INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

G.103

(12/98)

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

International telephone connections and circuits – General definitions

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Hypothetical reference connections

ITU-T Recommendation G.103

(Previously CCITT Recommendations)

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ITU-T RECOMMENDATION G.103

HYPOTHETICAL REFERENCE CONNECTIONS

Summary

This Recommendation was revised to introduce Integrated Services Digital Network and Integrated Digital Network Hypothetical Reference Connections, and also to allow for the introduction of ATM Technology into the PSTN. This Recommendation provides a number of Hypothetical Reference Connections that can be used to perform transmission impairment studies.

Source

ITU-T Recommendation G.103 was revised by ITU-T Study Group 12 (1997-2000) and was approved under the WTSC Resolution No. 1 procedure on the 3rd of December 1998.

FOREWORD

ITU (International Telecommunication Union) is the United Nations Specialized Agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the ITU. The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Conference (WTSC), which meets every four years, establishes the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

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As of the date of approval of this Recommendation, the ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

CONTENTS

Recommendation G.103

HYPOTHETICAL REFERENCE CONNECTIONS

(Mar del Plata, 1968; amended at Geneva, 1972, 1976 and 1980;
at Malaga-Torremolinos, 1984; revised in 1998)

1 Scope

This Recommendation provides a number of Hypothetical Reference Connections. In particular, connections involving hybrid, i.e. analogue/digital networks, and wholly digital networks are addressed. The ongoing transitional problems associated with the conversion of hybrid networks to wholly digital networks are addressed in clause 6.

2 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, signal processing impairments 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 ITU-T for national systems.

For these purposes, several models are desirable. In each model, the international circuits and exchanges are assumed to be digital. The one wholly digital hypothetical reference connection and the five hybrid 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.

3 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published.

[1] *Transmission planning of switched telephone networks*, ITU, Geneva, 1976.

[2] CCITT Recommendation E.171 (1988), *International telephone routing plan*.

[3] ITU-T Recommendation G.101 (1996), *The transmission plan*.

[4] ITU-T Recommendation G.111 (1993), *Loudness Ratings (LRs) in an international connection*.

[5] ITU-T Recommendation G.113 (1996), *Transmission impairments*.

[6] ITU-T Recommendation G.114 (1996), *One-way transmission time*.

[7] ITU-T Recommendation G.120 (1998), *Transmission characteristics of national networks*.

[8] ITU-T Recommendation G.121 (1993), *Loudness Ratings (LRs) of national systems.*

[9] CCITT Recommendation G.726 (1990), *40, 32, 24, 16 kbit/s Adaptive Differential Pulse Code Modulation (ADPCM).*

[10] ITU-T Recommendation M.60 (1993), *Maintenance terminology and definitions*.

[11] ITU-T Recommendation P.310 (1996), *Transmission characteristics for telephone-band (300 – 3400 Hz) digital telephones.*

4 Composition of hypothetical reference connections

4.1 The composition of the various connections is defined in Figures 1, 2, 3, 4, 5 and 6.

Figure 1 – The longest wholly digital Integrated Services Digital Network (ISDN) international connection with the maximum number of international and national circuits expected to occur in practice.

Figure 2 – The longest Integrated Digital Network (IDN) international connection comprising the maximum number of international and national circuits expected to occur in practice.

Figure 3 – An integrated digital network international connection comprising the maximum number of international circuits and the least number of national circuits expected to occur in practice.

Figure 4 – An international connection comprising the maximum number of digital international circuits and the least number of analogue national circuits expected to occur in practice.

Figure 5 – An international connection of moderate length (i.e. not longer than 2000 km) comprising the most frequent number of international and analogue national circuits. In such a connection, the noise contribution of the national systems would be expected to predominate.

Figure 6 – The longest international connection with the maximum number of digital international and analogue national circuits expected to occur in practice. In such a connection, the noise contribution of the national systems would be expected to predominate. The attenuation distortion, group delay, and group-delay distortion would also be higher than for the IDN case. Such connections are expected to be extremely rare.

4.2 *General remarks applicable to Figures 1, 2, 3, 4, 5 and 6.*

4.2.1 The hypothetical reference connections show the international circuits connected together at 0 dBr and 0 dBr virtual switching points, as they are digital switching points interconnected by digital facilities, instead of −3.5 dBr and −4 dBr points, the values normally assigned to analogue ISC switches. 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" analogue ISC −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.

4.2.2 The nomenclature is based on the international routing plan recommended in Recommendation E.171, i.e. ISC = International Switching Centre.

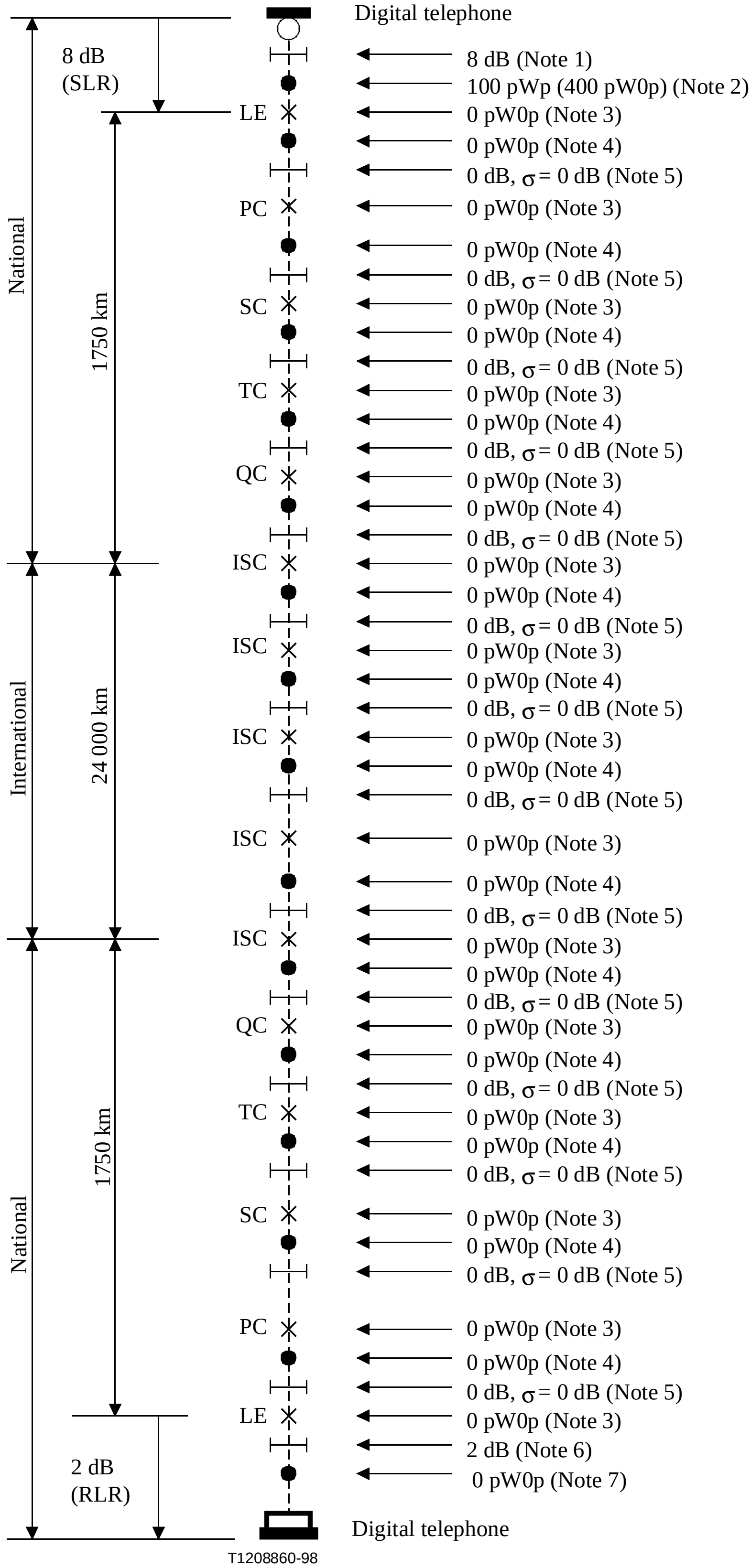
4.2.3 In each case, only one direction of transmission is shown.

4.2.4 The design objectives for the mean noise powers are indicated according to current national recommendations. For long-distance national analogue 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.

4.2.5 The abbreviation pW0p stands for picowatts psophometric referred to a point of zero relative level. In the case of analogue 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.

4.2.6 This Recommendation was prepared using the assumption that Plesiochronous Digital Hierarchy/Synchronous Digital Hierarchy (PDH/SDH) technology and ATM digital technology may be used in the PSTN.

4.2.7 It is recommended that the E-Model be used to evaluate the transmission performance of specific configurations, especially when speech compression technology, e.g. G.726 compliant Digital Circuit Multiplication Equipment (DCME), is used.



Legend for Figures 1, 2, 3, 4, 5 and 6

SLR	Sending Loudness Rating	SC	Secondary Centre	___	Analogue
RLR	Receiving Loudness Rating	TC	Tertiary Centre	- - -	Digital
LE	Local Exchange	QC	Quaternary Centre		
PC	Primary Centre	ISC	International Switching Centre		

Figure 1/G.103 – The longest ISDN international connection likely to occur in practice

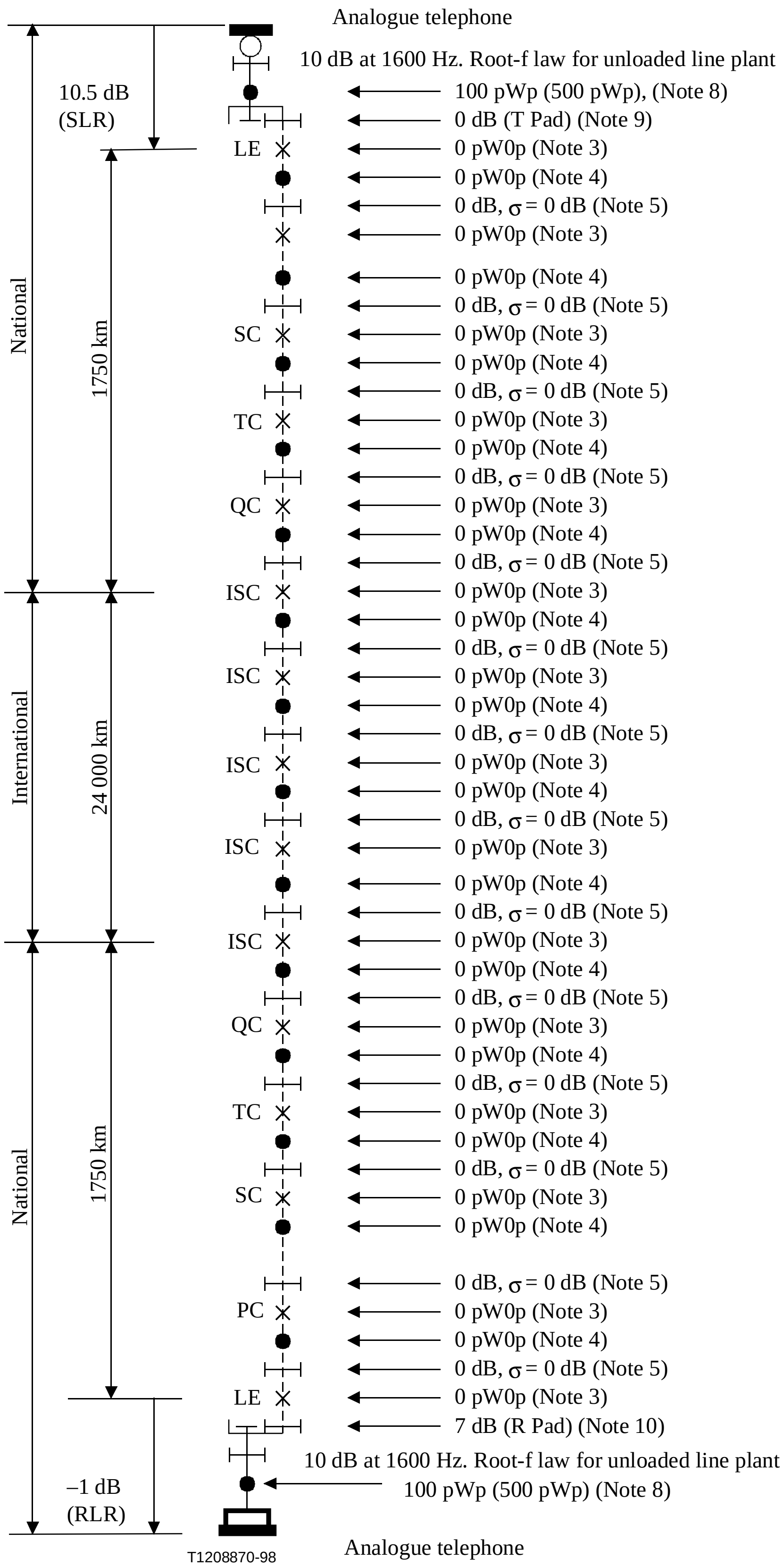


Figure 2/G.103 – The longest IDN international connection likely to occur in practice

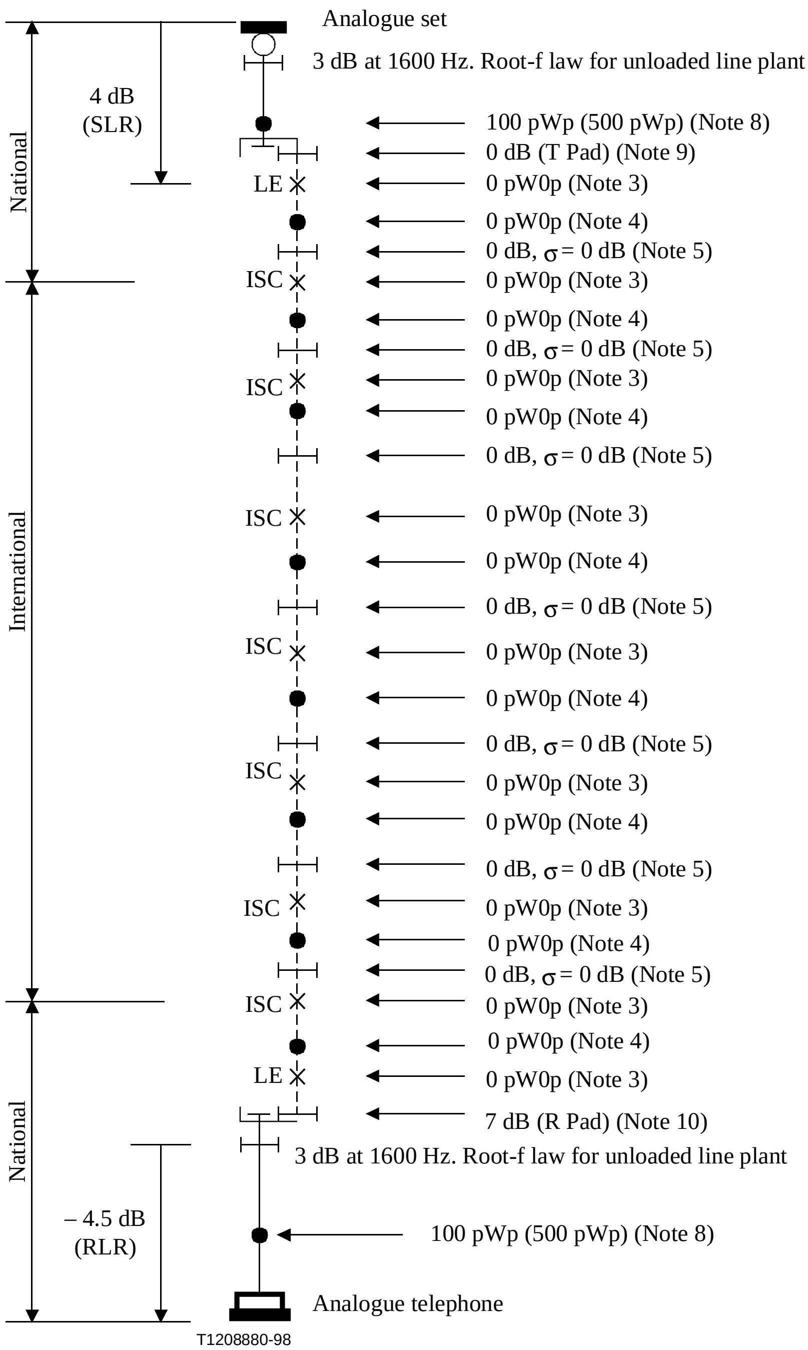


Figure 3/G.103 – An example of an IDN international connection of 4 international circuits between subscribers situated near the terminal ISCs

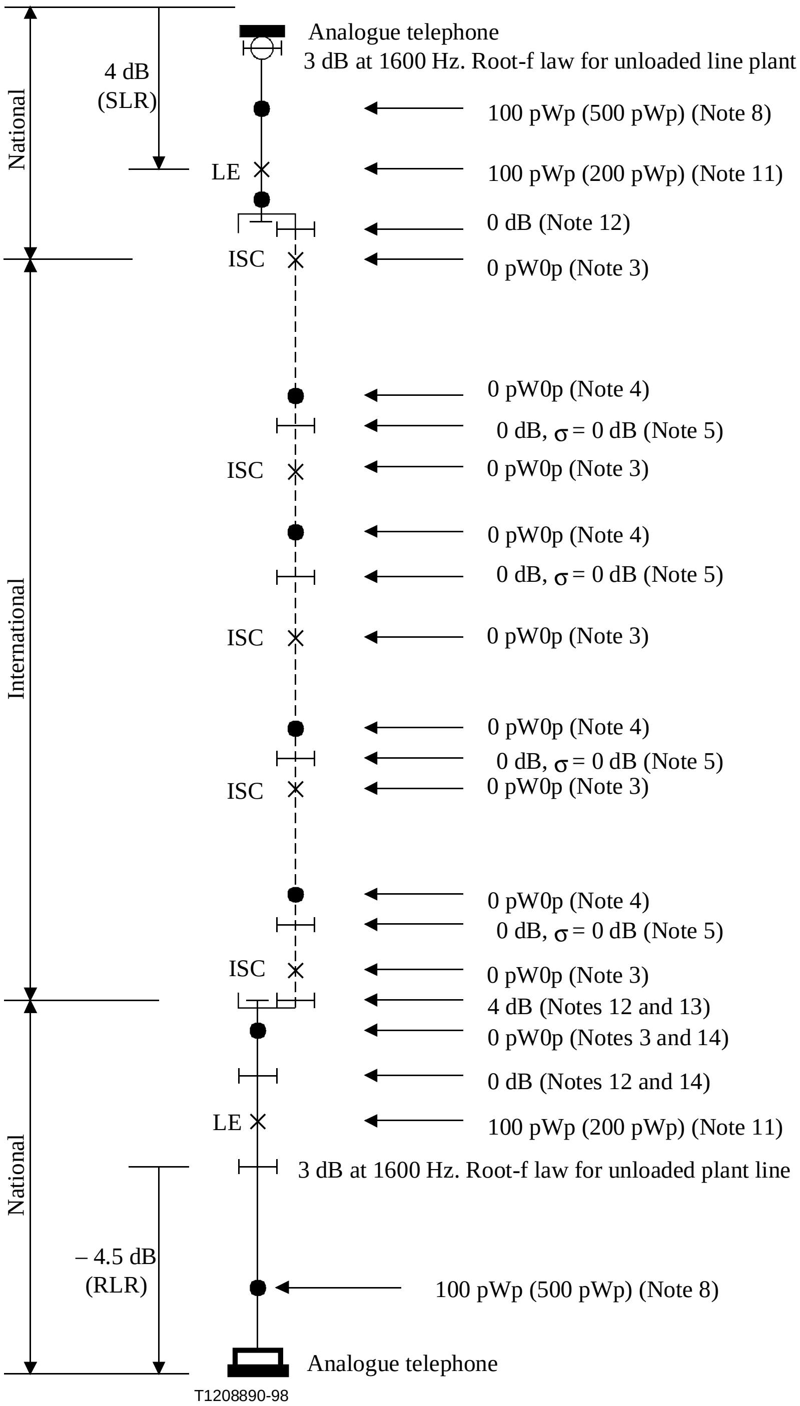


Figure 4/G.103 – An example of a hybrid international connection of 4 international circuits between subscribers situated near the terminal ISCs

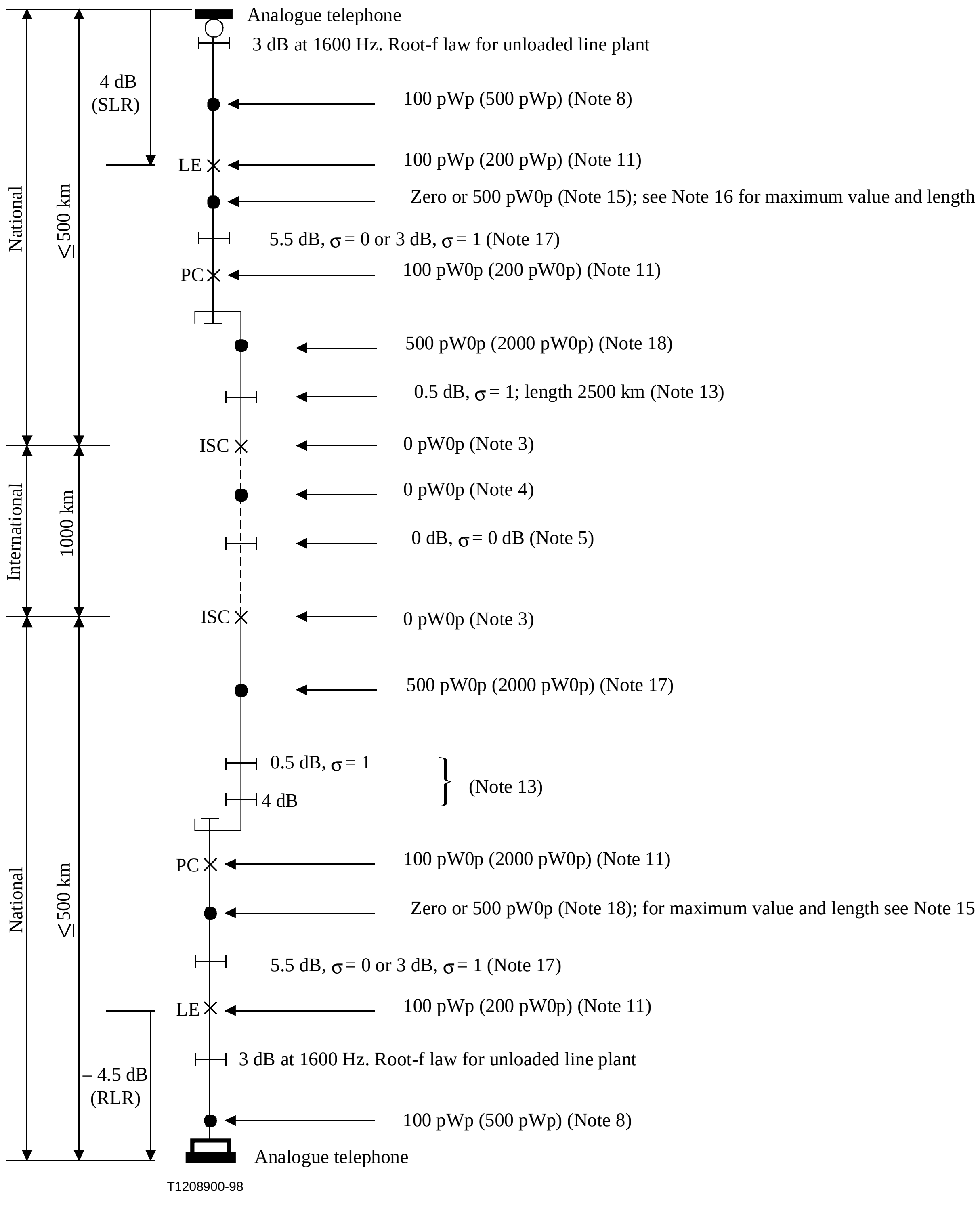


Figure 5/G.103 – An example of a hybrid international connection of moderate length with only one international circuit

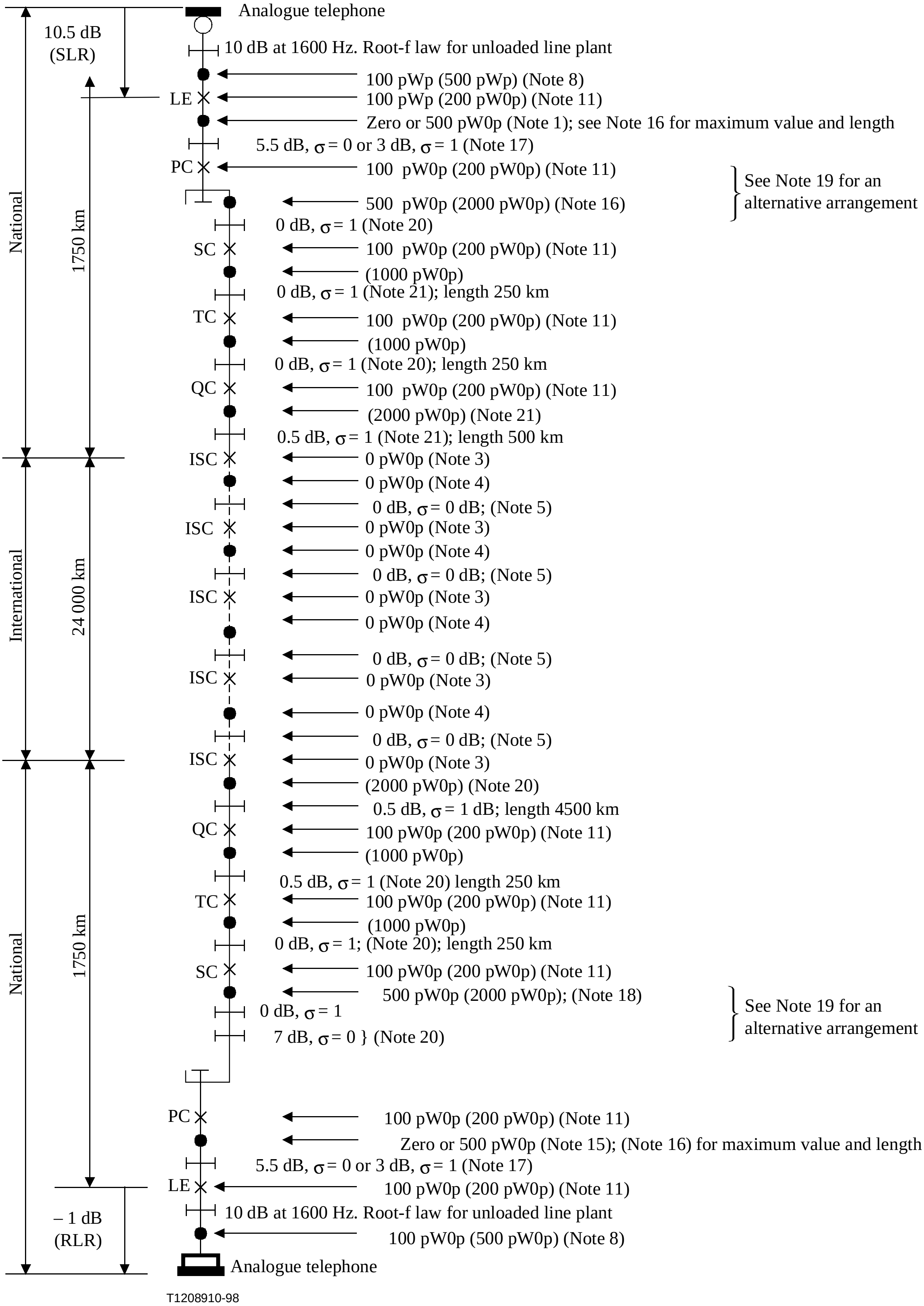


Figure 6/G.103 – The longest hybrid international connection likely to occur in practice

NOTES to Figures 1, 2, 3, 4, 5 and 6

NOTE 1 – A value of 8 dB was selected for the SLR of the digital telephone set to be consistent with Recommendation P.310.

NOTE 2 – A nominal value of noise of 100 pW0p (–70 dBm) was selected as a typical value for the noise generated by a digital telephone set. A value of 400 pW0p (–64 dBm0p) was selected as the maximum noise generated by the transmit section of a digital telephone set to be consistent with Recommendation P.310.

NOTE 3 – The noise contribution of a digital switch is assumed to be 0 pW0p.

NOTE 4 – The noise contribution of a digital trunk is assumed to be 0 pW0p.

NOTE 5 – The loss associated with a digital circuit is assumed to be 0 dB, $\sigma = 0$.

NOTE 6 – A value of 2 dB was selected for the RLR of the digital telephone set to be consistent with Recommendation P.310.

NOTE 7 – The noise contribution of a digital access and a digital telephone set receiver is assumed to be 0 pW0p.

NOTE 8 – 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. The maximum planning value should never exceed 500 pWp.

NOTE 9 – This is the T pad and a value of 0 dB was arbitrarily selected. The value of the T pad will depend upon the national transmission plan. Table C.1/G.121 provides values of T and R pads for various countries.

NOTE 10 – This is the R pad and a value of 7 dB was arbitrarily selected. The value of the R pad will depend upon the national transmission plan. Table C.1/G.121 provides values of T and R pads for various countries.

NOTE 11 – The value of 200 pW0p as the design objective for the maximum noise power in a national 4-wire automatic exchange was taken from clause 3/G.123, which is no longer in force. The same value, i.e. an absolute noise power of 200 pWp, has been assumed for national 2-wire exchanges. No assumption has been made concerning the position of any national zero relative level point.

NOTE 12 – The value of this pad will depend upon the national transmission plan.

NOTE 13 – 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, 4.2.12).

NOTE 14 – The local exchange and primary centre are assumed to be both co-sited with the ISC.

NOTE 15 – 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 16 – 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.

NOTE 17 – For circuits on physical line plant, the LR may be taken to have a nominal maximum value of 6 dB with $\sigma = 0$. This value was arrived at in the following way: Recommendation G.121 gives a 97% limit on 20 dB Sending 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 international circuits (i.e. to the primary centre) gives 16.5 dB. Reference [1] indicates that a 10.5 dB Sending 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, 4.2.12).

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 $A = 87.6$). Only 8-bit coding is recommended by the ITU-T.

NOTE 18 – The maximum planning value of 2000 pW0p provides for a circuit length of about 500 km with some margin.

NOTE 19 – 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 20 – 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, 4.2.12).

NOTE 21 – The noise value corresponds to a design objective of 4 pW0p/km for the most adverse noise power during the busy hour.

4.2.8 The pad symbols represent the nominal loss of the particular channel or circuit and the relative position of the noise generator. The pad also 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*.

4.2.9 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.

4.2.10 Information concerning the distributions of attenuation distortion and group-delay distortion for analogue circuits and exchanges is to be found in Annex A/G.113.

Recommendation G.114 gives information concerning group delay.

4.2.11 The standard deviation of transmission loss of circuits is in accord with the objectives of clause 10/G.120.

4.2.12 "Circuit" in these reference connections is defined in the sense of Recommendation M.60 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.

5 Number of modulation and demodulation equipments

For the study of transmission performance, the longest international connection expected to occur (see Figure 6) may be considered to have the following arrangement of modulator/demodulator pairs in the 4-wire chain. See Table 1.

Table 1/G.103 – Number of maximum modulator/demodulator pairs in a wholly analogue national 4-wire chain and wholly digital international 4-wire chain

	Eight national circuits	Circuits between ISCs	Total
Channel	8	0	8
Group	12	0	12
Supergroup	16	0	16

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.

6 Developments arising from the ongoing introduction of PCM digital processes

The worldwide telephone network is undergoing a transition from what is largely a hybrid network to a wholly digital network. Looking farther into the future, this transition is expected to continue and result in a network that would be predominantly wholly digital. Background on this transitional process is given in clause 4/G.101.

With reference to the hypothetical reference connections of Figures 1, 2, 3, 4, 5 and 6, 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 and wholly 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.

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 or speech compression. 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

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

A.1 Consider the connection shown in Figure A.1 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.

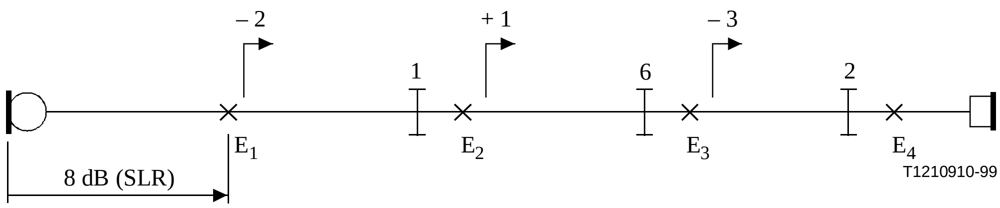


Figure A.1/G.103 – Connection with various send switching levels

A.2 We assume that noise powers of these circuits are N_1, N_2 and N_3 pW0p respectively. Figure A.2 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.

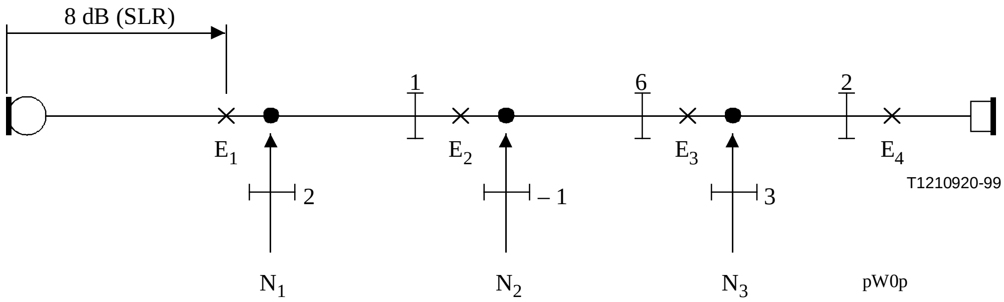


Figure A.2/G.103 – The noise powers added

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 Sending 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 in which all send switching levels are 0 dBr and all the other conditions are met as well.

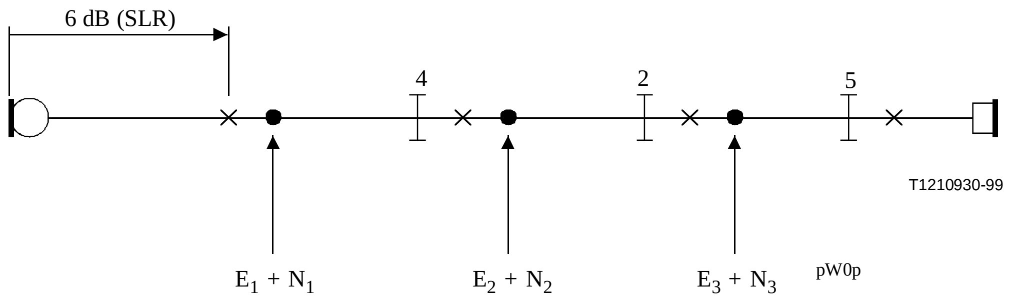


Figure A.3/G.103 – All send switching levels are 0 dBr

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.

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