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TRANSMISSION SYSTEMS AND MEDIA

GENERAL CHARACTERISTICS OF NATIONAL SYSTEMS FORMING PART OF INTERNATIONAL CONNECTIONS

LOUDNESS RATINGS (LRs) OF NATIONAL SYSTEMS

ITU-T Recommendation G.121

(Previously "CCITT Recommendation")

FOREWORD

The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of the International Telecommunication Union. 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, established the topics for study by the ITU-T Study Groups which, in their turn, produce Recommendations on these topics.

ITU-T Recommendation G.121 was revised by the ITU-T Study Group XII (1988-1993) and was approved by the WTSC (Helsinki, March 1-12, 1993).

NOTES

1 As a consequence of a reform process within the International Telecommunication Union (ITU), the CCITT ceased to exist as of 28 February 1993. In its place, the ITU Telecommunication Standardization Sector (ITU-T) was created as of 1 March 1993. Similarly, in this reform process, the CCIR and the IFRB have been replaced by the Radiocommunication Sector.

In order not to delay publication of this Recommendation, no change has been made in the text to references containing the acronyms "CCITT, CCIR or IFRB" or their associated entities such as Plenary Assembly, Secretariat, etc. Future editions of this Recommendation will contain the proper terminology related to the new ITU structure.

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

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PREAMBLE

Clauses 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 clause 6 for mixed analogue/digital or all-digital connections, clause 6 will govern.

All sending and receiving LRs in this Recommendation are "nominal values" as explained in clause 4 and are referred to the corresponding Virtual International Connecting Points (VICPs) of an international circuit at the International Switching Centre unless otherwise stated.

The definition of the Virtual International Connecting Points (VICPs) of international circuits can be found in Recommendation 2.12/G.101.

Additional information is given in Supplement No. 31 (to this Recommendation): "Principles of determining an impedance strategy for the local networks".

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.

Administrations employing CREs should preferably translate the LRs of this Recommendation into their national CREs by the methods given in Annex C/G.111 or, as a second choice, apply the values given in Volume III of the *Red Book* (Geneva, 1985).

NOTES

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

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

LOUDNESS RATINGS (LRs) OF NATIONAL SYSTEMS

(amended at Helsinki, 1993)

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.

In this Recommendation and in Recommendation G.111, the SLRs and RLRs of the national systems are referred to the Virtual International Connecting Points (VICPs) of the first international circuit, as defined in Recommendation 2.12/G.101.

The Virtual International Connecting Points are points in the international circuit at the International Switching Centre (ISC). The relative levels at the VICP are:

– Sending: 0 dBr;

– Receiving: 0 dBr for digital circuits;

–0.5 dBr for analogue and mixed analogue/digital circuits.

NOTES

1 These levels do not necessarily apply to national circuits, which are governed by the national transmission plan. In determining these levels, Recommendation 2.1/G.131 may have been applied, or 2-wire switching may still be in use; see Figure 6/G.101.

2 Earlier the "virtual analogue switching points (VASP)" having the relative levels –3.5 and –4 dBr were used as the reference points.

3 The concept of relative levels (dBr) and associated terms are defined and explained in Recommendation G.101 and Annex A/G.101.

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 clause 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 the VICP:

– SLR: 7 to 9 dB;

– RLR: 1 to 3 dB.

NOTES

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

– SLR: 7 to 15 dB;

– RLR: 1 to 6 dB.

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.

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.

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

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 3.2/G.111.

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 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 national [b] circuits in the 4-w chain above the primary centre	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 3.1/G.101.

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

The difference in nominal loss between the two directions of transmission on an international connection should not exceed 8 dB, preferably not 6 dB. It has been found practical to have a certain asymmetry in the nominal loss in the two directions of transmission in the national part of the connection. It is recommended that the difference between loss a-t and loss t-b (see Recommendation G.122) should be 3-9 dB.

In a national network where all 4-wire circuits are digital and extends down to the local exchange, this difference will be equal to the difference between the T and R pads in the local exchange (see Figure 1). Pads chosen by different Administrations are shown in Annex C.

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 minimum nominal value of SLR = +2 dB referred to the VICP 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.

NOTE – The value of +2 dB is under further study.

4 Determination of nominal Loudness Ratings

Loudness Ratings and their properties and uses are explained in Annex A/G.111. There it is explained how the LR of a complete connection can be determined as the sum of the CLRs of the circuits and the SLR and RLR of the local systems (telephone sets and subscriber lines).

The loudness loss between two electrical interfaces in a connection or a circuit, the Circuit Loudness Rating (CLR), is equal to the composite loss at the reference frequency 1020 Hz, when each interface is terminated by its nominal impedance which may be complex.

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

Variations with time, temperature, etc. are not included in the nominal CLRs.

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 the 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 clause 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/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 see Supplement No. 31 (to this Recommendation).

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 mismatches and/or acoustic echoes can have a substantial influence.

Under some difficult transmission circumstances, analogue telephone sets are also 4-wire connected to the network. This applies for (analogue) 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 A.1/G.111. How to determine STMR is described in A.3/G.111 and A.4/G.111. See also Annex B/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).

NOTES

1 Typically, an STMR = 7 or 8 dB corresponds to that average acoustic loss from the talker's mouth to his ear via the electric sidetone path is about 0 dB.

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

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

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.

5.3 Listener's sidetone LSTR

LSTR, the listener's sidetone rating is defined in A.1/G.111. How to determine LSTR is described in A.3/G.111 and A.4/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 1 – 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:

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

NOTE 2 – 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 3 – 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

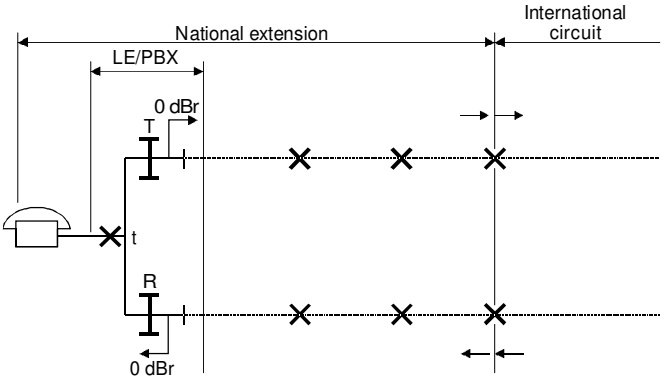
The incorporation of PCM digital processes into national extensions might require that existing national transmission plans be amended or replaced with new ones.

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.

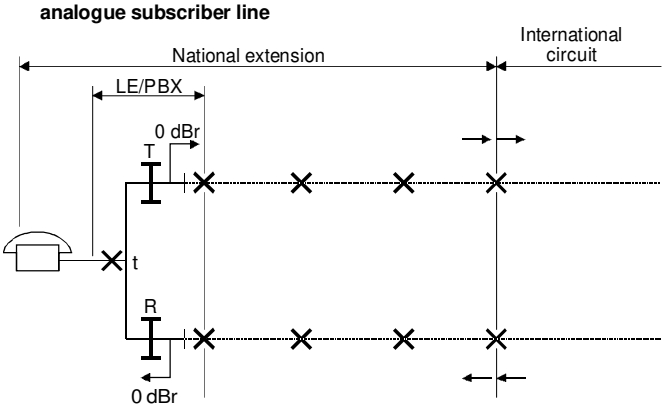
Thus, the transmission planning of transitional phases should preferably not involve any degradation of the quality previously experienced.

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.

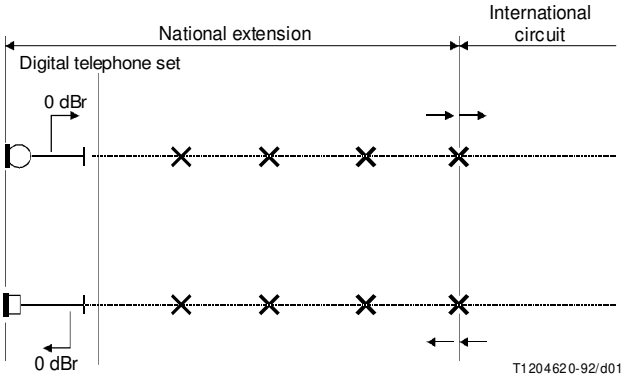


a) Case 1: 2-wire analogue switching at local exchange and 2-wire analogue subscriber line



NOTE – No 2-wire switch point between the subscriber's local line and the terminating unit at the local exchange.

b) Case 2: 4-wire digital switching at the local exchange but 2-wire analogue subscriber lines



c) Case 3: 4-wire switching at the local exchange, 4-wire digital subscriber line and digital telephone set

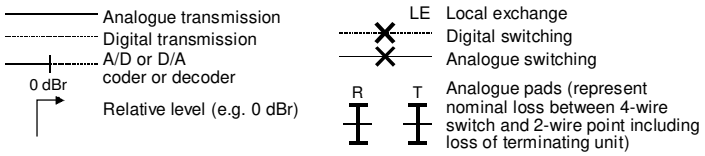


FIGURE 1/G.121

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

In case 1 and 2 of Figure 1, 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.

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 met. Examples of the values for R and T that have been adopted by some Administrations are given in Annex C.

In case 2 of Figure 1, 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 (See 2.2) which in turn implies that

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

However, a local exchange designed on these principles and which is at the end of a national extension containing asymmetric analogue portions cannot take the whole of the asymmetry allowance.

The R and T pads shown in Figure 1 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 4.4/G.101 and 4/G.103.

The arrangement in case 3 of Figure 1 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”.

The quantizing distortion on international connections is governed by Recommendation G.113.

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

Annex A

Evaluation of the nominal differences of loss between the two directions of transmission

(This annex forms an integral part of this Recommendation)

A.1 Consider an international connection between primary centres in two Administrations, established over one international circuit as shown in Figure A.1.

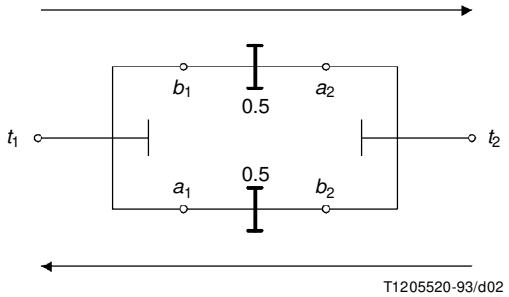


FIGURE A.1/G.121

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

$$1 \rightarrow 2 = t_1 b_1 + 0.5 + a_2 t_2 \qquad \text{(dB)}$$

and

$$2 \rightarrow 1 = t_2 b_2 + 0.5 + a_1 t_1 \qquad \text{(dB)}$$

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

$$(t_1 b_1 - a_1 t_1) - (t_2 b_2 - a_2 t_2) = d_1 - d_2$$

in which d signifies $d_1 = t_1 b_1 - a_1 t_1$ or $d_2 = t_2 b_2 - a_2 t_2$.

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 1.2.3-1.2.5/Q.551 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

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

(This annex forms an integral part of this Recommendation)

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.

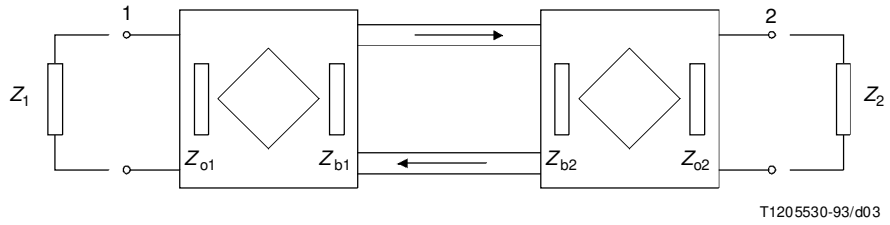


FIGURE B.1/G.121

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

In Figure B.1 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 (degrees);

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

We now define the following (complex) factors:

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

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

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

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

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

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

The balance return losses at port 1 and 2 are:

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

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 set-up 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- nor 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

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

A case of special interest is when by design Z_o is made identical with Z_b. Then equation (B-3) transforms into:

$$(L_{br})_{min} = -20 \log_{10} \left\{ \tan \tfrac{1}{2} (90° - |V|) \right\}$$

$$(Z_o = Z_b) \tag{B-5}$$

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:

$$|X| = |Z_o| \tag{B-6}$$

NOTES

1 In general, the more reactive Z_o and Z_b are, the lower the minimum balance return loss will be when unfortunate terminations are met within the network. For instance, if Z_o and Z_b are 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.

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.

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

$$L_{12} = L_1 + 20 \log_{10} \left| \frac{Z_2 \text{ (1.02 kHz)}}{Z_1 \text{ (1.02 kHz)}} \right| + 20 \log_{10} \left| \frac{Z_{o1} + Z_1}{2 Z_{o1}} \right| + \tag{B-7}$$

$$+ 20 \log_{10} \left| \frac{Z_{o2} + Z_2}{2 Z_2} \right| + 20 \log_{10} |1 - C_1 \cdot C_2 \cdot C_{r1} \cdot C_{r2}|$$

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 mismatch 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

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

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

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

Using equation (B-8) we get

$$L_{r1} = L_1 + L_2 + L_{br2} + 20 \log_{10} |1 - C_1 \cdot C_2 \cdot C_{b1} \cdot C_{r2}| \tag{B-10}$$

NOTES

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!

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, here we will study this case in some detail.

If a subscriber is connected directly to port 1 in Figure B.1, 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 A.4.3/G.111, using the telephone set input impedance Z_c and its equivalent sidetone balance impedance Z_{s0}. 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/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 mismatch 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/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/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. Long-delay echoes are far more noticeable than sidetone.

Annex C

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

(This annex forms an integral part of this Recommendation)

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 by using the relationship given in Figure C.1.

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1) Ignoring the last term.

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

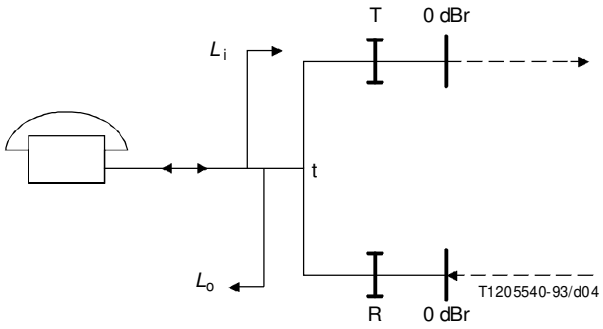

FIGURE C.1/G.121

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 represents all the loss between the 2-wire point, t, and the encoder 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:

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

NOTE – The modern trend is to use a complex nominal impedance at the 2-wire port. See the Note in 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/G.101 and 2.8/G.101 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 *Red Book* (1985)]. 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 2.2.

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.