INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

G.121

(11/1988)

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

International telephone connections and circuits – General characteristics of national systems forming part of international connections

---

LOUDNESS RATINGS (LRs) OF NATIONAL SYSTEMS

Reedition of CCITT Recommendation G.121 published in the Blue Book, Fascicle III.1 (1988)

NOTES

1 CCITT Recommendation G.121 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.121

LOUDNESS RATINGS (LRs) OF NATIONAL SYSTEMS

Preamble

Paragraphs 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 LRs 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 international switching centre unless otherwise stated.

The definition of the virtual analogue switching points of international circuits can be found in Figure 1/G.111.

The CCITT,

considering

(a) that loudness ratings (LRs) as defined in Recommendation P.76 have been determined by subjective tests described in Recommendation P.78 and that the difference between the values thus determined in various laboratories (including the CCITT Laboratory) are smaller than for Reference Equivalents;

(b) that for planning purposes, LRs are defined by objective methods as described in Recommendations P.65, P.64 and P.79;

(c) that the conversion formulae from Reference Equivalents and corrected reference equivalents (CREs) (see Annex C to Recommendation G.111) are not accurate enough to be applied to specific sets; that therefore, the Administrations who still rely on values of Reference Equivalents (determined in the past in the CCITT Laboratory) for the type of the sets they use need to find recommended values of CREs in CCITT documentation,

recommends

(1) that the values given below in terms of LR should be used by Administrations to verify that their national systems meet the general objectives resulting from Recommendation G.111,

(2) that Administrations employing CREs should preferably translate the LRs of this Recommendation into their national CREs by the methods given in Annex C to Recommendation G.111 or, as a second choice, apply the values given in Volume III of the *Red Book*.

Note 1 – The main terms used in this Recommendation are defined and/or explained in Annex A to Recommendation G.111.

Note 2 – For many telephone sets using carbon microphones, the SLR and STMR values can only be determined with limited accuracy.

1 Nominal LRs of the national systems

1.1 *Definition of nominal LRs of the national systems*

Send and Receive Loudness Ratings, SLRs and RLRs respectively, may in principle be determined at any interface in the telephone network. When specifying SLRs and RLRs of a national system, however, the interface is chosen to lie at the international exchange.

An increasing number of international systems will be connected to national systems via a *digital* interface where by definition the relative levels are 0 dBr. Therefore, in this Recommendation and in Recommendation G.111 the SLRs and RLRs of the *national systems* are referred to a *0 dBr exchange test point* at the international exchange. See Recommendation G.101, § 5. This convention is applied both for digital and analogue interconnections between the national and international systems (unless otherwise specified in particular cases).

However, the concept of “virtual analogue switching point”, VASP, has also been used in the planning of all-analogue, mixed analogue-digital and digital systems. If the connection to the international circuit is made on an analogue basis the *actual* relative levels at the interface may of course be chosen by the Administration concerned. For a discussion of these matters, see Recommendation G.111, § 1.1.

In this Recommendation, values at the VASP are also given.

1.2 *Traffic-weighted mean values of the distribution of send and receive loudness ratings, SLRs and RLRs*

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.

An appropriate subdivision of the overall loudness requirement is obtained by the following long-term objectives referred to a 0 dBr international switching point.

SLR : 7 to 9 dB

RLR : 1 to 3 dB

and at the VASP

SLR : 10.5 to 12.5

RLR : –3 to –1

Note 1 – In some networks the long-term values cannot be attained at this time and appropriate short-term objectives are at 0 dBr

SLR : 7 to 15 dB

RLR : 1 to 6 dB

and at the VASP

SLR : 10.5 to 18.5 dB

RLR : –3 to 2 dB

Note 2 – In some networks the actual traffic distribution is known only incompletely. In such cases, subscribers generating heavy traffic, like PBXs, should be given special consideration.

Note 3 – The long-term traffic weighted mean values of LRs should be the same for each *main* type of subscriber categories, such as urban, suburban and rural. Only considering the mean value for the *whole* country in the transmission plan might lead to a discrimination of some important customer groups.

Note 4 – The ranges stated for SLR and RLR are for planning and do not include measuring and manufacturing tolerances.

Note 5 – Some Administrations have found it advantageous in some circumstances to include a manual volume control in the receive part of the digital telephone set. See the remarks made in Rec. G.111, § 3.2.

2 Maximum Send and Receive Loudness Ratings, SLR and RLR

2.1 *Values for each direction of transmission*

The maximum SLRs and RLRs given below in Table 1/G.121 mainly apply when the national system is predominantly analogue. When modernizing networks by digital techniques, efforts should be made to avoid having those maximum values for the national system.

TABLE 1/G.121

Nominal maximum LRs recommended for national systems

Country size [a]	No. of nat. [b] circuits in the 4-w chain	0 dBr point		VASP	
		SLR	RLR	SLR	RLR
Average	Up to 3	16.5	13	20	9
Large	4	17	13.5	20.5	9.5
Large	5	17.5	14	21	10

[a] See Recommendation G.101, § 2.2.

[b] Analogue or mixed analogue/digital.

Note – When comparing these maximum values of LRs with LRs determined for existing networks some discrepancies may be found. If the actual LRs are greater by 2 or even 3 dB this is no cause for concern. On the other hand, if a margin of 2 or 3 dB seems to appear, the permissible attenuation for subscriber lines should not automatically be increased. The first step should instead be to use the margin to improve the traffic-weighted mean values referred to in § 1.2.

2.2 *Difference in transmission loss between the two directions of transmission in national systems*

It has been found pratical to introduce a certain difference in loss between the directions 4-wire-to-2-wire and 2-wire-to-4-wire. As can be seen from Figure 1/G.121 this difference is equal to $D_o = (R - T)$ dB referred to the 0 dBr 4-wire reference points. Referred to the VASPs as in Figure 1/G.122 the difference is $D_v = (R - T - 7)$ dB. For international transmission compatibility it is desirable that Administrations choose approximately the same value of these differences. Table C-1/G.121 indicates that $R = 7$, $T = 0$ dB are the most common pad values, giving $D_o = 7$, $D_v = 0$ on the average. For planning of new networks, these are the preferred values. Thus, the difference in loss between the two directions of transmission on an international connection should not exceed 8 dB, preferably not 6 dB.

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 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 LRs falling within the range found in practice, no great disadvantage attaches to any reasonable difference in LR between the two directions of transmission.

3) When devising national transmission plans, Administrations should take into account the needs of data transmission between modems complying with the pertinent Recommendations.

3 Minimum SLR

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 $SLR = -1.5$ dB referred to a 0 dBr point or 2 dB 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 loudness rating value may occur if unregulated telephone sets are used. Furthermore, the speech power applied to the international circuits by operators' sets must be controlled so that it does not become excessive.

4 Determination of nominal Loudness Ratings

Loudness Ratings and their properties and uses are explained in Annex A to Recommendation G.111. There it is described how a particular LR of a national system may be determined as a sum of the individual LRs of its parts. Also, rules are given for how to obtain the individual LRs of these parts, i.e. for telephone sets, subscriber lines, junctions, channel equipment, etc.

Note that Send and Receive Loudness Ratings of *analogue telephone sets* are measured under specified conditions which do not exactly correspond to those valid for a national system which is part of an international connection. The measurements are done with a terminating impedance of 600 ohms resistive and over a much wider bandwidth (100-8000 Hz or 200-4000 Hz) than the assured bandwidth of the international connection (300-3400 Hz).

Therefore, to avoid confusion, measured values of Send and Receive Loudness Ratings of *analogue* telephone sets are designated by the index "w" (for wideband). To get the proper values of SLR and RLR for *planning* international connections, 1 dB should be added to the measured values in order to compensate for bandwidth and impedance mismatch effects. Thus,

$$SLR = SLR_w + 1$$

$$RLR = RLR_w + 1$$

A *digital* telephone set, however, does not need these corrections because the codec and filters in the set limit the band anyhow.

In general, the loudness loss between *two electrical interfaces*, the Circuit Loudness Rating CLR, is equal to the corresponding difference in relative levels. (Unless an interface with a "jump" in relative level is included in the path. See § 6.3.)

"Nominal value" here signifies a "reasonable engineering average" for typical conditions as exemplified in what follows, excluding "worst cases".

With regard to circuits and other items of equipment, variations with time, temperature etc. are not included in the nominal CLRs, Circuit Loudness Ratings.

For telephone sets, most Administrations today have to accept a large variety of types which comply with some national specification having rather wide limits. The requirements for SLR and RLR usually refer to a measuring setup with a variable artificial line terminated by a feeding bridge and a nominal impedance which may be complex or, most often, 600 ohms.

The specification is often drawn up in the form of upper and lower limits for SLR_w and RLR_w as functions of line length (or possibly line current). The "nominal" SLR_w and RLR_w of telephone set plus subscriber line may then be interpreted as the arithmetic mean between the upper and lower limit curves.

In practice, the subjective quality impression of the overall loudness changes rather insignificantly for fairly large variations of OLR around the optimum value and it is unlikely that sets with worst possible LRs are associated with limiting line lengths. Therefore, rather wide manufacturing tolerances, commonly about ±3 dB, can be accepted for the individual set SLR (set) and RLR (set). (SLR (set) and RLR (set) refer to set measurements without the subscriber line but as function of line current, including the 1 dB bandwidth correction.)

Note however, that the *sum* of SLR (set) + RLR (set) for an individual 2-wire telephone set must be controlled more carefully so that is does not decrease below a certain minimum value. The reason is that, under certain circumstances, subscribers react very unfavourably to strong sidetone and talker echo. Both effects depend directly on this LR sum in addition to the unavoidable network impedance variations. This minimum limit is often translated into a minimum limit for STMR as measured against a specified impedance. See § 5 for a discussion.

5 Sidetone

5.1 *General*

Especially for those connections approaching the limits for high Loudness Ratings and/or noise, further transmission impairments should be avoided. One important precaution is to ensure that an adequate *sidetone* performance is maintained for the various circuit combinations occurring in the telephone system. ("Adequate" is in most cases to be interpreted as a sufficiently high sidetone loss.)

For 2-wire telephone sets, the sidetone performance is basically dependent on set sensitivity and impedance variation limits as explained in Annex A to Recommendation G.111. Thus, a national transmission plan should not only give rules for allocation of losses in the network but also provide an appropriate impedance strategy to follow. (An example is given in Supplement No. 10 of Vol. VI.)

Note that for sidetone evaluations one has to consider the line impedance “seen” by the 2-wire telephone set in the actual, *complete* connection. In modern system configurations this impedance cannot always be simulated by an artificial line terminated by a simple R-C network. Either one has to use a more elaborate measuring setup or resort to computations from known data of the circuits involved. (A number of computer programs exists which can be employed for such purposes.)

Of special interest is the fact that a 4-wire link inserted in a 2-wire connection may cause large impedance variations. As this is a common network practice - for instance digital exchanges - a simplified calculation method is discussed in Annex B.

Ideally, a 2-wire telephone set could be designed to have an adaptive sidetone balancing function, thus widening the acceptable range of line impedances. Such costly techniques are very exceptional, however, and should not be prescribed for the “standard” sets to be used in the network. A possible, cheaper alternative is to design a set with a Z_{so} varying in a predetermined manner with the line feeding current. (Z_{so} = equivalent sidetone balance impedance.) However, the best strategy is to control the impedances in the network. Thus, the use of complex nominal input impedances to exchanges is tending rather to reduce the range of impedances seen from the set.

Digital telephone sets are of course connected 4-wire to the digital network and thus there exists no near-end impedance mis-match to produce a sidetone effect. Instead, a small, internal feedback from send to receive is introduced. For judging the overall transmission quality the far-end effects have to be considered. However, those effects caused by impedance mis-matches and/or acoustic echoes can have a substantial influence.

Under some difficult transmission circumstances, analog telephone sets are also 4-wire connected to the network. This applies for (analog) mobile and maritime services and, in the past, for some exceptionally large, private networks.

5.2 *Talker's sidetone STMR*

STMR, the sidetone masking rating, is explained in Annex A.1 to Recommendation G.111. How to determine STMR is described in Annexes A.3 and A.4 to Recommendation G.111. See also Annex B to Recommendation G.121 and Recommendations P.76 and P.79.

In a face-to-face conversation there is a certain airpath feedback from the talker's mouth to his ear, partly via room reflexions. Using the handset in a telephone conversation the electric sidetone path should provide about the same feedback, the acceptable range being rather large. Unfortunately, in many present 2-wire connections the impedance deviations from the ideal are so large that the electric sidetone feedback becomes too strong, i.e. STMR too low. This causes the speaker to lower his voice and/or move the earphone away from his ear, thus impairing the acoustic transmission quality.

The following values are given as a guide for transmission planning.

For 2-wire telephone sets:

STMR = 7 – 12 dB: Preferred range.

STMR = 20 dB: Upper limit, above which the connection feels dead.

STMR = 3 dB: Lower limit, acceptable only for low-loss connections, i.e. low OLR.

STMR = 1 dB: Lowest (short-term) limit for exceptional cases, such as very short subscriber lines.

For digital (4-wire) telephone sets:

STMR = 15 ± 5 dB: Preferred range for near-end, introduced sidetone (far-end effects disregarded).

Note 1 – When *STMR* = 7 or 8 dB, this corresponds to the average acoustic loss from the talker's mouth to his ear via the electric sidetone path being about 0 dB in typical cases.

Note 2 – STMR has to be determined for the *complete* connection. (See the comments made in § 5.1.)

Note 3 – In the presence of high room noise, requirements on LSTR may be the controlling factor.

Note 4 – If the reflected electric signal has a noticeable delay it is interpreted as an echo rather than sidetone, which means it needs more suppression to avoid subscriber dissatisfaction. See Recommendations G.122 and G.131. (Recent investigations indicate that at a delay of 2-4 ms, the echo begins to be clearly distinguishable from even a strong “normal” sidetone.) The problem is under study in Question 9/XII.

5.3 *Listener's sidetone LSTR*

LSTR, the listener's sidetone rating is defined in Annex A.1 to Recommendation G.111. How to determine LSTR is described in Annexes A.3 and A.4 to Recommendation G.111.

The presence of a listener's sidetone means that room noise is picked up by the handset microphone and transmitted to the handset ear via the electric sidetone path. LSTR is a measure of how well this room noise sidetone is suppressed. Too low values of LSTR means that the room noise will be *amplified* at the handset ear. This is obviously very disturbing for subscribers in noisy environments, especially for high-loss connections.

Note – High noise gives the impression of lower received speech levels.

For a particular telephone set there is a fixed relation between the talker's and the listener's sidetone, STMR and LSTR respectively. For sets with linear microphones LSTR is typically between 1.5 and 4 dB higher than STMR, independent of the noise level. For carbon microphone sets the difference is dependent on the room noise level, a threshold effect being noticeable. For 60 dB(A) room noise (Hoth-type) the difference is in the order of 6 to 8 dB. (For other noise levels and some handset designs the difference can be as high as 15 dB.)

In general, subscribers prefer sets with linear microphones because the sound quality is much superior. However, when replacing old carbon microphone sets in noisy environments with modern linear sets, care must be taken to ensure that the LSTR-value is sufficiently high. (However, some linear microphone sets do include a noise threshold function.)

The following value should be striven for in modern telephone systems:

$$LSTR > 13 \text{ dB}$$

Note 1 – *LSTR* = 13 dB corresponds approximately to that of the earcap of the handset functions as a shield for the room noise with an average attenuation of 5 or 6 dB. (For the higher frequencies; the lower frequencies leak past the earcap.)

Note 2 – LSTR has to be determined for the *complete* connection. (See the comments made in § 5.1.)

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.

Thus, the transmission planning of transitional phases should preferably not involve any degradation of the quality previously experienced.

6.2 *Transmission loss considerations*

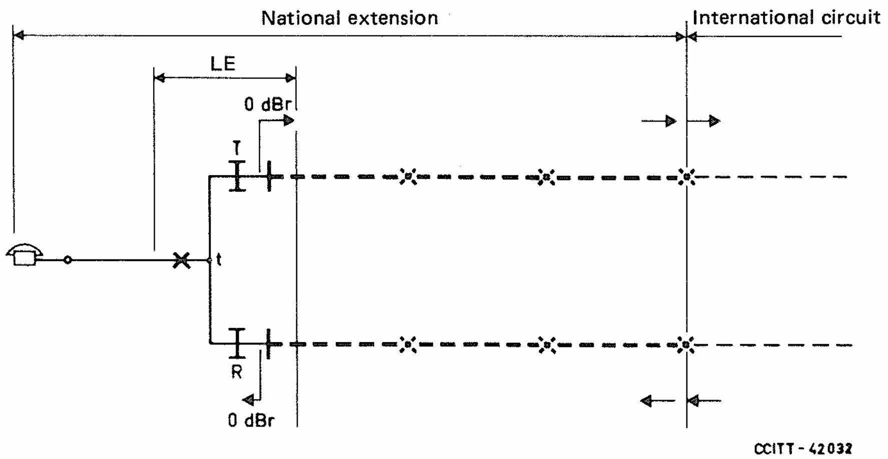
Where the national portion of the 4-wire chain is wholly digital between the local exchange and the international exchange, the transmission loss which the extension must contribute to the maintenance of stability and the control of echo on an international connection can be introduced at the local exchange. 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 1/G.121.

In case 1 and 2 of Figure 1/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 2-wire/4-wire terminating unit. Similarly, the T pad represents the transmission loss between the 2-wire side of the 2-wire/4-wire 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.

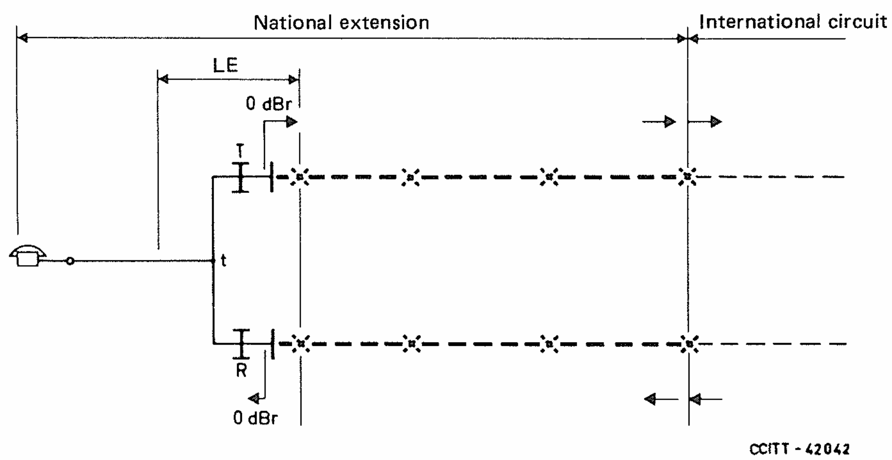
The individual values of R and T can be chosen to cater for the national losses and levels, provided that the CCITT Recommendations for international connections are always met. It is recognized that for evolving networks, the values of R and T may not be the same as the values appropriate to the all digital 4-wire national chain. However, for the case of an all-digital national chain, the choice of values of R and T is particularly important in determining the performance in respect of echo and stability. For example, if the balance return loss at the 2-wire/4-wire terminating unit can approach 0 dB under worst case terminating conditions, then the sum of R and T needs to be at least so high that the requirements of Recommendation G.122 are to be met. Examples of the values for R and T that have been adopted by some Administrations are given in Annex C to Recommendation G.121.

In case 2 of Figure 1/G.121, it is possible with a sufficiently high balance return loss to comply with the Recommendations concerning loudness ratings, 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 (§ 6.4 of this Recommendation) which in turn implies that

$$R - T = 3 \text{ to } 9 \text{ dB}$$

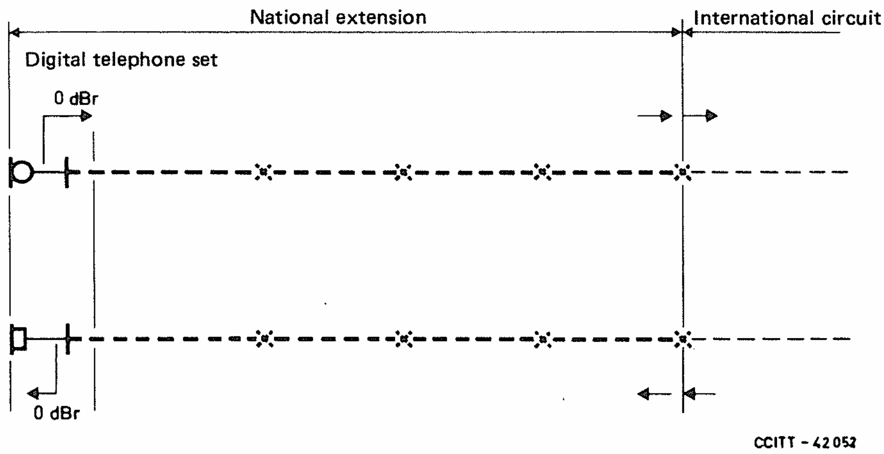


a) Case 1 – Two-wire analogue switching at local exchange and 2-wire analogue subscriber line



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

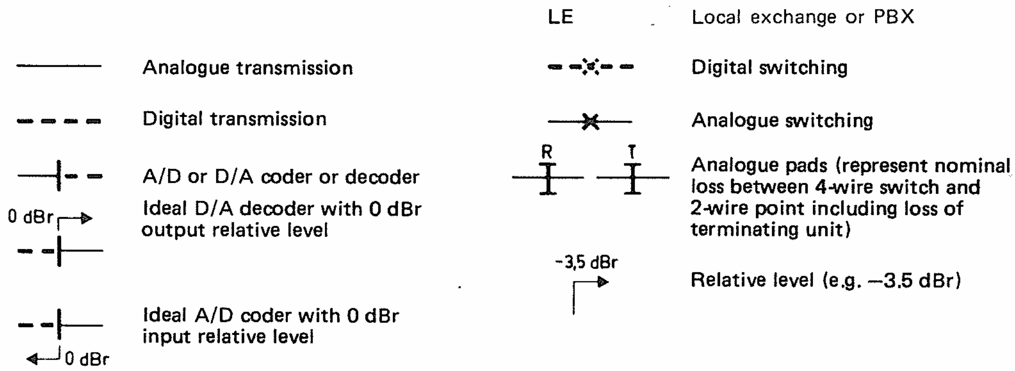


FIGURE 1/G.121

Examples of national extensions in which the digital 4-wire chain extends to a 4-wire local exchange

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.

The R and T pads shown in Figure 1/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.

For speech, the quantizing distortion will increase. See Recommendation G.113, § 4. The concept of relative levels is also affected by a digital pad. See § 6.3.

The arrangement in case 3 of Figure 1/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".

Stability and echo on international connections are governed by Recommendation G.122.

6.3 *The designation of relative levels and digital pads*

"Relative level" (expressed in dBr) is a useful concept in transmission planning by which one can determine gain or loss between points in a system as well as signal handling requirements for transmission equipment. The general definitions are found in Recommendation G.101. To clarify further the use of relative levels in Recommendations G.111 and G.121 some special aspects will be discussed here.

The relative level at a point of a circuit is in principle determined by comparison with the "transmission reference point", TRP, for that circuit, a *hypothetical* point used as the zero relative level point. Such a point exists at the sending end of each channel of a 4-wire switched circuit preceding the international exchange.

When the international connection is *digital* by means of a conventional PCM system, the transmission reference point is equal to the digital exchange test point i.e. the digital bit stream is associated with a relative level of 0 dBr. The power handling capacity of the digital bit stream is interpreted as the clipping level of a sinusoidal signal when introduced via an ideal codec: +3.14 dBm for the A-law, +3.17 for the μ-law (see Recommendation G.101, §§ 5.3.2.4 to 5.3.3.2).

When the international connection is established by an *analogue* (FDM) system, the transmission system would be designed to handle a power load of –15 dBm per channel at the transmission reference point if this existed in physical form. Thus, when the transmission system has a (nominal) power handling capacity of (–15 + S) dBm at the actual international interconnection point the relative level at that point is +S dBr.

In normal network situations, the relative level at a certain point is numerically equal to the "composite gain" between that point and the transmission reference point for the circuit concerned at the reference frequency 1020 Hz. For instance, for analogue international connections the sending relative level at VASP, the virtual analogue switching point, is –3.5 dBr (by definition). The loss of the international circuit is 0.5 (as recommended by the CCITT) and thus the relative level at the receive VASP in the other country is –4 dBr.

Likewise, in normal network cases, circuits are interconnected with matching power handling capabilities.

Thus digital (PCM) bit streams not subjected to digital gain or loss are always associated with a relative level of 0 dBr.

In some exceptional cases however, the rules relating relative level to "composite loss" and "power handling capacity" do not apply exactly. For practical reasons some types of interfaces will have "jumps" in relative levels because two (or more) different transmission reference points occur in tandem.

One example is digital gain or loss introduced in the send direction. Following the definition given in Recommendation G.101, § 5.3.2.6 there will be a jump in relative level as illustrated in Figure 2/G.121 at point B. The loss between points A and B is T dB but the difference in relative level is 0 dB.

Another example is to be found in certain international connections which include several 4-wire (analogue or mixed analogue-digital) systems in cascade between the VASPs. If there are no such circuits, for stability reasons the loss is then made equal to $n \cdot 0.5$ dB.

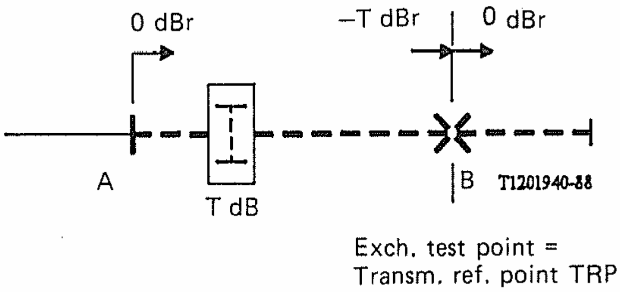


FIGURE 2/G.121

Exemple of a jump in relative level at an interface. (Point B)

Note 1 – The "power handling capacity" refers to a *nominal* load, not to the *actual* load which the system is subjected to. For instance, for an analogue system at the TRP the nominal load of –15 dBm corresponds to 0.032 mW of which 0.010 mW is considered to originate from signalling and tones, 0.022 mW from speech, carrier leaks and voice telegraphy. The nominal speech load at the TRP thus is –16.6 dBm taken as an average with time from a batch of channels during a busy hour. The actual average speech level may very well differ from this value. This is of course even more probable for an individual channel. (However, the aim should always be for the actual load to be close to the nominal load for which the transmissions system gives optimum performance.)

Note 2 – For many reasons, digital gain or loss should be used only exceptionally in a network.

Note 3 – If digital gain or loss is introduced the firm relations between relative level and power handling capacity may be lost. For instance, in an arrangement in accordance with Figure 2/G.121 the actual possible maximum peak level to the right of point B (i.e. at 0 dBr) will be T dB lower than + 3.14 dBm. Likewise, to the left of point B (i.e. at –T dBr) the noise threshold level will be T dB higher than in a normal PCM system.

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.

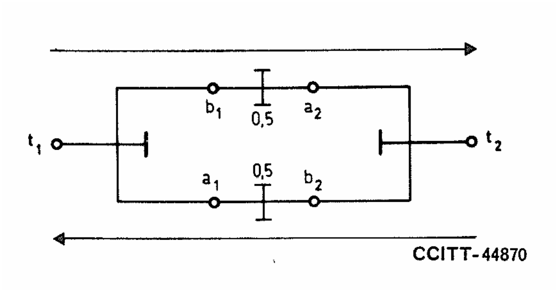


FIGURE A-1/G.121

The nominal overall losses in each of the two directions of transmission are:

$$1 \rightarrow 2 = t_1b_1 + 0.5 + a_2t_2 (\text{dB})$$

and

$$2 \rightarrow 1 = t_2b_2 + 0.5 + a_1t_1\ (\text{dB})$$

where a and b are defined as in Recommendation G.122, so that the difference between the two directions is:

$$(t_1b_1 - a_1t_1) - (t_2b_2 - a_2t_2) = d_1 - d_2$$

in which d signifies $d_1 = t_1b_1 - a_1t_1$ or $d_2 = t_2b_2 - a_2t_2$.

Note – As long as the 2-wire nominal impedance are resistive there is no problem in defining “loss”. The modern trend is toward using complex nominal impedances, however, and then some conventions have to be observed. In Recommendation Q.551, § 1.2.3 - § 1.2.5 is prescribed how to measure digital exchanges with analogue parts. In short, the rules are:

a) The equipment (circuit) is measured under nominally matched impedance conditions for the analogue ports. During the measurements, the 4-wire loop must be broken in the return direction. (In practice, this means *either* between two physical impedances as is the case for 600 ohms measurements *or* between a low-impedance generator and a high-impedance indicator. Either method can be used, depending on what is most practical. The measurement results do not differ very much.) Note when the second method is used, a 6 dB correction must be applied.

b) The nominal loss is the composite loss at the reference frequency 1020 Hz (i.e. the voltage loss corrected by 10 times the logarithm of the impedance ratio).

c) The attenuation distortion as a function of the frequency f is 20 times the logarithm of the ratio of the voltage at 1020 Hz to the voltage at f.

ANNEX B

(to Recommendation G.121)

Transmission considerations for a 4-wire loop inserted in a 2-wire circuit

B.1 *General*

A 4-wire loop normally exhibits a considerable change of phase as a function of frequency. Thus, it may have a large influence on the attenuation distortion and the impedances when inserted in a 2-wire circuit because of the reflexions encountered. In what follows exact expressions will be given for loss and impedance together with an approximate rule useful for estimating certain sidetone effects.

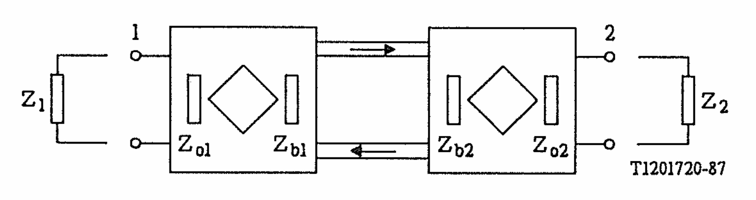


FIGURE B-1/G.121

A 4-wire loop inserted in a 2-wire connection

In Figure B-1/G.121 is shown a 4-wire loop with 2-wire ports Nos. 1 and 2. The following designations are used.

Terminating impedances: Z_1 and Z_2.

2-wire input impedances (4-wire loop open): Z_{o1} and Z_{o2}.

Balance impedances: Z_{b1} and Z_{b2}.

Loss and phase shift under matched load conditions, i.e. $Z_1 = Z_{o1}$ and $Z_2 = Z_{o2}$;

from port 1 to port 2 (4-wire loop open from port 2 to 1): L_1 dB, B_1 deg;

from port 2 to port 1 (4-wire loop open from port 1 to 2): L_2 dB, B_2 deg.

We now define the following (complex) factors:

$$C_1 = 10^{-L_1/20} \cdot (\cos B_1 - j \sin B_1)$$

$$C_2 = 10^{-L_2/20} \cdot (\cos B_2 - j \sin B_2)$$

$$C_{r1} = \frac{2Z_{o1}}{Z_{o1} + Z_{b1}} \cdot \frac{Z_1 - Z_{b1}}{Z_1 + Z_{o1}}$$

$$C_{r2} = \frac{2Z_{o2}}{Z_{o2} + Z_{b2}} \cdot \frac{Z_2 - Z_{b2}}{Z_2 + Z_{o2}} \qquad \text{(B-1)}$$

$$C_{b1} = \frac{Z_{o1} - Z_{b1}}{Z_{o1} + Z_{b1}}$$

$$C_{b2} = \frac{Z_{o2} - Z_{b2}}{Z_{o2} + Z_{b2}}$$

The balance return losses at port 1 and 2 are:

$$L_{br1} = -20 \log_{10} \left| C_{r1} \right|; \; L_{br2} = -20 \log_{10} \left| C_{r2} \right| \qquad \text{(B-2)}$$

Note that the balance return losses may become *negative* for some terminations. Therefore, a few comments will be given on this aspect as some peculiar circuit configurations can be encountered during the setup of a call.

The minimum balance return loss at a port with (2-wire) input impedance Z_o and balance impedance Z_b occurs when the terminating impedance is a *pure reactance*, the value of which depends on Z_o and Z_b. (Thus in general, neither the open- or the short-circuit condition!)

The minimum balance return loss value is:

$$(L_{br})_{min} = -20 \log_{10} \left\{ \frac{1}{\cos V} + \sqrt{(1 - S)^2 + (\tan V - T)^2} \right\} \qquad \text{(B-3)}$$

where

$$\left.\begin{aligned} V &= \text{phase angle of } (Z_o) \\ S + jT &= \frac{2Z_o}{Z_o + Z_b} \end{aligned}\right\} \qquad \text{(B-4)}$$

A case of special interest is when by design Z_o is made identical with Z_b. Then Equation (B-4) transforms into:

$$\begin{aligned} &(L_{br})_{min} = -20 \log_{10} \left\{\tan \tfrac{1}{2} (90^\circ - |V|)\right\} \\ &(Z_o = Z_b) \end{aligned} \qquad \text{(B-5)}$$

This minimum occurs when the terminating impedance is a pure reactance jX of *opposite* sign to the reactance of Z_o and has the value:

$$|X| = |Z_o| \qquad \text{(B-6)}$$

Note 1 – In general, the more reactive Z_o and Z_b are, the lower will the minimum balance return loss be when unfortunate terminations are met within the network. For instance, if Z_o and Z_b would be exactly matched to the unloaded subscriber cable characteristic impedance angle of –45°, $(L_{br})_{min}$, equals –7.7 dB. Thus, extremely reactive values of Z_o and Z_b should be avoided.

Note 2 – For *normal* cases encountered in the network the terminations, as well as the balancing networks, most often have a negative reactive component. The balance return loss and the return loss also do not differ very much numerically.

Note 3 – In many practical cases open- and short-circuit conditions represent “worst cases”.

B.2 *Attenuation*

According to the CCITT convention for loss with complex, nominal impedances, the loss from port 1 to port 2 with the 4-wire loop closed is

$$\begin{aligned} L_{12} = L_1 &+ 20 \log_{10} \left| \frac{Z_2\,(1.02\text{ kHz})}{Z_1\,(1.02\text{ kHz})} \right| + 20 \log_{10} \left| \frac{Z_{o1} + Z_1}{2Z_{o1}} \right| + \\ &+ 20 \log_{10} \left| \frac{Z_{o2} + Z_2}{2Z_2} \right| + 20 \log_{10} \left| 1 - C_1 \cdot C_2 \cdot C_{r1} \cdot C_{r2} \right| \end{aligned} \qquad \text{(B-7)}$$

The sum of the first four terms represents the loss which would be measured with the 4-wire loop broken in the return direction from port 2 to port 1. The second term is a correction for the terminating impedances being unequal. (Assuming Z_1 and Z_2 are the nominal, reference impedances.) The third and fourth terms represent mis-match effects.

Finally, the fifth term shows the ripple effects due to loop phase shift and non-perfect balancing at the ports, i.e. Z_{b1} not being equal to Z_1 and Z_{b2} not to Z_2.

B.3 *Impedance*

When the 4-wire loop is closed the input impedance at port 1 is:

$$Z_{in1} = Z_{o1} \frac{(Z_{o1} + Z_{b1}) + 2Z_{b1} \cdot C_1 \cdot C_2 \cdot C_{r2}}{(Z_{o1} + Z_{b1}) - 2Z_{o1} \cdot C_1 \cdot C_2 \cdot C_{r2}} \qquad \text{(B-8)}$$

A measure of the deviation of Z_{in1} from the nominal 2-wire input impedance Z_{o1} can be had from the return loss:

$$L_{r1} = 20 \log_{10} \left| \frac{Z_{in1} + Z_{o1}}{Z_{in1} - Z_{o1}} \right| \qquad \text{(B-9)}$$

Using Eq. (B-8) we get

$$L_{r1} = L_1 + L_2 + L_{br2} + 20 \log_{10} \left| 1 - C_1 \cdot C_2 \cdot C_{b1} \cdot C_{r2} \right| \qquad \text{(B-10)}$$

Note 1 – The last term in Equation (B-10) represents a (high-periodicity) ripple. However, often it is not very large. If $Z_o = Z_b$ it is zero!

Note 2 – If the loop loss ($L_1 + L_2$) is low, the effective input impedance at one port can be appreciably affected by conditions at the other.

B.4 *Sidetone considerations*

Sidetone effects can be most critical for subscribers very close to a digital exchange, i.e. with zero line length. Therefore, we will here study this case in some detail.

If a subscriber is connected directly to port 1 in Figure B-1/G.121, Equation (B-8) can be used to compute the impedance Z the telephone set sees at its terminals. Then the sidetone balance return loss A_{rst} and its weighted mean value A_m is calculated as is shown in Annex A.4.3 to Recommendation G.111, using the telephone set input impedance Z_c and its equivalent sidetone balance impedance Z_{so}. Finally, the talker's and the listener's sidetones, STMR and STLR respectively, are obtained using the value of A_m in Equation (A.4-3) in Annex A to Recommendation G.111.

The procedure just described is somewhat tedious as it involves the exact computation of the 2-wire impedance of the closed 4-wire loop. To give a rapid indication of the magnitude of sidetone effects the following simplified method can be used.

The sidetone mis-match effects are considered as the superposition of two "echo" effects, namely:

a) The sidetone balance return loss A_{rst1} between the telephone set and the nominal input impedance Z_{o1} of the (near-end) port to which the set is connected. The weighted mean value A_{m1} is computed using Equation (A.4-3) in Annex A to Recommendation G.111.

b) The far-end port impedance mis-balancing translated to the near-end part i.e. the return loss L_{r1} as given by Equation (C-10)[1)] is used to compute a mean value A_{m2} by means of Equation (A.4-3) in Annex A to Recommendation G.111.

Finally, the two "sidetone echoes" are added on a power basis to give a new weighted mean value:

$$A_m = -10 \log_{10} \left\{ 10^{\frac{-A_{m1}}{10}} + 10^{\frac{-A_{m2}}{10}} \right\}$$

Note – The far-end impedance mis-match effects will of course be interpreted not as a sidetone but as an echo if the round trip delay is long. The change from sidetone to echo perception might begin at a delay of about a few milliseconds. (This problem is under study in Question 9/XII.) Long-delay echoes are far more noticeable than sidetone.

1) Ignoring the last term.

ANNEX C

(to Recommendation G.121)

Examples of values of R and T pads adopted by some Administrations

This annex gives the values of R and T pads that have been adopted by some Administrations for their digital networks. The values given are those appropriate for digital connections between subscribers with existing analogue 2-wire subscriber lines on digital local exchanges. It is recognized that different values may be appropriate for connections in the evolving mixed analogue/digital network.

These values are given as guidance to developing countries who are considering the planning of new networks. If similar values are adopted for new networks then, in association with adequate echo and stability balance return losses, there are unlikely to be difficulties in meeting the requirements of Recommendation G.122.

Some Administrations consider losses in terms of the input and output relative levels. These values can be derived from Table C-1/G.121 by using the relationship given in Figure C-1/G.121.

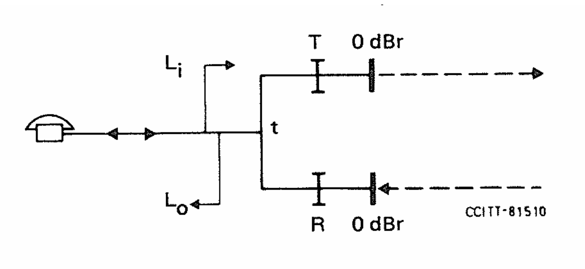


FIGURE C-1/G.121

Relation between relative levels and R- and T-pads

In this circuit, it is assumed that the relative levels of the encoder input and the decoder output are 0 dBr, that the T-pad represent all the loss between the 2-wire point, t, and the ecoder input, and that the R-pad represents all the loss between the decoder output and t. Accordingly, the relation between relative levels and losses is:

$$L_i = T, L_o = -R$$

Note – The modern trend is to use a complex nominal impedance at the 2-wire port. See the note in Annex A.1 for how "loss" should be interpreted in such a case.

In exceptional cases, some of the R and T losses may be achieved by digital pads. See § 6.2 and § 6.3 for a discussion.

In general, the range of input levels has been derived assuming that speech powers in the network are close to the conventional load assumed in the design of FDM systems. However, actual measurements reveal that this load is not being attained (see Supplement No. 5 to Fascicle III.2 of the *Yellow Book*). For this reason, it may be that there is some advantage in adopting different input (and output) levels for future designs of exchange. However, any possible changes need to take into account:

i) the range of speech powers encountered on an individual channel at the exchange input and the subjective effects of any peak clipping, noting that any impairment is confined to that channel;

ii) levels of non-speech analogue signals (e.g. from data modems or multifrequency signalling devices) particularly from customers on short exchange lines;

iii) the need to meet the echo and stability requirements of Recommendation G.122, particularly when the sum of R and T is less than 6 dB;

iv) the need to consider the difference in loss between the two directions of transmission, as required by § 6.3 of Recommendation G.121.

At this stage Administrations should note that there may be some advantage in considering a range of level adjustment for future designs of digital local exchange.

TABLE C-1/G.121

Values of R and T for various countries

	Connection type					
	Own exchange		Local via digital junctions (digital trunks)		Trunk via digital trunk exchange	
	R dB	T dB	R dB	T dB	R dB	T dB
Germany (F.R.) (For subscribers on short lines: R = 10 dB, T = 3 dB)	7	0	7	0	7	0
Australia	6	0	6	0	6	0
Austria	7	0	7	0	7	0
Belgium	7	0	7	0	7	0
Canada	0	0	3	0	6	0
Denmark	6	0	6	0	6	0
Spain	7	0	7	0	7	0
United States	0	0	3	0	6	0
Finland	7	0	7	0	7	0
France	7	0	(not used)	(not used)	7	0
India	6	0	6	0	6	0
Italy	7	0	7	0	7	0
Japan	4	0	8	0	8	0
The Netherlands	4.5	1.5	4.5	1.5	4.5 (National) 10.5 (International)	1.5
Norway	5	2	5	2	5	2
United Kingdom (Values shown are for median lines; additional loss is introduced on short local lines in both directions of transmission)	6	1	6	1	6	1
Sweden	5	0	5	0	5 (National) 7 (International)	0 (National) 0 (International)
USSR	7	0	7	0	7	0
Yugoslavia	7	0	7	0	7	0
New Zealand	7	0.5	7	0.5	7	0.5

ITU-T G-SERIES RECOMMENDATIONS

TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

INTERNATIONAL TELEPHONE CONNECTIONS AND CIRCUITS	
General definitions	G.100–G.109
General Recommendations on the transmission quality for an entire international telephone connection	G.110–G.119
General characteristics of national systems forming part of international connections	**G.120–G.129**
General characteristics of the 4-wire chain formed by the international circuits and national extension circuits	G.130–G.139
General characteristics of the 4-wire chain of international circuits; international transit	G.140–G.149
General characteristics of international telephone circuits and national extension circuits	G.150–G.159
Apparatus associated with long-distance telephone circuits	G.160–G.169
Transmission plan aspects of special circuits and connections using the international telephone connection network	G.170–G.179
Protection and restoration of transmission systems	G.180–G.189
Software tools for transmission systems	G.190–G.199
INTERNATIONAL ANALOGUE CARRIER SYSTEM	
GENERAL CHARACTERISTICS COMMON TO ALL ANALOGUE CARRIER-TRANSMISSION SYSTEMS	
Definitions and general considerations	G.210–G.219
General Recommendations	G.220–G.229
Translating equipment used on various carrier-transmission systems	G.230–G.239
Utilization of groups, supergroups, etc.	G.240–G.299
INDIVIDUAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON METALLIC LINES	
Carrier telephone systems on unloaded symmetric cable pairs, providing groups or supergroups	G.320–G.329
Carrier systems on 2.6/9.5 mm coaxial cable pairs	G.330–G.339
Carrier systems on 1.2/4.4 mm coaxial cable pairs	G.340–G.349
Additional Recommendations on cable systems	G.350–G.399
GENERAL CHARACTERISTICS OF INTERNATIONAL CARRIER TELEPHONE SYSTEMS ON RADIO-RELAY OR SATELLITE LINKS AND INTERCONNECTION WITH METALLIC LINES	
General Recommendations	G.400–G.419
Interconnection of radio-relay links with carrier systems on metallic lines	G.420–G.429
Hypothetical reference circuits	G.430–G.439
Circuit noise	G.440–G.449
COORDINATION OF RADIOTELEPHONY AND LINE TELEPHONY	
Radiotelephone circuits	G.450–G.469
Links with mobile stations	G.470–G.499
TESTING EQUIPMENTS	
TRANSMISSION MEDIA CHARACTERISTICS	
General	G.600–G.609
Symmetric cable pairs	G.610–G.619
Land coaxial cable pairs	G.620–G.629
Submarine cables	G.630–G.649
Optical fibre cables	G.650–G.659
Characteristics of optical components and subsystems	G.660–G.699

For further details, please refer to ITU-T List of Recommendations.

ITU-T RECOMMENDATIONS SERIES

Series A	Organization of the work of the ITU-T
Series B	Means of expression: definitions, symbols, classification
Series C	General telecommunication statistics
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	**Transmission systems and media, digital systems and networks**
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	Transmission of television, sound programme and other multimedia signals
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	TMN and network maintenance: international transmission systems, telephone circuits, telegraphy, facsimile and leased circuits
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks and open system communications
Series Y	Global information infrastructure and Internet protocol aspects
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2007