INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

YELLOW BOOK

VOLUME III - FASCICLE III.1

GENERAL CHARACTERISTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS

RECOMMENDATIONS G.101-G.171

VII^TH PLENARY ASSEMBLY
GENEVA, 10-21 NOVEMBER 1980

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[1] "Telematic services" is used provisionally.

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[1] "Telematic services" is used provisionally.

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Part I – Recommendations G.101 to G.171

General characteristics of international telephone connections and circuits

REMARKS

1 The Questions entrusted to each Study Group for the Study Period 1981-1984 can be found in Contribution No. 1 to that Study Group.

2 It is indicated (immediately after the titles of Recommendations or Supplements) whether the texts are new ones approved by the Plenary Assembly of Geneva, 1976 or are texts amended at the same period. Texts without any such indication date from at least as far back as the Plenary Assembly of New Delhi, 1960, when Volume III was divided into numbered Recommendations; certain of these tests may be even older.

3 *Units*

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

dBm the absolute (power) level in decibels;

dBm0 the absolute (power) level in decibels referred to a point of zero relative level;

dBr the relative (power) level in decibels;

dBm0p the absolute psophometric power level in decibels referred to a point of zero relative level.

CCITT NOTE

In this Fascicle, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

PART I

Recommendations G.101 to G.171

GENERAL CHARACTERISTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS

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SECTION 1

GENERAL CHARACTERISTICS FOR INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

1.0 General

Recommendation G.101

THE TRANSMISSION PLAN [1]

(Geneva, 1964; amended at Mar del Plata, 1968, Geneva, 1972, 1976 and 1980)

1 **Principles** (formerly Part A)

The transmission plan of the CCITT established in 1964 was drawn up with the object of making use, in the international service, of the advantages offered by 4-wire switching. It is referred to in the Recommendations appearing in Part I, Section 1 of the Series G Recommendations. However, the recommendations in the plan are to be considered as met if the use of technical means other than those described below gives an equivalent performance at the international exchange.

Recommendations G.121 and G.122 describe the conditions to be fulfilled by a national network for this transmission plan to be put into effect.

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

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

Note 3 – The Appendix to the present Section 1 of the Series G Recommendations contains the justification for the values of corrected reference equivalents appearing in Recommendations G.111 and G.121.

2 **Definition of the constituent parts of a connection** (formerly Part B)

2.1 *The international chain and the national systems*

A complete **international telephone connection** consists of three parts, as shown in Figure 1/G.101.

- An international chain made up of one or more 4-wire international circuits. These are interconnected on a 4-wire basis in the international transit centres and are also connected on a 4-wire basis to national systems in the international centres.
- Two national systems, one at each end. These may comprise one or more 4-wire national trunk circuits with 4-wire interconnection, as well as circuits with 2-wire connection up to the terminal exchanges and to the subscribers.

[1] This Recommendation is partly reproduced in Recommendation Q.40 [1].

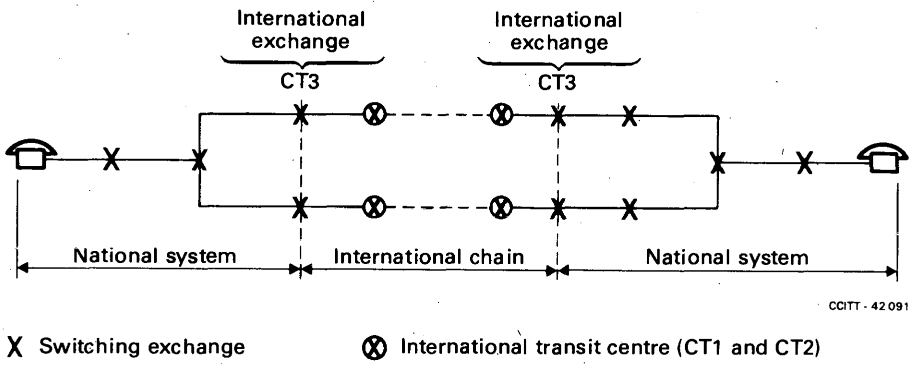


FIGURE 1/G.101

Definition of the constituent parts of an international connection

A 4-wire circuit is defined by its **virtual analogue switching points** in an international transit exchange or an international exchange. These are theoretical points with specified relative levels (see Figure 2/G.101; for further details see § 5 of this Recommendation).

The difference between the sending and receiving nominal relative levels at the reference frequency is, by definition, *the nominal transmission loss* of the 4-wire circuit *between virtual analogue switching points*.

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

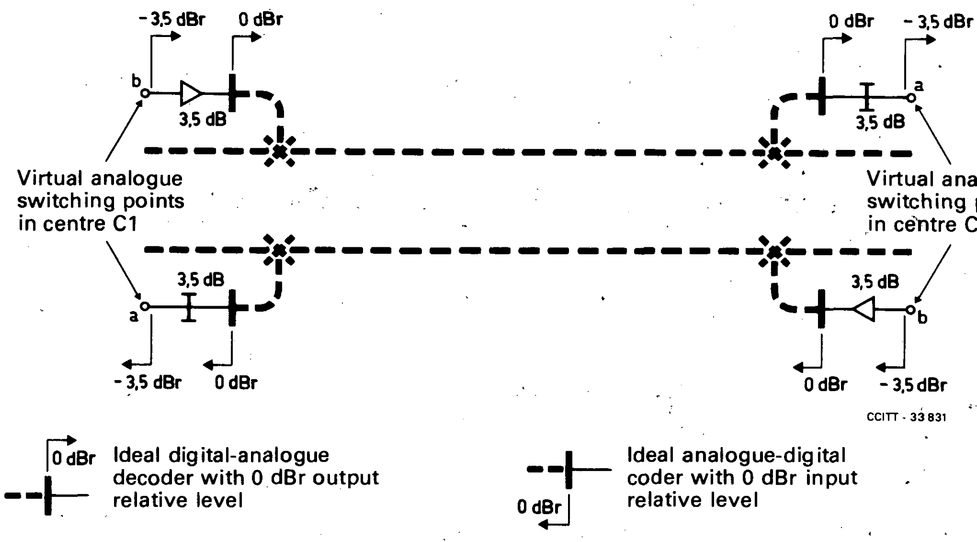
The virtual analogue switching points may not be the same as the points at which the circuit terminates physically in the switching equipment. These latter points are known as the *circuit terminals*; the exact position of these terminals is decided in each case by the Administration concerned.

2.2 *National extension circuits: 4-wire chain*

When the maximum distance between an international exchange and a subscriber who can be reached from it does not exceed about 1000 km or, exceptionally, 1500 km, the country concerned is considered as of average size. In such countries, in most cases, not more than three national circuits are interconnected on a 4-wire basis between each other and to international circuits. These circuits should comply with the Recommendations of Subsection 1.2.

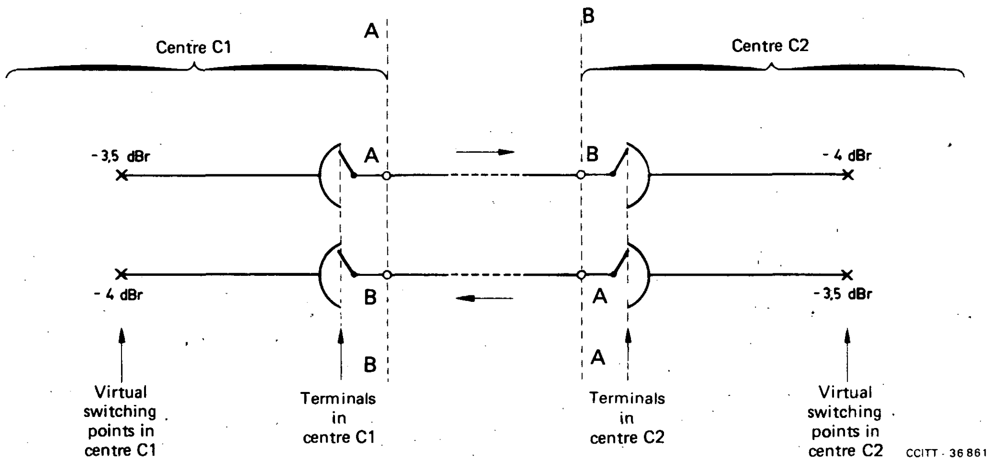
In a large country, a fourth and possibly a fifth national circuit may be included in the 4-wire chain, provided it has the nominal transmission loss and the characteristics recommended for international circuits used in a 4-wire chain (see Recommendation G.141, § 1, § 4 of this Recommendation and the Recommendations in Subsection 1.5).

Note – The abbreviation "a **4-wire chain**" (see Figure 3/G.101) signifies the chain composed of the international chain and the national extension circuits connected to it, either by 4-wire switching or by some equivalent procedure (as understood in § 1 above).



Note – Ideal coders and decoders are assumed to show a relation between analogue and digital signals and vice versa exactly in accordance with the appropriate tables for A-law or μ-law of Recommendation G.711 [2].

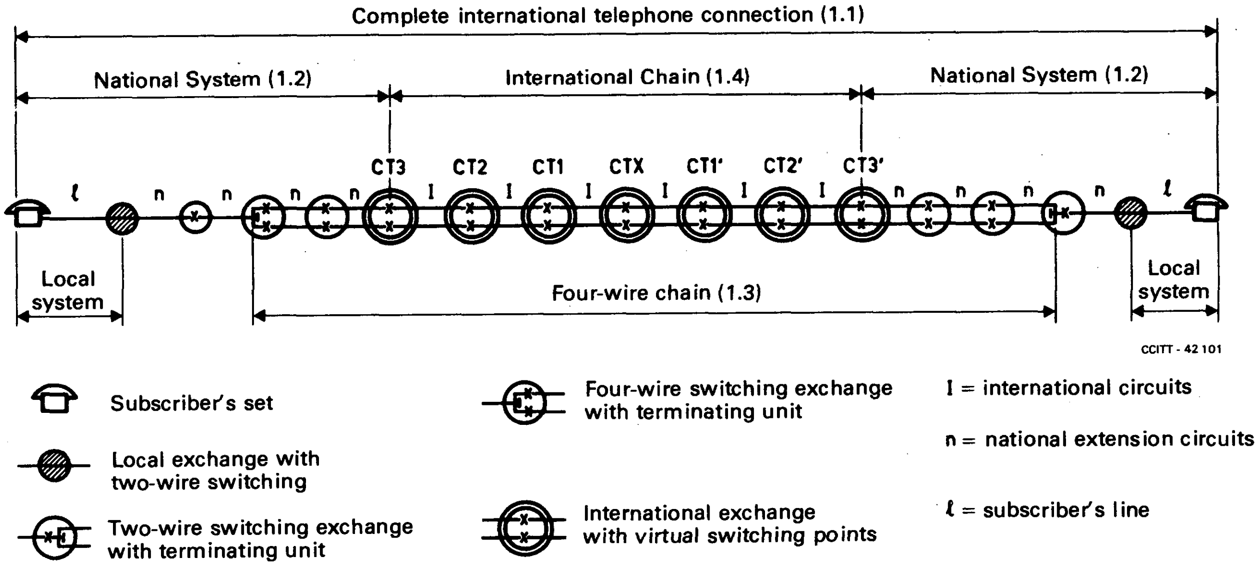
a) *Definition of virtual analogue switching points for a digital international circuit between digital international centres*



b) *Definition of virtual analogue switching points for an analogue international circuit between analogue international centres*

FIGURE 2/G.101

Definitions for international circuits



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

FIGURE 3/G.101
An international connection to illustrate the nomenclature adopted

3 **Number of circuits in a connection** (formerly Part C)

3.1 *National circuits*

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

In most modern national networks, the four circuits will probably include three 4-wire amplified circuits (usually set up on carrier systems) and one 2-wire circuit, probably unamplified. In some instances, however, local exchanges will be reached by four circuits, all of which may be 4-wire circuits.

The representative maximum international connection considered by the CCITT for the study of transmission performance (see Figure 3/G.101 and Figure 1/G.103) thus includes eight national circuits, besides the international ones. The cumulative distortion of these eight circuits is likely to be large, and close to the maximum allowable value. Consequently, the international circuits must not introduce any further appreciable deterioration. This principle has been borne in mind during the drafting of the Recommendations dealing with such circuits.

3.2 *International circuits*

Implementation of the routing plan for automatic and semi-automatic international telephone traffic (Recommendation Q.13 [3]) presupposes that the transmission plan is applied. In the routing plan, the CCITT has defined three classes of international centres, CT1, CT2 and CT3. In order to meet the network performance objectives, the CCITT has arranged to restrict the number of international circuits to five or, exceptionally, to six or seven. The CT3 connects international and national circuits; the CT2 and CT1 interconnect international circuits. In some connections, an international centre designated CTX, as well as the CT1s, may be encountered as shown in Figure 3/G.101. Certain exceptional routings, moreover, involve a seventh international circuit.

3.3 *Hypothetical reference connections*

See Recommendations G.103 and G.104.

3.4 Tables 1/G.101, 2/G.101 and 3/G.101 give the percentage relative and cumulative frequencies of the number of circuits likely to be encountered in an international connection taking account of traffic weighting.

TABLE 1/G.101

Relative frequencies of the number of circuits in the two national extensions and the international chain (expressed as percentages)

Number of circuits	Originating LE-CT3	International CT3-CT3′	Terminating CT3′-LE
1	33.8	95.1	32.9
2	38.9	4.5	39.5
3	20.2	0.3	20.4
4	6.0	—	6.1
5	1.0	—	1.0

Note – The relative frequencies of 6 and 7 circuits in the originating national system are 0.005% and 0.0005% respectively. The relative frequencies of 4, 5 and 6 international circuits are 0.03%, 0.00007% and 0.00009% respectively.

The mean and modal number of national circuits are both equal to 2. This applies to both originating and terminating national extensions. The mean number of international circuits is 1.1 and the modal number is 1.

TABLE 2/G.101

Relative and cumulative frequency of the total number of circuits between local exchanges (expressed as percentages)

Number of circuits LE to LE′	Relative frequency (%)	Cumulative frequency (%)
3	10.61	10.61
4	25.44	36.05
5	28.77	64.82
6	20.39	85.20
7	10.08	95.29
8	3.60	98.89
9	0.93	99.81
10	0.17	99.98
11	0.02	100.00

Note – The relative frequencies of connections with 12, 13 and 14 circuits are 0.0012%, 0.000088% and 0.0000049% respectively. The mean value is equal to 5.1 and the modal value is equal to 5.

TABLE 3/G.101

Relative and cumulative frequency of the number of circuits in the 4-wire chain (expressed as percentages)

Number of circuits in the 4-wire chain	Relative frequency (%)	Cumulative frequency (%)
1	2.65	2.65
2	14.16	16.81
3	27.49	44.30
4	26.43	70.73
5	17.28	88.01
6	8.33	96.34
7	2.83	99.18
8	0.70	99.88
9	0.11	99.99
10	0.0065	100.00

Note – The relative frequencies of 4-wire chains comprising 11 and 12 circuits are estimated to be 0.000475% and 0.0000322% respectively. The mean value is equal to 3.8 and the modal value is equal to 4.

Notes to Tables 1/G.101, 2/G.101 and 3/G.101

1 – The basic information, displayed in Table 1/G.101, derives from an analysis of the routing details of about 270 million telephone connections in 1973 conducted under the auspices of CCITT Study Group XIII in which 23 countries participated. LE signifies "local exchange".

2 – Table 2/G.101 is derived from Table 1/G.101 on the assumption that the three distributions of Table 1/G.101 are uncorrelated.

3 – Table 3/G.101 is derived from Table 1/G.101 on the basis of the following assumptions:

- Of all the international traffic handled by primary centres, 30% originates from (or terminates at) local exchanges co-sited with the primary centre. The remaining 70% involves a trunk junction between the local exchange and the primary centre.
- In the case of routings over 1 national circuit, 50% of those circuits are assumed to be 4-wire and 4-wire switched at the CT3 and thus to be included in the 4-wire chain. The other 50% are assumed to be 2-wire switched at the CT3, and thus do not participate in the 4-wire chain. This is assumed to be the case for both national extensions, independently.
- Any national routing involving 5 to 7 national circuits will incorporate a 2-wire switched trunk-junction.
- All the other routings (i.e. involving 2 to 4 national circuits) will be regarded as being with or without 2-wire switched trunk-junctions in the ratio 7:3.
- The routings in the two countries are uncorrelated.

4 Incorporation of unintegrated digital processes

4.1 *General*

The worldwide telephone network is now undergoing a transition from what is predominantly analogue operation to mixed analogue/digital operation. In the longer term, it is possible to foresee a continued transition to predominantly digital operation.

Figure 4/G.101 is intended to demonstrate how unintegrated analogue/digital PCM processes can occur in the international nework by illustrating a possible stage in the development of a national network as it progresses from all-analogue to all-digital. As indicated, subnetworks could arise in the country in which the transmission systems and the telephone exchanges are all-digital and fully integrated. Such subnetworks (referred to as "digital cells" by some) will require analogue/digital conversion processes in order to interface into the remainder of the network. Furthermore, some of the trunk-junctions (toll connecting trunks) and trunk-circuits (intertoll trunks) may be provided in some countries by 7-bit PCM systems, serving analogue exchanges. Conversely some digital exchanges may have to switch analogue circuits. Manual assistance switchboards, PBXs and subscribers' multiplex systems using PCM digital techniques are also allowed for. Naturally, any of the circuits indicated as 7-bit PCM could be either analogue or 8-bit PCM; but one of the worst cases is illustrated.

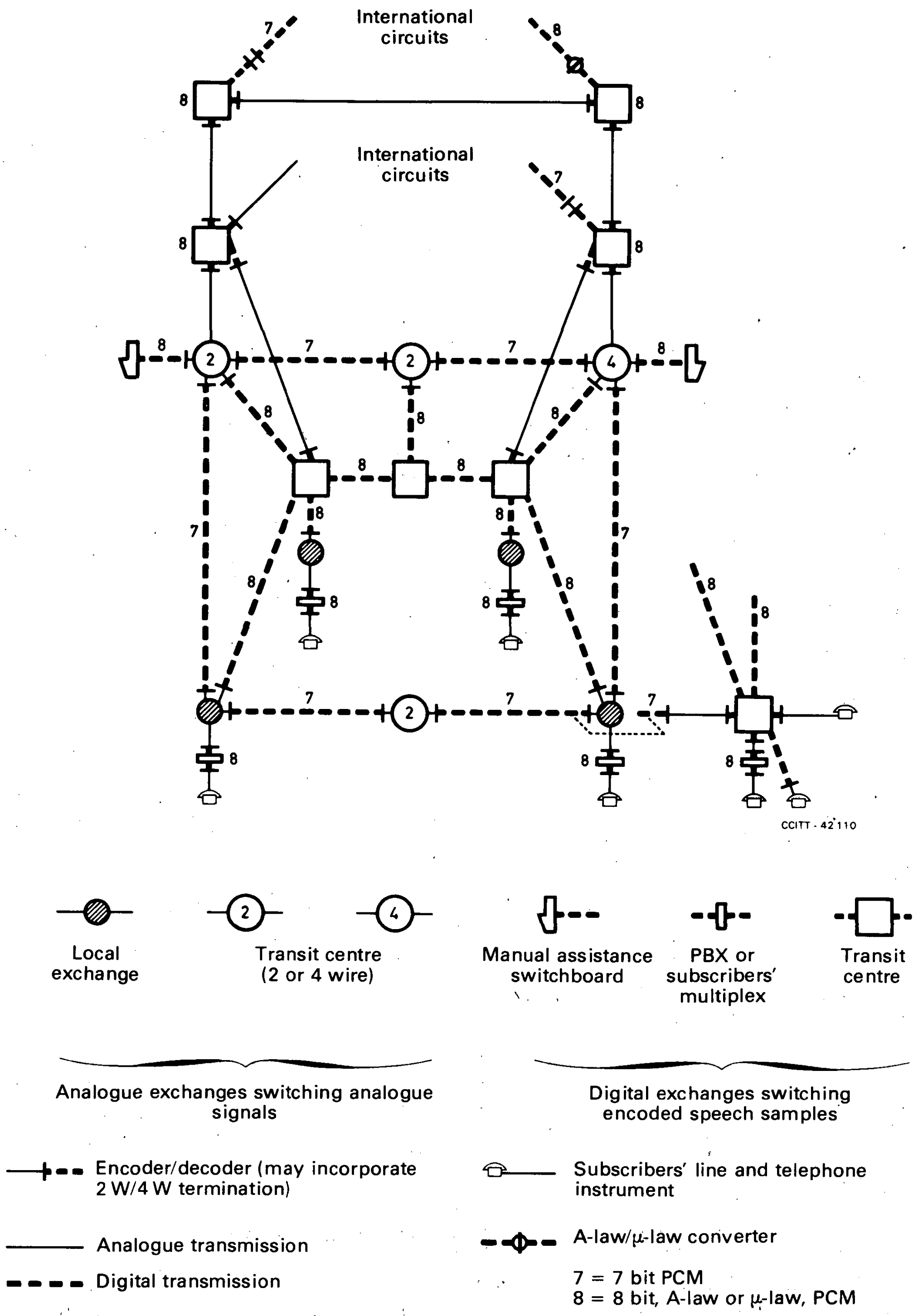


FIGURE 4/G.101

A possible intermediate stage of development in a national network

With regard to 7-bit PCM, it should be noted that such systems are not recommended by the CCITT. The only recommended analogue/digital (A/D) conversion processes for telephone services are 8-bit PCM processes (reference: CCITT Recommendation G.711 [2]). There are in some countries 7-bit PCM systems in operation which have been designed and installed prior to the appearance of Recommendation G.711 and, as existing systems, they should be taken into account, notwithstanding the fact that such systems are of a provisional nature as they will likely be removed from service as soon as their practical usefulness comes to an end.

In view of the foregoing, international telephone connections may for some time include one national 7-bit PCM trunk-junction (toll connecting trunk) or exceptionally two such 7-bit PCM circuits. In addition, international satellite circuits using 7-bit PCM coding may be encountered as well as A-law/μ-law conversion processes and digital pads.

The mixed analogue/digital period is expected to last a considerable number of years. Consequently, it will be necessary to ensure that transmission performance in this period will be maintained at a satisfactory level.

4.2 *Types of telephone circuits*

In the mixed analogue/digital period, international circuits could, in particular, consist of the types indicated in Figure 5/G.101. In all cases, the virtual analogue switching points are identified (conceptually) and the relative levels at these points, specified.

Although the circuit types shown in Figure 5/G.101 are classed as international circuits, the configurations involved could also occur in national telephone networks. However, in national networks the relative levels at the virtual analogue switching points of the circuits could be different from those indicated for international circuits.

The Type 1 circuit in Figure 5a)/G.101 represents the case where digital transmission is used for the entire length of the circuit and digital switching is used at both ends. Such a circuit can generally be operated at a nominal transmission loss of 0 dB as shown because of the transmission properties exhibited by such circuits (e.g., relatively small loss variations with time).

The Type 2 circuit in Figure 5b)/G.101 represents the case where the transmission path is established on a digital transmission channel in tandem with an analogue transmission channel. Digital switching is used at the digital end and analogue switching at the analogue end.

It might be possible, in some cases, to operate Type 2 circuits with a nominal loss of 0 dB in each direction of transmission. For example, where the analogue portion could be provided with the necessary gain stability and where the attenuation distortion would permit such operation.

The Type 3 circuit in Figure 5c)/G.101 represents the case where the transmission path is established over a tandem arrangement consisting of digital/analogue/digital channels as shown. Digital switching is assumed at both ends.

The Type 4 circuit in Figure 5d)/G.101 represents the case where the transmission path is established over a tandem arrangement consisting of analogue/digital/analogue channels as shown. Analogue switching is assumed at both ends.

The Type 5 circuit in Figure 5e)/G.101 represents the case where analogue transmission is used for the entire length of the circuit and analogue switching is used at both ends.

International circuits of this type are usually operated at a loss L, where L is nominally = 0.5 dB between virtual analogue switching points.

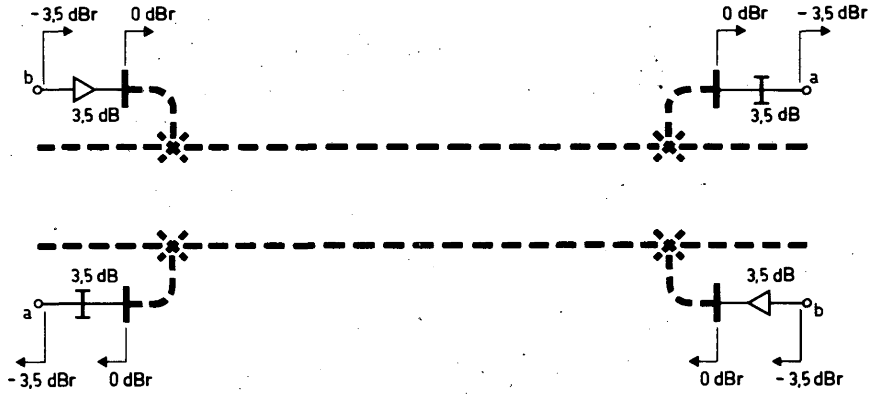
Note – *General remarks concerning the allocation of losses in the mixed analogue/digital circuits*

In circuit types 2, 3 and 4, the pads needed to control any variability in the analogue circuit sections (arising from loss variations with time or attenuation distortion) are shown in a symmetrical fashion in both directions of transmission. However, in practice, such arrangements may require nonstandard levels at the boundaries between circuit sections. Administrations are advised that should they prefer to adopt an asymmetric arrangement, e.g., by putting all the loss into the receive direction at only one end of a circuit (or circuit section); then, provided that the loss is small, e.g., a total of not more than 1 dB, there is no objection on transmission plan grounds.

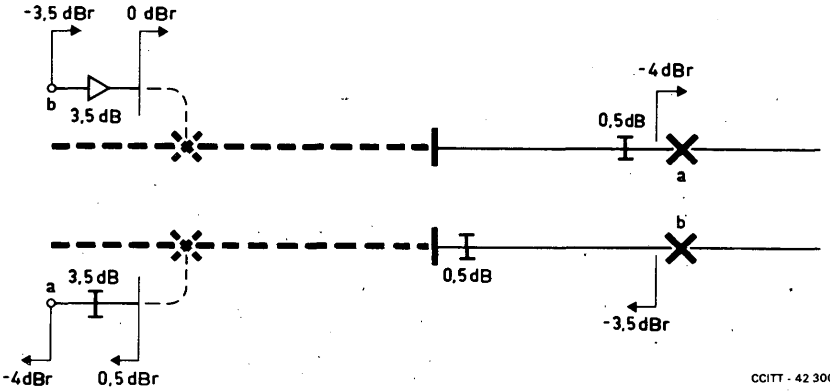
The small amount of asymmetry that results in the international portion of the connection will be acceptable, bearing in mind the small number of international circuits encountered in most actual connections.

As far as national circuits are concerned, Administrations may adopt any arrangements they wish provided that the requirements of Recommendation G.121, § 2.2, are complied with.

In some cases transmultiplexers may be used, in which case the circuits may not be available at audio-frequency at the point at which a pad symbol is used in the diagrams of Figure 5/G.101. Should the variability of the analogue portions merit additional loss, the precise way in which this loss can be inserted into the circuits is a matter for Administrations to decide bilaterally.

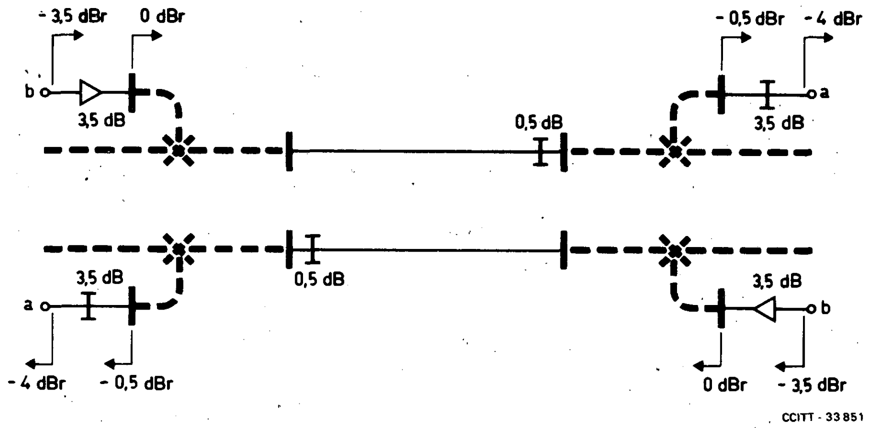


a) *Type 1 circuit – All digital circuit with digital switching at both ends*



Note – Pads required if the analogue circuit section introduces significant amounts of attenuation distortion or variation with time.

b) *Type 2 circuit – Digital/analogue circuit with digital switching at one end and analogue switching at the other end*

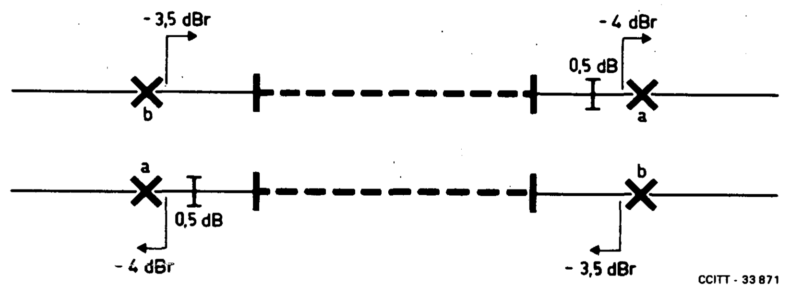


Note – Pads required if the analogue circuit section introduces significant amount of attenuation distortion or variation with time.

c) *Type 3 circuit – Digital/analogue/digital circuit with digital switching at each end*

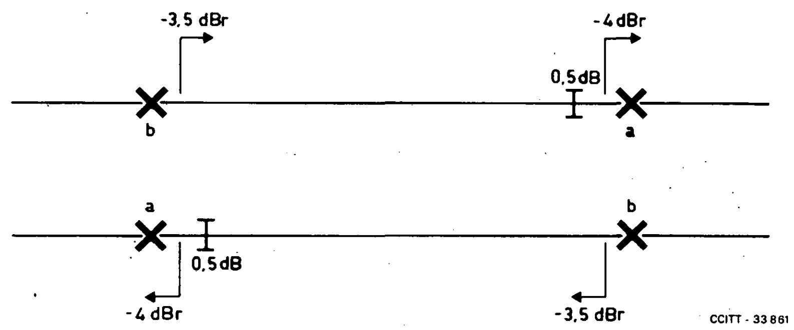
FIGURE 5/G.101

Types of international circuits

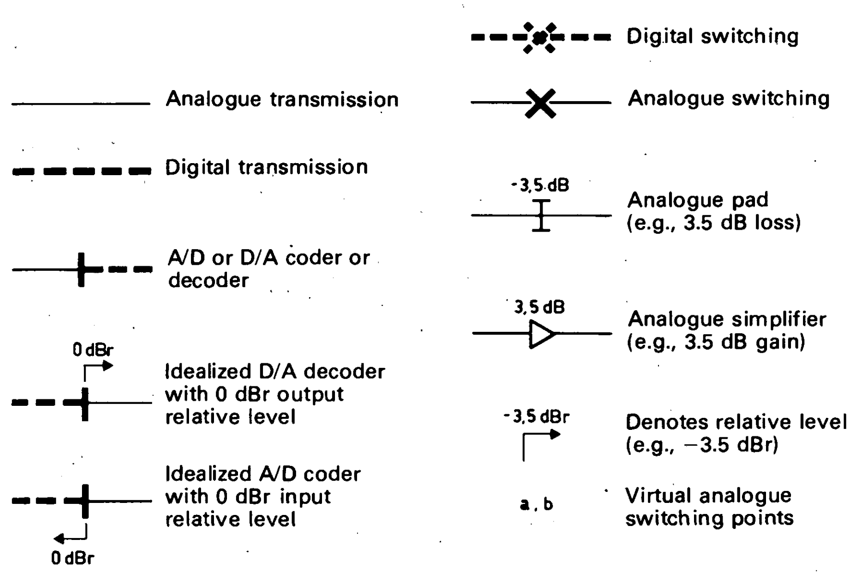


Note – Pads required if the analogue circuit sections introduce significant amount of attenuation distortion or variation with time.

d) *Type 4 circuit – Analogue/digital/analogue circuit with analogue switching at each end*



e) *Type 5 circuit – All analogue circuit with analogue switching at both ends*



Note – The pad symbols in the circuits are not intended to imply that real attenuators are needed. They are a convention of transmission planning engineers.

FIGURE 5/G.101 (end)

Types of international circuits

4.3 *Number of unintegrated PCM digital processes*

Restrictions due to transmission impairments

In the mixed analogue/digital period, it may be necessary to include a substantial number of unintegrated digital processes in international telephone connections. To ensure that the resulting transmission impairments (quantizing, attenuation and group-delay distortion) introduced by such processes do not accumulate to the point where overall transmission quality can be appreciably impaired, it is recommended that the planning rule given in Recommendation G.113 § 3 be complied with. The effect of this rule is to limit the number of unintegrated digital processes in both the national and international parts of telephone connections.

In the case of all-digital connections, transmission impairments can also accumulate due to the incorporation of digital processes (e.g., digital pads). The matter of accumulating such impairments under all-digital conditions is also dealt with in Recommendation G.113 § 3.

4.4 *Transmission of analogue and digital data*

In the mixed analogue/digital period, the presence in telephone connections of analogue/digital converters, encoding law converters, digital pads, or other types of digital processes, would not preclude the transmission of analogue data. However, on overall digital connections, digital type data could be adversely affected by devices such as encoding law converters and digital pads, since they involve signal recoding processes. Consequently, for the transmission of digital data, arrangements should be made to switch-out or bypass any device whose operation entails the recoding of digital data signals.

4.5 *General principle*

It is recognized that in the mixed analogue/digital period, there could be a considerable presence of unintegrated digital processes in the worldwide telephone network. Consequently, it is important that the incorporation of these processes should take place in such a way that when integration of functions can occur, unnecessary items of equipment would not remain in the all-digital network.

5 **Conventions and definitions**

5.1 *Virtual analogue switching points*

The concept "virtual switching points" has been useful in making transmission studies with regard to all-analogue connections. For example, these points have been used to define the boundary between international circuits as well as between international circuits and national extensions. The "virtual switching points" also provided convenient locations to which transmission quantities could be referred.

The incorporation of digital encoding processes into the worldwide telephone network no longer makes it possible, in all cases, to determine theoretical points which correspond to the "virtual switching points" of all-analogue connections. Since it would be desirable, in mixed analogue/digital connections to have analogous points, the concept of "virtual analogue switching points" has been adopted. This concept postulates the existence of ideal codecs through which the desired analogue points could be derived.

The term "virtual analogue switching points" is also used for all-analogue situations and replaces the older term "virtual switching points".

5.2 *Relative level specified in the virtual analogue switching points of international circuits*

The virtual analogue switching points of an international 4-wire telephone circuit are fixed by convention at points of the circuit where the nominal relative levels at the reference frequency are:

– sending: −3.5 dBr;
– receiving: −4.0 dBr, for analogue;
−3.5 dBr for digital circuits.

The nominal transmission loss of this circuit at the reference frequency between virtual analogue switching points is therefore 0.5 dB for analogue and 0 dB for digital circuits.

Note 1 – See the definition in § 5.3 below. The position of the virtual analogue switching points is shown in Figure 2/G.101, and in Figure 1/G.122.

Note 2 – Since the 4-wire terminating set forms part of national systems and since its actual attenuation may depend on the national transmission plan adopted by each Administration, it is no longer possible to define the relative levels on international 4-wire circuits by reference to the 2-wire terminals of a terminating set. In particular, the transmission loss in terminal service of the chain created by connecting a pair of terminating sets to a 4-wire international circuit cannot be fixed at a single value by Recommendations. The virtual analogue switching points of circuits might therefore have been chosen at points of arbitrary relative level. However, the values adopted above are such that in general they permit the passage from the old plan to the new to be made with the minimum amount of difficulty.

Note 3 – If a 4-wire analogue circuit forming part of the 4-wire chain contributes negligible delay and variation of transmission loss with time, it may be operated at zero nominal transmission loss between virtual analogue switching points. This relaxation refers particularly to short 4-wire tie-circuits between switching centres – e.g., circuits between a CT3 and a CT2 in the same city.

5.3 *Definitions*

5.3.1 **transmission reference point**

F: point de référence pour la transmission

S: punto de referencia para la transmisión

A hypothetical point used as the zero relative level point in the computation of nominal relative levels. At those points in a telephone circuit the nominal mean power level (–15 dBm) defined in the Recommendation cited in [4] shall be applied when checking whether the transmission system conforms to the noise objectives defined in Recommendation G.222 [5].

Note – For certain systems, e.g. submarine cable systems (Recommendation G.371 [6]), other values apply.

Such a point exists at the sending end of each channel of a 4-wire switched circuit preceding the virtual switching point; on an international circuit it is defined as having a signal level of +3.5 dB above that of the virtual switching point.

In frequency division multiplex equipment, a hypothetical point of flat zero relative level (i.e. where all channels have the same relative level) is defined as a point where the multiplex signal, as far as the effect of intermodulation is concerned, can be represented by a uniform spectrum random noise signal with a mean power level as defined in the Recommendation cited in [7]. The nominal mean power level in each telephone channel is –15 dBm as defined in the Recommendation cited in [4].

5.3.2 **relative (power) level**

F: niveau relatif de puissance

S: nivel relativo (de potencia)

5.3.2.1 The *nominal relative level* at a point in a transmission system characterizes the signal power handling capacity at this point with respect to the conventional power level at a zero relative level point.

If, for example, at a particular point the mean power handling capacity per telephone channel corresponds to an absolute power level of S dBm, the relative level associated with this point is $(S + 15)$ dBr. In particular, at a 0 dBr point, the conventional mean power level referred to one telephone channel is –15 dBm.

Note – The nominal relative levels at particular points in a transmission system (e.g. input and output of distribution frames or of equipment like channel translators) are fixed by convention, usually by agreement between manufacturers and users.

The Recommendations of the CCITT are defined in such a way that the absolute power level of any testing signal to be applied at the input of a particular transmission system, to check whether it conforms to these Recommendations, is clearly defined as soon as the nominal relative level at this point is fixed.

5.3.2.2 The *actual relative level* at a point on a circuit is the expression $10 \log_{10} (P/P_0)$ dBr, where P represents the power of a sinusoidal test signal at the point concerned and P_0 the power of that signal at the transmission reference point. This quantity is independent of the value of P_0, it is a level difference indicating a circuit gain.

Note – When a transmission system is set up, equipment must be assembled so as to ensure compatibility between the nominal and actual relative levels as imposed by the individual equipment. The diagram showing the relative levels of a circuit set up within a system is thus defined by the equipment used in it.

5.3.2.3 The relationship between the 0 dBr point and the level of T_{max} in PCM encoding/decoding processes standardized by the CCITT is set forth in Recommendation G.711 [2]. Figure 6/G.101 illustrates the principle of how the relative level at the input and output analogue points of a "real" codec can be determined. In particular, if the minimum nominal send reference equivalent of local systems referred to a point of 0 dBr of a PCM encoder is not less than 2.5 dB and the value of T_{max} of the process is set at +3 dBm0 (more accurately 3.14 dBm0 for A-law and 3.17 for μ-law), then in accordance with § 3 of Recommendation G.121, the peak power of the speech will be suitably controlled.

When the signal load is controlled as outlined above, the 0 dBr points of FDM and PCM circuits may be directly connected together and each will respect the other's design criteria. This is of particular importance when points in the two multiplex hierarchies are connected together by means of transmultiplexers, codecs or modems.

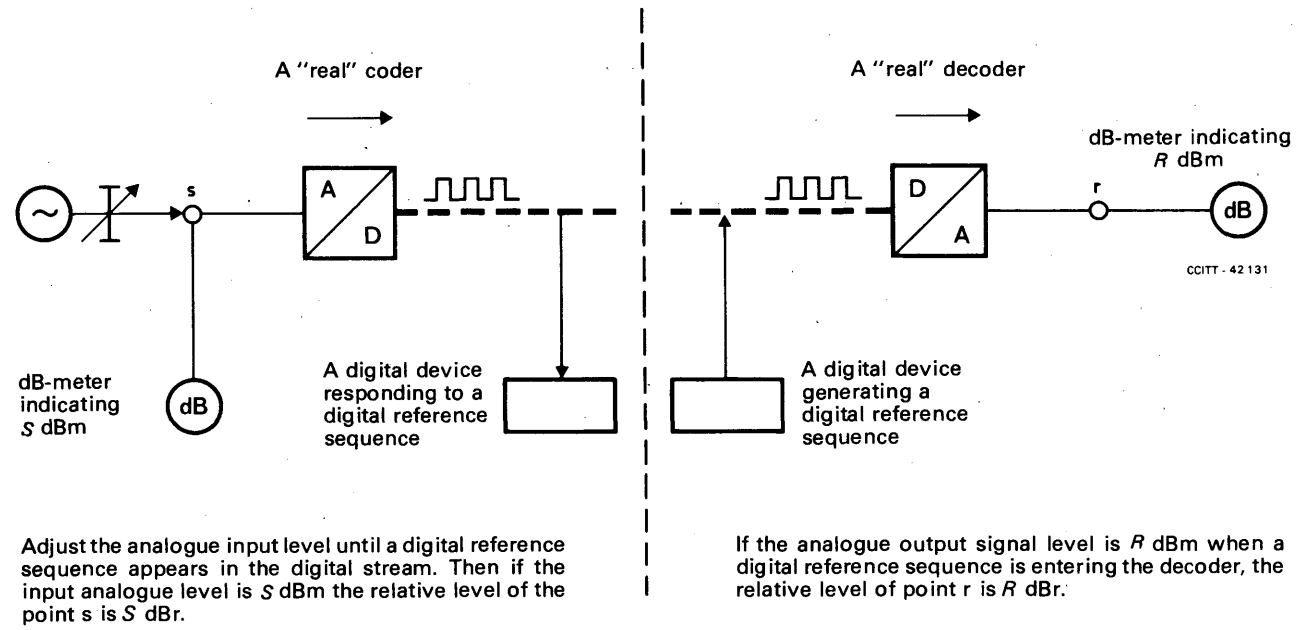


FIGURE 6/G.101

Set-up for determining the relative level at the input and output analogue points of a "real" codec using digital reference sequences

5.3.3 **PCM digital reference sequence (DRS)**

F: séquence numérique de référence MIC

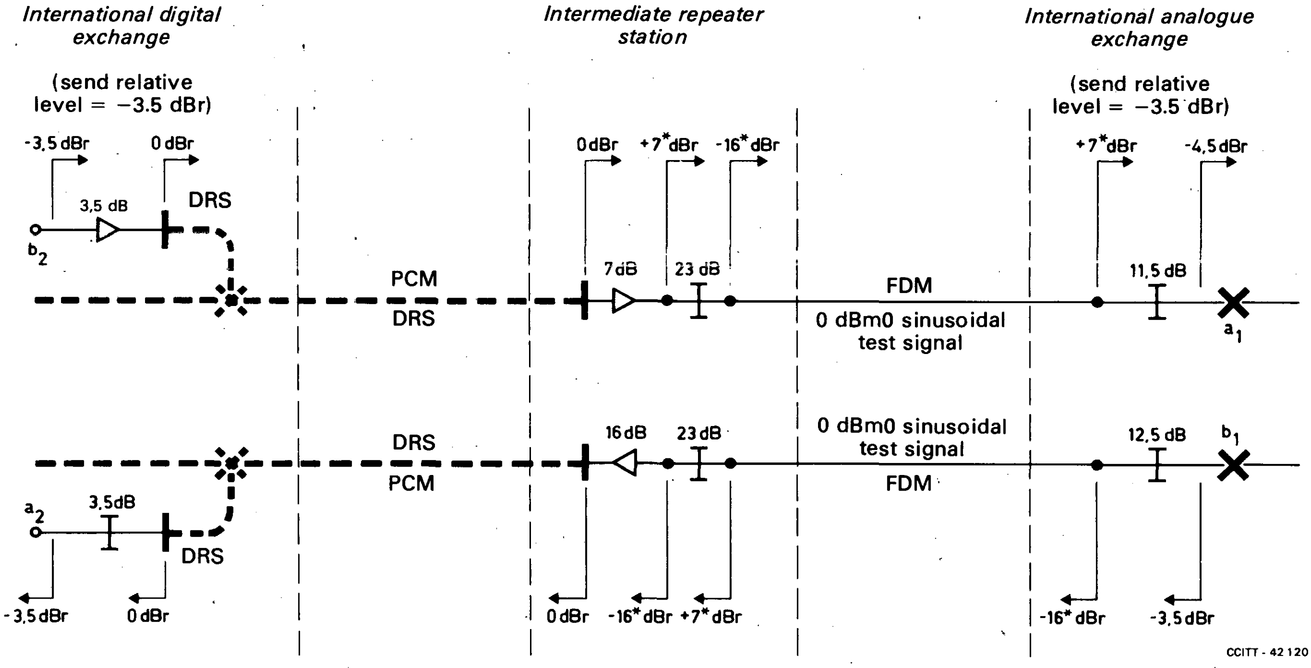
S: secuencia de referencia digital MIC (SRD)

5.3.3.1 A PCM digital reference sequence is one of the set of possible PCM code sequences that, when decoded by an ideal decoder, produces an analogue sinusoidal signal at the agreed test reference frequency (i.e. a nominal 800 or 1000 Hz signal suitably offset) at a level of 0 dBm0.

Conversely an analogue sinusoidal signal at 0 dBm0 at the test reference frequency applied to the input of an ideal coder will generate a PCM digital reference sequence.

Some particular PCM digital reference sequences are defined in Recommendation G.711 [2] in respect to A-law and μ-law codecs.

5.3.3.2 In studying circuits and connections in mixed analogue/digital networks, use of the digital reference sequence can be helpful. For example, Figure 7/G.101 shows the various level relationships that one obtains (conceptually) on a Type 2 international circuit where one end terminates at a digital exchange and the other end at an analogue exchange. In the example of Figure 7/G.101, the analogue portion is assumed to require a loss of 0.5 dB and that provision for this loss is made by introducing a 1.0 dB pad (0.5 dB for each direction of transmission) in the receive direction at the analogue exchange. This has been deliberately chosen to illustrate the utility of the concept of a digital reference sequence.



DRS Digital reference sequence
PCM PCM channel
FDM FDM channel
* one of the set of VF relative levels cited in [11] for the purpose of illustration
—●— Multiplex VF input/output point

Transmission loss: $b_2 - a_1 = 1.0$ dB
$b_1 - a_2 = 0$ dB

Note – For meaning of other symbols, see legend for Figure 5/G.101.

FIGURE 7/G.101

Use of a digital reference sequence in the design and line-up of a Type 2 international circuit

5.3.4 *Circuit test access point*

The CCITT has defined circuit test access points as being "4-wire test-access points so located that as much as possible of the international circuit is included between corresponding pairs of these access points at the two centres concerned". These points, and their relative level (with reference to the transmission reference point), are determined in each case by the Administration concerned. They are used in practice as points of known relative level to which other transmission measurements will be related. In other words, for measurement and lining-up purposes, the relative level at the appropriate circuit test access point is the relative level with respect to which other levels are adjusted.

5.3.5 *Measurement frequency*

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

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

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

Note 1 – Definitions 5.3.1 and 5.3.2 are used in the work of Study Group XVI. Definitions 5.3.4 and 5.3.5, taken from Recommendations M.640 [8] and M.580 [9], are included for information.

Note 2 – In order to take account of PCM circuits and circuit sections, the nominal frequencies 800 Hz and 1000 Hz are in fact offset by appropriate amounts to avoid interaction with the sampling frequency. Details can be found in Supplement No. 3.5 to Volume IV [10].

5.4 *Interconnection of international circuits in a transit centre*

In a transit centre, the virtual analogue switching points of the two international circuits to be interconnected are considered to be connected together directly without any additional loss or gain. In this way a chain of international circuits has a nominal transmission loss in transit equal to the sum of the individual circuit losses.

References

[1] CCITT Recommendation *Transmission Plan*, Vol. VI, Fascicle VI.1, Rec. Q.40.

[2] CCITT Recommendation *Pulse Code Modulation (PCM) of Voice Frequencies*, Vol. III, Fascicle III.3, Rec. G.711.

[3] CCITT Recommendation *The International Routing Plan*, Vol. VI, Fascicle VI.1, Rec. Q.13.

[4] CCITT Recommendation *Assumption for the Calculation of Noise on Hypothetical Reference Circuits for Telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 1.

[5] CCITT Recommendation *Noise Objectives for Design of Carrier-Transmission Systems*, Vol. III, Fascicle III.2, Rec. G.222.

[6] CCITT Recommendation *Carrier Systems for Submarine Cable*, Vol. III, Fascicle III.2, Rec. G.371.

[7] CCITT Recommendation *Assumption for the Calculation of Noise on Hypothetical Reference Circuits for Telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 2.

[8] CCITT Recommendation *Four-Wire Switched Connections and Four-Wire Measurements on circuits*, Vol. IV, Fascicle IV.1, Rec. M.640.

[9] CCITT Recommendation *Setting-Up and Lining-Up an International Circuit for Public Telephony*, Vol. IV, Fascicle IV.1, Rec. M.580.

[10] *Test frequencies on circuits routed over PCM systems*, Vol. IV, Fascicle IV.4, Supplement No. 3.5.

[11] CCITT Recommendation *12-Channel Terminal Equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 11.

Recommendation G.102

TRANSMISSION PERFORMANCE OBJECTIVES AND RECOMMENDATIONS

(Geneva, 1980)

1 General

The CCITT has drawn up (or is in the process of studying) Recommendations concerning transmission impairments and their permissible magnitude with the object of achieving satisfactory performance of the network. Such impairments include for example:

a) reference equivalent and loss,
b) noise,
c) attenuation distortion,
d) crosstalk,
e) single tone interference,
f) spurious modulation,
g) effects of errors in digital systems.

Some Recommendations state objectives for an impairment with the implicit assumption that other impairments are at their maximum value (e.g. noise and loss).

In many instances the objectives are based primarily on telephony; this however may require special measures to be applied when other, more demanding services (e.g. sound-programme transmission) are to be incorporated within the network or constituent parts thereof.

The following distinctions may be made between different types of objectives:

1) performance objectives for networks,
2) performance objectives for circuits, transmission and switching equipment,
3) design objectives for transmission and switching equipment,
4) commissioning objectives for circuits, transmission and switching equipment,
5) maintenance/service limits for circuits, transmission and switching equipment.

2 Explanation of a performance objective

The performance objective for a measurable transmission impairment for networks, entire connections, national systems forming part of international connections, international chains of circuits, individual circuits etc. often describes in statistical terms (mean value, standard deviation, or probability of exceeding stated value, etc.) the value to be aimed at in transmission network and systems planning. It describes the performance which, based for example on subjective or other performance assessment tests, it is desirable to aim at in order to offer the user a satisfactory service.

The items (circuits, systems, equipments) making up the network are normally assumed to have a performance related to that recommended by the performance objectives. Traffic weighting will, in some cases, be applied to calculations.

A powerful set of tools which may be used in analyses concerning network objectives and compliance therewith are the hypothetical reference connections described in Recommendation G.103.

3 Explanation of a design objective

The "design objective" for a measurable transmission impairment (e.g. noise, error-rate, attenuation-distortion) for an item of equipment (e.g. a line system, a telephone exchange) is its value when the item is operating in certain electrical/physical environments which might be defined by such parameters as power supply voltage, signal load, temperature, humidity, etc. Some of these parameters may be the subject of CCITT Recommendations and some may not, and it is for the Administrations to assign values to them when they prepare specifications. A suitable allowance may also be made for aging. The most adverse combination of the specified parameters is often assumed.

The purpose of a "design objective" is to provide a basis for the design of an item with respect to the quantity concerned. The significance of the design objective for an item, and examples of the relative frequency of impairment values, are illustrated in Figures 1/G.102 and 2/G.102 respectively.

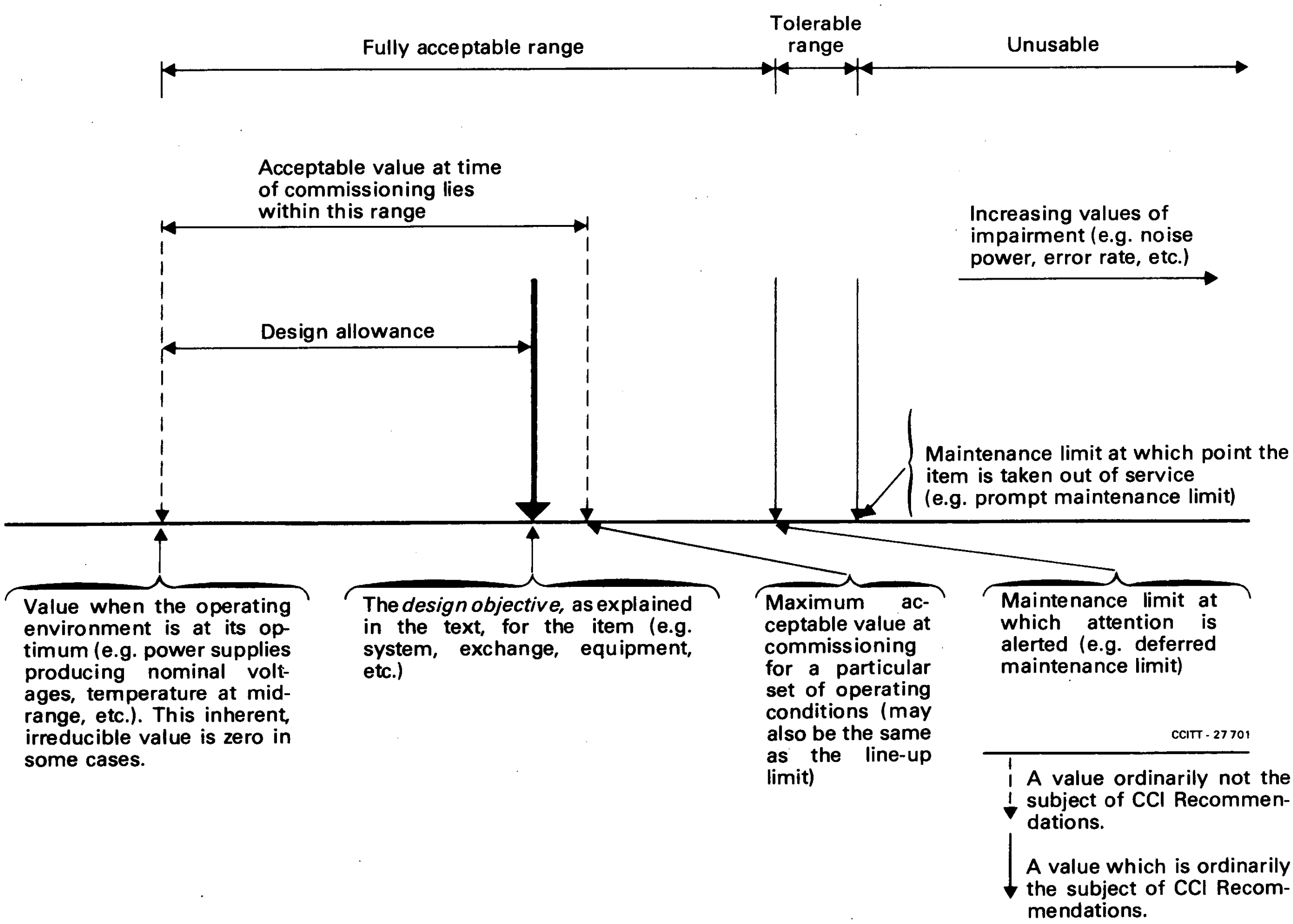
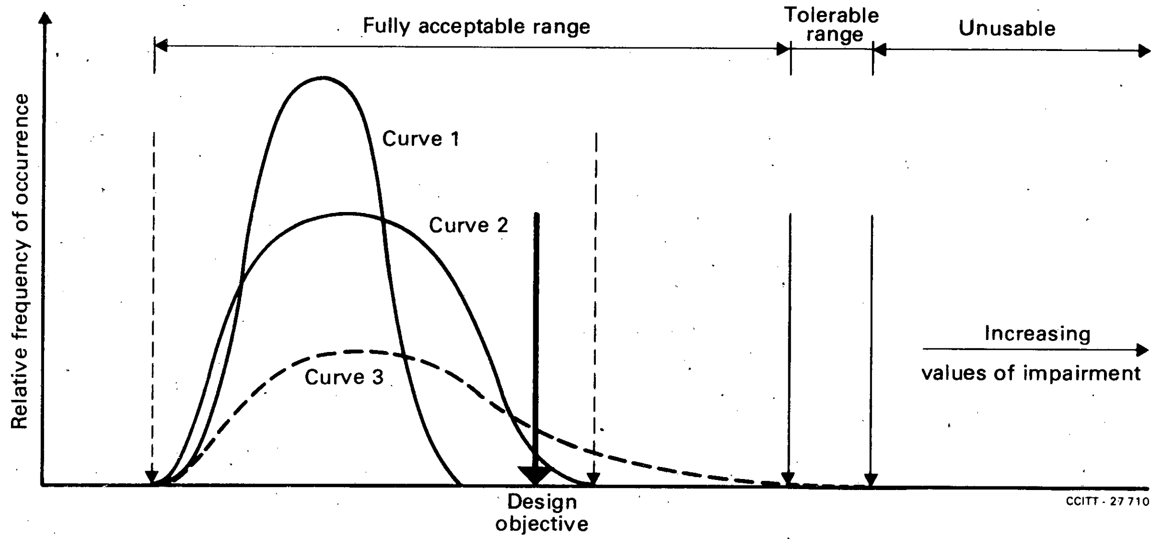


FIGURE 1/G.102

Illustration of the significance of design objective for an item



Such curves may be obtained for ensembles of items of equipment at the time of commissioning.
Alternatively curves may be plotted representing the performance of an item during its lifetime.

Curve 1 – Example of relative frequency of occurrence of impairments at time of commissioning in which the design value is met with some margin. A similar distribution might be achieved in service throughout the lifetime of an item of equipment if the effect of environmental conditions etc. is negligible. An example might be the attenuation distortion of transformers.

Curve 2 – Example of the relative frequency of occurrence of impairments at time of commissioning in which the design value is exceeded with some agreed probability because the item of equipment is used in a way which is more demanding than that in the design objectives. An example might be the effect of a repeater spacing of a radio or line system greater than anticipated.

Curve 3 – Example of the relative frequency of occurrence of impairments in service in which the working environment has parameters more onerous than or additional to those specified. Examples might be the effect of excessive loading, component failure or operational errors.

FIGURE 2/G.102

Examples of the relative frequency of impairment values

Design objectives will in many cases directly form the basis of a specification clause for the development and/or the purchase of equipments.

A powerful set of tools used in connection with applying design objectives are the hypothetical reference (HR) circuits and hypothetical reference (HR) digital paths (see relevant Recommendations in the G.100 and G.700 Series).

4 Explanation of a commissioning objective

The conditions encountered on real circuits and installed equipment may differ from the assumptions valid for the HR circuits and for the design of equipment. Therefore the performance to be expected at the time of commissioning cannot be deduced uniquely from Recommendations relating to HR circuits. Suitable allowances may have to be made for such matters as circuits being made up of equipments of different design, line systems differing substantially in length from a homogeneous section, etc. (see for example Recommendation G.226 [1] for noise on real links).

Commissioning objectives are not normally the subject of CCITT Recommendations.

5 Explanations of limits for maintenance purposes

In service, the performance of an item or assembly of items may deteriorate for various reasons: aging, excessive loading, excessive environmental conditions, operations errors, components failures, etc. and there is an economic penalty in service costs if such deterioration is always to be kept negligibly small. Therefore design objectives are chosen to confer as great a margin as possible to assure a satisfactory in-service performance.

With transmission impairments, there is often no value which represents a clear boundary between "tolerable" and "unusable" performance and in practice a range of impairments in excess of those provided by design objectives will give satisfactory service to customers. This is the case for telephony but for other services may be different.

Nevertheless it is often expedient to define a particular value of impairment above which the item is deemed to be "unusable" and at which the item will be withdrawn from service at the first opportunity so that remedial action can be taken to restore the performance to comply with some defined limit (e.g. limit for prompt maintenance action).

It is often useful to define a performance limit at which attention is alerted but (perhaps) no action is taken immediately (e.g. limit for deferred maintenance action).

These limits are usually independent of the type of service carried by that particular entity. However, it is sometimes necessary to define a performance limit for a particular type of service, beyond which the customer is no longer offered a satisfactory service quality. This limit may differ for various services; some may coincide with a prompt maintenance limit (service limit).

These limits (and others, if necessary) would fall above the design objective. These limits are illustrated in Figure 1/G.102 and a generic title for them is "maintenance limits".

Reference

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

Recommendation G.103

HYPOTHETICAL REFERENCE CONNECTIONS

(Mar del Plata, 1968; amended at Geneva, 1972, 1976 and 1980)

This Recommendation mainly deals with the analogue network, Recommendation G.104 deals with the digital network and § 4 of this Recommendation deals with the transitional problems when some digital circuits are introduced into the analogue network. Ultimately, it is envisaged that all reference connections, whether they refer to analogue or digital systems, will be combined within one Recommendation.

1 Purpose

A hypothetical reference connection for transmission impairment studies is a model in which the impairments contributed by circuits and exchanges are described.

Such a model may be used by an Administration:

- to examine the effect on transmission quality of possible changes of routing structure, noise allocations and transmission losses in national networks, and
- to test national planning rules for *prima facie* compliance with any statistical impairment criteria which may be recommended by the CCITT for national systems.

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

Hypothetical reference connections are *not* to be regarded as recommending particular values of loss or noise or other impairments, although the various values quoted are in many cases recommended values. Hypothetical reference connections are *not* intended to be used for the design of transmission systems.

2 Composition of hypothetical reference connections

2.1 The composition of the various connections is defined in Figures 1/G.103, 2/G.103 and 3/G.103.

Figure 1/G.103 – The longest international connection with the maximum number of international and national circuits envisaged in accordance with CCITT Recommendations. Such a connection would typically have high reference equivalents and high noise contributions, and the noise contribution from international circuits may be significant. The attenuation distortion, group delay, and group-delay distortion would also all be extremely high. Such connections are rare.

Figure 2/G.103 – An international connection of moderate length (say, not longer than 2000 km) comprising the most frequent number of international and national circuits. In such a connection, the noise contribution of the national systems would be expected to predominate. Such a connection is used in a large proportion of international calls.

Figure 3/G.103 – An international connection comprising the practically maximum number of international circuits and the least number of national circuits. Such connections are numerous.

2.2 *The following General Remarks apply to Figures 1/G.103, 2/G.103 and 3/G.103*

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

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

2.2.2 Use is made of the international routing plan nomenclature employed by the CCITT.

2.2.3 In each case only one direction of transmission is shown.

2.2.4 The design objectives for the hourly mean noise powers are indicated according to current recommendations. For long-distance carrier circuits they are proportional to length, the appropriate noise power rate, 4 pW/km or 1 pW/km, being used according to whether the basic hypothetical reference circuit is one 2500 km long or 7500 km long.

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

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

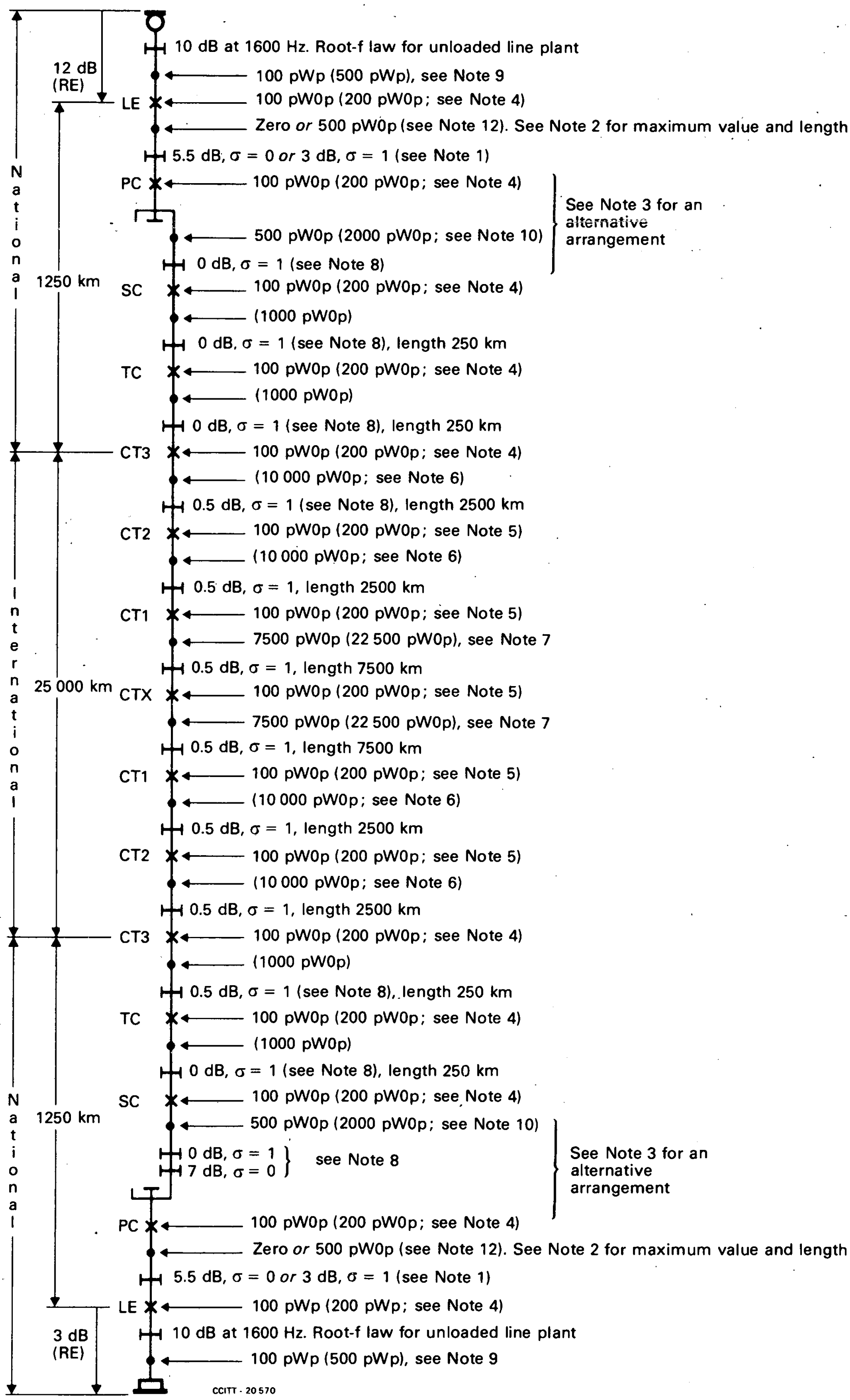
If it is required to refer the noise powers to some particular point on the connection (for example, the receiving local exchange or the point of zero relative level on the first international circuit) then the rule to be applied is as follows:

If a noise power level at a point *A* is to be referred to a point *B* downstream of its position, it is obtained by augmenting the level at point *B* by the sum of the losses that is imagined to be traversed from *A* to *B*. If it is to be referred to a point *C* upstream of its position, it is obtained by diminishing the level at point *C* by the sum of all the losses that is imagined to be traversed from *A* to *C*.

2.2.7 The nominal terminal loss of the connection [i.e. the normal overall loss less the sum of the transit losses (via net losses) of the individual circuits] is shown as one pad associated with the extreme right-hand circuit in the 4-wire chain. This artifice enables the noise powers to be indicated as if they were injected at zero relative level points on the individual circuits as explained in Annex A.

2.2.8 Information concerning the distributions of attenuation distortion and group-delay distortion is to be found in Annex A of Recommendation G.113. Calculated values of some possible combinations of basic transmission impairments are given in Supplement No. 20.

Recommendation G.114 gives information concerning group delay.



Legends for Figures 1/G.103, 2/G.103 and 3/G.103

RE reference equivalent	SC secondary centre
LE local exchange	TC tertiary centre
PC primary centre	CT transit centre

FIGURE 1/G.103

The longest international connection with the maximum number of international and national circuits envisaged in accordance with CCITT Recommendations

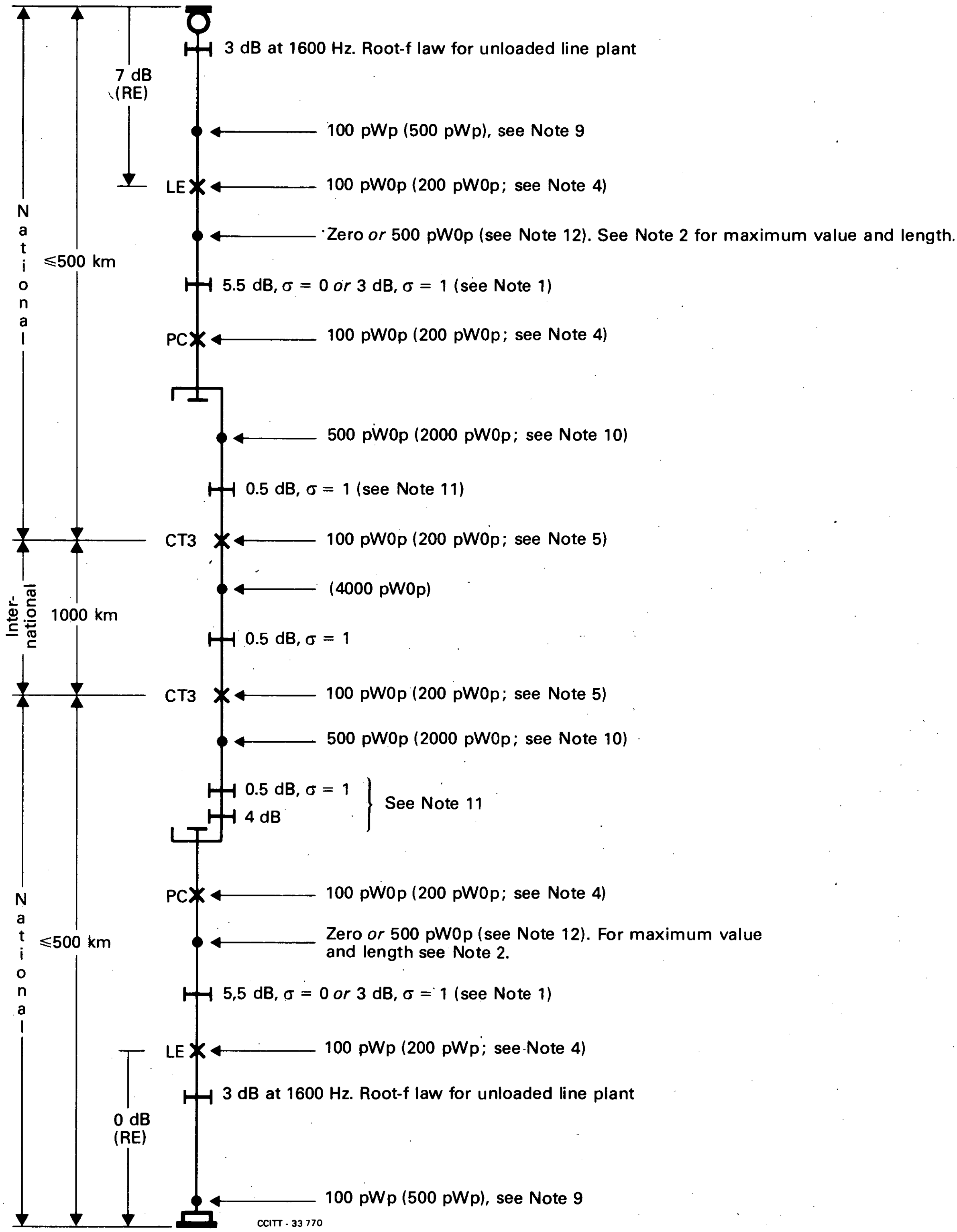


FIGURE 2/G.103

An international connection of moderate length comprising the most frequent number of international and national circuits

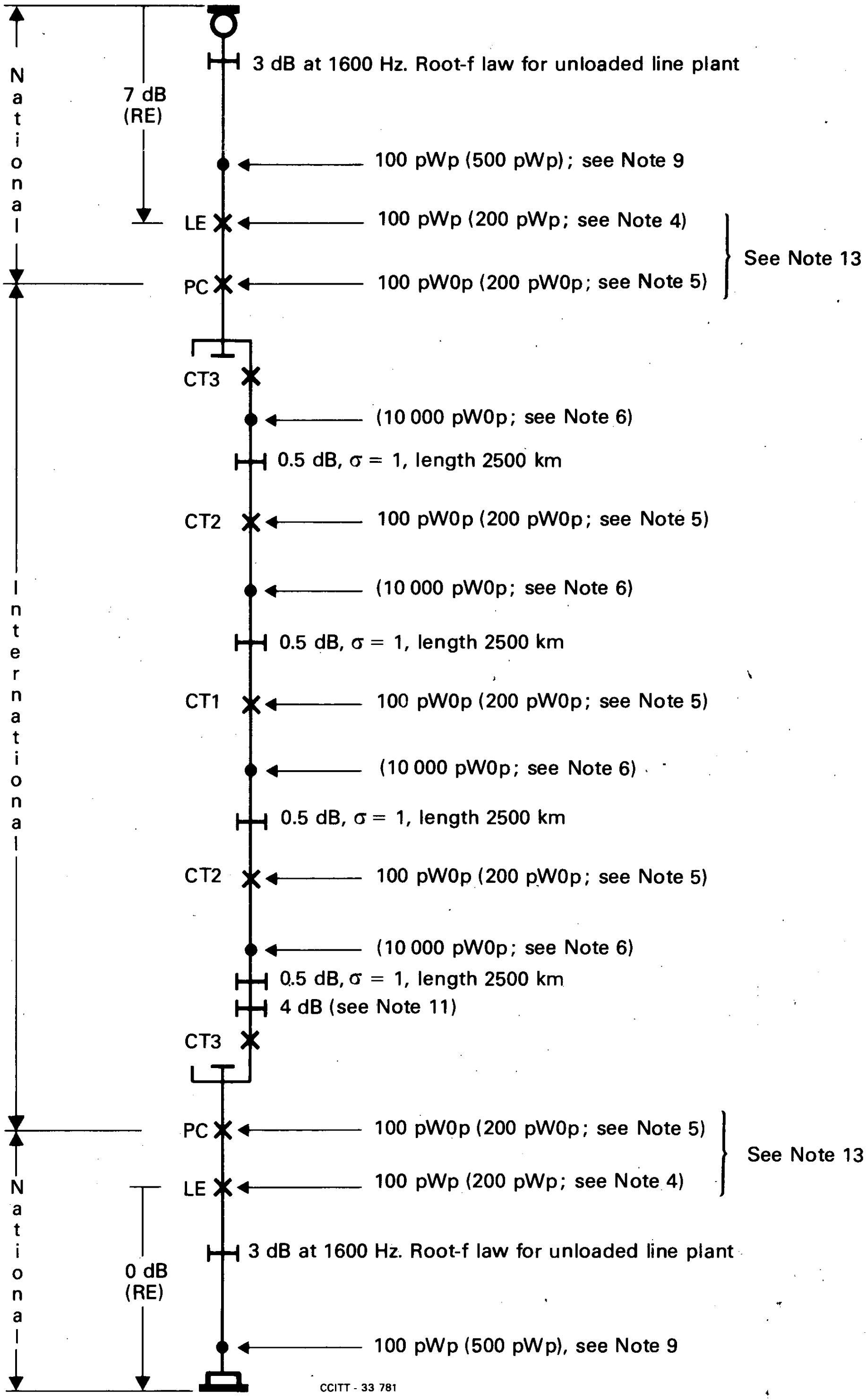


FIGURE 3/G.103

An international connection comprising the practically maximum number of international circuits and the least number of national circuits

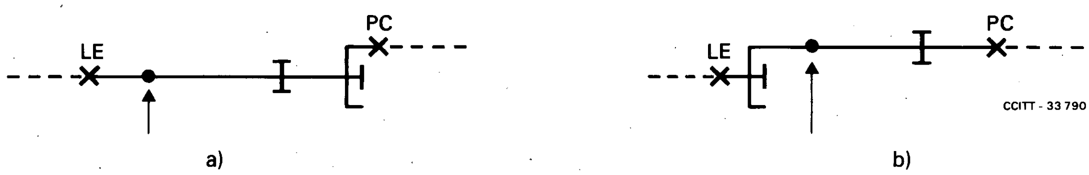
Notes to Figures 1/G.103, 2/G.103 and 3/G.103

Note 1 – For circuits on physical line plant the circuit loss may be taken to have a nominal maximum value of 5.5 dB with $\sigma = 0$. This value was arrived at in the following way: Recommendation G.121 gives a 97% limit on 21 dB sending reference equivalent referred to a point of –3.5 dBr on the international circuit at the CT3. Referring this to a zero relative level point at the input to the chain of national and international circuits (i.e. to the primary centre) gives 17.5 dB. Reference [3] indicates that a 12 dB sending reference equivalent is typical for maximum local lines, thus leaving 5.5 dB for the circuit from the local exchange to the primary centre, switching losses being included (see General Remark 2.2.10).

For FDM or TDM short-distance carrier circuits which are 2-wire switched at the primary centre, the nominal value of the circuit loss may be taken as 3 dB with $\sigma = 1$. This circuit may for instance be provided on a PCM system using either 7-bit encoding ($\mu = 100$ or A = 87.6) or 8-bit encoding ($\mu = 225$ or A = 87.6). Although only 8-bit coding is recommended by CCITT, a nonrecommended 7-bit coding is used in some countries.

Note 2 – For FDM or TDM short-distance carrier circuits not exceeding about 250 km, the maximum value of noise power may be taken to be 1000 pW0p. See Recommendation G.123.

Note 3 – The following arrangements may be encountered if 4-wire switching (space-division or time-division) is used at the primary centre. Clearly in principle the terminating set may be at any point between the 2-wire switch and the 4-wire switch, although in practice it is ordinarily associated with one or the other.



If arrangement b) is adopted, then the minimum loss *a-t-b* (called for in accordance with Recommendation G.122) must still be assured, irrespective of whether the national transmission plan uses the 3.5 + 0 + 0 + 0 or 2.5 + 0.5 + 0.5 + 0.5 basis, since there could now be an extra circuit in the 4-wire chain. Where an additional 0.5 dB is needed, this could in principle either be introduced by changing the loss of the tertiary centre/CT3 circuit from 0 to 0.5 dB, or by allocating it to the PC/LE circuits. Such arrangements may be encountered at either end of the connection.

Note 4 – The value of 200 pW0p as the design objective for the maximum noise power in a national 4-wire automatic exchange is taken from Recommendation G.123, § 3. The same value has provisionally been assumed for national 2-wire exchanges. No assumption has been made concerning the position of any national zero relative level point.

Note 5 – The value of 200 pW0p as the design objective for the maximum noise power in an international exchange is that recommended in Recommendation Q.45 [4].

Note 6 – The noise value corresponds to a design objective of 4 pW0p/km for the most adverse noise power during the busy hour.

Note 7 – The average value of 7500 pW0p for the CT1/CTX circuits assumes that 1 pW/km is the average value for line noise power. For the worst circuit, 3 pW/km is the design objective leading to the limit of 22 500 pW0p. Companders would be used to improve noise only if it exceed 40 000 pW0p (see Recommendation G.143).

Note 8 – Both countries are assumed to have the 3.5 + 0 + 0 + 0 dB type of plan. The nominal value of the pad in the receiving direction at the primary centre includes the loss of the terminating unit (see General Remark 2.2.10).

Note 9 – The average value of 100 pWp, for subscriber line noise is considered to be typical and is used by at least one Administration as an objective for maximum noise at the receiver.

Note 10 – The maximum value of 2000 pW0p provides for a circuit length of about 500 km with some margin.

Note 11 – Both countries are assumed to have the 2 + 0.5 + 0.5 + 0.5 dB type of plan. The nominal value of the 4 dB pad in the receiving direction at the primary centre includes the loss of the terminating unit (see General Remark 2.2.10).

Note 12 – The noise power level may be taken as negligible if the circuit is provided on physical line plant. A mean value of 500 pW0p is appropriate if the circuit is provided on a *FDM* or *TDM* short-distance carrier system.

Note 13 – The local exchange and primary centre are assumed to be both co-sited with the CT3.

2.2.9 The standard deviation of transmission loss of circuits is in accord with the objectives of Recommendation G.151 § 3 and also with the results obtained in practice and specified in [1].

2.2.10 "Circuit" in these reference connections is defined in the sense of Recommendation M.700 [2] as the whole of the line and the equipment proper to the line; it extends from the switches of one exchange to the switches of the next. In this way switching and exchange cabling losses are included in the values of transmission loss assigned to the circuits, together with the loss (or gain) introduced by the transmission system. If it is required to separately distinguish exchange losses, an additional pad symbol of appropriate value may be used.

It should also be noted that, according to this convention, the 3.5-dB loss ordinarily assigned to a terminating set does not figure explicitly in 2-wire/4-wire circuits; its value is also included in the loss assigned to the circuit.

3 Number of modulation and demodulation equipments

For the study of transmission performance, the longest international connection envisaged (see Figure 1/G.103) may be considered to have the arrangement of modulator/demodulator pairs in the 4-wire chain as shown in Table 1/G.103.

TABLE 1/G.103

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

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

4 Developments arising from the introduction of PCM digital processes

The worldwide telephone network is undergoing a transition from what is largely an analogue network to a mixed analogue/digital network. Looking farther into the future, this transition is expected to continue and result in a network that would be predominantly digital. Background on this transitional process is given in Recommendations G.101, § 4.1 and G.104.

With reference to the hypothetical reference connections of Figures 1/G.103, 2/G.103 and 3/G.103, the configurations used concerning numbers of circuits and numbers of exchanges should also be appropriate for network conditions in the mixed analogue/digital period. However, for transmission studies pertaining to mixed analogue/digital connections, account must also be taken of all unintegrated digital processes that might be present. Such unintegrated digital processes could have an important effect on overall transmission performance particularly with regard to such parameters as quantizing distortion, and transmission delay.

Where the worldwide network becomes all-digital, many of the transmission impairments that were present in the mixed analogue/digital period, due to the incorporation of unintegrated digital processes, would be eliminated. However, certain processes might remain which could introduce transmission penalties. These are the processes which operate on the basis of recoding the bit stream as is done, for example, in the case of digital pads. Although the accumulated transmission impairments introduced by such processes may be well within recommended limits, the resulting loss of bit integrity could be an important disadvantage. This is particularly true in the case of services requiring the preservation of bit integrity on an end-to-end basis. Consequently, processes of this type should be avoided where possible, or appropriate arrangements made to circumvent them, where services requiring bit integrity are to be carried over the affected connections.

ANNEX A

(to Recommendation G.103)

An explanation of how hypothetical reference connections can be drawn as if all send switching levels are 0 dBr

A.1 Consider the connection shown in Figure A-1/G.103 in which 3 circuits with losses of 1 dB, 6 dB and 2 dB are connected together by exchanges with actual send switching levels of −2, +1 and −3 dBr.

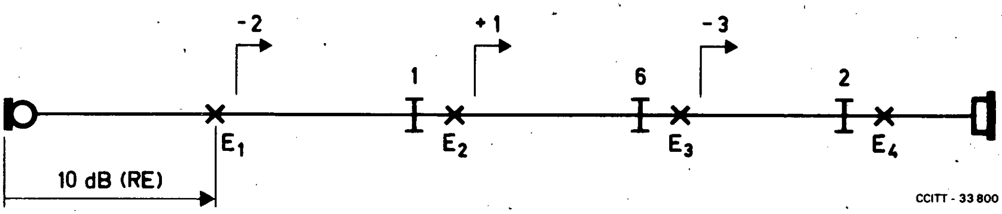


FIGURE A-1/G.103
Connection with various send switching levels

A.2 We assume that noise powers of these circuits are N_1, N_2 and N_3 pW0p respectivly. Figure A-2/G.103 shows these noise powers entering their circuits via appropriately valued pads chosen to take cognizance of the switching level concerned and dispense with the arrow symbols.

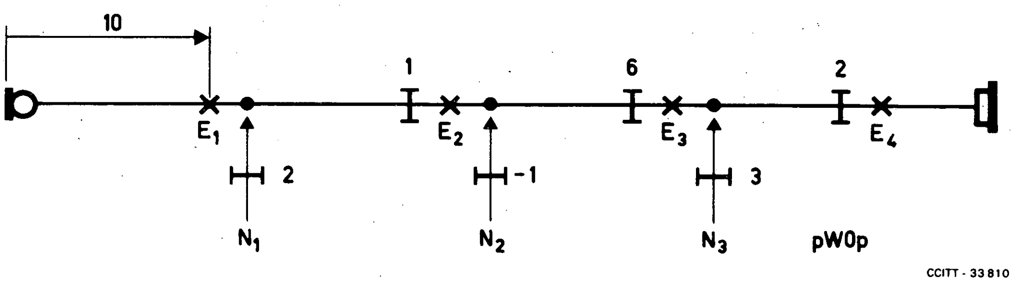


FIGURE A-2/G.103
The noise powers added

A.3 We note that N_1 traverses a total of 11 dB to reach E_4, N_2 a total of 7 dB, and N_3 a total of 5 dB. Also the difference of the accumulated SRE at each exchange to the corresponding circuit noise level is 8 dB (for N_1), 12 dB (for N_2) and 14 dB (for N_3). Hence we may redraw the connection reallocating the losses as shown in Figure A-3/G.103 in which all send switching levels are 0 dBr and all the other conditions are met as well.

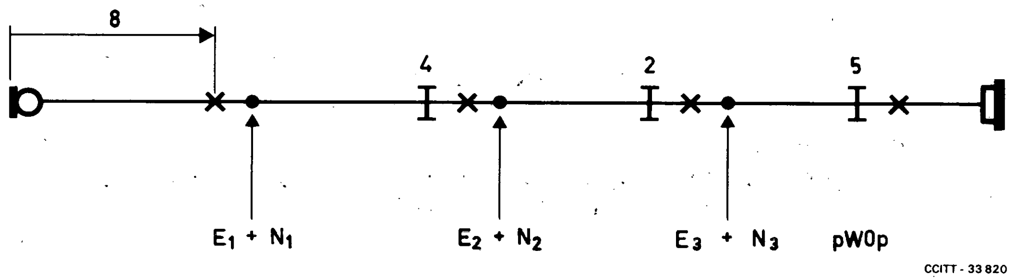


FIGURE A-3/G.103
All send switching levels are 0 dBr

A.4 Since the relative level of the immediate downstream circuit at each switch point is now arranged to be 0 dBr, the exchange noise powers can be added as is done in the hypothetical reference connections in Recommendation G.103.

References

[1] CCITT *Green Book*, Vol. IV.2, Section 4, Supplements, ITU, Geneva, 1973.

[2] CCITT Recommendation *Definitions for the maintenance organization*, Vol. IV, Fascicle IV.1, Rec. M.700.

[3] CCITT manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

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

Recommendation G.104

HYPOTHETICAL REFERENCE CONNECTIONS (DIGITAL NETWORK)

(Geneva, 1976)

1 Introduction

Hypothetical reference connections for the digital network have been drawn up. Their purpose is analogous to that for the reference connections recommended in Recommendation G.103. They are primarily based on telephony applications. Other reference connections may be defined for other services. Ultimately it is envisaged that all reference connections, whether they refer to analogue or digital systems, are combined within one Recommendation.

2 Purpose

A digital hypothetical reference connection is a model in which studies relating to overall performance may be made, thereby allowing comparisons with standards and objectives.

On this basis limits for various impairments can be allocated to the elements of the connection.

Such a model may be used:

a) by an Administration to examine the effect on transmission quality of possible changes of impairment allocations in national networks;

b) by the CCITT for studying the allocation of impairments to component parts of international networks;

c) to test national rules for *prima facie* compliance with any impairment criteria which may be recommended by the CCITT for national systems.

Hypothetical reference connections are *not* to be regarded as recommending particular values of impairments allocated to constituent parts of the connection, and they are not intended to be used for the design of transmission systems.

In order to initiate studies directed at the performance of a fully digital network, only the following arrangements are recommended:

1) an all digital path between the two local exchanges at each end of the connection;

2) an all digital path between the two subscribers involved.

This Recommendation should enable comparable results to be obtained when studies are carried out by different Administrations. (For studies relating to intermediate cases consisting of mixed use of analogue and digital items see Recommendation G.103, § 4 and Question 5/XVI [1]).

The following impairments may be studied with the aid of the hypothetical reference connections:

- digital errors,
- slips,
- jitter,
- delay.

3 Composition for telephony (64 kbit/s path)

1) The longest international connection envisaged in accordance with CCITT Recommendations. Such a connection would have a high impairment contribution from the international digital path. Such connections are rare. (See Figure 1/G.104.)

2) A typical international connection of moderate length comprising only one international digital path. In such a connection the impairment contribution by the national systems would be expected to be significant. Such a connection would be used in a large proportion of international calls. (See Figure 2/G.104.)

3) A typical international connection within a CT1 area, between subscribers situated near CT3 exchanges. Such connections are numerous. (See Figure 3/G.104.)

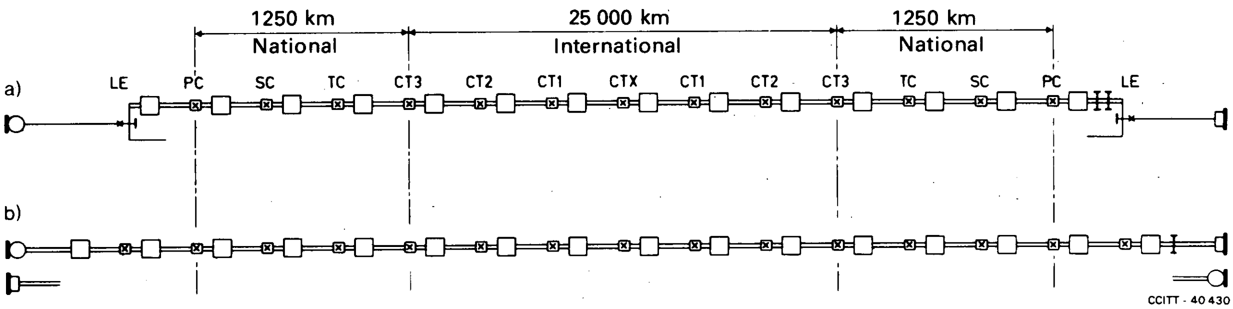


FIGURE 1/G.104

Longest reference connection for analogue and digital transmission and switching
(based on Figure 1/G.103)

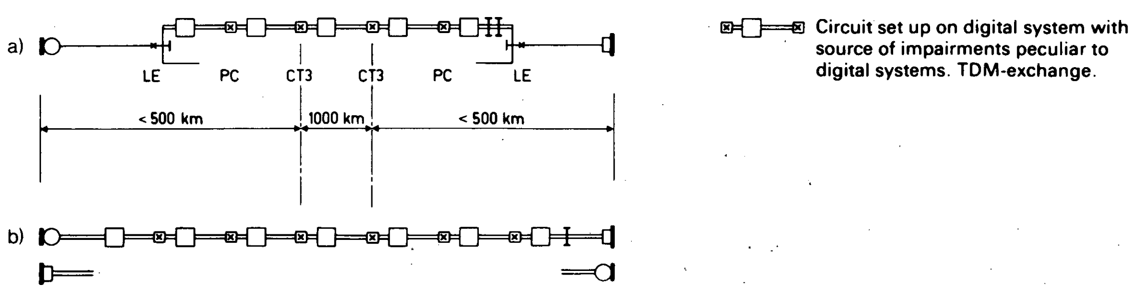


FIGURE 2/G.104

Typical international connection of moderate length

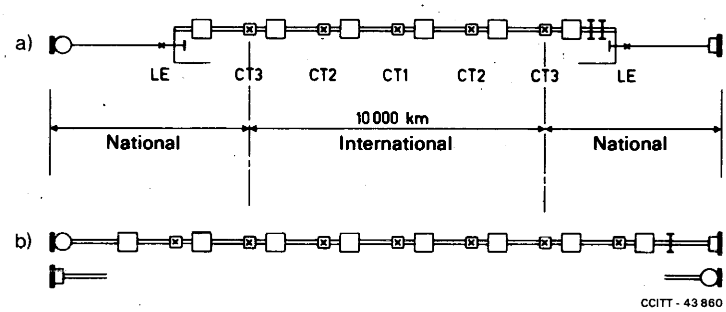


FIGURE 3/G.104
A typical international connection within a CT1 area between subscribers situated near terminal CT3 exchanges

Note 1 – The reference connections defined apply to telephony only. The necessity for defining similar reference connections for other services such as data, sound- and television-programme transmission, etc., will have to be studied.

Note 2 – The effect of digital concentrators, digital echo suppressors, satellite paths in the national network, etc. and the possible necessity of including these items in the reference connections is under study.

4 Remarks

It is common practice to estimate the performance of a reference connection from the knowledge of the individual design objectives of the component parts. It is recognized however that it is unlikely that every item is experiencing the most adverse combination of specified conditions, and also the working conditions of some items may be worse than those specified. Therefore the actual performance of a connection will only rarely be identical with the performance estimated by the calculations.

Reference

[1] CCITT Question 5/XVI, Contribution COM XVI-No. 1, Study Period 1981-1984, Geneva, 1981.

Recommendation G.105

HYPOTHETICAL REFERENCE CONNECTION FOR CROSSTALK STUDIES

(Geneve, 1980)

1 Purpose

This Recommendation gives guidance concerning the application of Recommendation P.16 [1] in the general switched telephone network and recommends the structure and parameters of a hypothetical reference connection specifically designed for crosstalk studies.

2 General remarks

2.1 *Accuracy of fundamental data*

2.1.1 There is always some degree of uncertainty in applying to real telephone conversation the results of tests in which subjects were asked to listen attentively to see if they were able to detect the presence of intelligible crosstalk. Furthermore, this type of test cannot be expected to indicate reliably the extent to which a subscriber's confidence in the privacy of his own conversation is undermined by overhearing another conversation. Hence in general the aim should be to reduce the risk of potentially intelligible crosstalk as much as possible.

2.1.2 In applying the calculation method given in Recommendation P.16 [1], errors can occur if the distributions of crosstalk attenuations and reference equivalents are skew, rather than normal, or are truncated by test acceptance procedures. This arises because we are generally seeking low probabilities of encountering intelligible crosstalk which are highly dependent on the tails of distributions being accurately defined. One way of avoiding this difficulty is to apply Monte-Carlo methods as described, for example, in the CCITT manual cited in [2], taking care to make enough iterations to secure the necessary accuracy.

2.1.3 Considerable care must be taken to obtain representative values of the loss and noise in crosstalk paths being studied. In particular, errors arising from small changes in mean values can easily result in the calculated probability of overhearing being in error by a factor of 10 or more (see, for example, [3]).

2.2 *Effect of line and room noise*

2.2.1 The masking effect of line noise is another aspect which is important and raises some difficulties. On the one hand if, for the purpose of establishing crosstalk limits, the level of line noise is assumed to be negligible, unrealistic demands may be placed on the crosstalk attenuation required to be introduced by items of plant. On the other hand, if it is assumed that circuits and exchanges in service introduce noise power levels comparable with their design objectives, e.g. the well known 4 pW0p/km, the incidence of overhearing may be unacceptably high, particularly when the network is lightly loaded so that noise power levels can be expected to be at their lowest.

As in many transmission studies, a compromise has to be made somewhere between these extremes. In some cases, it may be necessary to rely on measurements of noise power levels on established plant during light and busy traffic periods. However, it must not be overlooked that limits devised now must, if possible, take the future into account. It is a wise principle that the successful performance of equipment in one part of the network should not be dependent upon adventitious imperfections of other parts of the network, particularly if such imperfections are likely to be eliminated or reduced in the future, e.g. by new designs of local exchange or by the extensive use of digital long-distance transmission systems.

2.2.2 Unlike line noise the effect of room noise can be reduced by a determined listener. Hence Recommendation P.16 [1] recommends that negligible room noise be assumed when deriving a design objective for equipment.

2.3 *Probabilities and distributions involved*

2.3.1 When constructing the distribution of crosstalk attenuation introduced by equipment and cables, it is appropriate to consider only the worst (acceptable) values. For example, in a 10-pair cable only the worst disturber for each pair should be taken into account, i.e. 10 values. This distribution should not be diluted by the other 80 better values. In the busy period the worst potential disturber of a particular pair can be relied upon to be activated.

2.3.2 In respect of intelligible crosstalk between local calls established in the same local exchange network, the probability of a potentially disturbing subscriber making a call at the same time as the disturbed subscriber can be significantly low certainly in the case of residential subscribers, although this is probably not the case for business subscribers and PBXs. Information concerning this topic and showing how to calculate the probabilities concerned will be found in [4].

2.3.3 Multiple entries into a telephone connection of intelligible crosstalk signals all at significant levels and all derived from one source is so unlikely an event that it may be ignored for the purposes of deriving design limits. Hence the crosstalk mechanism of interest is assumed to be the dominant one when deriving limits, and all other sources are deemed to be negligible, and may thus attract the whole of the allowance.

However, when a network performance objective for crosstalk has to be divided among the exchanges and circuits making up the connection, it may be necessary to give some consideration to the number of potential crosstalk paths from different sources. For example, crosstalk limits may be assigned to complete paths through an exchange and to complete junction or trunk circuits. Thus, on simple other-exchange connections (ignoring, for the moment, crosstalk arising within local cables) there are three dominant sources of crosstalk, and if, for example, the aim were to be not greater than 1 in 100 for such connections, the probability of overhearing from each source should be reduced to 1 in 300 (assuming equal probabilities and no correlation between the sources).

Figures 1/G.105 and 2/G.105 illustrate some crosstalk paths of significance.

3 Hypothetical reference connections for crosstalk

Figure 3/G.105 illustrates the essential elements of two hypothetical reference connections appropriate to crosstalk studies in respect of telephone circuits and exchanges. It will be observed that the connections are much simpler than the corresponding ones in Recommendation G.103 used for studying noise and loss. It would be inappropriate to study the risk of potentially intelligible crosstalk between a pair of 12-circuit connections of near maximum length and noise, in order to arrive at, for example, a limit for channel equipment crosstalk, because the majority use of the channel equipment bought and installed to the specification is in much simpler, quieter, and more numerous connections.

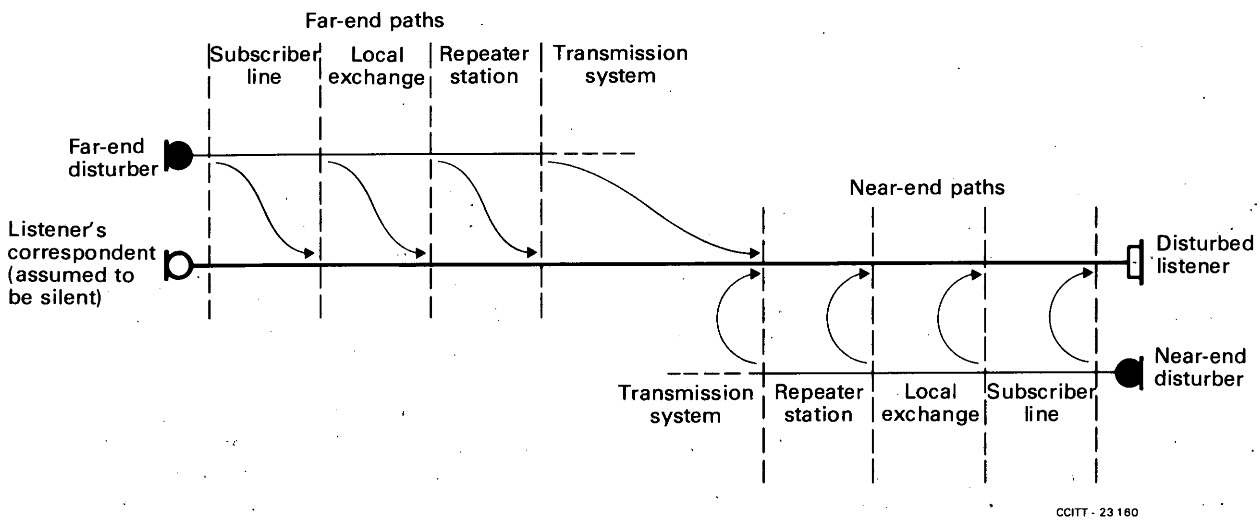
References

[1] CCITT Recommendation *Subjective effects of direct crosstalk; Thresholds of audibility and intelligibility*, Vol. V, Rec. P.16.

[2] CCITT Manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

[3] *Social Crosstalk in the Local Area Network*, Electrical Communication (ITT), Vol. 49, No. 4, pp. 406-417, 1974.

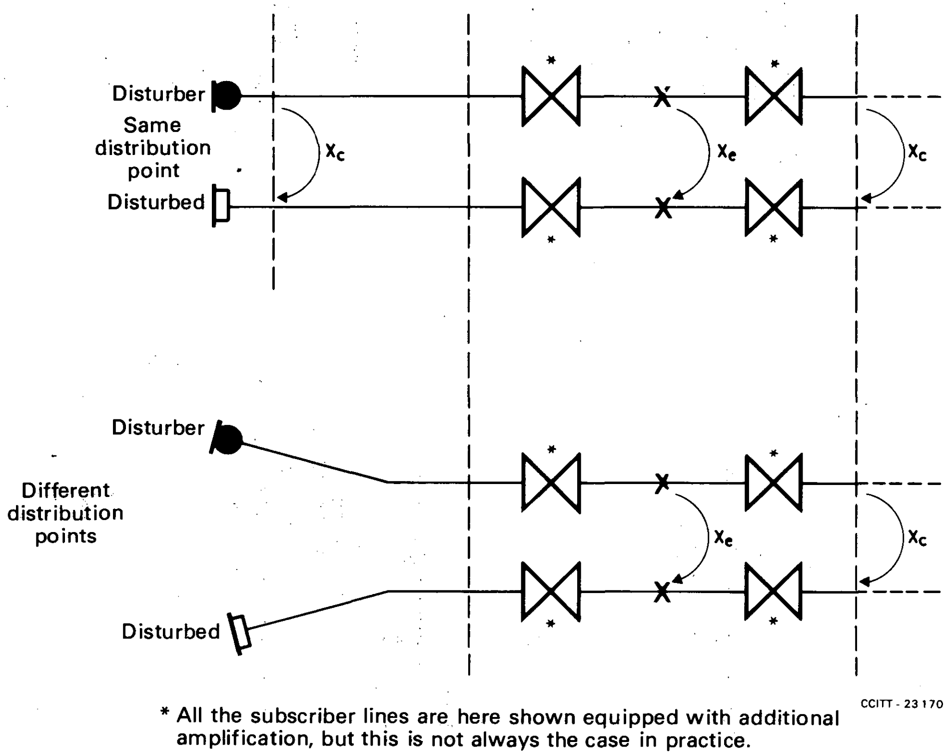
[4] LAPSA (P. M.): Calculation of multidisturber crosstalk probabilities, *Bell System Technical Journal*, Vol. 55, No. 7, September 1976.



Note – Individual crosstalk limits for "repeater stations" (e.g. multiplexing equipment) and "transmission systems" are not the subject of this Recommendation which only deals with subscriber lines, exchanges, and interexchange circuits. In particular, limits recommended for circuits would be apportioned by the competent CCI Study Group(s).

FIGURE 1/G.105

Some far-end and near-end crosstalk paths of significance when considering potentially intelligible overhearing between telephone connections



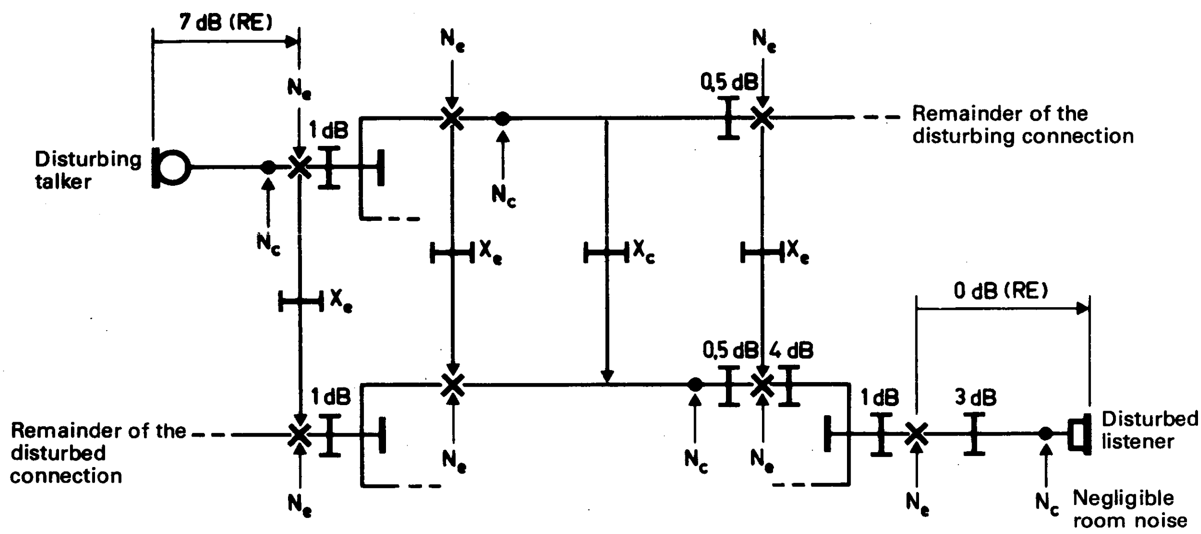
Note 1 – On own-exchange calls, overhearing between customers served by different distribution points may be assumed to be due only to exchange crosstalk or to crosstalk arising within local cables (near-end or far-end) on the far side of the exchange switching equipment. For other-exchange calls, the crosstalk paths are assumed to occur within the exchange and between junction or trunk circuits.

Note 2 – In the case of overhearing between customers served by the same distribution point, it should also be assumed that crosstalk can arise within the local cable (near-end crosstalk) or other permanently connected equipment. The particular customers who are unfavourably located in this respect will depend to a great extent on the type of local telephone circuits in use. When current-regulated telephones are used, customers on limiting length local lines are most at risk because the sensitivities of the telephone instrument are highest on these lines.

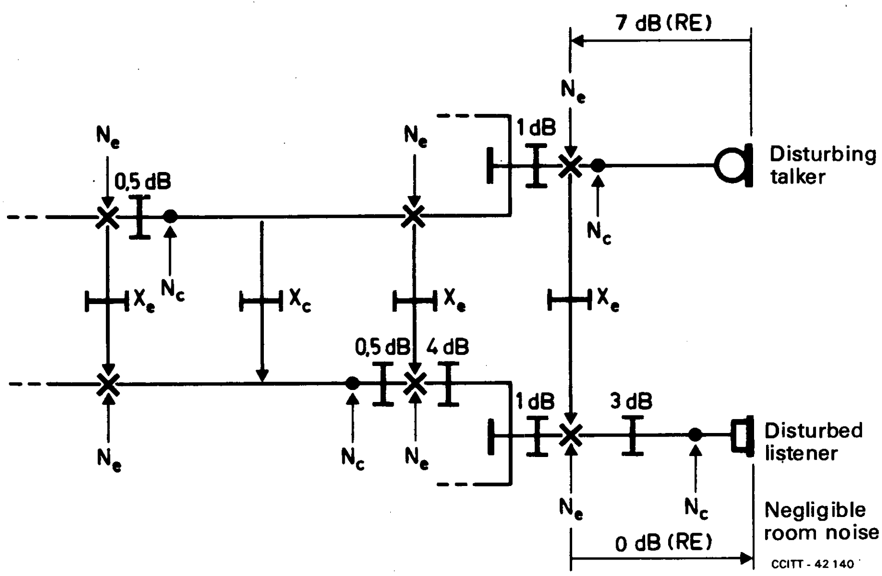
Note 3 – The effect of additional exchange amplification sometimes associated with long lines must be included where appropriate.

FIGURE 2/G.105

Some hypothetical crosstalk reference paths for studying crosstalk in the local exchange network



a) *Far-end crosstalk paths*



b) *Near-end crosstalk paths*

Note 1 – The disturbing connection should be assumed to have a somewhat high overall reference equivalent so that the correction factor $\bar{C}$ to take account of real talker volume becomes 4 dB, as explained in Recommendation P.16 [1].

Note 2 – The disturbed connection is taken to be a very simple one, the disturbed listener being connected to a local exchange co-sited with the trunk exchange (e.g. the CT3 or the national primary centre).

Note 3 – Suitable values for the various circuit and exchange noise powers are

Circuit noise (N_c):	subscribers local line:	100 pWp
	4-wire circuit:	500 pW0p
	(Satellite circuit:	10 000 pW0p)
Exchange noise (N_e):	local exchange:	50 pWp or pW0p (as appropriate)
	4-wire exchange:	100 pW0p

Note 4 – In accordance with the convention adopted in Recommendation G.103, the send switching level at all exchanges is shown as 0 dBr. In practice, other values of relative level are encountered and must be taken into account in the study.

Note 5 – Only one crosstalk mechanism is assumed to be dominant at any one time.

FIGURE 3/G.105

Hypothetical reference connections for crosstalk between switched telephone connections

CONCEPTS, TERMS AND DEFINITIONS RELATED TO AVAILABILITY AND RELIABILITY STUDIES

(Geneva, 1980)

1 Introduction

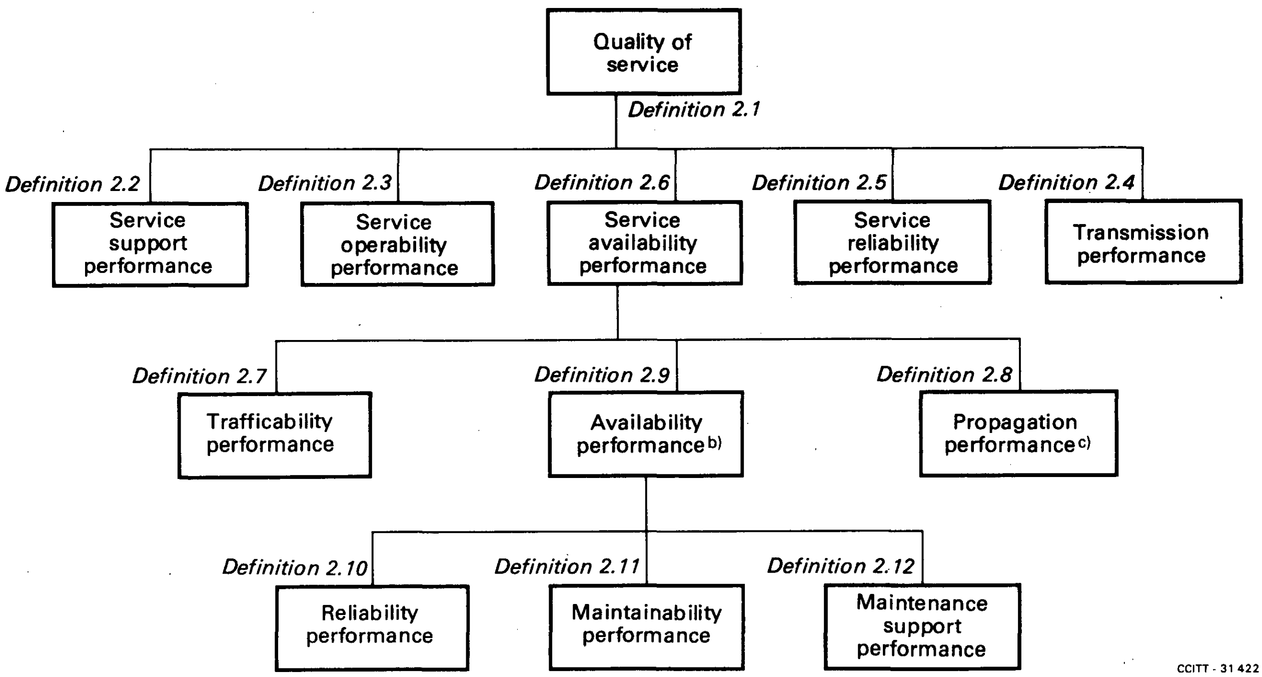
1.1 *Purpose*

The purpose of this Recommendation is to provide a systematic framework for organizing the concepts associated with the quality aspects of providing telecommunication services. The approach taken is intended to include these aspects as applied not only to individual functional units or items (e.g. a switching system or its subcomponents), but primarily to switched network services (e.g. the reliability and availability of a connection), and private line services (e.g. the reliability and availability of leased circuits).

The diagram in Figure 1/G.106 is intended to provide an overview of the factors which contribute collectively to the overall quality of service as perceived by the user of a telecommunication service. The terms in the diagram can be thought of as generally applying either to the service levels actually achieved in practice, to objectives which represent service goals to be achieved, or to requirements which reflect design specifications.

The diagram in Figure 1/G.106 is also structured to show that one service factor can depend on a number of others. It is important to note – although it is not explicitly stated in each of the definitions to follow – that the value of a characteristic measure of a particular factor may depend directly on corresponding values of other factors which contribute to it. This necessitates, whenever the value of a measure is given, that all of the conditions having an impact on that value be clearly stated.

In the definitions to follow, the term "ability" can be interpreted in either a qualitative or quantitative sense.



a) Not all relationships are shown in the figure.

b) Availability performance refers to any part of the network, hardware or software.

c) Propagation performance depends upon natural causes, such as attenuation due to rain or to multiple path, etc. Only its influence on availability is shown in this diagram. Its influences on quality, as in the case of short interruptions, for example, are taken into account under "Transmission performance" (see CCIR Recommendation 557 [1]).

FIGURE 1/G.106

Hierarchy of concepts relevant to the quality of service[a)]

2 Quality concepts, terms and definitions

2.1 quality of service

F: qualité de service

S: calidad de servicio

The collective effect of service characteristics which determine the degree of satisfaction of the user of this service.

Note – The quality of service is characterized by combined aspects of service availability, service reliability, service support, service operability and transmission performance.

2.2 service support performance

F: logistique du service

S: calidad del soporte del servicio

The ability of a telecommunication Administration to meet the requests of the customer.

Note – Measures of the service support include, for example, the mean time required to commission a required service, the mean time required to provide number assistance, etc.

2.3 service operability performance

F: facilité d'utilisation du service

S: calidad de la operabilidad del servicio; facilidad de utilización del servicio

The ability of a service to be successfully and easily operated by a user, from a human factors viewpoint.

2.4 transmission performance (of a service)

F: qualité de transmission (d'un service)

S: calidad de transmisión (de un servicio)

The degree to which a telecommunication service reproduces the offered signal.

Note – The quality of transmission can only be considered when the service is available.

2.5 service reliability performance

F: fiabilité du service

S: calidad de la fiabilidad del servicio

The ability of a service, once available, to continue to be provided under stated conditions for a stated period of time.

2.6 service availability performance

F: disponibilité du service

S: calidad de la disponibilidad del servicio

The ability of a service, under combined aspects of trafficability, propagation performance and equipment availability, to be provided within specified transmission tolerances and other stated operating conditions when requested by the user.

2.7 trafficability performance; traffic performance [1]

F: capacité d'écoulement du trafic

S: aptitud para el tráfico; calidad de la traficabilidad

The ability of a telecommunication system to handle the offered traffic under specified conditions.

Specified conditions refer to any combination of failed and nonfailed parts of the system.

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[1] Preferred by Study Group II.

2.8 propagation performance

F: caractéristiques de propagation

S: calidad de la propagación

The ability of a propagation medium to transmit signals within the specified tolerances.

Note – The specified tolerances may apply to variations in signal level, noise, interference levels, etc.

2.9 availability performance

F: disponibilité de l'équipement

S: calidad de la disponibilidad

The ability of an item – under combined aspects of its reliability performance, maintainability performance and of the maintenance support performance – to perform or to be in a state to perform a required function for a stated condition of time.

Note – Stated condition of time refers to a stated instant of time or to a stated interval of time.

2.10 reliability performance

F: fiabilité d'un équipement

S: calidad de la fiabilidad

The ability of an item to perform a required function, under stated conditions, for a stated period of time.

Note – The term reliability is used as a functional reliability performance measure.

2.11 maintainability performance

F: maintenabilité

S: calidad de la mantenibilidad

The ability of an item, under stated conditions of use, to be retained in, or restored to a state in which it can perform a required function, when maintenance is performed under stated conditions and using stated procedures and resources.

Note – The term maintainability is used as a functional maintainability performance measure, denoting the probability that the active maintenance is carried out within a given period of time.

2.12 maintenance support performance

F: logistique de maintenance

S: calidad del soporte de mantenimiento

The ability of a maintenance organization, under stated conditions, to provide upon demand the resources required to maintain an item.

Note 1 – Maintenance organization includes physical resources expected to act under a given maintenance policy.

Note 2 – The stated conditions are related to the item itself and to the conditions under which the item is used and maintained.

ANNEX A

(to Recommendation G.106)

A.1 *Failures and interruptions*

A.1.1 *Failure concepts*

A.1.1.1 failure; fault (deprecated)

F: dérangement; défaut (déconseillé)

S: fallo; avería (desaconsejado)

The termination of the ability of an item to perform a required function.

A.1.1.2 **failure occurrence**

F: apparition d'un dérangement

S: aparición de fallo

The event when an item loses its ability to perform a required function.

A.1.1.3 **failure state**

F: état de dérangement

S: estado de fallo

A state of an item characterized by lack of ability to perform a required function.

A.1.1.4 **failure mode**

F: mode de dérangement

S: modo de fallo

One of the possible states of an item defined as a failure state.

A.1.1.5 **up state**

F: état de disponibilité

S: estado de disponibilidad

A state of an item in which it can perform a required function.

A.1.1.6 **down state**

F: état d'indisponibilité

S: estado de indisponibilidad

A state of an item in which it cannot perform a required function.

A.1.2 *Classification of failures* [2)]

A.1.2.1 **complete failure**

F: dérangement complet

S: fallo total

A.1.2.2 **partial failure**

F: dérangement partiel

S: fallo parcial

A.1.2.3 **sudden failure**

F: dérangement brusque

S: fallo repentino

A.1.2.4 **gradual failure**

F: dérangement progressif

S: fallo gradual

A.1.2.5 **function preventing failure**

F: dérangement empêchant l'accomplissement des fonctions

S: fallo que impide la función

Failure of a subitem such as to cause complete lack of the required functions.

2) For the definition of the terms given in §§ A.1.2.1 - A.1.2.4, refer to the IEC publication cited in [2]. However, the terms and definitions in §§ A.1.2.5 - A.1.2.9 are given pending their publication by IEC.

A.1.2.6 **function degrading failure**

F: dérangement dégradant les fonctions

S: fallo gue degrada la función

Failure of a subitem such as to cause lack of part of the required functions.

A.1.2.7 **function permitting failure**

F: dérangement permettant l'accomplissement des fonctions

S: fallo gue permite la función

Failure of a subitem such as not to cause lack of the required functions.

A.1.2.8 **permanent failure**

F: dérangement permanent

S: fallo permanente

Failure of an item that persists until corrective maintenance (repair) actions are undertaken.

A.1.2.9 **intermittent failure**

F: dérangement intermittent

S: fallo intermitente

Failure of an item for a limited period of time following which the item recovers a required function without being subjected to any external corrective action.

Note – Such a failure is often recurrent.

A.1.3 *Interruption concepts*

A.1.3.1 **interruption of transmission (service)**

F: interruption de (service de) transmission

S: interrupción de la transmisión (de un servicio)

Discontinuation of transmission (a service) caused by a change beyond given limits for a given minimum period of time in any one or combination of more than one parameter that is essential to a transmission (service).

Note 1 – The parameters, periods of time and limits are to be specified as required.

Note 2 – Possible parameters involved in transmission interruption: power level, noise level, signal-to-noise ratio, group-delay distortion, degree of telegraph distortion, bit error rate, etc.

Note 3 – Possible parameters involved in service interruption: duration and frequency of transmission interruptions, reliability characteristics of switching equipment, etc.

A.2 *Maintenance, maintainability and maintenance support*

A.2.1 *Maintenance concepts*

A.2.1.1 **maintenance**

F: maintenance

S: mantenimiento

The combination of all technical and corresponding administrative actions intended to retain an item in, or restore it to, a state in which it can perform its required function.

A.2.1.2 **level of maintenance**

F: niveau de maintenance

S: nivel de mantenimiento

The type of maintenance actions to be carried out at a stated degree of breakdown of a complex item.

Note 1 – The criteria of the breakdown may be complexity of construction, accessibility, ease of replacement, safety, etc.

Note 2 – Examples are replacing a component, a printed circuit board, a subsystem, etc.

A.2.1.3 **line of maintenance**

F: ligne de maintenance

S: línea de mantenimiento

The position in an organization at which the maintenance of an item is to be carried out at stated levels of maintenance.

Note – The position is characterized by the skill of the personnel, the facilities available, the location, etc.

A.2.1.4 **failure recognition**

F: identification d'un dérangement

S: detección de fallo

The event of recognizing that an item has lost its ability to perform a required function.

A.2.2 *Classification of maintenance*

A.2.2.1 **preventive maintenance**

F: maintenance préventive

S: mantenimiento preventivo

The maintenance carried out at predetermined intervals or corresponding to prescribed criteria and intended to reduce the probability of failure or the performance degradation of an item.

A.2.2.2 **corrective maintenance; repair**

F: maintenance corrective; réparation

S: mantenimiento correctivo; reparación

The maintenance carried out after a failure has occurred and intended to restore an item to a state in which it can perform its required function.

A.2.2.3 **controlled maintenance**

F: maintenance dirigée

S: mantenimiento controlado

A method to sustain a desired quality of service by the systematic application of analysis techniques using centralized supervisory facilities and/or sampling to minimize preventive maintenance and to reduce corrective maintenance.

A.2.2.4 **scheduled maintenance**

F: maintenance programmée

S: mantenimiento programado

The maintenance carried out at a certain instant of time according to a given plan.

A.2.2.5 **unscheduled maintenance**

F: maintenance non programmée

S: mantenimiento no programado

The maintenance carried out after reception of an indication regarding the state of an item.

A.2.2.6 **function affecting maintenance**

F: maintenance affectant les fonctions

S: mantenimiento que afecta a la función

Such maintenance that affects one or more of the required functions of a maintained item.

Note – Function affecting maintenance is divided into function preventing and function degrading maintenance.

A.2.2.7 **function preventing maintenance**

F: maintenance empêchant l'accomplissement des fonctions

S: mantenimiento que impide la función

Such maintenance that prevents a maintained item from performing its required functions by causing complete loss of the functions.

A.2.2.8 **function degrading maintenance**

F: maintenance dégradant les fonctions

S: mantenimiento que degrada la función

Such maintenance that affects one or more of the required functions of a maintained item, but not to such an extent as to cause complete loss of the functions.

A.2.2.9 **function permitting maintenance**

F: maintenance permettant l'accomplissement des fonctions

S: mantenimiento que permite la función

Such maintenance that does not affect any of the required functions of a maintained item.

A.2.3 *Maintainability performance and maintenance support performance measures*

A.2.3.1 **maintainability**

F: maintenabilité

S: mantenibilidad

The probability that the active maintenance can be carried out within a stated period of time, when the maintenance is performed under stated conditions and using stated procedures and resources.

A.2.3.2 **repair rate**

F: taux de réparation

S: proporción de reparaciones

(to be defined)

A.2.3.3 **instantaneous repair rate**

F: taux instantané de réparation

S: proporción instantánea de reparaciones

The time limit of the ratio (if this exists) of the probability that the corrective maintenance action terminates in a time interval and the length of this time interval, when the length of the time interval tends to zero, given that the action had not terminated at the beginning of the interval.

A.2.3.4 **mean repair rate**

F: taux moyen de réparation

S: proporción media de reparaciones

The mean of the instantaneous repair rate in a stated time interval.

A.2.4 *Maintainability time concepts* (see also § A.4)

A.2.4.1 **undetected failure time**

F: durée de dérangement non détecté

S: tiempo de fallo no detectado

The period of time between the failure occurrence and failure recognition.

A.2.4.2 **administrative time for corrective maintenance**

F: durée administrative pour la maintenance corrective

S: tiempo administrativo para el mantenimiento correctivo

The period of time during which an item has failed and during which corrective maintenance actions are pending or prepared but not yet initiated.

A.2.4.3 **maintenance time**

F: durée de maintenance

S: tiempo de mantenimiento

The period of time during which maintenance actions, including delays inherent in the maintenance operations, are performed on an item either manually or automatically.

Note 1 – The inherent delays include those due to design or to prescribed maintenance procedures.

Note 2 – Maintenance may be carried out while the item is still performing a required function.

Note 3 – For breakdown of the maintenance time, see Figure A-1/G.106.

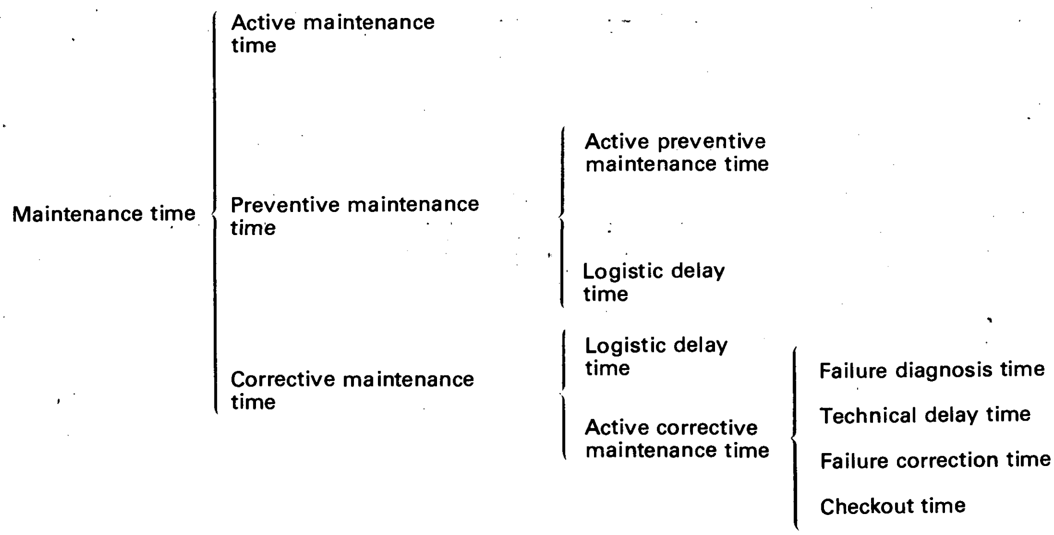


FIGURE A-1/G.106
Breakdown of maintenance time

A.2.4.4 **active maintenance time**

F: durée de maintenance active

S: tiempo de mantenimiento activo

That part of the maintenance time during which maintenance actions are performed on an item, either automatically or manually, including the time due to delays inherent in the maintenance operation.

Note – Active maintenance may be carried out while the item is performing a required function.

A.2.4.5 **preventive maintenance time**

F: durée de maintenance préventive

S: tiempo de mantenimiento preventivo

That part of the maintenance time during which preventive maintenance is performed on an item, including the time due to logistic delays inherent in the preventive maintenance operations.

Note 1 – The inherent delays include those due to design or to prescribed maintenance procedures.

Note 2 – Preventive maintenance time does not include any time taken to maintain an item which has been replaced.

A.2.4.6 **corrective maintenance time; repair time**

F: durée de maintenance corrective; durée de réparation

S: tiempo de mantenimiento correctivo; tiempo de reparación

That part of the maintenance time, including those due to logistic delays, during which corrective maintenance is performed on an item.

A.2.4.7 **active preventive maintenance time**

F: durée de maintenance préventive active

S: tiempo de mantenimiento preventivo activo

That part of the preventive maintenance time, including technical delays inherent in the actions, during which preventive maintenance actions are performed on an item either manually or automatically.

A.2.4.8 **logistic delay time**

F: délai logistique

S: tiempo de demora logística

That part of the maintenance time during which no maintenance actions are performed because of delays.

Note – Delays can be due, for example, to travel to unattended exchanges, the pending arrival of spare parts, specialists and test equipment.

A.2.4.9 **active corrective maintenance time; active repair time**

F: durée de maintenance corrective active; durée de réparation active

S: tiempo de mantenimiento correctivo activo; tiempo de reparación activo

That part of the active maintenance time in which corrective maintenance actions are performed on an item either automatically or manually, including the time due to delays inherent in the repair operation.

Note 1 – The inherent delays could for example include those due to design or to prescribed maintenance procedures.

Note 2 – Active corrective maintenance time does not include any time taken to repair an item which has been replaced as part of the corrective maintenance action under consideration.

A.2.4.10 **failure diagnosis time**

F: durée du diagnostic d'un dérangement

S: tiempo de diagnóstico de fallo

That part of the active corrective maintenance time during which it is determined which of the subitems of an item has failed.

A.2.4.11 **failure correction time**

F: durée de relève d'un dérangement

S: tiempo de correción de fallo

That part of active corrective maintenance time during which the ability of a failed item to perform its function is restored.

Note – That restoring action may be a replacement of a subitem of the item.

A.2.4.12 **technical delay time**

F: délai technique

S: tiempo de demora técnica

That part of maintenance time due to delays inherent in the maintenance process.

A.2.4.13 **check-out time**

F: durée de vérification

S: tiempo de verificación

That part of active corrective maintenance time during which function check-out is performed.

A.3 *Quality of service, availability performance and reliability performance measures*

A.3.1 *Quality of service measures*

A.3.1.1 **probability of successful service completion**

F: probabilité d'exécution correcte du service

S: probabilidad de realización satisfactoria de un servicio

The probability that a connection can be established, under satisfactory operating conditions, and retained for a given period of time.

A.3.2 *Availability performance measures (basic measures)*

A.3.2.1 **availability [unavailability]**

F: disponibilité [indisponibilité]

S: disponibilidad [indisponibilidad]

The probability that an item can (cannot) perform its required function under stated conditions for stated condition of time.

A.3.2.2 **instantaneous availability [unavailability]**

F: disponibilité [indisponibilité] instantanée

S: disponibilidad [indisponibilidad] instantánea

The probability that an item can (cannot) perform its required function under stated conditions at a stated instant of time.

A.3.2.3 **mean availability [unavailability]**

F: disponibilité [indisponibilité] moyenne

S: disponibilidad [indisponibilidad] media

The mean of the instantaneous availability [unavailability] in a stated interval of time.

Note – Mean availability [unavailability] can be estimated on the basis of continuous observation or by a sampling technique (scanning).

A.3.2.4 **asymptotic availability [unavailability]**

F: disponibilité [indisponibilité] asymptotique

S: disponibilidad [indisponibilidad] asintótica

The limit of the instantaneous availability [unavailability] function when the time tends to infinity, if such a limit exists.

Note – Asymptotic availability [unavailability] can be estimated on the basis of continuous observation or a sampling technique (scanning).

A.3.3 *Service availability performance measures*

A.3.3.1 **availability of a connection to be established**

F: disponibilité d'une communication à établir

S: disponibilidad de una conexión que ha de establecerse

The probability that a switched connection can be established, within specified transmission tolerances, to the correct destination, within some specified interval of time, when requested by the customer.

Note 1 – For subscriber-originated calls, availability of a switched connection could express the probability of a successful call establishment on the first attempt. For operator-handled calls, availability of a switched connection could represent the probability of having a satisfactory connection established within a specified time interval, for example 1 minute, 3 minutes or 10 minutes.

Note 2 – In general, the tolerances should correspond to an amount of transmission impairment which makes the connection unsatisfactory for service; for example, such that a substantial percentage of customers would not use the connection.

A.3.3.2 **availability of a leased circuit**

F: disponibilité d'un circuit loué

S: disponibilidad de un circuito arrendado

The probability that, under stated operating conditions, a leased circuit can perform its required function when requested by the subscriber.

A.3.4 *Availability time concepts* (see also § A.4)

A.3.4.1 **required [unrequired] time**

F: durée requise [non requise]

S: tiempo requerido [no requerido]

The period of time during which the user requires [does not require] the item to be in a condition to perform a required function.

A.3.4.2 **free time**

F: temps libre

S: tiempo libre

That part of the nonrequired time during which an item is in a condition to perform a required function.

A.3.4.3 **standby time**

F: temps de latence

S: tiempo en reserva

The period of time during which an item is needed to be in a condition to perform a required function but is not operated.

A.3.4.4 **operating [non-operating] time**

F: temps de fonctionnement [non fonctionnement]

S: tiempo de funcionamiento [no funcionamiento]

The period of time during which an item performs [does not perform] a required function.

A.3.4.5 **up [down] time**

F: durée de disponibilité [d'indisponibilité]

S: tiempo de disponibilidad [indisponibilidad]

The period of time during which an item is [is not] in a condition to perform a required function.

Note – Unless otherwise stated, down time will include any additional time necessary to reach the same stage in the working programme of the item as at the time of failure occurrence.

A.3.4.6 **internal [external] down time**

F: durée d'indisponibilité interne [externe]

S: tiempo de indisponibilidad interna [externa]

That part of down time which is caused [not caused] by failure of the item itself.

Note – External down time may be due to lack of external resources such as power, fuel, etc.

A.3.5 *Reliability performance measures (basic measures)*

A.3.5.1 **reliability**

F: fiabilité

S: fiabilidad

The probability that an item can perform a required function under stated conditions for a stated period of time.

A.3.5.2 **failure rate**

F: taux de dérangement

S: proporción de fallos

(to be defined)

A.3.5.3 **instantaneous failure rate**

F: taux instantané de dérangement

S: proporción instantánea de fallos

The limit (if this exists) of the ratio of the probability of failure of an item, in a time interval and the length of this time interval when the length of the time interval tends to zero, given that the item is in a state to perform a required function at the beginning of the interval.

A.3.5.4 **mean failure rate**

F: taux moyen de dérangement

S: proporción media de fallos

The mean of the instantaneous failure rate in a stated time interval.

A.3.5.5 **failure intensity**

F: intensité de dérangement

S: intensidad de fallos

(to be defined)

A.3.5.6 **instantaneous failure intensity**

F: intensité instantanée de dérangement

S: intensidad instantánea de fallos

The limit (if this exists) of the ratio of the mean number of failures of an item in a time interval and the length of this interval, when the length of the time interval tends to zero.

A.3.5.7 **mean failure intensity**

F: intensité moyenne de dérangement

S: intensidad media de fallos

The mean of the instantaneous failure intensity in a stated time interval.

A.3.6 *Service reliability performance measures*

A.3.6.1 **reliability of an established (telephone) connection**

F: fiabilité d'une communication (téléphonique) établie

S: fiabilidad de una conexión (telefónica) establecida

The probability that a switched (telephone) connection, once established, will operate within specified transmission tolerances without interruption for a given interval of time.

A.3.6.2 **mean time between interruptions**

F: temps moyen entre interruptions

S: tiempo medio entre interrupciones

The mean of the interval of time between consecutive interruptions of a required ability to an item or service.

A.3.7 *Reliability time concepts* (see also § A.4)

A.3.7.1 **time to first failure**

F: temps de fonctionnement avant la première défaillance

S: tiempo hasta el primer fallo

The total intervals of operating time of an item, from the instant it is put first in an up-state until it fails.

A.3.7.2 **time to failure**

F: temps de fonctionnement avant défaillance

S: tiempo hasta el fallo

The total intervals of operating time of an item, from the instant it goes from a down-state to an up-state, after a corrective maintenance action, until it fails.

A.3.7.3 **time between failures**

F: temps de bon fonctionnement

S: tiempo entre fallos

The interval of time between failures of a repaired item.

Note – Nonoperating time is included and should be identified.

A.3.7.4 **mean time to first failure**

F: moyenne des temps de fonctionnement avant la première défaillance

S: tiempo medio hasta el primer fallo

The mean value of the time to the first failure.

A.3.7.5 **mean time to failure**

F: temps de fonctionnement moyen avant défaillance

S: tiempo medio hasta el fallo

The mean value of the time to failure.

A.3.7.6 **mean time between failures**

F: moyenne des temps de bon fonctionnement

S: tiempo medio entre fallos

Mean time of the time between failures.

A.3.7.7 **useful life**

F: durée de vie utile

S: vida útil

The period from a stated time, during which, under stated conditions, an item has an acceptable failure intensity or until an unrepairable failure occurs.

A.3.7.8 **early failure period**

F: période initiale de dérangement

S: periodo de fallos inicial

That possible early period, beginning at a stated time and during which the failure intensity decreases rapidly in comparison with that of the subsequent period.

Note – In any particular case it is necessary to explain what is meant by decreases rapidly (see Figure A-2/G.106).

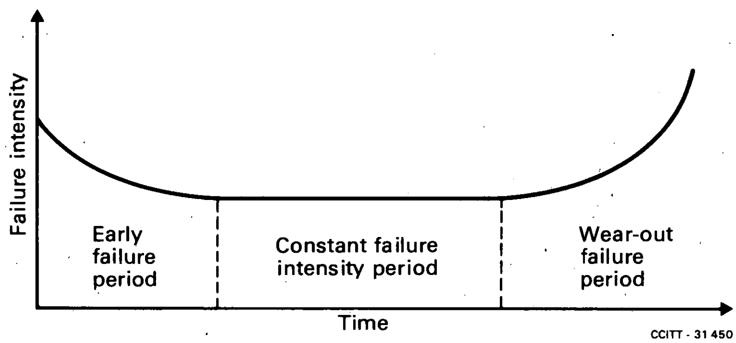


FIGURE A-2/G.106

Time periods with respect to failure occurrence during the lifetime of a repaired item

A.3.7.9 **constant failure intensity period**

F: période d'intensité constante de dérangement

S: periodo de intensidad de fallos constante

That possible period during which the failures occur at an approximately constant intensity.

Note – In any particular case it is necessary to explain what is meant by approximately constant intensity (see Figure A-2/G.106).

A.3.7.10 **wear-out failure period**

F: période de dérangement par usure

S: periodo de fallos par desgaste

That possible period during which the failure intensity increases rapidly in comparison with the preceding period.

Note – In any particular case it is necessary to explain what is meant by increases rapidly (see Figure A-2/G.106).

A.4 *Design concepts and time diagram*

A.4.1 *Design concepts*

A.4.1.1 **redundancy**

F: redondance

S: redundancia

In an item, the existence of more than one means for performing a required function.

A.4.1.2 **active redundancy**

F: redondance active

S: redundancia activa

That redundancy wherein all means for performing a required function are operating simultaneously.

A.4.1.3 **standby redundancy**

F: redondance en attente

S: redundancia pasiva

That redundancy wherein the alternative means for performing a required function are inoperative until needed.

A.4.1.4 **fail safe**

F: protection contre les dérangements

S: prevención contra fallos

A designed property of an item which prevents its failures from being critical failures.

A.4.1.5 **functional mode**

F: mode fonctionnel

S: modo funcional

A subset of the whole set of functions of an item.

A.4.2 *Time diagram*

The time concepts used throughout this Recommendation have been grouped naturally in the above to correspond most closely to their application. In § A.4.2 these concepts are presented in the form of a Karnaugh map to demonstrate their interrelationship. This map is shown in Figure A-3/G.106.

In specific cases of equipment and conditions the drawing of a more complex or a more simplified diagram may be appropriate or necessary. This may also be needed when times are to be shown in strict time order. An example of such a simplified diagram is given in Figure A-4/G.106.

It is advisable in practical applications to draw a separate diagram including those time concepts relevant to that study.

A.5 *Explanatory text*

A.5.1 *Failure terms*

The word **failure** is the basic term denoting either the termination of the ability of an item to perform a required function or, in combination with the term "state", the state (condition) of an item which has "failed". For some of the failure terms included in the list, an abbreviation has been used in such a way that the term "state" has been excluded where it has been considered appropriate to do so. In practical applications it may be necessary to add the term "state" to avoid misunderstanding. A failure term applies only to the item under consideration. Thus a complete failure of a particular subitem may imply only a partial failure of the item in which it is used.

A.5.2 *The use of modifiers*

The list contains, in principle, only basic concepts which are considered to have a wide application. In practical application, however, there is usually a necessity to be more precise. This precision is accomplished by the addition of modifiers to the basic terms. One should in every application carefully ascertain that the necessary modifiers are always added to the basic terms.

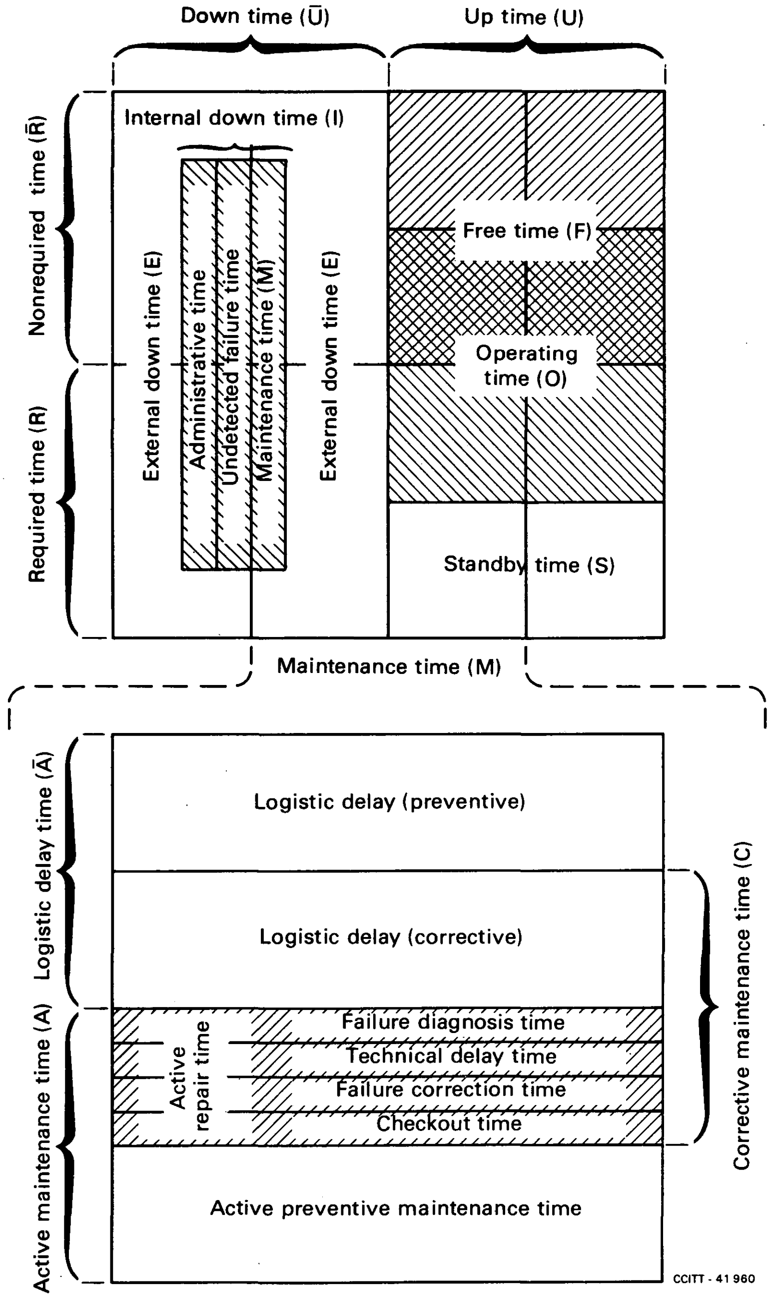


FIGURE A-3/G.106

Set diagram for time concepts as defined in §§ A.2.4.1 to A.2.4.13 and in §§ A.3.4.1 to A.3.4.6

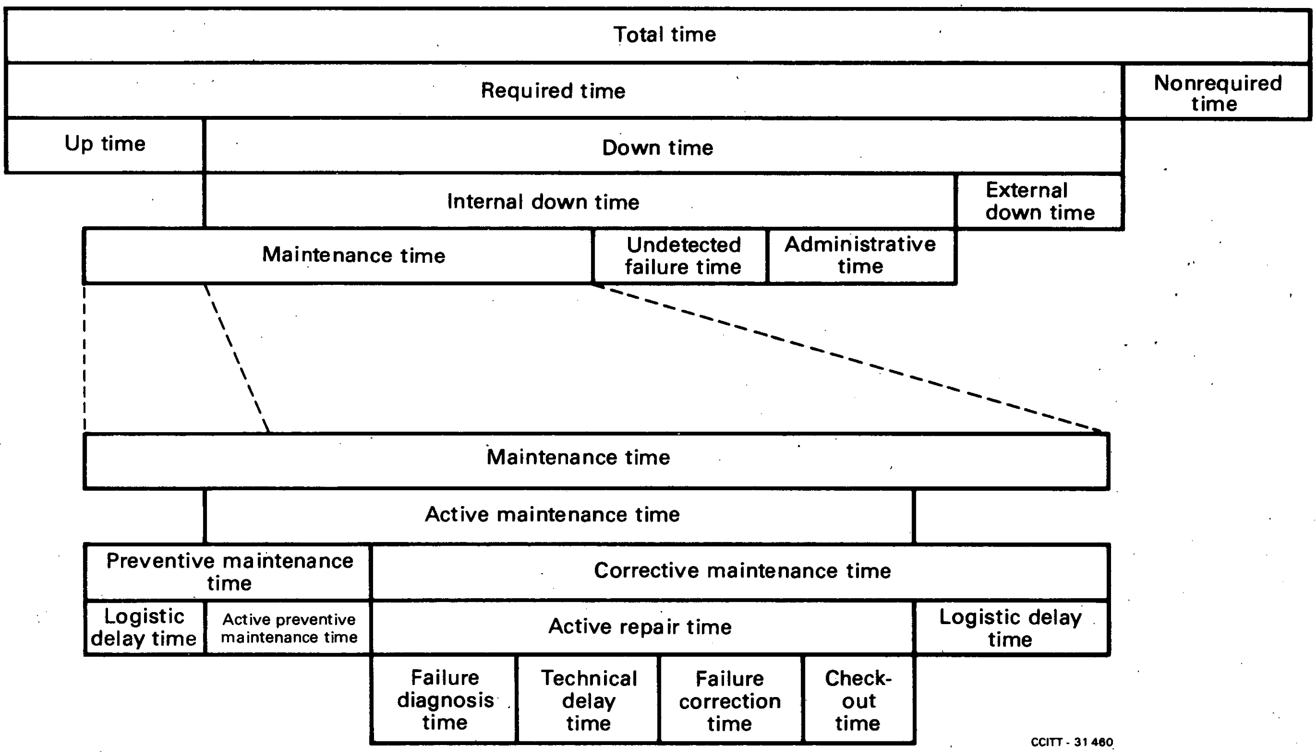


FIGURE A-4/G.106
Simplified time diagram

A.5.3 *Note on the terms "measure" and "characteristic"*

A **characteristic** is a property which helps to differentiate between the items of a given population. The differentiation may be either quantitative (by variables) or qualitative (by attributes).

The variables of interest for this publication are random variables. To each random variable is associated a probability distribution.

A **measure** is either a function or (usually) a single value description of such a random variable (e.g. mean, fractile). These measures may be used either in modelling situations where principles are described, without necessarily one having a possibility to make observations, or they may be used in the treatment of observations. The definition of the basic measure is the same in both cases.

The measures are themselves not observable in practice, but may be estimated using observed values and appropriate statistical theory.

It should be noted that in most cases it is not necessary to define each individual measure – only the random variables (usually times) need to be defined. The measures are then easily designed by use of the appropriate "statistical" modifier, in combination with the variable's name.

A.5.4 *The use of the concept of "probability"*

The concept of probability may be introduced in either of two forms depending on whether it is intended to designate a degree of belief or whether it is considered as the limit value of a frequency. In both cases, its introduction requires some precautions to be taken.

For practical reasons, however, it may be considered that, whenever the conditions of a test can be reproduced, the probability Pr(E), of an event E occurring, is the value around which the occurrence frequency of the latter oscillates and towards which it tends when the number of observations is indefinitely increased.

A.5.5 *Meaning of the term "item"*

The term **item** is used to denote any part, subsystem, equipment or system that can be individually considered. An "item" may partly or wholly consist of software. The term is also used to denote items, population of items, sample, etc.

In each practical application of the terms one should carefully define what is meant by "item".

The term "complex item" is used when a constellation of items is considered. The term "subitem" is used when there is a need to indicate that a possible breakdown of the item into smaller parts is specifically considered. For the practical application of measure concepts, clarifications may have to be made by introduction of suitable modifiers, such as:

- system, subsystem,
- device, processor,
- subscriber line, leased circuit, etc.

As the applicable set of item modifiers depends on the equipment under study, each such study should contain a statement of modifiers used.

A.5.6 *The difference between "operation" and "maintenance"*

The terms of this glossary are often applied to such a complex item called "system". These systems are in many cases maintained by the same personnel as that used for the operation of the system. It may thus be practical to make a distinction between "operation" and "maintenance".

This distinction may be made according to the following model:

A **system** is a collection of items intended to perform a given set of (transfer) functions. The system is observable in its environment by a set of output variables, which can be influenced, through the system, by a set of input variables.

In order to determine whether the system performs the intended functions, the actual output is compared with the required output. Deviations may be eliminated by two alternative actions : change the input *or* change the (transfer) functions.

We can now define

operation : the set of actions which change the input.

Further, there are two possible reasons for changing the (transfer) functions:

a) the set has changed from what was designed or manufactured into the system. We then define

   maintenance: the set of actions which restore the (transfer) functions to the original set.

b) the set has never been the intended one or are no longer sufficient for its purpose. We define this

   modification: the set of actions which alter the original set of (transfer) functions.

   Note: Modifications may be done also on other indications.

A.5.7 *Modifier concepts*

A.5.7.1 *Time and condition modifiers*

The statement of the value of a distribution parameter or another quantitative characteristic (measure) can be made before, during or after the instant of time or time interval for which the statement is intended to be valid. It can also refer to other conditions than those for which the observations were made.

When the conditions of the statement must be clarified, it shall be accompanied by one of the following modifiers:

true (value), predicted (value), estimated (value), extrapolated (value).

A.5.7.2 *Statistical modifiers*

They are the following: fractile, mean (expectation).

A.6 *Mathematical guide and symbols*

(to be prepared)

A.7 *Alphabetical index*

References

[1] CCIR Recommendation *Availability objective for a hypothetical reference circuit and a hypothetical reference digital path*, Vol. IX, Rec. 557, ITU, Geneva, 1978.

[2] IEC Publication No. 271.

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

Recommendation G.111

CORRECTED REFERENCE EQUIVALENTS (CREs) IN AN INTERNATIONAL CONNECTION

(Geneva, 1964; amended at Mar del Plata, 1968, Geneva, 1972, 1976 and 1980)

Preamble

Parts 1 to 5 of this Recommendation apply in general to all analogue, mixed analogue/digital and all digital international telephone connections. However, where recommendations are made on specific aspects in § 6 for mixed analogue/digital or all-digital connections, § 6 will govern.

In the international transmission plan, the Corrected Reference Equivalent (CRE) between two subscribers is not strictly limited; its maximum value results from all the various recommendations indicated below.

1 Nominal CREs of the national systems (formerly Part A)

1.1 *Definition of* **nominal CREs of the national systems**

The sending and receiving CRE of the national system are calculated to, and from, the virtual analogue switching points of the international system; that is to say, points a and b of Figure 1/G.111.

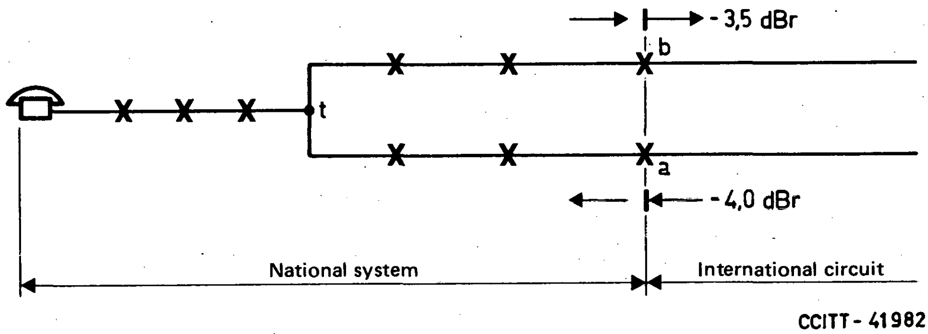
The definition of the corrected reference equivalent and explanations of its properties are given in Annex A.

The virtual analogue switching points of an international 4-wire telephone circuit are fixed by convention at points of the circuit where the nominal relative levels at the reference frequency are:

– sending: −3.5 dBr;
– receiving: −4.0 dBr (analogue circuits);
  −3.5 dBr (digital circuits).

The nominal value of the transmission loss of this circuit at the reference frequency between virtual switching points is therefore 0.5 dB, for analogue or 0 dB for digital circuits.

Note – The relative level at a given point of a 4-wire circuit is determined by reference to the specifications of the transmission system on which the circuit is set up, the performance of the system (noise, crosstalk, limiting, linearity, etc.) being evaluated at a point of zero relative level. For example, the nominal mean power of signals during the busy hour, at a point of zero relative level, is indicated in the Recommendation cited in [1]. For further details, see Recommendation G.101, § 5.



For the relative levels of digital circuits, see a) of Figure 2/G.101

Virtual analogue switching points of the international circuit

Note – The values of relative level shown are those of the international circuit. The values of the relative levels of the national circuit are not shown, since they depend on the national transmission plan. The virtual analogue switching points will generally have no physical existence, but are a necessary concept in the planning of national systems.

FIGURE 1/G.111

Definition of the virtual analogue switching points

1.2 *Recommended values*

Recommendation G.121 gives objectives for the nominal sending and receiving CREs of national systems.

2 **Nominal overall loss of the international chain** (formerly Part B)

The nominal loss between the virtual switching points of each international analogue circuit should in principle be 0.5 dB at 800 Hz or 1000 Hz. However, some circuits can be operated with higher losses (see Recommendation G.131, § 2.1) and certain analogue circuits may be operated at zero loss (see Note 3 of Recommendation G.101, § 5). Digital circuits are used with a nominal transmission loss of 0 dB (see § 6).

As far as transmission is concerned, there is no strict limit on the number of international circuits which may be interconnected in tandem, provided each of them has a nominal loss, between the virtual switching points, of 0.5 dB in the transit condition and provided there is a 4-wire interconnection. Naturally, the fewer the number of interconnected circuits the better the transmission performance is likely to be (see Recommendation G.101, § 3).

Note – Information on the actual number of circuits which are found in international connections is given in Recommendation G.101, § 3.

3 **CREs and directional effects in a complete connection** (formerly Part C)

3.1 *Nominal CREs for each transmission direction*

Section A.3 of Annex A shows how to calculate the CRE of a complete connection. In particular, if the attenuation distortion of the 4-wire chain attains the limits set in Recommendation G.132, the nominal CRE of an international connection is the sum of:

- the nominal CRE of the national sending system (see Recommendation G.121, § 4);
- the nominal equivalent of the international chain (see § 2 of the present Recommendation);
- the nominal CRE of the national receiving system (see Recommendation G.121, § 4).

3.2 *Traffic-weighted mean values of the distribution of overall CREs*

Subjective tests have shown that the preferred range of overall CREs for telephone connections is approximately 4 to 16 dB, with the preferred value in that range of about 7 dB.

Bearing in mind that long international telephone connections ordinarily require sufficient transmission loss to control echo and stability, it has been provisionally agreed that the long-term objective for the traffic-weighted mean value of the distribution of the planning values of the overall CREs for international connections should lie in the range 13 to 16 dB.

An objective for the mean value is necessary to ensure that satisfactory transmission is given to most subscribers.

Note 1 – The long-term values cannot be attained at this time and an appropriate short-term objective is a range of 13 to 25.5 dB for the mean value of the traffic-weighted distribution of the overall CREs.

Note 2 – The 0.5 dB transmission loss of each circuit in the international chain (see § 2 above) has been allowed for by noting that the average number of international circuits encountered in international connections, according to study conducted by Study Group XIII in 1975, is 1.1. (See Recommendation G.101, § 3.)

As a result the ranges mentioned above do not include allowances for connections between countries which:

– involve more than one 0.5 dB international circuit;

– involve a single international circuit which has a higher loss than 0.5 dB as permitted by Recommendation G.131, § 2.1.

Note 3 – Recommendation G.121, § 1 gives values for national systems based on the overall objectives of this Recommendation.

Note 4 – In planning future international and national telecommunication systems, especially when the use of digital systems is envisaged, the preferred range of overall CREs 4 to 16 dB should be aimed at.

3.3 *Difference in transmission loss between the two directions of transmission*

In an international connection between local exchanges the contribution to the asymmetry introduced by the two national systems is limited to not more than 8 dB by the provisions of Recommendation G.121, § 2.2. The international circuits could, in practical circumstances outlined in the General Remarks in Recommendation G.101, § 4 introduce additional asymmetry. This additional asymmetry will be acceptably small.

4 **Variation in time and effect of circuit noise** (formerly Part D)

4.1 *Variations in time*

The CRE values calculated for national systems (Recommendation G.121, § 4) do not cover variations in time of the loss of various parts of the national system. Recommendation G.151, § 3 gives the objectives recommended by the CCITT for transmission loss variations on international circuits and national extension circuits as compared with the nominal values.

4.2 *Effect of circuit noise*

See Recommendation G.113.

5 **Practical limits of the CRE between two operators or one operator and one subscriber** (formerly Part E)

These limits are being studied; the values recommended for the reference equivalent in the old transmission plan are given in the [2] and in applying them [3] should be borne in mind.

The values of the reference equivalent for the complete connections shown in the table in [4], and reproduced in the table of [5], are not applicable to the transmission plan now recommended by the CCITT.

6 **Incorporation of PCM digital processes in international connections**

6.1 *Connections with a digital 4-wire chain extending to the local exchanges*

As the national network develops, an international telephone connection might have the configuration indicated in Figure 2/G.111, in which the analogue/digital interface occurs at the local exchange. In such a connection, the nominal transmission loss introduced by the 4-wire chain of national and international digital circuits is 0 dB. Consequently, the 4-wire chain generally does not contribute to the control of stability and echo. However, part of the loss required to control stability and echo is at the local exchange, as indicated by the R and T pads, the remainder being provided by the balance return loss at the 2-wire/4-wire terminating unit (see also Recommendation G.122).

As an objective, it is provisionally recommended in Recommendation G.121, § 6, that the transmission loss to be introduced by the combination of the R and T pads in Figure 2/G.111, should be 6 or 7 dB [1]. With regard to the stability and echo balance return losses at the 2-wire/4-wire terminating unit, these losses may be small and often need special arrangements to improve them. However, the 6 or 7 dB lumped loss to be introduced is considered to be adequate in most cases for the maintenance of stability and in association with an adequate echo balance return loss also for the control of echo.

Other transmission considerations to be taken into account in the planning of connections involving 4-wire local exchanges in a mixed analogue/digital network include system loading and crosstalk.

The amount of loss to be introduced individually by the R and T pads of Figure 2/G.111, can be regarded as a national matter within the constraints referred to above. Within these constraints, individual national transmission plans should govern the values to be assigned to the R and T pads. This aspect is dealt with in some detail in Recommendation G.121, § 6.

Figure 2/G.111 also shows R and T as analogue pads. This need not always be the case since under some conditions it might be more practical or necessary to introduce the required loss by means of digital pads. However, if digital pads are used, their detrimental effect on digital data or other services requiring end-to-end bit integrity must be taken into account as indicated in Recommendations G.101, § 4.4 and G.103, § 4.

6.2 *Mixed analogue/digital connections*

To provide satisfactory transmission on international connections in the mixed analogue/digital period, it is likely that existing national transmission plans will have to be amended or new ones developed to provide for appropriate national extensions. All the relevant CCITT Recommendations should be complied with. The recommendations concerning national extensions with 4-wire chains extending to 4-wire local exchanges are given in Recommendation G.121, § 6.

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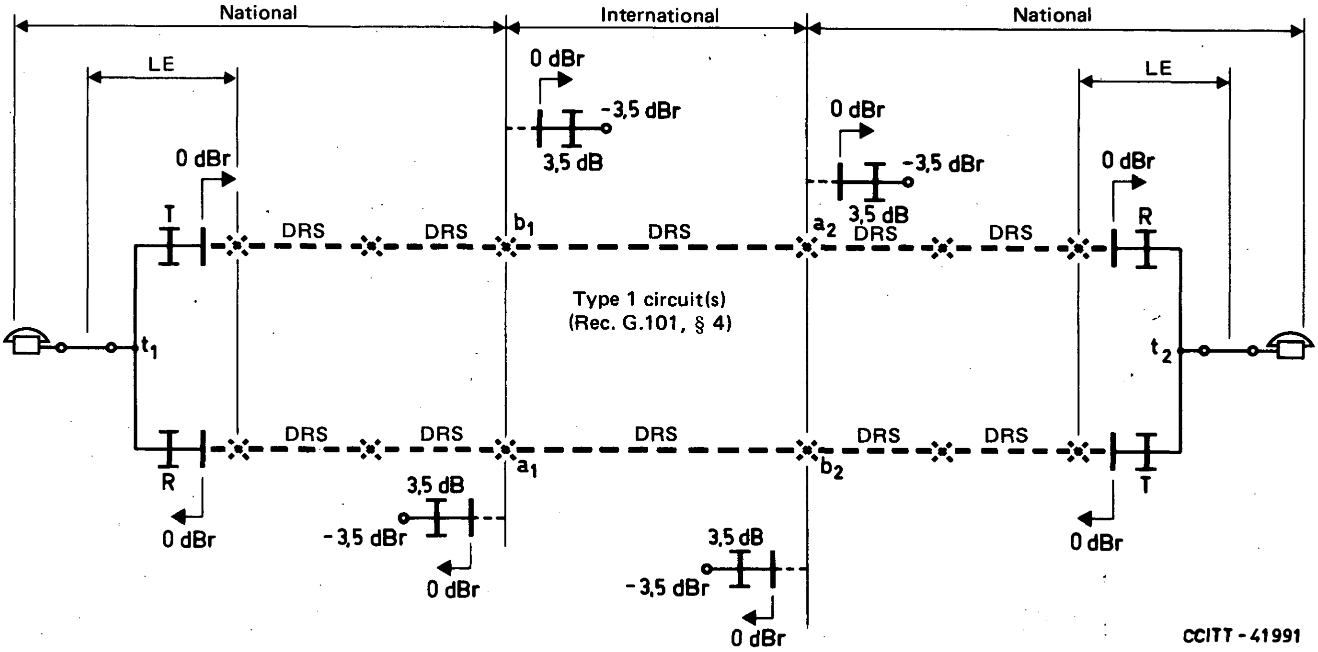
1) When a sufficiently high balance return loss can be assumed, e.g. by impedance correction or improved balance networks, other values for the sum of the R and T pads are considered possible by some Administrations. See [6].



DRS — Digital reference sequence

Analogue transmission

Digital transmission

R T — Analogue pads (represent nominal loss between 4-wire switch and 2-wire point including loss of the 2-wire/4-wire terminating unit)

Digital switching

a, b — Virtual analogue switching points

Analogue/digital or digital/analogue coder or decoder

0 dBr — Idealized digital/analogue decoder with 0 dBr output relative level

0 dBr — Idealized analogue/digital coder with 0 dBr input relative level

LE — Local exchange

FIGURE 2/G.111

Example of an international connection in which the digital 4-wire chain extends to 4-wire local exchange with 2-wire analogue subscriber lines

ANNEX A

(to Recommendation G.111)

Definition and properties of the CREs

A.1 *Introduction*

A.1.1 In the previous drafting of Recommendation G.111 [7], it was assumed that the "planning value of the overall reference equivalent of a complete connection" is the sum of the following nominal values:

– the reference equivalents, q, of the local sending and receiving systems which are involved;
– the transmission losses, x, (at 800 or 1000 Hz) of the chain of lines and exchanges interconnecting the two local systems.

In practice, the reference equivalents of the local systems are determined by subjective tests, in accordance with Recommendation P.72 [8], by comparing paths 3 or 4 of Figure A-1/G.111 (where x_3 and x_4 have been fixed at values taken at random between 24 and 34 dB) with the NOSFER reference system (path 2), x_2 being adjusted so as to obtain the same impression of loudness.

A.1.2 If a local system were to be associated with a circuit having a loss x and without distortion, it would be found that the reference equivalent of the system increases by a value smaller than x. Consequently, the "planning values" obtained by addition do not correspond to any physically well-defined quantity which can be determined directly by subjective tests or by calculations from objective measurements.

A.1.3 This situation has caused many difficulties in the study of Question 15/XII [9]. Tests made in the CCITT Laboratory have shown that these difficulties are connected with the method of determining reference equivalents in accordance with Recommendation P.72 [8] where the level of the sounds received varies with the reference equivalent to be determined.

A.1.4 As a first stage in the study of Question 19/XII (11/XVI) [10], the VIIth Plenary Assembly of the CCITT, (Geneva, 1980) approved the revision of Recommendations G.111 and G.121 on the basis of the "corrected reference equivalents" defined in § A.2 below. The sections or paragraphs of the Recommendations to which the paragraphs of this Annex apply are shown in brackets.

TABLE A-1/G.111

Values of $y = 0.0082\ q^2 + 1.148\ q + 0.48$ as a function of q

q (dB)		−10	−9	−8	−7	−6	−5	−4
y (dB)		−10.20	−9.20	−8.20	−7.16	−6.11	−5.06	−4.00
q (dB)	−3	−2	−1	0	1	2	3	4
y (dB)	−2.90	−1.80	−0.66	0.48	1.64	2.80	4.00	5.20
q (dB)	5	6	7	8	9	10	11	12
y (dB)	6.40	7.66	8.90	10.19	11.45	12.78	14.10	15.44
q (dB)	13	14	15	16	17		17.5	18
y (dB)	16.79	18.16	19.55	20.95	22.37		23.08	23.80

Note – This formula is applicable to a receiving system and to a (sending or complete) system comprising a linear microphone; in the case of a carbon microphone, experience shows that y should be reduced by 1.5 dB.

A.2 *Definition of* **Corrected Reference Equivalents (CREs)** *(Recommendation G.111, § 1.1)*

If x_2 is fixed at 25 dB in the NOSFER (path 2 of Figure A-1/G.111), all other provisions of Recommendation P.72 [8] being applied, then "R25 ratings" of a sending system (path 3), a receiving system (path 4) or a complete system (path 6) can be determined. In this case, the rating of a distortionless circuit is by definition equal to its loss x, which greatly simplifies planning. The introduction of a new subjective test method while there are available many reference equivalent values, q, already determined in accordance with Recommendation P.72 [8] would not, however, seem to be justified for the time being.

The "corrected reference equivalent" (CRE) of a local system or a complete system is termed y:

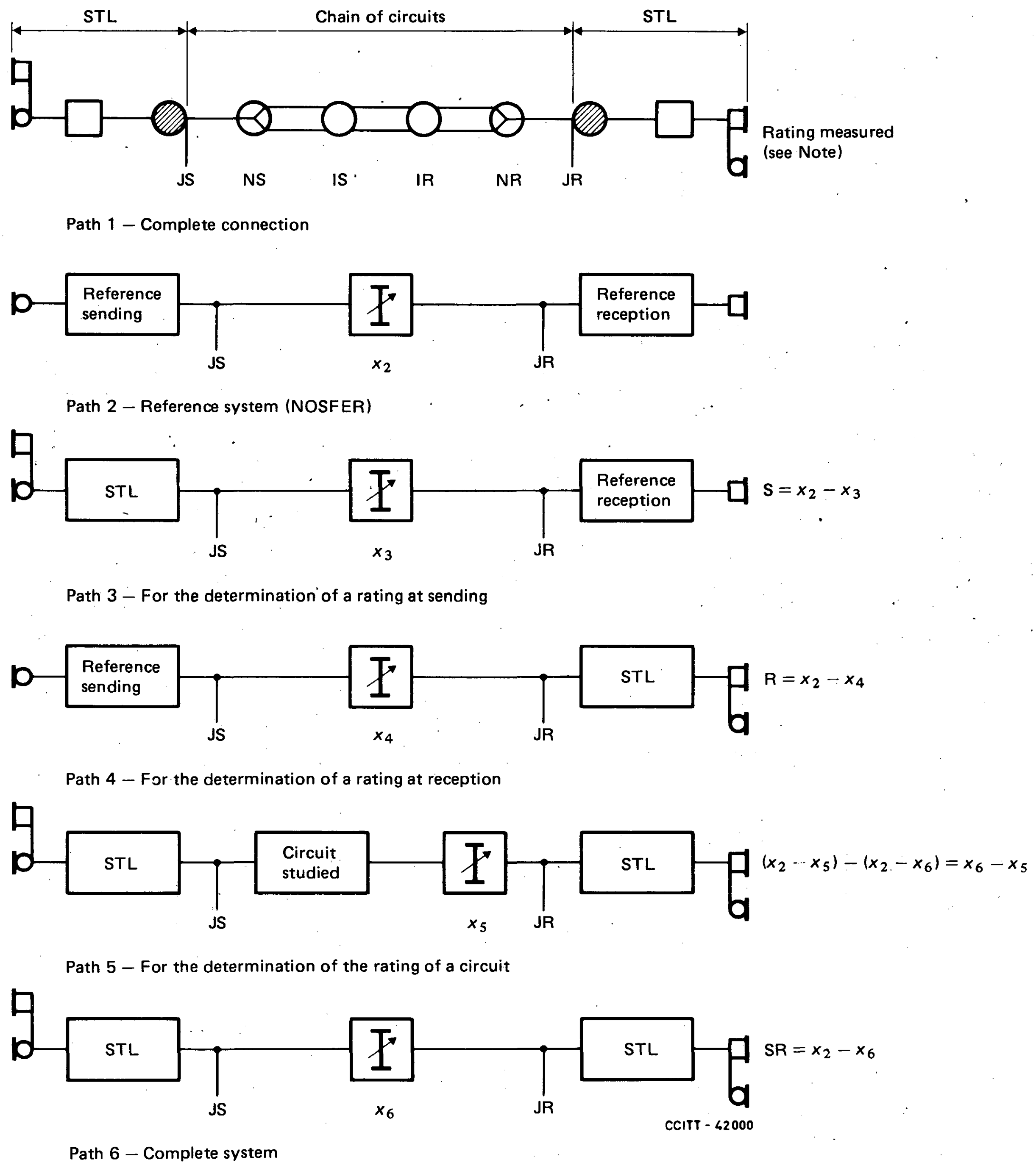
$$y = 0.0082\ q^2 + 1.148\ q + 0.48 \text{ dB} \qquad \text{(A-1)}$$

which can also be written:

$$y = 0.0082\ (q + 69.98)^2 - 39.7 \text{ dB}.$$

This formula has been deduced from tests in which IRS-2, which transmits a frequency band comparable to that of a commercial system, has been compared to NOSFER with a very wide range of variation of q. It has been found that R25 rating is obtained with a good approximation for various types of local systems (subscriber sets with their line) comprising, like IRS-2, a linear microphone.

Table A-1/G.111 gives the values y of CRE of the integral values of q within the range useful for network planning.



STL Local telephone system studied (telephone set + line + feeding bridge).

Note – x is obtained in each case by balancing the path concerning with NOSFER. The rating measured are:

a) Reference equivalents if x_2 is varied so as to obtain the balance,
b) R25 ratings if x_2 is adjusted at 25 dB.

FIGURE A-1/G.111

Connections and systems considered for the definition of reference equivalents and CREs

A.3 *Planning method*

A.3.1 *Additivity in laboratory tests*

Let S and R be the ratings of a local sending and a local receiving system (paths 3 and 4 of Figure A-1/G.111), and SR the rating determined for the complete system (path 6). Let us put D = SR − (S + R). The difference D is small for the loudness ratings, referred to IRS, or for the values measured for example with OREM-B. It is about −3 to −4 dB for the reference equivalents, or R25 ratings and CREs. This is due to the fact that if a commercial system with reduced bandwidth is compared to NOSFER, the system is penalized when S and when R are determined, and is therefore penalized twice when S + R are formed, whereas it is penalized only once when SR is determined.

A.3.2 *Effect of filters*

If we now wish to study the case of a real long-distance connection (path 1 of Figure A-1/G.111), we have to take into account the effect of the filters included in the carrier equipments. Tests on the subject have been made only for the reference equivalent. Between various combinations of local systems, sending and receiving, 1, 2 or 3 filters of the type used in SRAEN with characteristics conforming to Figure 2/P.44 [11] have been inserted.

The loss/frequency characteristic of each filter meets the requirements of Graph B, Figure 1/G.232 [12]; the set of three filters conforms to Figure 1/G.132 showing the desirable objective for a chain of 12 carrier circuits in tandem and which is usually attained for a chain of 6 circuits and 7 international exchanges. Then, from information contained in Recommendation G.101, § 3, the 4-wire chain comprises a maximum of 6 circuits in 96.3% (and 8 circuits in 99.9%) of international calls.

The results depend on the sets and their analysis is rather complex. The mean result is summarized in line "D (for q)" of Table A-2/G.111. Line "D (for y)" of that table may be deduced by calculation from line "D (for q)".

TABLE A-2/G.111

Mean values (in dB) of D = SR − (S + R), in the presence of SRAEN filters

Number of filters in tandem	0	1	2	3
D (for q) D (for y)	− 3 − 3.9	− 0.58 − 1.5	+ 0.49 − 0.4	+ 0.93 0
Increase of q and of y	2.4 (0→1)	1.1 (1→2)	0.4 (2→3)	

A.3.3 *Application to international calls (G.111, § 2 and § 3.1)*

In accordance with the foregoing and with the exact definition of b given in Annex C of Recommendation G.121, the total CRE is:

$$Y_c = a + b + c + \Sigma x_i + c' + b' + d' + D \qquad \text{(A-2)}$$

where a and d are the sending and receiving CREs, of a local system, b the CRE of a trunk junction, c the total of losses (at 800 or 1000 Hz) of long-distance national circuits, exchanges and of the terminating set, Σx_i, the total losses of the international circuits, D the appropriate value deduced from Table A-2/G.111; c', b' and d' relate to the country of the listening subscriber.

Note – CRE b takes into account the attenuation distortion of the trunk junction. However, the entire attenuation distortion of the 4-wire chain should be taken into account when choosing the value of D, since the last line of Table A-2/G.111 shows that equal increases of y are not obtained when 1, 2 and 3 filters of the same type are inserted successively; if other filters or circuits with sudden cut-off are outside the 4-wire chain, they should also be taken into account in the value of D.

A.3.4 *CRE of a national system (G.111, § 3.1 and G.121, § 4)*

If we consider the case where the attenuation distortion of the 4-wire chain reaches the limit of Recommendation G.132, which corresponds approximately to 97-99% of all international connections or to 3 SRAEN filters in Table A-2/G.111 (see § A.3.2 above), we get $D = 0$ and formula (A-2) may be written:

$$Y_c = \mathrm{SN} + \Sigma x_i + \mathrm{RN}' \qquad \text{(A-3)}$$

where *conventionally*

$$\mathrm{SN} = a + b + c \qquad \text{(A-4)}$$

and

$$\mathrm{RN}' = d' + b' + c' \qquad \text{(A-5)}$$

are called the CREs (sending and receiving) of the national systems.

For less complex international connections, the concept of CRE of a national system remains useful for planning; in order to estimate the CRE of a connection, the appropriate value of D must be taken, use being made of the statistical information contained for example in Recommendation G.101, § 3 and in Annex A to Recommendation G.113.

The values of q for a local system (with a specified type of subscriber set) are generally determined with the longest line permitted by the transmission plan and y is then calculated by formula (A-1). The effect on the CRE of lines of different compositions may be calculated or measured objectively by one of the methods described in Annex C of Recommendation G.121.

A.3.5 *National calls (G.120, § 2)*

The CRE may be calculated by the same method. It should be noted that for a local call, $D = -3.9$ dB, but account must also be taken of impedance mismatch, which may be considerable.

ANNEX B

(to Recommendation G.111)

CRE values and previously recommended RE values

CRE values recommended in Recommendation G.111 and previously recommended RE values are given in Table B-1/G.111.

TABLE B-1/G.111

		CRE	RE recommended previously
Preferred range for a connection (G.111, § 3.2)	minimum preferred maximum	4 7 16	6 9 18
Traffic weighted mean values for a connection: long-term objectives (G.111, § 3.2) short-term objectives (G.111, § 3.2)	minimum maximum maximum	13 16 25.5	13 18 23

References

[1] CCITT Recommendation *Assumptions for the calculation of noise on hypothetical reference circuits for telephony*, Vol. III, Fascicle III.2, Rec. G.223, § 1.

[2] CCITT Recommendation *Reference equivalents in a telephone connection*, Red Book, Vol. V, Rec. P.11, p. 10, Note 1, ITU, Geneva, 1962.

[3] *Ibid.*, Note 2.

[4] *Ibid.*, p. 9, table.

[5] CCITT *Orange Book*, Vol. III, Appendix to Section 1, table, ITU, Geneva, 1977.

[6] CCITT Question 5/XVI, Annex 7, Contribution COM XVI-No. 1, Study Period 1981-1984, Geneva, 1981.

[7] CCITT Recommendation *Reference equivalents in an international connection*, Orange Book, Vol. III, Rec. G.111, ITU, Geneva, 1977.

[8] CCITT Recommendation *Measurement of reference equivalents and relative equivalents*, Vol. V, Rec. P.72.

[9] CCITT Question 15/XII, Contribution COM XII-No. 1, Study Period 1981-1984, Geneva, 1981.

[10] *Ibid.*, Question 19/XII (11/XVI).

[11] CCITT Recommendation *Description and adjustment of the reference system for the determination of AEN (SRAEN)*, Vol. V, Rec. P.44, Figure 2/P.44.

[12] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, Figure 1/G.232, Graph B.

Recommendation G.113

TRANSMISSION IMPAIRMENTS

(Geneva, 1980)

1 Transmission impairment

1.1 The objectives for the attenuation distortion of a maximum-length 4-wire chain are given in Recommendation G.132 and those of the noise performance of such maximum-length connections are given in § 2 of this Recommendation. Bearing in mind that less complicated connections (which are more numerous) will have less attenuation distortion and less noise, then the maximum, average and minimum values of corrected reference equivalent recommended in Recommendation G.121 will ensure an adequate transmission performance on international connections.

1.2 Should values of attenuation distortion or noise greatly different from those recommended by the CCITT for systems and equipments be contemplated, then guidance concerning possible changes in transmission performance can be found in Recommendation P.11 and Annexes [1], with some indication of possible trade-offs between them.

2 Network performance objective for circuit noise on complete telephone connections

The CCITT recommends that the network performance objective for the mean value, expressed in decibels and taken over a large number of worldwide connections (each including six international circuits), of the distribution of one-minute mean values of noise power of the connections, should not exceed −43 dBm0p referred to the input of the first circuit in the chain of international circuits.

3 Transmission impairments due to digital processes

The incorporation of unintegrated digital processes in international telephone connections, particularly during the mixed analogue/digital period, can result in an appreciable accumulation of transmission impairments. It is, therefore, necessary to ensure that this accumulation does not reach a point where it can seriously degrade overall transmission quality.

3.1 *Quantizing distortion*

From the point of view of quantizing distortion, it is provisionally recommended that no more than 14 units of quantizing distortion should be introduced in an international telephone connection.

For telephone connections which incorporate unintegrated digital processes, it is permissible to simply add the units of quantizing distortion that have been assigned to the individual digital processes to determine the total or overall quantizing distortion. Some sources of quantizing distortion and the units tentatively assigned to them are given in § 3.2.

With regard to the concept of the unit of quantizing distortion, it is considered that an 8-bit PCM codec-pair (A/D + D/A conversions, A-law or μ-law) which complies with CCITT Recommendations, would introduce 1 unit (see Supplement No. 21 at the end of this fascicle).

3.2 *Sources of quantizing distortion*

The units of quantizing distortion tentatively assigned to a number of digital processes are given in Table 1/G.113. Background information on these assignments is given in Supplement No. 21 at the end of this fascicle.

TABLE 1/G.113

Sources of quantizing distortion

Digital process	Quantizing distortion	Notes
8-bit PCM codec-pair (according to Recommendation G.711 [2], A- or μ-law)	1 unit	Note 1
7-bit PCM codec-pair (A- or μ-law)	4 units	Note 1
Digital pad (8 bit PCM words, A- or μ-law)	1 unit	Note 2
A/μ-law or μ/A-law converter (according to Recommendation G.711 [2])	1 unit	
Transmultiplexer pair based on 8-bit PCM A- or μ-law	1 unit	Note 1
32 kbit/s ADPCM	5-6 units	Note 3
8-7-8 bit transcoding (A- or μ-law)	3 units	

Note 1 – For general planning purposes, half the value indicated may be assigned to either of the send or receive parts.

Note 2 – The impairment indicated is about the same for all digital pad values in the range 1-8 dB. One exception is the 6 dB A-law pad which introduces negligible impairment for signals down to about −30 dBm0 and thus attracts 0 units of quantizing distortion.

Note 3 – The penalty of 5-6 units of quantizing distortion for speech codecs using Adaptive Differential Pulse Code Modulation (ADPCM) at 32 kbit/s, is based on preliminary information provided by Study Group XII.

Note 4 – As a general remark concerning Table 1/G.113, the units of quantizing distortion entered for the different digital processes is that value which has been derived at a mean Gaussian signal level of about −20 dBm0. The cases dealt with in Supplement 21 (at the end of this fascicle) are in accordance with this approach.

3.3 *Effect of random bit errors*

Under study.

3.4 *Attenuation distortion and group-delay distortion*

The provisional recommendation made in § 3.1 specifies that the total quantizing distortion introduced by unintegrated digital processes in international telephone connections should be limited to a maximum of 14 units. It is expected that if this provisional recommendation is complied with, the accumulated attenuation distortion and the accumulated group-delay distortion introduced by unintegrated digital processes in such connections would also be kept within acceptable limits.

3.5 *Provisional planning rule*

As a consequence of the relationship indicated in § 3.4 above concerning quantizing distortion, attenuation distortion and group-delay distortion, it is possible to recommend a provisional planning rule governing the incorporation of unintegrated digital processes in international telephone connections. This provisional planning rule is in terms of units of transmission impairment which numerically are the same as the units of quantizing distortion allocated to specific digital processes as indicated in Table 1/G.113. The provisional planning rule is as follows:

The number of units of transmission impairment in an international telephone connection should not exceed: 5 + 4 + 5 = 14 units.

Under the above rule, each of the two national portions of an international telephone connection are permitted to introduce up to a maximum of 5 units of transmission impairment and the international portion up to a maximum of 4 units.

Note – It is recognized that in the mixed analogue/digital period, it might for a time not be practical for some countries to limit their national contributions to a maximum of 5 units of transmission impairment. To accommodate such countries, a temporary relaxation of the provisional planning rule is being permitted. Through this relaxation, the national portion of an international telephone connection would be permitted to introduce up to 7 units of transmission impairment. Theoretically, this could result in international telephone connections with a total of 18 units of transmission impairment. Such connections would not only introduce an additional transmission penalty insofar as telephone service is concerned, but they could also have an adverse effect on high speed analogue data (e.g., above 4800 bit/s). Administrations which find it necessary to have a national allowance of more than 5 units (but no more than 7 units) should make every effort to meet the 5 units limit at the earliest possible date.

3.6 *Limitations of the provisional planning rule*

In § 3.5, it is assumed that for estimating the transmission impairment due to the presence of unintegrated digital processes in international telephone connections, the units of transmission impairment correspond to the units of quantizing distortion and that the simple addition of such units would apply.

For international telephone circuits that include tandem digital processes in an all-digital environment, adding the individual units of quantizing distortion might not accurately reflect the accumulated quantizing distortion (and, consequently, the accumulated units of transmission impairment). This could be the case since the individual amounts of quantizing distortion power produced by the individual digital processes might not be uncorrelated and, therefore, the addition of individual units of quantizing distortion might, under some circumstances, indicate totals that could be different from those actually in effect. This is explained in some detail in Suplement No. 21 at the end of this fascicle.

Although the 5 + 4 + 5 = 14 rule given in § 3.5 might under some conditions provide only approximate results, the rule, nevertheless, is considered to be suitable for most planning purposes particularly in cases involving unintegrated digital processes.

ANNEX A

(to Recommendation G.113)

Information for planning purposes concerning attenuation distortion and group-delay distortion introduced by circuits and exchanges in the switched telephone network

A.1 The information given in Tables A-1/G.113 to A-6/G.113 is derived from measurements [1] on modern equipment. The performance of actual connections in the switched telephone network can be expected to be worse than would be calculated from the tabulated data because of:

- mismatch and reflexion;
- unloaded subscribers' lines;
- loaded trunk-junctions with a low cutoff frequency;
- older equipment.

A.2 The reference frequency for attenuation distortion is 800 Hz. The reference frequency for group-delay distortion (i.e. the frequency at which the group delay is a minimum) has been estimated in each case.

A.3 In the results for circuits no allowance has been made for line signalling terminations although in some cases these distortions are included in the data for exchanges.

TABLE A-1/G.113

Two-wire local and primary exchanges

Frequency	Attenuation distortion		Group-delay distortion	
	Mean Value	Standard deviation	Mean value	Standard deviation
(Hz)	(dB)	(dB)	(ms)	(ms)
200	1.69	1.20	0.56	0.07
300	0.63	0.81	0.28	0.05
400	0.30	0.43	0.23	0.05
600	0	0.28	0.11	0.03
800	0	0	0.05	0.02
1000	– 0.05	0.11	0.03	0.01
2000	– 0.04	0.35	0	0
2400	– 0.29	0.45	0	0
2800	– 0.45	0.50	0	0
3000	– 0.24	0.65	0	0
3400	– 0.29	0.63	0	0

Note – The group-delay distortion may be taken to be with respect to about 2000 Hz.

[1] Supplied by AT&T, Telecom Australia, Italy, British Telecom, NTT and Switzerland.

TABLE A-2/G.113

Four-wire exchanges

Frequency (Hz)	Attenuation distortion		Group-delay distortion	
	Mean value	Standard deviation	Mean value	Standard deviation
	(dB)	(dB)	(ms)	(ms)
200	0.32	0.14	0.40	0.02
300	0.16	0.28	0.14	0.02
400	0.13	0.21	0.14	0.03
600	0.02	0	0.07	0.02
800	0	0	0.03	0.01
1000	0	0	0.02	0.01
2000	0.01	0.14	0	0
2400	0.06	0.21	0	0
2800	0.02	0.02	0	0
3000	0.10	0.07	0	0
3400	0.20	0.50	0	0

Note – The group-delay distortion may be taken to be with respect to about 2000 Hz.

TABLE A-3/G.113

Trunk junctions

Frequency (Hz)	Attenuation distortion		Group-delay distortion	
	Mean value	Standard deviation	Mean value	Standard deviation
	(dB)	(dB)	(ms)	(ms)
200	4.29	1.95	3.05	0.36
300	0.86	0.49	1.42	0.18
400	0.36	0.31	0.78	0.09
600	0.09	0.17	0.34	0.06
800	0	0.03	0.16	0.02
1000	– 0.03	0.04	0.08	0.02
2000	0.14	0.20	0.02	0.01
2400	0.33	0.29	0.06	0.03
2800	0.58	0.35	0.18	0.06
3000	0.88	0.55	0.31	0.11
3400	2.21	1.06	0.92	0.26

Note 1 – The group-delay distortion may be taken to be with respect to about 1500 Hz.

Note 2 – The sample of trunk junctions included those on metallic lines, FDM, and PCM systems.

Note 3 – PCM circuits may exhibit a somewhat lower attenuation distortion at 200 Hz than that indicated above.

Note 4 – The values for trunk junctions are inclusive of 2-wire/4-wire terminations.

TABLE A-4/G.113

Circuits provided on a direct 12-channel group

Frequency (Hz)	Attenuation distortion		Group-delay distortion	
	Mean value	Standard deviation	Mean value	Standard deviation
	(dB)	(dB)	(ms)	(ms)
200	1.56	0.92	5.42	0.22
300	0.39	0.43	2.97	0.35
400	0.11	0.30	1.45	0.22
600	0.05	0.18	0.76	0.10
800	0	0	0.44	0.05
1000	– 0.01	0.11	0.26	0.02
2000	– 0.03	0.19	0.01	0.01
2400	0.04	0.21	0.06	0.02
2800	0.13	0.33	0.21	0.04
3000	0.16	0.43	0.45	0.04
3400	1.03	0.56	1.97	0.20

Note 1 – The group-delay distortion may be taken to be with respect to about 1800 Hz.

Note 2 – The data relates to 4 kHz FDM channel translating equipment, the principal source of distortion in telephone circuits provided on direct 12-channel groups, i.e., circuits with only one circuit-section.

TABLE A-5/G.113

Circuits provided on a direct 16-channel group

Frequency (Hz)	Attenuation distortion		Group-delay distortion	
	Mean value	Standard deviation	Mean value	Standard deviation
	(dB)	(dB)	(ms)	(ms)
200	2.80	1.63	9.74	0.40
300	0.04	0.19	4.39	0.27
400	– 0.07	0.20	2.49	0.09
600	0.02	0.09	1.02	0.56
800	0	0	0.47	0.35
1000	0.09	0.08	0.19	0.28
2000	0.06	0.12	0.03	0.14
2400	0.03	0.14	0.36	0.31
2800	0.03	0.16	1.59	1.06
3000	– 0.01	0.28	4.29	0.38

Note 1 – The group-delay distortion may be taken to be with respect to about 1200 Hz.

Note 2 – The data relates to 3-kHz FDM channel translating equipment, the principal source of distortion in telephone circuits provided on direct 16-channel groups, i.e., circuits with only one circuit-section.

TABLE A-6/G.113

Circuits comprising three circuit-sections (4 kHz + 3 kHz + 4 kHz)

Frequency (Hz)	Attenuation distortion		Group-delay distortion	
	Mean value	Standard deviation	Mean value	Standard deviation
	(dB)	(dB)	(ms)	(ms)
200	5.92	2.09	20.58	0.51
300	0.82	0.64	10.33	0.56
400	0.15	0.47	5.39	0.32
600	0.12	0.27	2.54	0.58
800	0	0	1.35	0.36
1000	0.07	0.17	0.71	0.28
2000	0	0.29	0.05	0.14
2400	0.11	0.33	0.48	0.31
2800	0.29	0.49	2.01	1.06
3000	0.31	0.67	5.19	0.38

Note 1 – This table has been derived from Tables A-4/G.113 and A-5/G.113, and relates to international circuits in which the middle section is routed on 3-kHz spaced channel equipment, e.g., a submarine circuit section.

Note 2 – The group-delay distortion may be taken to be with respect to about 1400 Hz.

References

[1] CCITT Recommendation *Effect of transmission impairments*, Vol. V, Rec. P.11 and Annexes.

[2] CCITT Recommendation *Pulse code modulation (PCM) of voice frequencies*, Vol. III, Fascicle III.3, Rec. G.711.

Recommendation G.114

MEAN ONE-WAY PROPAGATION TIME

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

The times in this Recommendation are the means of the propagation times in the two directions of transmission in a connection. When opposite directions of transmission are provided by different media (e.g. a satellite channel in one direction and a terrestrial channel in the other) the two times contributing to the mean may differ considerably.

1 **Limits for a connection** (formerly Part A)

It is necessary in an international telephone connection to limit the propagation time between two subscribers. As the propagation time is increased, subscriber difficulties increase, and the rate of increase of difficulty rises. Relevant evidence is given in references [1]-[10], particularly with regard to b) below.

As a network performance objective, the CCITT therefore *recommends* the following limitations on mean one-way propagation times when echo sources exist and appropriate echo control devices, such as echo suppressors and echo cancellers, are used:

a) 0 to 150 ms, acceptable.

   Note – Echo suppressors specified in Recommendation G.161 of the Blue Book [11] may be used for delays not exceeding 50 ms (see Recommendation G.131, § 2.2).

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

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

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

Note 1 – The above values refer only to the propagation time between two subscribers. However, for other purposes (e.g. in Recommendation G.131) the mean one-way propagation time of an echo path is to be estimated. The values in § 2 may be used in such estimations.

Note 2 – There is good evidence that echo cancellers fitted at both ends of a long-delay connection yield superior performance over current types of echo suppressors.

Note 3 – It should be noted that although an echo suppressor and an echo canceller on the same connection are compatible (they can satisfactorily interwork), the full benefits of echo cancellers are only experienced when both ends are so equipped. In particular, an Administration unilaterally replacing its echo suppressors with echo cancellers will cause little benefit to its own subscriber on international connections if the echo suppressor still remains at the other end.

2 **Values for circuits** (formerly Part B)

In the establishment of the general interconnection plan within the limits in § 1 the one-way propagation time of both the national extension circuits and the international circuits must be taken into account. The propagation time of circuits and connections is the aggregate of several components; e.g. group delay in cables and in filters encountered in FDM modems of different types. Digital transmission and switching also contribute delays. The conventional planning values given in § 2.1 may be used to estimate the total propagation time of specified assemblies which may form circuits or connections.

2.1 *Conventional planning values of propagation time*

Provisionally, the conventional planning values of propagation time in Table 1/G.114 may be used.

2.2 *National extension circuits*

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

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

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

2.3 *International circuits*

International circuits will use high-velocity transmission systems, e.g. terrestrial cable or radio-relay systems, submarine systems or satellite systems. The planning values of § 2.1 may be used.

TABLE 1/G.114

Transmission medium	Contribution to one-way propagation time	Remarks
Terrestrial coaxial cable or radio relay system; FDM and PCM transmission	4 μs/km	Allows for delay in repeaters and regenerators
Submarine coaxial cable system	6 μs/km	
Satellite system – 14 000 km altitude – 36 000 km altitude	 110 ms 260 ms	Between earth stations only
FDM channel modulator or demodulator	0.75 ms a)	Half the sum of propagation times in both directions of transmission
PCM coder or decoder	0.3 ms a)	
Transmultiplexer	1.5 ms	
Digitally switched exchange, digital-digital	0.45 ms b)	

a) These values allow for group-delay distortion around frequencies of peak speech energy and for delay of intermediate higher order multiplex and through-connecting equipment.

b) This is a mean value; depending on traffic loading, higher values can be encountered, e.g. 0.75 ms with 0.95 probability of not exceeding.

The magnitude of the mean one-way propagation time for circuits on high altitude communication satellite systems makes it desirable to impose some routing restrictions on their use. Details of these restrictions are given in Recommendation Q.13 [12].

References

[1] CCITT *Red Book*, Volume V *bis*, Annex E (United States), ITU, Geneva, 1965.

[2] *Ibid*.: Annex F (United Kingdom).

[3] *Ibid*.: Annex 4 to Question 6/XII (Italy).

[4] CCITT *White Book*, Volume V, Supplements 1-6, ITU, Geneva, 1969.

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

[6] HELDER (G. K.): Customer evaluation of telephone circuits with delay, *Bell System Technical Journal*, 45, September 1966, pages 1157-1191.

[7] RICHARDS (D. L.): Transmission performance of telephone connections having long propagation times, *Het P.T.T.-Bedrijf*, XV, No. 1/2, May 1967, pages 12-24.

[8] KARLIN (J. E.): Measuring the acceptability of long-delay transmission circuits used during the Early Bird transatlantic tests in 1965, *Het P.T.T.-Bedrijf*, May 1967, pages 25-31.

[9] DE JONG (C.): Observations on telephone calls between the Netherlands and the U.S.A., *Het P.T.T.-Bedrijf*, May 1967, pages 32-36.

[10] HUTTER (J.): Customer response to telephone circuits routed via a synchronous-orbit satellite, *P.O.E.E.J.*, Volume 60, October 1967, page 181.

[11] 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, ITU, Geneva, 1965.

[12] CCITT Recommendation *The international routing plan*, Vol. VI, Fascicle VI.1, Rec. Q.13.

TRANSMISSION ASPECTS OF UNBALANCE ABOUT EARTH

(Geneva, 1980)

1 Objective

This Recommendation gives a comprehensive set of prescriptive measurements of various balance parameters for one-port and two-port networks which are intended to be capable of being made in the field or in the factory with relatively simple test apparatus (e.g. standard transmission oscillators, level measuring sets), together with a special test bridge. The principles of suitable test bridges are discussed, but it is neither necessary nor desirable to specify a "recommended" test bridge; the requirements can be realized in a variety of ways.

The definitions and methods are so devised that the results obtained from separately-measured (or specified) items of equipment (e.g. feeding-bridges, cable pairs, audio inputs to chanelling equipment, etc.) can be meaningfully combined (though not necessarily by simple decibel addition) so that the performance of a tandem connection of such items can be predicted (or at least, bounds determined for that performance). Performance in this sense means those features affected by unbalanced conditions (e.g. level of impulsive noise, sensitivity to longitudinal exposure, crosstalk ratios, etc.).

The long-term objective is to propose, if need be, justifiable standards for the balance parameters of lines and equipment. Such proposals, if accepted, might form the basis of CCITT Recommendations for specification clauses.

2 Principles of the scheme of nomenclature

Many different terms are used throughout the literature concerning unbalance about earth, some conflicting, or in other respects inadequate. The descriptive titles of the quantities given in this Recommendation are, it is believed, an improvement on some of the existing ones and the following principles have been adopted:

a) A fundamental idea is mode *conversion*, e.g. a poor (unbalanced) termination will develop an unwanted transverse signal when excited by a longitudinal signal and the measure of this effect is here termed *longitudinal conversion ratio*, and when expressed in transmission units *longitudinal conversion loss*, or LCL.

b) When an *n*-port is involved in which for example an excitation at one port produces a signal at another port, then the designation will include the word *transfer*, to give for example *longitudinal conversion transfer ratio* and the corresponding *loss*, LCTL.

c) The impedance of the longitudinal path presented by a test object is a key parameter and we have used the term *longitudinal impedance ratio* the decibel expression of which is termed *longitudinal impedance loss*, LIL, to characterize the particular measurement here proposed.

d) Active devices which are sources of signals (e.g. an oscillator, the output port of an amplifier) are additionally characterized by the amount of unwanted longitudinal signal that is present in the output. The key word *output* is now included, to give *longitudinal output voltage*, and the corresponding *longitudinal output level*, LOL. When such unwanted signals are expressed as a proportion of the wanted (transverse) signal the key phrase is *signal balance* giving *output signal balance ratio*, the decibel expression of which is *output signal balance*. This is the convention already used by Study Group IV in Recommendation O.121 [1].

e) Devices which continuously respond to signals (e.g. level-measuring sets, the input port of an amplifier) and which can in principle respond to unwanted longitudinal signals by reason of internal mechanisms (i.e. even if their input impedances were perfectly balanced) are characterized by measures containing the words *input interference*. Thus we obtain *input longitudinal interference ratio* the corresponding decibel expression being *input longitudinal interference loss*. We do not trespass on the long-established and well-defined *common-mode rejection ratio* and we have also avoided the term *sensitivity coefficient* since this is widely used in the Directives, [2] and the work of Study Group V with a rather specialized meaning.

f) In the case of receiving devices in which the operation is not a linear continuous function of the level of the input signal (e.g. a group-delay measuring set or a data modem) the key idea is the *threshold* level of the interference at or above which unacceptable misoperation occurs. Thus we obtain *longitudinal interference threshold voltage* and the corresponding *level.*

3 Summary of the descriptive terms used

3.1 *One-port networks*

a) transverse reflexion factor (transverse return loss: RL),
b) transverse conversion ratio (loss: TCL),
c) longitudinal conversion ratio (loss: LCL),
d) longitudinal impedance ratio (loss: LIL),
e) transverse output voltage (level: TOL),
f) longitudinal output voltage (level: LOL).

(Voltages e) and f) are unwanted signals uncorrelated to the wanted signals.)

3.2 *Two-port networks*

For each port taken separately the one-port measures:

a) transverse reflexion factors (transverse return losses: RL),
b) transverse conversion ratio (loss: TCL),
c) longitudinal conversion ratios (losses: LCL),
d) longitudinal impedance ratios (losses: LIL),
e) transverse output voltage (levels: TOL),
f) longitudinal output voltage (levels: LOL).

In addition the following transfer parameters for each of the two directions of transmission:

g) transverse transfer ratios (losses: TTL),
h) transverse conversion transfer ratios (losses: TCTL),
i) longitudinal transfer ratios (losses: LTL),
j) longitudinal conversion transfer ratios (losses: LCTL).

3.3 *Signal generating devices*

a) Output signal balance ratio (output signal balance).

This is in addition to the six one-port measures listed in § 3.1 above.

3.4 *Signal receiving devices*

a) Input longitudinal interference ratio (loss).

b) Longitudinal interference threshold voltage (level).

These are in addition to the six one-port measures listed in § 3.1 above. If the wanted signal is longitudinal (e.g. as in a signalling system) and the interfering voltage transverse, replace the word *longitudinal* with *transverse* in the descriptive terms.

4 Definitions and measuring techniques based on idealized measuring arrangements

In § 4, the illustrated definitions are in terms of ideal test bridges which use lossless infinite-inductance centre-tapped coils, zero impedance voltage generators and infinite-impedance voltmeters.

An important aspect of this set of mutually consistent measurements is that the test bridge provides simultaneous defined reference terminations of Z ohms for the transverse paths, and Z/4 ohms for the longitudinal paths. From this starting point, the performance of cascaded items, each measured in the prescribed fashion, can be calculated, taking account of the fact that the cascaded items do not, in general, exhibit the reference impedances provided by the test conditions.

It simplifies the mathematical treatment if the reference impedance is nonreactive and this also accords with the important objective of being able to use readily-available transmission test-apparatus to obtain field and factory measurement results.

The test bridge configuration used in the following pages is shown in Figure 1/G.117.

The transverse and longitudinal sources E_T and E_L are activated as required by the particular measurement being made; in some cases, neither source is active, and the bridge then provides only passive terminations of Z and Z/4.

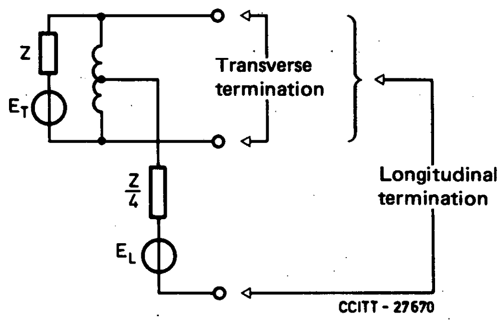
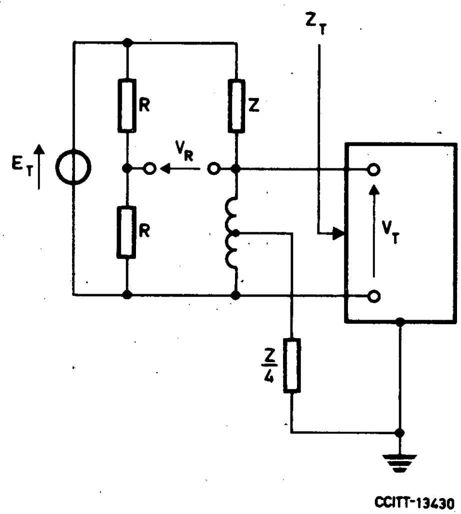


FIGURE 1/G.117

4.1 *One-port networks*

4.1.1 *Transverse reflexion factor (return loss)* (see Figure 2/G.117)



$$\text{Transverse reflexion factor } \rho = \frac{Z - Z_T}{Z + Z_T} = \frac{\text{reflected voltage}}{\text{forward voltage}} = \frac{2V_R}{E_T}$$

and

$$\text{Transverse return loss (RL)} = 20 \log_{10} \left| \frac{1}{\rho} \right| = 20 \log_{10} \left| \frac{E_T}{2V_R} \right| \text{ dB.}$$

Note 1 – The value of *R* is (theoretically) irrelevant. The potential divider across the zero-impedance generator is only needed to derive half the generator voltage, which is numerically equal to the forward voltage needed for the definition.

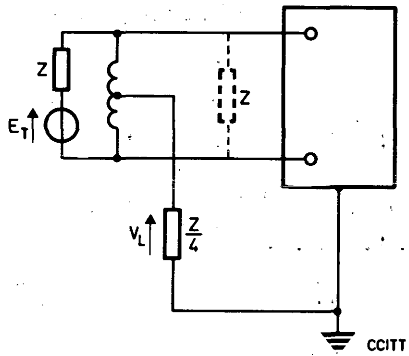
Note 2 – Conventional return-loss measuring bridges do not terminate the longitudinal path with *Z*/4. This is unimportant when the return loss is some 20 dB or so less than the longitudinal conversion loss of the test object. In this case the reflected power is substantially greater than the power diverted to the longitudinal path, and there is negligible error.

Note 3 – If Z_T is known then clearly $\rho = 1 - \frac{2V_T}{E_T}$ is not needed. If V_T is measured ρ can be calculated from the expression which is however somewhat inconvenient for high values of return loss.

Note 4 – The word transverse can be dropped from the designation when the context is clear.

FIGURE 2/G.117

4.1.2 *Transverse conversion ratio (loss)* (see Figure 3/G.117)



$$\text{Transverse conversion ratio, } k = \frac{2V_L}{E_T}$$

and

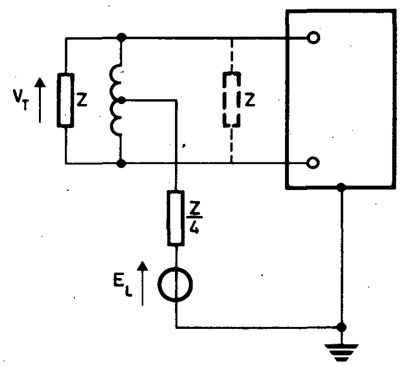
$$\text{Transverse conversion loss (TCL)} = 20 \log_{10}\left|\frac{1}{k}\right| = 20 \log_{10}\left|\frac{E_T}{2V_L}\right| \text{ dB.}$$

Note 1 – In the case where the network is linear passive and bilateral, this measure is identical to twice the longitudinal conversion ratio *c*. However, where, for example, amplifiers are used, $k = 0.5c$

Note 2 – The dotted component is needed for a two-terminal device which, when in use, only bridges the transmission circuit. The same remark applies in principle to all the other diagrams (except those concerned with return losses) and will not again be explicitly mentioned.

FIGURE 3/G.117

4.1.3 *Longitudinal conversion ratio (loss)* (see Figure 4/G.117)



$$\text{Longitudinal conversion ratio, } c = \frac{V_T}{E_L}$$

and

$$\text{Longitudinal conversion loss (LCL)} = 20 \log_{10}\left|\frac{1}{c}\right| = 20 \log_{10}\left|\frac{E_L}{V_T}\right| \text{ dB.}$$

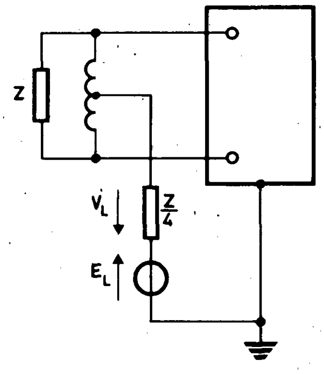
Note 1 – This measure is variously referred to as:

a) Impedance balance ratio (Recommendation O.121)
b) Longitudinal/transverse voltage ratio [3]
c) Longitudinal balance (Recommendation G.712 [4])
d) Degree of unbalance [2]
e) Unbalance (Recommendation K.10 [5])
f) Degree of longitudinal balance [6]

Note 2 – The longitudinal conversion ratio is applicable to any one-port, even to those which are sources of signals (e.g.: oscillator output terminals). In such cases the transverse voltage V_T must be measured selectively if it is required to measure this loss in respect of a working signal generator. See § 5.2.

FIGURE 4/G.117

4.1.4 *Longitudinal impedance ratio (loss)* (see Figure 5/G.117)



$$\text{Longitudinal impedance ratio, } q = \frac{E_L}{V_L}$$

and

$$\text{Longitudinal impedance loss (LIL)} = 20 \log_{10} |q| = 20 \log_{10} \left| \frac{E_L}{V_L} \right| \text{ dB.}$$

Note 1 – This is an additional measure that is needed if the performance of a cascade of items is to be predicted.

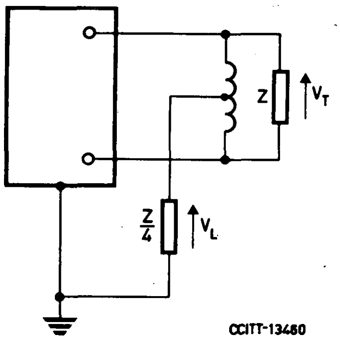
Note 2 – In the case of test-objects which are virtually earth free (e.g.: double-insulated, portable test apparatus with no deliberate connection to earth) the value of V_L will be very small and the corresponding ratio (and loss) will be very large. But in such cases the coupling introduced between longitudinal and transverse paths will be very small and the effect is not important.

Note 3 – As a result of earlier studies concerned with cable crosstalk effects arising from unbalanced terminations, a proposal is made (by British Telecom) in [3] which involves measuring an open-circuit voltage. This raises practical difficulties in the case of a well-balanced test object isolated from earth except for small stray capacitances of a few picofarads. For this reason the measure proposed in [3] is only suitable for networks with a deliberately earthed centre-point and with (relatively) low impedances to earth, e.g.: transmission feeding bridges in telephone exchanges.

We do not make explicit use of this measurement here, it being replaced by the longitudinal impedance function, which places no particular demands on the input impedance of measuring apparatus, although there is a loss of sensitivity.

FIGURE 5/G.117

4.1.5 *Transverse and longitudinal output voltages (levels)* (see Figure 6/G.117)



$$\text{Transverse output voltage} = V_T$$

$$\text{Transverse output level (TOL)} = 20 \log_{10} \left| \frac{V_T}{1 \text{ volt}} \right| \text{ dBV.}$$

$$\text{Longitudinal output voltage} = V_L$$

$$\text{Longitudinal output level (LOL)} = 20 \log_{10} \left| \frac{V_L}{1 \text{ volt}} \right| \text{ dBV.}$$

Note 1 – These measures relate to unwanted signals uncorrelated to the wanted signal. For example, a d.c. signalling system in the longitudinal path may deliver unwanted transverse signals. Similarly the output of an amplifier may deliver an unwanted longitudinal "hum" signal, or a cable pair may deliver unwanted longitudinal signals arising from induction or radiation.

Note 2 – The voltages are expressed as levels with respect to 1 V rms. However they could be measured with an impulse-noise counter and they would then be expressed in other terms. In this latter case, however, linear algebraic methods of analysis could not be used. (Such linear methods are under development by British Telecom.)

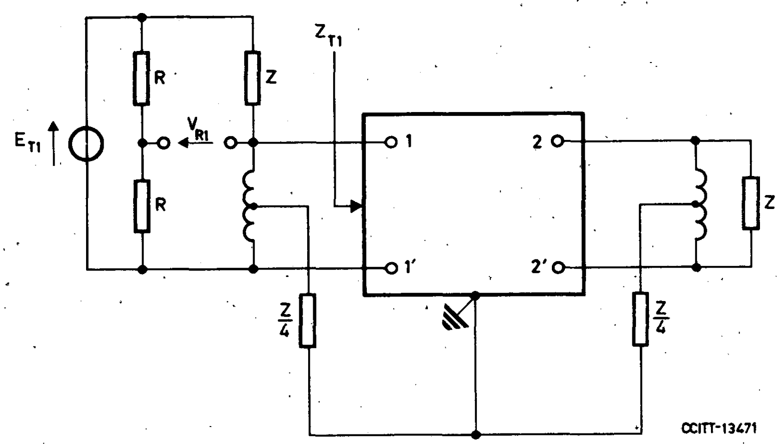
FIGURE 6/G.117

4.2 *Two-port networks*

These follow similar principles to those defined for one-port networks but now signals can be transferred from one port to the other. The two ports are distinguished by the subscripts 1 and 2 and there are two types of measurements:

- those in which the excitation and response are at the same side of the network; these are as already defined for a one-port but will carry a single subscript 1 or 2 as appropriate;
- those in which the excitation and response are at opposite sides of the network. The designation will contain the word transfer and the symbol two subscripts, the order of which indicates the direction of transmission.

4.2.1 *Transverse reflexion factors (return losses)* (see Figure 7/G.117)



$$\text{Transverse reflexion factor at end 1} = \rho_1 = \frac{Z - Z_{T1}}{Z + Z_{T1}} = \frac{2V_{R1}}{E_{T1}}$$

and

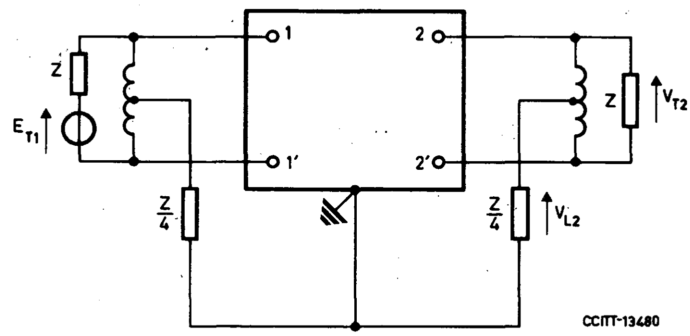
$$\text{Transverse return loss at end 1 } (RL_1) = 20 \log_{10}\left|\frac{1}{\rho_1}\right| = 20 \log_{10}\left|\frac{E_{T1}}{2V_{R1}}\right| \text{ dB}$$

and similarly for end 2 (RL_2).

Note – Z_{T_1} is the impedance presented by end 1 when end 2 is terminated with a test-bridge as shown.

FIGURE 7/G.117

4.2.2 *Transverse transfer ratios (losses) and conversion transfer ratios (losses)* (see Figure 8/G.117)



$$\text{Transverse transfer ratio 1 to 2} = g_{12} = \frac{2V_{T2}}{E_{T1}}$$

and

$$\text{Transverse transfer loss 1 to 2 (TTL}_{12}) = 20 \log_{10}\left|\frac{1}{g_{12}}\right| = 20 \log_{10}\left|\frac{E_{T1}}{2V_{T2}}\right| \text{ dB.}$$

$$\text{Transverse conversion transfer ratio 1 to 2} = t_{12} = \frac{2V_{L2}}{E_{T1}}$$

and

$$\text{Transverse conversion transfer loss 1 to 2 (TCTL}_{12}) = 20 \log_{10}\left|\frac{1}{t_{12}}\right| = 20 \log_{10}\left|\frac{E_{T1}}{2V_{L2}}\right| \text{ dB.}$$

Interchanging 1 and 2 gives the definitions for the transfer ratios and losses TTL_{21} and $TCTL_{21}$ for the other direction of transmission.

Note – In the case illustrated the transfer loss is numerically equal to the insertion loss. In the case in which the reference impedances are different at the two ends of the network the transfer loss is related to the *composite loss* [7] by the following relationship:

$$\text{transfer loss} = \text{composite loss} + 10 \log_{10}\left|\frac{Z_1}{Z_2}\right| \text{ dB}$$

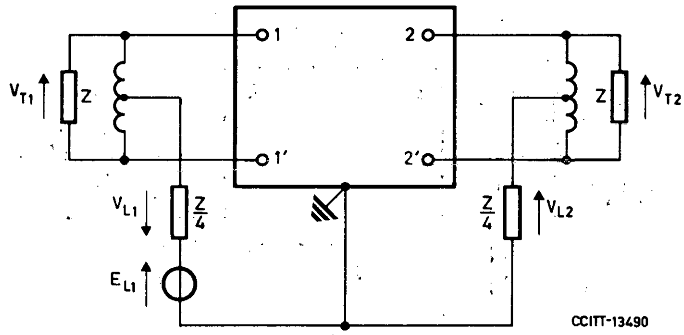
Where Z_1 and Z_2 are the reference impedances at the ends of the network. In this regard it should be noted that differences between relative levels in a transmission system in which there are changes of impedance are automatically expressed in terms of composite loss (or gain). The correction factor for *transducer loss* [8] involves the phase angle of general dissimilar reference impedances since the definition of transducer loss is based on ratios of true powers (rather than apparent powers which are used for insertion and composite losses).

$$\text{Transfer loss} = \text{Transducer loss} + 10 \log_{10}\left|\frac{Z_1}{Z_2}\right| + \log_{10}\left|\frac{\cos \theta_1}{\cos \theta_2}\right| \text{ dB}$$

in which θ_1 and θ_2 are the phase angles of Z_1 and Z_2.

FIGURE 8/G.117

4.2.3 *Longitudinal transfer ratios (losses) and conversion transfer ratios (losses)* (see Figure 9/G.117)



$$\text{Longitudinal transfer ratio 1 to 2} = m_{12} = \frac{V_{L2}}{E_{L1}}$$

and

$$\text{Longitudinal transfer loss 1 to 2 (LTL}_{12}) = 20 \log_{10}\left|\frac{1}{m_{12}}\right| = 20 \log_{10}\left|\frac{E_{L1}}{V_{L2}}\right| \text{ dB.}$$

$$\text{Longitudinal conversion transfer ratio 1 to 2} = h_{12} = \frac{V_{T2}}{E_{L1}}$$

and

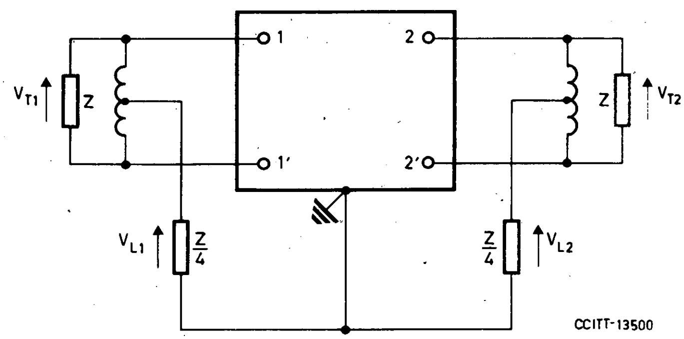
$$\text{Longitudinal conversion transfer loss 1 to 2 (LCTL}_{12}) = 20 \log_{10}\left|\frac{1}{h_{12}}\right| = 20 \log_{10}\left|\frac{E_{L1}}{V_{T2}}\right| \text{ dB.}$$

Interchanging 1 and 2 gives the definitions for the transfer ratios and losses LTL_{21} and $LCTL_{21}$ for the other direction of transmission.

Note – It would have been more in keeping with traditional transmission theory if these quantities were defined in terms of *half* the open-circuit emf. However the CCITT recommendations concerning balance parameters involving a longitudinal excitation are already in terms of the open-circuit emf. It is not thought useful to introduce a 6-dB "discrepancy" between existing practice and these new proposals.

FIGURE 9/G.117

4.2.4 *Transverse and longitudinal output voltages (levels)* (see Figure 10/G.117)



$$\text{Transverse output voltage at end 1} = V_{T1}$$

and

$$\text{Transverse output level at end 1 (TOL}_1) = 20 \log_{10}\left|\frac{V_{T1}}{1 \text{ volt}}\right| \text{ dBV}$$

$$\text{Longitudinal output voltage at end 1} = V_{L1}$$

and

$$\text{Longitudinal output level at end 1 (LOL}_1) = 20 \log_{10}\left|\frac{V_{L1}}{1 \text{ volt}}\right| \text{ dBV}$$

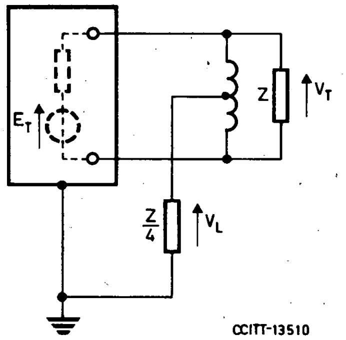
and similarly for end 2, TOL_2 and LOL_2.

FIGURE 10/G.117

4.3 *Signal generating devices*

In addition to the six one-port measures already defined, an additional measure is required to control the amount of unwanted signal correlated with the wanted signal delivered by the device to the circuit it is connected to. This special measure is:

4.3.1 *Output signal balance ratio (output signal balance)* (see Figure 11/G.117)



$$\text{Output signal balance ratio, } b = \frac{V_L}{V_T}$$

and

$$\text{Output signal balance} = 20 \log_{10} \left| \frac{1}{b} \right| = 20 \log_{10} \left| \frac{V_T}{V_L} \right| \text{ dB.}$$

Note 1 – This measure is a generalized version of the quantities referred to as:

a) generator signal balance ratio (Recommendation O.121) [1],
b) unbalance of output emf [9].

Note 2 – This measure is also related in a somewhat indirect and complicated fashion to the sensitivity coefficients for electromagnetic and electrostatic induction defined in [2], if one regards the cable pair as a simultaneous source of a transverse signal correlated with the induced longitudinal voltages.

Note 3 – The test object itself provides the source of signal. Hence a separate generator is not required.

Note 4 – The definition relates particularly to generators of transverse signals (e.g.: transmission oscillators) but can be readily extended to cover the case of a longitudinal signal generator (e.g.: a low-frequency signalling system using the earthed-phantom). In this case the ratio could be inverted so that the decibel expression remains positive.

Note 5 – The other quantities (return loss, longitudinal conversion loss, longitudinal impedance loss and the uncorrelated transverse and longitudinal output voltages) must be measured selectively in order that their values in working conditions be obtained.

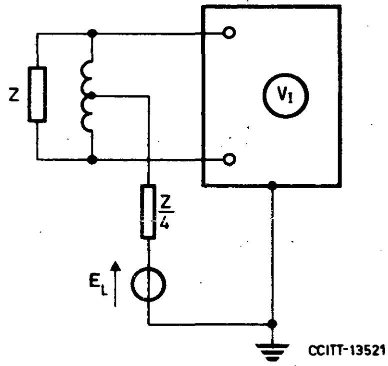
FIGURE 11/G.117

4.4 *Signal receiving devices*

In addition to the six one-port measures already defined, additional measures are required for signal receiving devices to control their sensitivity to unwanted signals. Two cases are important. Firstly, there are receiving devices in which the response is a linear, continuous function of the wanted signal level, e.g. the indication of a level-measuring set. In this case unwanted signals give rise to *inaccuracy*.

In the other kind of receiver such as data modems, group-delay distortion measuring sets, signalling receivers, unwanted signals cause errors or *misoperation*. We thus define two additional measures.

4.4.1 *Input longitudinal interference ratio (loss)* (see Figure 12/G.117)



$$\text{Input longitudinal interference ratio} = s = \frac{V_I}{E_L}$$

and

$$\text{Input longitudinal interference loss} = 20 \log_{10}\left|\frac{1}{s}\right| = 20 \log_{10}\left|\frac{E_L}{V_I}\right| \text{ dB},$$

in which V_I is the voltage indicated by the measuring set being tested.

Note 1 – This is a generalized version of the quantities referred to as:

a) receiver signal balance ratio (Recommendation O.121 [1]),

b) balance (Recommendation P. 53 [10]).

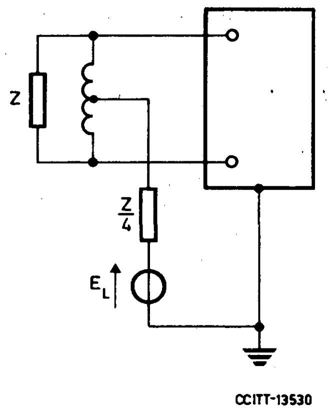
Note 2 – The measuring instrument itself provides one of the voltages required by the definition.

Note 3 – This measure is related to the well-known *common-mode rejection ratio* but not in any simple fashion. In particular it is not 6 dB different. This is because when the longitudinal rejection ratio is measured, the input transverse terminals are short-circuited and there is no transverse signal to engender any additional longitudinal signal via the unbalance of the input impedance. See § 5 for further explanation.

Note 4 – The concept could be extended if necessary to cover receivers which respond linearly to longitudinal signals, and where it is transverse signals that interfere. The designation would then be input *transverse* interference ratio (loss) with a correspondingly different circuit arrangement.

FIGURE 12/G.117

4.4.2 *Longitudinal interference threshold voltage (level)* (see Figure 13/G.117)



$$\text{Longitudinal interference threshold voltage} = E_L$$

and

$$\text{Longitudinal interference threshold level} = 20 \log_{10}\left|\frac{E_L}{1 \text{ volt}}\right| \text{ dBV},$$

in which E_L is the voltage at which misoperation of the test device just occurs.

Note 1 – "Misoperation" would have to be defined. For a data modem it might be in terms of error rate.

Note 2 – The threshold voltage may be specified as an rms value, or as an impulsive voltage as measured by an impulsive counter, or in terms of its waveshape (e.g.: square, triangular).

Note 3 – The concept could be extended to cover unwanted transverse signals affecting the operation of longitudinal receivers if required, with appropriate changes to the testing circuit and designation.

FIGURE 13/G.117

5 Other measurement definitions

5.1 The IEC describe a test method for measuring the open-circuit emf of a longitudinal source and its impedance illustrated in Figure 14/G.117.

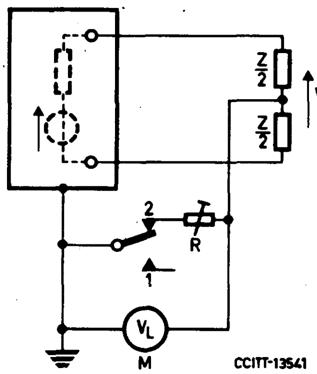


FIGURE 14/G.117

At position 1, N indicates $V_{L(o/c)}$ and at position 2 it indicates $V_{L(R)}$. The IEC defines

$$\text{Output voltage balance} = 20 \log_{10} \left| \frac{V_T}{V_{L(o/c)}} \right| \text{ dB.}$$

and estimates the internal impedance of the longitudinal source, Z_L as

$$Z_L \simeq \frac{V_{L(o/c)}}{V_{L(R)}} \cdot R$$

provided R has been adjusted (or selected) to give at least a 20-dB difference between $V_{L(o/c)}$ and $V_{L(R)}$, i.e.: $V_{L(o/c)} \geqslant 10\, V_{L(R)}$. The approximation and the condition imply that:

$$Z_M \gg Z_L \gg g_R \gg Z/4$$

in which

$$g = \frac{V_{L(o/c)}}{V_{L(R)}} \geqslant 10$$

Z_M = meter impedance

and

Z_L = longitudinal impedance of test object.

There is thus the difficulty in obtaining meter impedances substantially higher than the longitudinal impedance to earth (or case) of balanced sources isolated from earth (or case) such as are presented by portable transmission measuring equipment.

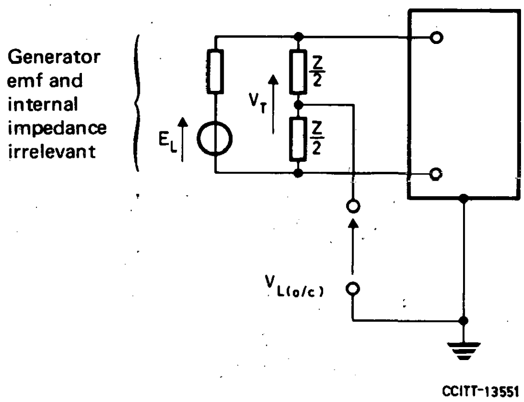
However, if the longitudinal impedance is so high unbalance should not be a problem.

5.2 A measure L_2 is defined in [3] and is illustrated in Figure 15/G.117.

This measure is used in cable crosstalk studies and applied to devices (e.g., feeding bridge) with a deliberately earthed centre-tap. It is not applicable to virtually earth-free devices.

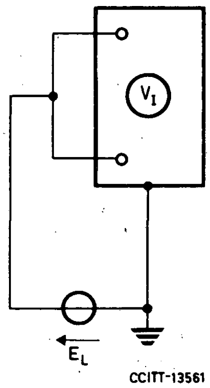
5.3 *Common-mode rejection ratio*

This is another quantity that is appropriate to signal receivers and is measured in accordance with the principle shown in Figure 16/G.117, the input terminals being short-circuited and then energized together.



$$L_2 = 20 \log_{10} \left| \frac{V_T}{V_{L(o/c)}} \right| \text{ dB.}$$

FIGURE 15/G.117



$$\text{Common-mode rejection ratio} = \left| \frac{E_L}{V_I} \right|$$

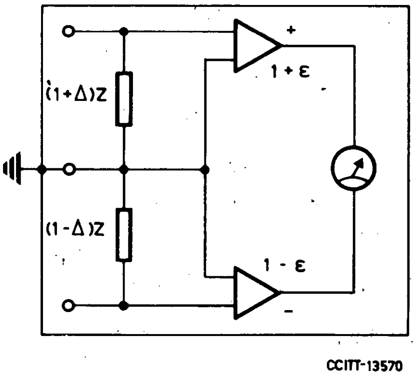
and

$$\text{Common-mode rejection} = 20 \log_{10} \left| \frac{E_L}{V_I} \right| \text{ dB.}$$

Note – V_I is the voltage indicated by the measuring set being tested.

FIGURE 16/G.117

It is clear that this measure is somewhat akin to the input common-mode sensitivity ratio but since there is no transverse signal (by reason of the short circuit) any transverse/longitudinal conversion mechanism within the test-object is not called into play. Hence, in general, there is no simple relationship between the two measures, as can be seen from the generalized measuring instrument illustrated in Figure 17/G.117 in which the input impedance is unbalanced and the gain ratios of the two halves of the differential amplifier are also slightly different. Provided ε, $\Delta \ll 1$ the various balance parameters will be as indicated and in particular the common mode rejection ratio is not twice the input longitudinal interference ratio, i.e. there is not a 6-dB difference between their decibel values.



Common mode rejection ratio	=	2ϵ	
Input longitudinal interference ratio	=	$\epsilon + \frac{\Delta}{2}$	$(\epsilon, \Delta \ll 1)$
Longitudinal impedance ratio	=	0.5	$(\Delta \ll 1)$
Longitudinal conversion ratio	=	$\frac{\Delta}{2}$	$(\Delta \ll 1)$

FIGURE 17/G.117

A measuring set in which there is both a passive unbalance and an internal active unbalance

6 Test bridges

6.1 The fundamental requirements of a practicable test bridge for quantitative measurements are:

- The impedances presented to the transverse and longitudinal signals should be defined and controlled.

  If the quantitative objectives of the study outlined in § 1 above (namely, to predict the performance of a cascade of separately-measured items) are to be attained, the impedances of the test bridge should be close to the nominal reference resistance e.g. 30-dB return loss versus 600 ohms (transverse) and 150 ohms (longitudinal). When other values are used it will be difficult to use the measurement results in quantitative studies. Such standardization is not required for qualitative assessments of balance.

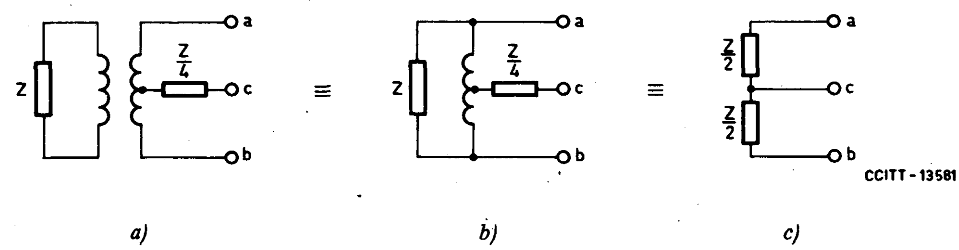
- The inherent balance of the test bridge should be substantially higher than that of the test object. This will ensure an adequate absolute accuracy and also, as a consequence, acceptably small differences between measurement results made by different test bridges on the same test object. An absolute accuracy of ± 1 dB should be aimed at so that differences are not greater than 2 dB. As a general rule ± 1 dB absolute accuracy can be assured if the longitudinal conversion loss of the test bridge is 20 dB higher than that of the test object.

- There should be facilities for simulating the variety of d.c. holding/feeding conditions encountered in practice so that items of telephone equipment (e.g. telephone instruments, line signalling terminations) can be measured in conditions similar to those prevailing in normal operation.

- There should be facilities for introducing longitudinal and transverse excitation as required and similarly measuring the responses.

6.2 The electrical correspondences illustrated in Figure 18/G.117 below show how the centre-tapped coil configuration can be replaced by centre-tapped resistors. The special arrangements to enable the longitudinal impedance and transverse conversion transfer ratios to be measured are illustrated in Figure 19/G.117.

Equivalent ways of measuring q the longitudinal impedance ratio are as follows. Analogous arrangements could be used to measure the transverse conversion transfer ratio.



Note 1 – In diagram *a)* the unbalanced parts of the measuring arrangement are isolated from the balanced portion by a transformer. In particular, measuring instruments need not have any exceptional degree of balance about earth.

Note 2 – In diagrams *a)* and *b)* the coil/transformer is iron-cored with an accurate centre-tapped connection (i.e., bifilar winding), both tightly-coupled half-windings being completely symmetrical with respect to the core. The inductance of the coil/transformer should be such that $\omega L \gg |Z|$ at all testing frequencies.

The physical $Z/4$ component provides a convenient impedance across which the voltage is a measure of the longitudinal current.

Special precautions are necessary in practice to preserve representative d.c. conditions which at the same time do not saturate the transformer.

Note 3 – For very low frequencies, the arrengements in diagrams *a)* and *b)* may be unsuitable and it may be more convenient to use the arrangement in diagram *c)*, a small (e.g., 1 ohm) resistor being inserted in the longitudinal arm so that a measure of the longitudinal current can be obtained without appreciably altering the circuit conditions. The two $Z/2$ components in the resistor-bridge must be precisely matched. An example of this is shown in *b)* of Figure 19/G.117.

FIGURE 18/G.117

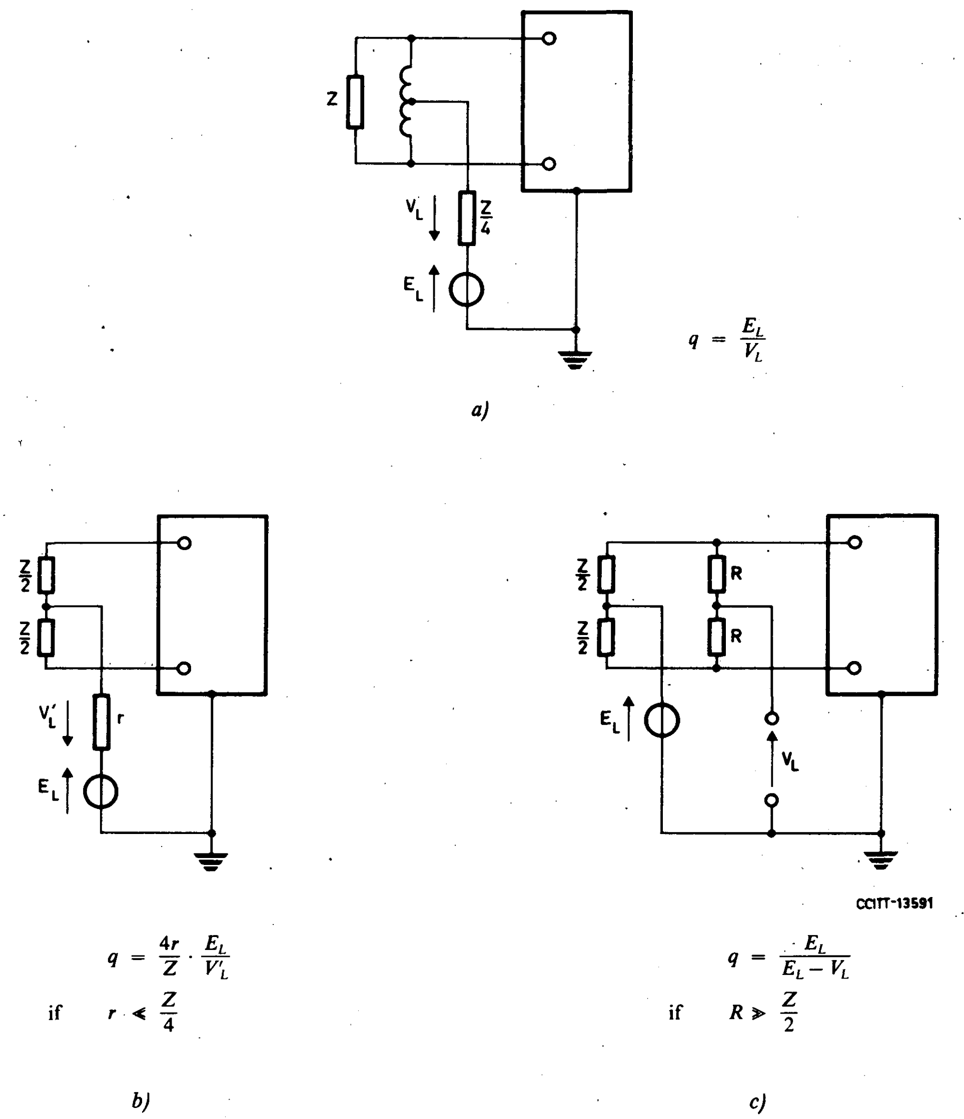


FIGURE 19/G.117

6.3 The inherent balance of the measuring arrangement can be checked by replacing the equipment being measured with a second test bridge as shown in Figure 20/G.117. The inherent longitudinal conversion loss of the measuring arrangement should be 20 dB greater than that to be measured for the specimen.

This balance should also be obtained when the connections at *a* and *b* are reversed as shown. This permits an accuracy in the order of ± 1 dB. The coil or transformer should be iron-cored with an accurate centre-tapped connection (i.e. bifilar winding), both the tightly-coupled half-windings being completely symmetrical with respect to the core. The inductance of the coil/transformer should be such that $\omega L \gg |Z|$ at all significant testing frequencies.

Figure 21/G.117 illustrates the principles of a practicable test bridge.

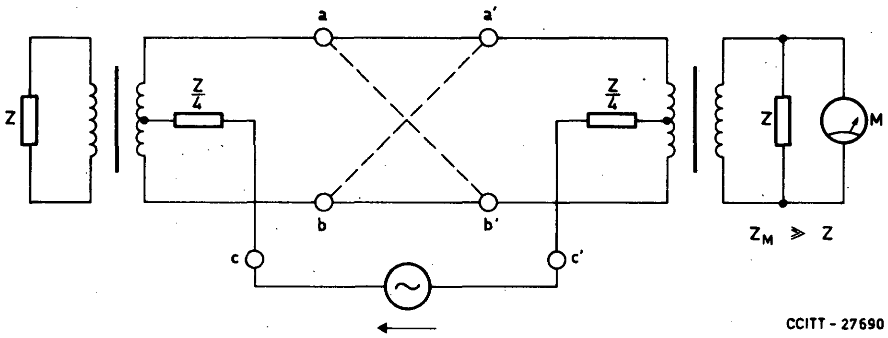


FIGURE 20/G.117

Verifying the adequacy of the inherent balance of a test-bridge

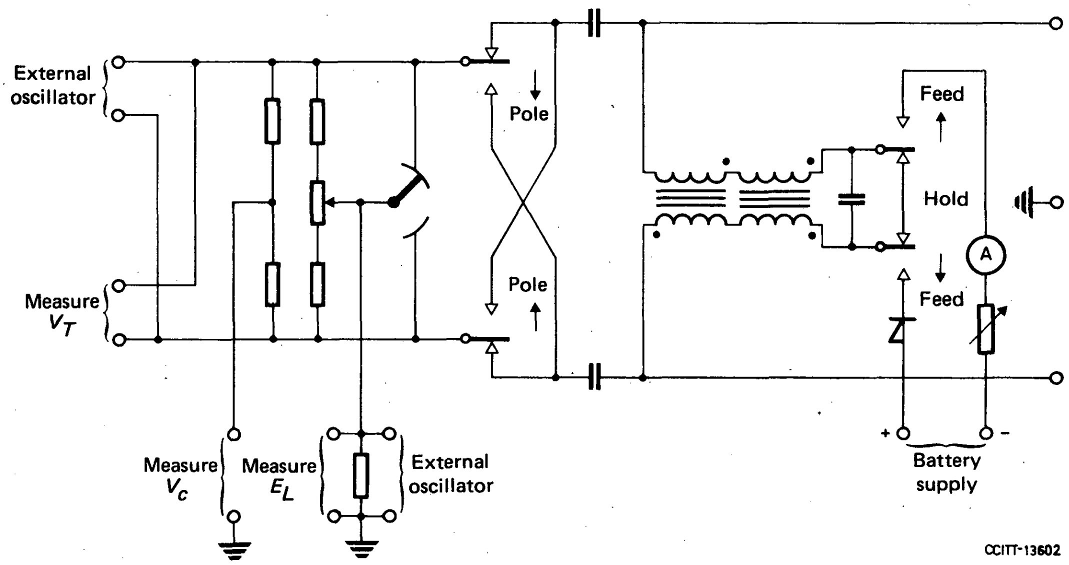


FIGURE 21/G.117

Principles of a practicable test bridge

References

[1] CCITT Recommendation *Definitions and measuring techniques concerning the degree of balance with respect to earth of transmission test apparatus*, Vol. IV, Fascicle IV.4, Rec. 0.121.

[2] CCITT *Directives concerning the protection of telecommunication lines against harmful effects from electricity lines*, Chapter XVI, ITU, Geneva, 1978.

[3] CCITT Question 4/XVI, Annex 2, Study Period 1968-1972, *Green Book*, ITU, Geneva, 1973.

[4] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Fascicle III.3, Rec. G.712.

[5] CCITT Recommendation *Unbalance of telecommunication installations*, Vol. IX, Rec. K.10.

[6] IEEE Standard 455-1976.

[7] CCITT Definition: *Composite loss (or gain)*, Vol. X, Fascicle X.1 (Terms and Definitions).

[8] CCITT Definition: *Transducer loss (or gain)*, Vol. X, Fascicle X.1 (Terms and Definitions).

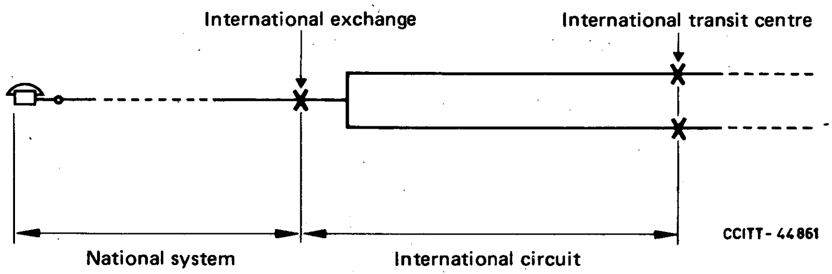
[9] IEC publication 268.

[10] CCITT Recommendation *Psophometers (apparatus for the objective measurement of circuit noise)*, Vol. V, Rec. P.53.

1.2 General characteristics of national systems forming part of international connections

The following subsection groups together the Recommendations which national systems must conform to if international communications are to be of reasonable quality.

The principles of these Recommendations also apply in cases where an international circuit is 2-wire switched at one end in an international centre. This case may arise while the CCITT transmission plan is being implemented. The figure below illustrates the arrangement.



Recommendation G.120

TRANSMISSION CHARACTERISTICS OF NATIONAL NETWORKS [1)]

1 Application of CCITT Recommendations on telephone performance to national networks (formerly Part A)

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

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

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

Note – Reference should also be made to Recommendations P.12 [2] and G.113.

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

Loaded-cable circuits should conform to Recommendation G.124 [3] and carrier circuits to Recommendation G.123.

1) Former Recommendation P.21 [1].

1.3 National trunk circuits should have characteristics enabling them to conform to Recommendations G.131, G.132 and G.134 as regards the other characteristics of the 4-wire chain constituted by the international telephone circuits and the national trunk extension circuits.

1.4 International centres should satisfy Recommendation Q.45 [4].

National automatic 4-wire centres should observe the noise limits specified in Recommendation G.123, § 3.

Manual telephone trunk exchanges should satisfy Recommendation P.22 [5].

Information on the transmission performance of automatic local exchanges is given in the CCITT manual cited in [6].

2 **National transmission plan** (formerly Part B)

Every Administration is free to choose whatever method it considers appropriate for specifying transmission performance and to adopt the appropriate limits to ensure satisfactory quality for national calls, it being understood that in addition the Recommendation relating to corrected reference equivalents (CREs) (Recommendation G.121) should be satisfied for international calls.

Note – To meet this twofold condition with respect to national and international calls, each Administration has to draw up a national transmission plan, i.e. it must specify limits for each part of the national network.

The manual cited in [6] contains descriptions of the transmission plans adopted by various countries and also some indications concerning the methods that can be used to establish such a plan.

In particular, if an Administration wishes to apply the CRE method to its national connections, it will find useful information in Annex A to Recommendation G.111.

References

[1] CCITT Recommendation *Application of CCITT Recommendations on telephone performance to national networks*, Red Book, Vols. V and V *bis*, Rec. P.21, ITU, Geneva, 1962 and 1965; amended at Mar del Plata, 1968, to become Rec. P.20 (G.120) *Transmission characteristics of national networks*, White Book, Vol. V (Vol. III), ITU, Geneva, 1969.

[2] CCITT Recommendation *Articulation reference equivalent (AEN)*, Vol. V, Rec. P.12.

[3] CCITT Recommendation *Characteristics of long-distance loaded-cable circuits liable to carry international calls*, Orange Book, Vol. III, Rec. G.124, ITU, Geneva, 1977.

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

[5] CCITT Recommendation *Manual trunk exchanges*, Orange Book, Vol. V, Rec. P.22, ITU, Geneva, 1977.

[6] CCITT manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

CORRECTED REFERENCE EQUIVALENTS (CREs) OF NATIONAL SYSTEMS

(Geneva, 1964; amended at Mar del Plata, 1968, Geneva, 1972, 1976 and 1980)

Preamble

Parts 1 to 5 of this Recommendation apply in general to all analogue, mixed analogue/digital and all digital international telephone connections. However, where recommendations are made on specific aspects in § 6 for mixed analogue/digital or all-digital connections, § 6 will govern.

All sending and receiving CREs in this Recommendation are "nominal values" as explained in § 4 of this Recommendation and are referred to the corresponding virtual analogue switching points of an international circuit at the CT 3.

The definition of the virtual analogue switching points of international circuits can be found in Figure 1/G.111.

1 Traffic-weighted mean values of the distributions of sending and receiving CREs (formerly Part A)

An objective for the mean value is necessary to ensure that satisfactory transmission is given to most subscribers. Transmission would not be satisfactory if the maximum values permitted in § 2 were consistently used for every connection.

It has been provisionally agreed, taking into account the long-term objectives for the overall CREs given in Recommendation G.111, § 3.2 and the need to control the mean power applied to long-distance FDM transmission systems, that an appropriate subdivision of the overall objective should place the long-term objectives for the sending and receiving national systems in the ranges:

sending CRE: 11.5-13 dB

receiving CRE: 2.5- 4 dB.

(These are the mean values of the traffic-weighted distributions. If the traffic distribution cannot be foreseen with sufficient accuracy, it can be assumed that all subscribers generate the same amount of traffic.)

Note – In some networks the long-term values cannot be attained at this time and it has been provisionally agreed that appropriate short-term objectives for these ranges are:

sending CRE: 11.5-19 dB

receiving CRE: 2.5-7.5 dB

corresponding to the short-term objective given in Recommendation G.111, § 3.2 of a range of 13-25.5 dB for the mean value of the traffic-weighted distribution of the overall CRE.

The short-term mean values have been determined under the assumption that the statistic distribution is normal (Gaussian). It might occur that a real distribution is not normal but asymmetric. In such cases it is acceptable that the mean values fall somewhat outside the stated limits, provided that the distribution as a whole leads to transmission conditions equal to those of a normal distribution having its mean value inside the stated range.

2 Maximum sending and receiving CREs (formerly Part B)

2.1 *Values for each direction of transmission*

It has been agreed that the national sending and receiving systems used to set up all actual outgoing or incoming calls in an average-sized country [see Recommendation G.101, § 2.2] should individually meet both the following objectives:

- the CRE of the sending system between a subscriber and the first international circuit should not exceed 25 dB (nominal maximum value);
- the CRE of the receiving system between the same two points should not exceed 14 dB (nominal maximum value).

In a large country these limits shall be, respectively, 25.5 dB and 14.5 dB if a fourth national circuit is part of the 4-wire chain, or 26 dB and 15 dB if five national circuits form part of the 4-wire chain.

In Figures 1/G.121 and 2/G.121, the numbers in rectangles are values recommended by the CCITT. The others are given only as examples of possible arrangements, subject to Recommendation G.122.

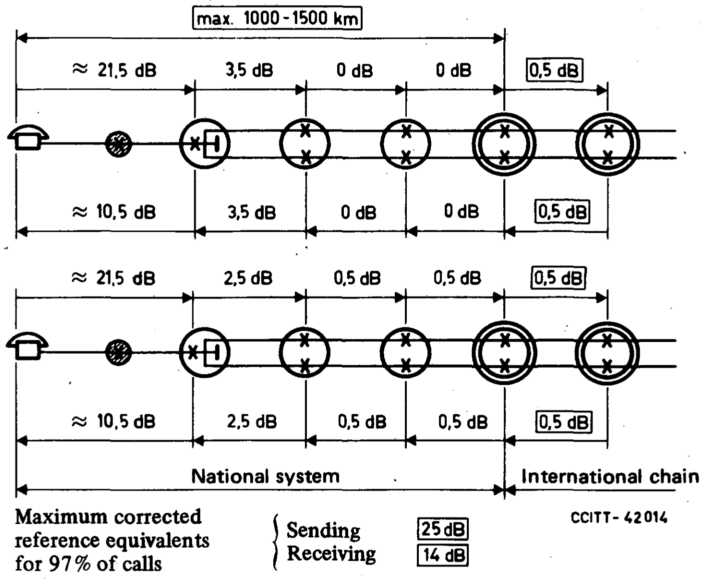


FIGURE 1/G.121

Examples of the allocation of maximum CREs for an international connection in a country of average size

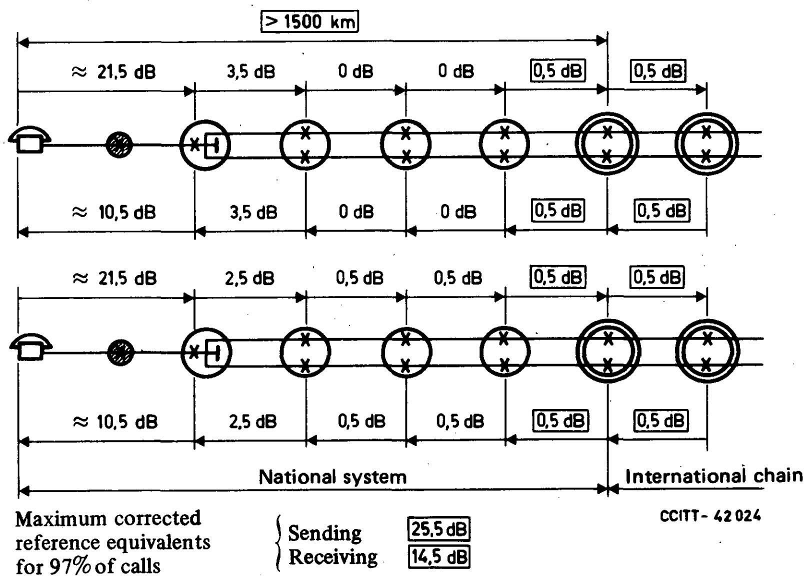


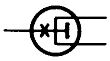
FIGURE 2/G.121

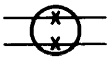
Examples of the allocation of maximum CREs for an international connection in a large country

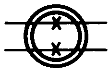
Notes and legend for Figures 1/G.121 and 2/G.121:

 Subscriber set

 Local exchange, with 2-wire switching

 Two-wire switching exchange with terminating unit. A switchable pad may also be used at this point to compensate for losses in the 2-wire side, provided that the limits given in Recommendation G.122, § 1 for stability and attenuation are respected.

 Four-wire switching exchange

 International exchange with virtual switching points

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Note 1 – These maximum values of CREs have been obtained from the old Recommendations (Volume III of the *Orange Book*, Geneva 1977), by taking some typical allocations of reference equivalents and converting them to CREs. If the new CRE limits are exceeded by 1 or even 1.5 dB in existing networks, this is no cause for concern, because planning calculations have a limited accuracy and, in the immediate future, it is impossible to avoid certain discrepancies due to the inexactitudes of the reference quivalent method. On the other hand, if in other cases a margin of 2 or 3 dB appears, the permissible attenuation for subscriber lines should not be automatically increased; the first step should be to consider the possibility of using the margin to improve the traffic-weighted values referred to in § 1.

Note 2 – The numbers in rectangles are figures recommended by the CCITT. The others are given only as examples of possible arrangements, subject to Recommendation G.122. They imply a particular choice of relative levels at each exchange. In practice, a variety of switching levels may be adopted which would result in unequal circuit losses in the two directions of transmission for particular circuits. In addition, the losses from the 2-wire point to the virtual switching points (i.e. the *a-t* and *t-b* losses in Figure 1/G.111) may not be equal, as shown by the examples in Table A-1/G.121.

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

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

The following points should be noted:

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

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

   Reference [1] is a résumé of the test results from various Administrations concerning the subjective effects of such asymmetry.

3) When devising national transmission plans, Administrations should take into account the needs of data transmission between modems complying with the pertinent Recommendations (e.g., V.2 [2], V.21 [3], V.23 [4]). Annex B gives some information on this point.

3 **Minimum CREs** (Part C)

Administrations must take care not to overload the international transmission systems if they reduce the attenuation in their national trunk network.

Provisionally, a nominal minimum value of 7 dB sending CRE referred to the send virtual analogue switching point of the international circuit is recommended in order to control the peak value of the speech power applied to international transmission systems. It should be noted that the imposition of such a limit does not serve to control the long-term mean power offered to the system.

In some countries a very low sending reference equivalent may occur if unregulated telephone sets are used. Therefore the speech power applied to the international circuits by operators' sets must be controlled so that it does not become excessive.

4 Determination of the Nominal CREs of a national system (formerly Part D)

4.1 *Definitions*

The CREs of a national system are defined in § A.3.4 of Annex A to Recommendation G.111.

Only the nominal values of the CREs are considered in Recommendations G.111 and G.121.

"Nominal value" here signifies "conventional, not actually measured or calculated but assumed for planning purposes". For example subscribers' local systems actually participating in international connections are not measured; what are measured, or rather calculated, are the CREs of typical local systems, as indicated in § 4.2).

These definitions indicate that the nominal CRE of a national system is the sum of the following values:

- the nominal CRE (at sending or receiving) of the local system (see § 4.2),
- the nominal CRE of the trunk junctions (see Annex C), and
- the sum of nominal losses (at 800 or 1000 Hz) of the national extension circuits, exchanges and 2-wire/4-wire terminating set.

4.2 *Nominal CREs of a local system*

These CREs are usually calculated by the formula giving $y(q)$ in § A.2 of Annex A to Recommendation G.111 from the reference equivalents q determined on local systems (consisting of a telephone set of the relevant type, an artificial line with a model feeding bridge) by subjective tests in accordance with Recommendation P.72 [5].

Note 1 – The CREs given for local systems are to be based upon the average values of the sensitivities of the transducers of a large number of working telephone sets. As far as carbon microphones are concerned, the average value of the sensitivity of the carbon microphones in the national network is effectively represented by the value of sensitivity corresponding to the long, stable period of their lifetime.

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

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

Note 2 – The variations with time of circuits and other items of equipment connecting the local exchange with the international centre are not included in the values of nominal CREs. Recommendation G.151, § 3 sets forth the objectives concerning variations with time of transmission losses of national extension circuits relative to the nominal values.

Note 3 – Reference equivalents are often determined with only one type of telephone set and only one length of line. To take account of the effect of other lines, one of the methods described in Annex C may be used.

5 Sidetone reference equivalent [1] (formerly Part E)

Every precaution must be taken to avoid further transmission impairment in communications which reach the reference equivalent and noise limits. Tests have shown that in these unfavourable conditions the sidetone reference equivalent (for speech) should be at least 17 dB. In fact, this value cannot be achieved without additional networks, which increase line costs and are only justified when the subscriber has to exchange calls frequently in very bad conditions. In most cases, values between 7 and 10.5 dB are to be expected.

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

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

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[1] Refer to § 6 of the Appendix to Section 1.

6 Incorporation of PCM digital processes in national extensions

6.1 *Effect on national transmission plans*

The incorporation of PCM digital processes into national extensions might require that existing national transmission plans be amended or replaced with new ones.

The national transmission plans to be adopted should be compatible with existing national analogue transmission plans and also capable of providing for mixed analogue/digital operation. In addition, the plans should be capable of providing for a smooth transition to all-digital operation.

6.2 *Transmission loss considerations*

Where the national portion of the 4-wire chain is wholly digital between the local exchange and the international exchange, the transmission loss which the extension must contribute to the maintenance of stability and the control of echo on an international connection can be introduced at the local exchange. The manner in which the required loss should be introduced is to be governed by the national transmission plan adopted. Three of possibly many different configurations of such national extensions are shown in Figure 3/G.121.

In case 1 and 2 of Figure 3/G.121, the R pad represents the transmission loss between the 0 dBr point at the digital/analogue decoder and the 2-wire side of the 2W/4W terminating unit. Similarly, the T pad represents the transmission loss between the 2-wire side of the 2W/4W terminating unit and the 0 dBr point at the analogue/digital coder. In practice there can be levels other than 0 dBr and hence consequential changes in the R and T pad-values.

The transmission loss introduced by the combination of the R and T pads in case 1 of Figure 3/G.121 is provisionally recommended to be 6 or 7 dB [2)]. However, the individual values of R and T can be chosen to cater for the national losses and levels, always provided that the CCITT recommendations for international connections are met.

In case 2 of Figure 3/G.121 it is possible with a sufficiently high balance return loss to comply with the recommendations concerning corrected reference equivalents, stability, and echo without requiring a particular value for the sum of the R and T pad values. However it will still be necessary to comply with the provisions concerning differential loss (§ 6.3 of this Recommendation) which in turn implies that

$$R - T = 3 \text{ to } 11 \text{ dB}.$$

However, a local exchange designed on these principles and which is at the end of a national extension containing asymmetric analogue portions cannot take the whole of the asymmetry allowance.

It may be desirable to reduce the range of 3 to 11 dB and this is under study (Question 5/XVI [6]).

The R and T pads shown in Figure 3/G.121 are also shown as analogue pads. This type of pad might not necessarily be introduced under all conditions. In some situations it might be more practical to introduce the required loss at the local exchange, or at some other point of the national extension, by means of digital pads. However, if digital pads are used, their detrimental effect on digital data or other services requiring end-to-end bit integrity must be taken into account as indicated in Recommendation G.101, § 4.4 and G.103, § 4.

The arrangement in Case 3 of Figure 3/G.121 assumes 4-wire digital switching at the local exchange in combination with a 4-wire digital local line and a 4-wire "digital telephone set".

For the three cases identified in Figure 3/G.121, the send and receive corrected reference equivalents calculated to and from the virtual analogue switching points at the international exchange are given by:

$$\text{Sending CRE} = \text{Sending CRE}_0 + 3.5 \text{ dB}$$

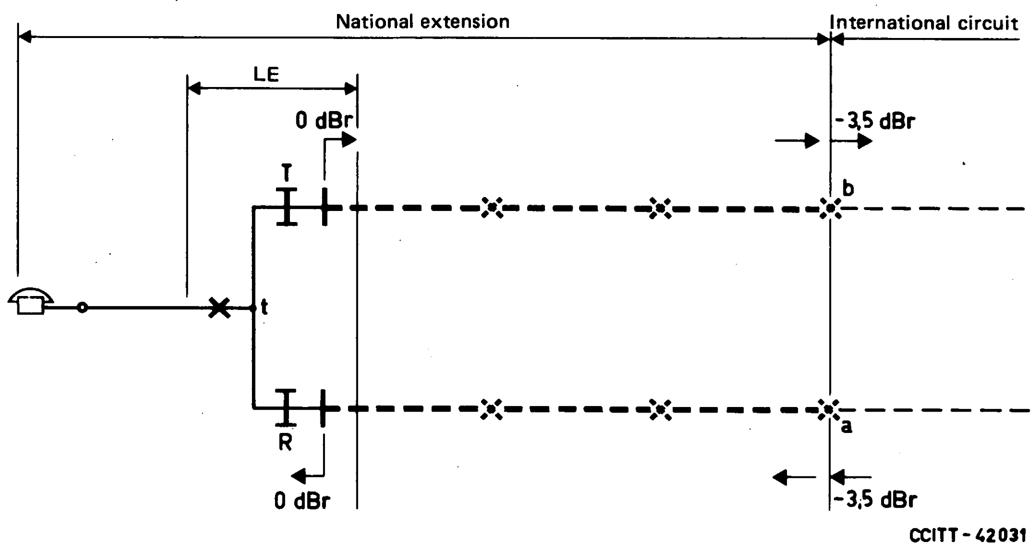
$$\text{Receiving CRE} = \text{Receiving CRE}_0 - 3.5 \text{ dB}.$$

---

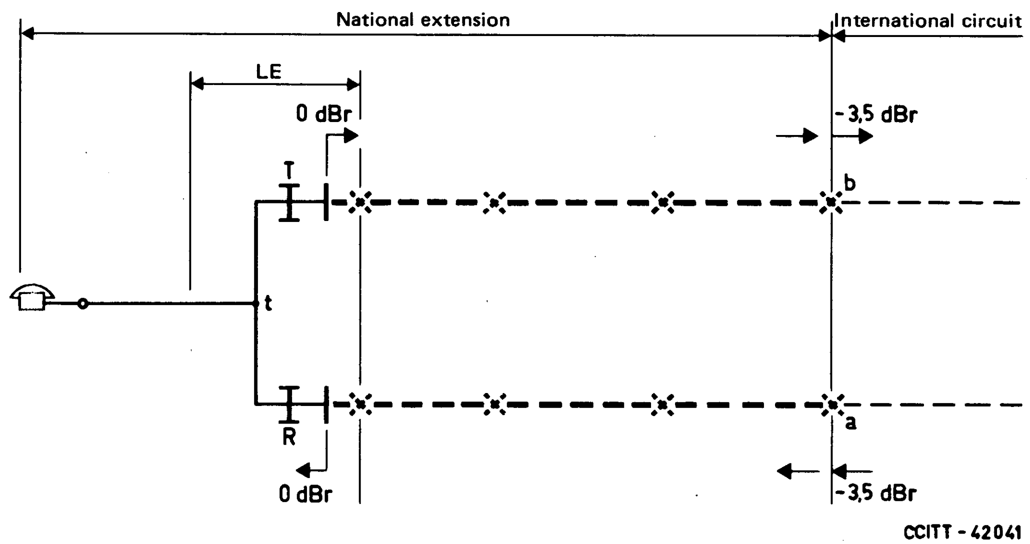
2) When a sufficiently high balance return loss can be assumed, e.g. by impedance correction or improved balance networks, other values for the sum of the R and T pads are considered possible by some Administrations. See Annex 7 to Question 5/XVI [7].

In the above relationships, the sending CRE_0 and the receiving CRE_0 are the sending and receiving CREs calculated to and from the 0 dBr points at the analogue/digital coder and the digital/analogue decoder. In Case 3, the analogue/digital coder and digital/analogue decoder are inside the telephone set (i.e., the analogue local line length is zero).

Stability and echo on international connections are governed by Recommendation G.122.

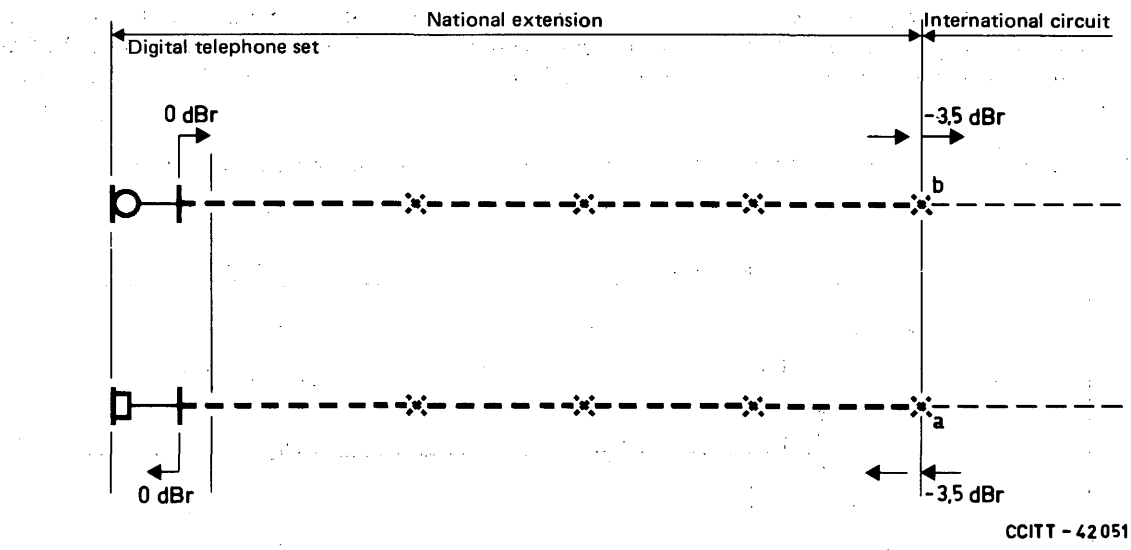


a) *Case 1 – Two-wire analogue switching at local exchange and 2-wire analogue subscriber line*



Note – No 2-wire switch point between the subscriber's local line and the terminating unit at the local exchange.

b) *Case 2 – Four-wire digital switching at the local exchange but 2-wire analogue subscriber lines*



c) *Case 3 – Four-wire switching at the local exchange, 4-wire digital subscriber line and digital telephone set*

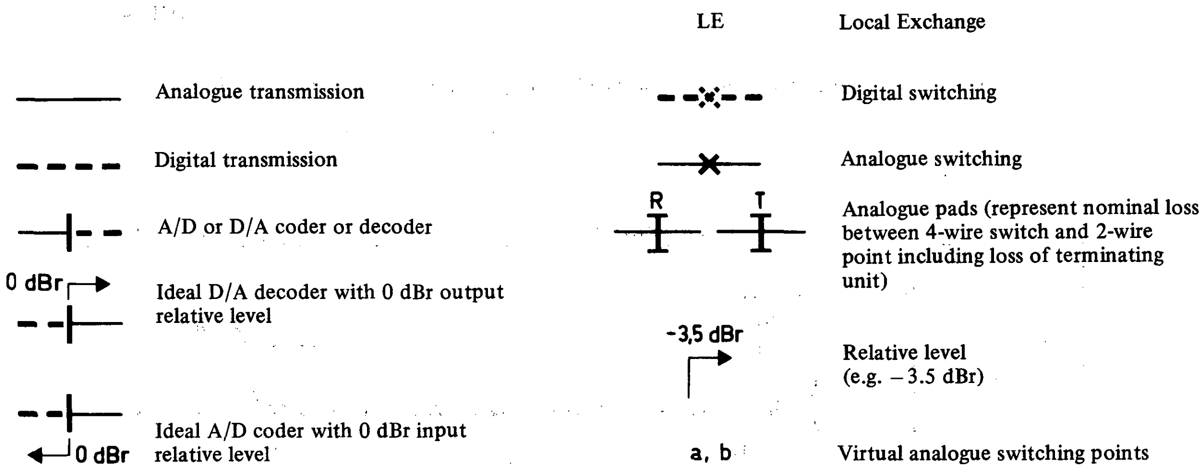


FIGURE 3/G.121

Examples of national extensions in which the digital 4-wire chain extends to a 4-wire local exchange

6.3 *Difference in transmission loss between the two directions of transmission*

In accordance with Recommendation G.111, § 6, the difference in transmission loss between the two directions of transmission on an international connection should not exceed 8 dB. This requirement applies to all types of connections, i.e., all-analogue, mixed analogue/digital and all-digital.

To comply with the above requirement, national extensions such as those of Figure 3/G.121 should not exhibit a difference of more than 4 dB between the loss *t-b* and the loss *a-t*, i.e., $|\text{loss}\ (t\text{-}b) - \text{loss}\ (a\text{-}t)| \leq 4$ dB.

Although differences in transmission loss of up to 8 dB between the two directions of transmission may be acceptable in the case of international telephone service, such differences may have adverse effects where analogue data is to be carried over connections having such differences. The information in § 2.2 and in Annex B, while pertinent to all-analogue connections, is also applicable to mixed analogue/digital and all-digital connections.

ANNEX A

(to Recommendation G.121)

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

A.1 Consider an international connection between primary centres in two administrations, established over one international circuit as shown in Figure A-1/G.121.

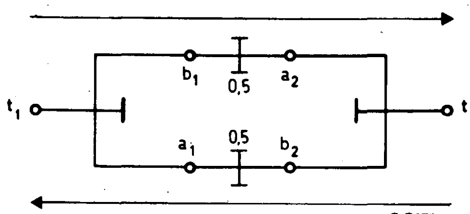


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FIGURE A-1/G.121

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

$$1 \rightarrow 2 = t_1 b_1 + 0.5 + a_2 t_2 \quad \text{(dB)}$$

and

$$2 \rightarrow 1 = t_2 b_2 + 0.5 + a_1 t_1 \quad \text{(dB)}.$$

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

$$(t_1 b_1 - a_1 t_1) - (t_2 b_2 - a_2 t_2) = d_1 - d_2$$

in which d signifies $d_1 = t_1 b_1 - a_1 t_1$ or $d_2 = t_2 b_2 - a_2 t_2$.

A.2 The value in decibels of losses $a_1 t_1$ and $b_1 t_1$ or $a_2 t_2$ and $b_2 t_2$ for each of several Administrations is given in Table A-1/G.121 together with the corresponding values of d, their difference. It will be seen that a maximum nominal difference $(d_1 - d_2)$ of 3 dB between the two directions of transmission can arise on connections between two Administrations with $d_2 = 0$ dB (e.g. Netherlands) and any of the Administrations with $d_1 = 3$ dB (e.g. North America). It will also be noted that most nominal differences are $d = 0$ dB, so that the nominal difference $(d_1 - d_2)$ on connections between the Administrations concerned is also 0 dB.

TABLE A-1/G.121

	$a_1 t_1$ or $a_2 t_2$	$t_1 b_1$ or $t_2 b_2$	$d = t_1 b_1 - a_1 t_1$ or $t_2 b_2 - a_2 t_2$	$s = t_1 b_1 + a_1 t_1$ or $t_2 b_2 + a_2 b_2$
* Australia	−0.5	0.5	1.0	0.0
Belgium	3.5	3.5	0.0	7.0
* Denmark	1.9	1.9	0.0	3.8
Federal Republic of Germany	3.5	3.5	0.0	7.0
* France	2.2	2.2	0.0	4.4
Hong-Kong	1.5	3.0	1.5	4.5
Japan	4.0	4.0	0.0	8.0
* Netherlands	3.5	3.5	0.0	7.0
* New Zealand	−1.5	1.5	3.0	0.0
* North America	−0.5	2.5	3.0	2.0
* Norway	0.5	3.5	3.0	4.0
* Sweden	3.5	3.5	0.0	7.0
Switzerland	3.5	3.5	0.0	7.0
United Kingdom (local exchange directly connected to CT3)	0.5	3.5	3.0	4.0
United Kingdom (all other exchanges)	3.5	3.5	0.0	7.0
U.S.S.R.	0.0	0.0	0.0	0.0

Note – For Administrations marked * a range of values is appropriate and in each case the nominal minimum values $a_1 t_1$ and $t_1 b_1$ or $a_2 t_2$ and $t_2 b_2$ are given. In each case the nominal difference is maintained for all values within the range. For such Administrations, the indicated sum is the nominal minimum value. North America signifies AT&T Co. and the Canadian Telecommunications Carriers Association. Values are shown in decibels.

A.3 The nominal differences of loss between the two directions of transmission on international connections between local exchanges and also between subscribers' premises (i.e. telephone instrument disconnected) may also be calculated from the table, but the results will be true only if national 2-wire switched trunk-junctions etc., are nominally symmetrical. This is usually the case.

A.4 The last column in the table indicates the sum $t_1 b_1 + a_1 b_1$ or $t_2 b_2 + a_2 b_2$. This value represents that component of the loss

$$a_1 - t_1 - b_1 \quad \text{or} \quad a_2 - t_2 - b_2$$

that is attributable to the national transmission plan and if, for example, the loss of the path *a-t-b* from the point of view of stability (or echo) is required, see Figure 1/G.122, the value in the last column must be augmented by the stability (or echo) balance return loss at *t*.

ANNEX B

(to Recommendation G.121)

The influence of the telephone transmission plan on data transmission

(Contribution of the Netherlands Administration)

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

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

- maximum circuit losses in national networks, estimated from national transmission plans (see the manual cited in [8]);
- a reasonable number of international circuits;
- variation of transmission loss of international circuits and national extension circuits (Recommendation G.151);
- the sending and receiving levels for data equipment and the attenuation range indicated for the design (Recommendations V.2 [2], V.21 [3] and V.23 [4]),

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

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

ANNEX C

(to Recommendation G.121)

CRE of a subscriber line, a junction or a trunk junction

C.1 *Definitions; subjective tests*

C.1.1 Let us assume that, by subjective tests, we have determined:

Q the overall reference equivalent of a certain line and subscriber set;

Q_0 the reference equivalent of the same set, without the line.

By definition, the effect of this line on the CRE (i.e., the part due to the line in the local system CRE) is:

$$y_L = y(Q) - y(Q_0) \tag{C-1}$$

where the function $y(q)$ is defined in Annex A to Recommendation G.111.

Note – The effect of the line may be different for sending and receiving, if only because the effect of feed current on sensitivity is different. If desired, this effect of feed current may be assessed separately.

C.1.2 The CRE of a junction or of a trunk junction can be determined directly by subjective tests by comparing path 5 in Figure A-1/G.111 with path 6 via path 2 where $x_2 = 25$ dB.

C.1.3 Administrations may need to calculate the CREs of various subscriber lines for local network transmission planning. The CCITT advises Administrations which do not possess many results of subjective tests to apply the objective measurements or calculation methods described below. It is understood that Administrations which have the necessary means to assess the CREs of the various types of lines used by them, with the telephone sets of the types used in their networks, may in all cases continue to apply any simple calculation methods which they may have already developed.

C.2 *Objective CRE measurement*

C.2.1 If we call:

I the indication of the OREM-B when measuring a subscriber set with a line, and

I_0 the corresponding value without a line, we approximately obtain:

$$y_L = I - I_0 \qquad \text{(C-2)}$$

This relation is satisfied in practice with sufficient accuracy for planning purposes [9].

Note – This procedure should be applied with caution to telephone sets having carbon microphones because the effect of feed current may be wrongly measured using this type of objective instrumentation. In this case the effect of feed current should be measured separately using real speech.

C.2.2 The CREs of junctions or trunk junctions can also be measured with the OBDM or the OREM-B; the results agree well with those of the subjective tests [10].

C.3 *Calculations based on insertion loss*

C.3.1 *General*

Note 1 – In the case of a subscriber line, if one of the methods described in C.3 is used, the effect of the line current (which would flow in practice) on the sensitivity of the microphone and on the regulator (if there is one) should be estimated separately.

Note 2 – These methods can be used for a subscriber line, a junction or a trunk junction; the insertion loss must, of course, be measured or calculated between the appropriate impedances.

C.3.2 *Case of an open-wire line*

The characteristic impedance of a line is, in this case, largely resistive and the line insertion loss can be calculated without difficulty from transmission theory. A suitable method of calculation will be found in [11]. Reference [12] also gives information on this point. Generally speaking, in the frequency band which can be used in telephony, the value of the insertion loss is more or less constant, which yields a sufficiently accurate estimate of the CRE.

If the insertion loss varies appreciably with frequency, the method described in § C.3.4 below should be applied.

C.3.3 *Case of a homogeneous cable line* (loaded or unloaded)

(See § C.3.4)

C.3.4 *Graphical method for calculating the part of the CRE which is due to the line*

C.3.4.1 The part of the CRE which is due to cable pairs having an appreciable attenuation distortion may be estimated approximately by a simple graphical calculation:

a) The insertion loss is measured or calculated (on the basis of the cable constants and the termination impedance) as a function of frequency.

b) The insertion loss is represented by a curve on a diagram which shows the frequency on a logarithmic scale and loss (in decibels) on a linear scale.

c) The mean value of the insertion loss in the frequency band 200-4000 Hz is calculated numerically by a suitable division of the band, or by drawing a horizontal straight line such that the surface between that straight line and the curve should be the same on either side of the straight line (see, however, § C.3.4.3).

d) If the cable pair is correctly terminated, the mean value of the insertion loss constitutes a good approximation to the part of the CRE which is due to that pair.

C.3.4.2 For a subscriber line on overhead wires, this estimate should be made by terminating the line on the subscriber side with a resistor representing the module of the subscriber set impedance measured at 800 Hz.

C.3.4.3 The same applies in the case of loaded cables, provided that their characteristic impedance does not differ appreciably from that of the subscriber set. If a considerable mismatch is observed, the method will not be used in this form.

This method of calculation may be inapplicable to loaded cables with a cut-off frequency well below 3400 Hz.

C.4 *Calculation from the image attenuation*

C.4.1 The formulae and values of K indicated below apply for homogeneous unloaded cable lines. Note 1 to § C.3.1 still applies.

C.4.2 *Case of a subscriber line*

The part y_L of the CRE due to a subscriber line (a homogeneous unloaded cable line) can be represented by a formula of the following type, with sufficient accuracy for planning purposes:

$$y_L = \mathrm{K} A_{800} \qquad \text{(C-3)}$$

where A_{800} is the image attenuation of the line at 800 Hz, and K is a constant, independent of the length of the subscriber line, but which to some extent depends on the diameter d of the conductors.

Administrations which do not possess measurement results obtained on their own network may use the values of K given in Table C-1/G.121.

This method is described in detail in [13].

TABLE C-1/G.121

Coefficient K for unloaded cable lines with copper conductors

d (mm)		0.32	0.4	0.5	0.6	0.65	0.7	0.8	1	1.27
K	For subscriber lines	1.43	1.27	1.17	1.13	1.12	1.11	1.11	1.12	1.17
	On 600 Ω		1.28	1.15	1.10		1.06	1.05		

C.4.3 *Case of a junction or a trunk junction*

Subjective tests and measurements by the method described in § C.2 on unloaded cables terminated on 600 ohms have shown [10] that a formula of form of Equation C-3 may be used in this case. The last line of Table C-1/G.121 gives the values of K.

C.5 *Case of nonhomogeneous cable lines*

Experience shows that the part of the CRE due to a line of this type can be determined without appreciable error by adding together the parts measured or calculated as indicated in §§ C.2, C.3 or C.4 for the various homogeneous sections (in a loaded or an unloaded cable) of which it is composed.

ANNEX D

(to Recommendation G.121)

CRE values and previously recommended RE values

CRE values recommended in this Recommendation and previously recommended RE values are given in Table D-1/G.121.

TABLE D-1/G.121

		CRE	RE recommended previously
Traffic weighted mean values for national system (G.121, § 1)			
long-term objectives			
– sending	minimum	11.5	10
	maximum	13	13
– receiving	minimum	2.5	2.5
	maximum	4	4.5
short-term objectives			
– sending	maximum	19	16
– receiving	maximum	7.5	6.5
Maximum values for national system (G.121, § 2.1)	sending	25	21
	receiving	14	12
Minimum for the national sending system (G.121, § 3)		7	6

References

[1] *Influence of speech path unbalance in terms of a reference equivalent on the quality of speech transmission*, CCITT Green Book, Vol. V, Supplement No. 7, ITU, Geneva, 1973.

[2] CCITT Recommendation *Power levels for data transmission over telephone lines*, Vol. VIII, Fascicle VIII.1, Rec. V.2.

[3] CCITT Recommendation *300 bits per second duplex modem standardized for use in the general switched telephone network*, Vol. VIII, Fascicle VIII.1, Rec. V.21.

[4] CCITT Recommendation *600/1200-baud modem standardized for use in the general switched telephone network*, Vol. VIII, Fascicle VIII.1, Rec. V.23.

[5] CCITT Recommendation *Measurement of reference equivalents and relative equivalents*, Vol. V, Rec. P.72.

[6] CCITT Question 5/XVI, Contribution COM XVI – No. 1, Study Period 1981-1984, Geneva, 1981.

[7] *Ibid.*, Annex 7.

[8] CCITT manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

[9] CCITT 1977-1980, COM XII, Contribution No. 78 (France).

[10] CCITT 1964-1968, COM XII, Contribution No. 15 (Sweden).

[11] CCITT manual *Transmission planning of switched telephone networks*, Annex III.3, ITU, Geneva, 1976.

[12] *Ibid.*, Annex IV.3.

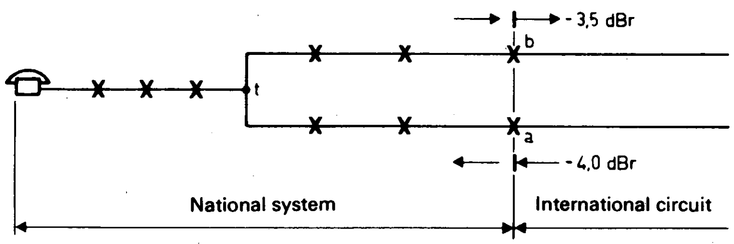
[13] *Ibid.*, Section 3 of Annex 6 (Austrialia) to Chapter V.

INFLUENCE OF NATIONAL NETWORKS ON STABILITY AND ECHO LOSSES IN NATIONAL SYSTEMS

(Geneva, 1964; amended at Mar del Plata, 1968, Geneva, 1972, 1976 and 1980)

The information provided in this Recommendation applies to all-analogue international telephone connections. The information on the maintenance of stability and the control of echo on all-digital and mixed analogue/digital connections is given in Recommendations G.111, § 6 and G.121, § 6.

The national portion of an international connection appears relative to the virtual analogue switching points *a* and *b* of the first international circuit as shown in Figure 1/G.122.



Virtual analogue switching points of the international circuit

Note – For the relative levels of digital circuits, see Figure 2/G.101, a)

FIGURE 1/G.122

Definition of the virtual switching points

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

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

b) it contributes to the control of echoes that can circulate in the 4-wire chain, and it should be noted that the operation of echo suppressors designed for connections with long propagation times is adversely affected by low values of transmission loss *a-t-b*. From the point of view of echo, the unweighted mean power ratio over the band 500 to 2500 Hz should provisionally be taken as the quantity characterizing the transmission loss *a-t-b*.

The balance return loss exhibited at a terminating set is that portion of the total transmission loss introduced by the terminating set between the receive and the send channels which is attributable to the degree of impedance match between the impedances closing the 2-wire line terminals and the balance terminals of the terminating set, Z_2 and Z_B respectively. It is given approximately by the expression in transmission units of the reciprocal of the reflection coefficient (current or voltage) between these two impedances:

$$\text{Coefficient of reflection} = \left| \frac{Z_2 - Z_B}{Z_2 + Z_B} \right|$$

This expression is exact when the impedances closing the 4-wire send and receive terminals of the terminating unit are also equal to Z_B and when the transformers are ideal.

The introduction of 4-wire digital circuits into the national extensions usually results in a reduction of the mean loss and variability of the extension. See Recommendation G.121, § 6.

The requirements stated in this Recommendation represent network performance objectives.

1 **Transmission loss of the path *a-t-b* from the point of view of stability; transmission loss of national extension circuits** (formerly Part A)

1.1 To ensure adequate stability of international connections, the attenuation measured or calculated between virtual switching points *a* and *b* in Figure 1/G.122 along the path *a-t-b* in the national network should have a value not less than

$$6 + \sum_{i=1}^{n} x_i$$

where x_i is the sum of the nominal losses in the two directions of transmission of the *i*-th circuit, and where *n* is the number of circuits in the national portion of the 4-wire chain. The value of x_i can be expected to lie in the range of 0 to 2 dB and should be chosen so that the risk of a stability loss (*a-b*) of 0 dB or less does not exceed 6 in 1000 when calculated according to the conventions of [1].

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

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

Note 1 – The stability of international telephone connections at frequencies outside the band of effectively transmitted frequencies (i.e. below 300 Hz and above 3400 Hz) is governed by the following transmission losses at the frequencies of interest:

- the balance return loss at the terminating units;
- the transmission losses of the terminating units;
- the transmission losses of the 4-wire circuits.

Note 2 – A risk of 6 in 1000 of a stability loss (*a-b*) equal to or less than 0 dB (in accordance with the convention of [1]) should also confer an acceptably small risk of loop stabilities on complete connections falling to 3 dB or less. This will be satisfactory for data transmissions over the switched network bearing in mind that the balance return losses will be those corresponding to a subscriber line terminated with a modem which can be expected to be greater than the unconditional stability return loss.

An estimate of the minimum additional transmission loss likely to be introduced at frequencies above and below the band 300-3400 Hz is given in Table 1/G.122 (see also [2]).

TABLE 1/G.122

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

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

It should be noted that these minima assume:

- zero balance return loss at the terminating unit, i.e. no balance return *gain*. A balance return gain might occur in practice, for example, if a telephone instrument presenting an inductive impedance were connected via a short subscriber line to a terminating unit equipped with a capacitive balance network;
- transformer-type terminating sets which exhibit a high-pass characteristic. This might not be so in the case of resistive terminating sets;
- national 4-wire extension circuits which introduce no relative gain above or below the 300-3400 Hz. This may not be so in the case of physical circuits uncorrected at the low-frequency end or equalized circuits.

1.2 For the purposes of calculation (e.g. in order to verify if a particular transmission plan is acceptable) it may be assumed that the mean value of the attenuation of the path *a-t-b* for the distribution of actual calls is $(10 + n)$ dB in the band 300-3400 Hz (this value may be increased by the amounts given in Table 1/G.122 above for frequencies outside this band), and that the values of attenuation over the whole band are distributed about the mean value with a standard deviation of $\sqrt{(6.25 + 4n)}$ dB. The actual distribution is not normal, but to facilitate calculations it may be assumed to be so. This assumption errs on the safe side. The graphs in Figure 1/G.131 were calculated on this assumption.

The mean and standard deviation mentioned above make allowance for:

1) the sum of the nominal values of the transmission losses *a-t* and *t-b*;
2) variation of these losses with time as given in Recommendation G.151, § 3, assuming unity correlation between the variations in the two directions of transmission for the same circuit;
3) the departure from nominal of the mean values of the transmission loss of the circuits;
4) the mean and standard deviation of the distribution of stability balance return loss at the terminating set *t*, this distribution being in principle determined for all the actual calls established over the national network.

1.3 When formulating new national plans for the routing and transmission of international calls Administrations are encouraged to aim at a mean value for the attenuation of the path *a-t-b* of the distribution of actual calls of at least $(10 + n)$ dB.

1.4 Denoting by s the sum

$$\sum_{i=1}^{n} x_i$$

referred to in § 1.1, the limit recommended therein may be met, for instance, by imposing the following simultaneous conditions on the national network:

1) The sum of the nominal transmission losses in both directions of transmission *a-t* and *t-b* measured between the 2-wire input of the terminating set *t*, and one or other of the virtual switching points on the international circuit, *a* or *b*, should not be less than $(4 + s)$ dB. There is no need for the two quantities *a-t* and *t-b* to be equal, so that differential gain can be used in the national network. This practice may be needed to meet the requirements of Recommendation G.121, § 2, but it implies that the transmission loss in terminal service of 4-wire chain plus the terminating sets may be different according to the direction of transmission. The choice of the nominal value of the transmission loss *t-b* should in all cases be made with an eye to Recommendation G.121, § 3 dealing with the minimum sending reference equivalent to be imposed in each national chain, to avoid any risk of overloading in the international network.
2) The balance return loss from the point of view of stability at the terminating set *t*, should have a value not less than 2 dB for the terminal conditions encountered during normal operation.

1.5 The target recommended in § 1.3 above could be attained if, in addition to meeting the condition of § 1.4 1), the mean value of the balance return loss from the point of view of stability at the terminating set were not less than 6 dB, this figure referring to the distribution of actual calls.

Note 1 – The CCITT manual cited in [3] describes some of the methods proposed, and in some cases successfully applied, by Administrations to improve balance return losses.

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

Note 3 – Attention is drawn to Note 3 of Recommendation G.101, § 5, concerning nominal transmission loss of short 4-wire circuits.

Note 4 – Attention is drawn to Recommendation Q.32 [4] concerning measures to be adopted to ensure the stability of international connections during the periods of setting-up and clearing a call.

2 Transmission loss of the path *a-t-b* from the point of view of echo

2.1 Provisionally, the transmission loss of the path *a-t-b* from the point of view of echo has been assumed to have a mean value of not less than $(15 + n)$ dB with a standard deviation from the mean of $\sqrt{(9 + 4n)}$ dB where n is the number of 4-wire circuits in the national chain.

2.2 The echo loss (*a-b*) is derived from the integral of the power transfer characteristic $A(f)$ weighted by a negative slope of 3 dB/octave starting at 300 Hz, extending to 3400 Hz, as follows:

$$\text{Echo loss } L_e = 3.85 - 10 \log_{10} \left[\int_{300}^{3400} \frac{A(f)}{f} \mathrm{d}f \right] \quad \text{dB.}$$

Note 1 – The above method replaces an earlier method in which the transmission loss of the path *a-t-b* from the point of view of echo was provisionally defined as the expression in transmission units of the unweighted mean of the power ratios in the band 500 – 2500 Hz. The new method has been found to give better agreement with subjective opinion for individual connections. However, one Administration has reported that echo path loss distributions for a large sample of actual connections calculated by the two methods have almost identical means and standard deviation. Therefore, data gathered by the older method is still considered useful in planning studies.

Note 2 – Evidence was presented which showed that a white noise signal is not necessarily optimum to measure the residual echo level after cancellation, because an echo cancellor does not converge to quite the same condition as it does with a real speech signal. It may be better to use the conventional telephone signal (Recommendation G.227 [5]) or better still, an artificial speech signal (see [6]). A good compromise is the weighted noise signal based on the principle recommended above.

2.3 An example of how the provisional limit quoted in § 2.1 above can be achieved would be for the mean value of the sum of the transmission losses *a-t* and *t-b* from the point of view of echo not to be less than $(4 + n)$ dB with a standard deviation from the mean not exceeding $2\sqrt{n}$ dB, accompanied by a balance return loss from the point of view of echo at the terminating set *t*, of not less than 11 dB with a standard deviation from the mean not exceeding 3 dB.

ANNEX A

(to Recommendation G.122)

Measurement of stability loss (*a-b*) and echo loss (*a-b*)

The stability loss (*a-b*) and the echo loss (*a-b*) as defined in §§ 1.1 and 2.2 respectively may be measured by apparatus at the international centre in accordance with the principle of Figure A-1/G.122.

In respect of the echo measurement, the combined response of the send and receive filters must be such that the provisional definition given in § 2.2) of the text is effectively implemented, e.g. such that the difference between a measured echo loss and one calculated from the loss/frequency characteristic does not exceed 0.25 dB.

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

- excessive interchannel interference is avoided in national transmission systems due to an unrestricted spectrum of the transmitted signal;
- unwanted signals that may give rise to errors, e.g. hum, circuit noise, carrier leak signals, are prevented from entering the receiver.

Appropriate arrangements (not shown) are needed for automatic or manual access to the 4-wire switches at the international centre and also to ensure that due account is taken of the transmission levels at the actual switching points.

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

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

To measure the echo loss (*a-b*), the output of the send filter is first connected to the input of the receive filter and the appropriate level set and noted. The apparatus is then connected as in Figure A-1/G.122 and the new reading on the meter noted. The loss so indicated is the echo loss (*a-b*).

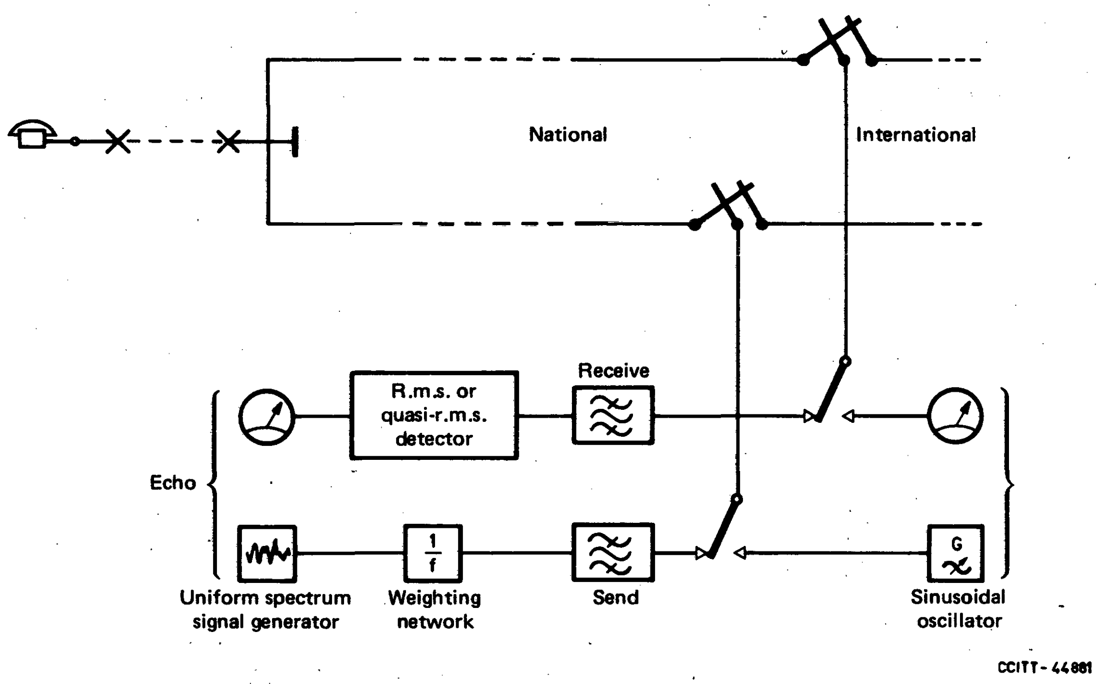


FIGURE A-1/G.122

Principle of measuring the transmission loss of the path *a-t-b* from the points of view of stability and of echo

ANNEX B

(to Recommendation G.122)

Explanation of terms associated with the path *a-t-b*

(Contribution of British Telecom and Australia)

B.1 *Return loss*

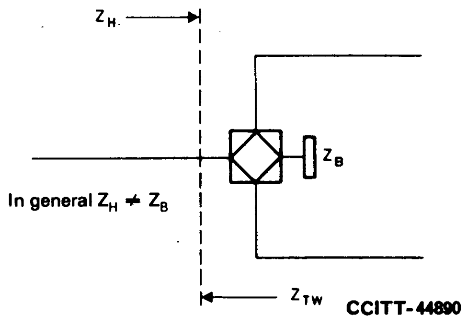
This is a quantity associated with the degree of match between two impedances and is given by the expression:

$$\text{Return loss of } Z_1 \text{ versus } Z_2 = 20 \log_{10} \left| \frac{Z_1 + Z_2}{Z_1 - Z_2} \right| \text{ dB}$$

The use of the expression "return loss" should be confined to 2-wire paths supporting signals in the two directions simultaneously.

B.2 *Balance return loss*

A clear definition is given in the preamble of Recommendation G.122. Figure B-1/G.122 illustrates the definition.



$$\text{Balance return loss} = 20 \log_{10} \left| \frac{Z_B + Z_{TW}}{Z_B - Z_{TW}} \right| \text{dB.}$$

FIGURE B-1/G.122

The 2-wire portion must be in the condition appropriate to the study, e.g., if speech echo is being studied the telephone set must be in the speaking condition.

In the particular case (which occurs very often) in which the impedances presented by each of the paths in the 4-wire portion is also Z_B (e.g. 600 ohms) then the terminating set presents an impedance of the 2-wire point which is substantially equal to Z_B. Figure B-2/G.122 illustrates this case.

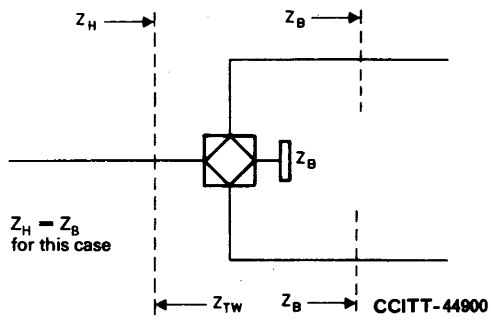


FIGURE B-2/G.122

The term "balance return loss" (*not* return loss) should always be used for the contribution to the loss of the path *a-t-b* attributable to the degree of match between Z_B and Z_{TW}.

B.3 *Transmission loss of the path* a-t-b

There is room for confusion here because the concept can be applied to arrangements in which there is no physical point "*t*" at all, e.g. as in some laboratory simulations of long connections in which echo is introduced by a controlled unidirectional path bridging the two 4-wire paths. The point "*t*" is necessary in the Recommendation because practical public switched telephone networks are being dealt with.

Thus in general two cases arise.

Case 1: There does exist a point "*t*" (Figure B-3/G.122).

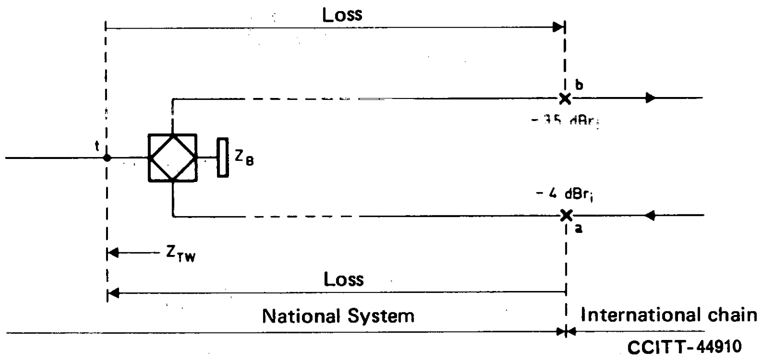


FIGURE B-3/G.122

The transmission loss of the path *a-t-b* may be calculated from

$$\text{loss}\,(a\text{-}t)\ +\ 20\log_{10}\left|\frac{Z_B + Z_{TW}}{Z_B - Z_{TW}}\right|\ +\ \text{loss}\,(t\text{-}b)$$

The diagram is drawn in terms of the virtual switching points of the international circuit with their associated relative levels. The subscript i in the abbreviation dBr$_i$ signifies that these relative levels are with respect to a 0 dBr point of the international circuit.

It is clear that any other convenient pair of relative levels (differing by 0.5 dB in the correct sense) can be used in practice, e.g., the actual switching levels used in an international centre.

Case 2: There does not exist any "*t*" (Figure B-4/G.122).

This relates particularly to laboratory testing arrangements.

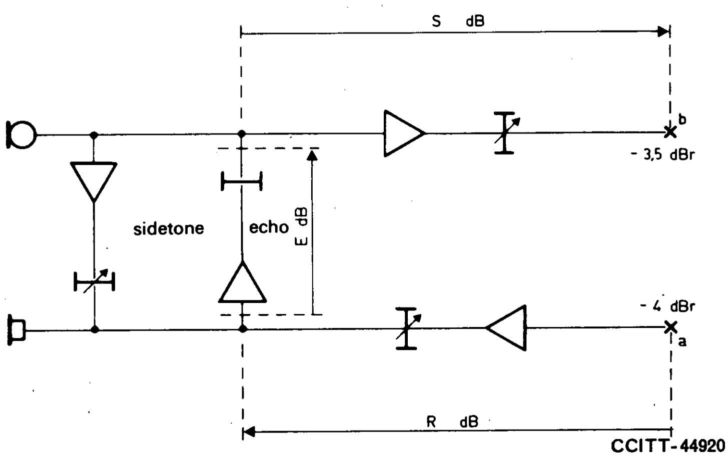


FIGURE B-4/G.122

In this case the loss of the path a-"t"-b may be calculated from: $(R + E + S)$ dB (assuming acoustic feedback at the 4-wire telephone to be negligible).

In both cases the loss of "the path a-t-b" can in principle be directly measured by the principles described in Annex A, i.e. by injecting a signal at a and measuring the result at b, so that one may properly say for all cases

$$\left\{ \begin{array}{l} \text{transmission loss} \\ \text{of the path } a\text{-}t\text{-}b \end{array} \right\} \equiv \left\{ \begin{array}{l} \text{transmission loss} \\ \text{between } a \text{ and } b \end{array} \right\}$$

or, more shortly

$$\text{loss } (a\text{-}t\text{-}b) \equiv \text{loss } (a\text{-}b)$$

B.4 *Stability and echo losses*

So far the quantities dealt with are functions of frequency and yield a graph of attenuation/frequency distortion. When it is required to characterize such a graph with a single number, additional qualifying phrases are used, e.g. "transmission loss of the path a-t-b from the point of view of stability (or of echo)". One may use the shorter expressions: stability loss $(a$-$b)$ and echo loss $(a$-$b)$.

The text of this Recommendation gives the definitions of these single-number descriptions thus: the stability loss $(a$-$b)$ is the least value (measured or calculated) in the band 0-4 kHz (see § 1), and the echo loss $(a$-$b)$ is a weighted integral of the loss/frequency function over the band 300-3400 Hz, as defined in § 2.

When the echo-path loss/frequency characteristic is available in graphical or tabular form, alternative techniques for the calculation of echo loss $(a$-$b)$ are desirable to that suggested for the field measurement given in Annex A.

Note — When evaluating echo loss from graphical or tabulated data, sufficient frequency points should be taken to ensure that the influence of the shape of the amplitude/frequency characteristic is adequately preserved. The more irregular the shape, the more points should be taken for a given accuracy.

Graphical data (trapezoidal rule)

If the loss/frequency characteristic of the echo-path is available in graphical form (or the data were suitably measured) the echo loss may be calculated by using the trapezoidal rule as follows:

1) Divide the frequency band (300 to 3400 Hz) into N sub-bands of equal width on a log-frequency scale.
2) Read off the echo loss at each of the $N + 1$ frequencies at the edges of the N sub-bands, and express it as an output/input power ratio, A_i.
3) Calculate the echo loss using the formula:

$$L_e = -10 \log_{10} \left[\frac{1}{N} \left(\frac{A_0}{2} + A_1 + A_2 \ldots + A_{N-1} + \frac{A_N}{2} \right) \right]$$

Tabulated data

When the loss/frequency data are only available at $N + 1$ discreet frequencies, which are nonuniformly spaced on a log-frequency scale, proceed as follows:

An approximation to the formula for echo loss $(a$-$b)$ given in the text is:

$$L_e = 3{,}24 - 10 \log_{10} \sum_{i=1}^{N} (A_i + A_{i-1}) (\log_{10} f_i - \log_{10} f_{i-1})$$

where

A_0 is the output/input power ratio at frequency of $f_0 = 300$ Hz,

A_i the ratio at frequency f_i, and

A_N the ratio at frequency $f_N = 3400$ Hz.

Note 1 – The approximation involved is to assume that within the sub-band f_{i-1}, to f_i, the power ratio is constant and has the value $A(f) = (A_i + A_{i-1})/2$.

Note 2 – The constant 3.24 in the approximate formula arises from a combination of the constant 3.85 in the definition and other constants produced by the approximation.

The sum of product terms in the approximation formula may be conveniently calculated as illustrated by the following example:

TABLE B-1/G.122

f_i (Hz) (1)	$\log_{10} f_i$ (2)	$\log_{10} f_i - \log_{10} f_{i-1}$ (3)	loss (dB) (4)	ratio A_i (5)	$A_i + A_{i-1}$ (6)	(3) × (6) (7)
300	2.477		∞	0		
		0.222			0.124	0.0275
500	2.699		9.05	0.124		
		0.204			0.402	0.0820
800	2.903		5.56	0.278		
		0.097			0.636	0.0617
1000	3.000		4.46	0.358		
		0.176			0.838	0.1475
1500	3.176		3.19	0.48		
		0.125			0.970	0.1213
2000	3.301		3.09	0.49		
		0.097			0.881	0.0855
2500	3.398		4.08	0.391		
		0.079			0.571	0.0451
3000	3.477		7.45	0.180		
		0.055			0.180	0.0099
3400	3.532		∞	0		
					Total	0.5804

$$L_e = 3.24 - 10 \log 0.5804 = 5.6 \text{ dB}$$

B.5 *Reference equivalent of the echo path*

Recommendation G.131 is concerned with complete talker echo paths and it is convenient to characterize this path in terms of reference equivalent. By convention we may regard the echo balance return loss as the contribution it makes to the overall reference equivalent of the mouth-ear echo path. Naturally, as indicated in § 2 of the text, the echo loss (*a-b*), when this is already known, may be used instead of the sum of three quantities: the loss (*a-t*), the echo balance return loss at *t*, and the loss (*t-b*).

Hence the nominal overall reference equivalent of the echo path or, more shortly, the "echo reference equivalent" may be calculated as illustrated in Figure B-5/G.122.

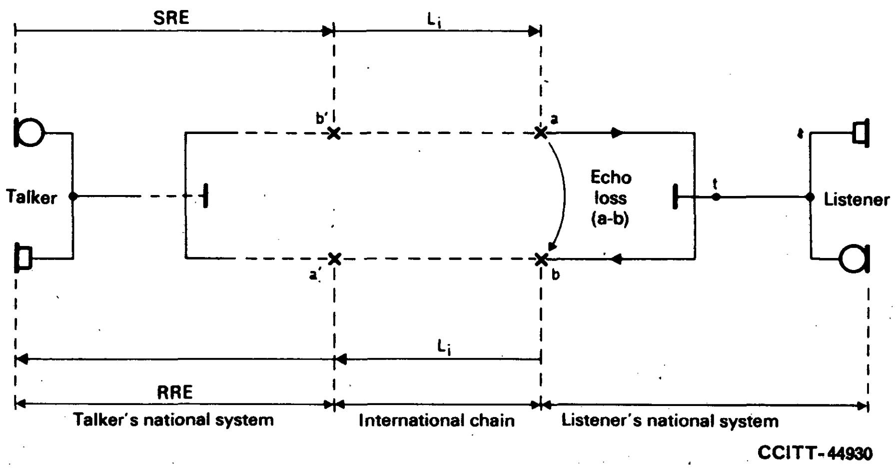


FIGURE B-5/G.122

Echo reference equivalent

= SRE + RRE of the talker's national system,

+ twice the loss of the international chain (i.e.: $2L_i$ at 800 Hz or 1000 Hz),

+ the echo loss (*a-b*) of the listener's national system (i.e. averaged according to this Recommendation).

B.6 *Résumé of useful terms*

return loss – Relates to a 2-wire bidirectional circuit; classical definition.

balance return loss – Proportion of the loss at the *a-t-b* path attributable to the degree of match between the 2-wire impedance and the balance impedance at the terminating unit. Applicable only if there is a point "*t*".

transmission loss of the path *a-t-b* – Can be regarded as the loss (*a-b*), whether there exists a physical point "*t*" or not.

stability loss (*a-b*) – The least value of the loss (*a-b*) in the band 0-4 kHz.

echo loss (*a-b*) – The loss (*a-b*) averaged according to the definition in § 2 of the text.

echo balance return loss – A balance return loss averaged according to § 2 of the text.

echo reference equivalent – The sum of the sending reference equivalent and receiving reference equivalent of the talker's national system, twice the loss of the international chain, and the echo loss (*a-b*) of the listener's national system.

References

[1] *Calculations of the stability of international connections established in accordance with the transmission and switching plan*, CCITT Green Book, Vol. III-2, Supplement No. 1, ITU, Geneva, 1973.

[2] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 2.

[3] CCITT manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

[4] CCITT Recommendation *Reduction of the risk of instability by switching means*, Vol. VI, Fascicle VI.1, Rec. Q.32.

[5] CCITT Recommendation *Conventional telephone signal*, Vol. III, Fascicle III.2, Rec. G.227.

[6] CCITT Question 8/XII, Annex 2, Contribution COM XII – No. 1, Study Period 1981-1984, Geneva, 1981.

CIRCUIT NOISE IN NATIONAL NETWORKS

(Geneva, 1964, amended at Mar del Plata, 1968 and at Geneva, 1972, 1976 and 1980)

1 Noise induced by power lines (formerly Part A)

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

It should be noted that, even in the case of perfectly balanced lines [1], the insertion of equipment having too great a degree of unbalance to earth may cause unacceptable noise at the terminals of a subscriber's receiver.

In every national network, it is usually possible, in practice, to find switching centres such that some of the lines [1] that terminate at those centres (lines [1] in cable, conforming to CCITT specifications) are free from noise arising from neighbouring power lines. It is then sufficient to determine the psophometric e.m.f.s arising from all the power lines affecting one or more parts of the chain of lines [1] joining such a centre to the subscriber's set.

2 Noise contributed by transmission systems (formerly Part B)

2.1 *Analogue systems*

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

If an extension circuit more than 2500 km long is used in a large country, it will have to meet all the recommendations applicable to an international circuit of the same length (Recommendation G.153). This implies that the equipment design objective for the line noise in channels used to provide these circuits should not exceed 2 pW0p/km.

2.1.2 *Circuit ranging in length from very short distances up to 2500 km*

These circuits should meet the requirements of Recommendation G.152. This implies that according to the noise objectives of Recommendation G.222 [1] the accumulated line noise should correspond to an average of not more than 3 pW0p/km and the noise power produced by the various modulating equipments should meet the provisions of the Recommendation cited in [2].

Taking account of the particular structure of a real circuit the pertinent Recommendations CCITT/G.226 [3] (for cable systems) or CCIR/395-2 [4] (for radio-relay systems) must be applied when assessing its noise performance.

Note 1 – The permissible noise contributions from equipment do not depend on whether the circuits form part of the international 4-wire chain or are connected to it by 2-wire switching. However, the circuit noise powers assume that the hypothetical reference connections of Recommendation G.103 are, or will be in future, reasonably typical of connections. They also assume that the total length of circuits connecting the local exchange to the primary centre is not excessive. The attention of Administrations is drawn to a conclusion of studies carried out by the CCITT during the 1964-1968 Study Period, that if the additional percentage of "poor or bad" opinions on the quality of connections due to noise introduced by the circuits connecting the local exchange to the primary centre is not to exceed one half of that caused by the presence in the connection of all other sources of circuit noise, then the noise contributed by each one of these circuits should be limited to about 500 pW0p (mean for all the channels of the system during any hour).

Note 2 – Under the above conditions and assuming the maximum noise values permitted for pairs of channel modulators (200 pW0p), group modulators (80 pW0p) and supergroup modulators (60 pW0p), a total noise power of 500 pW0p will not be exceeded by a circuit connecting the local exchange to the primary centre (Figure 1/G.103) when its length is less than about 50 to 100 km.

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[1] "Line" as used in this § 1 should be understood as meaning subscriber's line, trunk junction or trunk circuit.

Note 3 – In the case that those circuits are operated with compandors conforming to Recommendation G.162, the permitted noise powers are to be understood inclusive of the effect of the compandor gain.

2.2 *Digital system*

Circuits provided by PCM systems which accord with the G.700 Series of Recommendations, in particular Recommendation G.712 [5], will have an acceptable noise performance which is substantially independent of their length.

3 **Noise in a national 4-wire automatic exchange** [2] (formerly Part C)

3.1 *Definition of a* **connection through an exchange**

Noise conditions in a national 4-wire automatic exchange are defined by reference to a "connection" through this exchange. By "connection through an exchange" is to be understood the pair of wires corresponding to a direction of transmission and connecting the input point of a circuit incoming in the exchange to the output point of a different circuit outgoing from the exchange. These input or output points are those defined in Recommendation Q.45 (points A and D of Figure 1/Q.45 [8]) and are not necessarily the same as the text access points defined in Recommendation M.640 [9].

3.2 *Equipment design objective for the mean noise power during the busy-hour*

The mean of the noise over a long period during the busy-hour should not exceed the following values:

1) Psophometrically weighted noise: −67 dBm0p (200 pW0p),

2) Unweighted noise: −40 dBm0 (100 000 pW0) measured with a device with a uniform response curve throughout the band 30-20 000 Hz.

Note – A sufficient variety of connections should be chosen to ensure that the measurements are representative of the various possible routes through the exchange.

3.3 *Equipment design objective for the impulsive noise during the busy-hour*

Noise counts should not exceed 5 counts in 5 minutes at the threshold level of −35 dBm0 (see the Recommendation cited in [10] for measurement procedure).

Note – Figure 3/Q.45 [11] shows the maximum number of impulsive noise counts acceptable in a 5-minute period.

4 **Noise allocation for a national system** (guide for planning purposes) (formerly Part D)

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

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

The psophometric noise power introduced by the national sending system at a point of zero relative level on the first international circuit must not exceed either (4000 + 4L) or (7000 + 2L) pWp, whichever is less, and where L is the total length in kilometres of the long-distance FDM carrier systems in the national chain. The corresponding quantities referred to the send virtual switching point are (1800 + 1.8L) and (3100 + 0.9L) pWp.

The derivation of this rule is explained in the Annex A.

Note – A problem, which has already arisen in some national networks, as regards the receiving direction, is that when losses are reduced the circuit noise becomes more noticeable, particularly during periods of no conversation. This is particularly relevant in the case of large countries in which the noise contribution from line systems is high. Hence if an Administration complies with a recommendation concerning national noise power levels and then subsequently improves transmission, perhaps by introducing 4-wire switching in lower-order exchanges, it may find itself in a worse situation as regards noise. It follows that it is important to preserve a proper balance between noise and loss.

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[2] In accordance with Recommendation Q.31 [6], the limits are the same as in Recommendation Q.45 [7].

ANNEX A

(to Recommendation G.123)

Noise allocation for a national system

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

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

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

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

The relevant hypothetical reference chain for the national sending system is given in Figure A-1/G.123 [3]. The circuit between the local exchange and the primary centre is assumed to be routed on an FDM carrier system of length not exceeding 250 km and operated at a nominal loss of 3 dB. The noise power on this circuit is taken to be the maximum value of 2000 pW0. The circuit between the primary centre and the secondary centre is also assumed to be routed on an FDM carrier system of the same type.

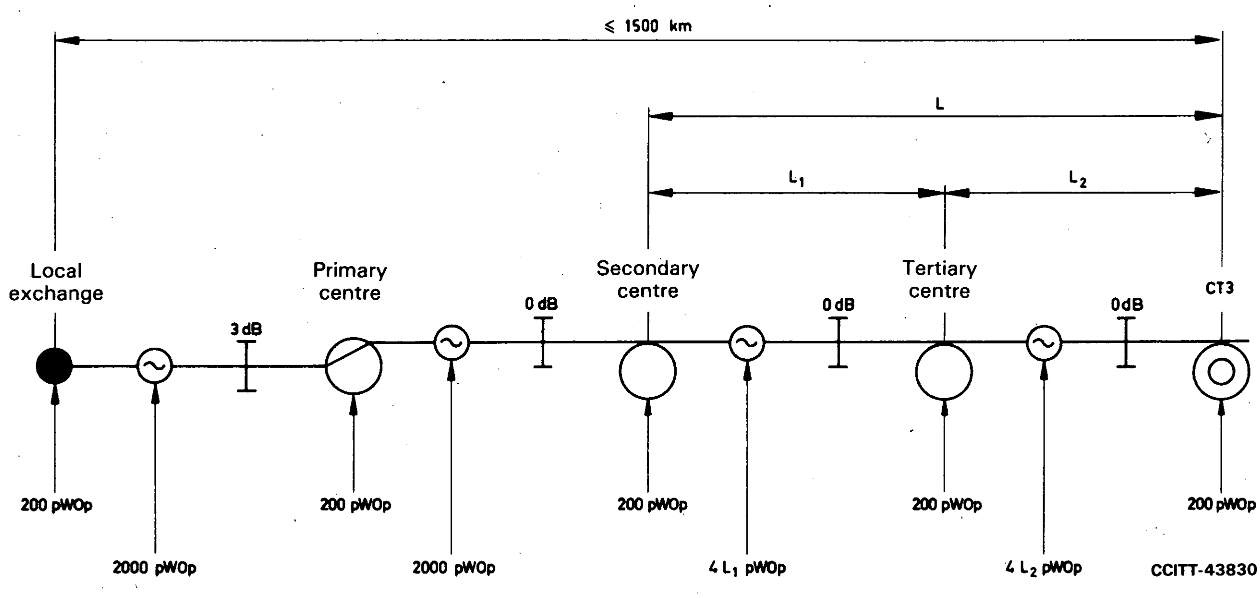


FIGURE A-1/G.123

[3] *Note by the CCITT Secretariat.* – the noise values shown in this figure are maximum values; see also the corresponding part of Figure 1/G.103.

The line noise power rate of the two long-distance trunk circuits is assumed to be 4 pW/km and the total line length of these two circuits ($L_1 + L_2$ in Figure A-1/G.123 approaches the limit of 1500 km arbitrarily defining "a country of average size" in Recommendation G.121. It is thus assumed that the distance covered by the two short-haul systems is a very small proportion of the total length of the complete national sending system.

Each exchange is assumed to contribute 200 pWp in accordance with § 3 of the text, or Q.31 [6].

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

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

where $L = L_1 + L_2$. This may be conveniently rounded off to $4000 + 4L$ pW0.

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

A.5 *Large countries*

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

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

The rule for large countries has been established as shown in Figure A-2/G.123 in which the $4000 + 4L$ rule is shown passing through the point (1500 km, 10 000 pW). A line with a slope of 2 pW/km is constructed to pass through the same point and its intercept is seen to be 7000 pW. Hence the rule for large countries is $7000 + 2L$ pW0. (The 0.5-dB nominal loss of the last national circuit has been ignored for simplicity's sake.)

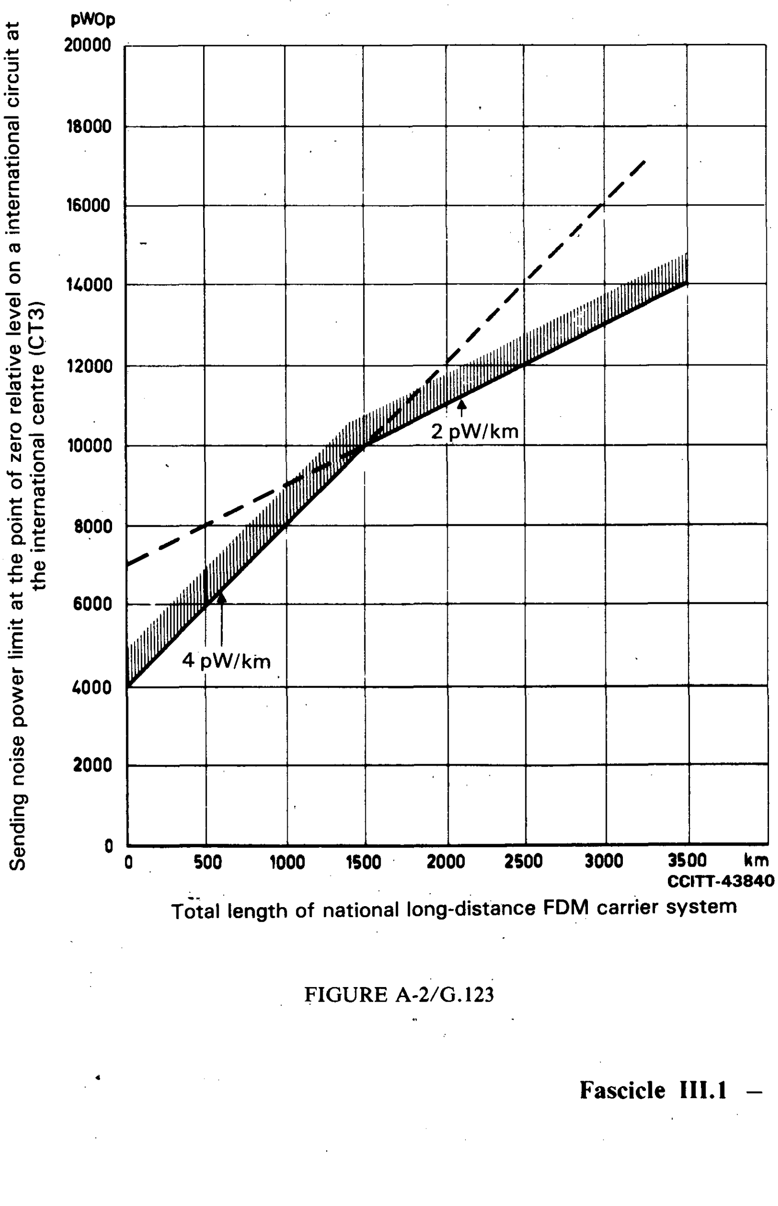


FIGURE A-2/G.123

References

[1] CCITT Recommendation *Noise objectives for design of carrier-transmission systems*, Vol. III, Fascicle III.2, Rec. G.222.

[2] *Ibid.*, § 4.

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

[4] CCIR Recommendation *Noise in the radio portion of circuits to be established over real radio-relay links for FDM telephony*, Vol. IX, Rec. 395-2, ITU, Geneva, 1978.

[5] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Fascicle III.3, Rec. G.712.

[6] CCITT Recommendation *Noise in a national 4-wire automatic exchange*, Vol. VI, Fascicle VI.1, Rec. Q.31.

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

[8] *Ibid.*, Figure 1/Q.45.

[9] CCITT Recommendation *Four-wire switched connections and four-wire measurements on circuits*, Vol. IV, Fascicle IV.1, Rec. M.640.

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

[11] *Ibid.*, Figure 3/Q.45.

Recommendation G.125

CHARACTERISTICS OF NATIONAL CIRCUITS ON CARRIER SYSTEMS

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

Carrier circuits which are likely to form part of international connections should meet the requirements of Recommendation G.132 as far as attenuation distortion is concerned. The circuits should transmit all types of signal (e.g. speech, data, facsimile) which might normally be expected, according to Recommendations over this part of the connection.

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

1.3 General characteristics of the 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)

1 Stability of telephone transmission (formerly Part A)

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, § 1).

The stability of international connections has been calculated and the results are displayed graphically in Figure 1/G.131, which shows the proportion of connections (out of all the possible connections) likely to exhibit a stability of less than or equal to 0 dB or 3 dB as a function of the number of circuits comprising the 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.

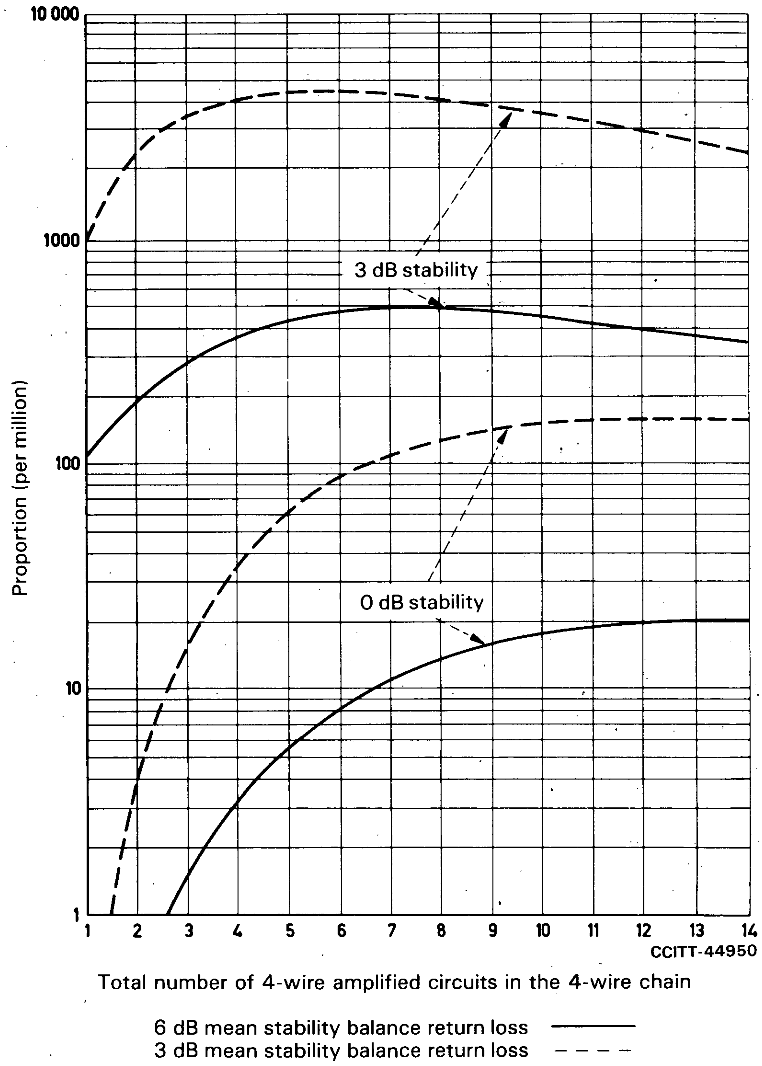


FIGURE 1/G.131

Proportion of possible connections with a stability equal to or less than 0 dB or 3 dB

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

The simplifying assumptions underlying the calculations are:

a) National circuits are added to the international chain in compliance with Recommendation G.122, § 1.

b) The standard deviation of transmission loss among international circuits routed on groups equipped with automatic regulation is 1 dB. This accords with the assumptions used in Recommendation G.122, § 1.2). 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** (formerly Part B)

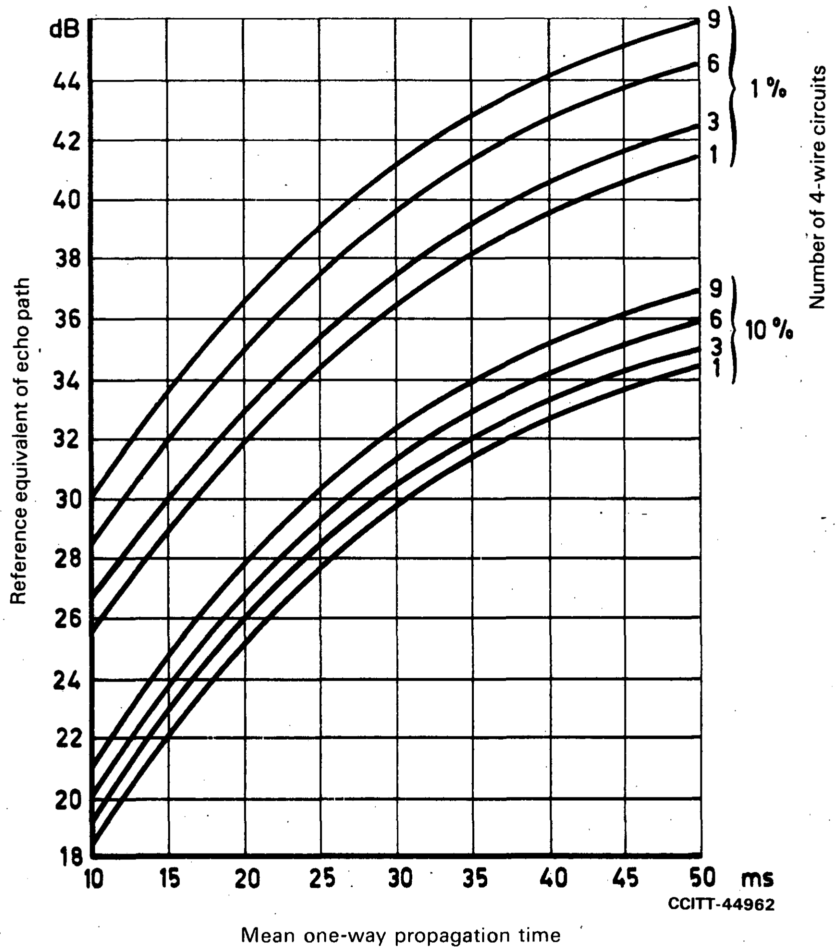
The main circuits of a modern telephone network providing international communications are high-velocity carrier circuits on symmetric or coaxial pairs or radio-relay systems. Echo control devices such as echo suppressors and echo cancellers are not normally used except on connections involving very 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 nominal reference equivalent [1)] in the echo path that must be introduced if no echo suppressor is to be fitted. The reference equivalent 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.

1) While Figure 2/G.131 is based on nominal values of loss of trunk junction and trunk circuits, it refers to minimum SRE (send reference equivalent) and RRE (receive reference equivalent) values of subscriber systems. Refer also to § I.7 of the Appendix to Section 1 of the Series G Recommendations.



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

Note 2 – The reference equivalent of the echo path is here defined as the sum of:

- the values of the transmission loss in the two directions of transmission between the 2-wire end of the talking subscriber's line in the terminal local exchange and the 2-wire terminals of the 4W/2W terminating set at the listener's end;
- the mean value of the echo balance return loss at the listener's end; and
- the simultaneous-minimum sending and receiving reference equivalents of subscribers' telephone sets and lines at the talker's local exchange.

FIGURE 2/G.131

Echo tolerance curves

The curves are applicable to a chain of 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 return losses at these points, for example, a mean value of 27 dB with a standard deviation of 3 dB.

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

– up to 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.

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]. In Recommendation G.164, echo suppressors with new functions are described. Another type of echo control can be obtained by echo cancellers. The characteristics are given in Recommendation G.165. Rules governing the use of echo cancellers are under study. Pending this study the general principle of the rules given in §§ 2.3 and 2.4 should be applied.

2.3 *Rules governing the limitation of echoes*

Only telephony is considered here. Echo suppressors are a source of trouble to data and other telegraph-type transmission. Use of echo suppressors with tone disablers is recommended for data transmission. (See the Recommendation cited in [4].) Compatibility with signalling systems for the switched telephone service is ensured by Recommendation Q.115 [5].

2.3.1 *Ideal rules*

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

2.3.1.1 *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 sending and receiving reference equivalents are assumed for the talker's telephone and line.

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 *Rule B*

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

2.3.1.3 *Rule C*

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

2.3.1.4 *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 mutilated by the echo suppressors because the hangover times can be very short.

2.3.2 *Practical rules*

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

2.3.2.1 *Rule E*

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 [2)] is valid only in those cases where it would otherwise be necessary, according to Rule A [2)], to use an echo suppressor solely for these connections, and where there is no need for echo suppressors on connections between the regions in the immediate neighbourhood of the two international centres concerned.

2.3.2.2 *Rule F*

If, as is appreciated, Rule D above cannot be complied with, the echo suppressor may be fitted at the international exchange or at an appropriate national transit centre. However, each half-echo suppressor should be located sufficiently near to the respective subscribers for the end delays not to exceed the maximum value recommended in the Recommendation cited in [6]. For countries of average size, this will normally mean that the originating and terminating half-echo suppressors will be in the countries of origin and destination of the call.

2.3.2.3 *Rule G*

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

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

2.3.2.4 *Rule H*

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

2.3.2.5 *Rule J*

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

Where a terminating international 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 suppressors should be connected in all cases.

2.3.2.6 *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.

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2) Recommendation Q.115 [5] is a study of the application of rules A and E to the United Kingdom-European network relations.

2.3.2.7 *Rule L*

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

2.4 *Insertion of echo suppressors in a connection*

Ways of doing this which have been considered are:

1) provide a pool of echo suppressors common to several groups of circuits, and arrange for an echo suppressor to be associated with any circuit that requires one (see Recommendation Q.115 [5]);

2) arrange for the circuits to be permanently equipped with echo suppressors but switch them out (or disable them) when they are not required (see [7]);

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

4) 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 suppressors in international connections complies, overall, with the practical rules of § 2.3.2 above.

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

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 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 in Figure A-1/G.131.

For a given pair of exchanges, all eight items are known or can be estimated. A plot of reference equivalent [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 circuits in the 4-wire chain.

TABLE A-1/G.131

Quantities needed for echo assesment

Reference equivalent of the echo path, made up of the sum of: 1) the minimum of the sum of the values of the sending and receiving reference equivalents of the local system of country A (talker end); 2) the nominal transmission loss from, and to, the virtual 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 transmission loss 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 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: 8) the number of circuits in the 4-wire chain (see Figure 3/G.101).

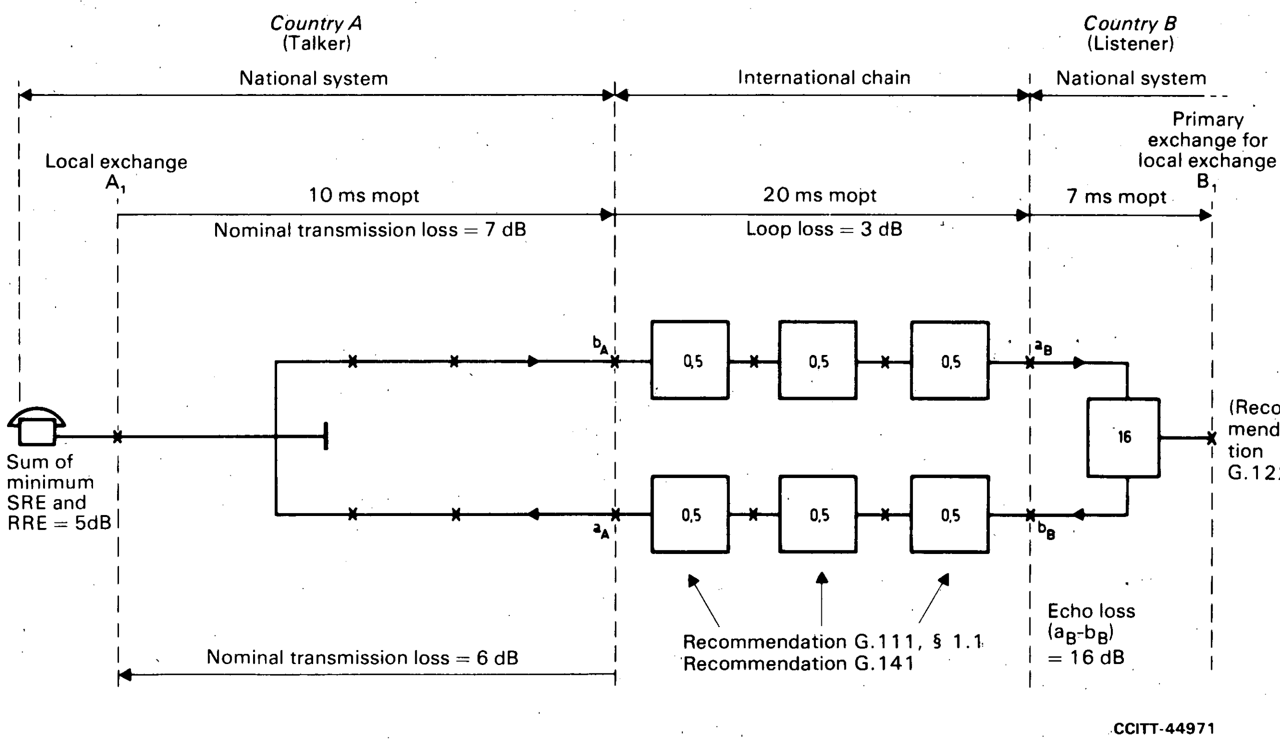

FIGURE A-1/G. 131

Example of application of Figure 2/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-t* and *t-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, § 2, viz., a mean value of $(15 + n)$ dB where n is the number of circuits in the listener's national 4-wire chain.

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, § 2. 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
Mean one-way propagation time from local exchange A_1 to international exchange	10 ms [4]
Simultaneous-minimum sending and receiving reference equivalents (sum) of the local system	5 dB
Loss from local exchange to international exchange (b_A)	7 dB
Loss 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 [3]
Distance	3200 km
Mean one-way propagation time	20 ms [4]
Loop echo path loss $2 \times 3 \times 0.5$ dB	3 dB

Listener's country B

Mean echo loss $(a_B - b_B)$ $(15 + 1)$ dB	16 dB (Recommendation 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	7 ms [4]
Number of 4-wire circuits	1

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

Total mean one-way propagation time $= 10 + 20 + 7 = 37$ ms . . . (A-1)

Total reference equivalent of the echo path $= 5 + 7 + 6 + 3 + 16 = 37$ dB . . . (A-2)

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

4) Assuming a velocity of propagation of 160 km/ms.

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.

Conclusion

a) An echo-suppressor 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).

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] *Ibid.*, Section C.

[5] CCITT Recommendation *Control of echo suppressors*, Vol. VI, Fascicle VI.1, Rec. Q.115.

[6] CCITT Recommendation *Echo-suppressors suitable for circuits having either short or long propagation times*, Orange Book, Vol. III, Rec. G.161, § B.b), ITU, Geneva, 1977.

[7] 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 and Geneva, 1972)

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

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

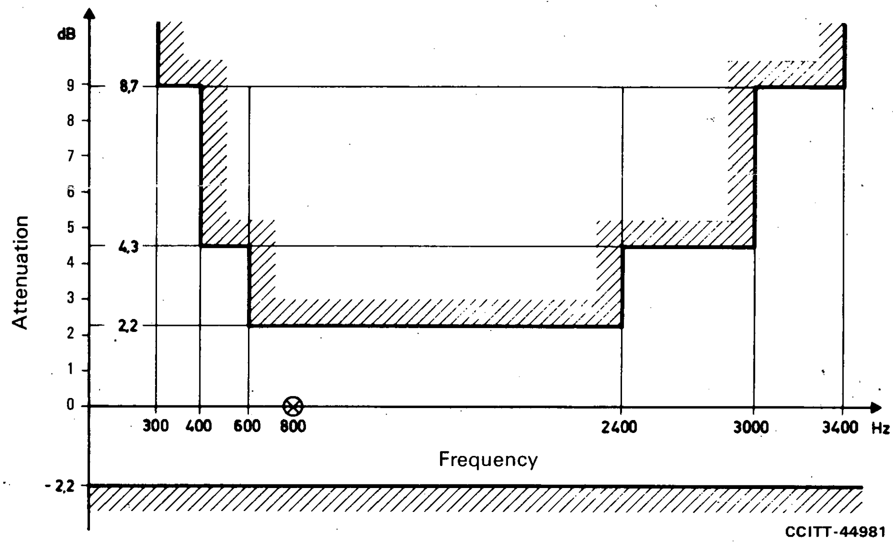

FIGURE 1/G.132

Permissible attenuation variation with respect to its value measured at 800 Hz (objective for worldwide 4-wire chain of 12 circuits in terminal service)

References

[1] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 1.

[2] CCITT Question 2/XII, Contribution COM XII-No. 1, Study Period 1981-1984, Geneva, 1981.

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.

TABLE 1/G.133

	Lower limit of frequency band (ms)	Upper limit of frequency band (ms)
International chain	30	15
Each of the national 4-wire extensions	15	7,5
On the whole 4-wire chain	60	30

LINEAR CROSSTALK [1]

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

1 Linear crosstalk between different 4-wire chains of circuits (formerly Part A)

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 (formerly Part B)

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 [2]:

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.

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

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

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

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, Fascicle VI.1, Rec. Q.45.

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

[3] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 9.2.

[4] CCITT Recommendation *Conventional telephone signal*, Vol. III, Fasicle III.2, 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 [1)] there is about 1% probability that the frequency difference between the beginning and the end of the connection will exceed 3 Hz and less than 0.1% probability that it will exceed 4 Hz.

References

[1] CCITT Recommendation *Recommendations relating to the accuracy of carrier frequencies*, Vol. III, Fascicle III.2, Rec. G.225.

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

[3] CCIR Report *The effects of doppler frequency-shifts and switching discontinuities in the fixed satellite service*, Vol. IV, Report 214-3, ITU, Geneva, 1978.

1) In fact, the chain considered for these calculations comprised 16 (instead of 12) modulator-demodulator pairs to allow for the possibility that submarine cables with equipments in conformity with Recommendation G.235 [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 [3].

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

Recommendation G.141

TRANSMISSION LOSSES, RELATIVE LEVELS AND ATTENUATION DISTORTION

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

Parts A and B in previous issues of this Recommendation dealt with "Conventions and definitions" and the "Interconnection of international circuits in a transit centre" respectively. The latter information has been amended and now forms part of Recommendation G.101, § 5.

1 Attenuation distortion (formerly Part C)

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, Fascicle III.2, Rec. G.232, § 1.

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

[3] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Fascicle III.3, Rec. G.712, Figure 1/G.712.

TRANSMISSION CHARACTERISTICS OF EXCHANGES

(Geneva, 1980)

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 text of which is reproduced below. 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.

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 [1].

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.

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).

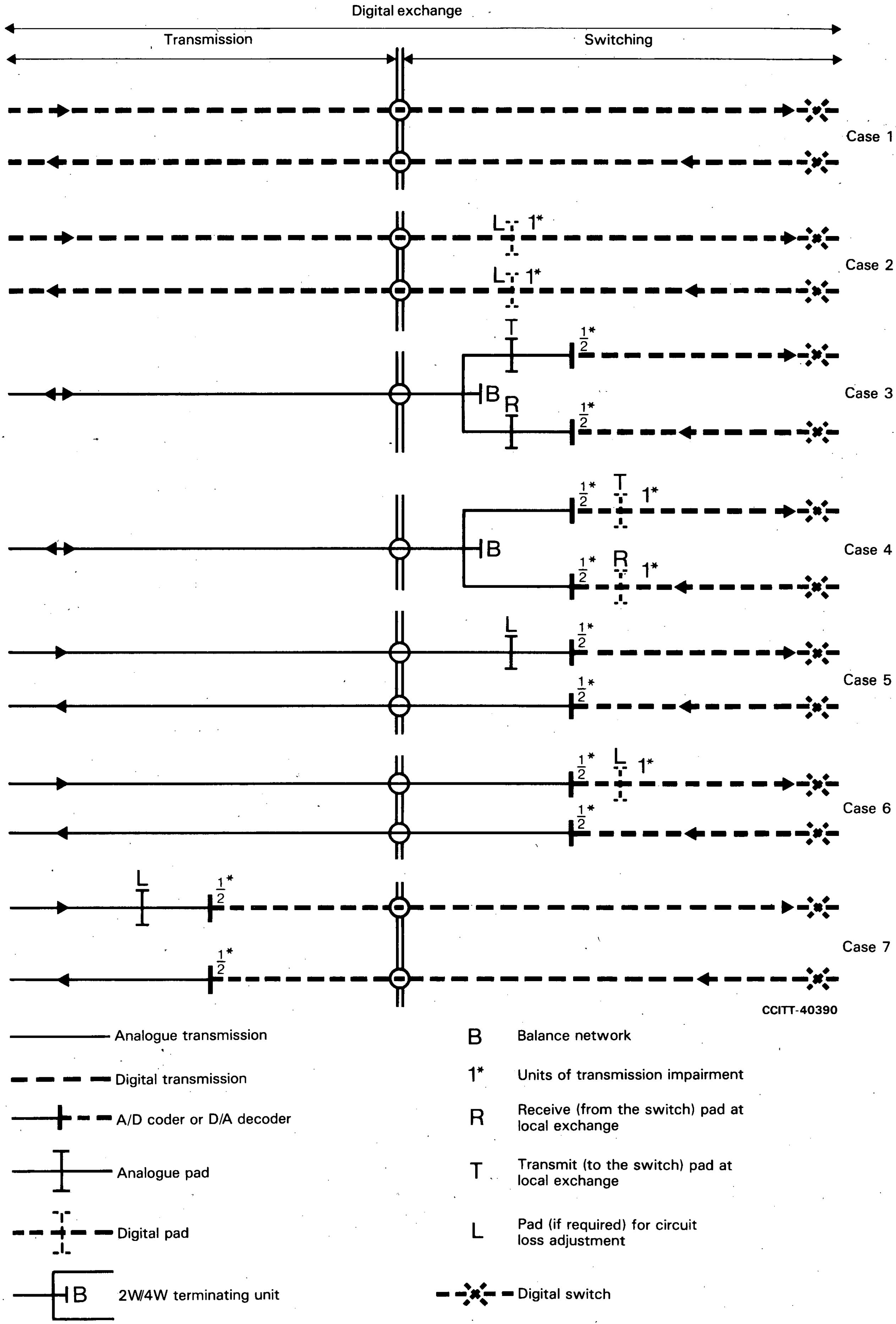

FIGURE 1/G.142

Transmission paths at digital exchanges

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 *Stability and echo control*

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.

2.5 *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 corrected reference equivalent 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.

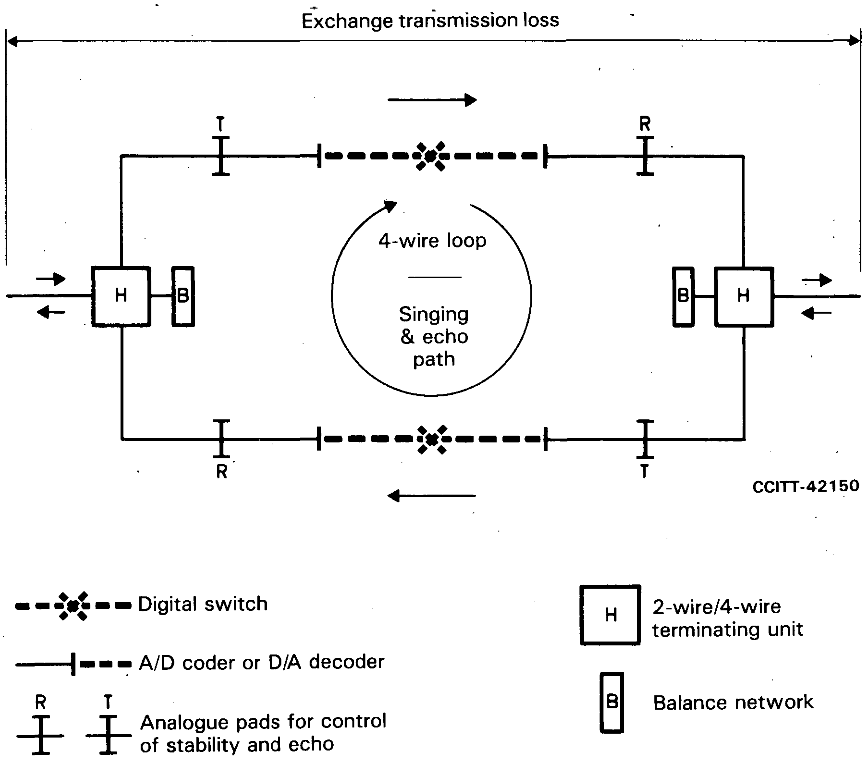

FIGURE 2/G.142

Configuration of digital local exchange on 2-wire to 2-wire connections

2.6 *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.

2.7 *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.

As a matter of information for purposes of transmission planning, the transmission delays that might be encountered at digital exchanges are indicated below.

2.7.1 *For digital exchange (national or international)* (see Table 1/G.142)

TABLE 1/G.142

Both ways transmission delays

Interconnection	Mean value	95% probability of not exceeding
Digital-digital	⩽ 900 μs	1500 μs
Digital-analogue	⩽ 1500 μs	2100 μs
Analogue-analogue	⩽ 2100 μs	2700 μs

2.7.2 *For digital local exchange*

The transmission delays that might be encountered at a digital local exchange are under study.

Reference

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

Recommendation G.143

CIRCUIT NOISE AND THE USE OF COMPANDORS

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

1 Noise objectives for telephony (formerly Part A)

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 50 000 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 10 000 pW at a zero level point on the circuit, level −50 dBm0p).

However, as connections longer than 25 000 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:

TABLE 4/M.580

Maintenance noise objectives for public telephone circuits

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

Note 2 – Strictly speaking, the noise objective for communication-satellite systems (see Recommendation G.153, § 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* [1)]

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

2 Use of syllabic compandors (formerly Part B) [2)]

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 G.152. Furthermore, the circuit noise produced by transmission systems can increase above the values originally achieved because of ageing effects, and changes of system loading. There is therefore a need for a simple practical criterion that can be applied for planning purposes to an international circuit to determine if, as far as noise power is concerned, it is suitable for establishing multicircuit worldwide telephone connections or whether it can be made suitable by fitting compandors [2)].

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

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

The following planning rule is recommended by the 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 (40 000 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.

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 (formerly Part C)

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

4 Noise limits for data transmission (formerly Part D)

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.

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

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

4.2 *Switched connections*

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

References

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

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

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

[4] CCITT Recommendation *Noise objectives for design of carrier-transmission systems of 2500 km*, Vol. III, Fascicle III.2, Rec. G.222.

[5] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony*, Vol. IV, Fascicle IV.1, Rec. M.580, § 6.

[6] CCITT Recommendation *Transmission requirements of international voice-frequency telegraph links (at 50, 100 and 200 bauds)*, Vol. III, Fascicle III.4, 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 (formerly Part A)

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]).

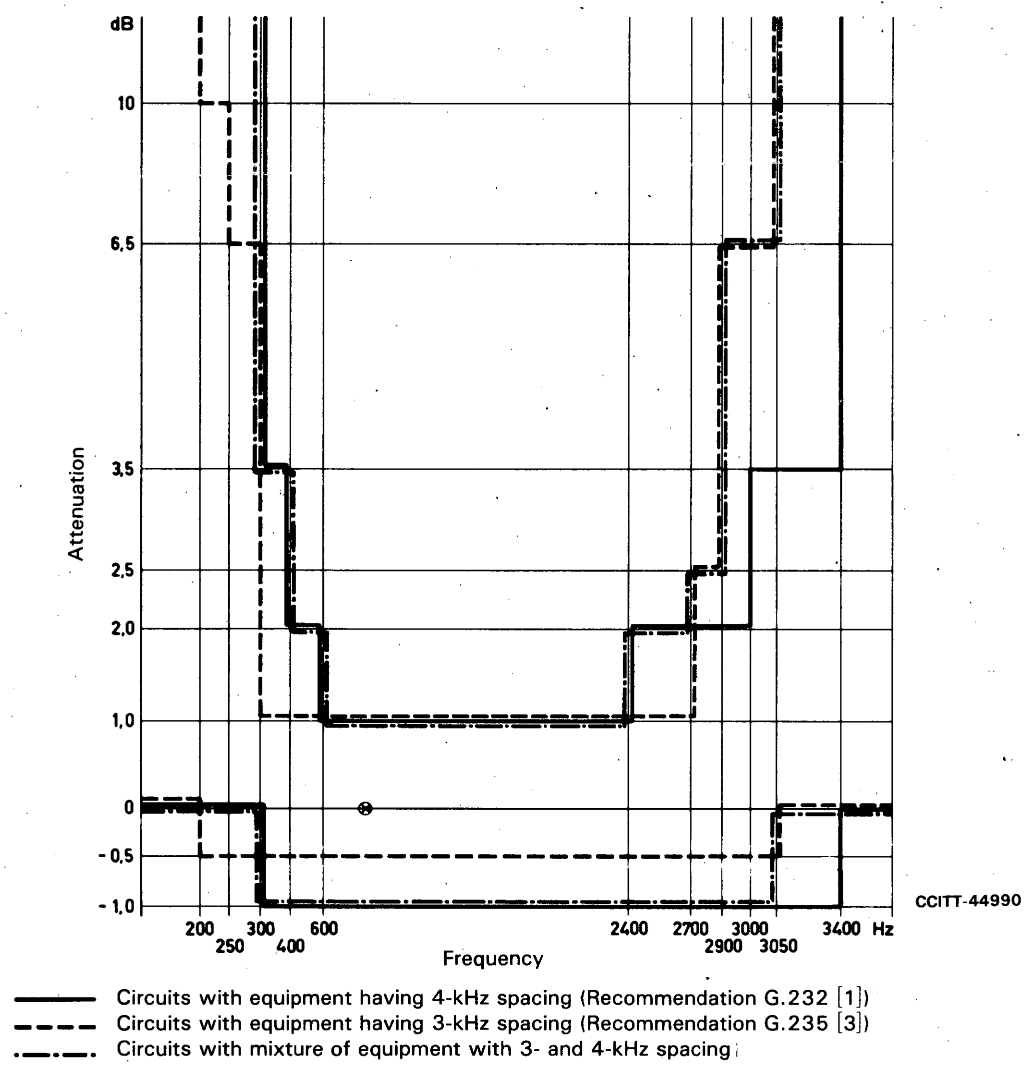

FIGURE 1/G.151

Line-up limits of circuits with 3-kHz and 4-kHz channel equipment

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** (formerly Part B)

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** (formerly Part C)

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** [1] (formerly Part D)

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 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.

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

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 (formerly Part E)

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 (formerly Part F)

See Recommendation G.135.

7 Interference at harmonics from the mains and other low frequencies (formerly Part G)

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, Fascicle III.2, Rec. G.232.

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

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

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

[5] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 6.

[6] CCITT Recommendation *Characteristics of 1.2/4.4-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.622.

[7] CCITT Recommendation *Characteristics of 2.6/9.5-mm coaxial cable pairs*, Vol. III, Fascicle III.2, Rec. G.623.

[8] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, § 9.1.

[9] *Ibid.*, § 9.3.

[10] CCITT Recommendation *Performance characteristics of 15-kHz type sound-programme circuits*, Vol. III, Fascicle III.4, 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 (formerly Part A)

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 ($L \leqslant 2500$ 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 (formerly Part B)

The CCIR has defined a hypothetical reference circuit and fixed circuit performance objectives in its Recommendations 396-1 [3] and 397-3 [4] respectively.

3 Circuits on open-wire carrier systems (formerly Part C)

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, Fascicle III.2, Rec. G.222.

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

[3] CCIR Recommendation *Hypothetical reference circuit for trans-horizon radio-relay systems for telephony using frequency-division multiplex*, Vol. IX, Rec. 396-1, ITU, Geneva, 1978.

[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. 397-3, ITU, Geneva, 1978.

[5] CCITT Recommendation *General characteristics of systems providing 12 carrier telephone circuits on an open-wire pair*, Vol. III, Fascicle III.2, Rec. G.311, § 8.

[6] CCITT Recommendation *Setting-up and lining-up an international circuit for public telephony*, Vol. IV, Fascicle IV.1, 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).

TABLE 1/G.153

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

Psophometric power		Type of objective or limit	
pW0p	dBm0p	For a connection, a chain of circuits, or a leased circuit	For a circuit which may form part of a switched connection
40 000	−44		Limit for a telephone circuit used without a compandor (Recommendation G.143, § 2)
50 000	−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)	
80 000	−41	Limit for FM VF telegraphy, in accordance with CCITT standards (Recommendation H.22 [2])	
100 000	−40	Limit for data transmission over a leased circuit (Recommendation G.143, § 4.1)	
250 000	−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 eqipped 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.

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

In many cases circuits of this kind, between 2500 km and about 25 000 km long will, throughout most of their length, be carried in land-cable systems or radio-relay systems already used to give international circuits not more than 2500 km long, and designed on the basis of the objectives already recommended for such systems in Recommendation G.222 [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 25 000 km long should be designed on the basis of the noise objectives at present recommended for 2500-km hypothetical reference circuits.

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 50 000 pW (−43 dBm0p) for more than 0.3% of any month and the unweighted noise power, measured or calculated with an integrating time of 5 ms, shall not exceed 10^6 pW (−30 dBm0) for more than 0.03% of any month. It is to be understood that these objectives are derived pro rata from the objectives for circuits of 2500 km length (Recommendation G.222 [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 (formerly Part B)

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 [1]) 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 (formerly Part C)

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 352-3 [8]) and the allowable noise power in this reference circuit (CCIR Recommendation 353-3 [9]).

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

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, Fascicle IV.1, Rec. M.580.

[2] CCITT Recommendation *Transmission requirements of international voice-frequency telegraph links (at 50, 100 and 200 bauds)*, Vol. III, Fascicle III.4, Rec. H.22.

[3] CCITT Recommendation *Noise objectives for design of carrier-transmission systems of 2500 km*, Vol. III, Fascicle III.2, Rec. G.222.

[4] *Ibid.*, § 3.

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

[6] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232.

[7] CCITT Recommendation *The international routing plan*, Vol. VI, Fascicle VI.1, Rec. Q.13.

[8] CCIR Recommendation *Hypothetical reference circuits for telephony and television in the fixed satellite service*, Vol. IV, Rec. 352-3, ITU, Geneva, 1978.

[9] CCIR Recommendation *Allowable noise power in the hypothetical reference circuit for frequency-division multiplex telephony in the fixed satellite service*, Vol. IV, Rec. 353-3, ITU, Geneva, 1978.

1.6 Apparatus associated with long-distance telephone circuits

Recommendation G.161

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

(See Vol. III of the *Orange Book*, ITU, Geneva, 1977).

1) See footnote [2]) in Recommendation G.143, §2.

CHARACTERISTICS OF COMPANDORS FOR TELEPHONY

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

These characterisics are applicable to compandors of modern design for use either on very long international circuits or on national and international circuits of moderate length.

Some of the clauses given below specify the joint characteristics of a compressor and an expander in the same direction of transmission of a 4-wire circuit. The characteristics specified in this way can be obtained more easily if the compressors and expanders are of similar design; in certain cases close cooperation between Administrations may be necessary.

It should also be noted that the equipement produced so far for circuits of moderate length may be completely satisfactory for those circuits and yet not quite meet the clauses of this Recommendation.

1 Definition and value of the unaffected level

The unaffected level is the absolute level, at a point of zero relative level on the line between the compressor and the expander of a signal at 800 Hz, which remains unchanged whether the circuit is operated with the compressor or not. The unaffected level is defined in this way in order not to impose any particular values of relative level at the input to the compressor or the output of the expander.

The unaffected level should be, in principle, 0 dBm0. Nevertheless, to make allowances for the increase in mean power introduced by the compressor, and to avoid the risk of increasing the intermodulation noise and the overload which might result, the unaffected level may, in some cases, be reduced by perhaps as much as 5 dB. However, this reduction of unaffected level entails a diminution of the improvement in signal-to-noise ratio provided by the compandor. This possible reduction should be made by direct agreement between the Administrations concerned. No reduction is necessary, in general, for systems with less than 60 channels.

Note – The increase in the mean power in the transmitted band determined by the compressor in the telephone channel depends on the value of the unaffected level, the attack and recovery times, the distribution of the speech volumes and the mean power level of transmitted speech. When 0 dBm0 is adopted for the unaffected level, it appears that the effective increase in the mean power level is of the order of 2 or 3 dB.

2 Ratio of compression and expansion

2.1 *Definition and preferred value of the ratio of compression*

The ratio compression of a compressor is defined by the formula:

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

where:

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

The preferred value of α is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between +10 °C and +40 °C.

2.2 *Definition and preferred value of the ratio of expansion*

The ratio of expansion of an expander is defined by the formula:

$$\beta = \frac{n'_s - n'_{s0}}{n'_e - n'_{e0}}$$

where:

n'_e is the input level;
n'_{e0} is the input level corresponding to 0 dBm0;

n'_s is the output level;
n'_{s0} is the output level corresponding to an input level of n'_{e0}.

The preferred value of β is 2, though lower values are permissible, provided sufficient noise improvement is obtained. The value shall not exceed 2.5 for any level of input signal and at any temperature between +10 °C and +40 °C.

2.3 *Range of level*

The range of level over which the recommended value of α and β should apply should extend at least:

from +5 to −45 dBm0 at the input of the compressor, and
from +5 to −50 dBm0 at the nominal output of the expander.

2.4 *Variation of compressor gain*

The level at the output of the compressor, measured at 800 Hz, for an input level of 0 dBm0, should not vary from its nominal value by more than ± 0.5 dB for a temperature range of +10 °C to +40 °C and a deviation of the supply voltage of ± 5% from its nominal value.

2.5 *Variation of expander gain*

The level at the output of the expander, measured at 800 Hz for an input level of 0 dBm0, should not vary from its nominal value by more than ± 1 dB for a temperature range of +10 °C and +40 °C and a deviation of the supply voltage of ± 5% from its nominal value.

Note – It is desirable, especially for compandors intended for very long circuits, to set stricter limits than the values of +0.5 dB and ± 1 dB given under § 2.4 and § 2.5; +0.25 dB and +0.5 dB respectively are preferable.

2.6 *Conditions for stability*

The insertion of a compandor shall not appreciably reduce the margin of stability. To ensure this, for the combination of an expander and a compressor on the same 4-wire circuit and at a given station, the error of the output level of the compressor with respect to any value of expander input level shall not exceed + 0.5 dB. This error is referred to the level obtained at the compressor output when the input level is 0 dBm0. This limit shall be observed at all frequencies between 200 and 4000 Hz within the temperature range +10 °C to +40 °C. No negative limit is specified for the error. In this test an attenuator shall be inserted between the expander and the compressor, the value of which is to be set in accordance with the following Note 1.

Note 1 – This Note concerns the influence of a compandor on the loop gain of a 4-wire circuit and on the margin of stability.

In examining this problem, a connection was considered made up of three 4-wire circuits, *AB*, *BC* and *CD*, which link the terminal stations *A* and *D* (at which the terminating sets are located) through the intermediate stations *B* and *C*. It is assumed that the circuit *BC* is equipped with compandors. It is desired to determine the tolerances for the gain of the combination of expander and compressor at *C* in order to limit the reduction in the margin of stability caused by their insertion. To facilitate study of this question it is assumed that, in normal use, the expander output and compressor input are points of the same relative level.

The following expression then gives the loss between the output of the expander at *C* and the input of the compressor at *C*:

$$a_s = a_0 + a_r + a_x + a_y$$

where

a_0 is the nominal transmission loss of the chain of circuits between the 2-wire terminals at *A* and *D*;
a_r is the balance return loss at the terminating set at *D*;
a_x is the departure of transmission loss of channel *CD* from its nominal value;
a_y is the departure of transmission loss of channel *DC* from its nominal value.

The two latter values may be positive or negative.

It may be concluded that, in order that the measurement of the gain of the combination of an expander and a compressor at the same station may satisfactorily determine the total effect on the margin of stability, the following conditions must be observed:

The expander must be connected to the compressor via an attenuator, the loss of which should cover the entire range of values for a_s which actually occur when there is a risk of instability. To take account of all practical conditions, it would probably be necessary to consider a very wide range.

However, considering only the important example of a terminal compandor and zero balance return loss, then $a_s = a_0$ and this is the value which is generally recommended for the loss of the attenuator between expander and compressor in this test.

Nevertheless, when it is possible to determine the exact values of a_r, a_x and a_y, corresponding to the most probable condition of instability, the exact value of a_s can be specified.

It has been assumed that the expander output and the compressor input are normally points of the same relative level. If this is not the case, and if the relative level at the expander output is a_c dB higher than the relative level at the compressor input, the loss in the attenuator should be increased by a_c (which may be positive or negative).

Note 2 – Cross-connection between the control circuits of the compressor and expander may have advantages from the point of view of circuit echoes; hence, its use should be allowed. On the other hand its use, which has some disadvantages from the point of view of signalling-to-voice break-in, will certainly be confined to exceptional cases. In consequence, there seems no need for any special recommendations on the subject.

2.7 *Tolerances on the output levels of the combination of compressor and expander in the same direction of transmission of a 4-wire circuit*

The compressor and expander are connected in tandem. A loss (or gain) is inserted between the compressor output and expander input equal to the nominal loss (or gain) between these points in the actual circuit in which they will be used. Figure 1/G.162 shows, as a function of level of 800-Hz input signal to the compressor, the permissible limits of difference between expander output level and compressor input level. (Positive values indicate that the expander output level exceeds the compressor input level.)

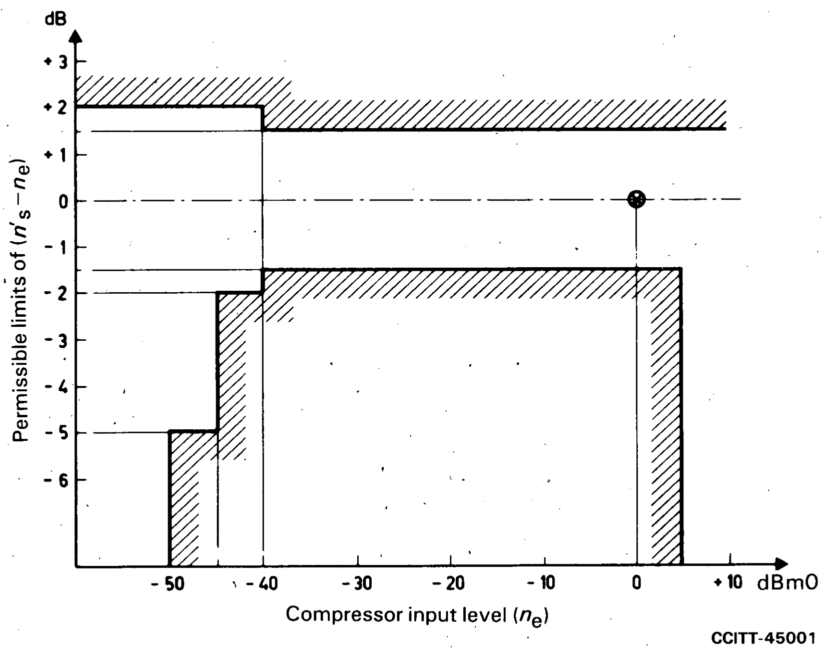


FIGURE 1/G.162

The limits shall be observed at all combinations of temperature of compressor and temperature of expander in the range +10 °C to +40 °C. They shall also be observed when the test is repeated with the loss (or gain) between the compressor and expander increased or decreased by 2 dB.

Note – The change of gain (or loss) of 2 dB mentioned in § 2.7 above is equal to twice the standard deviation of transmission loss recommended as an objective for international circuits routed on single group links in Recommendation G.151, § 3.

3 Impedances and return loss

The nominal value of the input and output impedances of both compressor and expander should be 600 ohms (nonreactive).

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

4 Operating characteristics at various frequencies

4.1 *Frequency characteristic with control circuit clamped*

The control circuit is said to be clamped when the control current (or voltage) derived by rectification of the signal is replaced by a constant direct current (or voltage) supplied from an external source. For purposes here, the value of this current (or voltage) should be equal to the value of the control current (or voltage) obtained when the input signal is 0 dBm0 at 800 Hz.

For the compressor and the expander taken separately, the variations of loss or gain with frequency should be contained within the limits of a diagram that can be deduced from Figure 1/G.132 by dividing the tolerance shown by 8, the measurement being made with a constant input level corresponding to a level of 0 dBm0.

These limits should be observed over the temperature range +10 °C and +40 °C.

4.2 *Frequency characteristic with control circuit operating normally*

The limits given in § 4.1 should be observed for the compressor when the control circuit is operating normally, the measurement being made with a constant input level corresponding to a level of 0 dBm0.

For the expander, under the same conditions of measurement, the limits can be deduced from Figure 1/G.132 by dividing the tolerances shown by 4.

These limits should be observed over the temperature range +10 °C to +40 °C.

5 Nonlinear distortion

5.1 *Harmonic distortion*

Harmonic distortion, measured with an 800-Hz sine wave at a level of 0 dBm0, should not exceed 4% for the compressor and the expander taken separately.

Note – Even in an ideal compressor, high output peaks will occur when the signal level is suddenly raised. The most severe case seems to be that of voice-frequency signalling, although the effect can also occur during speech. It may be desirable, in exceptional cases, to fit the compressor with an amplitude limiter to avoid disturbance due to transients during voice-frequency signalling.

5.2 *Intermodulation tests*

It is necessary to add a measurement of intermodulation to the measurements of harmonic distortion whenever compandors are intended for international circuits (regardless of the signalling system used), as well as in all cases where they are provided for national circuits over which multi-frequency signalling, or data transmission using similar types of signals, is envisaged.

The intermodulation products of concern to the operation of multi-frequency telephone signalling receivers are those of the third order, of type $(2f_1 - f_2)$ and $(2f_2 - f_1)$, where f_1 and f_2 are two signalling frequencies.

Two signals at frequencies 900 Hz and 1020 Hz are recommended for these tests.

Two test conditions should be considered: the first, where each of the signals at f_1 and f_2 is at a level of −5 dBm0 and the second, where they are each at a level of −15 dBm0. These levels are to be understood to be at the input to the compressor or at the output of the expander (uncompressed levels).

The limits for the intermodulation products are defined as the difference between the level of either of the signals at frequencies f_1 or f_2 and the level of either of the intermodulation products at frequencies $(2f_1 - f_2)$ or $(2f_2 - f_1)$.

A value for this difference which seems adequate for the requirements of multi-frequency telephone signalling (including end-to-end signalling over three circuits in tandem, each equipped with a compandor) is 26 dB for the compressor and the expander separately.

Note 1 — These values seem suitable for Signalling System No. 5, which will be used on some long international circuits.

Note 2 — It is inadvisable to make measurements on a compressor plus expander in tandem, because the individual intermodulation levels of the compressor and of the expander might be quite high, although much less intermodulation is given in tandem measurements since the characteristics of compressor and expander may be closely complementary. The compensation encountered in tandem measurements on compressor and expander may not be encountered in practice, either because there may be phase distortion in the line or because the compressor and expander at the two ends of the line may be less closely complementary than the compressor and expander measured in tandem.

Hence the measurements have to be performed separately for the compressor and the expander. The two signals at frequencies f_1 and f_2 must be applied simultaneously, and the levels at the output of the compressor or expander measured selectively.

6 Noise voltages

The effective value of the sum of all noise voltages referred to a zero relative level point, the input and the output being terminated with resistances of 600 ohms, shall be less than or equal to the following values:

– at the output of the compressor:	(10 mV unweighted	−38 dBm0)
	(7 mV weighted	−41 dBm0p)
– at the output of the expander:	(0.5 mV weighted	−84 dBm0p)

It is not considered useful to specify a value of unweighted noise voltage for the expander.

7 Transient response

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission of a 4-wire circuit fitted with compandors shall be checked as follows:

The compressor and expander are connected in tandem, the appropriate loss (or gain) being inserted between them as in § 2.7.

A 12-dB step signal at a frequency of 2000 Hz is applied to the input of the compressor, the actual values being a change from −16 to −4 dBm0 for attack, and from −4 to −16 dBm0 for recovery. The envelope of the expander output is observed. The overshoot (positive or negative), after an upward 12-dB step expressed as a percentage of the final steady-state voltage, is a measure of the overall transient distortion of the compressor-expander combination for attack. The overshoot (positive or negative) after a downward 12 dB step, expressed as a percentage of the final steady-state voltage is a measure of the overall transient distortion of the compressor-expander combination for recovery. For both these quantities the permissible limits shall be ± 20%. These limits shall be observed for the same conditions of temperature and of variation of loss (or gain) between compressor and expander as for the test in § 2.7.

In addition, the attack and recovery times of the compressor alone shall be measured as follows:

Using the same 12-dB steps as above for attack and recovery respectively, the attack time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 1.5 times its steady-state value. The recovery time is defined as the time between the instant when the sudden change is applied and the instant when the output voltage envelope reaches a value equal to 0.75 times its steady-state value.

The permissible limits shall be not greater than:

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

The following additional test shall be used to check the effect of the compandor on certain signalling systems which may be sensitive to envelope distortion immediately following the sudden application of a sinusoidal signal.

The overall transient response of the combination of a compressor and expander which are to be used in the same direction of transmission on a 4-wire circuit is measured with an "infinite" upward input step, i.e. with a signal applied after a period with no input.

The level of the signal to be applied is -5 dBm0.

Provided the measurement is effected with an interval of at least 50 ms between the pulses, the limits shown by an unbroken line in Figure 2/G.162 should be observed for the overshoot of the final voltage V_1; in most cases an attempt should be made if possible to observe the narrower limits, indicated in the figure by a broken line.

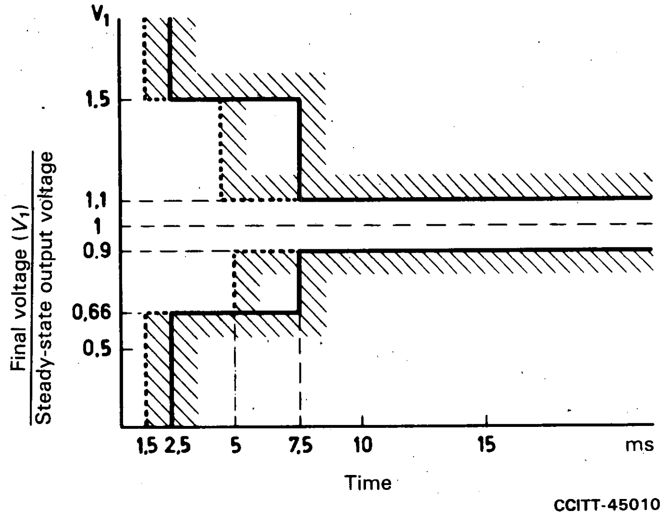


FIGURE 2/G.162

These limits shall be observed for the same conditions of temperature loss (or gain) between compressor and expander as for the tests with 12-dB steps.

Note 1 – The tests of transient distortion described involve the measurement of the overshoot or undershoot of the envelope of the applied sinusoidal signal. It may happen that, due to small unbalances in the variable loss device, very-low-frequency components of the control current appear at the output. These are not a modulation of the signal frequency, but they produce an unsymmetrical waveform and render it difficult to determine the overshoot or undershoot of the envelope. While it is undesirable that these low-frequency components should be so large as to increase significantly the risk of overload of the line equipment, they are of no importance for speech transmission and will not affect tuned signalling receivers. However, it is desirable to consider whether these components may affect the guard circuits of some signalling receivers. If so, it may be necessary to specify a maximum value for these components and to include an appropriate test in this Recommendation.

To simplify the measurement of the true envelope amplitude in the presence of these unbalance components, it is admissible and convenient to insert at the input to the measuring oscillograph a high-pass filter having a cut-off frequency of about 300 Hz. However, a filter which is effective in removing unbalance components may itself introduce additional transient distortion in the signal envelope. To avoid this difficulty, the following method of calculation may be adopted which does not require a filter.

If at any instant the amplitude of the envelope in a positive direction is $+E_1$, and in the negative direction is $-E_2$ then the two-envelope amplitude is given by

$$\frac{1}{2}\left[(+E_1) - (-E_2)\right] \equiv \frac{1}{2}\left[|E_1| + |E_2|\right]$$

and the unbalance component is given by

$$\frac{1}{2}\left[(+E_1) + (-E_2)\right] \equiv \frac{1}{2}\left[|E_1| - |E_2|\right]$$

This method is not only simple and free of the transient distortion problem which occurs with a filter, but it also provides direct information on the unbalance which, as indicated above, may be important.

Note 2 – The time constants of the expander control circuit should in principle be equal to those of the compressor control circuit so as to avoid any overshoot (positive or negative) in the transient response.

Note 3 – If an Administration prefers to use a direct method of measuring expander attack and recovery times, the following might be adopted:

To define the attack and recovery times of the expander, a sudden change in level from −8 to −2 dBm0 should be applied to its input for measurement of the attack time, and from −2 to −8 dBm0 for measurement of the recovery time. The attack time is represented by the time between the moment when the abrupt variation is applied and the moment when the output voltage reaches a value x times its final value. The recovery time is represented by the time between the moment when the abrupt variation is applied and the moment when output voltage reaches a value y times its final value. The times thus measured should lie between the same limits as those shown for the compressor. Bearing in mind detailed differences in the construction of the various compandors now in use, specific figures for x and y cannot be given. Hence, each Administation will have to determine the correct values of x and y for the type of compandor concerned.

For an ideal expander, 0.57 and 1.51 are valid for x and y; by way of example, the Italian Administation has found 0.65 for x and 1.35 for y for a certain type of construction.

Some Administrations have said that it might be preferable to specify fixed values of x and y, for all types of expander, leaving Administrations free to choose the limit values for attack and recovery times according to the different types of expander. Values of 0.75 and 1.5 are proposed for x and y in this method of measurement.

Note 4 – The "infinite" step transient response measurements refer to a compressor-expander combination connected in tandem; moreover, several Administrations have investigated the possibility of meeting the limits shown in the Figure 2/G.162, even for a chain of three compandors in tandem, by bringing also the channel modulating and demodulating equipment into the connection. This modem equipment may cause an undesirable transient phenomenon in the step at the expander output; this phenomenon, and the intermodulation of the third order associated with it, may influence the multi-frequency signalling.

Recommendation G.163

CALL CONCENTRATING SYSTEMS

(Mar del Plata, 1968)

1 Characteristics

The characteristics of the TASI system which is now in operation on submarine cable systems are given in references [1] and [2].

The characterisitics of the CELTIC system are given in reference [3].

ATIC (Time Assignment with Sample Interpolation) is a time assignment system for pulse code transmission. A description of the basic function is given in reference [4] and another article on its statistical efficiency is quoted in reference [5].

Note – The use of these concentrating systems involves various restrictions; for example, they may call for a special signalling system and they increase system loading (see the Recommendation cited in [6]).

2 Possibility of interconnection

To ensure satisfactory speech quality when call concentrating systems of the TASI type are operated in tandem, it is necessary that each concentrator introduce only a very small speech impairment at the peak of the busy hour. The present TASI concentrators were designed with the objective that the average speech lost during the peak of the busy hour will be approximately 0.5%. In addition, the interpolation process in TASI is designed so that there is a very small probability that the amount of speech lost in any speech spurt will be greater than the length of an average syllable (about 250 ms). Subjective tests [7] have been made on individual working TASI systems and the results, obtained by interviewing customers, show that the impairment due to a properly loaded and maintained TASI is essentially undetectable by the customer. No such tests have been carried out on call concentration systems in tandem.

Because of the subjective problems involved, estimates made of the speech impairment that would result from tandem call concentration systems must be qualitative without subjective tests. The probability of excessive clipping, even in a system of three concentrators in tandem with each having the same busy hour, can be kept to a satisfactory level by arranging the system so that the impairment introduced by each concentrator is small, as in the case of the present TASI system. If the tandem concentrators are located in different time zones or in areas with different peak traffic hours, the lighter loaded concentrators will cause negligible additional impairment.

Assuming that present and future concentrators will be operated and designed so as to meet the criterion of very small speech impairment during the peak of the busy hour, it is recommended that no restrictions be imposed on tandem operation of concentrators at this time. In addition, it is recommended that no test on tandem operation should be made until tandem operation of concentrators is a reality. At such time, tests could be made under working conditions to determine the effects of tandem concentrators on speech and to establish whether any adjustment of the ratio of number of simultaneous calls to the number of channels would be required to keep speech clipping to a negligible amount.

The estimated probability that the forward-transfer pulse for the CCITT No. 5 Signalling System will be clipped for a certain length of time in one, two, and three TASIs in tandem can be found in [8].

References

[1] FRASER (J. M.), BULLOCK (D. B.) and LONG (N. G.).: Overall characteristics of a TASI system, *Bell System Technical Journal*, Vol. XLI, No. 4, July 1962.

[2] MIDEMA (H.) and SCHACHTMAN (M. G.).: TASI quality-effect of speech detectors and interpolation, *B.S.T.J.*, *ibid.*

[3] DAYONNET (F. D.), JOUSSET (A.) and PROFIT (A.).: Le CELTIC: Concentrateur exploitant les temps d'inactivité des circuits, *L'Onde Electrique*, Vol. XLII, No. 426, pp. 675-687, September 1962.

[4] LYGHOUNIS (E.).: Il sistema A.T.I.C., *Telecommunicazioni*, No. 26, pp. 21-29, March 1968.

[5] BONATTI (M.) and MOTOLESE (F.).: Probabilità di attività delle giunzioni di un doppio fascio telefonico, *Télecommunicazioni*, No. 23, pp. 24-28, June 1967.

[6] CCITT Recommendation *FDM carrier systems for submarine cable*, Vol. III, Fascicle III.2, Rec. G.371, § 3.

[7] HELDER (G. K.).: Customer evaluation of telephone circuits with delay, *B.S.T.J.*, Vol. XLV, No. 7, September 1966.

[8] *TASI characteristics affecting signalling*, Green Book, Vol. VI.4, Supplement No. 2, ITU, Geneva, 1973.

ECHO SUPPRESSORS

(Geneva, 1980)

1 General

1.1 *Application*

This Recommendation is applicable to the design of echo suppressors used on international telephone connections which have:

1.1.1 mean one-way propagation times between subscribers of up to the maximum regarded as acceptable in Recommendation G.114. (The design of the echo suppressor should not impose any lower limit of delay on its use);

1.1.2 a level of circuit noise entering the send-in (S_{in}) port or receive-in (R_{in}) port of up to −40 dBm0p;

1.1.3 round trip end delays between the receive-out (R_{out}) port and the S_{in} port of the echo suppressor of up to 24 ms (including all transmission and switching plant).

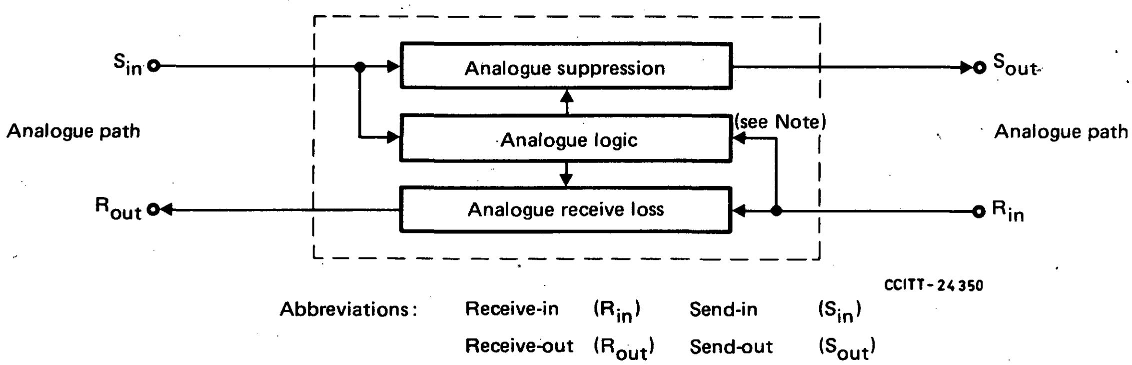
Note – Recommendation G.161 [1] refers to 25 ms. The value of 24 ms, a multiple of 2, is used in this Recommendation as being more applicable to the design of digital echo suppressors;

1.1.4 a loss of the echo path in dB (see the Recommendation cited in [2] that is likely to be such that the minimum loss from R_{out} port to the S_{in} port of the echo suppressor will be equal to the difference between relative levels at these two ports plus 6 dB.

Echo suppressors must be designed to perform in a satisfactory manner under all the conditions described above.

1.2 *Design features*

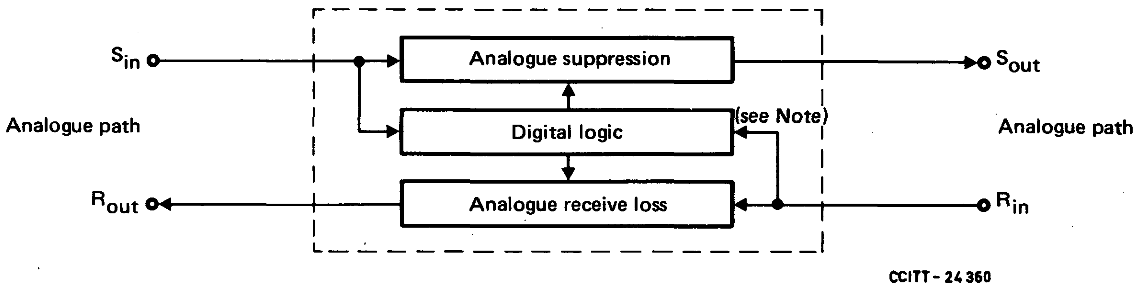
Echo suppressors conforming to the characteristics given in this Recommendation are terminal, half-echo suppressors having differential operation and a break-in algorithm which incorporates a partial break-in state. They may be further characterized by whether the transmission paths, the logic functions and the speech processing (suppression and receive loss) use analogue or digital techniques. The combinations of these which are most likely to be practicable and to which this Recommendation is particularly addressed are shown in Figures 1/G.164, 2/G.164, 3/G.164 and 4/G.164 as Types A, B, C and D. All the requirements of this Recommendation apply equally to Types A, B, C and D except where noted. The same design features apply to the variants of adaptive echo suppressors referred to in § 1.5.2.



Note – **This input may be connected to either side of the receive loss, depending on the logic circuitry.**

FIGURE 1/G.164

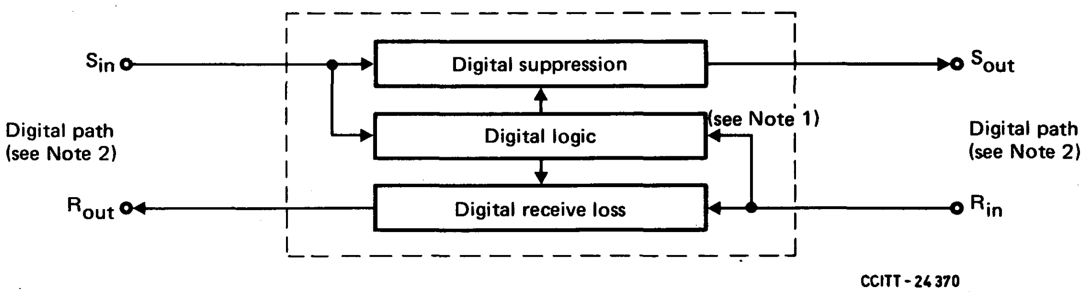
Type A echo suppressor



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

FIGURE 2/G.164

Type B echo suppressor

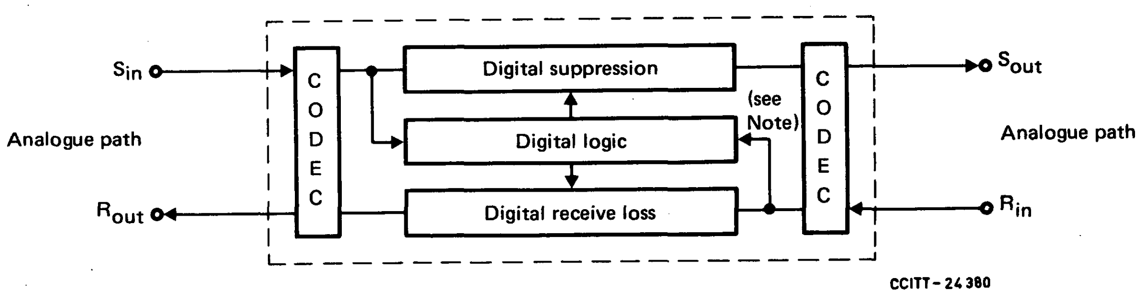


Note 1 – This input may be connected to either side of the receive loss, depending on the logic circuitry.

Note 2 – The digital path may be at any digital interface, i.e. 64 kbit/s, 1544 or 2048 kbit/s or at any higher order interface.

FIGURE 3/G.164

Type C echo suppressor



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

FIGURE 4/G.164

Type D echo suppressor

1.3 *Compatibility*

It is necessary for all echo control devices used on international connections to be compatible with each other. Echo suppressors designed according to this Recommendation will be compatible with each other, with echo suppressors conforming to Recommendation G.161 [1] and with echo cancellers designed to Recommendation G.165. Compatibility is defined as follows:

Given:

1) that a particular type of echo control device (say Type I) has been designed so that satisfactory performance is achieved when any practical single or multilink connections are equipped throughout with one or more pairs of such devices; and

2) that another particular type of echo control device (say Type II) has likewise been designed;

then Type II is said to be compatible with Type I if it is possible to replace one or more than one echo control devices of one type at any point in the connection with those of the other type, without degrading the performance of the connection to an unsatisfactory level.

In this sense compatibility does not imply that the same test apparatus or methods can necessarily be used to test both Type I and Type II echo control devices.

1.4 *Need for test methods*

Objective test methods are very important to permit measurement of essential operating characteristics of echo suppressors. Suitable test methods are therefore given in § 5 of this Recommendation.

1.5 *Variants*

1.5.1 Recommendation G.161 [1] is still applicable for the design of analogue echo suppressors. Analogue echo suppressors must conform to either Recommendation G.164 or Recommendation G.161 [1].

1.5.2 Echo suppressors incorporating an adaptive break-in function are described in Annex A. Characteristics of such echo suppressors are under study.

1.6 *Enabling/disabling*

Each echo suppressor should be equipped with:

a) a facility which provides for enabling or disabling by an externally derived ground (earth) from the trunk circuit. The enabler should function to permit or prevent normal echo suppressor operation. Certain Type C echo suppressors may be disabled directly by a digital signal;

b) a tone disabler which functions to prevent the introduction of the suppression and receive loss when specified disabling tone signals are transmitted through the suppressors. Thus it should disable for specified tones but should not disable on speech. (See § 4.)

1.7 *Explanatory notes*

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

1.7.2 The result of break-in is to transform the circuit from one permitting speech in one direction to one permitting speech on both directions simultaneously, and a necessary consequence of this action is to permit echo to return unsuppressed. To reduce the amount of echo returned during break-in, loss is inserted in the receive path. This, of course, attenuates the received speech. If the break-in action is adjusted to minimize the echo, the speech of one or both double-talking parties will still be chopped to some extent as the control of the echo suppressor transfers from one party to the other. The basic requirements in the design of an echo suppressor are therefore two:

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

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

The second requirement involves two mutually exclusive functions:

a) avoidance of chopping of double-talking speech;

b) elimination of echo during and after double-talking.

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

1.7.4 A variety of break-in decision algorithms are possible. All have the objective of reliable break-in for double-talking speech with protection against false break-in due to echo or to impulse noise. A two-step process is recommended:

a) The state of partial break-in is entered initially. This state is characterized by short break-in hangover times. The receive loss may or may not be inserted but, if used, must have an equally short break-in hangover time.

b) After the signal conditions producing break-in have persisted for some time, the full break-in state is entered. Receive loss must be inserted and longer break-in hangover times applied.

2 Definitions relating to echo suppressors

2.1 echo suppressor

F: suppresseur d'écho

S: supresor de eco

A voice-operated device placed in the 4-wire portion of a circuit and used for inserting loss in the transmission path to suppress echo. The path in which the device operates may be an individual circuit path or a path carrying a multiplexed signal.

2.2 full echo suppressor

F: suppresseur d'écho complet

S: supresor de eco completo

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

2.3 half-echo suppressor

F: demi-suppresseur d'écho

S: semisupresor de eco

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

2.4 **differential echo suppressor**

F: suppresseur d'écho différentiel

S: supresor de eco diferencial

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

2.5 **partial break-in echo suppressor**

F: suppresseur d'écho à intervention partielle

S: supresor de eco con intervención parcial

An echo suppressor which includes partial and full break-in functions.

2.6 **adaptive break-in echo suppressor** (see Annex A)

F: suppresseur d'écho à intervention adaptable

S: supresor de eco con intervención adaptativa

An echo suppressor in which the break-in sensitivity is automatically adjusted according to the attenuation of the echo path.

2.7 **suppression loss**

F: affaiblissement de blocage

S: atenuación para la supresión

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

2.8 **receive loss**

F: affaiblissement à la réception

S: atenuación en la recepción

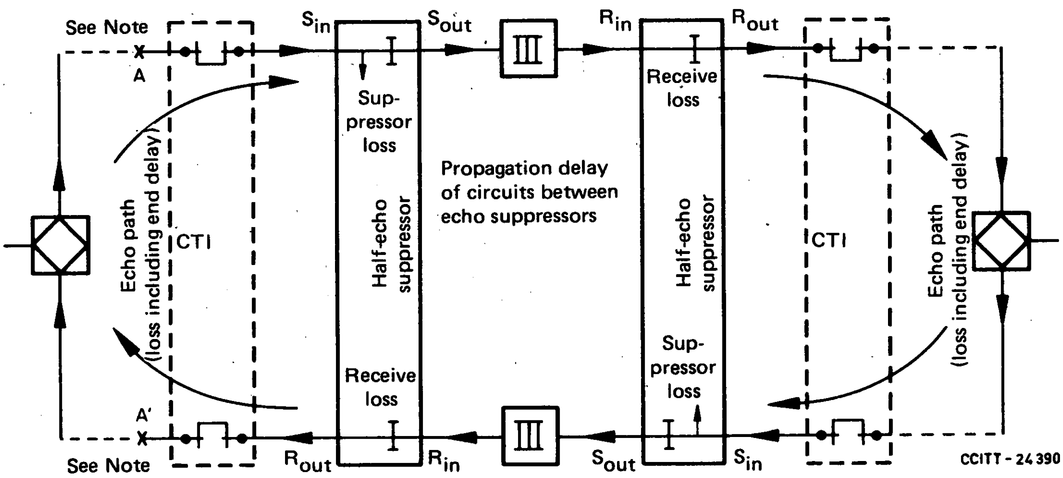
The specified loss which an echo suppressor introduces into the receive path (of the echo suppressor) to reduce the effect of echo currents during break-in.

2.9 **terminal echo suppressor** (see Figure 5/G.164)

F: suppresseur d'écho terminal

S: supresor de eco terminal

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



CTI International switching centre

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

FIGURE 5/G.164

2.10 **suppression operate time**

F: temps de fonctionnement pour le blocage

S: tiempo de funcionamiento para la supresión

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

2.11 **suppression hangover time**

F: temps de maintien pour le blocage

S: tiempo de bloqueo para la supresión

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

2.12 **partial break-in**

F: intervention partielle

S: intervención parcial

A temporary condition of break-in which exists at the onset of break-in. This state is characterized by a short break-in hangover time. The receive loss may be inserted during partial break-in provided it also has the short break-in hangover time.

2.13 **partial break-in operate time**

F: temps de fonctionnement pour l'intervention partielle

S: tiempo de funcionamiento para la intervención parcial

The time interval between the instant when defined test signals, applied to the send- and/or receive-in ports, are altered in a defined manner such as to remove suppression and the instant when suppression is removed. Insertion of loss in the receive path may occur at the same time or slightly after removal of suppression.

2.14 **full break-in**

F: intervention totale

S: intervención total

A stable condition of break-in which follows the partial break-in condition once it has been determined, with high probability, that the signal causing break-in is speech. This state is characterized by the insertion of receive loss and longer break-in hangover times.

2.15 **full break-in operate time**

F: temps de fonctionnement pour l'intervention totale

S: tiempo de funcionamiento para la intervención total

The time interval between the instant when defined test signals, applied to the send- and/or receive-in ports, are altered in a defined manner such as to remove suppression and extend the hangover time and the instant when the extended hangover time is applied. Removal of suppression occurs at the same time as for partial break-in. Insertion of loss in the receive path may occur at the same time or slightly after removal of suppression.

2.16 **break-in hangover time**

F: temps de maintien pour l'intervention

S: tiempo de bloqueo para la intervención

The time interval between the instant when defined test signals, applied to the send- and/or receive-in ports, are altered in a defined manner such as to restore suppression and the instant when suppression is restored. The hangover time for removal of loss in the receive path may be longer than that for restoration of suppression.

2.17 **differential sensitivity**

F: sensibilité différentielle

S: sensibilidad diferencial

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

3 Characteristics of echo suppressors suitable for circuits having either short or long propagation times

3.1 *Transmission performance*

The performance characteristics apply, unless otherwise noted, when steady state signals are separately applied to the send and receive paths.

The limits on transmission characteristics specified below shall be observed over the temperature range +10 °C to 40 °C and over the power supply variations permitted by individual Administrations.

Echo suppressors of Types A, B and D are placed in the voice-frequency portion of a 4-wire circuit which is nominally of 600-ohms impedance. The send (transmit or office-to-line) and the receive (line-to-office) paths are at different relative levels in different national networks; two such sets of levels are:

1) send, −16 dBr; receive, +7 dBr;
2) send, −4 dBr; receive, +4 dBr.

Test tone frequencies are 800 Hz or 1000 Hz, nominal. To avoid submultiples of the 8000-Hz sampling frequency, test tone frequencies should fall within the ranges 804 to 860 Hz and 1004 to 1020 Hz respectively.

3.1.1 *Type A and B echo suppressors*

3.1.1.1 *Insertion loss*

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

3.1.1.2 *Attenuation distortion*

The attenuation distortion shall be such that if Q dB is the loss at 800 Hz (or 1000 Hz), the loss shall be within the range $(Q + 0.3)$ dB to $(Q - 0.2)$ dB at any frequency in the band 300-3400 Hz, and at 200 Hz within the range of $(Q + 1.0)$ dB to $(Q - 0.2)$ dB.

3.1.1.3 *Delay distortion*

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

3.1.1.4 *Impedance*

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

1) The nominal value of the inputs and outputs shall be 600 ohms (nonreactive).
2) The return loss with respect to the nominal impedance shall not be less than 20 dB from 300-600 Hz nor less than 25 dB from 600-3400 Hz.
3) The impedance unbalance to earth of each port shall not be less than 50 dB over the frequency range 300 to 3400 Hz.

3.1.1.5 *Overload*

The insertion loss at 800 Hz (or 1000 Hz) shall not increase by more than 0.2 dB for test tone levels from 0 to +5.0 dBm0.

3.1.1.6 *Harmonic distortion*

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

3.1.1.7 *Intermodulation*

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

3.1.1.8 *Transient response*

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

3.1.1.9 *Noise*

The mean weighted psophometric power introduced by an echo suppressor shall not exceed −70 dBm0p. The mean unweighted noise power in a band of 300-3400 Hz introduced by an echo suppressor shall not exceed −50 dBm0.

3.1.1.10 *Crosstalk*

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

3.1.1.11 *Spurious outputs produced by the echo suppressor*

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

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

3.1.2 *Type C echo suppressor*

3.1.2.1 *General*

An echo suppressor of Type C inserted into a digital transmission path between codecs meeting the performance characteristics of Recommendation G.712 [3] should not alter such performance.

3.1.2.2 *Group delay*

The group delay through the echo suppressor shall not exceed 0.25 ms.

3.1.2.3 *Effect of digital loss pads*

Digital loss pads inserted into the receive path during the break-in mode may increase the quantizing distortion. Type C echo suppressors, which maintain signalling bit integrity for channel associated signalling for systems in accordance with Recommendation G.733 [4] by bypassing the least significant bit, are likely to exhibit a greater increase in quantizing distortion during the break-in mode than Type C echo suppressors used in systems with common channel signalling. The permissible limits are under study.

3.1.2.4 *Effect of instantaneous digital compressors*

(The values given below are provisional.)

When an instantaneous compressor is employed in the receive path of the suppressor during break-in, it shall not produce distortion exceeding the following limits:

a) *Harmonic distortion*

With a sinusoidal input signal of 0 dBm0 at any frequency between 300 Hz and 1 KHz, the third harmonic distortion produced should not exceed -30 dBm0.

b) *Intermodulation distortion*

With an input signal of two equal amplitude sinusoids at $f_1 = 900$ and $f_2 = 1020$ Hz at levels of -3 to -35 dBm0, the distortion products at $(2f_1 - f_2)$ and $(2f_2 - f_1)$ should not exceed a level of -16 dB relative to the output level of each tone. For input levels below -35 dBm0 this ratio should be at least -20 dB.

3.1.3 *Type D echo suppressors*

3.1.3.1 *General*

The performance characteristics of Recommendation G.712 [3] apply for the codecs.

3.1.3.2 *Group delay*

The group delay shall not exceed that of the codecs alone by more than 0.25 ms.

3.1.3.3 *Effect of digital loss pads*

Digital loss pads inserted into the receive path during the break-in mode may increase the quantization distortion over the limits specified in Recommendation G.712 [3]. The permissible limits are under study.

3.1.3.4 *Effect of instantaneous digital compressors*

See § 3.1.2.4.

3.2 *Characteristics with steady-state input signals applied independently to the send and receive paths*

3.2.1 The action of an echo suppressor which incorporates the general features described in § 1 is explained below with the aid of the idealized operational diagram shown in Figure 6/G.164. The significant combinations of input signals are represented by the areas X, Y, Z, W and V.

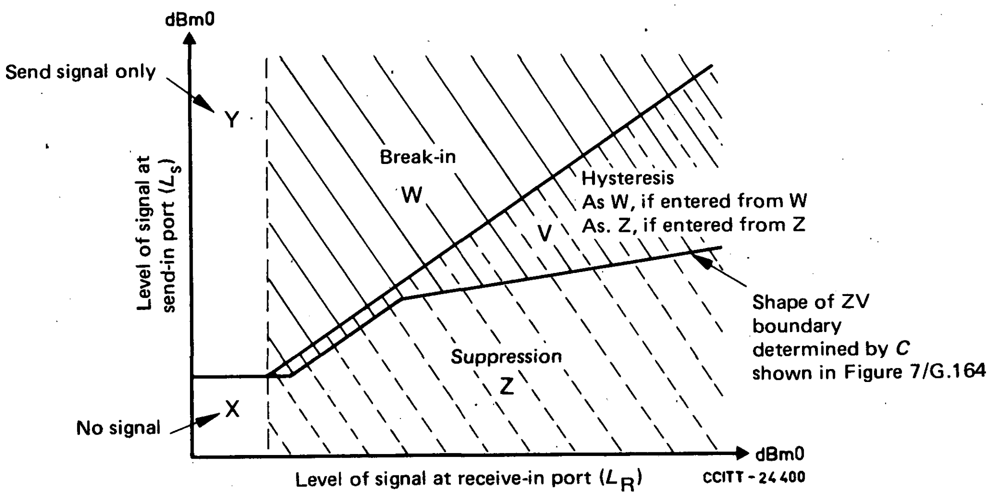


FIGURE 6/G.164

Conceptual diagram showing operational states of echo suppressors under ideal conditions

3.2.2 The area X corresponds to the absence of any appreciable signal on either the send or the receive path. The area Y corresponds to the presence of signals only on the send path. The area Z represents those combinations of signal levels for which the echo suppressor should provide suppression in the send path. The area W corresponds to break-in when the suppression should be absent. The area V corresponds to hysteresis that is provided to ensure that the break-in condition is retained when the signal on the send path has fallen slightly below the minimum level at which break-in would be initiated; the area V therefore represents a bistable condition. Table 1/G.164 shows the losses that should be inserted in the two paths, when each of the five areas X, Y, Z, W and V is occupied continuously. Figure 7/G.164 shows the boundaries for the receiving loss *C*, that should be inserted in the receive path during break-in. The information given in Figures 6/G.164 and 7/G.164 and in Table 1/G.164 applies for steady-state signals with the inter-area boundaries being crossed very slowly.

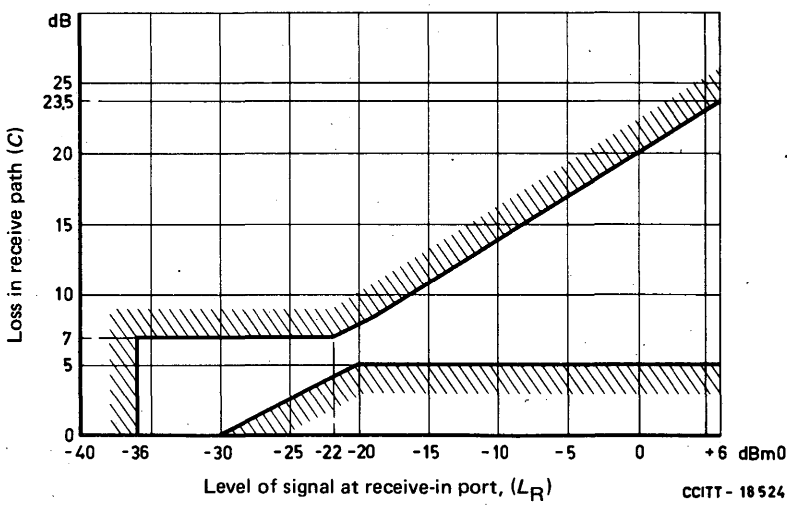
TABLE 1/G.164

Key to operational diagram Figure 6/G.164

Area	Loss in send path (dB)	Loss in receive path (dB)
X	0	0
Y	0	0 [b]
W	0	Within limits for *C* shown in Figure 7/G.164
Z	50 minimum [a]	0
V	As W, if entered from W As Z, if entered from Z	

[a] When echo suppressors of type *C* are used on long digital circuits, suppression of the far end noise may be objectionable due to noise contrast. This is under study.

[b] When the loss in the receive path is provided by a speech compressor, the loss should be zero for receive signals ⩽ −36 dBm0.



Note – The recommended values are those enclosed in the nonshaded area.

FIGURE 7/G.164

Recommended loss C, to be inserted in receive path during break-in

3.2.3 The features shown in Figure 6/G.164 are concerned only with characteristics that can be determined without knowledge of, or access to, the internal circuits of echo suppressors. These characteristics are determined by application of test signals to the external terminals of the echo suppressor and observation of its state by external measurements. Test methods for measurements to verify compliance with the requirements are given in § 5.

3.2.4 The signal levels that define the various thresholds are given in Table 2/G.164.

TABLE 2/G.164

Inter-area threshold levels

Boundary	Symbol of threshold	At 1000 Hz (see Note 1) dBm0 at 20 ± 5° C	At 1000 Hz (see Note 1) dBm0 between 10 and 40° C	Variation with frequency
Suppression				
X to Z	Txz	$-33 \leqslant Txz \leqslant -29$ for $L_S = -40$	$T'xz = Txz \pm 1$	
Z to X	$Tzx_{max.}$ $Tzx_{min.}$	Txz −0 dB Txz −3 dB	$T'xz$ −0 dB $T'xz$ −3 dB	Figure 8/G.164
Break-in				
V to W (previous input Z)	Tvw	$L_R - 3 \leqslant L_S \leqslant L_R$ (see Notes 3, 4, 5) $(-26.5 \leqslant L_R \leqslant +3)$		$T'vw = Tvw \pm 1.5$ dB between 500 and 3000 Hz (see Note 2)
V to Z (previous input W)	$Tvz_{max.}$ $Tvz_{min.}$	$Tvw - C + 2$ dB (see Notes 3, 4, 5) $Tvw - C - 3$ dB (see Note 1) $(-26.5 \leqslant L_R \leqslant +3)$		$T'vz = Tvz \pm 1.5$ dB between 500 and 3000 Hz (see Note 2)

L_S Level (dBm0) at send-in port.

L_R Level (dBm0) at receive-in port.

C The loss inserted in the receiving path during break-in. This characteristic must conform with the limits shown in Figure 7/G.164.

Note 1 – The test frequency is 1004 to 1020 Hz to avoid submultiples of the 8000 Hz sampling frequency.

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

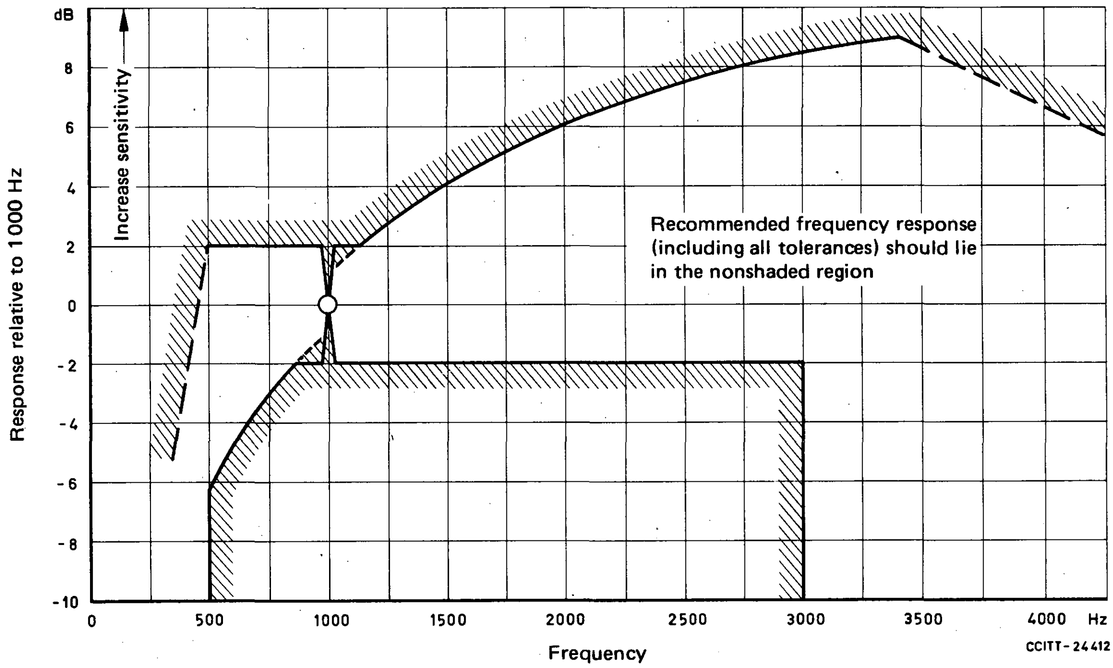
Note 3 – This excludes tolerances due to codecs (± 0.5 dB in G.712 [3]).

Note 4 – The Tvw and Tvz tolerance limits may occasionally be exceeded by up to 1 dB in the range $-26.5 \leqslant L_R \leqslant +3$ dBm0 due to quantizing effects. This can, in theory, cause false retention of break-in when using steady state test signals (see test 8). This does not occur for speech signals.

Note 5 – The limiting values of the Tvw and Tvz thresholds combined with small values of echo path loss and small values of C can, in theory, cause oscillation between suppression and break-in for tests using low-level steady state signals. This has not been observed on existing echo suppressors and does not occur for speech signals.

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

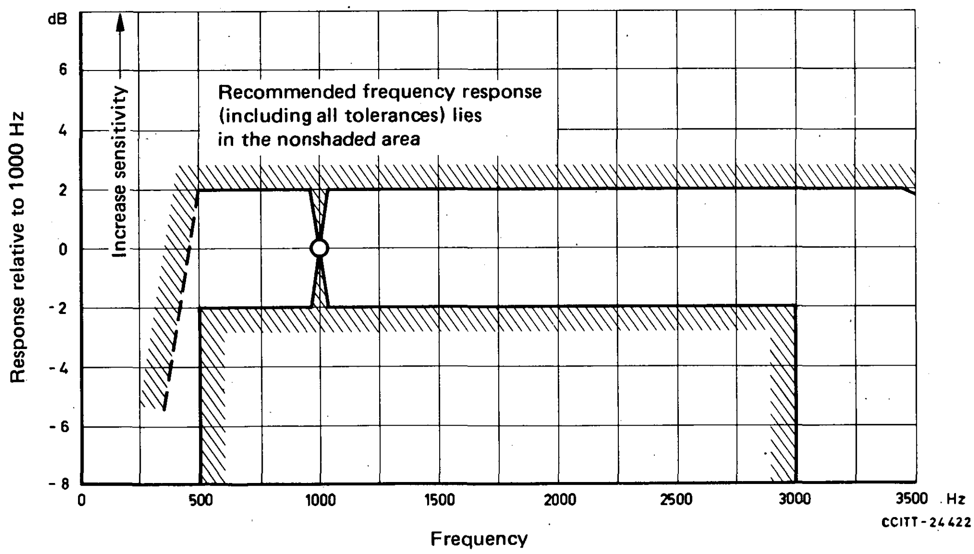
3.2.4.2 The frequency response limits of the suppression control path are given in Figure 8/G.164. The frequency response limits of the break-in control paths are given in Figure 9/G.164. It is desirable to provide such filtering in echo suppressors. However, this is difficult to implement in the case of Types C and D. Therefore, for these types, this filtering may be omitted where Administrations can ensure that any interfering signals are at such a low level that they do not adversely affect echo suppressor operation.



Note – Decrease in sensitivity below 500 and above 3400 Hz should have a value of at least 12 dB/octave.

FIGURE 8/G.164

Recommended frequency response of suppression control path of echo suppressor



Note – Decrease in sensitivity below 500 and above 3400 Hz should have a nominal value of at least 12 dB/octave.

FIGURE 9/G.164

Recommended frequency response of each control path of break-in detector of echo suppressor

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

3.3.1 The dynamic characteristics can be specified by stating the time that elapses when the conditions of the signals pass from a point in one area to one in another before the state appropriate to the second area is established (Figure 6/G.164 and Figure 11/G.164). When passing from X to Z, this is termed the suppression operate time and when passing in the opposite direction it is termed suppression hangover time. When passing from the Z area through V to W (or Y) it is termed the break-in operate time and when passing from W through V to Z it is termed the break-in hangover time. The V/W and V/Z boundaries may, in practice, be crossed at any angle; the requirements in Table 3/G.164 deal with vertical and horizontal directions.

3.3.2 The suppression (X/Z) operate time should be nearly constant for the sudden application of any signal in the receive path greater than the threshold (-31 dBm0) in the absence of any appreciable signal in the send path. Similarly, for transitions from suppression to break-in for L_R constant (Z/V/W), the operate times shown in Table 3/G.164 should in general apply to the complete range of possible signal pairs (L_R and L_S) and not just to the two pairs shown in Table 3/G.164.

3.3.3 The hangover times shown in Table 4/G.164 should in general apply whenever suppression or break-in has occurred irrespective of the levels of the causative signals.

3.3.4 When sudden changes are made in the levels of sinusoidal test signals at a frequency of 1000 Hz, the times of operation given in Table 3/G.164 apply and the recommended values of hangover given in Table 4/G.164 apply. The right-hand part of each table refers to tests described in § 5.

3.3.5 The operate times of the receive pad in the Y/W transition is not separately stated or tested, but should be within the limits allowed for the suppression operate time.

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

The foregoing requirements apply when the echo suppressor is tested under conditions such that the signals in the send and receive paths are independent. In practice, satisfactory performance must also be maintained when the send path is connected to the receive path through an echo path that may have end-delay and low loss. Three features of the dynamic performance must be checked under these conditions. § 5 describes test arrangements suitable for measuring these conditions. The three conditions are described as follows:

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

3.4.2 If insufficient protection against end-delay is incorporated in the echo suppressor, the break-in circuit may operate on the trailing edge of the echo. This can occur with the sudden removal of a signal at the R_{in} port when the echo-path loss is low and the end-delay is large (see Test No. 7).

3.4.3 In certain designs it can happen that the hysteresis represented by the bistable area V (see Figure 6/G.164) is excessive in relation to the amount of loss inserted in the receive path. This can result in the false retention of break-in by echo occurring under the following conditions: A steady-state signal is present at the R_{in} port and is coupled to the S_{in} port via the echo path. A signal of sufficient amplitude and duration to cause break-in is then applied to the S_{in} port. Upon cessation of this signal, the echo of the receive signal falsely maintains the break-in condition (see Test No. 8).

TABLE 3/G.164

Operate times

Boundary	Initial signals (see Note)		Final signals (see Note)		Recommended value (ms)	Test No.	Excursion (see Figure 11/G. 164)	Test circuit (Figure number)	Oscilloscope trace (Figure number)
	Send L_S (dBm0)	Receive L_R (dBm0)	Send L_S (dBm0)	Receive L_R (dBm0)					
Suppression X/Z	–40 –40	–40 –40	–40 –40	–25 –11	≤ 1	4	a → b a → d	13/G.164	14/G.164
Break-in Z/V/W L_S constant	–15 –15 –15	–10 – 5 0	–15 –15 –15	–25 –25 –25	24-36	5	h → i g → i f → i	13/G.164	15/G.164
Break-in Z/V/W L_R constant	–40 –40	–25 –15	–19 – 9	–25 –15	Partial: ≤ 2 Full: 6-10	6	b → k c → j	16/G.164	17/G.164

Note – See also § 3.3.2.

TABLE 4/G.164

Hangover times

Boundary	Initial signals		Final signals		Recommended value (ms)	Test No.	Excursion (see Figure 11/G.164)	Test circuit (Figure number)	Oscilloscope trace (Figure number)
	Send L_S (dBm0)	Receive L_R (dBm0)	Send L_S (dBm0)	Receive L_R (dBm0)					
Suppression Z/X	–40 –40	–25 –11	–40 –40	–40 –40	24-36	4	b → a d → a	13/G.164	14/G.164
Break-in W/V/Z L_R constant	–19 – 9	–25 –15	–40 –40	–25 –15	Partial: ≤ 26 Full: 48-66 (see Note)	6	k → b j → c	16/G.164	17/G.164

Note – The hangover time of the receive loss should be that shown (48-66 ms). The possible beneficial effects of having an extended hangover time of the receive loss for circuits having very long propagation times are under study.

4 Characteristics of echo-suppressor tone disablers

4.1 *General*

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

4.2 *Disabling characteristics* (see Figure 10/G.164)

The disabling tone transmitted is 2100 Hz ± 15 Hz at a level of −12 ± 6 dBm0. The frequency of the tone applied to the disabler is 2100 Hz ± 21 Hz (see Recommendation V.21 [5]). The disabling channel bandwidth should be chosen wide enough to encompass this tone (and possibly other disabling tones used within national networks). At the same time, the disabling channel bandwidth should be such that, in conjunction with guard action and timing, adequate protection is provided against false operation of the disabler by speech signals. The disabling channel sensitivity (threshold level) should be such that the disabler will operate on the lowest expected power of the disabling tone. The band characteristics shown in Figure 10/G.164 will permit disabling by the 2100-Hz disabling tone as well as others used in North America. The figure indicates that in the frequency band 2079 Hz to 2121 Hz disabling *must* be possible whilst in the band 1900 Hz to 2350 Hz it *may* be possible.

Providing that only the recommended 2100-Hz disabling tone is used internationally, interference with signalling equipment will be avoided. Unintentional disabling of the echo suppressor by signalling tones is not considered detrimental, since the echo suppressor serves no needed functions during the time when signalling tones are present on the circuit.

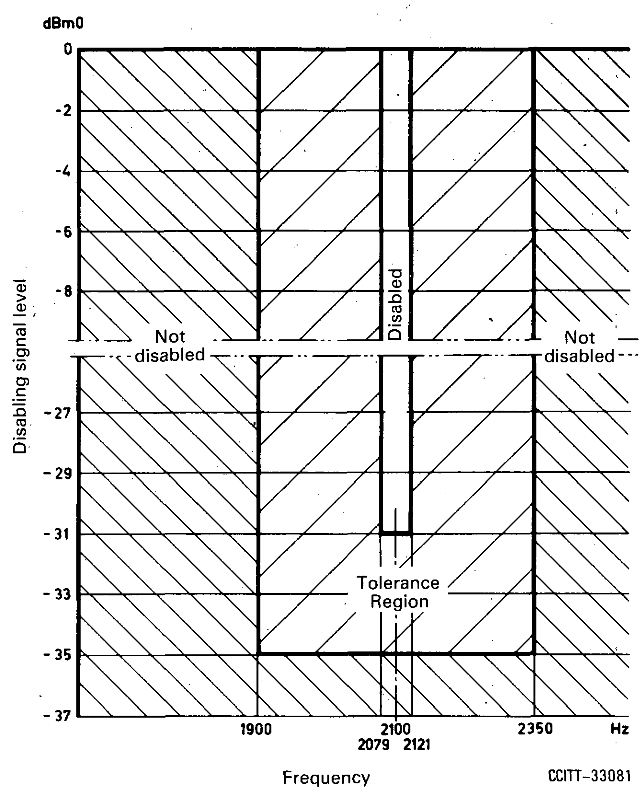


FIGURE 10/G.164

Required disabling band characteristics

4.3 *Guard band characteristics*

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

Given that white noise (in a band of approximately 300-3400 Hz) is applied to the tone disabler simultaneously with a 2100-Hz signal, the 2100-Hz signal is applied at a level 3 dB above the midband disabler threshold level. The white noise energy level required to inhibit disabling should be no greater than the level of the 2100-Hz signal and no less than a level 5 dB below the level of the 2100-Hz signal. As the level of the 2100-Hz signal is increased over the range of levels to 30 dB above the midband disabler threshold level, the white noise energy level required to inhibit disabling should always be less than the 2100-Hz signal level.

4.4 *Holding-band characteristics*

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

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

4.5 *Operate time*

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

4.6 *False operation due to speech currents*

It is desirable that the tone disabler should rarely operate falsely on speech. To this end, a reasonable objective is that, for an echo suppressor installed on a working circuit, usual speech currents should not on the average cause more than 10 false operations during 100 hours of speech. In addition to the talk-off protection supplied by the disabling channel bandwidth, by guard band operation and by the operate time, talk-off protection can be supplied by recycling. That is, if speech which simulates the disabling signal is interrupted because of inter-syllabic periods, before disabling has taken place the operate timing mechanism should reset. However, momentary absence or change of level in a true disabling signal should not reset the timing.

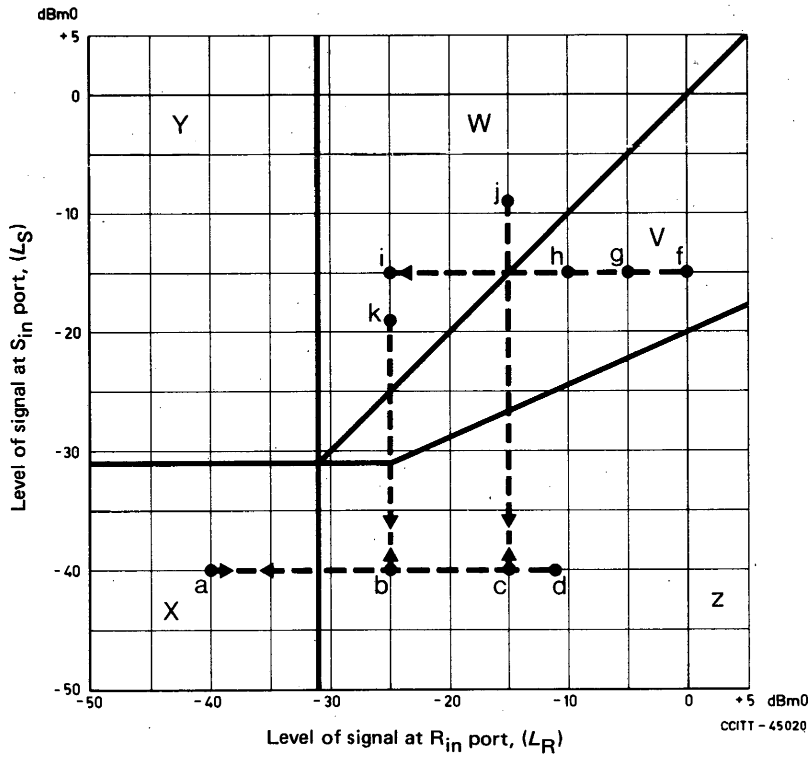
4.7 *Release time*

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

5 **Test arrangements to measure essential operating characteristics of echo suppressors**

5.1 *General considerations*

5.1.1 An echo suppressor with sinusoidal signals applied to its S_{in} and R_{in} ports will assume one of a number of states depending on the relative levels of the two signals. Any given combination of levels of the two input signals may be represented by a point on a typical operational diagram (Figure 11/G.164). Each area on this diagram corresponds (under steady conditions) to a particular state identified by the losses in the two speech paths and the internal organization of its logic.



Note – The boundaries shown are typical. The lower boundary of the V region is shown for the maximum loss *C* allowed by Figure 7/G.164.

FIGURE 11/G.164

Operational diagram showing levels used in dynamic tests (see Table 3/G.164 and 4/G.164)

5.1.2 The tests described here assume the use of analogue test signals. In the case of Type C echo suppressors, codecs meeting Recommendation G.712 [3] will be required to interface the suppressor to the analogue test equipment. When tests are performed on Types C and D echo suppressors, due account must be made for the added propagation delays due to the codecs when measuring operate times by the observation of output signals. Further, in level measurements due account must be made for codec tolerances. Frequencies which are submultiples of the sampling frequency may give misleading results and should be avoided in these tests. Note that if external filtering is required to meet the requirements of § 3.2.4.2, it should be included when these tests are performed.

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

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

The various tests described in § 5 are summarized in Table 5/G.164.

5.1.4 The descriptions of the test circuits presented here are given so as to indicate a possible method for the application of the appropriate test signals. Other techniques for producing these signals (for example, the use of separate sine wave generators for send and receive) may be employed. Although the test frequency is nominally 1000 Hz, a frequency in the range of 1004-1020 Hz should be chosen to avoid a submultiple of the sampling frequency.

TABLE 5/G.164

Recommended tests for echo suppressors

Test	Characteristic measured	Block diagram (Figure)	Oscilloscope trace (Figure)
1	Suppression threshold and loss	12/G.164	–
2	Y/W threshold and receive loss	12/G.164	–
3	Break-in differential sensitivity	12/G.164	–
4	Suppression operate and hangover times	13/G.164	14/G.164
5	Break-in L_S constant	13/G.164	15/G.164
6	Partial and full break-in L_R constant	16/G.164	17/G.164
7	False break-in protection	18/G.164	–
8	Test for excessive hysteresis	19/G.164	20/G.164

5.2 *Measurement of static characteristics*

The static characteristics measured are losses in the send and receive paths and the inter-area threshold levels (Tables 1/G.164 and 2/G.164). The equipment required is:

– one oscillator with 600-ohm balanced output impedance;
– two 600-ohm balanced attenuators;
– one 600-ohm mixing pad;
– two level-measuring sets with 600-ohm balanced input impedance.

The diagram of connections is shown in Figure 12/G.164.

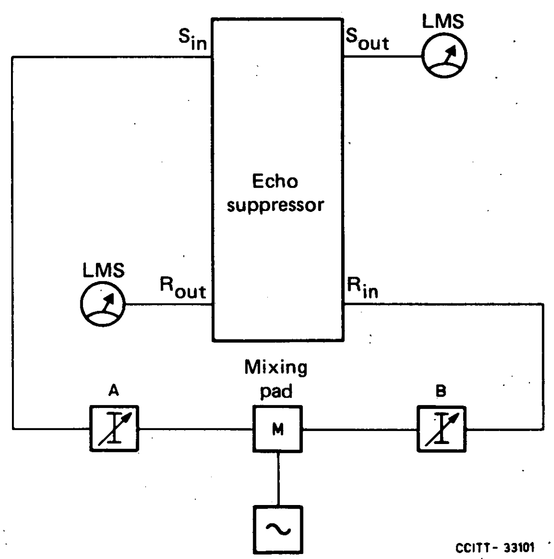


FIGURE 12/G.164

Test circuit for measurement of static characteristics (Tests 1, 2 and 3)

5.2.1 *Test No. 1 – Suppression threshold and loss*

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust *A* so that $L_S = -40$ dBm0.

3) Adjust *B* so that $L_R = -40$ dBm0.

4) Increase L_R until suppression occurs and note the value of L_R and the suppression loss. Requirement: $-33 \leq (L_R = T_{xz}) \leq -29$ dBm0 (see Table 2/G.164).

5) Decrease L_R until suppression releases and note the value of L_R. Requirement: $T_{xz} - 3 \leq L_R \leq T_{xz}$ (see Table 2/G.164).

6) Set the oscillator to appropriate frequencies to check for conformity within the bounds shown in Figure 8/G.164 and repeat steps 2 to 5.

5.2.2 *Test No. 2 – Y/W threshold and receive loss in break-in state*

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust *A* so that $L_S = +3$ dBm0.

3) Adjust *B* so that L_R varies over the range -40 dBm0 $\leq L_R \leq L_S$. Operation within the boundaries of Figure 7/G.164 is observed by monitoring $L_{R\text{in}} - L_{R\text{out}}$ which equals loss *C*. Y/W threshold occurs where $C > 0$ dB.

Note – Record values of *C* as a function of L_R for use in Test No. 3, step 5.

5.2.3 *Test No. 3 – Break-in differential sensitivity*

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust *A* so that $L_S = -40$ dBm0.

3) Adjust *B* so that $L_R = -26.5$ dBm0.

4) Increase L_S until suppression is removed and loss is inserted in the receive path. Note the value of L_S. Requirement: see T_{vw}, Table 2/G.164.

5) Decrease L_S until suppression is inserted and loss is removed from the receive path. Note the value of L_S. Requirement: see T_{vz}, Table 2/G.164.

6) Increase L_R in appropriate steps up to $+3$ dBm0 and repeat steps 4 and 5.

7) Set the oscillator to appropriate frequencies to check for the conformity within the bounds shown in Figure 9/G.164 and repeat steps 2 to 6.

5.3 *Measurement of dynamic characteristics when L_S and L_R are applied independently*

The dynamic characteristics measured are the suppression and break-in operate and hangover times (Tables 3/G.164 and 4/G.164). The equipment required is:

- one oscillator with 600-ohm balanced output impedance, set to 1000 Hz;
- three 600-ohm balanced attenuators;
- three 600-ohm mixing pads;
- two tone-burst generators, the ON and OFF periods of which must be independently variable from zero to at least 200 ms each, and which are capable of being held manually in either state. The input and output impedance in both states must be 600 ohms. One tone-burst generator is driven by the other and has 100 ms delay such that it turns ON 100 ms after the other turns ON;
- two 600-ohm terminating resistors;
- one dual beam oscilloscope, preferably with long persistence screen.

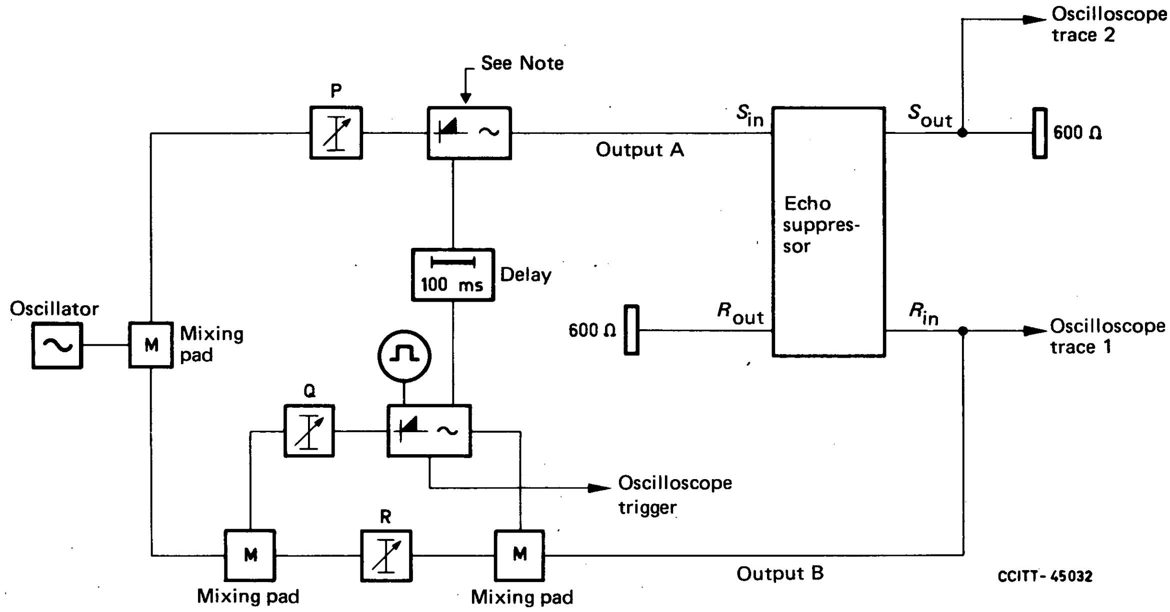
Note – If the ON or OFF periods of the tone pulses are not stated then the value of 200 ms for either should be assumed. Refer to Tables 3/G.164 and 4/G.164 for appropriate performance requirements for Test Nos. 4, 5 and 6.

5.3.1 *Tests in which L_S is maintained constant*

5.3.1.1 *Test No. 4 – Suppression operate and hangover times*

1) Adjust attenuators P, Q and R shown in Figure 13/G.164 to produce the L_R and L_S values of Tables 3/G.164 and 4/G.164.

2) Read times as shown in Figure 14/G.164.



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

FIGURE 13/G.164

Test circuit for the measurement of dynamic characteristics with constant L_S [Suppression (Test No. 4) and break-in (Test No. 5)]

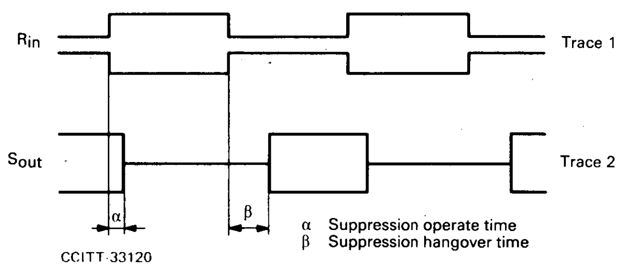


FIGURE 14/G.164

Trace for suppression operate and hangover times

5.3.1.2 *Test No. 5 – Break-in operate time, L_S constant*

In this test, L_R is decreased while a constant L_S is maintained, and a break-in operate time is measured. Since break-in hangover with L_S constant is difficult to measure (due to the difficulty of ensuring a return to the Z state), it is not possible to distinguish between partial and full break-in. This is not considered to be important for break-in with L_S constant.

1) Adjust attenuators P, Q and R shown in Figure 13/G.164 to produce the L_R and the L_S values of Table 3/G.164.

2) Read times as shown in Figure 15/G.164.

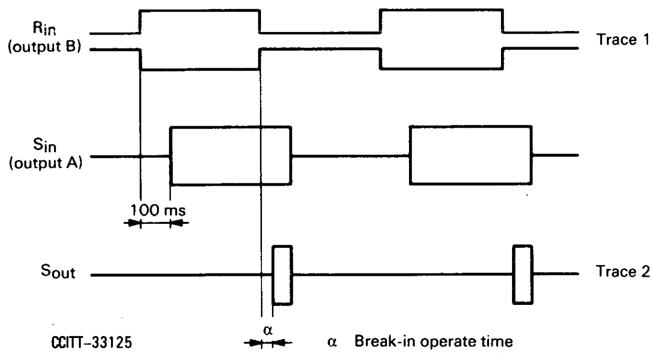


FIGURE 15/G.164

Trace for break-in operate time, L_S constant

5.3.2 *Test in which L_R is maintained constant*

5.3.2.1 *Test No. 6 – Partial and full break-in operate and hangover times, L_R constant*

The equipment required is the same as for Tests Nos. 4 and 5, set up according to Figure 16/G.164. In this test L_R is kept constant, L_S is increased, and the partial and full break-in operate and hangover times are measured. To test for partial and full break-in, the duration of time L_S is in the ON state must be varied.

1) Set oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust attenuator P of Figure 16/G.164 to produce $L_R = -25$ dBm0.

3) Adjust attenuators Q and R of Figure 16/G.164 to produce $L_S = -40$ dBm0 in the OFF state and $L_S = -19$ dBm0 in the ON state.

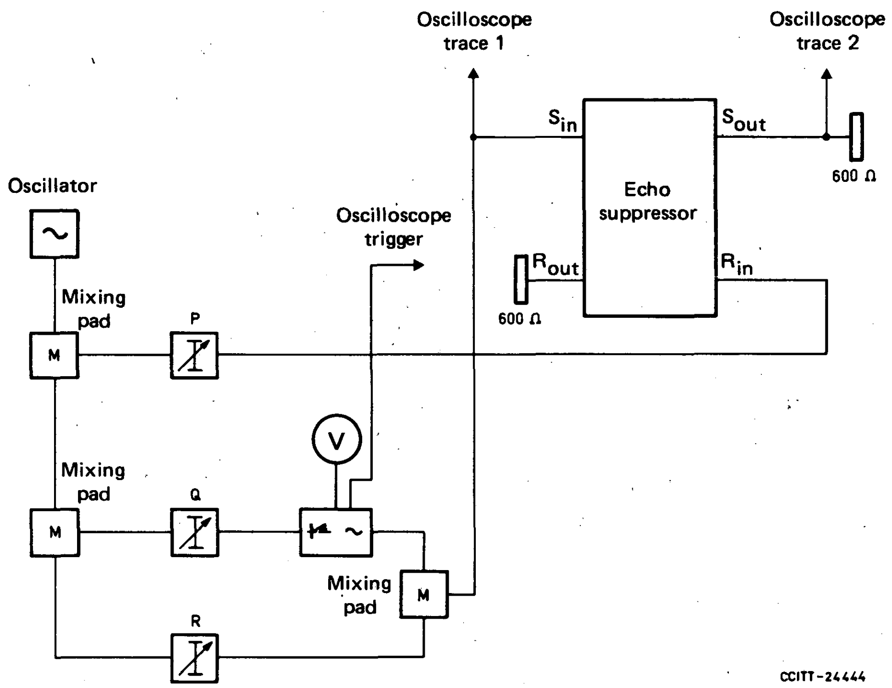
4) Starting with a 0 ms duration ON state for L_S, increase the duration of the ON state until partial break-in occurs. Partial break-in is characterized by the short operate and hangover times given in Tables 3 and 4/G.164. Note the oscilloscope traces in a) of Figure 17/G.164 for the definitions of the times.

5) Continue to increase the duration of L_S ON until full break-in, characterized by the extended operate and hangover times of Tables 3/G.164 and 4/G.164 occurs. Note the oscilloscope traces in b) of Figure 17/G.164 for the definitions of the times.

6) Repeat steps 3 to 5 for other pairs of levels given in Tables 3/G.164 and 4/G.164. Note that for all values of $L_R > -26.5$ dBm0 and L_S increasing from below threshold to a value $> L_R$, partial and full break-in should occur.

5.4 *Measurement of echo-suppressor operation when the S_{in} port is connected to the R_{out} port through an echo path that may include delay as well as loss*

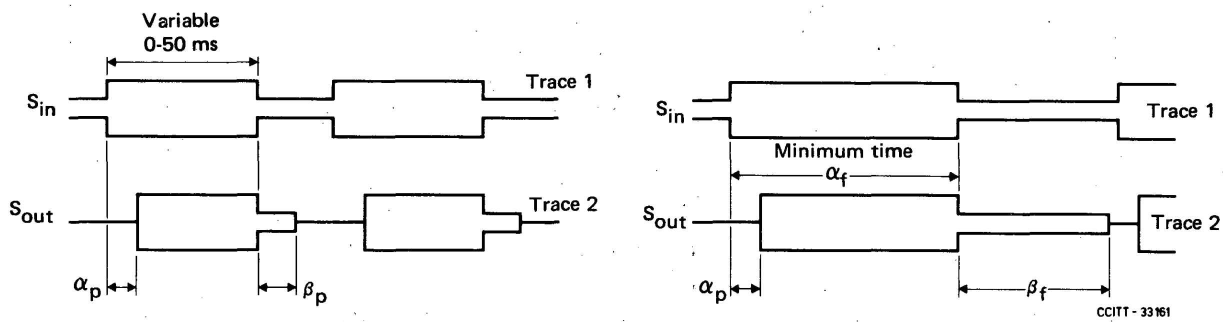
In this test, the echo suppressor is checked for false break-in on returning echo.



Note – Variable element V allows the ON and OFF times of the toneburst generator to be separately varied from 0 to 100 ms.

FIGURE 16/G.164

Test circuit for measurement of dynamic characteristics with constant L_R [break-in, Z/V/W, (Test No. 6)]



α_p Partial break-in operate time

β_p Partial break-in hangover time

a) Partial break-in

α_f Full break-in operate time. This time is the minimum duration of $L_S > L_R$ necessary to just cause the extended hangover time β_F characteristic of full break-in.

β_f Full break-in hangover time.

b) Full break-in

FIGURE 17/G.164

Trace for partial and full break-in operate and hangover times, L_R constant

5.4.1 *Test No. 7 – False operation of break-in*

The diagram of connections is shown in Figure 18/G.164, and the equipment required is:

– one oscillator with 600-ohm balanced output impedance;

– three 600-ohm balanced attenuators;

– one 600-ohm terminating resistor;

– two 600-ohm mixing pads;

– one tone-burst generator;

– one audio-frequency delay device variable in the range 0-24 ms;

– one dual beam oscilloscope.

1) Set oscillator to 1000 Hz, and delay element to zero delay (for tolerances, see § 5.1.4).

2) Adjust X so that the total loss of echo path (*a-t-b*) is equal to the difference in test levels on the send and receive path, plus 6 dB.

3) Adjust Y so that the OFF signal is –26 dBm0.

4) Adjust Z so that the ON signal is –20 dBm0.

5) While the pulsed signal is applied to the R_{in} port, check for absence of signal on Trace 2 of the oscilloscope, indicating correct operation.

6) Reduce X until false break-in occurs, and note that the decrease in echo path loss is not less than 2 dB.

7) Repeat steps 4, 5 and 6 with signals at R_{in} of –10 and 0 dBm0 when the pulse generator is ON.

8) Repeat steps 2, 4 and 7 with signals at R_{in} of –40 dBm0 when the pulse generator is OFF.

9) Repeat steps 2 to 8 with the delay set to 24 ms.

Note that false break-in should not occur for *any* pulsed pair of signal levels at the R_{in} port with the delay set at up to 24 ms, and the echo path loss 6 dB or greater.

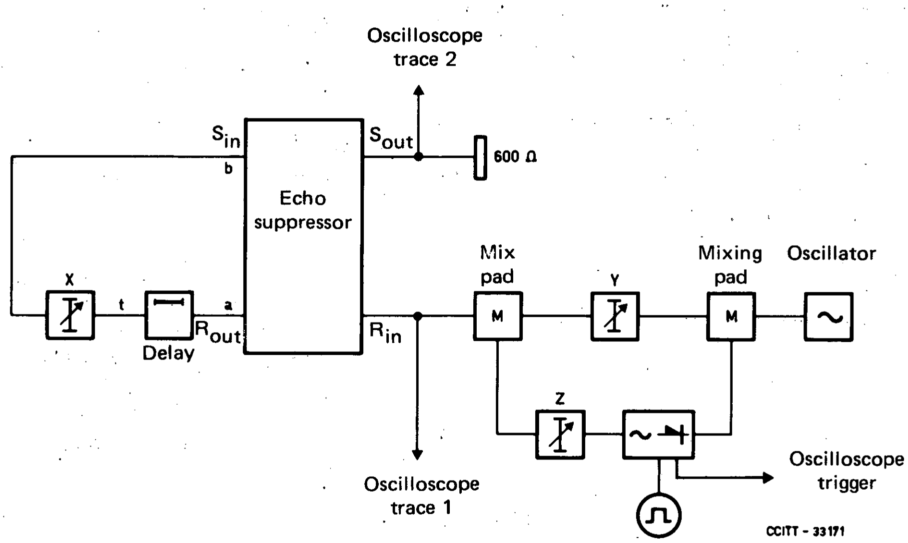


FIGURE 18/G.164

Test circuit for false break-in

5.4.2 *Test No. 8 – False retention of break-in due to provision of excessive hysteresis*

The diagram of connections is shown in Figure 19/G.164 and the equipment required is:

- one oscillator with 600-ohm balanced output impedance;
- three 600-ohm balanced attenuators;
- two 600-ohm mixing pads;
- one 600-ohm terminating resistor;
- one tone-burst generator;
- one amplifier (used as buffer);
- one dual beam oscilloscope.

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust Q so that the path loss between R_{out} and S_{in} is equal to the difference in test levels at these points plus 6 dB.

3) Adjust R so that $L_R = -28$ dBm0.

4) Adjust P so that $L_S \doteq (L_R + 3)$ dBm0.

5) Check that the signal on trace 2 of the oscilloscope is proper (see Figure 20/G.164) denoting non-occurrence of false retention of break-in.

6) Repeat steps 3 to 5 for values of L_R of −16 and 0 dBm0.

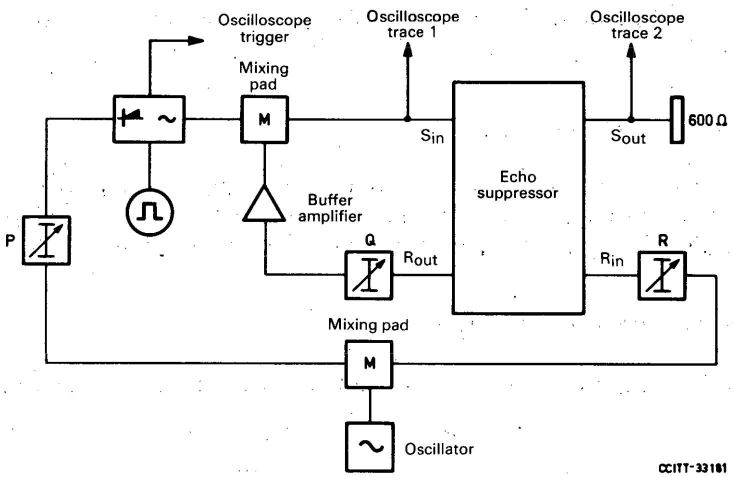


FIGURE 19/G.164

Test circuit for false retention of break-in due to provision to excessive hysteresis

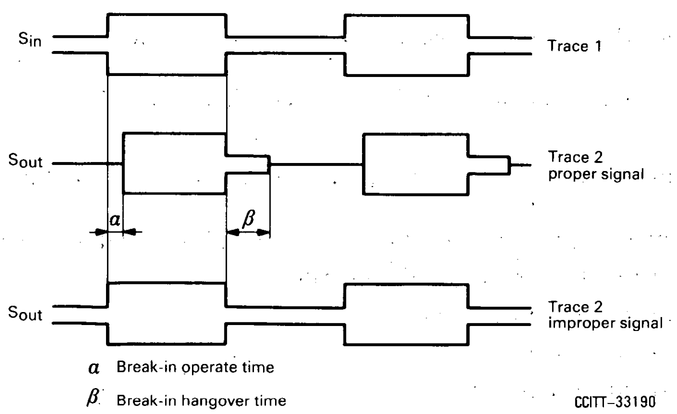


FIGURE 20/G.164

Traces for false retention of break-in due to provision of excessive hysteresis

ANNEX A

(to Recommendation G.164)

Adaptive break-in echo suppressors

The following information was provided by the French and German Administrations and by KDD (Japan).

The adaptive function of echo suppressors, as defined in § 2.6 of the Recommendation, may provide some improvement. Its break-in strategy is based on the fact that, in most cases, the mean value of attenuation of the echo path is higher than the minimum value of 6 dB. Fixed adjustment of the break-in sensitivity to the minimum value results in a low sensitivity threshold for activating the break-in functions. In that case a low level talker may have difficulty breaking-in. By adaptive adjustment of the sensitivity threshold of break-in to the real attenuation of the echo paths, an improvement in break-in operation is obtained.

Adaptive adjustment is considered an additional option for new designs of echo suppressors. The following additions to the text of Recommendation G.164 are provisionally recommended for adaptive echo suppressors (see Question 10/XV [6]).

A.1 *Definition: adaptive attenuation*

Controlled attenuation a_x in the receive control path of the logic circuitry for effecting the break-in function, automatically matched to the attenuation of the echo path.

A.2 *Improvement provided by the adaptive function*

Fixed adjustment of the echo suppressor according to the minimum possible attenuation of the echo path may result in a low sensitivity threshold for activating the break-in functions. By adaptive adjustment to the real attenuation of the echo path, this sensitivity may be improved, resulting in less speech mutilation during break-in.

A.3 *Definition of inter-area threshold level, Tv_iw_i*

For an adaptive echo suppressor, the Tv_iw_i threshold at every instant, i, is given by the following formula:

$$L_R - a_x - 3 \leqslant L_S \leqslant L_R - a_x$$

$$0 \leqslant a_x \leqslant a_E - 6 \text{ dB}$$

where

a_E is the real attenuation in the echo path.

The formula reduces to:

$$L_R - 3 \leqslant L_S \leqslant L_R \text{ when } a_x = 0.$$

A.4 *Characteristic of the adaptive attenuation, a_x* (See Table A-1/G.164)

For the definition of area boundaries see Figure A-1/G.164.

A.5 *Test methods* (for those parameters of the suppressors affected by the addition of the adaptive functions)

The diagram of connection is shown Figure A-2/G.164 and the equipment required is:

- one oscillator with 600-ohm balanced impedance;
- three 600-ohm balanced attenuators;
- three 600-ohm mixing pads;
- one amplifier (used for buffer);
- one dual beam oscilloscope;
- one level measuring set with 600-ohm balanced impedance;
- one tone-burst generator with period variable up to 10 sec.

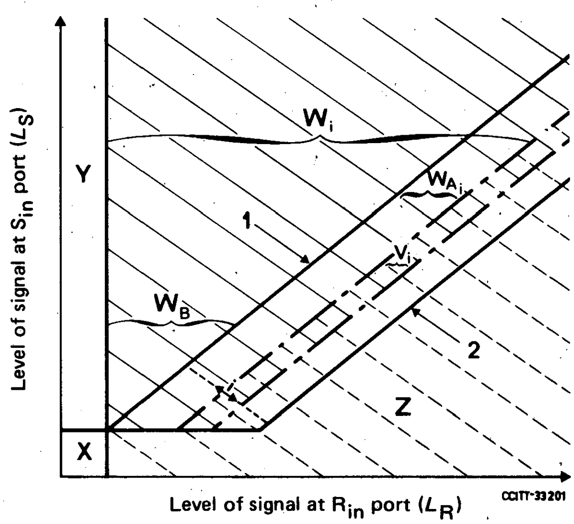
TABLE A-1/G.164

Operational area (see Figure A-1/G.164)	Attenuation characteristic, a_x	Time condition
Z	Increasing to maximum possible value of $a_E - 6$ dB	6 dB in $t_1 < 1.5$ s[a)]
Y	Last value is stored	–
W_{ai}	Decreasing to minimum possible value of 0 dB	6 dB in $t_2 < 1.5$ s[a)]
W_B	Last value is stored[b)]	–
X	Decreasing to minimum possible value of 0 dB	6 dB in $t_3 < 1.5$ s[a)]
V_i		As W_i, if entered from W As Z, if entered from Z

a) The optimum values t_1, t_2, t_3, are under study.

b) One Administration prefers to use the same procedure as in W_A area. More practical experience using the two methods is necessary.

Note – The minimum range of the adaptive attenuation, a_x, must be 20 dB.



Note 1 – $W_i = W_B + W_{A_i}$ and W_{A_i} varies at every instant i.

Note 2 – Line i ($L_S = L_R - a_x$) may vary between line 1 ($L_S = L_R$) and line 2 ($L_S = L_R - a_E + 3$).

FIGURE A-1/G.164

Area boundaries for adaptive echo suppressors

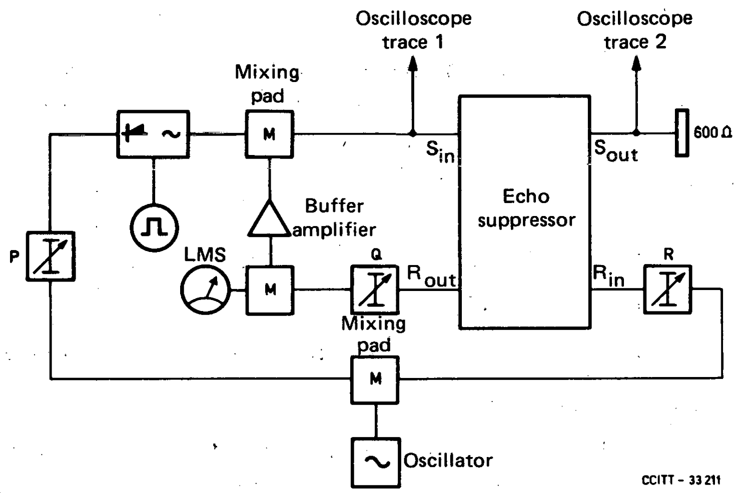


FIGURE A-2/G.164

Test circuit for adaptive break-in differential sensitivity and receive loss

A.5.1 *Static characteristics* (adaptive break-in area)

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust Q so that the attenuation a_E between R_{out} and S_{in} is equal to the difference in test levels at these points, plus 6 dB.

3) Adjust R so that $L_R = -15$ dBm0.

4) Using P, increase L_S until suppression is removed and loss is inserted in the receive path. Check on trace 2 of the oscilloscope (see Figure A-3/G.164) that T_{vw} satisfies

$$L_R - a_E + 3 \leqslant L_S \leqslant L_R - a_E + 6.$$

5) Using P, decrease L_S until suppression is inserted and loss is removed from the receive path. Check on trace 2 of the oscilloscope that T_{vz} satisfies $T_{vw} - C$.

6) Repeat the test procedure items 2 to 5 for $L_R = -8$ dBm0 and 0 dBm0.

7) Repeat the test procedure items 2 to 6 for $a_E = 15$ dB and for $a_E = 24$ dB.

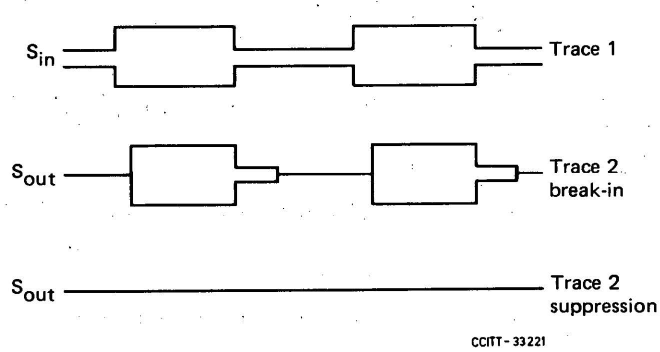


FIGURE A-3/G.164

Traces for adaptive break-in differential sensitivity (static characteristics)

A.5.2 *Static characteristics* (nonadaptive break-in area)

1) Set the oscillator to 1000 Hz (for tolerances see § 5.1.4).

2) Adjust Q so that $a_E = 15$ dB.

3) Adjust R so that $L_R = -26.5$ dB.

4) Using P, increase L_S until suppression is removed and loss is inserted in the receive path. Check on trace 2 of the oscilloscope (see Figure A-3/G.164) that T_{vw} satisfies $-29.5 \leqslant L_S \leqslant -26.5$.

5) Using P, decrease L_S until suppression is inserted and loss is removed from the receive path. Check that T_{vz} satisfies $T_{vw} - C$.

A.5.3 *Dynamic characteristics of echo suppressors*

1) Set the oscillator to 1000 Hz (for tolerances, see § 5.1.4).

2) Adjust Q so that $a_E = 20 \pm 2$ dB.

3) Adjust R so that $L_R = 0 \pm 2$ dBm0.

4) Adjust P so that $L'_s = -14 \pm 2$ dBm0.

5) Adjust t'_1 on trace 1 [see a) of Figure A-4/G.164] of oscilloscope to 3.5 s (see Note 1). Check that break-in disappears after T_1 on trace 2 (see Note 2).

6) Adjust t'_2 on trace 1 [see b) of Figure A-4/G.164] of oscilloscope to at least 4 s. Check that T_2 on trace 2 is less than 3.5 sec (see Note 1).

Note 1 – The value of 3.5 s is derived from the following formula:

$$\frac{a_E - 6}{6} \times t_{j\max}$$

where

$a_E = 20$ dB

$t_{j\max} = 1.5$ s

$j = 1$ or 2.

Note 2 – The end of break-in occurs when a_x has decreased to threshold level.

$$L_R - C - L_S - 3 \leqslant a_x \leqslant L_R - C - L'_S.$$

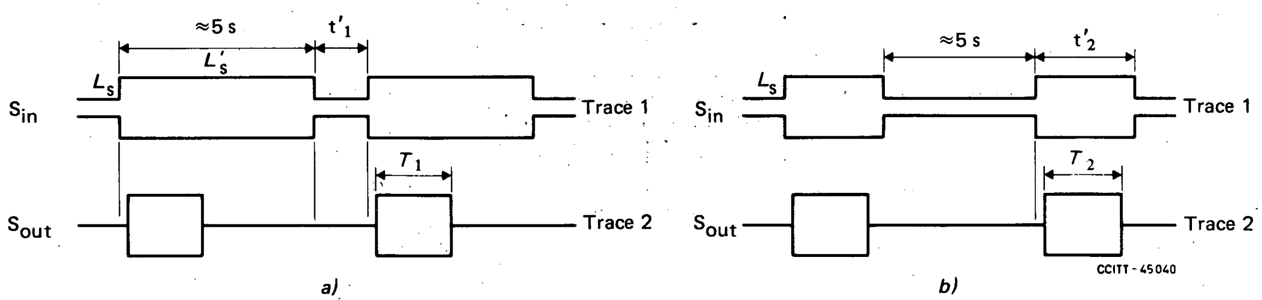


FIGURE A-4/G.164

Traces for dynamic characteristics of the echo suppressor

References

[1] CCITT Recommendation *Echo suppressors suitable for ciruits having either short or long propagation times*, Orange Book, Vol. III, Rec. G.161, ITU, Geneva, 1977.

[2] CCITT Recommendation *Influence of national networks on stability and echo in international connections*, Orange Book, Vol. III, Rec. G.122, Part B, b), ITU, Geneva, 1977.

[3] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Fascicle III.3, Rec. G.712.

[4] CCITT Recommendation *Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s*, Vol. III, Fascicle III.3, Rec. G.733.

[5] CCITT Recommendation *200-baud modem standardized for use in the general switched telephone network*, Vol. VIII, Fascicle VIII.1, Rec. V.21.

[6] CCITT Question 10/XV, Contribution COM XV-No. 1, Study Period 1981-1984, Geneva, 1981.

Recommendation G.165

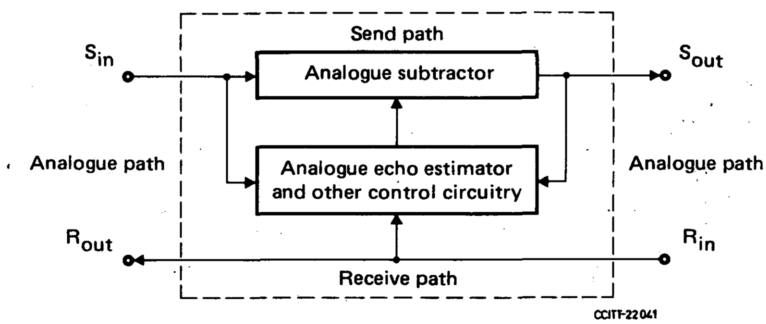
ECHO CANCELLERS

(Geneva, 1980)

1 General

1.1 Echo cancellers are voice operated devices placed in the 4-wire portion of a circuit (which may be an individual circuit path or a path carrying a multiplexed signal) and are used for reducing the echo by subtracting an estimated echo from the circuit echo. They may be characterized by whether the transmission path, the control functions and echo estimation are analogue or digital (see Figures 1/G.165, 2/G.165, 3/G.165 and 4/G.165).

1.2 This Recommendation is applicable to the design of echo cancellers using digital or analogue techniques. Echo cancellers designed to this Recommendation will be compatible with each other and with echo suppressors designed in accordance with Recommendations G.161 [1] and G.164. Compatibility is defined in Recommendation G.164 [2], § 1.3. Freedom is permitted in design details not covered by the requirements.



Abbreviations: Receive-in (R_{in}) Send-in (S_{in})
Receive-out (R_{out}) Send-out (S_{out})

FIGURE 1/G.165

Type A echo canceller

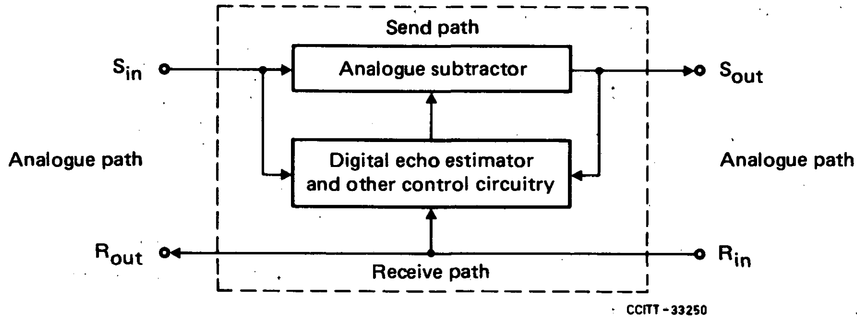
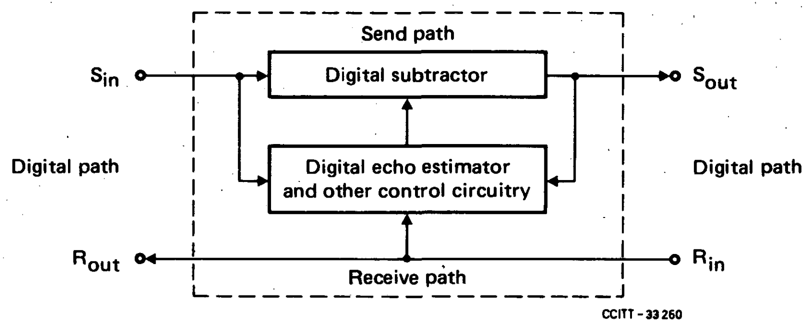


FIGURE 2/G.165

Type B echo canceller



Note – The digital path may be at any digital interface, i.e. 64 kbit/s, 1544 or 2048 kbit/s or at any higher order interface.

FIGURE 3/G.165

Type C echo canceller

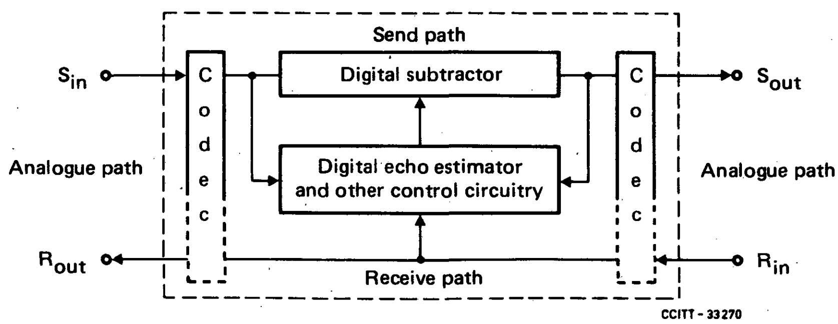


FIGURE 4/G.165

Type D echo canceller

2 Definitions relating to echo cancellers [1)]

In the definition and text, L will refer to the relative power level of a signal, expressed in dBm0 and A will refer to the attenuation or loss of a signal path expressed in dB.

2.1 echo canceller (see Figure 5/G.165)

F: compensateur d'écho

S: compensador de eco

A voice operated device placed in the 4-wire portion of a circuit (which may be an individual circuit path or a path carrying a multiplexed signal) and used for reducing the echo by subtracting an estimated echo from the circuit echo. (See Recommendation G.122, § 2.2.)

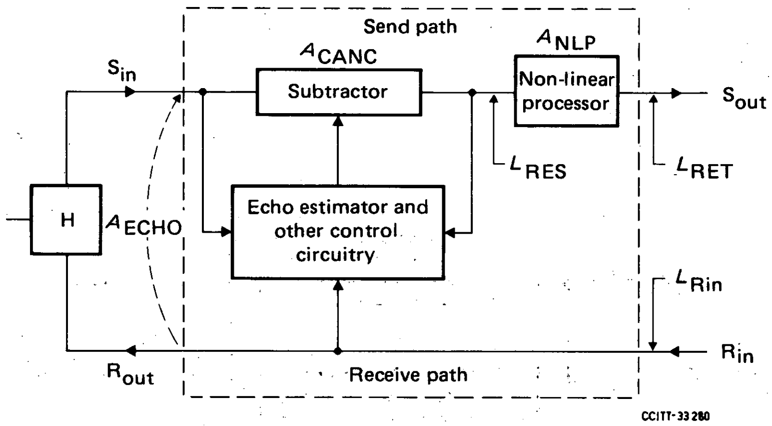


FIGURE 5/G.165

2.2 echo loss (A_{ECHO})

F: affaiblissement d'écho (A_{ECHO})

S: atenuación del eco (A_{ECO})

The attenuation of a signal from the receive-out port to the send-in port of an echo canceller, due to transmission and hybrid loss, i.e. the loss in the echo path.

2.3 cancellation (A_{CANC})

F: compensation (A_{COMP})

S: compensación (A_{COMP})

The attenuation of the echo signal as it passes through the send path of an echo canceller. This definition specifically excludes any nonlinear processing on the output of the canceller to provide for further attenuation.

2.4 residual echo level (L_{RES})

F: niveau d'écho résiduel (N_{RES})

S: nivel de eco residual (N_{RES})

---

1) These definitions assume that nonlinear processing, e.g. centre clipping, is not present in the send or receive paths unless otherwise specified and that the signal at the S_{in} port is purely echo.

The level of the echo signal which remains at the send-out part of an operating echo canceller after imperfect cancellation of the circuit echo. It is related to the receive-in signal L_{Rin} by

$$L_{RES} = L_{Rin} - A_{ECHO} - A_{CANC}$$

Any nonlinear processing is not included.

2.5 **nonlinear processing loss** (A_{NLP})

F: affaiblissement par traitement non linéaire (A_{TNL})

S: atenuación por procesos no lineales (A_{PNL})

Additional attenuation of the residual echo level by a nonlinear device (e.g. centre clipper) placed in the send path of an echo canceller.

Strictly speaking the attenuation of a nonlinear process cannot be characterized by a loss in dB. However, for purposes of illustration and discussion of echo canceller operation, the careful use of A_{NLP} is helpful.

2.6 **returned echo level** (L_{RET})

F: niveau de retour d'écho (N_{RET})

S: nivel del eco devuelto (N_{DEV})

The level of the signal at the send-out port of an operating echo canceller which will be returned to the talker. The attenuation of a nonlinear processor is included, if one is normally present. L_{RET} is related to L_{Rin} by

$$L_{RET} = L_{Rin} - (A_{ECHO} + A_{CANC} + A_{NLP}).$$

If nonlinear processing is not present, note that $L_{RES} = L_{RET}$.

2.7 **combined loss** (A_{COM})

F: affaiblissement combiné (A_{COM})

S: atenuación combinada (A_{COMB})

The sum of echo loss, cancellation loss and nonlinear processing loss (if present). This loss relates L_{Rin} to L_{RET} by,

$$L_{RET} = L_{Rin} - A_{COM}, \text{ where } A_{COM} = A_{ECHO} + A_{CANC} + A_{NLP}.$$

2.8 **centre clipping**

F: écrêtage du centre

S: limitación de amplitud en el centro de les señales

A nonlinear process used to increase the effective combined loss by forcing all signals which fall below a defined threshold to some minimum level.

2.9 **convergence**

F: convergence

S: convergencia

The process of developing a model of the echo path which will be used in the echo estimator to produce the estimate of the circuit echo.

2.10 **convergence time**

F: temps de convergence

S: tiempo de convergencia

For a defined echo path, the interval between the instant a defined test signal is applied to the R_{in} port of an echo canceller with an initially zero echo path model and the instant the returned echo level at the S_{out} port reaches a defined level.

2.11 **leak time**

F: temps de fuite

S: tiempo de fuga

The interval between the instant a test signal is removed from the receive-in port of a fully-converged echo canceller and the instant the echo path model in the echo canceller changes such that, when a test signal is reapplied to the R_{in} port with the convergence circuitry inhibited, the returned echo is at a defined level.

This definition refers to echo cancellers employing, for example, leaky integrators in the convergence circuitry.

3 Characteristics of echo cancellers

3.1 *General*

This Recommendation is applicable to the design of echo cancellers. The echo cancellers are assumed to be "half" echo cancellers, i.e. those in which cancellation takes place only in the send path due to signals present in the receive path.

3.2 *Purpose, operation and environment*

Echo, in any 2-wire or combination 2- and 4-wire telephone circuit, is caused by impedance mismatches. An echo canceller can be used to reduce this echo to tolerable levels.

The echo present at the send-in port of an echo canceller is a distorted replica of the incoming speech from the far end, i.e. the echo is the incoming speech as modified by the echo path. The echo path is commonly described by its impulse response (see Figure 6/G.165). This response of a typical echo path shows a pure delay due to the delays inherent in the echo path transmission facilities, and a dispersed signal due to band limiting and multiple reflections. The values of delay and dispersion will vary depending on the properties of the echo paths, e.g. they may vary for different national networks. It is assumed that the echo paths are linear and time invariant [2]. The loss of the echo path in dB (see Recommendation G.122, § 2.2) is likely to be such that the minimum loss from the R_{out} port to the S_{in} port of the echo suppressor will be equal to the difference between relative levels at these two ports plus 6 dB.

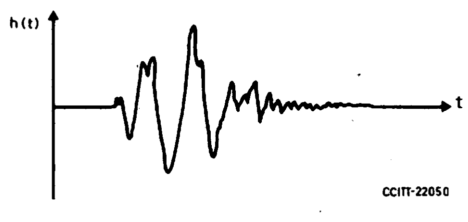


FIGURE 6/G.165

Example of an impulse response of an echo path

An echo canceller must be able to synthesize a replica of the echo path impulse response. Many echo cancellers model the echo path using a sampled data representation, the sampling being at the Nyquist rate (8000 Hz). Such an echo canceller, to function properly, must have sufficient storage capacity for the required number of samples [3]. Typically, too few storage locations will prevent adequate synthesis of all echo paths; too many storage locations will create undesirable additional noise due to the unused locations which, because of

[2] Echo cancellers designed specifically for echo paths which are nonlinear and/or time variant are likely to be much more complex than those not so designed. It is felt that insufficient information exists to include such echo cancellers in this Recommendation.

[3] Echo cancellers having storage capacities of 16 ms to 40 ms have been successfully demonstrated. Maximum end delay in the network in which the canceller will be used will determine the required storage capacity.

estimation noise, are generally not zero. It should be recognized that an echo canceller introduces an additional parallel echo path. If the impulse response of the echo path model is sufficiently different from the echo path impulse response, the total returned echo may be larger than that due to the echo path only.

The echo paths change as the echo canceller is used in successive connections. When speech first arrives at the R_{in} port, the echo canceller must adapt or converge to the new echo path, and it is desirable that this be fairly rapid, e.g. about one-half second. This is typically determined in large part by a feedback gain constant, K. Also the residual echo should be small regardless of the level of the receive speech and the characteristics of the echo path. Some Administrations feel that a slightly higher residual echo level may be permitted provided it is further reduced using a small amount of nonlinear processing, e.g. centre clipping (see § 5).

When there is receive speech and the near party begins to double talk, an echo canceller may interpret the transmit signal as a new echo signal and attempt to adapt to it. This can seriously degrade the subjective quality of the connection. Not only is the echo cancellation reduced but distortion of the double talking speech may occur as the echo canceller dynamically attempts to adapt. Two common approaches are taken as a solution. The first is to make the feedback gain constant, K, small so as to increase the effective averaging time. The second is to employ a double talk detector, similar to that used in echo suppressors. The echo canceller double talk detector, however, generally should favour break-in at the expense of false operation on echo. This differs from the double talk detector in an echo suppressor.

Thus, echo cancellers have the following fundamental requirements:

1) to converge rapidly;

2) to have a low returned echo level during single talking;

3) to diverge very little during double talking.

3.3 *Tests and requirements for performance with input signals applied to the send and receive paths*

3.3.1 *Transmission performance*

The appropriate transmission performance requirements of Recommendation G.164 also apply to echo cancellers except as noted below.

3.3.1.1 *Delay distortion – Types A and B (provisional)*

The delay distortion relative to the minimum delay shall not exceed the values given in Table 1/G.165.

TABLE 1/G.165

Frequency band (Hz)	Delay distortion (μs)
500 - 600	300
600 - 1000	150
1000 - 2600	50
2600 - 3000	250

3.3.1.2 *Attenuation distortion – Types A and B (provisional)*

The attenuation distortion shall be such that if Q dB is the attenuation at 800 Hz (or 1000 Hz) the attenuation shall be within the range (Q + 0.5) dB to (Q – 0.2) dB at any frequency in the band 300-3400 Hz and at 200 Hz, within the range of (Q + 1.0) dB to (Q – 0.2) dB.

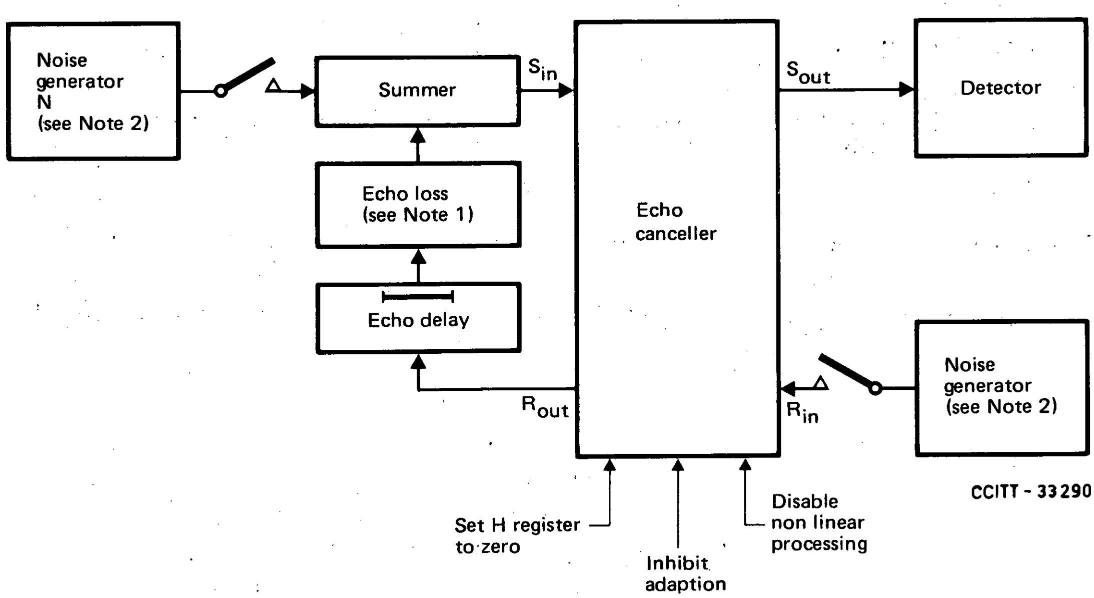
3.3.1.3 *Group delay – Types C and D (provisional)*

The group delay of processing in the send path shall not exceed 0.375 ms.

3.3.2 *Echo canceller performance (provisional)* [4)]

Experimental results obtained using two types of echo cancellers have been reported. One type uses nonlinear processing, i.e. centre clipping, to reduce the residual echo level (see reference [1]) while the second type may provide sufficient cancellation so that nonlinear processing need not be used (see reference [2]). The performance of these cancellers, as reported in references [3] and [4] has been shown to be significantly better than echo suppressors on long propagation delay circuits. The presence or absence of the nonlinear processing on the send path results in different objective measures of performance. The test requirements take this difference into account as noted in the individual tests. In the tests it is assumed that the echo path impulse response store (H register) can be cleared (set to zero) and that adaption can be inhibited.

The requirements are described in terms of tests made by applying signals to the R_{in} and S_{in} ports of an echo canceller, and mesasuring the S_{out} signals. The test set up is as shown in Figure 7/G.165. The ports are assumed to be at equal relative level points. Band limited white noise (300-3400 Hz) is used as the receive input test signal (see Note 2 to Figure 7/G.165).



Note 1 – The frequency shaping (impulse response) of the echo path used in these tests must be specified. This is under study.

Note 2 – The frequency weighting applied to the noise sources should be specified. Two suggestions are band limited white noise and noise shaped in accordance with Recommendation G.227 [5]. This is under study.

FIGURE 7/G.165

4) It should be noted that while the specified values are provisional, they are based upon measurements made using band limited white noise test signals on satisfactorily field tested echo cancellers (see Note 2 to Figure 7/G.165).

3.3.2.1 *Test No. 1 – Steady state residual and returned echo level test*

This test is meant to ensure that the steady state cancellation (A_{CANC}) is sufficient to either:

a) produce a residual echo level which is sufficiently low that further processing is not required; or

b) produce a residual echo level which is sufficiently low to permit the use of nonlinear processing without undue reliance on it.

The H register is initially cleared, a receive signal is applied for a sufficient time for the canceller to converge producing a steady state residual echo level.

Requirement (provisional)

With the H register initially set to zero, the nonlinear processor disabled, for all values of receive input signal level such that $L_{Rin} \geqslant -30$ dBm0 and $\leqslant -10$ dBm0 and for all values of echo loss $\geqslant$ 10 dB and flat echo delay $\leqslant \Delta$ms [5], the residual echo level should be (see Note 1):

a) $\leqslant L_{Rin} - K$ dB (see Note 2) if nonlinear processing is not used in the normal operating mode; or

b) $\leqslant -40$ dBm0 if nonlinear processing is used in the normal operating mode. When the nonlinear processor is enabled, the *returned echo level* must be less than -65 dBm0.

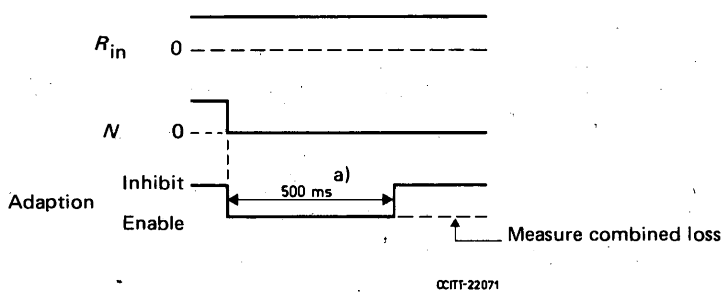
Note 1 – For $L_{Rin} < -30$ dBm0 the residual echo level for case a) should be $\leqslant -65$ dBm0; the returned echo level for case b) should be $\leqslant -65$ dBm0. The requirements for $L_{Rin} > -10$ dBm0 are under study.

Note 2 – Considering Recommendation G.111 [6], and informations received during the Study Period 1977-1980 a tentative value, K = 40 has been suggested. Further study may show that a different value of K is necessary.

3.3.2.2 *Test No. 2 – Convergence test*

This test is meant to ensure that the echo canceller converges rapidly for all combinations of input signal levels and echo paths and that the returned echo level is sufficiently low. The H register is initially cleared and adaption is inhibited. The double talk detector, if present, is put in the double talk mode by applying signals to the S_{in} and the R_{in} ports. The signal at S_{in} is removed and simultaneously adaption is enabled. The degree of adaption, as measured by the returned echo level, will depend on the convergence characteristics of the echo canceller and the double talk detection hangover time.

The test procedure is to clear the H register and inhibit adaption. Signal N is applied at a level -10 dBm0 and a signal is applied at R_{in}. Then N is removed and simultaneously adaption is enabled (see Figure 8/G.165). After 500 ms inhibit adaption and measure the returned echo level. If a nonlinear processor is used in normal operation, it should be enabled.



a) This valve is provisional. Upper and lower bounds for the convergence time are under study.

FIGURE 8/G.165

[5] Different echo cancellers may be designed to work satisfactorily for different echo path delays depending on their application in various networks. Thus Δ, whenever it appears in this Recommendation, represents the echo path delay for which the echo canceller is designed.

Requirement (provisional)

With the H register initially set to zero, for all values $L_{Rin} \geqslant -30$ dBm0 and $\leqslant -10$ dBm0 and present for 500 ms and for all values of echo loss $\geqslant$ 10 dB and flat echo delay $\leqslant \Delta$ ms, the combined loss ($A_{COM} = A_{ECHO} + A_{CANC} + A_{NLP}$) should be $\geqslant$ 27 dB.

3.3.2.3 *Test No. 3 – Performance under conditions of double talk (provisional)*

The two parts of this test are meant to test the performance of the canceller under various conditions of double talk. The tests make the assumption that, upon detection of double talk, measures are taken to prevent or slow adaption in order to avoid excessive reduction in cancellation.

3.3.2.3.1 Test No. 3a is meant to ensure that the double talk detection is not so sensitive that echo and low level near-end speech falsely cause operation of the double talk detector to the extent that adaption does not occur. The test procedure is to clear the H register; then for some value of echo delay and echo loss, a signal is applied to R_{in}. Simultaneously (see Figure 9/G.165) an interfering signal which is sufficiently low in level to not seriously hamper the ability of the echo canceller to converge, is applied at S_{in}. This signal should not cause the double talk detector to be activated, and adaption and cancellation should occur. After 1 s the adaption is inhibited and the residual echo measured. If a nonlinear process is used in normal operation, it should be *disabled.*

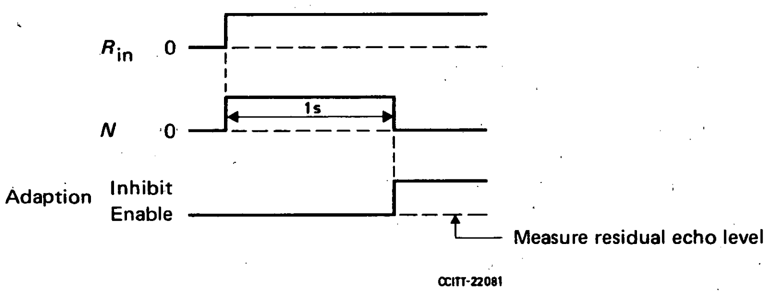


FIGURE 9/G.165

Requirement (provisional)

With the H register initially set to zero for all values of $L_{Rin} \geqslant -25$ dBm0 and $\leqslant -10$ dBm0, $N = L_{Rin} - 15$ dB, $A_{ECHO} > 6$ dB and flat echo delay $\leqslant \Delta$ ms, convergence should occur within 1.0 s and L_{RES} should be $\leqslant N$.

3.3.2.3.2 Test No. 3b is meant to ensure that the double talk detector is sufficiently sensitive and operates fast enough to prevent large divergence during double talking.

The test procedure is to fully converge the echo canceller for a given echo path. A signal is then applied to R_{in}. Simultaneously (see Figure 10/G.165) a signal N is applied to S_{in} which has a level at least that of R_{in}. This should cause the double talk detector to operate. After any arbitrary time, $\delta t > 0$, the adaption is inhibited and the residual echo measured. If a nonlinear process is used in normal operation, it should be *disabled.*

Requirement (provisional)

With the echo canceller initially in the fully converged state for all values of $L_{Rin} \geqslant -30$ dBm0 and $\leqslant -10$ dBm0, and for all values of $N \geqslant L_{Rin}$ and for all values of echo loss $\geqslant$ 10 dB and flat echo delay $\leqslant \Delta$ ms, the residual echo level after the simultaneous application of L_{Rin} and N for any time period should not increase more than 10 dB over the steady state requirements of Test No. 1.

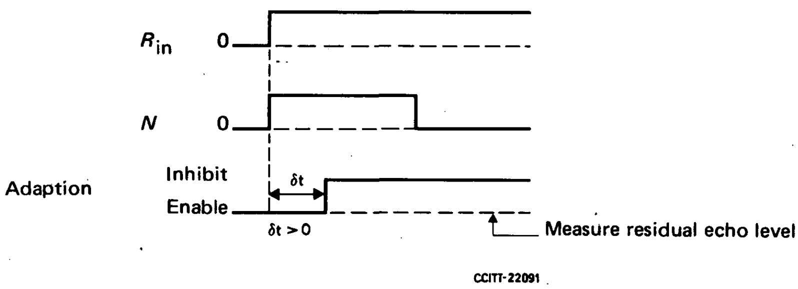


FIGURE 10/G.165

3.3.2.4 *Test No. 4 – Leak rate test*

This test is meant to ensure that the leak time is not too fast, i.e. that the contents of the H register do not go to zero too rapidly.

The test procedure is to fully converge the echo canceller for a given echo path and then to remove all signals from the echo canceller. After two minutes the contents of the H register are frozen, a signal applied to R_{in} and the residual echo measured (see Figure 11/G.165). If a nonlinear process is used in normal operation, it should be *disabled.*

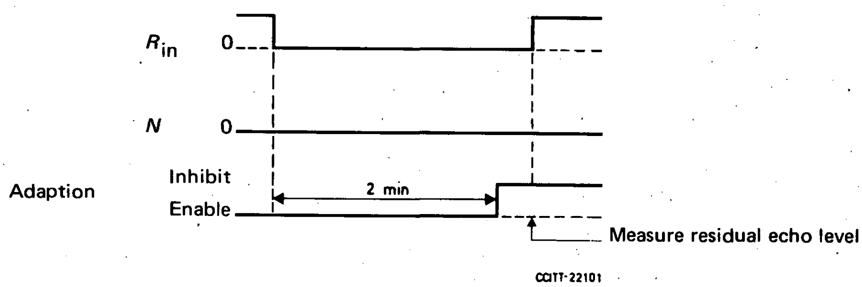


FIGURE 11/G.165

Requirement (provisional)

With the echo canceller initially in the fully converged state for all values of $L_{Rin} \geq -30$ dBm0 and ≤ -10 dBm0, two minutes after the removal of the R_{in} signal, the residual echo level should not increase more than 10 dB over the steady state requirement of Test No. 1.

3.3.2.5 *Test No. 5 – Infinite return loss convergence test*

This test is meant to ensure that the echo canceller has some means to prevent the unwanted generation of echo. This may occur when the H register contains an echo path model, either from a previous connection or the current connection, and the echo path is opened (circuit echo vanishes) while a signal is present at the R_{in} port.

The test procedure is to fully converge the echo canceller for a given echo path. The echo path is then interrupted while a signal is applied to R_{in}. 500 ms after interrupting the echo path the returned echo signal at S_{out} should be measured (see Figure 12/G.165). If a nonlinear process is in normal operation, it should be *disabled.*

Note – The value of 500 ms is provisional. Upper and lower bounds for the convergence time are under study.

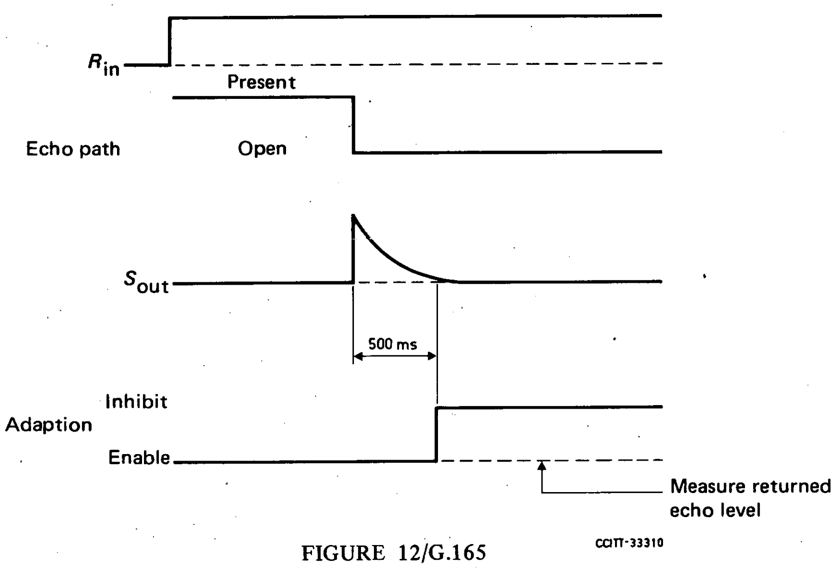


FIGURE 12/G.165

Requirement (provisional)

With the echo canceller initially in the fully converged state for all values of echo loss $\geqslant$ 10 dB, and for all values of $L_{Rin} \geqslant -30$ dBm0 and $\leqslant -10$ dBm0, the returned echo level at S_{out}, 500 ms after the echo path is interrupted, should be $\leqslant -40$ dBm0.

3.4 *External enabling/disabling*

An option should be included in the echo canceller to provide for enabling or disabling by an externally derived ground (earth) from the trunk circuit. The enabler should function to permit or prevent normal echo canceller operation. Certain type C echo cancellers may be disabled directly by a digital signal.

4 Characteristics of echo canceller tone disablers

If a tone disabler is used to disable an echo canceller for in-band data transmission, the tone disabler should conform to Recommendation G.164, § 4.

5 Characteristics of nonlinear processors

(Under study.)

References

[1] CCITT Recommendation Echo-suppressors suitable for circuits having either short or long propagation times, Orange Book, Vol. III.1, Rec. G.161, ITU, Geneva, 1977.

[2] HORNA, (O. A.): Echo Canceller with Adaptive Transversal Filter Utilizing Pseudo-Logarithmic Coding, *COMSAT Technical Review*, Vol. 7, No. 2, 1977.

[3] DUTTWEILER, (D. L.) and CHEN, (Y. S.): A Single-Chip VLSI Echo Canceller, *Bell System Technical Journal*, Vol. 59, No. 2, 1980.

[4] CANADA: BELL-NORTHERN RESEARCH/CANADIAN TELECOMMUNICATIONS CARRIERS ASSOCIATION: Subjective Performance Evaluations of Echo Control Devices on Terrestrial and Satellite Circuits, CCITT COM XV-No. 306, COM XII-No. 154, COM XVI-No. 105, 1977-1980.

[5] AMERICAN TELEPHONE AND TELEGRAPH: Satellite User Reaction Tests – A Subjective Evaluation of Echo Control Methods, CCITT COM XII-No. 165, XVI-No. 112, 1977-1980. To be published as *Bell System Technical Journal* article.

[6] CCITT Recommmendation *Conventional telephone signal*, Vol. III, Fascicle III.2, Rec. G.227.

[7] CCITT Recommendation *Reference equivalents in an international connection*, Orange Book, Vol. III, Rec. G.111, ITU, Geneva, 1977.

TRANSMISSION CHARACTERISTICS OF LEASED CIRCUITS FORMING PART OF A PRIVATE TELEPHONE NETWORK

(Geneva, 1980)

1 General

This Recommendation primarily concerns privately switched networks for telephony. In certain circumstances these networks may also be suitable for the transmission of analogue encoded data signals but no special arrangements have been made to ensure satisfactory performance in this respect.

It should be noted that not all Administrations provide such a facility. Others permit interconnection between private telephone networks and the public telephone network. In this latter case assurance cannot always be given that transmission performance to CCITT standards will be obtained.

It is not intended that this Recommendation should prevent the making of bilateral agreements for special network configurations. In such circumstances it is suggested that the network plans given here are used as a guide to permissible alternative arrangements.

2 Network configuration

Recommendations are made here concerning both 2-wire switched networks and 4-wire switched networks. For reasons of maintaining loss and distortion within reasonable limits, larger networks (e.g. more than three switched circuits in tandem – see § 4, *Note 3*) will need to use 4-wire tandem switching exchanges interconnected by 4-wire circuits. However, 2-wire switching nodes may still be employed in a predominantly 4-wire switched network (without undue penalty) provided that they are only used for switching originating and terminating traffic. A maximum of seven analogue circuits in tandem is permitted by the 4-wire switched plan. It is provisionally recommended that this allowance should be divided into three international circuits and two national circuits for each national extension.

3 Nominal transmission loss of international circuits

3.1 *Four-wire circuits*

Recommendation G.111 is applicable to this type of circuit and therefore the normal transmission loss at the reference frequency (800 Hz) between the virtual analogue switching points will be 0.5 dB for circuits employing analogue transmission. An indication of the locations of the virtual analogue switching points is also given in Recommendation G.111 and conceptually these will be at the private exchange on which the circuit terminates. Four-wire circuits should not contain 2-wire circuit sections.

3.2 *Two-wire presented circuits*

This nomenclature is intended to cover circuits which are not available with a 4-wire interface (e.g., circuits between 2-wire switching nodes).

For the purposes of this Recommendation the location of the virtual analogue switching points for this type of circuit can be considered as being adjacent to the 2-wire/4-wire terminating unit (4-wire side). It can then be treated in the same way as a 4-wire circuit.

Notes to § 3

Note 1 – The real loss of the circuit between actual switching points at the reference frequency cannot be exactly specified without prior knowledge of the switching levels.

Note 2 – Differences between the two directions of transmission in the real loss of the circuit may occur. The annexes to Recommendation G.121 examine this effect in some detail.

Note 3 – A circuit is defined as the complete transmission path between the switch points of the two private exchanges concerned.

4 Nominal transmission loss of national circuits

4.1 *Four-wire circuits*

The nominal loss at the reference frequency (800 Hz) should be 0 dB.

4.2 *Two-wire presented circuits*

This nomenclature is intended to cover circuits which are not available with a 4-wire interface (e.g., circuits between 2-wire switching nodes).

The nominal loss at the reference frequency (800 Hz) should not exceed 7 dB, and should preferably be lower, for example 3 or 4 dB.

Notes to § 4

Note 1 – Certain national arrangements may be encountered which require the nominal loss of 4-wire circuits to be 0.5 dB at the reference frequency.

Note 2 – Since leased circuits may contain circuit sections routed in local unloaded distribution cable pairs, care will be needed to ensure that there is an adequate stability bearing in mind the relative gain introduced by unloaded cable pairs.

Note 3 – The total nominal loss of the circuits forming the connection for any possible switched combination should not exceed 15 dB. In the case of 2-wire switched networks, this will permit either a maximum of two international circuits in tandem or one international and two national circuits in tandem provided that the national circuits each have a loss of 4 dB or less. Should either of the national circuits have a nominal 2-wire/2-wire loss at the reference frequency greater than 4 dB (as may be required for stability reasons or for some national practices), the network will then be limited to a maximum of two circuits in tandem.

5 Stability

5.1 *National 2-wire presented circuits*

Provisionally the nominal loss around the 4-wire loop should not be less than 6 dB at any frequency in the band 0 to 4 kHz, for all the terminal conditions encountered in normal operation (e.g., including the set-up phase of the connection).

5.2 *Terminating systems for international circuits*

National terminating systems which interface with international circuits should comply with the stability requirements of Recommendation G.122. In the case of 2-wire presented international circuits, the virtual analogue switching points can be considered as being adjacent to the 2-wire/4-wire terminating unit (4-wire side).

Notes to § 5

Note 1 – The note to Recommendation G.122, § 1.1 gives general guidance to the stability loss above and below the band 300 to 3400 Hz.

Note 2 – In order to obtain the recommended value of stability on 2-wire presented low-loss (e.g. 3 dB) circuits, it will be necessary for the 2-wire/4-wire terminating units to be located at the private exchanges. This may not be necessary on circuits with a higher nominal loss. The CCITT manual cited in [1] gives guidance on this topic.

6 Corrected reference equivalents (CREs) of extension circuits

6.1 *Loading*

Administrations must ensure that the technical arrangements that they authorize in respect of operating levels, sensitivities, etc. for private networks are not in conflict with the design criteria of the international transmission system. Attention is drawn to Recommendation G.121, § 3, which specifies a nominal minimum value of 4 dB sending CRE (6 dB sending reference equivalent) referred to the virtual analogue switching point.

6.2 *Sending CRE*

The maximum sending CRE of the 2-wire telephone extension circuit (that portion analogous to the local telephone circuit in the public network) should not exceed 15.5 dB (12-dB sending reference equivalent). This value is in accord with the example of a maximum local telephone circuit used in Figure 1/G.103. In practice, it is to be expected that most sending reference equivalent values will be considerably lower than this limit.

Administrations should attempt to choose values such that they comply with the preferred long-term objective of Recommendation G.121, § 1 (value referred to the virtual analogue switching point).

6.3 *Receiving CRE*

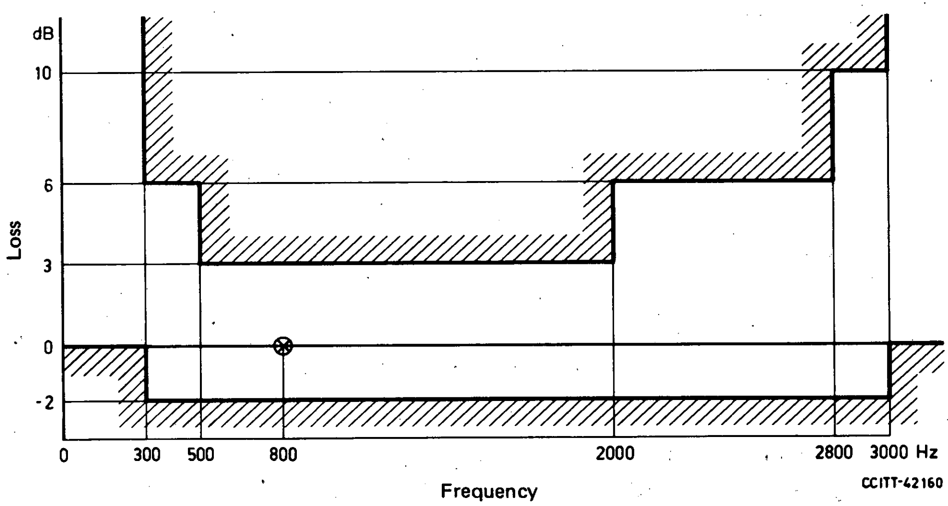
The maximum receiving CRE of the 2-wire extension circuit (that portion analogous to the local telephone circuit in the public network) should not exceed 4 dB (3-dB receiving reference equivalent). This value is in accord with the example of a maximum local telephone circuit used in Figure 1/G.103. In practice it is to be expected that most receiving reference equivalent values will be considerably lower than this limit although due account must be taken of the need to preserve adequate margins against excessive noise, crosstalk and sidetone.

Administrations should attempt to choose values such that they comply with the preferred long-term objective of Recommendation G.121, § 1 (values referred to the virtual analogue switching point).

7 **Loss/frequency distortion**

7.1 *Four-wire circuits*

The loss/frequency distortion of each two-wire presented circuit should not exceed the limits shown in Figure 1/G.171. These limits are also applicable to the 4-wire portion of the circuit if exceptionally it is terminated in a 2-wire switching mode (see § 2).



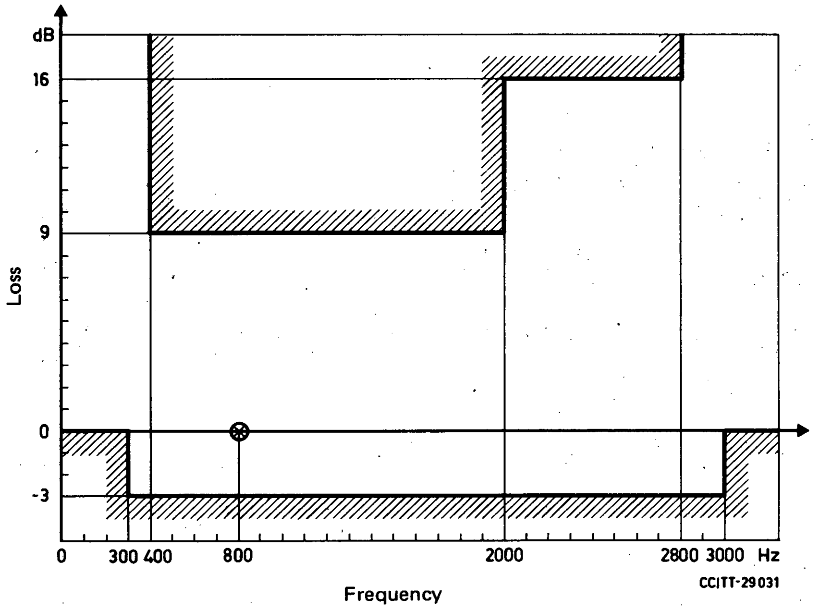
Note – The figures of 300 Hz and 3 kHz for the limitation of edge-band gain are provisional because Recommendation G.232 [2] permits a wider frequency range for FDM terminal equipment.

FIGURE 1/G.171

Limits for overall loss of the circuit relative to that at 800 Hz for 4-wire circuits

7.2 *Two-wire presented circuits*

The loss/frequency distortion of each 2-wire presented circuit should not exceed the limits shown in Figure 2/G.171.



Note – The figures of 300 Hz and 3 kHz for the limitation of edge-band gain are provisional because Recommendation G.232 [2] permits a wider frequency range for FDM terminal equipment.

FIGURE 2/G.171

Limits for overall loss of the circuit relative to that at 800 Hz for 2-wire presented circuits

8 Noise

The requirements of the relevant Recommendations should be met in respect of noise by each of the circuit sections and Recommendations G.123 and G.143, § 1 give some general guidance on system noise characteristics. The nominal level of random noise power at the private exchange will depend upon the actual constitution of the circuit but should not exceed –38 dBm0p (provisional maintenance limit for circuits longer than 10 000 kilometres). In practice circuits of shorter length will exhibit substantially less random noise. Figure 3/G.171 serves as a guide to the expected performance.

9 Echo control

9.1 The provisions of Recommendations G.122, § 2 and G.131, § 2 concerning echo control should be observed insofar as they are applicable.

9.2 It is recommended that when echo control devices (e.g., echo supressors or echo cancellors) are necessary they be fitted at the private and not at the terminal international centre. In this way the problems of end delay are avoided.

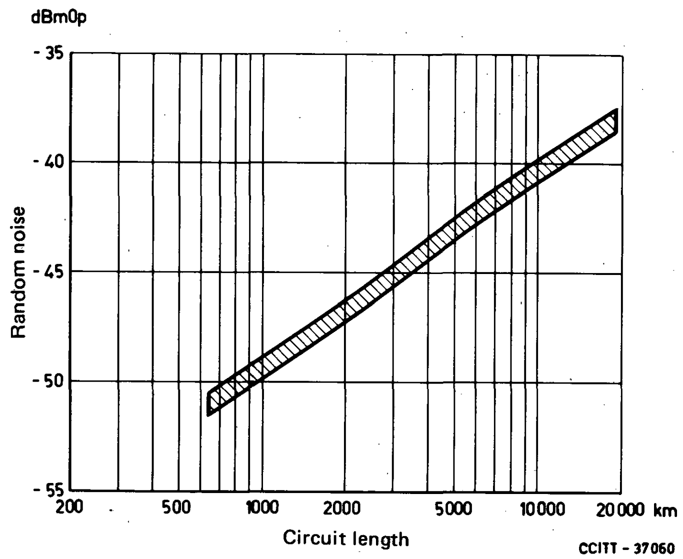


FIGURE 3/G.171

Random noise circuit performance

References

[1] CCITT manual *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

[2] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232.

APPENDIX I TO SECTION 1 OF VOLUME III

Justification for the values of CRE appearing in Recommendations G.111 and G.121

I.1 *Principles*

In redrafting Recommendations G.111 and G.121 on the basis of corrected reference equivalent (CRE), the following two principles have been observed:

a) Administrations which use planning methods based on the previous Recommendations should not have any serious difficulties in applying the new Recommendations;

b) The quality of transmission provided for subscribers must not deteriorate.

The following sections show how these principles were applied to derive the values of CRE now appearing in these Recommendations, from the values of reference equivalent given in the Orange Book.

I.2 *Preferred values (G.111, § 3.2)*

The old Recommendation indicated a "preferred range of overall reference equivalents" q_c of about 6-18 dB, with a preferred value of about 9 dB. In fact, if we consider, for example, the tests conducted in the United Kingdom described in [1], we find that:

$$q_c = q_s + q_r + x$$

where

$q_s = +7$ dB and $q_r = -2$ dB are the reference equivalents (sending and receiving) of the local systems and x the loss between these two systems.

Since no filter is inserted in these tests, we get $D = -3.9$ dB according to Table A-2/G.111 and $y_s = 8.9$, $y_r = -1.8$ according to formula (A-1) of Annex A to Recommendation G.111 and hence (A-2 of that annex) $Y_c = 8.9 + x - 1.8 - 3.9 \sim q_c - 2$ dB.

The preferred value $Y_1 = 9 - 2 = 7$ dB is equal to the minimum CRE of the sending system (§ I.5) and therefore the lower limit $Y_0 = 4$ dB seems to be of little practical value for planning.

The upper limit $Y_2 = 18 - 2 = 16$ dB is important for what follows.

Note – The symbol Y is used for the CRE of connections or national systems, y is restricted to values for local systems, derived from reference equivalent values by formula (A-1).

I.3 *Nominal maximum values for national systems (G.121, § 2.1)*

Let us consider national systems barely satisfying the limits of old Recommendation G.121 for the reference equivalent (RE) planning values in Table I-1. Case 1 corresponds to a typical distribution of the REs and attenuations in the old transmission plan; cases 2 and 3 correspond approximately to the extreme distributions which may occur in practice.

TABLE I-1
Calculation of CREs of a national system (in dB)

Part of the system	Case 1		Case 2		Case 3	
	RE	CRE	RE	CRE	RE	CRE
Local sending system (a)	10	12.8	17.5	23.1	5	6.4
Unloaded trunk junction (b)	3.5	4	0	0	7	8
Trunk junction with low distortion + Long-distance circuits + Exchanges and terminal unit (c)	Attenuation 7.5	7.5	3.5	3.5	9	9
Total, sending ($a + b + c$)	21	24.3	21	26.6	21	23.4
Local receiving system (d)	1	1.6	8.5	10.8	– 4	– 4.0
Total, receiving ($b + c + d$)	12	13.1	12	14.3	12	13.0

Corresponding values of y have been calculated for local systems (a and d) by formula (A-1) of Annex A to Recommendation G.111 and for the trunk junction (b) in accordance with Annex C to Recommendation G.121 with K = 1.15.

The overall CRE values are found to vary by about 3 dB for sending and 1 dB for receiving systems. An easy method satisfying condition a) in § I.1 would be to recommend the highest values, but this might fail to meet condition b).

Also, the values for (a) apply to the case of a linear microphone; they must be reduced by 1.5 dB for carbon microphones, which have actually been used in the past to choose the old limits, but a single limit (irrespective of the type of microphone) must be chosen to keep the same quality of transmission.

It was therefore felt desirable to recommend $Y_3 = 25$ dB for sending and $Y_4 = 14$ dB for receiving as limits. Note 1 to Figures 1/G.121 and 2/G.121 in § 2 of the revised text of Recommendation G.121 mentions the problems which may arise when applying these values.

I.4 *Traffic-weighted mean values (G.111, § 3.2 and G.121, § 1)*

I.4.1 The maximum value of reference equivalent for the *long-term objective* ($q_c = 18$ dB) was the maximum value of the preferred range. The corresponding value of Y_c is 16 dB. If it is assumed that attenuation distortion in this case corresponds to D = –1.5 dB, the objective may be broken down into $Y_5 = 13$ dB for sending, $Y_6 = 4$ dB for receiving, and 0.5 dB for an international circuit.

The minimum value corresponds to what is considered feasible. With the notations of Table I-1, the typical distribution of Table I-2 may be obtained for q and the CRE values may be deduced from it.

TABLE I-2

Typical distribution of the minimum objective

	Transmission		Reception	
	q	CRE	q	CRE
a	5	$y = 6.4$		
b	0	0		
c	5	5		
Total sending $a + b + c$	10	$Y_7 = 11.4$		
d			−2.5	$y = -2.4$
Total reception $b + c + d$			2.5	$Y_8 = 2.6$

For the connection, we shall obtain $Y_9 = 11.4 + 2.6 + 0.5 - 1.5 = 13$ dB.

I.4.2 For the *short-term objective* the minimum value is the same. The maximum reference equivalents ($q_s = 16$, $q_r = 6.5$) had been deduced from a typical distribution law; they were 5 dB and 5.5 dB below the 97% values previously recommended. The dispersion of the values of Y should be slightly greater, about 5×1.2 or 5.5×1.2, or 6-6.5 dB, hence

$Y_{10} = 25 - 6 = 19$ dB for sending,

$Y_{11} = 14 - 6.5 = 7.5$ dB for reception.

The value for a connection (with a single international circuit) is

$Y_{12} = 19 + 7.5 + 0.5 - 1.5 = 25.5$ dB.

I.5 *Minimum CREs for the national sending system (G.121, § 3)*

$q = 6$ dB, with the notations of Table I-1 might correspond, for example,

to $a = 2.5$ $b = 0$ $c = 3.5$, hence $Y = 3.4 + 3.5 = 6.9$
or $a = 4$ $b = 0$ $c = 2$, hence $Y = 5.2 + 2 = 7.2$

$Y_{13} = 7$ dB may be taken as a minimum.

I.6 *Sidetone reference equivalent (G.121, § 5)*

Until a complete reply to Question 9/XII [2] is available, the method of Recommendation P.73 [3] and the present value expressed as a reference equivalent should be retained.

I.7 *Other values*

Several Recommendations contain "echo path reference equivalents" (G.131), "cross-talk reference equivalents" (G.116), which were certainly calculated by inexact addition. A note should be inserted to that effect, without changing the present terms and these texts should be revised during the coming study period.

References

[1] RICHARDS (D. L.): Telecommunication by Speech, *Butterworths*, pp. 279-281, 1973.

[2] CCITT Question 9/XII, Contribution COM XII-No. 1, Study Period 1981-1984, Geneva, 1981.

[3] CCITT Recommendation *Measurement of the sidetone reference equipment*, Vol. V, Rec. P.73.

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PART II

SUPPLEMENTS TO SECTION 1
OF THE SERIES G RECOMMENDATIONS

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TALKER ECHO ON INTERNATIONAL CONNECTIONS

(Geneva, 1964, amended at Mar del Plata, 1968 and Geneva, 1976 and 1980; referred to in Recommendation G.131, § 2)

The curves of Figure 2/G.131 may be used to determine whether a given international connection requires an echo suppressor. Alternatively they may be used to find what value of nominal overall transmission loss shall be adopted for the 4-wire chain of a complete connection so that an echo suppressor is not needed. Before the curves can be used it must be decided what proportion of calls are to be allowed to exhibit an objectionable echo and Recommendation G.131, § 2, gives guidance on this matter.

The coordinates of the graph represent two of the parameters of a telephone connection that govern echo, i.e. the reference equivalent of the echo path and the mean one-way propagation time. By making certain assumptions (discussed below) these two parameters become the principal ones.

Each curve divides the coordinate plane into two portions and the position, relative to the curve, of the point describing the connection indicates whether an echo suppressor is needed, bearing in mind the percentage of calls permitted to exhibit an objectionable echo.

Factors governing echo

The principal factors which must be considered in order to decide whether an echo suppressor is needed on a particular connection are:

a) the number of echo paths;

b) the time taken by the echo currents to traverse these paths;

c) the reference equivalent of the echo paths including the subscriber lines;

d) the tolerance to echo exhibited by subscribers.

These factors are discussed in turn in the following.

When circuits are switched together 4-wire there is only one echo path, assuming negligible go-to-return crosstalk. This is also substantially true if the circuits are switched together 2-wire. Reasonable values of echo return losses are achieved at the connection points, because the principal echo currents are those due to the relatively poor echo return losses at the ends of the two extreme 4-wire circuits, where the connection is reduced to 2-wire.

The time taken to traverse the echo path is virtually dependent solely on the length of the 4-wire connection, because the main circuits of modern national and international networks are high-velocity circuits.

The reference equivalent of the talker echo path for a symmetrical connection is approximately given by the sum of:

– twice the transmission loss of the connection between the 2-wire point in the talker's local terminal exchange and the 2-wire side of the 4-wire/2-wire terminating set at the listener's end;

– the echo balance return loss at the listener's end; and

– the sum of the sending and receiving reference equivalents of the talker's telephone and subscriber line.

In general, values of reference equivalents corresponding to low-loss subscriber lines should be used.

The echo experienced by subscribers on lines with more loss will be further attenuated. This is therefore a safe assumption.

The echo return loss is assumed to have a mean value of not less than 11 dB, with a standard deviation of 3 dB expressed as a weighted mean-power ratio over the band 500-2500 Hz. The mean value of the transmission loss is assumed to be uniform over this band and the standard deviation of transmission loss for each 4-wire circuit is assumed to be 1 dB for each direction of transmission. The correlation between the variations of loss of the two directions of transmission is assumed to be unity.

The data on tolerance to echo exhibited by subscribers given in Table 1 are furnished by the American Telephone and Telegraph Co. and are based on a series of studies completed in 1971. These tests provided information on the reference equivalent of the echo path for echo, just detectable, as a function of echo-path delay. In addition, ratings of quality on a five-point scale (excellent, good, fair, poor, unsatisfactory) were also obtained. Table 1 indicates the mean echo path loss for the threshold of detectability and for ratings of unsatisfactory. These mean values are the reference equivalent of the echo path for 50% detectability and 50% unsatisfactory. The standard deviation is also given.

TABLE 1
Results of echo tolerance tests

One-way propagation time (ms)	Reference equivalent of echo path			
	Threshold		Unsatisfactory	
	Mean (dB)	Standard deviation (dB)	Mean (dB)	Standard deviation (dB)
10	26	≃ 4	9	≃ 6
20	35	≃ 4	16	≃ 6
30	40	≃ 4	20	≃ 6
40	45	≃ 4	23	≃ 6
50	50	≃ 4	25	≃ 6

Construction of Figure 2/G.131

The mean margin against poor or unsatisfactory echo performance is given by:

$$M = 2T + B - E + SRE + RRE$$

where

T = mean transmission loss of the connection between the 2-wire point in the talker's local terminal exchange and the 2-wire side of the 4-wire/2-wire terminating set at the listener's end. The loss is assumed to be the same in both directions of transmission;

B = mean echo balance return loss at the listener end;

E = mean value of reference equivalent of the echo path required for an opinion rating of unsatisfactory [1)]

1) This corresponds to the value of reference equivalent of the echo path at which 50% of the opinion ratings are unsatisfactory.

SRE = sending reference equivalent to the 2-wire point in the originating local exchange for short subscriber lines;

RRE = receiving reference equivalent to the 2-wire point in the originating local exchange for short subscriber lines.

The standard deviation of the margin is given by:

$$m^2 = n(t^2_1 + 2rt_1 t_2 + t^2_2) + b^2 + e^2$$

where

m = standard deviation of the margin;

t_1, t_2 = standard deviation of the transmission loss in the two directions of transmission of one 4-wire circuit, national or international;

b = standard deviation of echo balance return loss;

e = standard deviation of the distribution of reference equivalents echo path required for opinion ratings of unsatisfactory;

r = correlation factor between t_1 and t_2;

n = the number of 4-wire circuits in the 4-wire chain.

Inserting $t_1 = t_2 = 1$ dB; $r = 1$; $b = 3$ dB; $e = 6$ dB gives $m^2 = (4n + 45)$.

In Recommendation G.131, § 2.3, Rules A and E refer to 1% and 10% probabilities of encountering unsatisfactory echo and for these cases nine 4-wire circuits will be assumed (3 national + 3 international + 3 national). For both the 1% and 10% curves therefore $m = 9.0$ dB.

For 10% probability, the margin may fall to 1.28 times the standard deviation. The corresponding factor for the 1% curve is 2.33. Hence the corresponding values of M are:

$M = 1.28 \times 9.0$ dB $= 11.5$ dB for 10% probability
$M = 2.33 \times 9.0$ dB $= 21$ dB for 1% probability.

Putting these values into $M = 2\,T + B - E + SRE + RRE$ gives the following values for the mean talker echo attenuation, $2\,T + B + SRE + RRE$.

$2\,T + B + SRE + RRE = 11.5$ dB $+ E$ for 10% probability
$2\,T + B + SRE + RRE = 21$ dB $+ E$ for 1% probability.

The values in Table 2 have been calculated (to the nearest whole decibel) using these equations. The figures in the length of connection column have been calculated assuming a velocity of propagation of 160 km/ms.

TABLE 2

Mean one-way propagation time (ms)	Length of connection (km)	Reference equivalent of mean echo path $2T + B + SRE + RRE$ (dB)	
		10% unsatisfactory	1% unsatisfactory
10	1600	21	30
20	3200	28	37
30	4800	32	41
40	6400	35	44
50	8000	37	46

Figure 2/G.131 has been constructed from these values and similar values calculated for other values of n.

POSSIBLE COMBINATIONS OF BASIC TRANSMISSION IMPAIRMENTS IN HYPOTHETICAL REFERENCE CONNECTIONS

(Geneva, 1980; quoted in Recommendation G.103)

TABLE 1

Connection	Fig. 1/G.103		Fig. 2/G.103		Fig. 3/G.103	
Transmission plan	a)	b)	a)	b)	a)	b)
CRE – max. s = 15.4 dB r = 4.0 dB	41.6 dB		37.6 dB	35.6 dB	26.9 dB	24.9 dB
– mean s = 8.9 dB r = 0.5 dB	25.6 dB		22.0 dB	20.0 dB	14.5 dB	12.5 dB
– min. s = 8.9 dB r = –4.0 dB	15.6 dB		10.7 dB	8.7 dB	10.0 dB	8.0 dB
RE – max. s = 12 dB r = 3 dB	36 dB		33.5 dB	31.5 dB	24 dB	21 dB
– mean s = 7 dB r = 0 dB	23 dB		20.5 dB	18.5 dB	16 dB	13 dB
– min. s = 7 dB r = –4 dB	15 dB		12.5 dB	10.5 dB	12 dB	9 dB
CN – max. r′ = 3 dB r′ = 0 dB r′ = –4 dB	3 690 pWp 7 360 pWp 18 490 pWp	3 840 pWp 7 680 pWp 19 190 pWp	820 pWp 1 640 pWp 4 110 pWp	1 030 pWp 2 060 pWp 5 150 pWp	3 320 pWp 6 650 pWp 16 620 pWp	4 630 pWp 9 260 pWp 23 160 pWp
– mean r′ = 0 dB	3 100 pWp	3 220 pWp	730 pWp	870 pWp	3 320 pWp	4 630 pWp
CN – max. r′ = 3 dB r′ = 0 dB r′ = –4 dB	–54.3 dBmp –51.3 dBmp –47.3 dBmp	–54.1 dBmp –51.1 dBmp –47.1 dBmp	–60.8 dBmp –57.8 dBmp –53.8 dBmp	–59.9 dBmp –56.9 dBmp –52.9 dBmp	–54.8 dBmp –51.8 dBmp –47.8 dBmp	–53.3 dBmp –50.3 dBmp –46.3 dBmp
– mean r′ = 0 dB	–55.1 dBmp	–54.9 dBmp	–61.4 dBmp	–60.6 dBmp	–54.8 dBmp	–53.3 dBmp
AD – max. (see Note 1)	14 aadu (4 + 6 + 4)		5 aadu (2 + 1 + 2)		4 aadu (0 + 4 + 0)	
– mean	5 aadu (2 + 1 + 2)		5 aadu* (2 + 1 + 2)*		1 aadu* (0 + 1 + 0)*	
– min.	3 aadu (1 + 1 + 1)		3 aadu (1 + 1 + 1)		1 aadu (0 + 1 + 0)	

Note 1 – Case a): transmission plan based on (3.5 + 0 × n) dB rule.
Case b): transmission plan based on (2 + 0.5 × n) dB rule.

Note 2 – AD means attenuation distortion in aadu (analog attenuation distortion unit) in a chain of assumed 4-wire circuits between two local exchanges.

Note 3 – A mark* signifies an entry assumed.

Note 4 – r′ means RRE.

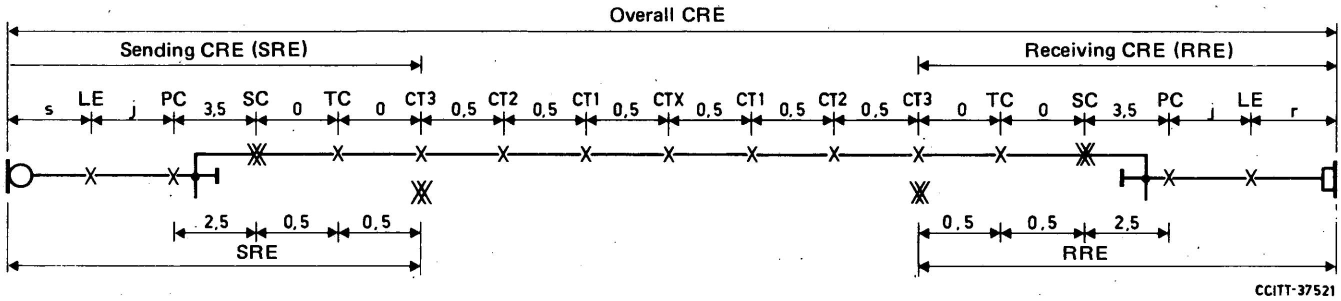


FIGURE 1

The longest international connection envisaged in accordance with CCITT Recommendations (modified HRC based on Figure 1/G.103)

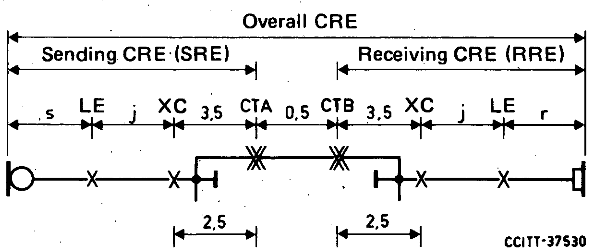


FIGURE 2

An international connection of moderate length comprising the most frequent number of international and national circuits (modified HRC based on Figure 2/G.103)

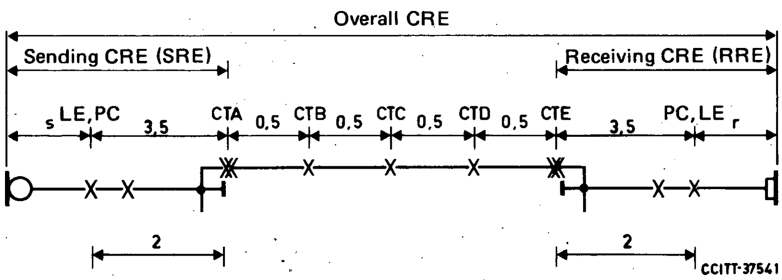


FIGURE 3

An international connection comprising the practically maximum number of international circuits and the least number of national circuits (modified HRC based on Figure 3/G.103)

TABLE 2

Corrected reference equivalent (CRE)

	RE (dB)		Loss (dB)	CRE (dB)	Figure 1 a) and b)			Figure 2 a)			Figure 2 b)			Figure 3 a)			Figure 3 b)		
	s	r	j		Sending CRE	Receiving CRE	Overall CRE	Sending CRE	Receiving CRE	Overall CRE	Sending CRE	Receiving CRE	Overall CRE	Sending CRE	Receiving CRE	Overall CRE	Sending CRE	Receiving CRE	Overall CRE
Maximum	12	3	5.5	6.1	25.0	13.6	41.6	25.0	13.6	37.6	24.0	12.6	35.6	18.9	7.5	26.9	17.9	6.5	24.9
Mean	7	0	3	3.3	15.7	7.3	25.6	15.7	7.3	22.0	14.7	6.3	20.0	12.4	4.0	14.5	11.4	3.0	12.5
Minimum	7	−4	1	1.1	13.5	0.6	15.6	13.5	0.6	10.7	12.5	−0.4	8.7	12.4	−0.5	10.0	11.4	−1.5	8.0

Note – Unloaded cables are assumed for the circuit LE-PC.

TABLE 3

Reference equivalent (RE)

	RE (dB)			Figure 1, a) and b)			Figure 2, a)			Figure 2, b)			Figure 3, a)			Figure 3, b)		
	s	r	j	SRE	RRE	ORE	SRE	RRE	ORE	SRE	RRE	ORE	SRE	RRE	ORE	SRE	RRE	ORE
maximum	12	3	5.5	21	12	36	21	12	33.5	20	11	31.5	15.5	6.5	24	14	5	21
mean	7	0	3	13.5	6.5	23	13.5	6.5	20.5	12.5	5.5	18.5	10.5	3.5	16	9	2	13
minimum	7	−4	1	11.5	0.5	15	11.5	0.5	12.5	10.5	−0.5	10.5	10.5	−0.5	12	9	−2	9

TABLE 4

Circuit noise (CN) (j = 3 dB)

	Exchange (2 w, 4 w)	LE-PC (250 km)	PC-SC, CT (500 km)	SC-TC (250 km)	TC-CT (250 km)	CT3-CT2, CT2-CT1 (2500 km)	CT-CT (1000 km)	CT1-CTx, CT1 (7500 km)
CN – max.	200	1000	2000	1000	1000	10 000	4000	22 500
(pW0p) mean	100	500	500	500	500	5 000	2000	7 000

TABLE 5

Attenuation distortion (AD) in dB

	Exchange (LE, 2 w)	2 w/4 w Term. U.	Exchange (4 w) Rec. Q.45 [1]	Circuit (4 w) (Graph A of Figure 1/G.232 [2]	Circuit (4 w) (Graph B of Figure 1/G.232 [2])
– Maximum	Not specified	Not specified	0.5	1.7	3.0
– Mean			0.15	0.65	1.05
– Minimum			–0.2	–0.4	–0.9

Note – The values in dB are insertion loss at 300 Hz (= at 3400 Hz).

References

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

[2] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Fascicle III.2, Rec. G.232, Figure 1/G.232.

Supplement No. 21

THE USE OF QUANTIZING DISTORTION UNITS IN THE PLANNING OF INTERNATIONAL CONNECTIONS (CONTRIBUTION OF BELL-NORTHERN RESEARCH)

(Geneva, 1980; quoted in Recommendation G.113)

Introduction

This supplement provides background information on the use of the concept of associating quantizing distortion units (qd units) with digital signal processing devices. This concept may be used in the planning of international connections involving several unintegrated PCM processes, to ensure that the overall quantizing distortion is within limits. The supplement discusses the basis for the use of qd units, provides values for several commonly occurring digital processes, and shows how the concept may be used in a mixed analogue/digital and an all-digital network. Exact calculations for the all-digital network are also included.

1 Basic principles of quantizing distortion units

The basic principle for assigning qd units to a digital process is that the associated quantizing distortion power is uncorrelated with the distortion produced by other processes, and individual qd units can therefore be added algebraically to give the overall distortion for a complete connection.

It is convenient to use the quantizing distortion produced by a single 8-bit PCM process (i.e., one encoder and decoder, A-law or μ-law) as the basic reference and to assign it a value of 1 unit. With this reference a single 7-bit PCM process, which is known to produce 6 dB more quantizing distortion (i.e., 4 times more power), would be assigned 4 qd units. A further subdivision can be made, so that an individual 8-bit encoder or decoder is assigned 0.5 units and similarly an individual 7-bit encoder or decoder is assigned 2 units. Other processes can also be converted into equivalent qd units.

An overall limit of 14 qd units has been assigned for an international connection, to be divided into 5 units for each national extension and 4 units for the international portion. This corresponds to 14 times more distortion than a single 8-bit PCM process, or an 11.5 dB (i.e., $10 \log_{10} 14$) reduction in signal-to-distortion ratio (SDR). Since a practical 8-bit codec might have an SDR of about 36 dB (for a Gaussian input signal, and distortion flat-weighted in the band 300 to 3400 Hz), 14 qd units therefore represents an overall SDR of about 24.5 dB. This is consistent with previously published estimates (about 24 db) [1] of the subjective limit for overall signal to distortion ratio.

2 Values of quantizing distortion units for other digital processing devices

To calculate a qd unit value for other digital processing devices it is necessary first of all to estimate the increase in quantizing distortion for that process relative to a single 8-bit PCM process. This can be conveniently derived from calculations of SDR for the particular process, compared to the SDR for 8-bit PCM alone. Examples of such calculations of SDR (for a Gaussian input signal, and distortion flat-weighted in the band 300 to 3400 Hz) for various processes are given in Figures 1, 2 and 3. For each process the reduction in SDR compared to 8-bit coding alone can be converted into the equivalent qd unit. For example, if the reduction in SDR $= x$ dB then the qd value $= 10^{x/10}$.

Some processes, however, give a reduction in SDR which is not constant with input signal level. In these cases the reduction in SDR at a mean input signal level of −20 dBm0 has been used.

There is little practical difference between the use of A− or μ-law coding *except* when digital pads are considered. Both A− and μ-law pads cause a reduction in SDR which varies with the specific pad value, but is approximately 3 dB over the normal range of input levels, as shown in Figures 2 and 3. The exception is the special case of a 6 dB A-law pad which, because of the unique binary nature of A-law coding decision levels, causes negligible impairment for signal levels down to about −30 dBm0 and thus corresponds to 0 qd units. Table 1 lists the qd units associated with the various digital processes.

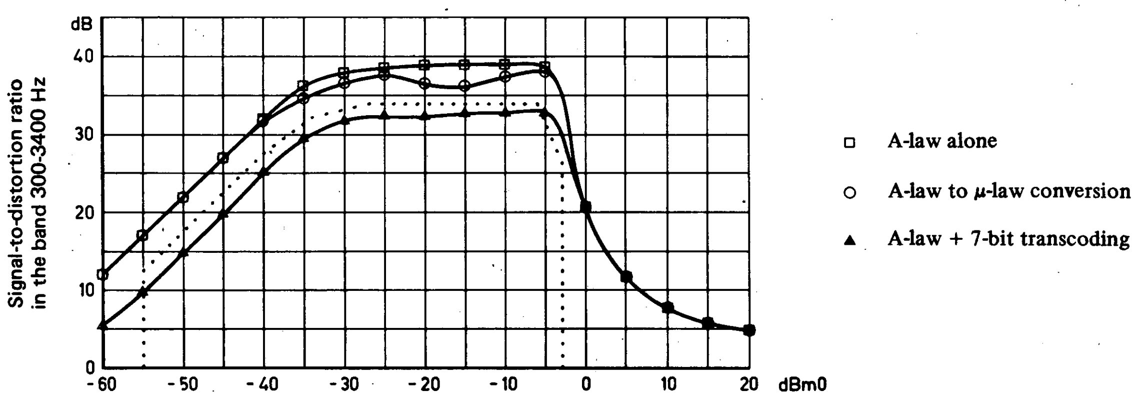
3 Examples of the use of quantizing distortion units

It is important to differentiate between two separate applications of quantizing distortion units.

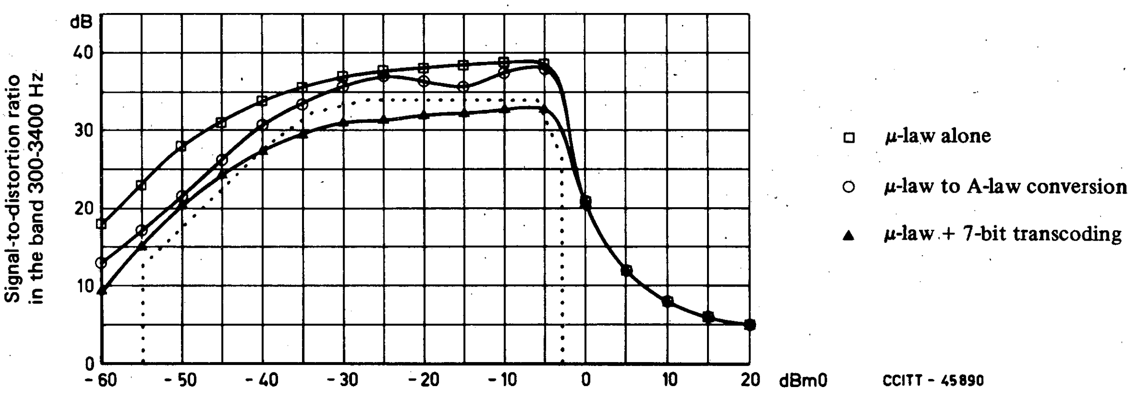
3.1 *Use in a mixed analogue/digital network*

For a tandem connection of unintegrated PCM processes interconnected at voice frequency, the total distortion can be expected to add on a power basis, since the distortion powers in each process will be uncorrelated. Since the distortion in each process is represented by its qd unit value, addition of the qd values of all the processes will give the overall distortion.

For example, a connection such as that shown in Figure 4 would have an overall rating of 7 units, or a 8.5-dB reduction in SDR compared to a link with a single 8-bit codec. Notice that this result holds for either direction of transmission and is independent of the order in which the individual processes are cascaded.



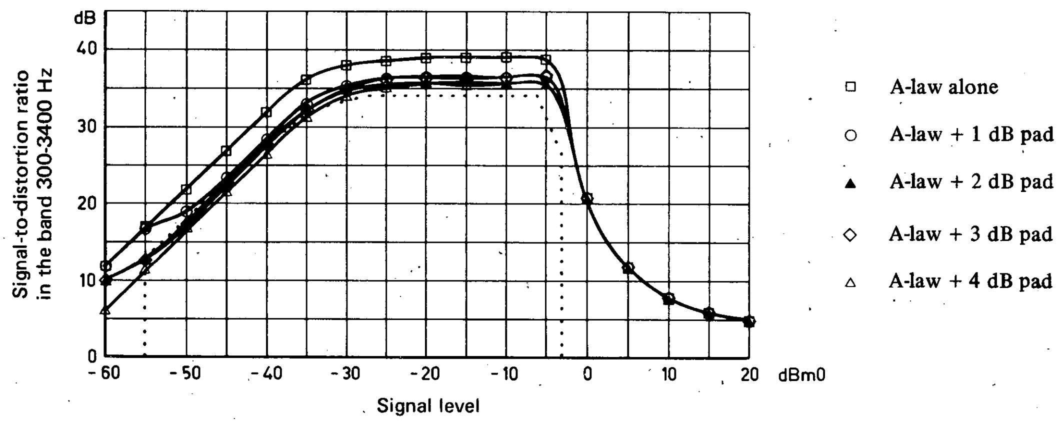
a) *A-law PCM*



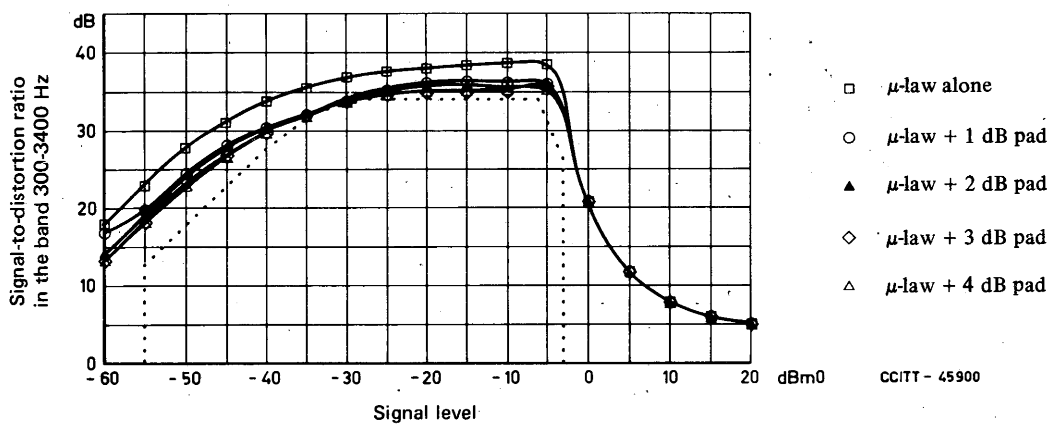
b) *μ-law PCM*

FIGURE 1

Effect of individual devices on ideal 8-bit A-law and μ-law PCM



a) *A-law PCM*



b) *μ-law PCM*

FIGURE 2

Effect of digital pads on ideal 8-bit A-law and μ-law PCM

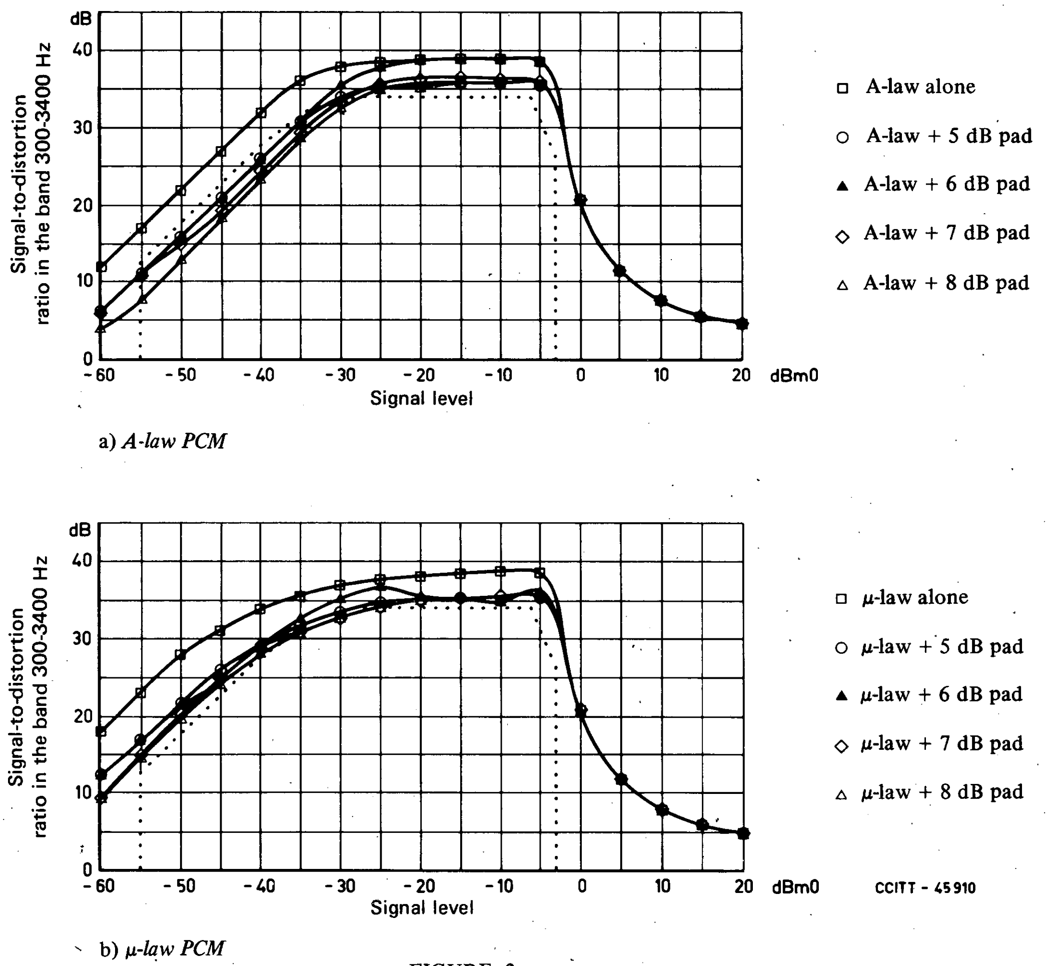


FIGURE 3

Effect of digital pads on ideal 8-bit A-law and μ-law PCM

TABLE 1

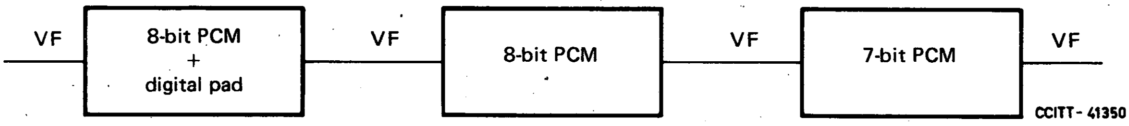
Quantizing distortion units for various digital signal processing devices including the effect of the codec

Configuration	Reduction in SDR	qd unit value
8-bit PCM alone	0 dB	1
7-bit PCM alone	6 dB	4
8-bit to 7-bit to 8-bit transcoding [a)]	6 dB	4
8-bit + digital pad [b)]	3 dB	2
8-bit + A/μ-law code conversion	3 dB	2
Transmultiplexer	c)	0.5

a) This might be used in a digital speech interpolation scheme.

b) See remarks in § 2.

c) Assumed equivalent to single 8-bit encoding *or* decoding.



				Total
qd units	2.0	1.0	4.0	7.0

FIGURE 4

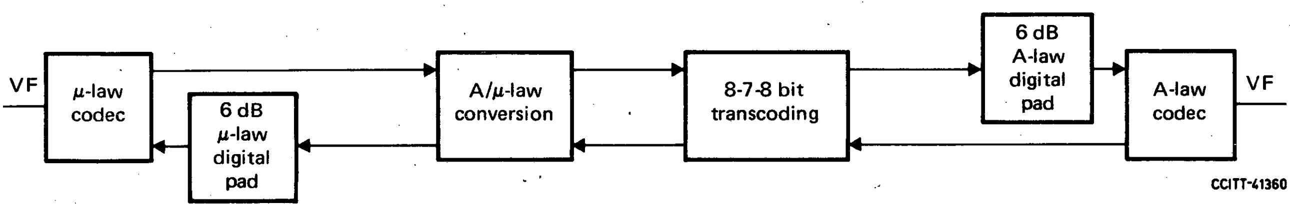
Mixed analogue/digital connection

3.2 *Use in an all-digital network*

In an all-digital network it is no longer correct to assume that the distortion powers in each process are uncorrelated. This means that, in general, it is not possible to simply add the qd units associated with each process to get the total distortion. This also implies that the overall distortion in either direction of transmission may not be the same. The overall distortion arising from an all-digital connection involving various signal processing devices can only be calculated exactly, therefore, by using a computer model of the whole process, rather than using the qd units for the individual processes.

For example, the connection shown in Figure 5 represents an international connection including an A/μ-law conversion, an 8-bit to 7-bit to 8-bit transcoding (as might be used in a digital speech interpolation scheme), and a 6-dB digital pad. Summation of the qd units gives a total of 5 units or 7 dB more distortion than a single 8-bit process, for the direction μ to A. For the direction A to μ the total is 6 units or 7.8 dB more distortion. The slight discrepancy in either direction is due to the difference in qd unit values between an A and μ-law 6 dB pad.

The exact calculation, using a computer model of the complete connection, gives an increase in distortion of 6.0 dB for the direction μ to A and 6.1 dB for A to μ.



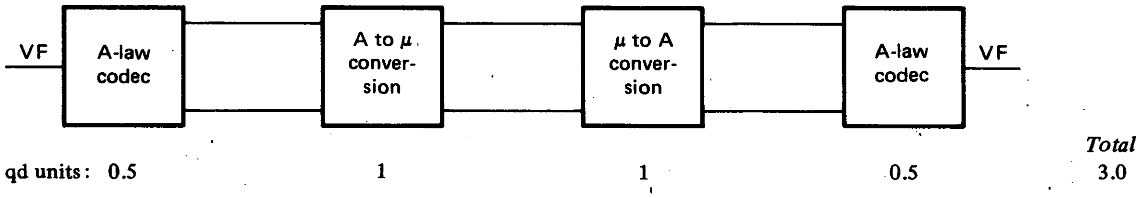
							Total
qd units	0.5	–	1.0	3.0	0	0.5	5.0
	0.5	1.0	1.0	3.0	–	0.5	6.0

FIGURE 5

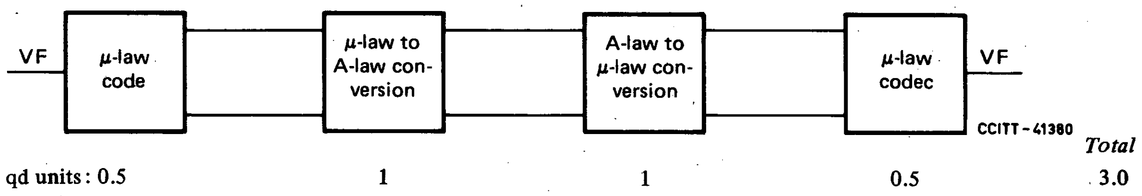
All-digital international connection

A further example is shown in part a) of Figure 6, which represents a tandem A-law to μ-law to A-law conversion. In this case the total qd unit value is 3, corresponding to a 4.8-dB reduction in SDR relative to 8-bit PCM. The exact calculation (see also part a) of Figure 7) shows, however, approximately a 3-dB reduction in SDR (similar to a single A-law to μ-law conversion). Part b) of Figure 6 shows the corresponding tandem μ to A to μ configuration. This has precisely the same total of qd units as Figure 6a, but the exact calculation (see also part b) of Figure 7), shows a negligible (less than 0.1 dB) reduction in SDR relative to 8-bit PCM.

In both of the above examples there is correlation between the distortion produced in the separate conversion processes, so qd units cannot simply be added to give the correct answer.



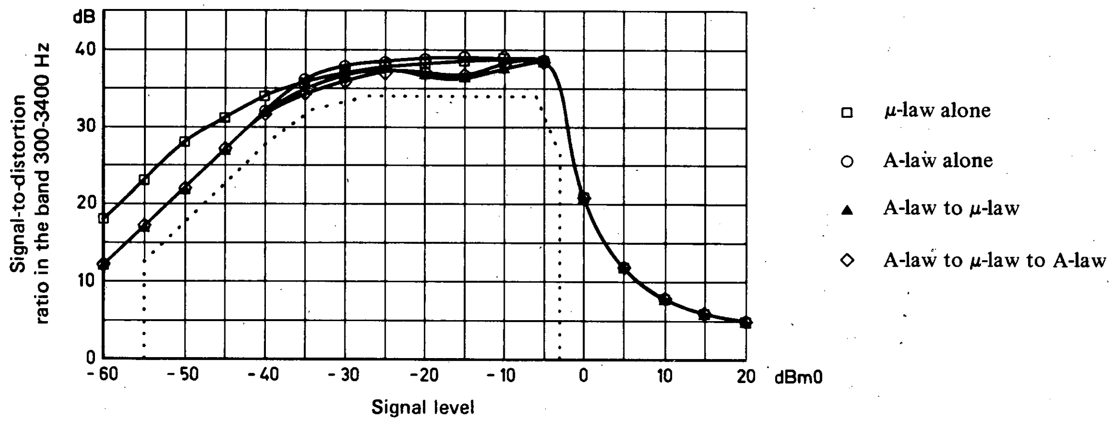
a) *A-law to μ-law to A-law tandem conversion*



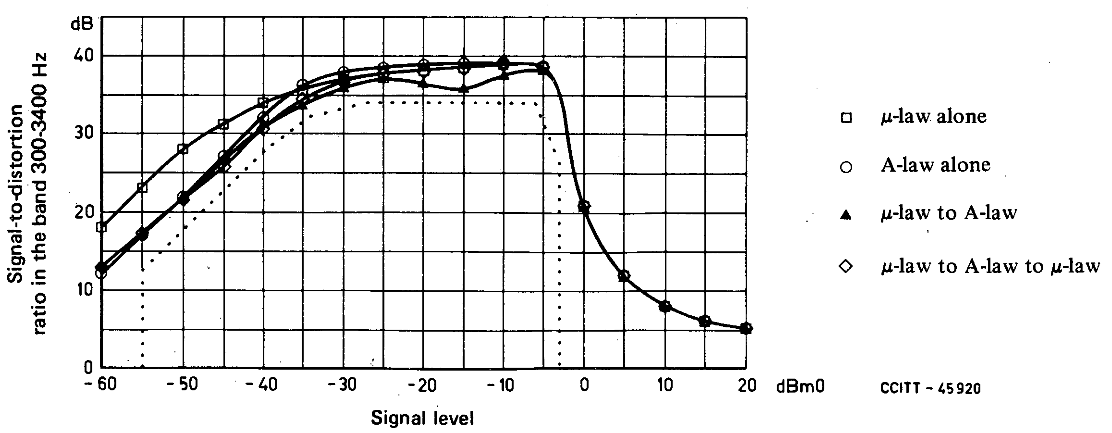
b) *μ-law to A-law to μ-law tandem conversion*

FIGURE 6

Tandem conversions



a) *A-law to μ-law*



b) *μ-law to A-law*

FIGURE 7

Effect of tandemmed code conversions

4 *Summary*

This supplement has analyzed the concept of using qd units in the planning of telephone connections involving different digital signal processing devices. The method to be used in assigning a qd unit value to a PCM process has been described, and values given for several commonly occurring processes.

It is shown that the use of qd units is valid in a mixed analogue/digital network containing unintegrated PCM processes. The use of qd units will not necessarily give correct answers for an all-digital network, although the method may still be useful for obtaining an approximate result.

Reference

[1] CCITT manual *Economic and technical aspects of the choice of transmission systems*, Section B.I, § 3.2.2, ITU, Geneva, 1976.

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