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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

General characteristics of international telephone connections and circuits – General

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THE TRANSMISSION PLAN

Reedition of CCITT Recommendation G.101 published in the Blue Book, Fascicle III.1 (1988)

NOTES

1 CCITT Recommendation G.101 was published in Fascicle III.1 of the *Blue Book*. This file is an extract from the *Blue Book.* While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation G.101

THE TRANSMISSION PLAN[1)]

(Geneva, 1964; amended at Mar del Plata, 1968,
Geneva, 1972, 1976 and 1980; Malaga-Torremolinos, 1984)

1 Principles

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

2.1 *The international chain of circuits and the national systems*

A complete **international telephone connection** consists of three parts, as shown in Figure 1/G.101. The division between these parts is determined by the *virtual analogue switching points* in the originating/terminating international switching centres (ISCs). These are theoretical points with specified relative levels (see Figure 2/G.101 and §§ 5.1 and 5.2 of this Recommendation).

The three parts of the connection are:

– 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 local exchanges and the subscriber sets with their subscriber lines.

– An international chain made up of one or more 4-wire international circuits. These are interconnected on a 4-wire basis in the international centres which provide for transit traffic and are also connected on a 4-wire basis to national systems in the international centres.

An international 4-wire circuit is delimited by its virtual analogue switching points in an international switching centre.

Note 1 – In principle the choice of values of the relative levels at the virtual analogue switching points on the side of a national system is a national matter. In practice, several countries have chosen –3.5 dBr for receiving as well as for sending. These are theoretical values; they need not actually occur as any special equipment item; however, they serve to determine the relative levels at other points in the national network. If, for instance, the loss "*t-b*" or "*a-t*" is 3.5 dB (as is the case in several countries, cf. Table A-l/G.121), then it follows that the relative levels at point *t* are 0 dBr (input) and –7 dBr (output).

Note 2 – 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.

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

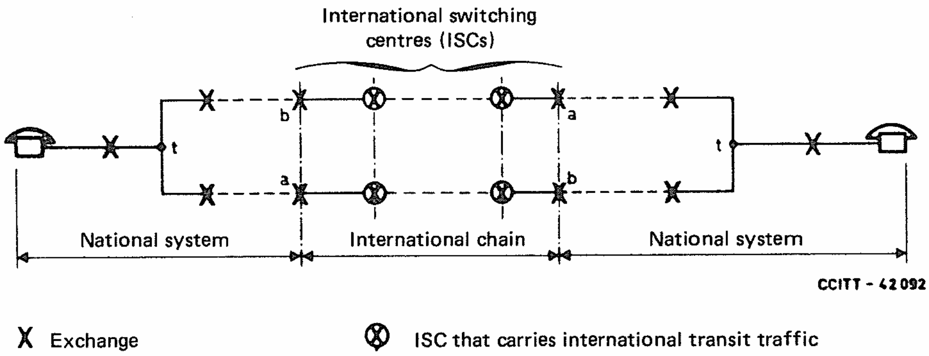


FIGURE 1/G.101

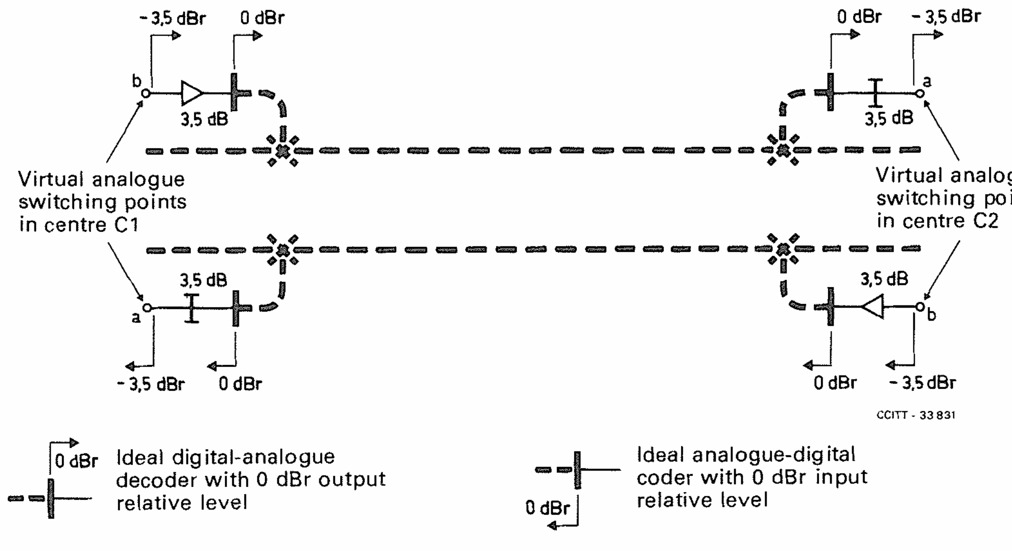
Definition of the constituent parts of an international connection

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.

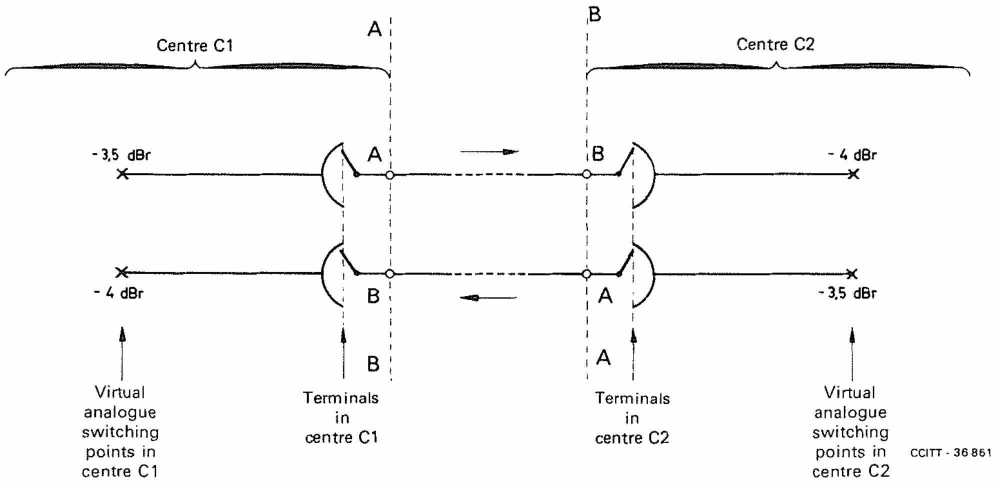
In a large country, a fourth and possibly a fifth national circuit may be included in the 4-wire chain, provided it has the nominal transmission loss and the characteristics recommended for international circuits used in a 4-wire chain (see Recommendation G.141, § 1, § 4 of this Recommendation and the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

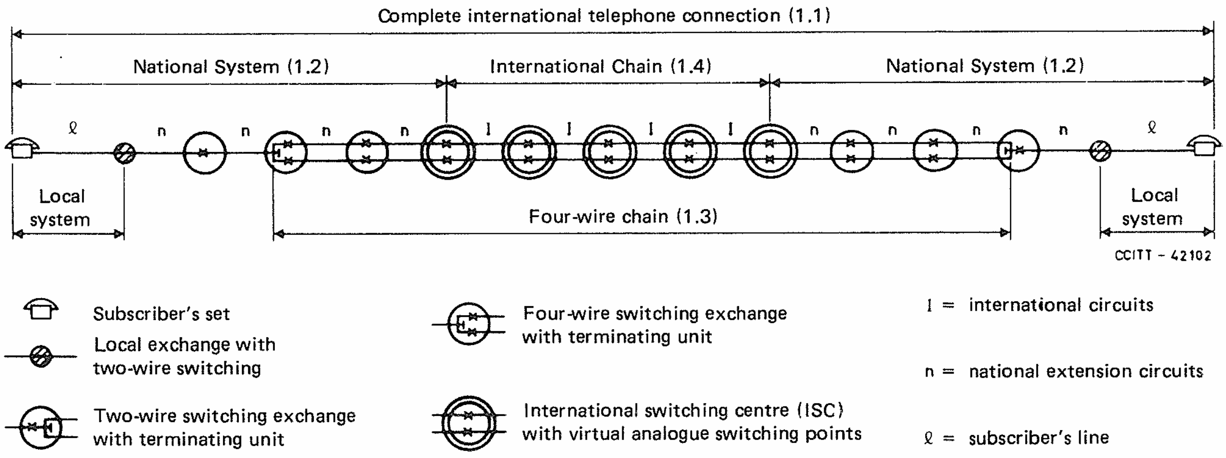
a) *Definition of virtual analogue switching points for a digital international circuit between digital international centres*



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

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 FDM carrier systems) and one 2-wire circuit, probably unamplified. However, cases in which local exchanges are be reached by four amplified circuits, among them usually at least one PCM circuit, are becoming more and more frequent. All these circuits may be 4-wire circuits.

3.2 *International circuits*

According to the International Telephone Routing Plan (Recommendation E.171), the number of international circuits is restricted to four.

3.3 *Hypothetical reference connections*

See Recommendation G.103.

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 encountered in an international connection calculated from a survey of about 270 million international telephone connections taken in 1973. These tables take traffic weighting into account.

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% 0.0005% respectively. The relative frequencies of 4, 5 and 6 international circuits are 0.0 0.00007% and 0.00009% respectively.

The means and modal numbers of national circuits are both equal to 2. This applies to bo originating and terminating national extensions. The mean number of international circuits is 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.

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.

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 routing 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.

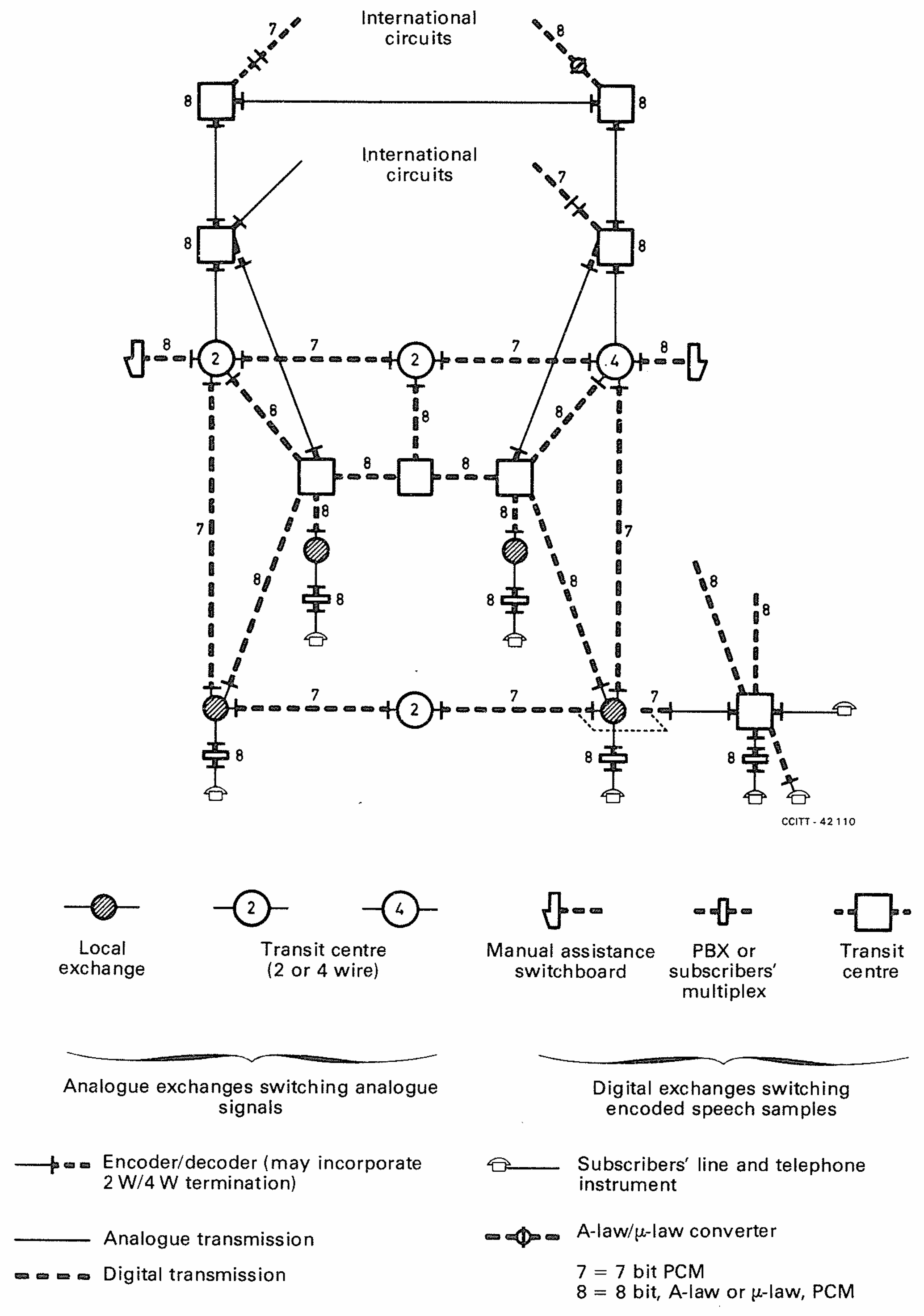


FIGURE 4/G.101

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.

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.

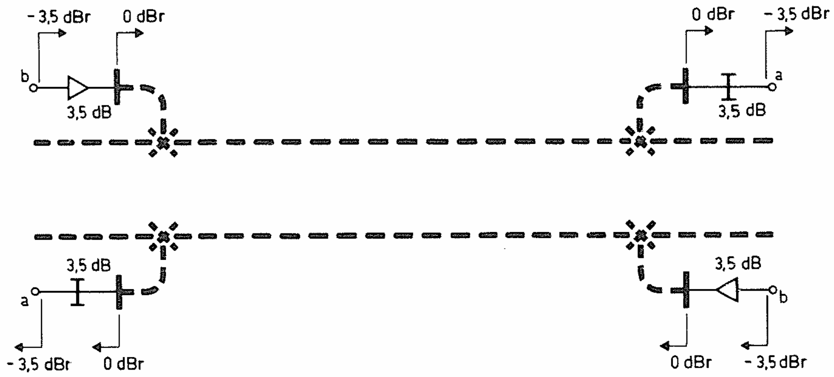
5 Conventions and definitions

5.1 *Virtual analogue switching points*

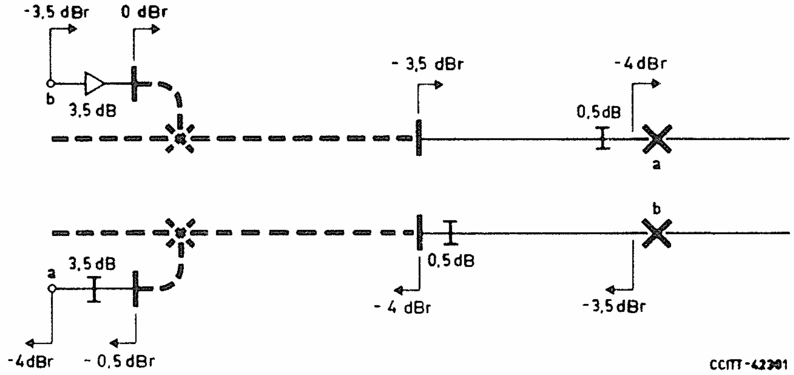
The concept "virtual switching points" has been useful in making transmission studies with regard to all-analogue connections. For example, these points have been used to define the boundary between international circuits as well as between international circuits and national extensions. The "virtual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

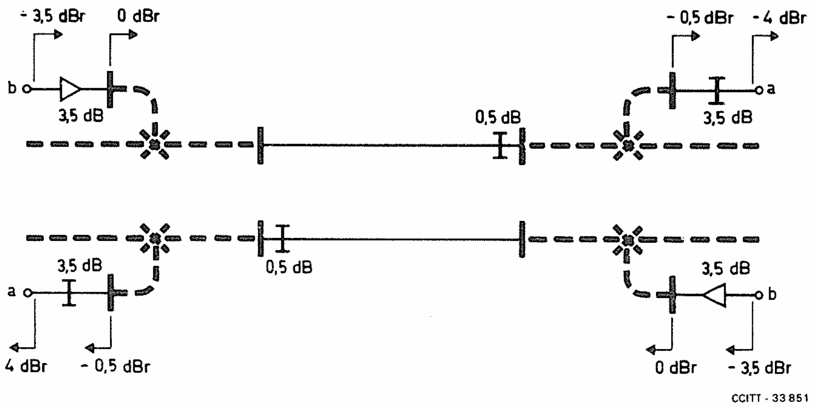


a) *Type 1 circuit – All digital circuit with digital switching at both ends*



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*

Note — Conventions and symbols adopted for "real" and ideal codecs:

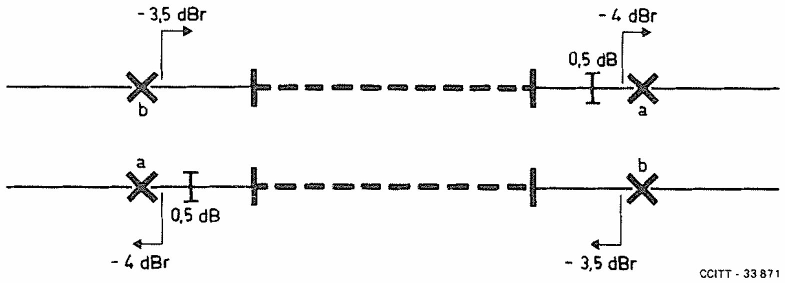
— Ideal coders and decoders are assumed to show a relation between analogue and digital signals and vice versa exactly in accordance with the appropriate tables for A-law or μ-law of Recommendation G.711.

— "Real" coders and decoders are assumed to be such that the performance characteristics of an encoder/decoder pair between audio frequency ports will meet the requirements of Recommendation G.712.

— The symbol for a "real" codec does not include a relative level for the analogue input or output port. If it is desired to specify the relative level, then this should be done by denoting the relative level on the analogue transmission side of the codec. This will avoid any possible confusion with the symbol for an ideal codec.

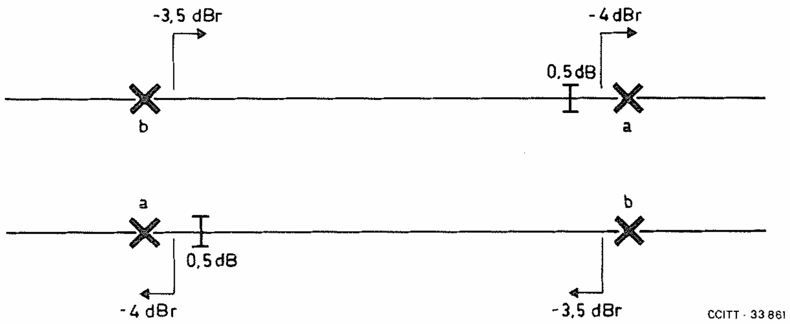
FIGURE 5/G.101

Types of international circuits

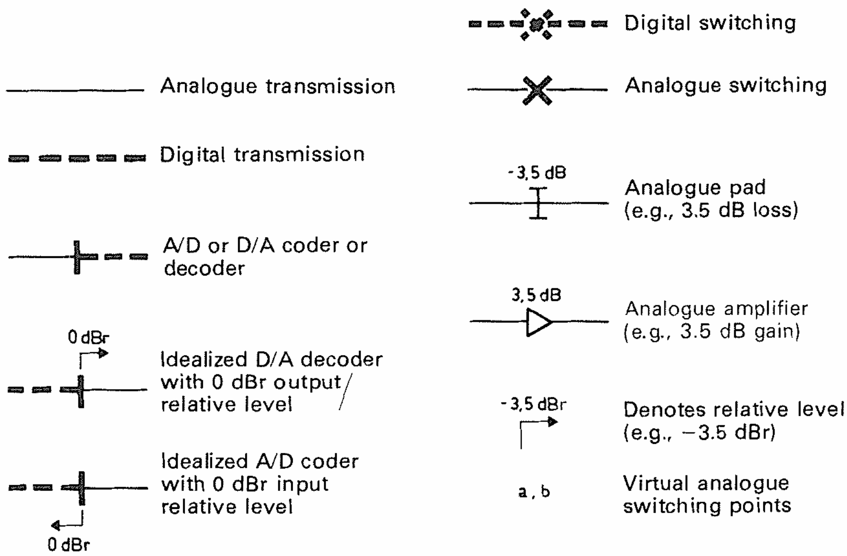


Note – Pads required if the analogue circuit sections introduce significant amount of attenuation distortion or variation with time.

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

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 or mixed analogue/digital circuits;
  –3.5 dBr for digital circuits or for the very short circuits mentioned under Note 3 below.

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 two international switching centres 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 Recommendation G.223 [3] shall be applied when checking whether the transmission system conforms to the noise objectives defined in Recommendation G.222 [4].

Note – For certain systems, e.g. submarine cable systems (Recommendation G.371 [5]), 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 Recommendation G.223 [6]. The nominal mean power level in each telephone channel is –15 dBm as defined in Recommendation G.223 [3].

5.3.2 **relative (power) level**

F: niveau relatif de puissance

S: nivel relativo (de potencia)

5.3.2.1 *Basic significance of relative level in FDM systems*

The 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[2].

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[2] Taking into account such aspects as (basic) noise, intermodulation noise, peak power, etc. (see Recommendation G.223).

If, for example, at a particular point an FDM system designed for a large number of channels 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 0 dBr point, the conventional mean power level referred to one telephone channel is –15 dBm.

5.3.2.2 *Definition of relative level, generally applicable to all systems*

The relative level at a point on a circuit is given by 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 is numerically equal to the composite gain (definition in *Yellow Book*, Fascicle X.1) between the transmission reference point and the point concerned, for a nominal frequency of 1000 Hz. For example, if a reference signal of 0 dBm at 1000 Hz is injected at the transmission reference point, the level at a point of *x* dBr will be *x* dBm (apparent power $P_x = 10^{x/10}$mW). In addition, application of a digital reference sequence (DRS, § 5.3.3) will give a level of *x* dBm at a point of *x* dBr. The voltage of a 0 dBm0 tone at any voiceband frequency at a point of *x* dBr is given by the expression:

$$V = \sqrt{10^{x/10} \times 1\ \mathrm{W} \times 10^{-3} \, | Z_R |_{1000}} \quad \text{volts}$$

where $|Z_R|_{1000}$ is the modulus of the nominal impedance of the point at a nominal frequency of 1000 Hz.

Note 1 – The nominal reference frequency of 1000 Hz is in accordance with Recommendation G.712, § 16. For existing (analogue) transmission systems, one may continue to use a reference frequency of 800 Hz.

Note 2 – The 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 elaborated 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 relative level at this point is fixed.

Note 3 – The impedance Z_R may be resistive or complex; in the latter case the power P_x is an apparent power.

Note 4 – It is assumed that between the virtual analogue switching points of a circuit, established over international transmission systems, only points of equal relative level are interconnected in those systems, so that the transmission loss of the circuit will be equal to the difference in relative levels at the virtual analogue switching points (see § 5.2 of this Recommendation).

5.3.2.3 *Relation between corrected send reference equivalents, loudness ratings and relative levels*

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]. In particular, if the minimum nominal corrected send reference equivalent (CSRE) of local systems referred to a point of 0 dBr of a PCM encoder is not less than 3.5 dB, or the minimum nominal send loudness rating (SLR) under the same conditions is not less than –1.5 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.

5.3.2.4 *Compatibility of relative levels of analogue and digital systems*

When the signal load is controlled as outlined in § 5.3.2.3, points of equal relative levels 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.

5.3.2.5 *Determination of relative level*

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.

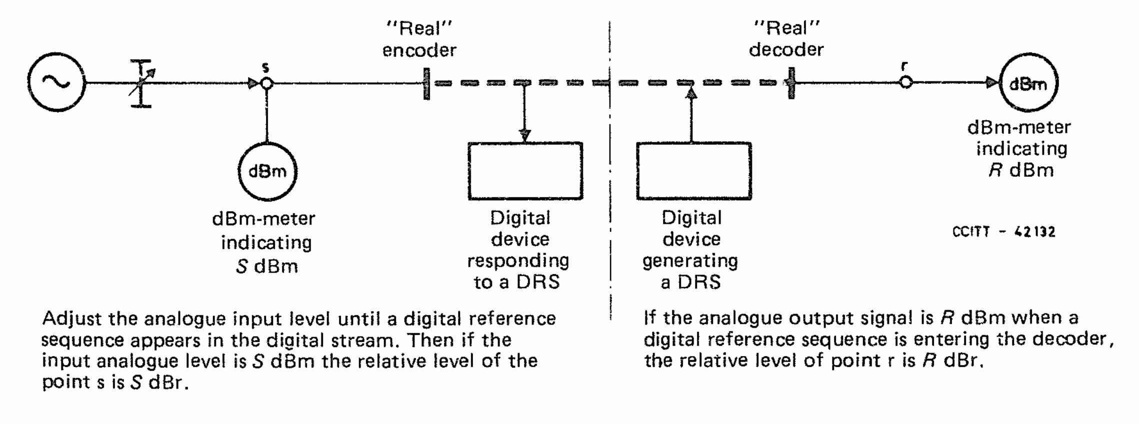


FIGURE 6/G.101

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

When using Figure 6/G.101 to determine the relative levels of a "real" codec with non-resistive impedances at the analogue input and output ports, the following precautions must be observed:

i) the test frequency should be 1000 Hz with a suitable offset;

ii) the power at points *s* and *r* is expressed as apparent power, i.e.

$$\text{Apparent power level} = 10 \log_{10} \left[\frac{(\text{Voltage at point})^2 \times 10^3}{(\text{Modulus of nominal impedance at 1000 Hz})\ (1\ \text{W})} \right] \text{dBm}$$

iii) point *r* is terminated with the nominal design impedance of the decoder to avoid significant impedance mismatch errors.

Note – Precautions ii), iii) above are, of course equally applicable to the case of resistive input and output impedances and would generally be observed by conventional test procedures. Standardizing the reference frequency as in i) above is, however, essential for complex impedances because of the variation of nominal impedance with the test frequency.

5.3.2.6 *Relative level of a point in a digital link*

The relative level to be associated with a point in a digital path carrying a digital bit stream generated by a coder lined-up in accordance with the principles of § 5.3.2.3 above is determined by the value of the digital loss or gain between the output of the coder and the point considered. If there is no such loss or gain the relative level at the point considered is, by convention, said to be 0 dBr.

The equivalent absolute power level of a digital link may be established as in Figure 7/G.101 by using an ideal decoder. The relative level at a point X in the bit stream can then be assigned by comparing the power at the output of the ideal decoder with that at the analogue zero relative level point originating the digital signal.

5.3.3 PCM digital reference sequence (DRS)

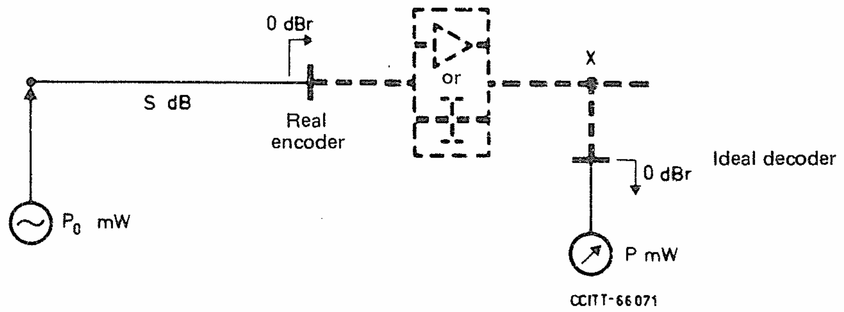
F: séquence numérique de référence MIC

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.



Procedure

An analogue input signal is applied to the coder with a level of P_0 mW at the 0 dBr point. If this signal results in an analogue signal of P mW at the output of the ideal decoder then:

$$\text{Relative level at point X} = 10 \log_{10} \left(\frac{P}{P_0}\right) \text{ dBr}$$

Note – It is understood that the signal is always within the dynamic range of the conversion process.

FIGURE 7/G.101

Procedure for determining the relatvie level of a point in a digital link

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 8/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 8/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.

Figure 8/G.101 gives an example where all the analogue loss is introduced in the output direction at the analogue exchange. In this case the relative levels at the various codecs can be derived from either the DRS or the transmission reference point at the input of the international circuit with no ambiguity.

If, however, in Figure 8/G.101 the analogue circuit section is lined up so as to give an overall loss in the direction $b_1 - a_2$, care must be taken in the use of the DRS. In this case the 0 dBm0 sinusoidal reference signal and DRS may result in different levels at the point a_2. Account should be taken of this effect when designing lining-up procedures for mixed analogue/digital circuits.

As a general principle, the relative levels on a mixed analogue/digital circuit should be referred to the transmission reference point at the input of the 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.

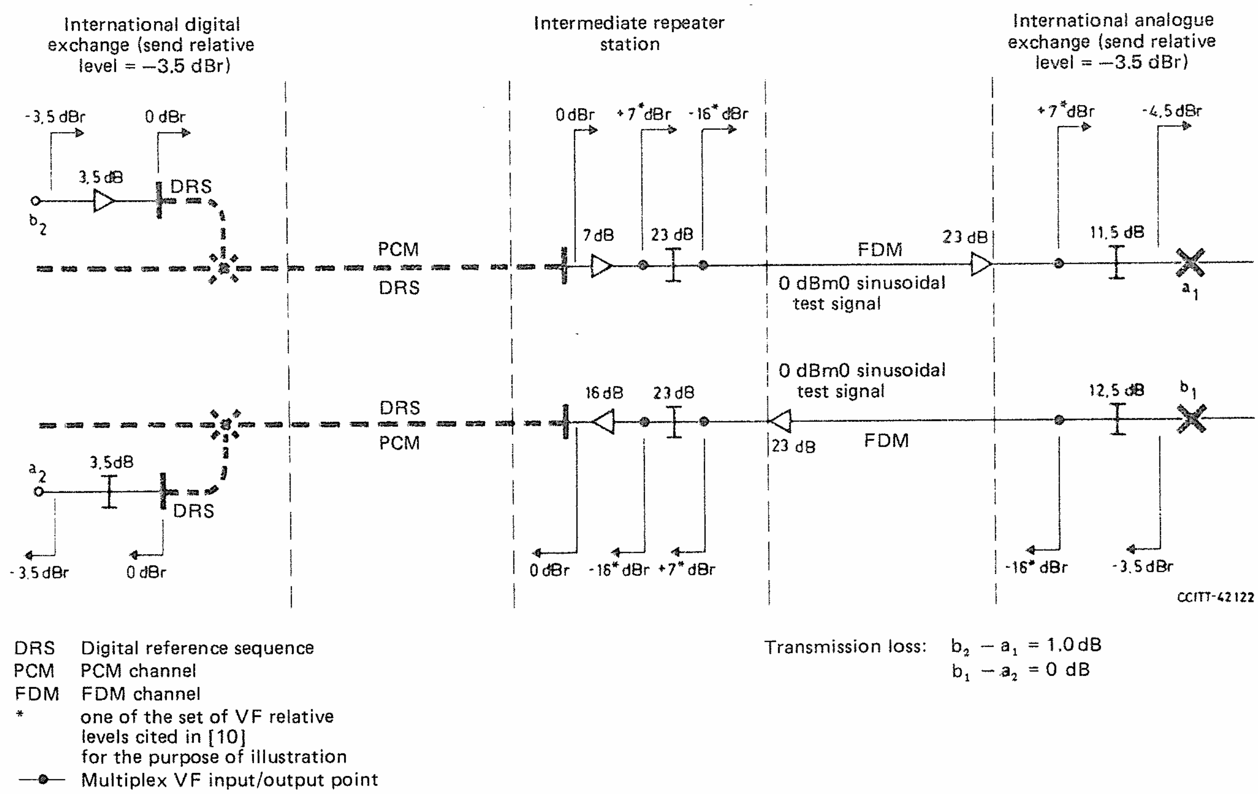
Multifrequency measurements made to determine the loss/frequency characteristic will include a measurement at 800 Hz and the frequency of the reference measurement signal for such characteristics can still be 800 Hz.

Note 1 – Definitions of §§ 5.3.1 and 5.3.2 are used in the work of Study Group XII. Definitions of §§ 5.3.4 and 5.3.5, taken from Recommendations M.565 [7] and M.580 [8], 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 [9].

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.



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

FIGURE 8/G.101

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

References

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

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

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

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

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

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

[7] CCITT Recommendation *Access points for international telephone circuits*, Vol. IV, Rec. M.565.

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

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

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

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