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GENERAL CHARACTERICTICS OF INTERNATIONAL TELEPHONE CONNECTIONS AND INTERNATIONAL TELEPHONE CIRCUITS

HYPOTHETICAL REFERENCE CONNECTIONS

ITU-T Recommendation G.103

Superseded by a more recent version

(Extract from the *Blue Book*)

NOTES

1 ITU-T Recommendation G.103 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.103

HYPOTHETICAL REFERENCE CONNECTIONS

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

This Recommendation mainly deals with the analogue network, Recommendation G.104 deals with the wholly 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 expected to occur in practice. Such a connection would typically have high corrected 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.

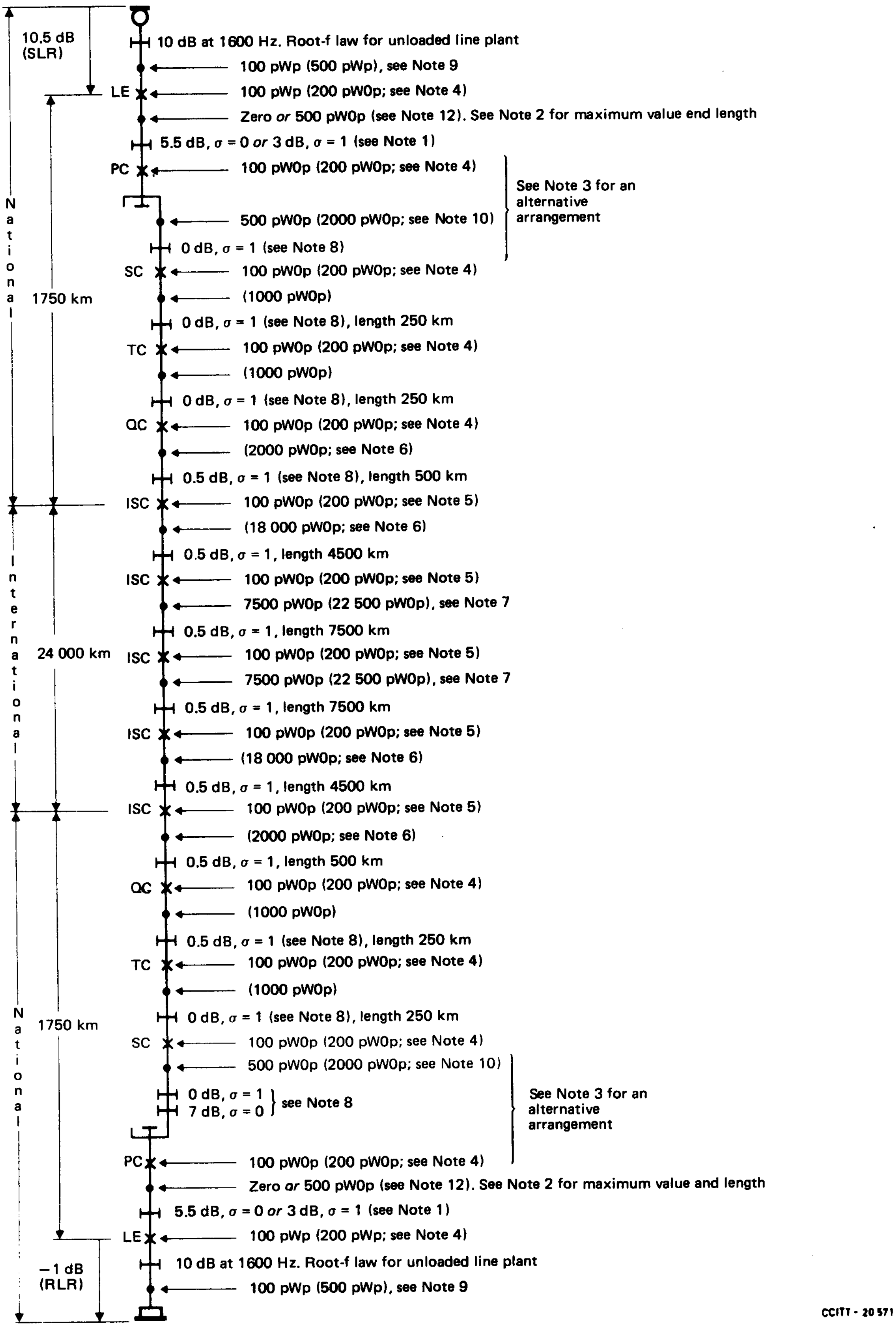
It might be felt that it is somewhat inconsistent that the hypothetical reference connections do not use "conventional" -3.5/-4 dBr virtual switching points. However, if the reference connections are drawn using that convention, the noise power figures appearing on the diagram can no longer be the familiar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

2.2.2 The nomenclature is based on the international routing plan recommended in Recommendation E.171, i.e. ISC = International Switching Centre (formerly referred to as CT3), ITC = International Transit Centre.

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

2.2.4 The design objectives for the 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.



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

SLR	sending loudness rating	SC	secondary centre
RLR	receiving loudness rating	TC	tertiary centre
LE	local exchange	QC	quaternary centre
PC	primary centre	ISC	international switching centre

FIGURE 1/G.103

The longest international connection likely to occur in practice

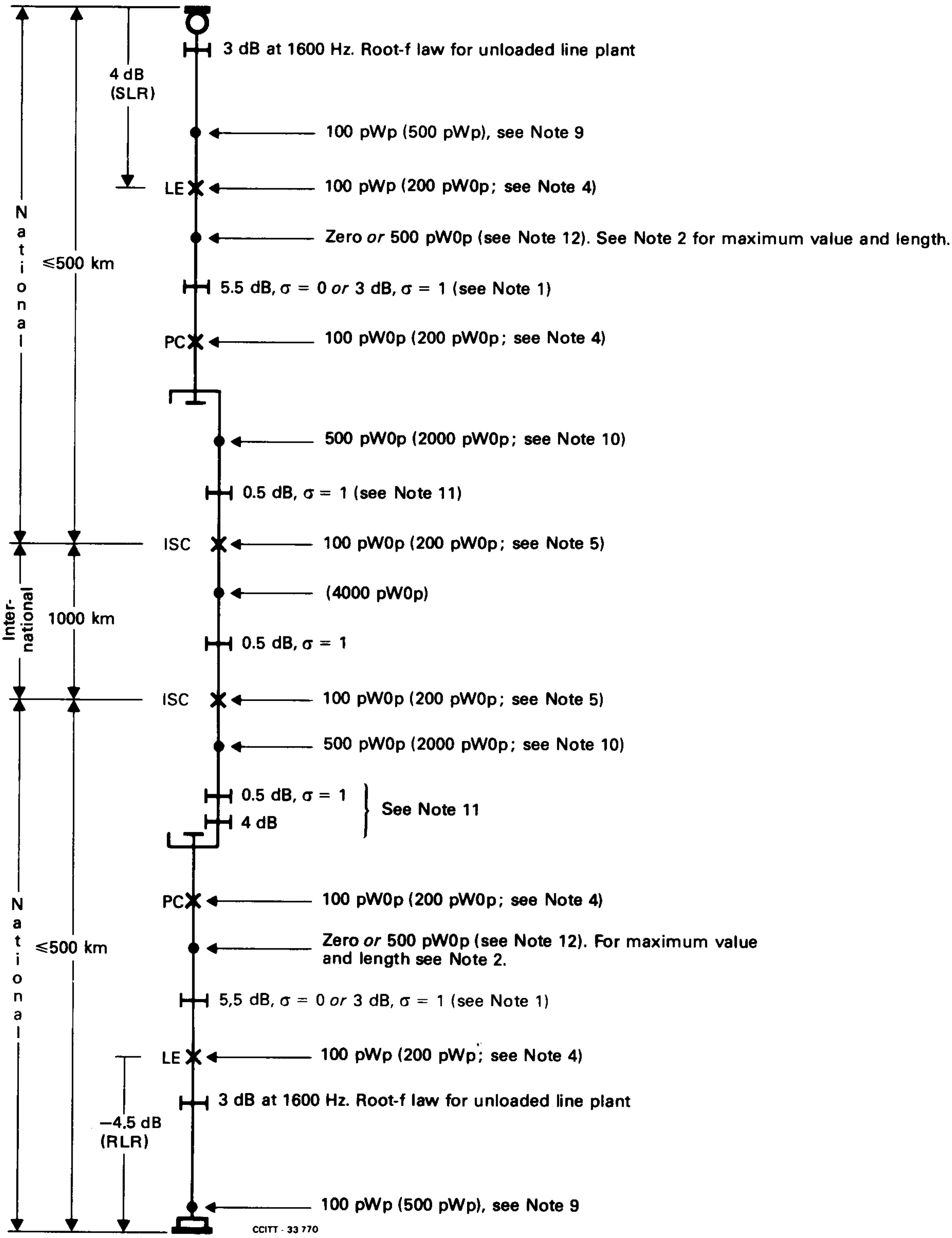


FIGURE 2/G.103

An example of an international connection of moderate length with only one international circuit

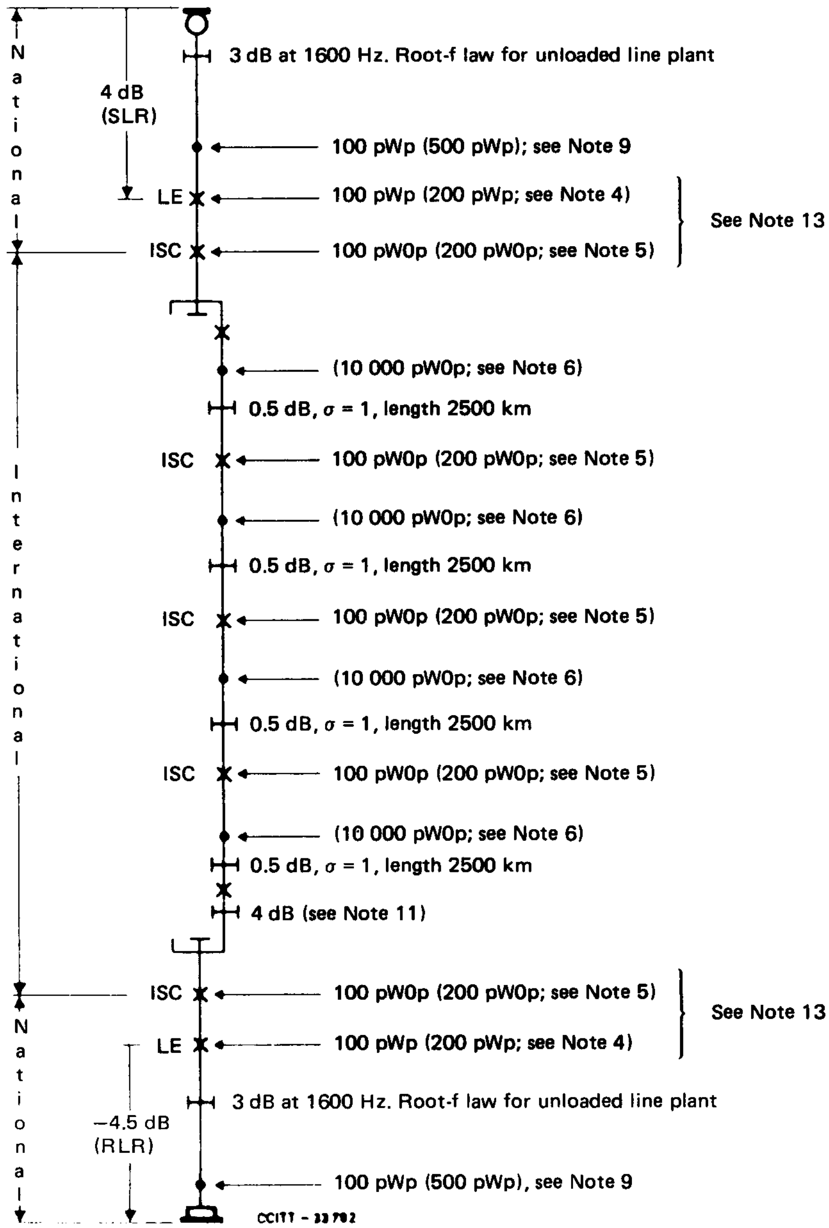


FIGURE 3/G.103

An example of an international connection of 4 international circuits between subscribers situated near the terminal ISCs

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

Note 1 - For circuits on physical line plant the LR may be taken to have a nominal maximum value of 6 dB with σ = 0. This value was arrived at in the following way: Recommendation G.121 gives a 97% limit on 20 dB send loudness rating (SLR) referred to a point of -3.5 dBr on the international circuit at the IC. Referring this to a zero relative level point at the input to the chain of national and intemational circuits (i.e. to the primary centre) gives 16.5 dB. Reference [3] indicates that a 10.5 dB send loudness rating (SLR) is typical for maximum local lines, thus leaving 6 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 σ = 1. This loss is equal to the LR of the circuit; its loss-distortion effect is estimated by including an additional long-distance circuit in the connection (Recommendation G.111, § A.3.2). This circuit may for instance be provided on a PCM system using either 7-bit encoding (μ = 100 or A = 87.6) or 8-bit encoding (μ = 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.

a) b)

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/ISC 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, i.e. an absolute noise power of 200 pWp, 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 ISC/ISC 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 22500 pW0p. Companders would be used to improve noise only if it exceed 40000 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 switching 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 ISC.

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, *Red Book,* Fascicle III.1.

Recommendation G.114 gives information concerning group delay.

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 expected to occur (see Figure 1/G.103) may be considered to have the following arrangement of modulator/demodulator pairs in the 4-wire chain.

TABLE 1/G.103

	Number of modulator/demodulator pairs in a wholly analogue 4-wire chain		
	Eight national circuits	Circuits between ISCs	Total
Channel	8	4	12
Group	12	10	22
Supergroup	16	20	36

Of the 12 channel modulator/demodulator pairs a maximum of three may be of the special type which provide 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 (Recommendation G.113), and transmission delay. Guidance is provided on the use of appropriate hypothetical reference connections for a mixed analogue/digital network in Annex B.

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 he drawn assuming 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.

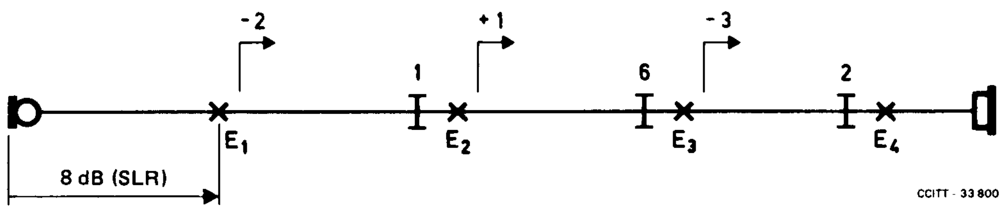


FIGURE A-1/G.103

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 respectively. 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.

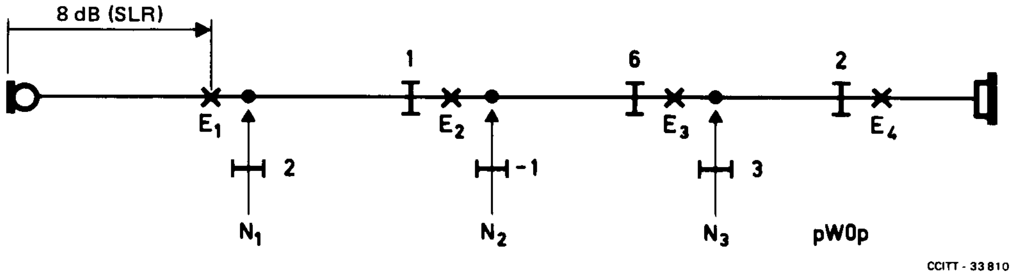


FIGURE A-2/G.103

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 between the accumulated send loudness rating (SLR) at each exchange and the corresponding circuit noise level is 6 dB (for N_1), 10 dB (for N_2) and 12 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.

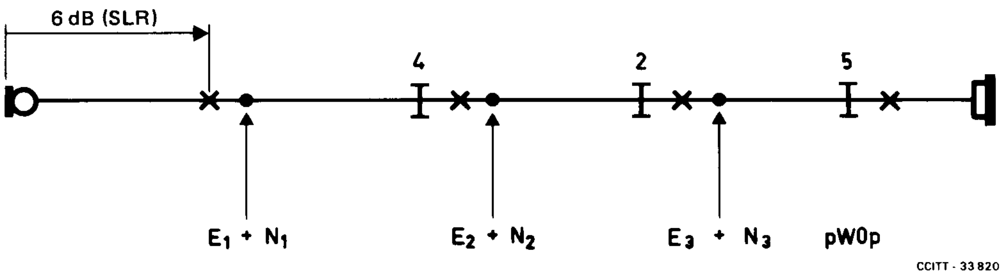


FIGURE A-3/G. 103

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.

ANNEX B

(to Recommendation G.103)

Guidance on hypothetical reference connections for a mixed analogue/digital connection

This annex provides guidance on a method to model a mixed analogue/digital network. For simplicity and for ease of comparison with an all-analogue network, retention of the network configurations now given in Figures 1/G.103 to 3/G.103 is appropriate. Figures 1/G.103 and 2/G.103, in particular, represent respectively, examples of the longest, though infrequent, type of connection and a connection of moderate length which occurs most frequently. The three connections provide an adequate range of connection types for most purposes but some guidance is desirable with respect to the selection of the circuits and exchanges which should be analogue and those which should be digital. This choice may depend on the matter under study. Two examples are designated for each of the connections: one which maximizes the number of digital processes and one which would be more representative of an evolving network. The worst case situation can be represented by making all of the exchanges digital and leaving all of the circuits analogue. A set of more representative connections is obtained by defining islands of digital connectivity such that the number of independent digital processes in each connection is approximately one-half of the maximum. For the representative connections all exchanges are assumed to be digital. In addition, the specific circuits designated in Table B-1/G.103 are also assumed to be digital with digital connection to the digital switches at each end of the circuit. This has the effect of creating "digital islands" with integrated digital processes, such that each island may be regarded as a single digital process.

TABLE B-1/G.103

Assumed digital circuits (listed from top to bottom)		
Figure 1/G.103	Figure 2/G.103	Figure 3/G.103
PC to SC TC to QC 1st ISC to 2nd ISC 4th ISC to 5th ISC QC to TC SC to PC	PC to ISC ISC to PC	LE to ISC 2nd ISC to 4th ISC[a)] ISC to LE

a) Single digital island.

Note - For an explanation of abbreviations, see Figure 1/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, 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, Rec. Q.45.