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1.3 General characteristics of the 4-wire chain formed by the international circuits and national extension circuits

This subsection gives the overall characteristics recommended for the 4-wire chain defined in Recommendation G.101, § 2.

Recommendation G.131

STABILITY AND ECHO

(Geneva, 1964; amended at Mar del Plata, 1968, and Geneva, 1972, 1976,

and 1980; Malaga-Torremolinos, 1984 and Melbourne, 1988)

1 Stability of telephone transmission

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

— the variation of transmission loss with time and among circuits (Recommendation G.151, § 3);

— the attenuation distortion of the circuits (Recommendation G.151, § 1);

— the distribution of stability balance return losses (Recommendation G.122, §§ 2 and 3).

The stability of international connections has been calculated and the results are displayed graphically in Figure 1/G.131, which shows the proportion of connections (out of all the possible connections) likely to exhibit a stability of less than or equal to 0 dB or 3 dB as a function of the number of all analogue circuits comprising the 4-wire chain and the mean values of stability balance return loss that may be assumed. Of course the proportion of connections actually established which exhibit a stability lower than or equal to the values considered will be very much smaller.

Note — If digital circuits are included in the 4-wire chain, the stability is likely to be better than shown in Figure 1/G.131, as these circuits will exhibit a lower transmission loss variability than is assumed in that figure.

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

Figure 1/G.131, p.

The simplifying assumptions underlying the calculations are:

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

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

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

d) The departure of the mean value of the transmission loss from the nominal value is zero. As yet there is little information concerning international circuits maintained between 4-wire points.

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

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

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

h) All distributions are Gaussian.

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

Details of the calculations are set out in [1].

2 Limitation of echoes

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

Echoes may be controlled in one of two ways: either the overall loss of the 4-wire chain of circuits may be adjusted so that echo currents are sufficiently attenuated (which tacitly assumes a particular value for the echo return loss) or an echo control device can be fitted.

2.1 *Transmission loss adjustment*

The curves of Figure 2/G.131 indicate the minimum value of the overall loudness rating (OLR) in the echo path that must be introduced if no echo suppressor is to be fitted. The OLR is shown as a function of the mean one-way propagation time. Supplement No. 2, at the end of this fascicle, explains how these curves have been derived and Annex A to this Recommendation gives an example of their application.

The solid curves are applicable to a chain of analogue circuits which are connected together 4-wire. However, they may also be used for circuits connected together 2-wire if precautions have been taken to ensure good echo return losses at these points (i.e. averaged in accordance with Recommendation G.122) for example, a mean value of 27 dB with a standard deviation of 3 dB.

Note — This value is only sufficient to assure average echo losses (a -b) of (15 + n) dB, as currently called for in Recommendation G.122 § 4.1.

While Figure 2/G.131 is based on nominal values of LR of trunk junction and trunk circuits, it refers to minimum SLR and RLR values of subscriber systems.

The dashed curve is applicable to fully digital connections with analogue subscriber lines (such as shown in Figure 2/G.111), and, under certain assumptions (see Supplement No. 2), to fully digital connections with digital subscriber lines (such as shown in *b)* of Figure 1/G.104. In the latter case the echo path includes the acoustical path between earpiece and mouthpiece of the handset.

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

— up to 500 km route distance: 0.5 dB;

— between 500 km and 1000 km route distance: 1.0 dB;

— for every additional 500 km or part thereof: 0.5 dB.

However, such a circuit may not form part of multicircuit connections unless the nominal transmission loss is restored to 0.5 dB.

Figure 2/G.131, p.

2.2 *Echo control devices*

The preferred type of echo suppressor is a terminal, differential, half-echo suppressor operated from the far end. There are several types of half-echo suppressor in use in the international network, one suitable only for use in connections with mean one-way propagation times not exceeding 50 ms, referred to as a short-delay echo suppressor, and the others suitable for use in connections with any mean one-way propagation time, especially times well over 50 ms, referred to as a long-delay echo suppressor like those used on circuits routed on communication-satellite systems. The characteristics of the short-delay echo suppressors are given in [2]. The characteristics of echo suppressors which can be used on connections with either short or long propagation times are given in [3] and in Recommendation G.164 (echo suppressors with new functions). Another type of echo control can be obtained by echo cancellers. The characteristics are given in Recommendation G.165.

From subjective test information received, it is concluded that:

1) Echo cancellers in accordance with Recommendation G.165 provide superior speech transmission performance (at the 0.05 confidence level) to that provided by:

a) echo suppressors according to Recommendation G.161 (*Orange Book*);

b) echo suppressors according to Recommendation G.164 with fixed break-in differential sensitivity, FBDS;

Note — Two Administrations have the view that echo cancellers according to Recommendation G.165 and echo suppressors according to Recommendation G.164 with adaptative break-in differential sensitivity (ABDS) provide about the same performance when the echo path loss is considerably above the lower end of its range; calculations based on Recommendation G.122, § 2 and assuming a minimum echo loss of 6 dB, indicate that the majority of echo path losses will be greater than the minimum value.

2) echo suppressors in accordance with Recommendation G.164 with ABDS provide superior speech transmission performance to that provided by echo suppressors with FBDS.

3) echo control devices of different types (i.e. echo suppressors or cancellers in accordance with the series G Recommendations) placed at opposite ends of a connection will operate compatibly. In this case the subjective quality perceived at one end is almost uniquely dependent on the performance of the echo control device installed at the opposite end.

Note 1 — Regional satellite circuits routed in parallel with terrestrial circuits, without perceivable echo, will benefit from the use of echo control devices of the best quality. Otherwise any degradation of the normal quality by routing over the satellite circuit may be found objectionable by the subscriber.

Note 2 — Bilateral agreement between Administrations may facilitate the introduction in the network of echo control devices of better quality.

2.3 *Rules governing the limitation of echoes*

The rules given below are subdivided into ideal rules and practical rules. It is recognized that no practical solution to the problem could comply with rules so exclusive and inflexible as the ideal rules. Practical rules are suggested in the hope that they will ease the switching and economic problems. They should not be invoked unless the ideal rules cannot reasonably be complied with.

2.3.1 *Rules for connections without echo control devices*

2.3.1.1 *Ideal rule — Rule A*

For a connection between any pair of local exchanges in different countries, the probability of incurring the opinion ‘‘unsatisfactory’’ due to talker echo shall be less than 1%, when minimum practical nominal send and receive loudness ratings are assumed for the talker’s telephone and line.

The rules in this Recommendation have been updated (to include echo cancellers) and regrouped, compared with previous versions of Recommendation G.131. The letters indicating the rules are the same as in previous versions of Recommendation G.131 in order to provide a degree of continuity.

Note — Calls between a given pair of local exchanges may encounter different numbers of 4-wire circuits, according to the routing discipline and time of day. Figure 2/G.131 permits compliance with this rule to be assessed for the separate parts of the total traffic which encounter 1, 2, 3 . | | 9 4-wire circuits, under certain conventional assumptions. (See Supplement No. 2 at the end of this fascicle.)

2.3.1.2 *Practical rule — Rule E*

Recommendation Q.115 [4] is a study of the application of Rules A and E to the United Kingdom-European network relations.
For connections involving the longest national 4-wire extensions of the two countries, a probability of incurring an ‘‘unsatisfactory’’ opinion due to echo not of 1% (Rule A) but of 10% can, by agreement between the Administrations concerned, be tolerated. This Rule E is valid only in those cases where it would otherwise be necessary, according to Rule A , to use an echo control device solely for these connections, and where there is no need for echo control devices on connections between the regions in the immediate neighbourhood of the two international centres concerned.

2.3.2 *Rules for connections with echo control devices*

2.3.2.1 *Ideal rules*

2.3.2.1.1 *Rule B*

1) Not more than the equivalent of one full echo suppressor (i.e. two half-echo suppressors) should be included in any connection needing an echo suppressor. When there is more than one full echo suppressor the conversation is liable to be clipped; lockout can also occur.

2) Circuits equipped with echo cancellers (Recommendation G.165) can be connected together in tandem without echo performance degradation.

3) A circuit equipped with echo suppressors (Recommendation G.164) can be connected with another circuit equipped with echo cancellers (Recommendation G.165) without additional performance degradation.

Note — The overall performance will not be better than that provided by the poorer performing device.

2.3.2.1.2 *Rule D*

The half-echo suppressors should be associated with the terminating sets of the 4-wire chain of the complete connection. This:

— reduces the chance of speech being multilated by the echo suppressors because the hangover times can be very short;

— reduces the change of ineffective echo canceller operation as end delays are short and minimum required echo losses can be assured.

2.3.2.2 *Practical rules*

2.3.2.2.1 *Rule F*

If, as is appreciated, Rule D above cannot be complied with, the echo control device may be fitted at the international exchange or at an appropriate national transit centre. However, each echo control device should be located sufficiently near to the respective subscribers for the end delays not to exceed the maximum value recommended in Recommendation G.161, (*Orange Book*) and Recommendations G.164 and G.165 of this fascicle. For countries of average size, this will normally mean that the originating and terminating control devices will be in the countries of origin and destination of the call.

2.3.2.2.2 *Rule G*

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

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

2.3.2.2.3 *Rule K*

On a connection that requires an echo suppressor, up to the equivalent of two full echo suppressors (e.g. three half-echo suppressors or two half-echo suppressors and a full one) may be permitted. Every effort should be made to avoid appealing to this relaxation because the equivalent of two or more full echo suppressors, with long hangover times, on a connection can cause severe clipping of the conversation and considerably increases the risk of lockout. This rule does not apply to echo cancellers (see Rule B).

2.3.2.2.4 *Rule L*

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

2.3.3 *General rules*

2.3.3.1 *Ideal rule — Rule C*

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

2.3.3.2 *Practical rules*

2.3.3.2.1 *Rule H*

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

2.3.3.2.2 *Rule J*

It is accepted that a connection that does not require an echo control devices may in fact be unnecessarily equipped with one or two half-echo suppressors, or a full echo suppressor or echo cancellers. (The presence of an echo suppressor in good adjustment on a circuit with modest delay times can hardly be detected and in the case of echo cancellers it may improve the overall performance of the connection.)

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

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

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

echo control devices should be connected in all cases.

2.3.3.2.3 *Rule M*

It has been found in actual practice that echo can be made tolerable by providing loss in the circuit if the one-way propagation time (delay) of the echo is less than about 25 ms. For delays longer than this, too much circuit loss is needed to attenuate echo, and echo control devices are required.

Note — The equivalent of this rule is stated in Recommendation G.161, § B.b. (*Orange Book*). This rule has not been expressed in earlier versions of Recommendation G.131.

2.4 *Insertion of echo control devices in a connection*

Ways of inserting echo control devices in a connection which have been considered are the following:

1) provide a pool of echo control devices common to several groups of circuits, and arrange for an echo control device to be associated with any circuit that requires one (see Recommendation Q.115 [4]);

2) arrange for the circuits to be permanently equipped with echo control devices but switch them out (or disable them) when they are not required (see [5]);

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

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

Whichever method is used, due regard must be paid to the last sentence of § 2.1 above. Methods of achieving the required reduction of circuit losses are under study by the CCITT. The nature and volume of the traffic carried by a particular connection will also influence the economics of the methods and hence the choice among them.

The CCITT is currently studying what recommendations are necessary to ensure that the insertion of echo control devices in international connections complies, overall, with the practical rules given above.

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

2.5 *Speech processing devices*

Some speech processing devices, such as speech interpolation devices , have an inherent echo-suppressor function. However, such devices may only suppress echo during the single talk mode and not during double talking conditions (see Recommendation G.164, § 1.7) unless they are equipped to perform full echo-suppressor functions. When devices without full echo control are connected in tandem with echo cancellers, performance degradation due to echo may occur during double talking conditions as the intermediate echo canceller will not be effective during double talk.

ANNEX A
(to Recommendation G.131)

Application of Recommendation G.131, § 2

Recommendation G.131, § 2.3.1.1, Rule A, requires, for each pair of countries, an assessment of echo conditions for each possible pair of local exchanges to ascertain whether the plot of corrected reference equivalent of echo path against mean one-way propagation time for that pair of exchanges, lies above or below the appropriate 1% line in Figure 2/G.131.

The variables in the problem are indicated in Table A-1/G.131 and illustrated for all analogue connections in Figure A-1/G.131 and for all digital connections in Figure A-2/G.131.

For a given pair of exchanges, all eight items are known or can be estimated. A plot of overall loudness rating [1) + 2) + 3) + 4) of Table A-1/G.131] as a function of mean one-way propagation time [5) + 6) + 7) of Table A-1/G.131] on Figure 2/G.131 may be assessed in relation to the 1% curve, for a given number of analogue circuits in the 4-wire chain for fully analogue connections and mixed analogue/digital connections or, for fully digital connections using the appropriate curve.

H.T. [T1.131]

TABLE A-1/G.131

Quantities needed for echo assessment

{
Overall loudness rating of the echo path
, made up of the sum
of:
}
{
1)
the minimum of the sum of the values of the sending and
receiving loudness ratings of the local system of
country A (talker end));
}
{
2)
the nominal loudness rating from, and to, the virtual
analogue switching points (*a*
A and *b*
A) of the chain of national
circuits in country A, connecting the local exchange to the
international exchange;
}
{
3)
the nominal loudness rating in each direction of transmission of
the international chain;
}
{
4)
the echo loss (*a*
B-*b*
B) of the
national system of country B (listener
end).
}
{
Mean one-way propagation time
,
made up of half the sum of the propagation
times of:
}
{
5)
the paths from the telephone set in
country A, to and from the virtual analogue switching
points *a*
A and *b*
A;
}
{
6)
the two directions of
transmission of the international chain;
}
{
7)
the path *a*
B-*b*
B of country B.
}
{
In addition, there will be needed for fully analogue or
mixed analogue/digital
connections:

} { 8) the number of analogue circuits in the 4-wire chain (see Figure 3/G.101). }

Tableau A-1/G.131 [T1.131], p. 3

Figure A-1/G.131, p.

Figure A-2/G.131, p.

A.1 *Full analogue connections* (Figure A-1/G.131)

For the purpose of this Recommendation, it may be assumed that the principal reflection at the listener's end occurs at the 4-wire/2-wire terminating set, which may be assumed to be located at the primary exchange associated with the listener's local exchange. The components of 4) of Table A-1/G.131 are then the losses a_B-*t* and *t* -b_B, plus the echo balance return loss at the 2-wire port of the terminating set. This return loss will be the mean overall, of the off-hook subscriber's lines, which may be presented to the 2-wire port of the terminating set by the listener's local exchange. (Figure 2/G.131 assumes that the standard deviation of the return loss is 3 dB.) If the mean value is not known, it may be assumed that 4) of Table A-1/G.131 is in accordance with Recommendation G.122, § 4, viz., a mean value of (15 + *S*) dB where *S* is the sum of the nominal losses in the two directions of transmission of the circuits in the listener's national 4-wire chain (*S* is assumed to be 1 dB in this case).

For a given pair of local exchanges, successive connections may encounter different numbers of 4-wire circuits, and the total traffic may be regarded as a number of packets of various proportions encountering from one to nine 4-wire circuits. Each ''packet'' may be tested with the aid of Figure 2/G.131 and the results combined in order to assess whether Rule A is complied with for the totality of traffic.

Figure A-1/G.131 shows, as an example, an application of Recommendation G.131, § 2, where a listener's *a -t -b* path is assumed to be in accordance with Recommendation G.122. For simplicity, it is assumed that 100% of the traffic encounters the given conditions. Values for the example are as follows:

Talker's country A

Distance from local exchange A_1 to international exchange 1600 km

Assuming a velocity of propagation for the transmission systems of 250 km/ms, 3 FDM channel modulators and demodulators of 1.5 ms each for talker's country A and the international chain of circuits A to B, and a 12 ms constant for listener's country B (see Recommendation G.114).

Mean one-way propagation time from local exchange A_1 to international exchange 11 ms

Simultaneous-minimum sending and receiving loudness rating (sum) of the local system 5 dB

It is assumed that the loaded trunk-junction introduces an additional 1 dB (in each direction) when changing from nominal transmission loss to loudness rating.

Loudness rating from local exchange to international exchange (b_A) 7 dB

Loudness rating from international exchange to local exchange (a_A) 6 dB

Number of 4-wire circuits 2

International chain A to B

Number of circuits 3

Distance 3200 km

Mean one-way propagation time 17 ms

Sum of loudness ratings in both directions $2 \times 3 \times 0.5$ dB 3 dB

Listener's country B

Mean echo loss (a_B-b_B) = (15 + 1) dB 16 dB (Rec. G.122)

Distance from international exchange to primary exchange associated with local exchange B_1 (i.e. point of principal reflection) 1120 km

Mean one-way propagation time corresponding to above distance 16 ms

Number of 4-wire circuits 1

An unusually large number, chosen only to illustrate the principle of addition of loss.

Total number of 4-wire circuits = 2 + 3 + 1 = 6

Total mean one-way propagation time = 11 + 17 + 16 = 44 ms (A-1)

Total loudness rating of the echo path = 5 + 7 + 6 + 3 + 16 = 37 dB (A-2)

If (A-1) and (A-2) are plotted on Figure 2/G.131, the point lies below the 1% line for six 4-wire circuits, indicating a probability of more than 1% of incurring an ‘‘unsatisfactory’’ opinion. The conclusion also applies to other possible numbers of 4-wire circuits.

A.2 *Fully digital connections* | Figure A-2/G.131)

It may be assumed that the principal reflection at the listener’s end occurs at the 4-wire/2-wire terminating set, which is located at the listener’s local exchange. The components of 4) of Table A-1/G.131 are then the losses a_B-t and t -$b_B$plus the echo balance return loss at the 2-wire port of the terminating set. This return loss will be the mean, overall, of the off-hook subscriber’s lines, which may be presented to the 2-wire port of the terminating set by the listener’s local exchange. (Figure 2/G.131 assumes that the standard deviation of the return loss is 3 dB.) If the mean value is not known, it may be assumed that it is in accordance with Recommendation G.122, § 4.3, viz., a mean value of 11 dB.

In order to apply Figure A-2/G.131 the value of *n* is not required in this case (as the digital circuits in the 4-wire chain do not contribute to the overall circuit loss variability). However, the number of digital exchanges has an effect on the propagation time, for instance, in accordance with Table 1/G.114, that each digital transit exchange adds 0.45 ms to the mean one-way propagation time of the connection.

Figure A-2/G.131 shows an example where the sum of the R and T pads is either 6 or 7 dB. Values for the example are as follows:

Talker's country A

Distance from local exchange A_1 to international exchange 1600 km

Assuming a velocity of propagation for the transmission systems of 250 km/ms, 4 exchange delays of 0.45 ms each and 0.3 ms delay in the coder or decoder. (In practice a local digital exchange will contribute a little more than 0.45 ms, see Recommendation G.114.)
Mean one-way propagation time from local exchange A_1 to international exchange 8.5 ms

Simultaneous-minimum sending and receiving loudness rating (sum) of the local system 5 dB

Sum of loudness ratings in both directions of transmission $(t_1\text{-}b_A) + (a_A\text{-}t_1)$ 6 dB

International chain A to B

Distance 3200 km

Mean one-way propagation time 13.7 ms

Loudness rating of international chain 0 dB

Listener's country B

Distance from local exchange B_1 to international exchange 1600 km

Mean one-way propagation time 8.5 ms

Mean echo loss $(a_B\text{-}b_B)$ = (11 + 7) dB 18 dB

Total mean one-way propagation time = 8.5 + 13.7 + 8.5 = 30.7 ms (A-3)

Total loudness rating of the echo path = 5 + 6 + 0 + 18 = 29 dB (A-4)

If (A-3) and (A-4) are plotted on Figure 2/G.131, the point lies below the 1% line (and also the 10% line) for fully digital connections, indicating a propability of more than 1% incurring an ‘‘unsatisfactory’’ opinion.

Conclusion

Assuming a velocity of propagation for the transmission systems of 250 km/ms and 2 exchange delays of 0.45 ms each.

a) An echo control device should be used on the connection; or

b) the loss in the echo path should be increased (but the limitations of Recommendation G.121 must be observed).

Note — It should be noted, when contemplating to increase the loss in the echo path, that digital pads placed in digital circuits need to be switched out for digital data signals (but not for voiceband data signals) as they destroy the bit transparency for such signals.

A.3 *Mixed analogue/digital connections*

The examples given in Figures A-1/G.131 and A-2/G.131 allow the construction of mixed analogue/digital connection models by combining the appropriate elements of the two figures. The quantities stated in Table A-1/G.131 can be calculated with these models. (Quantity 8) of this table (number of circuits) should now be taken as the number of analogue circuits in the 4-wire chain (thus not including the digital circuits). The appropriate solid curve in Figure 2/G.131 will approximate the required echo tolerance curve with good accuracy.

Note — In mixed analogue/digital networks the propagation time can become larger than in purely analogue or digital networks. The latter occurs in particular when digital exchanges are connected with analogue transmission systems through PCM/FDM equipments in tandem or transmultiplexers. Many different configurations may arise.

References

[1] *Calculation of the stability of international connection established in accordance with the transmission and switching plan* , Green Book, Vol. III, Supplement No. 1, ITU, Geneva, 1973.

[2] CCITT Recommendation *Definitions relating to echo suppressors and characteristics of a far-end operated, differential, half-echo suppressor* , Blue Book, Vol. III, Rec. G.161, Section B, ITU, Geneva, 1964.

[3] CCITT Recommendation *Echo-suppressors suitable for circuits having either short or long propagation times* , Orange Book, Vol. III, Rec. G.161, Sections B and C, ITU, Geneva, 1977.

[4] CCITT Recommendation *Control of echo suppressors* , Vol. VI, Rec. Q.115.

[5] CCITT — *Insertion and disablement of echo suppressors* , Blue Book, Volume VI.1, Question 2/XI, Annex 3, ITU, Geneva, 1966.

Recommendation G.132

ATTENUATION DISTORTION

(Geneva, 1964; Mar del Plata, 1968; Geneva, 1972 and Melbourne, 1988)

The network performance objectives for the variation with frequency of transmission loss in terminal condition of a worldwide 4-wire chain of 12 circuits (international plus national extensions), each one routed over a single group link, are shown in Figure 1/G.132, which assumes that no use is made of high-frequency radio circuits or 3-kHz channel equipment.

Note 1 — The design objectives contained in the Recommendation cited in [1], for carrier terminal equipments are such that for a chain of 6 circuits (international and national extensions) in tandem, each circuit being equipped with one pair of channel translating equipments, the attenuation distortion would in most cases be less than 9 dB between 300 and 3400 Hz. For the case of 12 circuits in tandem it can be expected that in most cases the attenuation distortion will not exceed 9 dB between about 400 and 3000 Hz. As far as the international chain is concerned, see Recommendation G.141, § 1.

Note 2 — It is only in a small proportion of international connections that the 4-wire chain will in fact comprise 12 circuits.

Note 3 — Limits given in Figure 1/G.132 should be met also for mixed connections using the analogue-digital equipments. Probably, the number of analogue-digital equipment (pair codecs) for the mixed connections with 12 circuits does not exceed 6 (see Recommendation G.103, Annex B).

It should be recognized that a connection containing six coder-decoder pairs where each pair just meets the attenuation distortion requirements found in Recommendation G.712 will not meet the attenuation distortion requirement found in Recommendation G.132 for 3400 Hz.

However, it is likely that real coder-decoder pairs will have attenuation distortion performance better than in Recommendation G.712, so for practical purposes the likelihood of not complying with Recommendation G.132 is very small.

Note 4 — Studies are being carried out by Study Group IV and Study Group XII about how well this objective is being met in practice, about the expectation with which it should be met in future (taking account of Note 2 and Note 3 and about any possible consequential need for notifications to Recommendations referring to equipments.

Figure 1/G.132, p.

Reference

[1] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232, § 1.

Recommendation G.133

GROUP-DELAY DISTORTION

(Geneva, 1964; amended at Geneva, 1980)

The network performance objectives for the permissible differences for a worldwide chain of 12 circuits each on a single 12-channel group link, between the minimum group delay (throughout the transmitted frequency band) and the group delay at the lower and upper limits of this frequency band are indicated in the Table 1/G.133.

Group-delay distortion is of importance over a band of frequencies where the attenuation is of importance, i.e. at which the attenuation is less than 10 dB relative to the value at 800 Hz. This will normally be the case for frequencies higher than about 260-320 Hz and lower than about 3150-3400 Hz respectively for the lower and upper limit of the frequency band as indicated in Table 1/G.133.

H.T. [T1.133]

TABLE 1/G.133

. **Lower limit of frequency band (ms) }** **Upper limit of frequency band (ms) }**	**{** **{**	
International chain	**30.5**	15**.5**
{ Each of the national 4-wire extensions }	15**.5**	7.5
On the whole 4-wire chain	60**.5**	30**.5**

Note — Limits given in Table 1/G.133 should be met both for analogue circuits and mixed circuits with analogue and digital sections.

Table 1/G.133 [T1.133], p.

LINEAR CROSSTALK

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

1 Linear crosstalk between different 4-wire chains of circuits (analogue and mixed)

As a network performance objective, the signal-to-crosstalk ratio which may exist between two 4-wire chains of circuits comprising international and national circuits is restricted by Recommendation G.151, § 4.1, as regards circuits, and by Recommendation Q.45 [1], as regards international centres.

2 Linear crosstalk between go and return channels of the 4-wire chain of circuits (analogue and mixed)

As a network performance objective, the signal-to-crosstalk ratio between the two directions of transmission of a 4-wire chain of circuits is restricted by Recommendation G.151, § 4.2, as regards circuits and by Recommendation Q.45 [1] as regards international centres.

ANNEX A

(to Recommendation G.134)

Methods for measuring crosstalk in exchanges,

on international telephone circuits and on a chain of international telephone circuits

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

a) crosstalk in an exchange arising mainly from a single source or from several nearby sources;

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

A.2 Available methods for measuring crosstalk are as follows :

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

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

c) measurements made using a uniform spectrum random noise or closely spaced harmonic series signal shaped in accordance with a speech power density curve. Such measurements should be made in accordance with the Recommendation cited in [3];

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

Recommended methods for the measurement of crosstalk are described in Annex A.

It is a question here of the measurement of the frequency (or frequencies) to be used; the measure of the crosstalk for a given frequency is described in [2]

A.3 Pending further study, the following methods are provisionally recommended for ‘‘ type tests ´acceptance tests ´sp 9p

A.3.1 *Crosstalk in exchanges*

Crosstalk should be measured at 1100 Hz which, in the experience of some Administrations, is equivalent to a measurement made with a conventional telephone signal generator (Recommendation G.227 [4]) and a psophometer.

A.3.2 *Crosstalk on an international telephone circuit or chain of international telephone circuits*

Crosstalk should be measured using a uniform spectrum random noise or closely spaced harmonic series signal shaped in accordance with the speech power density curve of Recommendation G.227 [4]. The measurements should be made in accordance with the Recommendation cited in [3].

Note 1 — In cases of difficulty with A.2.a) and A.2.b), voice/ear tests are recommended.

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

References

[1] CCITT Recommendation *Transmission characteristics of an international exchange* , Vol. VI, Rec. Q.45.

[2] *Measurement of crosstalk* , Green Book, Vol. IV.2, Supplement No. 2.4, ITU, Geneva, 1973.

[3] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232, § 9.2.

[4] CCITT Recommendation *Conventional telephone signal* , Vol. III, Rec. G.227.

Recommendation G.135

ERROR ON THE RECONSTITUTED FREQUENCY

(Mar del Plata, 1968)

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

To attain this objective, the CCITT recommends that the channel and group carrier frequencies of the various stages should have the accuracies specified in the corresponding clauses of Recommendation G.225 [1].

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

Calculations indicate that, if these recommendations are followed, in the 4-wire chain forming part of the hypothetical reference connection defined in Figure 1/G.103 there is about 1% probability that the frequency difference between the beginning and the

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In fact, the chain considered for these calculations comprised 16 (instead of 12) modulator-demodulator pairs to allow for end of the connection will exceed 3 Hz and less than 0.1% probability that it will exceed 4 Hz.

the possibility that submarine cables with equipments in conformity with Recommendation G.235 [2] might form part of the chain. No allowance was made, however, for the effects of Doppler frequency-shift due to inclusion of a non-stationary satellite; values for this shift are given in CCIR Report 214 [3].

The CCITT notes that in mixed circuits having several digital sections the requirements concerning frequency error are met more easily since digital systems do not change the frequency of an audio frequency channel.

References

[1] CCITT Recommendation *Recommendations relating to the accuracy of carrier frequencies* , Vol. III, Rec. G.225.

[2] CCITT Recommendation *16-channel terminal equipments* , Vol. III, Rec. G.235.

[3] CCIR Report *The effects of doppler frequency-shifts and switching discontinuities in the fixed satellite service* , Vol. IV, Report 214, ITU, Geneva, 1986.

1.4 General characteristics of the 4-wire chain of international circuits; international transit

Recommendation G.141

ATTENUATION DISTORTION

(Geneva, 1964; amended at Mar del Plata, 1968 and Geneva, 1972 and 1980)

1 Attenuation distortion

1.1 *All-analogue conditions*

The design objectives recommended for carrier terminal equipment by the Recommendation cited in [1] are such that for a chain of six circuits, each equipped with a single pair of channel translating equipments in accordance with that Recommendation, the network performance objective for the attenuation distortion given by Figure 1/G.132 will in most cases be met. The distortion contributed by the seven international centres is thereby included.

Note — To assess the attenuation distortion of the international chain, the limits indicated for international circuits in Recommendation G.151, § 1 must not be added to the limits for international centres mentioned in Recommendation Q.45 [2]. In fact, on the one hand, some exchange equipment would be counted twice if this addition were made; on the other, the specification limits of Recommendation Q.45 [2] apply to the worst possible connection through an international exchange, while the maintenance limits of Recommendation G.151, § 1 apply to the poorest international circuit. The specifications of the various equipments are such that the mean performance will be appreciably better than could be estimated by the above-mentioned addition.

1.2 *Mixed analogue/digital conditions*

In the mixed analogue/digital period, it is expected that the attenuation/frequency characteristics of the analogue carrier terminal equipment that is to be used in international telephone connections will continue to be governed by existing Recommendations that are relevant to this type of circuit.

Where unintegrated PCM digital processes are to be included in international telephone connections, it is recommended that the attenuation/frequency characteristic of the bandpass filters associated with such processes should comply with the more stringent version of Figure 1/G.712 [3]. The latter Recommendation applies specifically to cases where integrated PCM digital processes are associated with trunk junctions (toll connecting trunks), trunk circuits (intertoll trunks), and international circuits.

With regard to the incorporation of unintegrated PCM digital processes in local telephone networks, the required attenuation/frequency characteristics of the bandpass filters involved are still under study.

References

[1] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232, § 1.

[2] CCITT Recommendation *Transmission characteristics of an international exchange* , Vol. VI, Rec. Q.45.

[3] CCITT Recommendation *Performance characteristics of PCM channels between 4-wire interfaces at voice frequencies* , Vol. III, Rec. G.712, Figure 1/G.712.

Recommendation G.142

TRANSMISSION CHARACTERISTICS OF EXCHANGES

(Geneva, 1980; amended at Melbourne, 1988)

This Recommendation consists of two parts. The first part, § 1, is concerned with the voice-frequency transmission characteristics of international analogue exchanges. The information involved is encompassed within Recommendation Q.45 [1]. The second part, § 2, is concerned with the voice-frequency transmission considerations that should be taken into account in the design of digital exchanges and their incorporation into the network. The digital exchanges referred to include local exchanges and transit exchanges (national and international). The transmission considerations relate primarily to the properties which digital exchanges should possess to enable them to

operate under different and changing network conditions with respect to the content of analogue, mixed analogue/digital and all-digital plant.

Detailed transmission characteristics for digital exchanges are contained in Recommendations Q.551, Q.552, Q.553 and Q.554 (Fascicle VI.5).

1 International analogue exchange

The commissioning objectives for the transmission requirements to be respected by an international analogue exchange are included in Recommendation Q.45 or Q.45 | fIbis .

2 Digital exchanges

2.1 *Digital processes — Effect on transmission*

Digital (TDM) exchanges, to varying degrees, are required to include such digital processes as analogue-to-digital coders, digital-to-analogue decoders and digital recoding processes, examples of which are companding law converters and digital pads. The extent to which such digital processes might be included in a digital exchange is determined by the network environment in which the exchange is to operate (i.e., all-analogue, mixed analogue/digital or all-digital).

Digital processes such as those referred to above, attract transmission penalties. These penalties can be expressed in terms of ‘‘units of transmission impairment’’.

A limit is placed on the permissible accumulation of units of transmission impairment in an international telephone connection. Details of the planning rule resulting from this limit and the penalties introduced by individual digital processes are given in Recommendations G.101, § 4 and G.113, § 3.

In accordance with Recommendation G.113, § 3 it is provisionally recommended that no more than 14 units of transmission impairment be permitted to accumulate in an international connection. Of these 14 units, a maximum of 5 units could be introduced by each national extension and a maximum of 4 units by the international portion. Since one 8-bit PCM codec pair (coder and decoder) introduces 1 unit of transmission impairment, it is clear that unintegrated PCM digital processes involving analogue/digital conversions,

(e.g. codecs) or digital processes involving the recoding of information (e.g. digital pads) should not be allowed to proliferate in an uncontrolled fashion. Figure 1/G.142 shows some of the transmission paths that might be established through a digital exchange and the ''units of transmission impairment'' attributable to the digital processes in these paths.

Figure 1/G.142, p.

2.2 *Transmission loss through a digital exchange*

The 4-wire digital switching function at a digital exchange should introduce a nominal transmission loss of 0 dB. Thus, in Figure 1/G.142 (Case 1) if a 0 dBm0 sinusoidal test signal is introduced at the analogue terminals of an ideal coder connected to the input of a digital switch, a Digital Reference Sequence (DRS) should be transmitted unaltered through the switch and produce a 0 dBm0 sinusoidal signal at the analogue terminals of a decoder connected to the output of the digital switch.

Except for the transmission loss considered above (and perhaps the possible loss due to exchange wiring) all transmission losses which are to be introduced by a digital exchange, either in a digital or analogue form, are to be governed by the applicable transmission plan (see § 2.4 below).

2.3 *Relative levels*

On digital paths within an all-digital network, relative levels have no real meaning or use. However, as long as a substantial portion of the worldwide telephone network is of an analogue nature, it is necessary and useful to assign relative levels to digital exchanges.

The relative levels assigned to a digital exchange are applicable at the virtual analogue switching points of the exchange. The virtual analogue switching points are theoretical points as explained in Recommendation G.101, § 5.1. The concept of applying relative levels at the virtual analogue switching points of a digital exchange is dealt with in Recommendations G.101, § 4.2 and G.101, § 5.2.

In accordance with Recommendation G.101, § 5.2 the send relative level at an international digital exchange should be —3.5 dBr. In the case of digital exchanges in national extensions, the send relative levels should be governed by the applicable national transmission plan.

With regard to the receive relative level at a digital exchange, this level is related to the transmission loss of the circuits terminating at the exchange. In the case of an international digital exchange, it is desirable to have the receive relative level at —3.5 dBr to avoid having to introduce digital pads. But see the general Note in Recommendation G.101, § 4.2 for exceptions. In the case of national extensions, the receive relative levels, as in the case of the send relative levels, are to be determined on the basis of the applicable national transmission plan.

2.4 *Echo and stability control*

The overall echo and stability losses presented by a national extension are a function of the relevant transmission losses and, in the case of the use of 2-wire conversion circuits, the balance return loss introduced by the 2-wire/4-wire conversion circuit. Both contributions need to be considered in the design of digital local exchanges where there is generally scope for improving the echo and stability losses. Such improvements are likely to be needed as connections in digital networks will tend to have lower losses and longer delays than analogue connections with a consequent worsening in echo performance.

2.4.1 *Transmission loss contribution*

The requirements for controlling stability and echo on international connections under all-digital or mixed analogue/digital network conditions are dealt with in Recommendation G.122. In accordance with the latter Recommendation, the national extensions are to be mainly responsible for effecting this control. Arrangements for doing so are dealt with in Recommendation G.121, § 6.

Recommendation G.121, § 6 provides the framework within which individual national transmission plans are to provide for the necessary features to effect the required control. In the case of a digital 4-wire national extension (i.e., all-digital down to the local exchange but with 2-wire analogue subscriber lines), the control can be effected entirely at the local exchange. Where the national extension is to be of a mixed analogue/digital nature, the control under some national transmission plans might be distributed among the different parts of the national extension but the main burden would in general still lie with the local exchange. Figure 1/G.142 contains examples of some of the different arrangements that might be encountered at a digital exchange.

The arrangement in Case 1 of Figure 1/G.142 deals with the termination of a digital circuit at what might be a national or international digital exchange. In this particular case, the circuit is to be operated without introducing additional loss at the exchange.

The arrangement in Case 2 of Figure 1/G.142 also deals with the termination of a digital circuit at a national or international digital exchange. However, in this case, the relevant transmission plan requires that loss should be associated with the circuit at the exchange through the medium of digital pads. See § 2.6 below regarding the use of digital pads.

The arrangement in Case 3 of Figure 1/G.142 deals with the termination of a 2-wire subscriber's line at a digital local exchange. The pads designated R and T are pad symbols intended to represent loss or level adjustment made in the analogue portion. Recommendation G.121, § 6 is concerned with the appropriate choice of values for R and T.

The arrangement in Case 4 of Figure 1/G.142 is similar to that of Case 3 except that the losses R and T are shown as being provided in the digital portion. See § 2.6 below regarding the use of digital pads.

The arrangement in Cases 5, 6 and 7 of Figure 1/G.142 deals with the termination of analogue circuits at a national or international digital exchange. In Case 5, an analogue pad (L) is used to develop the required loss of the circuit in accordance with the relevant transmission plan. Case 6 is similar to Case 5 except that a digital pad (L) is used to develop the required circuit loss. Case 7 is also similar to Case 5 except that the

analogue pad (L) as well as the A/D coder and D/A decoder are provided as part of the transmission equipment associated with the circuit rather than by equipment that is built-in as part of the switching system. Although not shown in Figure 1/G.142, the A/D coders, the D/A decoders, the 2-wire/4-wire terminating units and the pads involved in Cases 2, 3 and 4 can also be provided as part of the transmission equipment on the transmission side of the exchange rather than by equipment that is built-in as part of the switching system.

2.4.2 *Balance return loss contribution*

The contribution of balance return loss to the overall echo and stability losses is illustrated in Cases 3 and 4 of Figure 1/G.142 which show the situation of 2-wire local lines terminating on a digital local exchange. The achieved balance return loss is determined by the match between the impedance presented by the 2-wire local line and customer terminating apparatus and the balancing impedance chosen for the digital exchange line card.

In many designs of digital local exchange there is no 2-wire switch and the 2-wire line is permanently connected to the line card. This arrangement has significant advantages for balance return loss as there is likely to be a significant reduction in the range of impedances presented to any single line card. It is then possible to choose a line card balancing impedance more closely matched to the local line impedances and obtain an improvement in balance return loss compared with the conventional compromise impedances.

The optimum balancing impedance will not be the same for all Administrations as it needs to take into account the local cable types used together with the range of customer apparatus impedances. It is possible that the use of different exchange balancing impedances for different local line classes will give an improvement in performance at the expense of some increase in network Administration. In general it has been found that the use of balancing networks which resemble the impedance presented by local cable give the optimum performance. Examples of balancing impedances adopted by a number of Administrations are given in Recommendation Q.552.

Further improvement in balance return loss is possible where the impedance of the customer apparatus can be influenced by the Administration. Telephone instruments with an input impedance close to the impedance of the local cable can result in an improvement in the balance return loss at the digital local exchange in the order of 10 dB on short local lines.

2.5 *Local transmission*

On local calls between subscribers served by the same digital local exchange , the switching of 2-wire subscriber lines such as those shown in Figure 1/G.142, Case 3, results in an equipment arrangement which takes on the appearance of a voice-frequency repeater — see Figure 2/G.142. As is well known, such an arrangement must include sufficient loss around the loop to provide for an adequate margin of stability. To provide for this loss, some 2-wire to 2-wire attenuation may be acceptable in some cases. The attenuation might be supported by the national transmission plan, as it provides adequate loudness rating distribution for local calls. However, in cases where the 2-wire to 2-wire attenuation is to be comparable to that generally prevailing at an analogue exchange, i.e., approximately 0 dB, adequate balance return losses must be provided at the 2-wire/4-wire junctions. This could entail increasing the existing values of balance return loss at these points. Methods for doing this are under study by Study Group XII.

Increasing the balance return losses as referred to above should also be beneficial to the control of echo and stability in national connections beyond the local exchange as well as on international connections.

Figure 2/G.142, p.

2.6 *Sidetone and input impedance*

Digital local exchanges can have a significant influence on the sidetone performance of telephone instruments, particularly those instruments on relatively short local lines. The reason for this can be seen in Figure 2/G.142 where the impedance presented by the exchange to the local line is a function of the input impedance of the line card and the characteristics of the singing and echo path within the exchange.

For optimum sidetone performance on short local lines the input impedance of the exchange line card should be close to the anti-sidetone impedance of the telephone instrument. In the case where the telephone instrument is designed to give good sidetone performance on long local lines this anti-sidetone impedance is likely to be close to the characteristic impedance of the 2-wire local cable. This would lead to the digital local exchange also presenting an impedance close to that of the 2-wire local cable.

On longer local lines the exchange impedance will have less effect on the sidetone performance as the impedance presented to the telephone is masked by the local cable impedance.

The final choice of exchange impedance needs to take into account a number of factors:

— telephone set impedance and sensitivity characteristics;

— local line network characteristics;

— digital exchange current feeding arrangements,

the objective being that the customer should not see a worsening in sidetone performance when connected to a digital exchange. The impedance chosen by a number of Administrations are given in Recommendation Q.552 and it is clear that there is a considerable difference between the impedances which reflects the differences between the national networks.

2.7 *Digital pads*

The use of a digital pad to produce the required transmission loss in a digital path attracts a transmission penalty. This penalty has to come out of the allowance of ‘‘units of transmission impairment’’ allotted to the national and international portions of international connections — see Recommendation G.113, § 3. Additionally, since digital pads involve the use of digital recoding processes, the use of such pads in paths where bit integrity must be preserved is unattractive. This can be an important consideration where multipurpose networks are contemplated. Consequently, if digital pads must be introduced, arrangements should be made to switch them out or to bypass them.

2.8 *Transmission delay*

Transmission delays through digital exchanges could be significant. For example, such delays could have the effect of decreasing the length of connections on which echo control devices (e.g., echo suppressors or echo cancellers) should be applied. Transmission delays at digital local exchanges (or at digital PBXs) could in some cases also affect the impedance match between subscriber lines and the exchange (or PBX) in a way that could adversely affect subscriber sidetone. Transmission delays through digital exchanges should, therefore be minimized. See Recommendation G.114, § 2 for details of the delay introduced by various items of digital equipment and systems.

For transmission delays that might be encountered at digital exchanges; see Recommendation Q.551.

Reference

[1] CCITT Recommendation *Transmission characteristics of an international exchange* , Vol. VI, Rec. Q.45.

Recommendation G.143

CIRCUIT NOISE AND THE USE OF COMPANDORS

(Geneva, 1964; amended at Mar del Plata, 1968;

Geneva, 1972 and 1980 and Malaga-Torremolinos, 1984)

1 Noise objectives for telephony

1.1 *Principle*

Taking into account the network performance objectives for noise allowed in national networks (Recommendation G.123), it is desirable that the circuit performance objective for the mean psophometric power in any hour of the total noise generated by a chain of six international circuits, some of which may exceed 2500 km in length, on a connection used for international telephone calls, should not exceed 50 | 00 picowatts referred to a zero relative level point of the first circuit in the chain (level —43 dBm0p).

Of course, a lower value of the total noise may be expected when the international chain consists of only a small number of international circuits, not exceeding 2500 km in length and conforming to Recommendation G.152 (in particular, the circuit performance objective for the noise of such circuits is that the mean psophometric power in any hour does not exceed 10 | 00 pW at a zero level point on the circuit, level —50 dBm0p).

However, as connections longer than 25 | 00 km will be set up, the CCITT recommends, as an objective, that on sections longer than 2500 km used for international traffic, line equipment be supplied with a circuit performance objective for noise not greatly exceeding L picowatts on a circuit L km long (see [1]). There is obvious advantage in working to the same standard on short sections when this can reasonably be done.

Note 1 — Noise objectives for maintenance purposes are the subject of Recommendation M.580 [2]. Table 4/M.580 of that Recommendation is reproduced here:

H.T. [T1.143]

TABLE 4/M.580

Maintenance noise objectives for public telephone circuits

Distance (km)	< | 20	321 to 640	641 to 1600	1601 to 2500	2501 to 5000	5001 to 10 | 00	10 | 01 to 20 | 00
Noise (dBm0p)	—55	—53	—51	—49	—46	—43	—40

Table 4/M.580 [T1.143], p.

Note 2 — Strictly speaking, the noise objective for communication-satellite systems (see Recommendation G.153, § 3) cannot be expressed in the form of a given number of picowatts per km. See also the Note of Recommendation M.580 [2].

1.2 *Noise produced by equipment*

The equipment design objective for noise produced by the modulating equipment in the international chain of circuits in the longest hypothetical reference connection (see Figure 1/G.103) can be estimated on the assumption that such equipment comprises:

— 6 channel-modulation pairs, or 8 to 10 if 3-kHz-spaced channel equipment is used on transoceanic routes;

— 12 to 14 group-modulation pairs;

— 18 to 24 supergroup-modulation pairs;

for all of which a total circuit performance for the combined psophometric power of 5000 to 7000 pW0p (at a point of zero relative level on the first circuit of the international chain of 4-wire circuits) is a generous assumption.

The equipment design objective of —67 dBm0p for the hourly-mean psophometric power level at each international switching point quoted in Recommendation Q.45 [3] is equivalent to about 2000 pW0p at a point of zero relative level on the first circuit in the 4-wire chain.

It may thus be seen that the equipment design objective for the noise produced by the equipment does not constitute a large part of the network performance objective for the total noise generated by the international chain.

1.3 *Division of the overall circuit performance objective for noise*

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

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

1.4 *Circuits operated with speech concentrators*

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

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

2 Use of syllabic compandors ' '

For many years, international (and national) circuits will continue to be provided on existing transmission systems which have been designed to other standards, e.g. 4 pW/km, as given in Recommendation | .152. Furthermore, the circuit noise produced by transmission systems can increase above the values originally achieved because of ageing effects, and changes of system loading. There is therefore a need for a simple practical criterion that can be applied for planning purposes to an international circuit to

determine if, as far as noise power is concerned, it is suitable for establishing multicircuit worldwide telephone connections or whether it can be made suitable by fitting compandors

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

Compandors conforming to Recommendation G.166 may be used in the network provided planning is done to minimize the number of compandored circuits in tandem. It is desirable to have at most one compandored circuit in a connection. Preliminary results obtained by one Administration indicate that for voice operation no more than three compandored circuits in tandem should be allowed. Some high speed modems (9.6 kbit/s) may experience difficulty on a connection with even one compandored circuit. To ensure compliance not more than one compandored circuit should be used in the international segment. Additional information is required before a firm planning rule can be established including possible application in national extensions on circuits with moderate noise levels.

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

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

If the hourly-mean psophometric circuit noise power level of an international circuit substantially longer than 2500 km (e.g. 5000 km or more) is less than —44 dBm0p (at a point of zero relative level on the circuit) no compandor is necessary.

If the circuit noise power level is —44 dBm0p (40 | 00 pW0p) or greater, a compandor should be fitted.

It is, of course, to be understood that circuits of length 2500 km or less will always meet the appropriate general noise objectives (Recommendation G.222 [4]) without the need for compandors.

Note 1 — This rule has been devised to make possible the planning of the international telephone network, using presently available circuits. It should in no way be interpreted as relaxation of the design objectives recommended in § 1 of this Recommendation, nor should it be applied for maintenance purposes (see Note 1 of § 1.1 above).

Note 2 — The compandors used should conform to the limits proposed in Recommendation G.162 or in Recommendation G.166.

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

For characteristics of syllabic compandors for telephony on high capacity long distance systems, see Recommendation G.166.

See Annex A for further considerations relating to the use of syllabic compandors.

Note 3 — In accordance with the Recommendation cited in [5], circuits with a noise power level of —37 dBm0p or worse are removed from service.

3 Noise limits for telegraphy

Noise limits for telegraphy are given in Recommendation H.22 [6].

4 Noise limits for data transmission

The following objectives are acceptable for data transmission at data signalling rates not exceeding 1200 bit/s. It is expected that the values actually experienced on many circuits and connections will be better than the following limits.

4.1 *Leased circuits for data transmission*

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

4.2 *Switched connections*

For switched connections a limit of, say, —36 dBm0p without compandors may be taken for interconti nental circuits on which compandors may be used.

ANNEX A
(to Recommendation G.143)

Additional considerations relating to the use of syllabic compandors

(The following information was available from Study Group XII)

This annex addresses compandor advantage in § A.1, followed by a recommendation of the permissible advantage limits for planning purposes (§ A.2). A requirement of circuit stability between compressor and expander is given in § A.3, and §§ A.4 and A.5 deals with aspects of system loading and companded circuits in tandem.

A.1 *Compandor advantage*

To define **compandor advantage** , assume:

a) an international circuit not equipped with compandors and contributing *N* dBm0 of noise to the overall end-to-end connection (including typical national extensions) and meeting the noise objectives of Recommendation G.152 or Recommendation G.153, and

b) the same international circuit equipped with compandors and connected to typical national extensions, yielding the noise performance subjectively equivalent to or better than that of the circuit described in a), while contributing *N* ‘ dBm0 of noise in between compressor and expander.

Then the compandor advantage for the international circuit of b) is defined as (*N* ‘ — *N*) dB.

A.2 *Compandor advantage limit*

For planning purposes, the compandor advantage defined in § A.1 should not exceed 10 dB.

Note — It should be emphasized that this value applies to the international portion of the connection only. Other portions of the connection could permit a higher value when selected with due regard to the effect it has on the total noise of the end-to-end connection during the presence of the signal.

A.3 *Circuit stability*

The international circuit between compressor and expander should have an insertion loss which, when considered over a long period of time, has a standard deviation not exceeding 0.75 dB.

A.4 *Circuit loading*

It is generally advisable to select the unaffected level of the compandor equal to —10 dBm0. However, if Administrations mutually desire to operate at a different value of unaffected level, it should be selected such

that it results in a system loading which minimizes total distortion due to noise, intermodulation, or other load-dependent characterisics and should always be dictated by the allowable compandor advantage limit.

A.5 *Compandored circuits in tandem*

The following paragraphs apply to circuits fitted with compandors according to Recommendation G.162.

Results of experiments with compandored circuit links in tandem show that two compandored links in tandem can produce a noticeable degradation only if the second link exceeds, by a considerable margin, the recommended compandor advantage limit of 10 dB. The experiment was admittedly designed to uncover gross effects by limiting the subjective judgement to only seven persons per test condition.

The conclusion drawn was that two links in tandem, each of which is limited to 10 dB compandor advantage, will not pose a restriction to users. This however, does not constitute sufficient guidance for application for the number of compandored links permissible in an end-to-end international connection.

References

[1] CCITT *Red Book* , Vol. V **|** fIbis , Annexes B and C, ITU, Geneva, 1965.

[2] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony* , Vol. IV, Rec. M.580.

[3] CCITT Recommendation *Transmission characteristics of an international exchange* , Vol. VI, Rec. Q.45.

[4] CCITT Recommendation *Noise objectives for design of carrier-transmission systems of 2500 km* , Vol. III, Rec. G.222.

[5] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony* , Vol. IV, Rec. M.580, § 6.

[6] CCITT Recommendation *Transmission requirements of international voice-frequency telegraph links (at 50, 100 and 200 bauds)* , Vol. III, Rec. H.22.

1.5 General characteristics of international telephone circuits and national extension circuits

Recommendation G.151

GENERAL PERFORMANCE OBJECTIVES APPLICABLE TO ALL MODERN INTERNATIONAL CIRCUITS AND NATIONAL EXTENSION CIRCUITS

(Geneva, 1964; amended at Mar del Plata, 1968 and Geneva, 1972 and 1980)

1 Attenuation distortion

The circuit performance objectives for attenuation distortion of international circuits and national extension circuits should individually be such that the network performance objectives of Recommendation G.132 are complied with.

Recommendation G.232 [1] gives equipment design objectives.

It follows from the Recommendations mentioned above that, as a rule, the frequency band effectively transmitted by a telephone circuit, according to the definition adopted by the CCITT (i.e. the band in which the attenuation distortion does not exceed 9 dB compared with the value for 800 Hz), will be a little wider than the 300-3400 Hz band, and for a single pair of channel terminal equipments of this type, the attenuation distortion at 300 Hz and 3400 Hz should never exceed 3 dB and in a large number of equipments should not average more than 1.7 dB (see Graphs A and B in Figure 1/G.232 [2]). Even more complex circuits, and circuits using terminal equipments with 3-kHz-channel spacing in accordance with Recommendation G.235 [3], should satisfy the limits in Figure 1/G.151; to ensure that these limits are respected, equalizers are inserted, if necessary, when the circuits are set up (Recommendation M.580 [4]).

Figure 1/G.151, p.

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

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

2) However, such an extension would probably have the following disadvantages:

a) it would slightly increase the cost of equipment;

b) it would introduce some difficulties in balancing the terminating sets at the ends of the 4-wire chain, if it were desired to use 4-wire circuits without exceeding the values of nominal transmission loss recommended in the new transmission plan;

c) it would increase the possible susceptibility to interference, whether as subjective noise or as disturbances interfering with carrier equipment (see the Recommendation cited in [5]) or affecting compandor gain;

d) the additional energy transmitted in consequence of extending the band could increase the loading of carrier systems;

e) the out-of-band signalling systems recognized by the CCITT could not be used.

In view of the above, the CCITT has issued the aforementioned Recommendations concerning signals transmitted at frequencies between 300 and 3400 Hz.

Note 2 — In applying the Recommendations, Administrations may mutually agree to transmit signals at frequencies below 300 Hz over international circuits. Every Administration may, of course, decide to transmit signals at frequencies below 300 Hz over its national extension circuits, provided it is still able to apply the CCITT transmission plan to international communications.

2 Group delay

The group-delay performance objectives of international circuits and national extension circuits should be such that the network performance objectives of Recommendations G.114 and G.133 are met.

3 Variations of transmission loss with time

The CCITT recommends the following circuit performance objectives [objective a) has been used to assess the stability of international connections — see Recommendation G.131, § 1]:

a) The standard deviation of the variation in transmission loss of a circuit should not exceed 1 dB. This objective can be obtained already for circuits on a single group link equipped with automatic regulation and should be obtained for each national circuit, whether regulated or not. The standard deviation should not exceed 1.5 dB for other international circuits.

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

4 Linear crosstalk

4.1 *Between circuits*

The circuit performance objective for the near-end or far-end crosstalk ratio (intelligible crosstalk only) measured at audio-frequency at trunk exchanges between two complete circuits in terminal service position should not be less than 65 dB.

Note 1 — When a minimum noise level of at least 4000 pW0p is always present in a system (e.g. this may be the case in satellite systems, for example) a reduced crosstalk ratio of 58 dB between circuits is acceptable.

Note 2 — Coaxial pair cables complying with Recommendations G.622 [6] and G.623 [7] already allow this condition to be fulfilled if it is assumed that the frequency bands for which crosstalk is caused by the cable and those for which crosstalk is due to the

The methods recommended for measuring crosstalk are described in Annex A to Recommendation G.134.

equipments are not the same. On the other hand FDM systems on symmetric pair cables do not always allow a limit more stringent than 58 dB to be met.

Note 3 — In cases where the length of a homogeneous section of a real transmission system substantially exceeds the length of a homogeneous section of the HRC, the 65 dB limit may not be met in all cases for all the channels in the system.

4.2 *Between the go and return channels of a 4-wire circuit*

4.2.1 *Ordinary telephone circuit* (see Note 1 below)

Since all ordinary telephone circuits may also be used as VF telegraph bearers, the circuit performance objective for the near-end crosstalk ratio between the two directions of transmission should be at least 43 dB.

4.2.2 *Circuits used with a speech concentrator*

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

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

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

Note 1 — Telephone circuits which are not equipped with (or used in conjunction with) modern echo suppressors designed for long propagation times are referred to in § 4.2.1 above. Circuits which can form part of switched connections with a long propagation time and which then lie between terminal half-echo suppressors of modern design should, wherever possible, conform to the higher standards given in this § 4.2.3.

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

Speech concentrators

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

Echo suppressors

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

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

3) More than one circuit between the suppressors: this occurs when intermediate adjacent half-echo suppressors are switched out (or disabled) and the go-to-return crosstalk arises in a fashion analogous to that described in 2) above, circuits replacing circuit sections.

Note 3 — If channel equipments just conforming to the Recommendation cited in [8] are used on a circuit comprising three circuit sections, then assuming r.m.s. addition of crosstalk paths the crosstalk ratio would be approximately 60 dB.

Note 4 — If channel equipments used on a circuit comprising three circuit sections just comply with the Recommendation cited in [9], then the least go-to-return crosstalk ratio, assuming r.m.s. addition of the various paths, would be approximately 56 dB which is 2 dB less than is required for speech concentrators in § 4.2.2 above. However, the assumptions are most pessimistic and there is not likely to be any difficulty in practice. The limit for echo suppressor in § 4.2.3 above is complied with.

Note 5 — Some types of symmetrical-pair line transmission systems introduce significantly low go-to-return crosstalk ratios on the derived circuits and wherever possible such systems should not be used to provide circuits or circuit sections for use with speech concentrators or modern echo suppressors.

Note 6 — Some attention must be given to the unbalance of the audio parts of FDM channel equipments if the crosstalk of 65 dB is not to be diminished by crosstalk in station cabling due to unbalanced cable terminating equipment.

5 Nonlinear distortion

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

Note — In carrier telephone circuits, the nonlinear distortion produced by the line amplifiers and by modulation stages other than the

channel-translating equipment can be ignored. Hence the above remarks are applicable to circuits of any length.

6 Error on the reconstituted frequency

See Recommendation G.135.

7 Interference at harmonics from the mains and other low frequencies

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

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

Note 2 — For limits applicable to sound-programme circuits, see the Recommendation cited in [10].

Note 3 — The main causes of interference due to power sources are:

a) residual ripples at the terminals of d.c. supply which are directly transmitted to equipments through the power-fed circuits;

b) the a.c. to the dependent power-fed stations in some systems, which interferes through the power-separating filter or through the iron tapes of coaxial pairs;

c) the induction voltages in the d.c. supply line to power-fed dependent stations in some systems;

d) the amplitude and phase unwanted modulations of the various carriers due to cause a) which are increased in the frequency-multiplying equipments.

Note 4 — The effect of the modulation process is that an input signal of frequency f Hz will produce, for example, corresponding output signals at frequencies f, $f \pm 50$, $f \pm 100$, $f \pm 150$ Hz, etc.

8 Single tone interference in telephone circuits

The single tone interference level in a telephone circuit should not be higher than —73 dBm0p (provisional value, pending the conclusion of studies by Study Group XII). Psophometric weighting should only be accounted for when the frequency of the interference is well defined.

References

[1] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232.

[2] *Ibid.* , Figure 1/G.232, Graphs A and B.

[3] CCITT Recommendation *16-channel terminal equipments* , Vol. III, Rec. G.235.

[4] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony* , Vol. IV, Rec. M.580.

[5] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232, § 6.

[6] CCITT Recommendation *Characteristics of 1.2/4.4-mm coaxial cable pairs* , Vol. III, Rec. G.622.

[7] CCITT Recommendation *Characteristics of 2.6/9.5-mm coaxial cable pairs* , Vol. III, Rec. G.623.

[8] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232, § 9.1.

[9] *Ibid.* , § 9.3.

[10] CCITT Recommendation *Performance characteristics of 15-kHz type sound-programme circuits* , Vol. III, Rec. J.21, § 3.1.7.

Recommendation G.152

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

(Geneva, 1964; amended at Mar del Plata, 1968 and Geneva, 1972 and 1980)

This Recommendation applies to all modern international circuits not more than 2500 km in length. It also applies to national trunk circuits in an average-size country, and which may be used in the 4-wire chain of an international connection.

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

1 Circuits on land or submarine cable systems or on line-of-sight radio-relay systems

The circuits in question are mostly set up in cable or radio-relay link carrier systems, such that the noise objectives of Recommendation G.222 [1] are applicable to a circuit with the same make-up as the hypothetical reference circuit 2500-km long.

A consequence of Recommendation G.222 [1] is that, for a circuit L -km long (L 2500 km), the circuit performance objective for the mean psophometric noise power during any hour should be of the order of $4L$ picowatts, excluding very short circuits and those with a very complicated composition, this latter case being dealt with in Recommendation G.226 [2].

2 Circuits on tropospheric-scatter radio-relay systems

The CCIR has defined a hypothetical reference circuit and fixed circuit performance objectives in its Recommendations 396 [3] and 397 [4] respectively.

3 Circuits on open-wire carrier systems

The Recommendation cited in [5] contains relevant noise objectives.

Note — Recommendation M.580 [6] deals with noise objectives for maintenance purposes. See Note 1 of Recommendation G.143, § 1.1.

References

[1] CCITT Recommendation *Noise objectives for design of carrier-transmission systems of 2500 km* , Vol. III, Rec. G.222.

[2] CCITT Recommendation *Noise on a real link* , Vol. III, Rec. G.226.

[3] CCIR Recommendation *Hypothetical reference circuit for trans-horizon radio-relay systems for telephony using frequency-division multiplex* , Vol. IX, Rec. 396, ITU, Geneva, 1986.

[4] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit of trans-horizon radio-relay systems for telephony using frequency-division multiplex* , Vol. IX, Rec. 397, ITU, Geneva, 1986.

[5] CCITT Recommendation *General characteristics of systems providing 12 carrier telephone circuits on an open-wire pair* , Vol. III, Rec. G.311, § 8.

[6] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony* , Vol. IV, Rec. M.580.

Recommendation G.153

CHARACTERISTICS APPROPRIATE TO INTERNATIONAL CIRCUITS

MORE THAN 2500 KM IN LENGTH

(Geneva, 1964; amended at Mar del Plata, 1968, and Geneva, 1972 and 1980)

These circuits should meet the general requirements set forth in Recommendation G.151 and should, in addition, according to the kind of system on which they are set up, meet the particular provisions of §§ 1, 2, 3 and 4 below.

Note 1 — Some circuits which do not meet the noise objectives specified in the present Recommendation can nevertheless be used for telephony (if they are fitted with compandors), telegraphy or data transmission (§§ 2, 3 and 4 of Recommendation G.143; Table 1/G.153 summarizes these Recommendations).

Note 2 — Recommendation M.580 [1] deals with noise objectives for maintenance purposes. See Note 1 of Recommendation G.143, § 1.1).

1 Circuits more than 2500 km in length on cable or radio-relay systems, with no long submarine cable section

In many cases circuits of this kind, between 2500 km and about 25 | 00 km long will, throughout most of their length, be carried in land-cable systems or radio-relay systems already used to give international circuits not more than 2500 km long, and designed on the basis of the objectives already recommended for such systems in Recommendation G.222 [3].

Moreover, it is unlikely that the number of channel demodulations will exceed that envisaged in the corresponding part of the longest international connection referred to in Recommendation G.103. There will also be cases where it will be possible to establish such circuits on systems designed on the basis of national hypothetical reference circuits of the type referred to in the Recommendation cited in [4]. This being so, the CCITT issues the following recommendations:

1.1 *Variations in transmission loss with time*

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

1.2 *Performance objectives for circuit noise*

It is provisionally recommended that systems to provide such international circuits not more than 25 | 00 km long should be designed on the basis of the noise objectives at present recommended for 2500-km hypothetical reference circuits.

H.T. [T1.153]

TABLE 1/G.153

Noise objectives or limits | ua) **for very long circuits providing various services** | ub)

Psophometric power pW0p	dBm0p	Type of objective or limit	
		For a connection, a chain of circuits, or a leased circuit	For a circuit which may form part of a switched connection
40 | 00	—44		Limit for a telephone circuit used without a compandor (Recommendation G.143, § 2)
50 | 00	—43	Objective for a chain of 6 international circuits, obtained in practice by a combination of circuits with circuit performance objectives of 1, 2 or 4 pW/km (Recommendation G.143, § 1)	
80 | 00	—41	Limit for FM VF telegraphy, in accordance with CCITT standards (Recommendation H.22 | 2])	
100 | 00	—40	Limit for data transmission over a leased circuit (Recommendation G.143, § 4.1)	
250 | 00	—36		Acceptable for data transmission over the switched network (Recommendation G.143, § 4.2). A circuit exceeding this limit without a compandor cannot be used in a chain of 6 telephone circuits, even if it is equipped with a compandor (Recommendation G.143, § 2)
10^6	—30	Tolerable for a certain system of synchronous telegraphy (Recommendation H.22 | 2])	

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

b) The noise limits are determined according to the minimum performance requirements of each service. The noise objectives are commissioning objectives for various transmission systems.

TABLE 1/G.153 [T1.153], p.

Whenever possible lower noise objectives should be sought and it is recognized that in some large countries systems forming part of a circuit substantially longer than 2500 km (e.g. 5000 km) are constructed according

to the principles referred to in the Recommendation cited in [4]. Alternatively lower noise figures can be obtained by a suitable choice of telephone channels making up the circuits. Provisionally the short-term noise performance objectives for circuits of this kind of length up to about 7500 km are as follows:

The one-minute mean noise power shall not exceed 50 | 00 pW (—43 dBm0p) for more than 0.3% of any month and the unweighted noise power, measured or calculated with an integrating time of 5 ms, shall not exceed 10^6 pW (—30 dBm0) for more than 0.03% of any month. It is to be understood that these objectives are derived pro rata from the objectives for circuits of 2500 km length (Recommendation G.222 [3]); for lengths between 2500 and 7500 km proportionate intermediate values should apply.

The CCITT is not yet able to recommend objectives for short-term noise performance on circuits of the above type which exceed 7500 km in length.

2 Circuits more than 2500 km with a long submarine cable section

2.1 *Attenuation distortion*

A circuit of this kind may, for reasons of economy, comprise terminal equipments with carriers spaced 3 kHz apart, in accordance with Recommendation G.235 [5].

If terminal equipment be used with carrier spacing of 4 kHz, it must at least meet the requirements of Recommendation G.232 [6]. Some countries use improved terminal equipment in circuits permanently used for intercontinental operation.

2.2 *Performance objectives for circuit noise attributable to the submarine cable section*

2.2.1 *Without compandor*

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

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

2.2.2 *With compandor*

At present, the CCITT does not propose to study systems which, by relying on the *systematic* use of compandors, have noise objectives which are greatly different from those of § 2.2.1 above.

2.3 *Performance objectives for circuit noise attributable to other sections*

The other sections of the circuit should comply with the recommendations given in § 1 of this Recommendation.

3 Circuits on communication-satellite systems

The CCIR and the CCITT are considering the extent to which circuits set up on communication-satellite systems may be integrated into the worldwide network; some of the limitations on the use of such circuits are outlined in Recommendation Q.13 [7].

The CCIR has made recommendations as far as circuit noise is concerned and has defined a hypothetical reference circuit (CCIR Recommendation 352 [8]) and the allowable noise power in this reference circuit (CCIR Recommendation 353 [9]).

4 Circuits more than 2500 km in length set up on open-wire lines

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See footnote 2) in Recommendation G.143, § 2.

Paragraph 4 is not published in this Book, but can be found under Part D of Recommendation G.153, *Orange Book* , ITU, Geneva, 1977.

References

[1] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony* , Vol. IV, Rec. M.580.

[2] CCITT Recommendation *Transmission requirements of international voice-frequency telegraph links (at 50, 100 and 200 bauds)* , Vol. III, Rec. H.22.

[3] CCITT Recommendation *Noise objectives for design of carrier-transmission systems of 2500 km* , Vol. III, Rec. G.222.

[4] *Ibid.* , § 3.

[5] CCITT Recommendation *16-channel terminal equipments* , Vol. III, Rec. G.235.

[6] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232.

[7] CCITT Recommendation *The international routing plan* , Vol. VI, Rec. Q.13.

[8] CCIR Recommendation *Hypothetical reference circuits for telephony and television in the fixed satellite service* , Vol. IV, Rec. 352, ITU, Geneva, 1986.

[9] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit for frequency-division multiplex telephony in the fixed satellite service* , Vol. IV, Rec. 353, ITU, Geneva, 1986.

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