checks to, say, an even number of 1's. In this operation incorrect blocks remain undetected only when 4 bits form a rectangle as indicated by the dots in Figure 148*a*. The so-called Hamming minimum distance is $d = 4$ in this case. This distance can be improved by adding diagonal checks to the above as sketched in Figure 148*b* (where the matrix should be visualized as extended to the right and left in order to cover all bits). Here, not less than 6 incorrect bits in a certain arrangement ($d = 6$) would result in an unidentified incorrect block. Figure 148*c* shows a three-dimensional arrangement or cube where the verticals are checked apart from the lines and columns. In this case, an incorrect block remains undetected only when 8 faulty bits are located in a spatial arrangement as indicated ($d = 8$).

The faulty-block probability p_{ch} has been approximated by a calculation which showed p_{ch} to have a maximum depending on p, but not corresponding to $p = 0.5$. This maximum p_{ch} alone is of interest; in Figure 149 it is plotted as a function of the ratio n/m (ratio of all block bits to information bits). This ratio is a measure for the redundancy of the code. The figures entered along the curves in this diagram denote the block sizes n. The curves represent the three block codes of Figures 148 *a*, *b* and *c*. In addition, a plot designated " repetition " is given as computed for single repetition and bit-by-bit comparison of the original and repeated messages; it will be seen that this mode of operation is unsuitable inasmuch as the above-evolved block size $n < 200$ cannot be placed into the area of interest where $p_{ch} \leqslant 10^{-6}$ and $n/m \leqslant 2$. In this respect, the code after Figure 148*a* would also require too large blocks (1000 bits). The block codes after Figures 148*b* and 148*c* with three parity checks per information bit, however, appear suitable to meet the requirement. The redundancy of the block code Figure 148*b* is less than that of Figure 148*c*.

Thus the specification for a high accuracy (low p_{ch}) can apparently be realized even for blocks having the optimum size of about 100 bits as required for operation on noisy telephone lines, and the problem can be solved even by purely digital error detection.

WORKING GROUP 43: REPORT

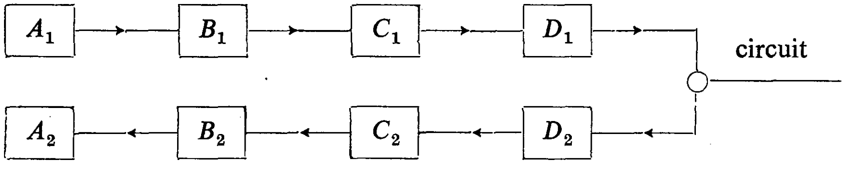
(Extracts from contribution GT.43, No. 20, March 1960)

6.2. *Sharing of responsibility.*

With the high modulation rate to be expected in the case of transmission over telephone type circuit, it will not be possible to have direct current control from the user's end of modulating equipment located in the stations of the operating Administration (although this will ordinarily be the case with telegraph circuits having a low modulation rate). For the local ends, up to the subscriber's premises, alternating current with an appropriate modulation method will be used.

The following diagram, taken from the Federal Republic of Germany's Contribution gives an idea of the terminal arrangement for a connection of this type:

Typical layout of apparatus for subscribers using data-processing systems



A_1 = data-processing system (sending end) or secondary source, for example perforated tape transmitter, magnetic tape transmitter, etc. Standardization of such apparatus is difficult and unnecessary.

B_1 = Code and speed converter. The purpose of this apparatus is to convert the special code and the speed of system A_1 into the code and speed required for transmission. It is desirable to standardize the code and modulation speed at the output of B_1.

C_1 = Apparatus for protection against errors (sending end). The German Administration considers that it is desirable to standardize the method to be used for error detection and correction. This apparatus could be omitted if the requirements concerning error rate are not too rigorous.

D_1 = Terminal transmitting apparatus (sending end). This apparatus comprises the modulator and transmitter. If each subscriber is to be in a position to co-operate with any other subscriber, the shape and significance of signals at the output of D_1 must be standardized in every detail. This apparatus may also include the switching unit.

A_2, B_2, C_2 and D_2 are the corresponding sets of apparatus at the receiving end. In practice, the design may be such that several of these basic functions (*A*, *B*, *C* and *D*) may be performed by the same apparatus.

The question will arise of what exactly is the " demarcation line " between the used and the operating Administration, e.g. should the terminal transmission equipment at the user's end (*D*1 and *D*2 of the diagram) be adjusted and maintained by the Administration or the user. This appears to be an internal matter, but in any case it will be necessary to define limits for the different responsibilities and to specify values and measuring methods for checking purposes and for assigning responsibility.

The role of Administrations seems to be limited to making lines available for data transmission and to supplying the necessary information. If the modulating/demodulating equipment at the user's premises is under the responsibility of the Administration, its role may extend to the question of codes and protection against undetected errors.

However that may be, it is the user who knows what undetected error rate he can accept; the choice of a protection method against errors should be left to the designer and the resulting code would be free, subject perhaps to a few restrictions due particularly to the requirements of protection against interference with the signalling conditions.

INTERCONNECTION OF DATA TESTING AND TERMINAL EQUIPMENT WITH A COMMUNICATION CHANNEL

(Extracts from contribution GT.43, No. 20, March 1960)

Introduction.

This paper gives a general view of the various problems arising from the association of a data terminal equipment with a communication channel. It is based on a preliminary report of E.I.A. Sub-Committee TR—24.3 on data terminal equipment and it is recognized that there has not been an opportunity for these suggestions to be examined widely.

The paper was prepared to meet the immediate need for establishing practices for the interconnecting circuits between testing (or comparable terminal equipment), and modulator-demodulator equipment for digital data transmission at rates higher than 100 bauds. It constitutes a proposal directed only towards existing or immediately contemplated practice rather than to what might be ultimate solutions to the digital data transmission problem.

This proposal does not cover the important area of synchronization methods, nor are standards specified for the communication channel itself with respect to distortion, errors or interruption of service.

1. *Purpose and scope of coverage.*

1.1. This paper is intended to describe a method of interconnecting data terminal equipment and a data communication channel including the modulator-demodulator when each is furnished by different organizations. It defines a means of exchanging control signals and binary serialized data signals between data testing or terminal equipment and a data communication channel in cases where the interchange point is as shown in Figure 150.

1.2. The data communication channel includes transmitting and receiving signal converters to permit the data communication channel to exchange standardized signals with the data terminal equipment. These standardized signals are defined in Section 4.

1.3. The data are to be serialized by the data testing of terminal equipment, so that the design of the data communication channel may be independent of the character length and code used by the data terminal equipment.

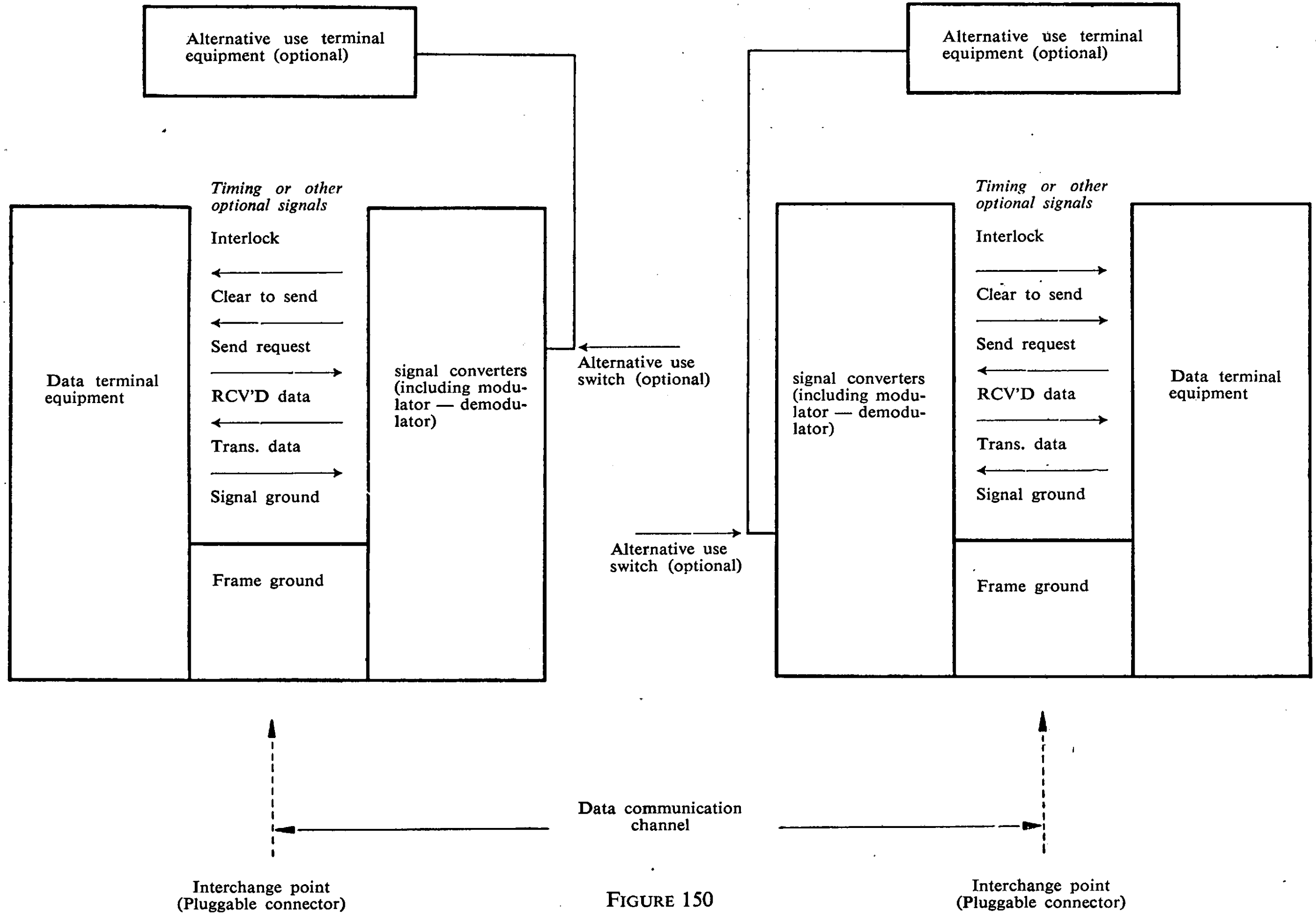

Alternative use terminal equipment (optional)
Alternative use terminal equipment (optional)
Timing or other optional signals
Interlock
Clear to send
Send request
RCV'D data
Trans. data
Signal ground
Frame ground
Data terminal equipment
signal converters (including modulator — demodulator)
Alternative use switch (optional)
Alternative use switch (optional)
Timing or other optional signals
Interlock
Clear to send
Send request
RCV'D data
Trans. data
Signal ground
Frame ground
signal converters (including modulator — demodulator)
Data terminal equipment
Data communication channel
Interchange point (Pluggable connector)
Interchange point (Pluggable connector)

FIGURE 150

1.4. It is intended that the signal interchange shall be located on the customer's premises and that the interchange circuits shall convey signals over relatively short distances (i.e. less than fifty feet).

1.5. Performance standards herein are not specified for the data communication channel or its associated equipment, either for maximum distortion of the received signals, transmission error rates, or interruptions of normal service. It is recognized that, in the future, if the performance requirements of the complete system are more stringent than the expected performance of the data communication channel, the data terminal equipment may include error-checking arrangements.

1.6. This proposal neither requires nor prohibits pulse regeneration equipment associated with the data communication channel.

1.7. This proposal is intended for modulation rates above 100 bauds.

1.8. The control circuits at the signal interchange are arranged to permit the alternate use of a higher class of communication service, as follows:

(a) Data terminal equipment designed for " send-only " service may also use either half-duplex or full-duplex service.

(b) Data terminal equipment designed for " receive-only " service may also use either half-duplex or full-duplex service.

(c) Data terminal equipment designed for half-duplex service may also use full-duplex service.

The substitution of a higher class of communication service does not require a change in the operation of the control circuits.

2. *Interchange circuits.*

2.1. Seven interchange circuits are defined.

2.1.1. *Frame grounding rack earth circuit.*

This conductor shall be electrically bonded to the machine frame and/or to any conducting parts which are normally exposed to operating personnel. This circuit may further be connected to external grounds (earths) as may be required.

2.1.2. *Signal ground* (signal earth).

This conductor establishes the electrical ground reference potential for all interchange circuits except the frame grounding rack earth circuit.

2.1.3. *Transmitted data circuit.*

Signals on this circuit are originated by the data terminal equipment for transmission on the data communication channel. This circuit is not required for " receive-only " service.

2.1.4. *Received data circuit.*

Signals on this circuit are originated by the receiving signal converter, in response to signals received over the communication medium. This circuit is not required for " send-only " service. In half-duplex service, the receiving signal converter shall hold marking condition on the received data circuit when the remote data terminal equipment has its " send request " circuit in the " off " condition. (See paragraph 4.10.4.) Optionally, in half-duplex service, the received data circuit may be used to monitor transmitted signals (e.g., to provide a local copy).

2.1.5. " *Send request* " *circuit.*

Signals on this circuit are originated in the data terminal equipment to select whether the signal converter is to be conditioned to transmit or to receive. For half-duplex service, when the signal on the " send request " circuit is switched to the " on " condition, the signal converter shall switch to the transmit condition, without regard to any signals that may be received from the communication facility. When this signal is switched to the " off " condition, the signal converter shall switch to the receive condition, without regard to any signals on the transmitted data circuit.

Data terminal equipment intended for use with " send-only " service shall hold the " send request " circuit in the " on " condition at all times. Data terminal equipment intended for use with " receive-only " service shall hold the " send request " circuit in the " off " condition at all times. This circuit is not required for full-duplex service.

2.1.6. " *Clear-to-send* " *circuit.*

Signals on this circuit are originated in the signal converter. For " send-only " and full-duplex service, the signal converter shall hold the " clear-to-send " circuit in the " on " condition at all times. This circuit is not required for " receive-only " service.

For half-duplex service, when the " send request " signal is switched to the " on " condition, the " clear-to-send " circuit shall be switched to the " on " condition, after a time delay sufficient to effect the reversal of direction of transmission of the data communication channel and all associated equipment. When the " send-request " circuit is switched back to the " off " condition, the " clear-to-send " circuit shall be switched back to the " off " condition.

2.1.7. *Interlock circuit.*

The signal on this circuit originates in the signal converter and shall be in the " on " condition only when all the following conditions are met:

(a) that its internal switching circuits are arranged for signalling on a communication facility;

(b) that it is not in any abnormal or test condition which disables or impairs any normal function associated with the class of service being used.

2.2. Additional interchange circuits may be provided to perform special functions, such as to convey timing information or to notify the data terminal equipment that the data communication channel is not in use. Such additional circuits shall conform to the electrical specifications in Section 4.

3. *Line of demarcation.*

3.1. The interchange point may be a pluggable connector. The female connector shall be associated with the data communication channel and should be mounted in a fixed position near the data terminal equipment. An extension cable with a male connector may be provided with the data terminal equipment. The total length of cable between the data terminal equipment and the data communication equipment should be short (less than approximately 50 ft.—see Sections 1.2 and 4.7).

4. *Electrical signal characteristics and wiring.*

4.1. All interchange circuit equipment shall conform to approved safety standards.

4.2. The wiring of interchange circuits shall be such that no circuit except the frame grounding (rack earth) circuit is directly exposed to contact by operating personnel.

4.3. The maximum open-circuit voltage to ground (earth) (either frame ground (rack earth) or signal ground) (transmission earth) on any interchange circuit shall not exceed 50 volts, and the maximum short-circuit current flow between any two conductors (including grounds) shall not exceed one-half ampere.

4.4. Any circuitry used to generate a signal voltage on an interchange circuit shall be so designed that no damage will be caused by either an open circuit condition or a short circuit to either frame ground or signal ground (rack earth or transmission earth). Any circuitry used to receive signals from an interchange circuit shall be designed for continuous operation with any input signal within the maximum voltage limits specified in Section 4.3.

4.5. The signal on an interchange circuit shall be considered to be in the " marking " or " off " condition when the voltage on the circuit is more negative than minus three volts with respect to signal ground, and the signal shall be considered to be in the " spacing " or " on " condition when the voltage is more positive than plus three volts with respect to signal ground.

The " marking " and " spacing " terminology will be used for the transmitted-data circuit and received-data circuit, while the " off " and " on " terminology will be used for all other circuits.

4.6. The operation of the circuitry that receives signals from an interchange circuit shall be dependent only on the signal voltage, as specified in Section 4.5, and should therefore be insensitive to the rise time, fall time, presence of signal overshoot, etc. The design of this circuitry shall minimize the effects of any circuit time-constants which would delay the circuit response, thus introducing time distortion in the signals.

4.7. The terminating impedance of the receiving end of an interchange circuit shall have a d. c. resistance of not less than 1000 ohms, and the voltage in the open-circuited condition shall not exceed two volts. The effective shunt capacitance of the receiving end of a signal interchange circuit, measured at the pluggable connector, shall not exceed 2500 micromicrofarads.

4.8. The source impedance of the sending end of an interchange circuit is not specified.

4.9. For the transmitted-data circuit and received-data circuit, neither the rise nor the fall time through the 6-volt range in which the signal conditions are not defined, shall exceed 3 per cent of the nominal pulse period. The circuitry used to generate a signal voltage on an interchange circuit shall meet this specification with any receiving termination which complies with Section 4.7.

4.10. The following are offered as a guide for equipment design to obtain reliable operation and ease of maintenance with minimum timing distortion introduced by the interchange circuits:

1) the nominal signal voltage on all interchange circuits should be $\pm$ 6 volts with a minimum of $\pm$ 3 volts with respect to signal ground (referred to in Section 4.5) and not greater than $\pm$ 20 volts with respect to signal ground.

Note. — Since the interchange connections will be short (Section 3.1.) the transmission protection afforded by polar transmission of signals may not be required. Therefore, in some instances, neutral operation might be permissible and may be used in the interest of circuit simplicity.

2) The signals should have approximately rectangular waveforms.

3) In order to avoid inducing voltage surges on interchange circuits, signals from interchange circuits should not be used to drive inductive devices, such as relay coils. (Note that relay or switching contacts may be used to generate signals on an interchange circuit.)

4) It should be noted that on some types of communication channels it may not be economically feasible to provide a " mark hold " specification as indicated in Section 2.1.4. It may therefore be desirable for operation of the data terminal equipment to be independent of this specification for " mark hold ".

C.C.I.T.T. SECRETARIAT: VOCABULARY FOR DATA TRANSMISSION

(Extracts from contribution GT.43, No. 2, June 1959)

When a new technique is introduced, technicians always try to create their own technical language. They do not attempt to find out whether suitable terminology already exists in a neighbouring field; nor do they avoid using terms which are already well established with a different meaning.

It would not matter so much if designers used the terms " channels (voies) ", " levels (niveaux) " or " feedback (retour) " with meanings different from those attached to them in telecommunication were it not that we are now faced with the problem of transmission.. If the C.C.I.T.T. does not control these tendencies great confusion will ensue.

Here are a few examples of bad terminology:

(a) Bit per second (used instead of baud).

The word " bit " was defined as follows in C.C.I.R. Warsaw Recommendation 166: " this unit of quantity of information corresponds to a ' message unit ' consisting of a random choice between two equally probable signals ".

The " bit per second " would be a unit of flow of information.

A baud is a unit of modulation rate; it corresponds to a modulation rate of one unit interval per second.

For data transmission, modulation rate (in bauds) and information flow (in bits per second) may be expressed by quite different values.

Example. — Automatic data transmission by means of a standardized start-stop teleprinter code, by pulses with a unit interval of 20 milliseconds.

One character is sent by means :

of one start pulse of a duration of 20 milliseconds,
of coded pulses carrying information, each pulse having a duration of 20 milliseconds at least, there being not more than 5 pulses,
of a stop pulse (deduct 30 milliseconds for example).
Total duration of transmission of one character = 150 milliseconds.
The modulation rate is $\frac{1}{0.020}$ bauds, i.e. 50 bauds.

In one second, there is a flow of $\frac{1}{0.150}$ characters over the circuit, at a rate of 5 bits per character, i.e. $\frac{1}{0.150}$ bits per second, or *33.3 bits per second.*

It is the additional signals—or signals elements—for synchronism and code protection, which, in a binary modulation with series transmission, are the causes of this difference between bauds and bits per second.

Binary modulation with parallel transmission effected, for example, by means of 5 different frequencies and pulses lasting 20 milliseconds, has a modulation rate of 50 bauds and permits the transmission of $5 \times 20 = 250$ bits in one second.

There is thus a considerable difference between bauds and bits per second.

(b) Channel (voie), *level* (niveau) to designate the unit intervals (intervalles unitaires) used, according to the code, to compose the signal corresponding to a character (six-channel code, six-level code, channel number 2 to designate all the perforations in a tape corresponding to the 2nd unit of the signals, etc.). It is superfluous to point out the confusion which this terminology will lead to in data transmission, where the terms and level will always be used with the meaning normally attributed to them in telecommunication.

Suitable terminology already exists in telecommunication: the terms " unit " (moments) or " unit interval " (intervalle unitaire) should be used. The word " track " (piste) may be used to designate all the perforations (or recordings) corresponding to a unit of the same rank.

(c) In data transmission, as in telegraphy, one of the transmission channels of a circuit is used for the transmission of information from the sending to the receiving apparatus, while the other channel is used to transmit certain signals in the opposite direction to control the rhythm of emission (for example, signals enabling the receiving apparatus to indicate to the sending apparatus whether the control of the protection against errors is satisfactory or not). Data-processing experts are accustomed to calling these signals "*feedback signals*". This terminology could lead to confusion, whereas the terms "backward signals" (signaux en retour, signaux vers l'arrière) are currently used in telegraph and telephone signalling for this purpose.

(d) The terms *signal, word, block* will have to be clearly defined. In coded telegraphy, "signal" corresponds to a character or a function; it will be easy to extend this definition to data transmission, as signal corresponds to a character (generally a figure) or to a function; "word" has a clear meaning in telegraphy and a word is limited by the "space" signal. It would be useful to keep this meaning in data transmission, if only because texts are frequently used in data transmission.

In data transmission, it is usual to carry out a check (parity check or otherwise), after a given number of signals have been transmitted, in order to detect errors; for this check, supplementary signals are added to the train of signals being checked; emission is suspended until a backward signal is received to indicate that the receiver has made the check and agrees. The characters in the train of signals thus checked are usually printed at this moment, or transferred to an element of the data-processing machine.

It is proposed that "block" should be taken to designate the whole of the signals grouped for submission to a common check for protection against errors.

PROPOSED WAY OF DEFINING OVERALL PERFORMANCE CHARACTERISTICS OF DATA-TRANSMISSION SYSTEMS

(Extracts from contribution GT.43, No. 20, March 1960)

Let the elementary time intervals of any code in any data-transmission system, independently of their actual length, be referred to as *significant bits*, if they are supposed to carry useful information (which excludes all redundant bits added for error detection and correction or any start and stop signals).

For any given time interval t, let:

s be the number of significant bits transmitted,

r be the number of significant bits correctly received.

The number of significant bits in error is then $s-r$.

It is now possible to define the overall performance of any system of data transmission in a very general and uniform way, by the following figures:

1) error rate for significant bits: $\varepsilon = \dfrac{s - r}{s}$,

2) transmission rate for significant bits: $R = \dfrac{s}{t}$.

This applies, without any restriction, to all systems using binary codes, even though they differ in every other respect, in particular as regards their respective bandwidths, modes of modulation and transmission (serial or parallel), methods of error detection and correction, types of codes, size of blocks, etc.

It at the same time provides a common basis for practical comparison of different systems of data transmission.

It is therefore suggested that the results of tests on data-transmission systems be expressed in terms of the two essential parameters, as defined above. This may prove helpful in studying the problem of how the changes in some specific parameters (e.g. size of blocks, signal-to-noise ratio, etc.) affect the general performance of the systems under consideration. It may also help to decide which one of any particular set of alternative systems is most suitable for any specific application.

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- *a)* German publications — publications allemandes;
- *b)* publications in English — publications en langue anglaise.

III. Connected questions — Questions connexes:
- *a)* German publications — publications allemandes;
- *b)* publications in English — publications en langue anglaise;
- *c)* Russian publication — publication russe.

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