INTERNATIONAL TELECOMMUNICATION UNION

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

Q.552

(11/2001)

SERIES Q: SWITCHING AND SIGNALLING

Digital exchanges – Transmission characteristics

Transmission characteristics at 2-wire analogue interfaces of digital exchanges

ITU-T Recommendation Q.552

ITU-T Q-SERIES RECOMMENDATIONS

SWITCHING AND SIGNALLING

SIGNALLING IN THE INTERNATIONAL MANUAL SERVICE	Q.1–Q.3
INTERNATIONAL AUTOMATIC AND SEMI-AUTOMATIC WORKING	Q.4–Q.59
FUNCTIONS AND INFORMATION FLOWS FOR SERVICES IN THE ISDN	Q.60–Q.99
CLAUSES APPLICABLE TO ITU-T STANDARD SYSTEMS	Q.100–Q.119
SPECIFICATIONS OF SIGNALLING SYSTEM No. 4	Q.120–Q.139
SPECIFICATIONS OF SIGNALLING SYSTEM No. 5	Q.140–Q.199
SPECIFICATIONS OF SIGNALLING SYSTEM No. 6	Q.250–Q.309
SPECIFICATIONS OF SIGNALLING SYSTEM R1	Q.310–Q.399
SPECIFICATIONS OF SIGNALLING SYSTEM R2	Q.400–Q.499
DIGITAL EXCHANGES	Q.500–Q.599
Introduction and field of application	Q.500–Q.509
Exchange interfaces, functions and connections	Q.510–Q.539
Design objectives and measurement	Q.540–Q.549
Transmission characteristics	**Q.550–Q.599**
INTERWORKING OF SIGNALLING SYSTEMS	Q.600–Q.699
SPECIFICATIONS OF SIGNALLING SYSTEM No. 7	Q.700–Q.799
Q3 INTERFACE	Q.800–Q.849
DIGITAL SUBSCRIBER SIGNALLING SYSTEM No. 1	Q.850–Q.999
PUBLIC LAND MOBILE NETWORK	Q.1000–Q.1099
INTERWORKING WITH SATELLITE MOBILE SYSTEMS	Q.1100–Q.1199
INTELLIGENT NETWORK	Q.1200–Q.1699
SIGNALLING REQUIREMENTS AND PROTOCOLS FOR IMT-2000	Q.1700–Q.1799
SPECIFICATIONS OF SIGNALLING RELATED TO BEARER INDEPENDENT CALL CONTROL (BICC)	Q.1900–Q.1999
BROADBAND ISDN	Q.2000–Q.2999

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

ITU-T Recommendation Q.552

Transmission characteristics at 2-wire analogue interfaces of digital exchanges

Summary

This Recommendation provides characteristics for 2-wire analogue interfaces, input and output connections with 2-wire analogue interfaces and half-connections with 2-wire analogue interfaces in accordance with definitions given in ITU-T Q.551.

This Recommendation is valid for equipment that may terminate an international long-distance connection via 4-wire circuits interconnected by 4-wire exchange. It also includes, in a separate category, characteristics for interfaces which cannot terminate an international connection and are therefore entirely national in application.

Source

ITU-T Recommendation Q.552 was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 29 November 2001.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. 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 Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 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

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

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, 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

Page

Page

ITU-T Recommendation Q.552

Transmission characteristics at 2-wire analogue interfaces of digital exchanges

1 General

This Recommendation provides characteristics for:

– 2-wire analogue interfaces (Type C_2 and Z);

– input and output connections with 2-wire analogue interfaces; and

– half-connections with 2-wire analogue interfaces;

in accordance with definitions given in ITU-T Q.551 particularly in Figure 1/Q.551.

The characteristics of the input and output connections of a given interface are not necessarily the same. The characteristics of half-connections are not necessarily identical for different types of interfaces.

This Recommendation is valid for equipment that may terminate an international long-distance connection via 4-wire circuits interconnected by 4-wire exchanges. It also includes, in a separate category, characteristics for interfaces which cannot terminate an international connection and are therefore entirely national in application.

2 Characteristics of interfaces

NOTE – For measuring 2-wire analogue interface conditions it is necessary to apply a quiet code, i.e. a PCM signal corresponding to decoder output value 0 (μ-law) or output value 1 (A-law), with the sign bit in a fixed state, to the exchange test point T_i, when no test signal is stipulated.

2.1 Characteristics of interface C_2

The recommended values of interfaces C_2 are valid for digital exchanges including PABXs with transit functions and routing capabilities for originating and terminating traffic. Depending on the type of traffic to be handled, two different sets of relative levels are required. This suggests subdivision into C_{21} and C_{22} interface specifications. The interface C_{21} provides the termination of outgoing and incoming international long-distance connections and possible national connections, with the exchange acting as transit switch. The interface C_{22} provides for the connection of a 2-wire trunk line. A typical example is the interconnection of a Z interface with a C_{22} interface in a local exchange for routing through the 2-wire analogue trunk network. A C_{22} interface cannot be part of the international 4-wire chain (see Figure 2/Q.551).

2.1.1 Exchange impedance

2.1.1.1 Nominal value

Nominal values of exchange impedance should be defined depending on national conditions. The definition shall include a test network for the exchange impedance. Network operators may want to adopt different test networks corresponding to the cable types used (e.g. unloaded and loaded).

2.1.1.2 Return loss

The return loss of the impedance presented by a C_2 interface against the test network for the exchange impedance should comply with the limits given in Figure 1.

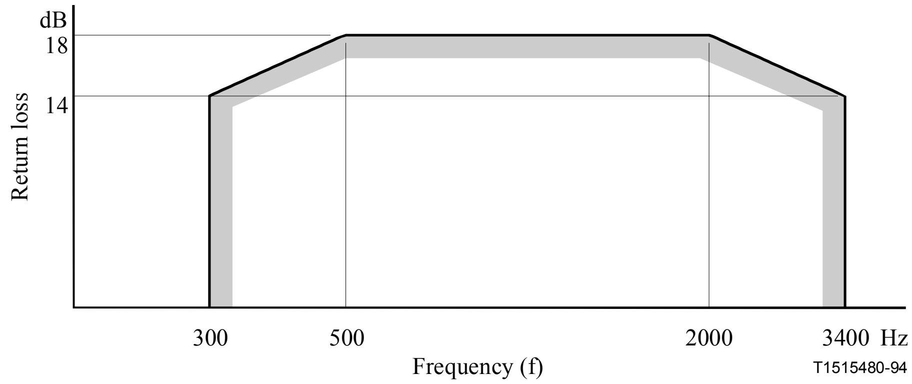


Figure 1/Q.552 – Minimum value of return loss against the test network for the exchange impedance at a 2-wire interface

2.1.2 Impedance unbalance about earth

The Longitudinal Conversion Loss (LCL) at the interface, defined in 4.1.3/G.117, should exceed the minimum values of Figure 2 with the equipment under test in the normal talking state, in accordance with ITU-T K.10.

NOTE 1 – A network operator may adopt other values and in some cases a wider bandwidth, depending on actual conditions in its telephone network.

NOTE 2 – A limit may also be required for the Transverse Conversion Loss (TCL), as defined in 4.1.2/G.117, if the exchange termination is not reciprocal with respect to the transverse and longitudinal paths. A suitable limit would be 40 dB to ensure an adequate near-end crosstalk attenuation between interfaces.

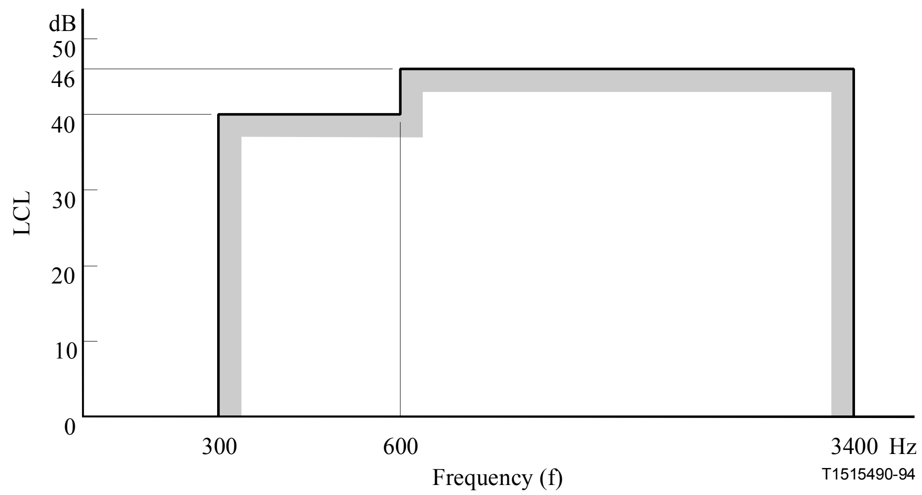
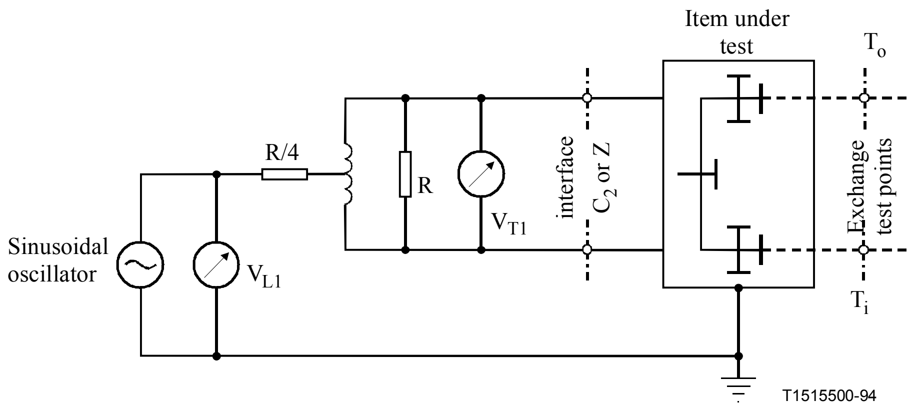


Figure 2/Q.552 – Minimum values of LCL measured in the arrangement shown in Figure 3

Test method

Longitudinal conversion loss at the C_2 equipment port should be measured in accordance with the principles given in 4.1/O.9. Figure 3 shows an example of the basic measuring arrangement for digital exchanges. Arrangements containing two resistors each of value R/2 may also be used (see 5.1/O.9).

Measurements of the longitudinal and transverse voltages should preferably be done with a frequency-selective level meter.



R should be in the range of 600-900 Ω

Longitudinal conversion loss (LCL) = $20 \log_{10}\left|\frac{V_{L1}}{V_{T1}}\right|$ dB

NOTE 1 – Provisions should be made for representative DC currents to be present.

NOTE 2 – Special care must be taken in those applications using active hybrids.

Figure 3/Q.552 – Arrangement for measuring LCL

2.1.3 Relative levels

2.1.3.1 Nominal levels

2.1.3.1.1 Interface C_{21}

C_{21} interfaces should meet the recommended values for Z interfaces in 2.2.3.1 if no loss compensation comparable to 2.2.3.3 is provided.

2.1.3.1.2 Interface C_{22}

To adjust the transmission loss of a digital transmission section to the values of national transmission planning for local or national traffic, depending on the relative levels given in 2.1.3.1.1 and 2.2.3.1, the following ranges encompass the requirements for C_{22} interfaces of a large number of network operators:

– input level: $L_i = +3.0$ to -7.0 dBr in 0.5 dB steps;

– output level: $L_o = +1.0$ to -8.0 dBr in 0.5 dB steps.

In order to compensate loss on long toll or junction lines, a network operator may, to satisfy local conditions, choose values of relative levels derived from the basic values as follows:

$$L_i' = L_i + x \, \text{dB}$$

$$L_o' = L_o - x \, \text{dB}$$

where x should take a negative value. The value of x is in national competence. Such compensation of loss requires careful selection and application of balance networks.

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire level range.

2.1.3.2 Tolerances of relative levels

The difference between the actual relative level and the nominal relative level should lie within the following values:

– input relative level: −0.3 to +0.7 dB;

– output relative level: −0.7 to +0.3 dB.

These differences may arise, for example, from design tolerances, cabling between analogue ports and the (DF), and adjustment increments.

NOTE – Level adjustment procedures are given in clause 3/G.712.

2.2 Characteristics of interface Z

The recommended values of interface Z are valid for digital local exchanges, PABXs and digital remote units. For PABXs, see 2.1.1/Q.551.

2.2.1 Exchange impedance

Guidance for network operators can be found in Appendix I.

2.2.1.1 Nominal value

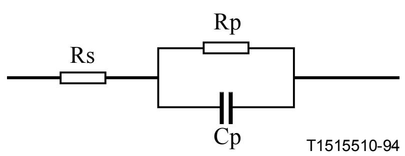
The principal criterion governing the choice of the nominal value of the exchange impedance is to ensure an adequate sidetone performance for telephone sets, particularly those operated on short lines. If this criterion is met, the impedance will also be suitable for subscriber lines fitted with voiceband modems.

As a general rule a complex exchange impedance with a capacitive reactance is necessary to achieve satisfactory values of stability, echo and sidetone. For additional information, see ITU-T G.111 and ITU-T G.121.

The use of the preferred configuration below will minimize the diversity of types of exchange impedances. At present no unique component values can be recommended. However, to provide guidance for network operators, examples of nominal values chosen by some network operators are given in Table 1.

Table 1/Q.552 – Test networks for exchange impedances being considered

	Rs (ohms)	**Rp (ohms)**	**Cp (farads)**
Austria, FRG	220	820	115 n
BT	300	1000	220 n
NTT	600	infinity	1 µ
USA	900	infinity	2.16 µ
ETSI	270	750	150 n



NOTE 1 – The test network and the component values represent a configuration that exhibits the required exchange impedance. It need not necessarily correspond to any actual network provided in the exchange interface.

Table 1/Q.552 – Test networks for exchange impedances being considered

NOTE 2 – The range of component values reflects the fact that there are substantial differences in the sensitivity and sidetone performance of the various telephone instruments throughout the world. In general, the combination of short lines and sensitive telephone sets might be rather common in the future due to increased use of remote concentration. In order to control sidetone performance, network operators need to take into account telephone set parameters. Not only should the parameters of existing telephone sets be considered but also the parameters that may be desirable in the future to allow improvement in sidetone performance to be achieved. NOTE 3 – It may be necessary to group the subscriber lines of a particular exchange into classes, each requiring a different exchange impedance of the Z interface.

2.2.1.2 Return loss

Tolerances are needed for values of exchange impedance. For this purpose, the return loss of the impedance presented by a 2-wire interface against the test network for the exchange impedance should comply with limits which depend on the particular conditions of the subscriber network considered. These are given in the template of Figure 1.

Some network operators may want to specify higher values. Examples of limit values for the return loss, currently accepted by some network operators, are given in Table 2 for guidance.

Table 2/Q.552 – Examples of limit values of return loss against the exchange impedance

Austria	14.5 dB at 300 Hz, rising (log *f* scale) to 18 dB at 500 Hz remaining at 18 dB to 2500 Hz and then falling (log *f* scale) to 14.5 dB at 3400 Hz.
BT	18 dB: 200-800 Hz; 20 dB: 800-2000 Hz; 24 dB: 2000-4000 Hz.
FRG, ETSI	14 dB at 300 Hz, rising (log *f* scale) to 18 dB at 500 Hz remaining at 18 dB to 2000 Hz and then falling (log *f* scale) to 14 dB at 3400 Hz.
NTT	22 dB: 300-3400 Hz.
USA	20 dB: 200-500 Hz; 26 dB: 500-3400 Hz.
NOTE – The 12 dB spread in values stems from the difference in telephone sets and subscriber loops characteristics. See also Appendix I.	

2.2.2 Impedance unbalance about earth

The Longitudinal Conversion Loss (LCL) at the equipment post of the Z interface should meet the values given in 2.1.2 and Figure 2, measured in accordance with the test method given in Figure 3.

2.2.3 Relative levels

Operation of the Z interface in the ranges of relative levels given below is recommended when the interface terminates an entirely 4-wire international long-distance connection. Pairs of input and output levels can be chosen for internal, local, or national long-distance traffic in a wider range if these connections can be discriminated from international ones for correct level switching. If digital pads are used, the additional distortion must be considered (see Table 1/G.113).

In assigning the relative levels for international long-distance connections to the interface, it should be noted that:

– The limiting of "difference in transmission loss between the two directions of transmission" in 2.2/G.121 must be taken into account. For the national extension, this is the value "loss (t-b)-loss(a-t)". (See the text in the cited Recommendation for guidance.) This difference is limited to ±4 dB. However, to allow for additional asymmetry of loss in the rest of the national network, only part of this difference can be used by the digital exchange.

– If within the ranges of L_i and L_o given under 2.2.3.1.1 and 2.2.3.1.2, the values are chosen such that $L_i - L_o \geq 6$ dB and if adequate balance networks are used (e.g. 3.1.8 and Figure 10), the requirements of clause 6/G.121 (Incorporation of PCM digital processes in national extensions) as well as for ITU-T G.122 (Stability and echo loss) will be satisfied.

2.2.3.1 Nominal levels

2.2.3.1.1 Input relative level

According to Annex C/G.121 (columns 3, 5 and 7 of Table C.1/G.121), the following range of input relative level for all types of connections (internal, local, national and international) encompasses the requirements of a large number of network operators:

$$L_i = 0 \text{ to } +2.0 \text{ dBr}$$

NOTE – Clause 3.6/G.101 and clause 3/G.121 indicate that if the minimum nominal Send Loudness Rating (SLR) of the local system under the same conditions is not less than +2 dB, then the peak power of the speech will be suitably controlled. It follows that, for instance, the value L_i = 0 dBr (lower limit of the range for L_i) is suited to a send loudness rating ≥ +2 dB.

2.2.3.1.2 Output relative level

According to Annex C/G.121 (column 6 of Table C.1/G.121), the following range of output relative level for international long-distance connections encompasses the requirements of a large number of network operators:

$$L_o = -5.0 \text{ to } -8.0 \text{ dBr}$$

The chosen value may be used for connections entirely within a national network as well.

The nominal output relative levels for local or national connections can take other values in accordance with national transmission planning. According to Annex C/G.121 (columns 2 and 4 of Table C.1/G.121), the following range encompasses the requirements of a large number of network operators:

$$L_o = 0 \text{ to } -8.0 \text{ dBr}$$

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire range.

2.2.3.2 Tolerances of relative levels

The difference between the actual relative level and the nominal relative level should lie within the following limits:

– input relative level: –0.3 to +0.7 dB;

– output relative level: –0.7 to +0.3 dB.

These differences may arise, for example, from design tolerances, cabling (between analogue ports and the DF) and adjustment increments. Short-term variation of loss with time as discussed in 3.1.1.3 is not included.

NOTE – Procedures for adjusting relative level are given in clause 3/G.712.

2.2.3.3 Consideration of short and long subscriber lines

In order to compensate for the loss of short or long subscriber lines, a network operator may choose values of the relative levels derived from the basic values as follows:

$$L_i' = L_i + x\,\text{dB}$$

$$L_o' = L_o - x\,\text{dB}$$

The value of x is within national competence (e.g. $x = 3$ dB for short subscriber lines).

The use of values of $x < 0$ requires careful selection of balance networks; values of $x < -3$ dB are not recommended.

3 Characteristics of half-connections

For interfaces C_2, this Recommendation is valid for digital local and transit exchanges and for C_{21} interfaces of PABXs connected to the digital local exchange by a digital transmission system.

For interface Z, this Recommendation is valid for digital local and combined local/transit exchanges, for PABXs and for digital remote units, each connected to the digital local exchange by a digital transmission system. For further information concerning PABXs, see 2.1.1/Q.551.

NOTE – In measuring an input connection it is necessary to apply a quiet code, i.e. a PCM signal corresponding to decoder output value 0 (μ-law) or output value 1 (A-law) with the sign bit in a fixed state to the exchange test point T_i. (See 1.2.3.1/Q.551.)

3.1 Characteristics common to all 2-wire analogue interfaces

3.1.1 Transmission loss

3.1.1.1 Nominal value

The nominal transmission loss according to 1.2.4.1/Q.551 is defined in 3.2.1 and 3.3.1 for input and output connections of half-connections with a 2-wire analogue interface.

3.1.1.2 Tolerances of transmission loss

The difference between the actual transmission loss and the nominal transmission loss of an input or output connection, according to 2.1.3.2 and 2.2.3.2 should lie within the following range:

$$-0.3 \text{ to} + 0.7 \text{ dB}$$

These differences may arise, for example, from design tolerances, cabling (between analogue interfaces and the DF) and adjustment increments. Short-term variation of loss with time as discussed in 3.1.1.3 is not included.

3.1.1.3 Short-term variation of loss with time

When a sine wave test signal at the reference frequency of 1020 Hz and at a level of −10 dBm0 is applied to the 2-wire analogue interface of any input connection, or a digitally simulated sine wave signal of the same characteristic is applied to the exchange test point T_i of any output connection, the level at the corresponding exchange test point T_o and the 2-wire analogue interface respectively should not vary by more than ±0.2 dB during any 10-minute interval of typical operation under the steady state condition of permitted variations in the power supply voltage and temperature.

3.1.1.4 Variation of gain with input level

With a sine wave test signal at the reference frequency 1020 Hz and at a level between −55 dBm0 and +3 dBm0 applied to the 2-wire analogue interface of any input connection, or with a digitally simulated sine wave signal of the same characteristic applied to the exchange test point T_i of any output connection, the gain variation of that connection, relative to the gain at an input level of −10 dBm0, should lie within the limits given in Figure 4.

The measurement should be made with a frequency-selective level meter to reduce the effect of the exchange noise. This requires a sinusoidal test signal.

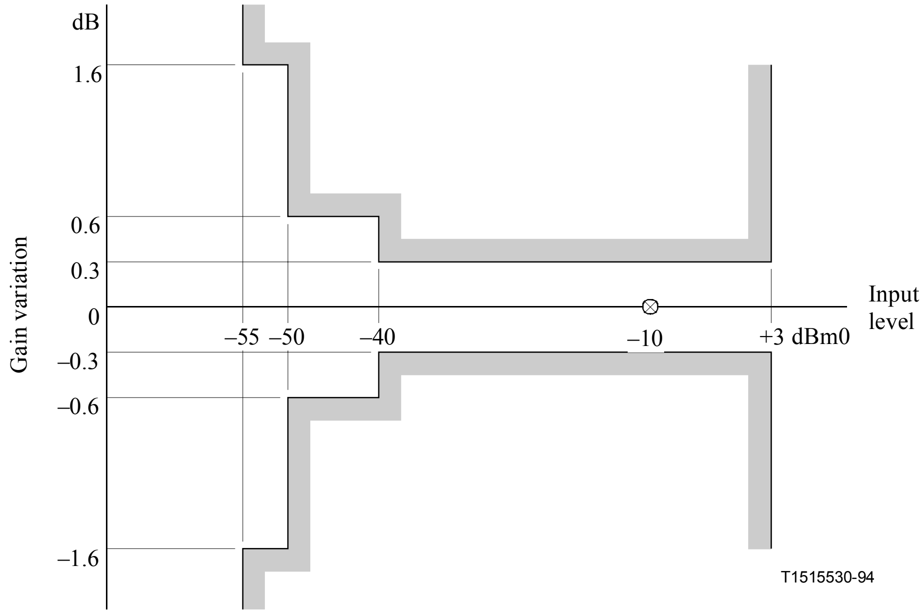
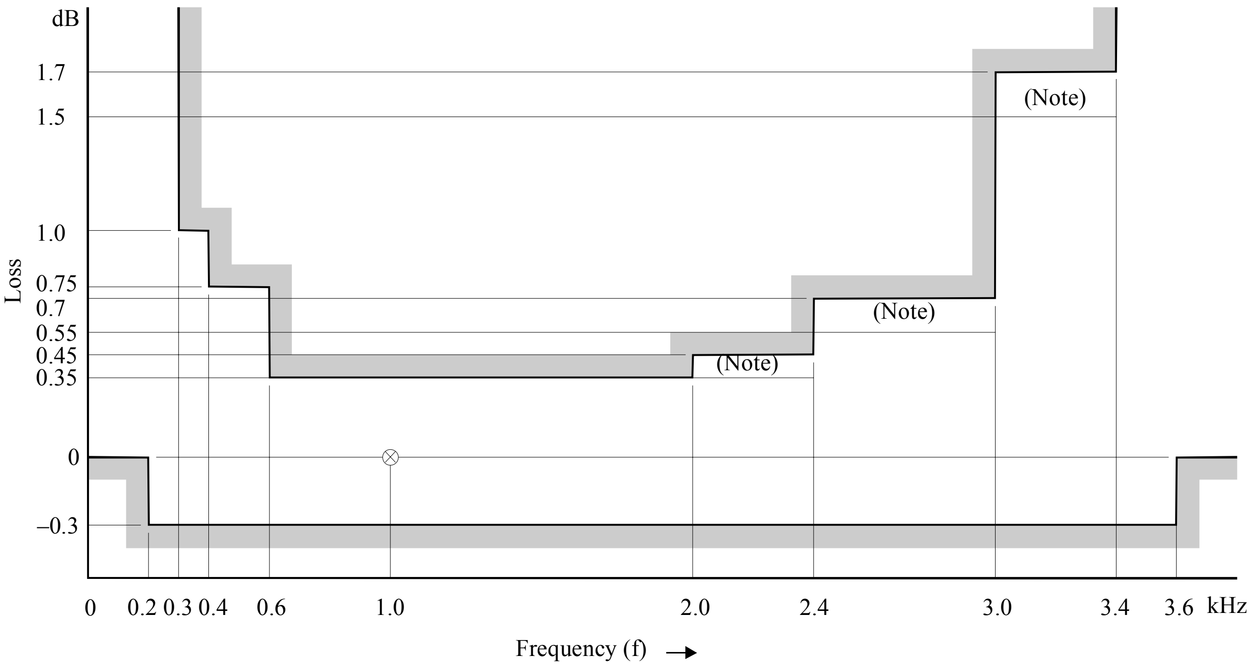


Figure 4/Q.552 – Variation of gain with input level

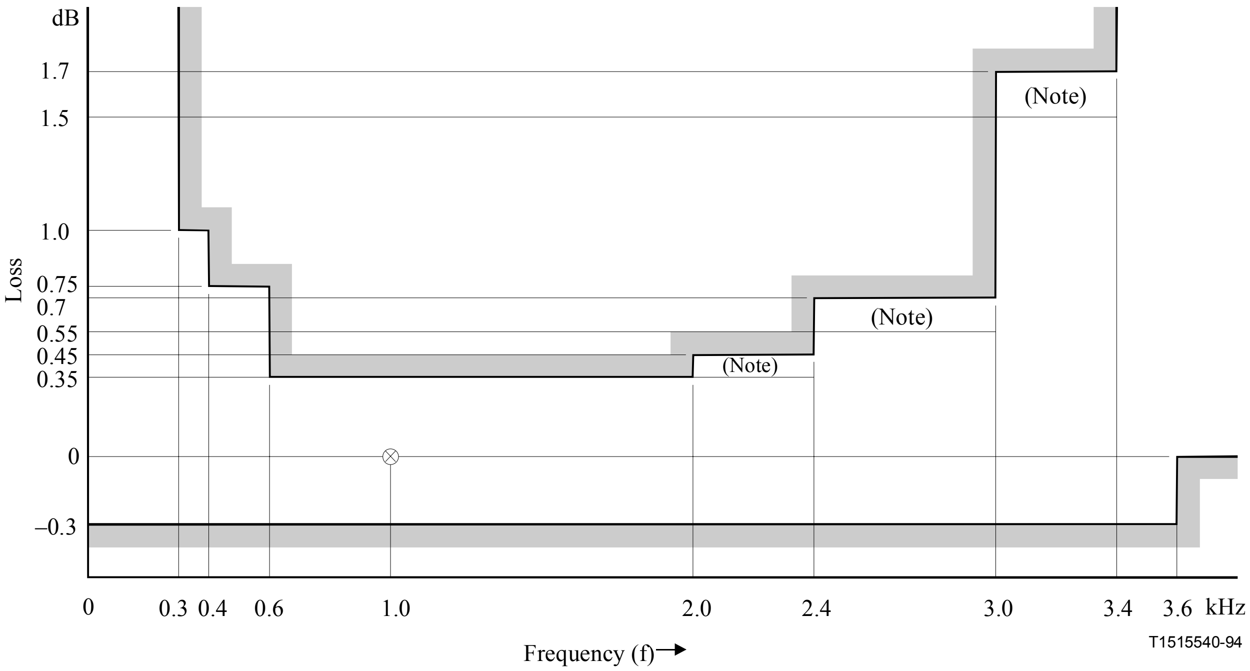
3.1.1.5 Loss distortion with frequency

The loss distortion with frequency of any input or output connection according to 1.2.5/Q.551 should lie within the limits shown in the mask of Figure 5 a) or 5 b) respectively using an input level of -10 dBm0.

NOTE – The limits of this clause shall not apply to Z half-connections which include equalization for the loss distortion in the subscriber line.



a) Input connection



b) Output connection

NOTE – In the marked frequency ranges relaxed limits are shown which apply if the maximum length of exchange cabling (see clause 2/Q.551) is used. The more stringent limits shown apply if no such cabling is present.

Figure 5/Q.552 – Loss distortion with frequency

3.1.2 Group delay

"Group delay" is defined in the ITU-T Q.9 (1988).

3.1.2.1 Absolute group delay

See 3.3.1/Q.551.

3.1.2.2 Group delay distortion with frequency

Taking as the reference the minimum group delay, in the frequency range between 500 Hz and 2800 Hz, of the input or output connection, the group delay distortion of that connection should lie within the limits shown in the template of Figure 6. Group delay distortion is measured in accordance with ITU-T O.81.

These requirements should be met at an input level of −10 dBm0.

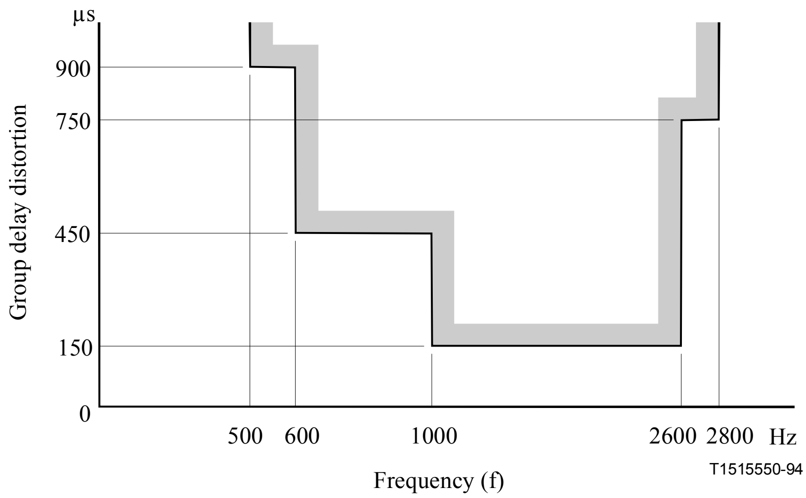


Figure 6/Q.552 – Group delay distortion limits with frequency

3.1.3 Single frequency noise

The level of any single frequency (in particular the sampling frequency and its multiples), measured selectively at the interface of an output connection, should not exceed −50 dBm0. Between 300 and 3400 Hz, the level of any single frequency measured selectively and corrected by the psophometric weighting factor (see Table 1/O.41) should not exceed −73 dBm0 (provisional value).

NOTE – See 1.2.3.1/Q.551 with regard to common measurement conditions.

3.1.4 Crosstalk

For crosstalk measurements, auxiliary signals are injected as indicated in Figures 7 and 8. These signals are:

– the quiet code (see 1.2.3.1/Q.551);

– a low-level activating signal, e.g. a sine wave at a level in the range from −33 to −40 dBm0. Care must be taken in the choice of frequency and the filtering characteristics of the measuring apparatus in order that the activating signal does not significantly affect the accuracy of the crosstalk measurement.

3.1.4.1 Far-end and near-end crosstalk measured with analogue test signal

A sine wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0, applied to an analogue 2-wire interface, should not produce a level in any other half-connection exceeding – 73 dBm0 for near-end crosstalk (NEXT) and –70 dBm0 for far-end crosstalk (FEXT) (see Figure 7).

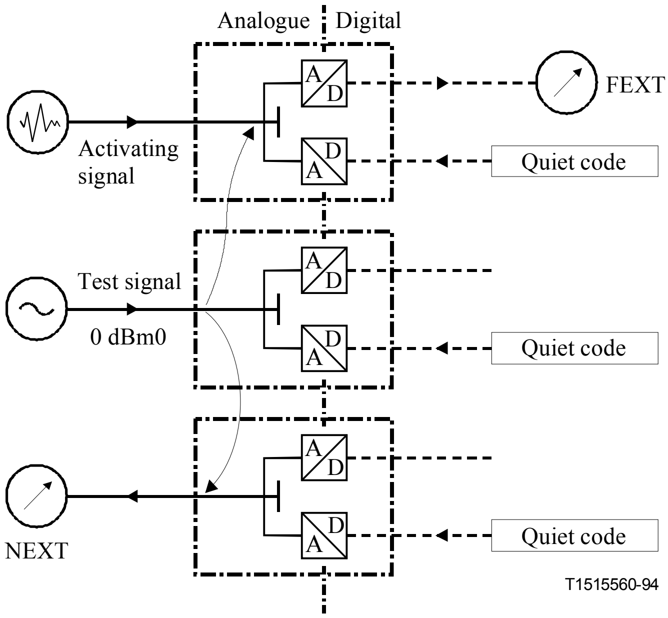


Figure 7/Q.552 – FEXT and NEXT measurements with analogue test signal

3.1.4.2 Far-end and near-end crosstalk measured with digital test signal

A digitally simulated sine wave test signal at the reference frequency of 1020 Hz applied at a level of 0 dBm0 to an exchange test point T_i, should not produce a level in any other half-connection exceeding −70 dBm0 for near-end crosstalk (NEXT) and −73 dBm0 for far-end crosstalk (FEXT) (see Figure 8).

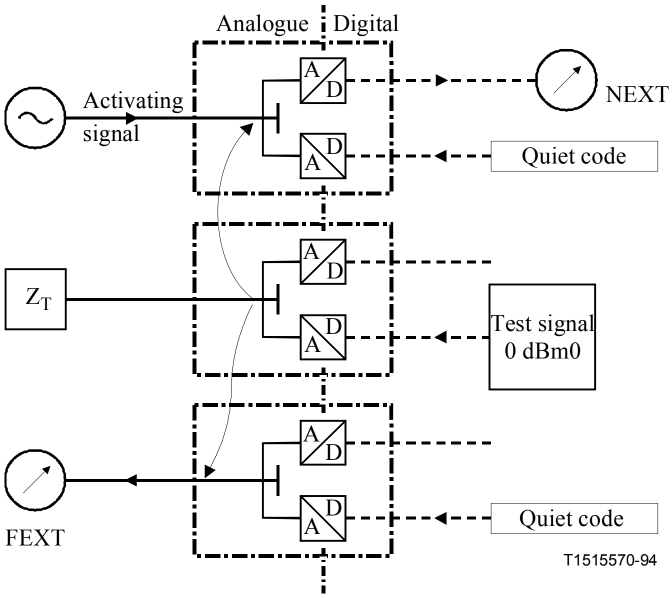


Figure 8/Q.552 – FEXT and NEXT measurements with digital test signal

3.1.5 Total distortion including quantizing distortion

With a sine wave test signal at the reference frequency of 1020 Hz (see ITU-T O.132) applied to the 2-wire interface of an input connection, or with a digitally simulated sine wave signal of the same characteristic applied to the exchange test point T_i of an output connection, the signal-to-total-distortion ratio, measured at the corresponding outputs of the half-connection with a proper noise weighting (see Table 1/O.41) should lie above the limits given in 3.2.3, Figures 12 and 13 for interface C_2 and in 3.3.3, Figure 14 for interface Z.

NOTE – The sinusoidal test signal is chosen to obtain results independent of the spectral content of the exchange noise.

3.1.6 Discrimination against out-of-band signals applied to the input interface

(Only applicable to input connections.)

3.1.6.1 Input signals above 4.6 kHz

With a sine-wave signal in the range from 4.6 kHz to 72 kHz applied to the 2-wire interface of an input connection at a level of −25 dBm0, the level of any image frequency produced in the time slot corresponding to the input connection should be at least 25 dB below the level of the test signal. This value may need to be more stringent to meet the overall requirement.

3.1.6.2 Overall requirement

Under the most adverse conditions encountered in a national network, the half-connection should not contribute more than 100 pW0p of additional noise in the band 10 Hz to 4 kHz at the output of the input connection, as a result of the presence of out-of-band signals at the 2-wire interface of the input connection.

3.1.7 Spurious out-of-band signals received at the output interface

(Only applicable to an output connection.)

3.1.7.1 Level of individual components

With a digitally simulated sine wave signal in the frequency range 300 to 3400 Hz and at a level of 0 dBm0 applied to the exchange test point T_i of a half-connection, the level of spurious out-of-band image signals measured selectively at the 2-wire interface of the output connection should be lower than −25 dBm0. This value may need to be more stringent to meet the overall requirement.

3.1.7.2 Overall requirement

Spurious out-of-band signals should not give rise to unacceptable interference in equipment connected to the digital exchange. In particular, the intelligible and unintelligible crosstalk in a connected FDM channel should not exceed a level of −65 dBm0 as a consequence of spurious out-of-band signals at the half-connections.

3.1.8 Echo and stability

Terminal Balance Return Loss (TBRL) as defined in 3.1.8.1 is introduced in order to characterize the exchange performance required to comply with the network performance objective of ITU-T G.122 with respect to echo and stability. The TBRL of an interface is measured in the talking state as in an established connection through a digital exchange.

The parameter "Stability Loss", as defined in ITU-T G.122, applies to the worst terminating conditions encountered at a 2-wire interface in normal operation.

3.1.8.1 Terminal Balance Return Loss (TBRL)

The term TBRL is used to characterize an impedance balancing property of the 2-wire analogue interface.

The expression for TBRL is:

$$TBRL = 20\log\frac{Z_o + Z_b}{2Z_o} \times \frac{Z_t + Z_o}{Z_t - Z_b}$$

where:

Z_o is the exchange impedance of a 2-wire equipment port;

Z_b is the impedance of the balance network;

Z_t is the impedance of the balance test network presented at a 2-wire interface

Some network operators have found that it is advantageous to choose $Z_o = Z_b$ in order to optimize TBRL. In this case the expression is reduced to:

$$TBRL = 20\log\left|\frac{Z_t + Z_b}{Z_t + Z_b}\right|$$

and the balance test network will be identical to the test network for the exchange impedance.

The balance test network should be representative of the impedance conditions to be expected from a population of terminated lines connected to 2-wire interfaces, as determined by the national transmission planning.

The TBRL is related to the loss a_{io} between the exchange test point T_i and T_o of a half-connection as follows:

$$TBRL = a_{io} - (a_o + a_i)$$

where a_o and a_i are the losses between the exchange test point T_i and the 2-wire interface and between the 2-wire interface and the exchange test point T_o, respectively.

TBRL can thus be determined by measurement of a_{io} provided the sum $(a_o + a_i)$ is known. This can be derived in several ways:

a) a_o and a_i are assigned their nominal values NL_o and NL_i as defined in 3.2.1 and 3.3.1. Then:

$$TBRL = a_{io} - (NL_o + NL_i)$$

b) a_o and a_i are measured with the load matched to the exchange impedance as actual transmission loss AL_o and AL_i (see 3.1.1.2). Then:

$$TBRL = a_{io} - (AL_o + AL_i)$$

c) the loss a_{io} is measured with the 2-wire equipment port open- and short-circuited, giving losses a'_{io} and a''_{io} respectively.

$$TBRL = a_{io} - \frac{a'_{io} + a''_{io}}{2}$$

Method b) provides the most accurate results.

Using the arrangement of Figure 9 and sinusoidal test signals, the measured TBRL should exceed the limits shown in Figure 10.

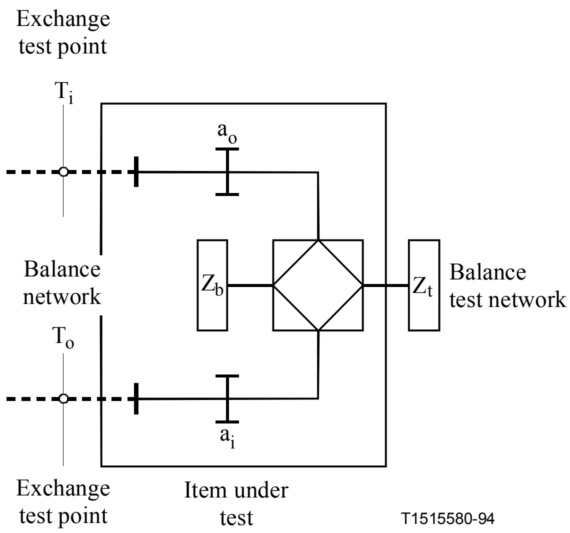


Figure 9/Q.552 – Arrangement for measuring the loss a_{io}

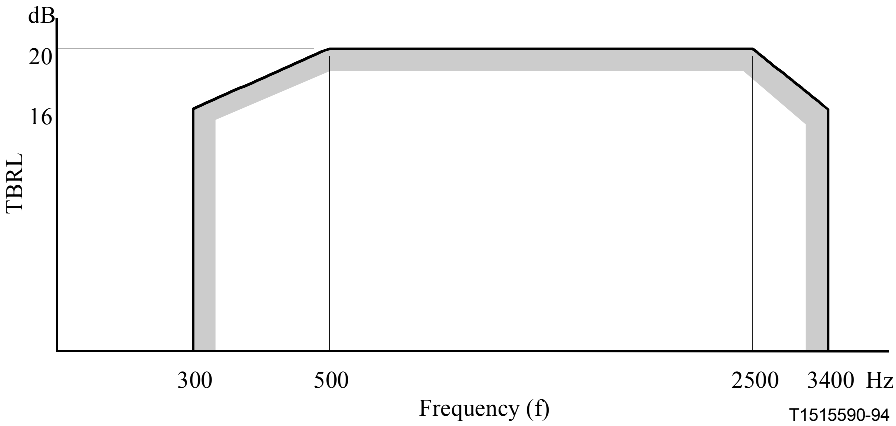


Figure 10/Q.552 – Limits for TBRL

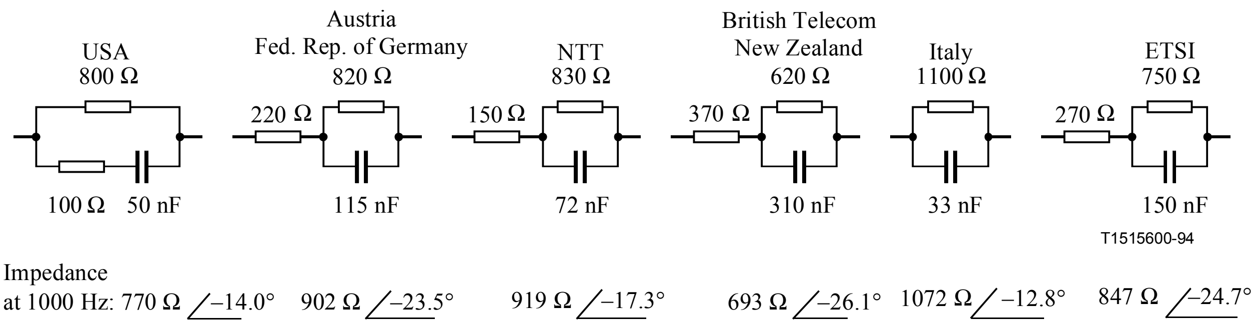


Figure 11/Q.552 – Examples of test networks to be used by some network operators (applicable to unloaded subscriber lines)

Figure 11 gives examples of balance test networks adopted by some network operators for unloaded subscriber lines. These examples may provide guidance for other network operators in order to minimize the diversity of types of test networks; see also Appendix I.

NOTE – Some network operators may need to adopt several balance test networks to cover the various types of unloaded and loaded cables.

3.1.8.2 Stability loss

The stability loss should be measured between the exchange test points T_i and T_o of a half-connection (see Figure 9) by terminating the 2-wire interface with stability test networks representing the "worst terminating condition encountered in normal operation". Some network operators may find that open- and short-circuit terminations are sufficiently representative of worst-case conditions. Other network operators may need to specify, for example, an inductive termination to represent the worst-case condition.

Where the digital exchange is connected to the international chain using only 4-wire switching and transmission, the half-connection of the digital exchange may provide the total stability loss of the national extension. The value of Stability Loss (SL) that is required for a 2-wire interface is a matter of national control provided that the requirements of ITU-T G.122 are met. A SL value of at least 6 dB at all frequencies between 200 Hz and 3600 Hz will ensure that the G.122 requirements are met. However, SL values of between 6 dB and 0 dB will formally comply with the present requirements of G.122. One network operator has found that a value of 3 dB is satisfactory in its environment.

NOTE – It is suggested that the half-connection of a digital PABX, or of a digital remote unit, when connected to the digital local exchange by a digital transmission system, should also meet the requirements of 3.1.8.

3.2 Characteristics of interface C_2

3.2.1 Nominal value of transmission loss

According to the relative levels defined in 2.1.3.1, the nominal transmission losses of input or output connections NL_i and NL_o of a half-connection with C_2 interfaces are in the following ranges:

C_{21} interfaces

$$NL_i = 0 \text{ to } 2.0 \text{ dB for all types of connections}$$

$$NL_o = 5.0 \text{ to } 8.0 \text{ dB for international connections}$$

$$0 \text{ to } 8.0 \text{ dB for local or national connections}$$

C_{22} interfaces

$$\left.\begin{aligned} NL_i &= -7.0 \text{ to } 3.0 \text{ dB} \\ NL_o &= -1.0 \text{ to } 8.0 \text{ dB} \end{aligned}\right\} \text{for all types of connections}$$

It has been recognized that it is not necessary for a particular design of equipment to be capable of operating over the entire range of nominal transmission losses.

If a loss compensation is applied the nominal loss NL_i and NL_o should be corrected by the value of x dB chosen in connection with 2.1.3.1.2 or 2.2.3.3.

3.2.2 Noise

3.2.2.1 Weighted noise

For the calculation of noise, worst-case conditions at the C_2 interface are assumed. The band limiting effect of the encoder on the noise has not been taken into account.

3.2.2.1.1 Output connection

Two components of noise must be considered. One of these is the noise arising from the quiet decoder, the other comes from analogue sources, such as signalling equipment and the analogue circuit for impedance and level adaptation. The first component is limited to −70 dBm0p or −75 dBmp respectively in accordance with Table 7/G.712; the other component is limited to

-67 dBm0p (200 pW0p) in accordance with Annex A/G.120, i.e. −(67 + 3) dBm0p = −70 dBm0p for one 2-wire analogue interface.

This results in the maximum values for the overall weighted noise in the talking state at the C_2 interface of a digital exchange:

- equipment with signalling on separate wires:

  −70 dBm0p for output relative levels $L_o \geq -5$ dBr;

  −75 dBmp for output relative levels $L_o < -5$ dBr;

- equipment with signalling on the speech wires:

  −67 dBm0p for output relative levels $L_o \geq -5$ dBr;

i.e. −72.5 dBmp and −73.2 dBmp respectively for output relative levels $L_o = -6$ dBr and −8 dBr.

Values for other output relative levels cited in 2.1.3.1 can be calculated by using the formula given in 3.4.1/Q.551.

3.2.2.1.2 Input connection

Two components of noise must be considered. One of these arises from the encoding process, the other from analogue sources, such as signalling equipment and the analogue circuit for impedance and level adaptation. The first component is limited to −67 dBm0p as idle channel noise in accordance with Table 7/G.712; the other component is limited to –67 dBm0p (200 pW0p) in accordance with Annex A/G.120, i.e. –(67 + 3) dBm0p = −70 dBm0p for one 2-wire analogue interface.

The maximum values for the overall weighted noise in the talking state at the exchange test point T_o of a digital exchange should be not more than:

–67.0 dBm0p for equipment with signalling on separate wires;

–65.2 dBm0p for equipment with signalling on the speech wires.

3.2.2.2 Unweighted noise

This noise will be more dependent on the noise from the power supply and on the rejection ratio.

3.2.3 Values of total distortion

The total distortion including quantizing distortion of a half-connection with a C_2 interface is measured in accordance with 3.1.5.

The signal-to-total distortion ratio for a half-connection at interface C_2 should lie above the limits shown in Figure 12 for equipment with signalling on separate wires, and in Figure 13 for equipment with signalling on the speech wires both measured in the talking state.

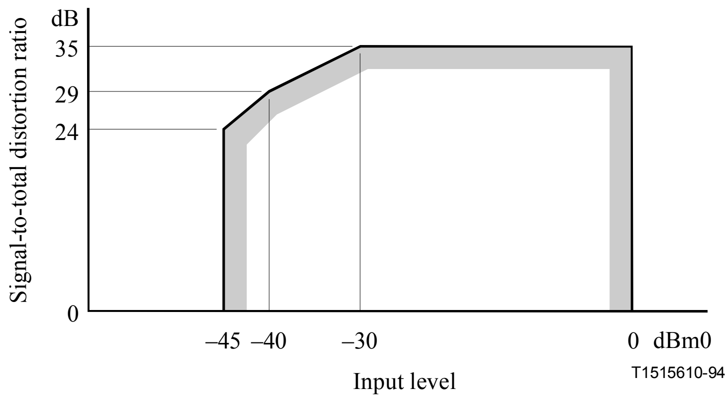


Figure 12/Q.552 – Limits for signal-to-total distortion ratio as a function of input level; input or output connection with signalling on separate wires

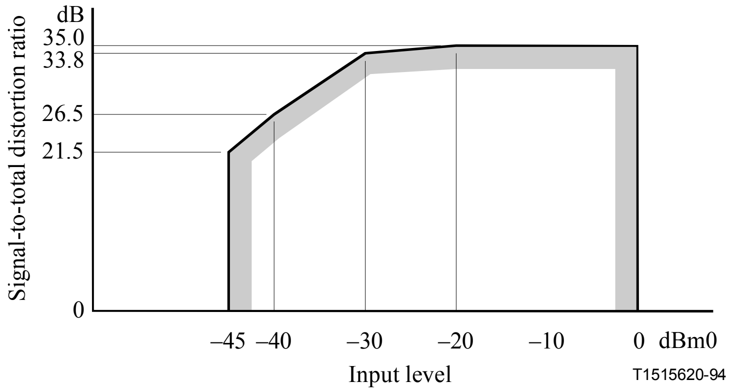


Figure 13/Q.552 – Limits for signal-to-total distortion ratio as a function of input level; input or output connection with signalling on the speech wires

The values of Figure 13 include the limits for the encoding process given in Figure 12/G.712 and the allowance for the noise contributed via signalling circuits from the exchange power supply and other analogue sources (e.g. analogue coupling), which is limited to –67 dBm0p (200 pW0p) in accordance with Annex A/G.120, i.e. –(67 + 3) dBm0p = –70 dBm0p for one C_2 analogue interface.

3.3 Characteristics of interface Z

3.3.1 Nominal value of transmission loss

According to the relative levels defined in 2.2.3.1, the nominal transmission losses of input or output connections NL_i and NL_o of a half-connection with Z interfaces are in the following ranges:

NL_i = 0 to 2.0 dB for all types of connections

NL_o = 5.0 to 8.0 dB for international connections

0 to 8.0 dB for internal, local or national connections.

If a compensation for the loss of short or long subscriber lines is applied, the nominal loss NL_i and NL_o should be corrected by the value of x dB chosen in connection with 2.2.3.3.

3.3.2 Noise

3.3.2.1 Weighted noise

For the calculation of noise, worst-case conditions at the Z interface are assumed. The band limiting effect of the encoder on the noise has not been taken into account.

3.3.2.1.1 Output connection

Two components of noise must be considered. One of these, namely noise arising from the decoding process, is dependent upon the output relative level. The other, for example power supply noise from the feeding bridge and circuit noise, is independent of the output relative level. The first component is limited to −70 dBm0p in accordance with Table 7/G.712; the other component is limited to 200 pWp (−67 dBmp) in accordance with Annex A/G.120. Possible sources of this latter component are the main DC power supply, auxiliary DC-DC converters and the circuit for 4-wire to 2-wire conversion with impedance and level adaptation.

For an output relative level of $L_o = -7.0$ dBr, the resulting total noise level for the output connection is:

$$L_{TNo} \le -66.6 \text{ dBmp}$$

Values for other output relative levels cited in 2.2.3.1.2 can be calculated by using the formula given in 3.4.1/Q.551.

3.3.2.1.2 Input connection

Two components of noise must be considered. One of these, namely noise arising from the encoding process is independent to the input relative level. The other, for example power supply noise from the feeding bridge and the circuit noise, is dependent upon the input relative level. The first component is limited to –67 dBm0p as idle channel noise in accordance with Table 7/G.712; the other component is limited to 200 pWp (–67 dBmp) in accordance with Annex A/G.120. For an input relative level of L_i = 0 dBr the resulting total noise level for the input connection is: L_{TNi} = –64.0 dBm0p.

The total psophometric power allowed at the exchange test point T_o with an input relative level of L_i = 0 dBr is:

$$P_{TNi} = P_{AN} \cdot 10^{\frac{-L_i}{10}} + 10^{\frac{90+L_{TNi}}{10}} \text{ pWp}$$

and the total noise level is:

$$L_{TNi} = -64.0 \text{ dBm0p}$$

Values for other input relative levels cited in 2.2.3.1.1 can be calculated by using the formula given in 3.4.1/Q.551.

3.3.2.2 Unweighted noise

This noise will be more dependent on the noise from the power supply and on the rejection ratio.

3.3.3 Values of total distortion

The total distortion including quantizing distortion on half-connections with Z interfaces is measured in accordance with 3.1.5.

Resulting templates for the signal-to-total distortion ratio of input and output connections in a local exchange are shown in Figure 14 a) and 14 b) as an example where L_i = 0 dBr and L_o = −7 dBr respectively.

Values for other relative levels cited in 2.2.3.1 can be calculated by using the formula given in 3.4.2/Q.551.

The values of Figure 14 include the limits for the coding process given in Figure 12/G.712 and the allowance for the noise contributed via signalling circuits from the exchange power supply and other analogue sources, which is limited to −67 dBmp (200 pWp) for a Z interface (with feeding) by Annex A/G.120.

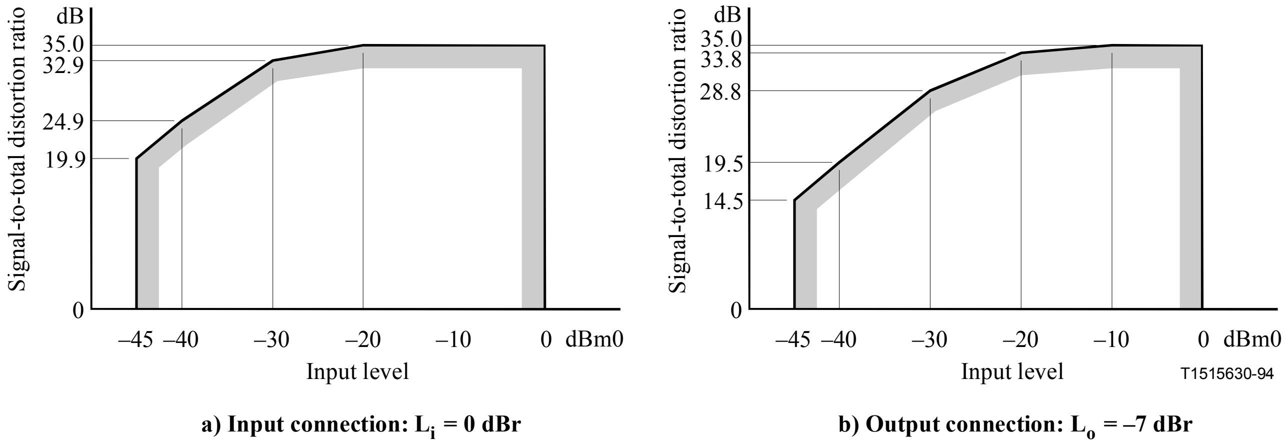


Figure 14/Q.552 – Limits for signal-to-total distortion ratio as a function of input level including analogue noise

Appendix I

Impedance strategy in 2-wire networks

I.1 Introduction

The aim of this appendix is to describe in more detail the methodologies which can be applied to determine termination impedances and balance networks. While termination impedance may affect sidetone on some telephones, echo which is controlled by the balance network is of much greater importance. Therefore, balance network selection is very critical no matter what termination impedance is selected. Additional information is also available in [1].

In order to provide a network with good echo and sidetone performance, it is necessary to employ a certain impedance strategy in the 2-wire analogue parts of the network where the signals are transmitted simultaneously in both directions on the same pair of wires. It is of course necessary to separate the signals – transmit and receive – from each other at the ends of a 2-wire section and this is done by means of so-called hybrids which have in principle four ports (see Figure I.1):

– the 2-wire port (2);
– the 4-wire transmit port (T);
– the 4-wire receive port (R);
– the balance network port (B).

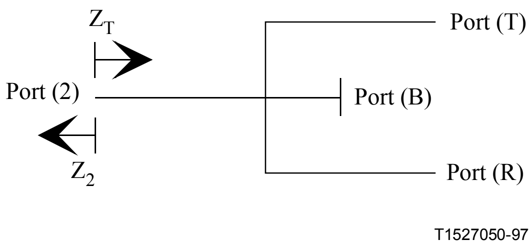


Figure I.1/Q.552 – General hybrid

NOTE 1 – The balance port may not always be physically accessible in the hybrid, i.e. it may exist only notionally.

The transmission properties of the hybrid are specified by the following parameters:

–	2-wire impedance connected to the 2-wire port of the hybrid	Z_2
–	input impedance at the port (2) of the hybrid	Z_T
–	balance impedance at the port (B)	Z_B
–	matched loss between ports (R) and (2)	L_R
–	matched loss between ports (2) and (T)	L_T
–	balance return loss	L_{br}

NOTE 2 – "Matched loss" implies that the loss is to be measured for the special case when the impedance Z_2 is made equal to Z_T.

The separation between transmit and receive signals by means of a hybrid depends mainly on the impedance matching at the 2-wire port of the hybrid between:

- the impedance Z_2 connected to the 2-wire port of the hybrid; and
- the so-called balance impedance Z_B of the hybrid.

The loss L_{TR} between ports (T) and (R) is given by the relation:

$$L_{TR} = L_T + L_{br} + L_R \tag{I-1}$$

where:

$$L_{br} = 20 \cdot \log\left|\frac{Z_T + Z_B}{2Z_T} \cdot \frac{Z_2 + Z_T}{Z_2 - Z_B}\right| \text{dB} \tag{I-2}$$

NOTE 3 – L_{br} is in general a function of frequency. Equations (I-1) and (I-2) apply for all possible designs of hybrids.

In case of impedance Z_T being equal to Z_B, L_{br} results in:

$$L_{br} = 20 \cdot \log\left|\frac{Z_2 + Z_B}{Z_2 - Z_B}\right| \tag{I-3}$$

NOTE 4 – This equation is similar to the "return loss"-equation used for the comparison of two impedances.

A connection in a digital PSTN in principle consists of two analogue telephone sets which include the microphone and the earphone, the 2-wire analogue subscriber lines and the 4-wire digital connection. The transitions from 2-wire to 4-wire and vice versa are made by hybrids which are situated in the telephone set and in the exchange line circuit (see Figure I.2).

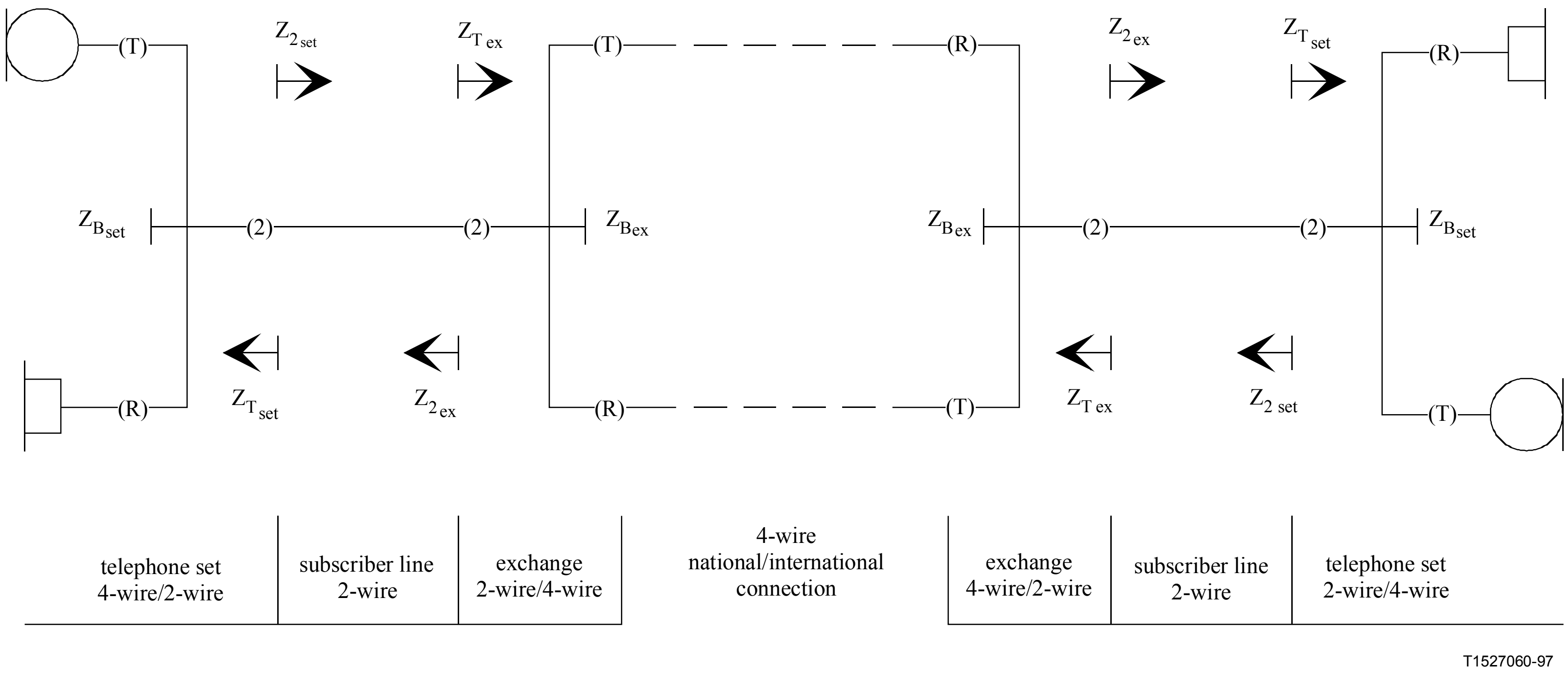


Figure I.2/Q.552 – Telephone connection via 2-wire analogue subscriber lines

At the telephone set, port (T) corresponds to the microphone, port (R) to the earphone receiver. The impedance $Z_{2_{set}}$ is the cable input impedance of the subscriber line terminated by the 2-wire input impedance $Z_{T_{ex}}$ of the digital exchange (nominal input impedance for open 4-wire loop). The loss L_{TR} corresponds to the sidetone loss.

At the exchange line circuit, ports (T) and (R) correspond to the digital 4-wire ports. The impedance $Z_{2_{ex}}$ is the cable input impedance of the subscriber line terminated by the 2-wire input impedance $Z_{T_{set}}$ of the telephone set. The loss L_{TR} corresponds to the echo loss at the listener's exchange.

It is immediately apparent that the impedance Z_2 (i.e. $Z_{2_{ex}}$ or $Z_{2_{set}}$ respectively) must not vary too much from the balance impedance Z_B (i.e. $Z_{B_{ex}}$ or $Z_{B_{set}}$ respectively) if the balance return loss is to be kept high. To achieve this with different cable types of varying lengths the terminating impedances have to be chosen with care. This will be discussed in I.3 and I.4. An example will be given in I.8.

I.2 General equations for unloaded cables

For the sake of completeness, the impedance equations for cables will be presented.

For uniformly distributed lines the transmission characteristics are calculated from the electrical primary cable constants per unit length:

$$R' \text{ in } \frac{\Omega}{\text{km}}; L' \text{ in } \frac{H}{\text{km}}; G' \text{ in } \frac{S}{\text{km}}; C' \text{ in } \frac{F}{\text{km}}; f \text{ in Hz}; \varpi = 2\pi f$$

NOTE – L' and G' can be disregarded for unloaded cables in the range of voiceband frequencies.

The **image (characteristics) impedance** of a cable is:

$$Z_C = \sqrt{\frac{R' + j\varpi L'}{G' + j\varpi C'}} \qquad \text{(I-4)}$$

The **propagation constant** of a cable is:

$$\gamma = \alpha + j\beta = \sqrt{(R' + j\varpi L')(G' + j\varpi C')} \qquad \text{(I-5)}$$

and expresses the attenuation α in nepers per unit length and the phase shift β in radians per unit length.

If the cable is terminated by an impedance $Z_T = Z_C$ the cable input impedance Z_2 will also be equal to Z_C and therefore independent of the cable length. If the cable is terminated by an impedance $Z_T \neq Z_C$ its **input impedance** $\boldsymbol{Z_2}$ is dependent on the loop length (l) and will be:

$$Z_2 = \frac{Z_T + Z_C \cdot \tan h(\gamma \cdot l)}{1 + \frac{Z_T}{Z_C} \cdot \tan h(\gamma \cdot l)} \qquad \text{(I-6)}$$

Two impedances at port (2) can be compared by the **reflection coefficient**:

$$r = \frac{Z_2 - Z_T}{Z_2 + Z_T} \qquad \text{(I-7)}$$

I.3 General impedance considerations of a hybrid

The separation characteristic of a hybrid is defined by the impedances Z_2, Z_T and Z_B (see equation I-2). The impedance Z_2 is connected to the hybrid and is given by the subscriber line network while the impedances Z_T and Z_B are part of the hybrid itself and are to be chosen carefully.

I.3.1 Cable input impedance Z_2 and the hybrid input impedance Z_T

If the cable is not terminated by its characteristic impedance Z_C, the cable input impedance Z_2 depends on the cable parameters and the input impedance Z_T of the cable termination equipment (telephone set or exchange line circuit) (see equation I-6).

At the port (2) of the telephone set, the input impedance $Z_{2_{set}}$ is determined by the subscriber cable parameters and $Z_{T_{ex}}$ of the exchange.

At the port (2) of the exchange line circuit, the input impedance $Z_{2_{ex}}$ is determined by the subscriber cable and $Z_{T_{set}}$ of the telephone set (normally in a network different types of telephone sets with different input impedances exist).

The better the termination impedance Z_T approximate to the characteristic impedance Z_C of the cable, the less the cable input impedance Z_2 vary with the length. With regard to the balance impedance (see next clause) and due to the capacitive complex property of the characteristic impedance in the voice frequency range, it is advantageous to define also a capacitive complex impedance Z_T for the cable termination, i.e. $Z_{T_{set}}$ for the telephone set or $Z_{T_{ex}}$ respectively for the exchange line circuit. (However, in practice it is not always possible to choose an "optimum" terminating impedance as the only alternative because one must also consider what already exists in the real network. See the discussion in I.7.)

I.3.2 Balance impedance Z_B

The fixed balance network $Z_{B_{ex}}$ in the exchange line circuit has direct consequences for the talker echo performance at the listener's exchange while $Z_{B_{set}}$ effects the sidetone for the telephone set. For practical reasons it is desirable to have only one balance impedance Z_B to make a balancing of the whole range of impedances Z_2 in a network. (However, in those circumstances, when the impedance range seen by the exchange is very wide, one may need to choose several options for balance impedance.)

In order to choose a suitable balance impedance Z_B, it is necessary to consider the network with regard to:

- the types of cables and their cumulative length distribution;
- the range of termination impedances and their tolerances;
- the required balance return loss with regard to the transmission plan and the permissible echo limits.

I.4 Echo considerations

I.4.1 Talker echo loudness rating TELR

The talker echo loudness rating TELR is calculated according to equation I-8 (see ITU-T G.111).

$$TELR = SLR + RLR + L_e \quad \text{(I-8)}$$

where SLR, RLR are the send and receive loudness ratings from the talker's side, referred to the 0 dBr digital transmit and receive ports of the exchange, and the echo loss L_e is the weighted average of L_{TR} (see equation I-1).

NOTE – In ITU-T G.122, the weighting equation for TELR is specified for a linear frequency scale.

I.4.2 Sidetone masking rating STMR and listener sidetone rating LSTR

The sidetone masking rating STMR can be computed for analogue terminals in a similar way, according to Annex A/G.111:

$$STMR = SLR(set) + RLR(set) - 1 + L_{st} \qquad \text{(I-9)}$$

where SLR (set) and RLR (set) refer to the telephone set itself and L_{st} is the weighted average of L_{TR} (see equation I-1).

The listener sidetone rating LSTR is:

$$LSTR = STMR + D \qquad \text{(I-10)}$$

where D is the difference in sensitivity between direct and diffuse sound of the handset microphone.

However, L_e and L_{st} can also be computed – according to ITU-T G.111 – as averages over a logarithmic frequency scale, preferably using a third-octave division, giving 14 points between 200 and 4000 Hz. The general equation is:

$$L = -\frac{10}{m} \cdot \log\left\{\sum_{i=1}^{14} K_i 10^{-0.1 \cdot m \cdot L_{TR}}\right\} \qquad \text{(I-11)}$$

In Table I.1 the weighting coefficients K_i for sidetone (from Table A.1/G.111) and K_i for echo (calculated with equation A.4-8/G.111) are summarized; for calculation of L_e (echo loss), m = 1; for calculation of L_{st} (sidetone), m = 0.2.

Table I.1/Q.552 – Weighting coefficients K_i for talker echo (L_e) and sidetone (L_{st})

i	f_i [Hz]	$K_i(L_e)$	$K_i(L_{st})$
1	200	0	0
2	250	0	0.01
3	315	0.05	0.02
4	400	0.1	0.03
5	500	0.1	0.04
6	630	0.1	0.05
7	800	0.1	0.08
8	1000	0.1	0.12
9	1250	0.1	0.12
10	1600	0.1	0.12
11	2000	0.1	0.12
12	2500	0.1	0.12
13	3150	0.05	0.12
14	4000	0	0.05

Between echo and sidetone calculation there is a difference in the weighting. The talker echo weighting is flat, while the sidetone weighting emphasizes the frequencies above 800 Hz. This implies that for the talker echo, an impedance matching is needed over the total speech band, while for the sidetone only the range above 800 Hz is of importance.

I.5 Applications

A transmission plan for a telephone network must include, among a multitude of items, considerations for the loop plant design and the parameters of the telephone sets. As these factors differ among network operators, it is not surprising that different exchanges and balance impedances have been chosen as evidenced from Table 1 and Figure 11.

In this context, it is useful to consider the limit for satisfactory sidetone and talker echo performance.

For sidetone, the limiting parameter is the listener side tone rating LSTR, which should be higher than 13 dB. This guarantees that the listener will not be disturbed by room noise picked up via the listener sidetone path even under rather noisy conditions.

For talker echo, the requirements on the talker echo loudness rating TELR depends on the particular network rule for applying echo cancellers, i.e. above which mean one-way transmission time T [ms] they must be deployed. ITU-T G.131 gives TELR as function of T [ms] for acceptable echo performance without echo control.

I.6 Analysis of loop impedance variation by means of a special impedance diagram

Knowledge about the actual loop impedance conditions in a network can be obtained in several ways, for instance by field measurements. Another method is to collect the statistical data for the terminals and for the cables, types and lengths and then compute the impedances.

One can proceed in several ways to analyse the impedance data and arrive to suitable impedance matchings. A fairly simple method for a quick analysis is to plot the impedances in a special type of diagram which is so designed that a certain distance between two impedance points always corresponds to the same return loss. This is achieved by making the abscissa and the ordinate

$X = k \cdot \ln |Z|$ $\quad\quad$ $Y = k \cdot \arg \{Z\}$ radians; k is a constant

Figure I.3 shows the principle. The scale at the bottom of the figure can be used to estimate return losses. (For the sake of clarity, the impedance angles are graduates in degrees, not in radians.) Thus, in a plot containing several impedances their mutual return losses can be roughly estimated by inspection.

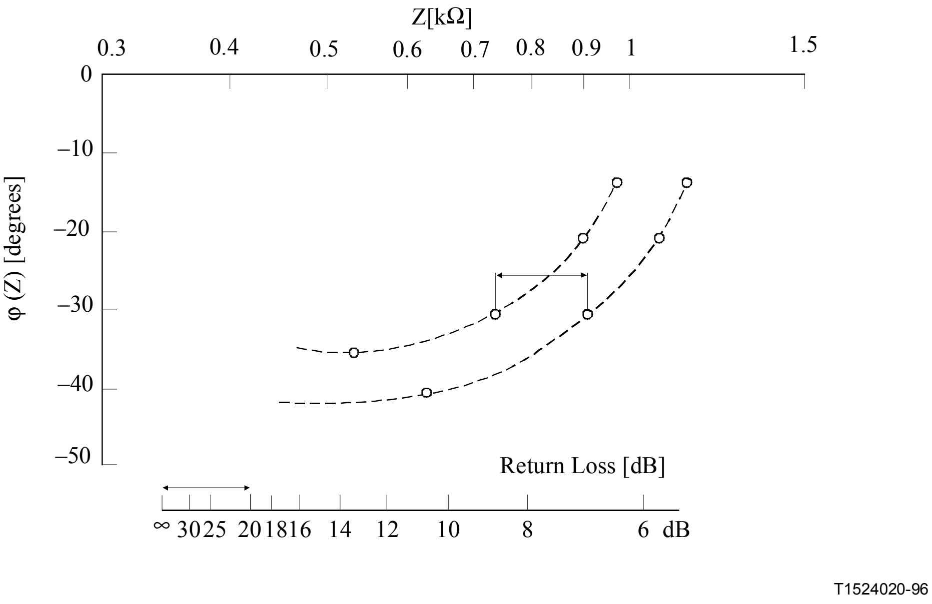
The calibration for the scale with regard to a return loss A is derived from the expression:

$$R = \frac{k}{2}\left\{R_x + R_y\right\}$$

where:

$$R_x = \ln\left\{\frac{1+10^{-\frac{A}{20}}}{1-10^{-\frac{A}{20}}}\right\} \qquad\qquad R_y = 2 \cdot arctg\left\{10^{-\frac{A}{20}}\right\}$$

Figure I.4 shows as an example impedance curves for constant return losses against 600 Ω. Note that the curves are almost circles for loss values > 10 dB.



X-axis absolute value in kΩ
Y-axis argument in degrees

Figure I.3/Q.552 – A special impedance diagram where the return loss between two-impedance points can be read from the "return loss" distance scale (20 dB shown)

Figure I.4/Q.552 – Constant return loss curves for 10, 15, 20, 30 dB against 600 Ω

Applications of this special diagram are also given in I.8.

When a large amount of impedance data have to be analysed, it is more convenient to make separate impedance diagrams for frequency points included in the survey in order to find an optimum balance impedance point for that frequency. In principle, this optimum can be chosen according to different criteria. One way would be to choose the point as "the centre of gravity" which give the best "r.m.s." average of echo (or sidetone) suppression at that frequency for the cases considered. Another way would be to enclose the points with the smallest circle and choose the centre of this circle as the optimum impedance point.

When it comes to match these points with a suitable impedance function, the echo loss or sidetone weighting should be considered.

I.7 Conclusions

By the methods shown here, a network planner can find optimum terminating and balancing impedances for the networks he is responsible for. In general, if unloaded cable are used in a controlled network, a capacitive complex impedance as a compromise may be preferred as the nominal impedance. Then, quite high echo losses can be obtained which may reduce the need of echo cancellors. However, for many networks it may not be very critical to obtain very high echo losses in the subscriber network because, for other reasons, echo cancellors must be/are inserted in many trunks anyhow. Likewise, the levels in the network can be such that the send and receive sensitivity of the telephone sets on short lines need not be too high, i.e. the nominal exchange impedance need not be complex. In that case, for regulated telephones the sidetone circuit is designed for a medium-to-long cable, terminated with for instance 600 Ω. Moreover, in deregulated telecom markets the network operator may not have a very close control of what terminals are used in their network and what their parameters are.

For other networks, however, one may wish to avoid a widespread of echo cancellors and/or use more sensitive telephone sets near the exchange. Then the rules and observations mentioned earlier in this appendix are worth noticing when choosing input and balance impedances.

I.8 Examples of impedances Z_2 and compromise nominal impedances Z_T and Z_B

Only to illustrate the subject given in I.1 to I.7 to the reader, this clause gives some detailed numerical examples for a chosen limited range of subscriber cables. It is also assumed that the network operator had the authority to prescribe a common nominal impedance to be used for future equipment. However, the operator also had to consider equipment with 600 Ω resistive input impedance.

The problem for the operator is to choose the input impedance $Z_{T_{ex}}$ of the digital exchange in such a way that the sidetone performance of the telephone set becomes adequate, and to choose the input impedance $Z_{T_{set}}$ of the telephone set so that the talker echo for the subscriber at the other end is adequately suppressed.

Some network operators have found that by their telephone set designs, sidetone and therefore input impedance is not a very critical parameter such as it is with more sensitive telephones.

It can be seen from equation (I-4) that the characteristic impedance of the unloaded cable is inversely proportional to the cable diameter and inversely proportional to the square root of the cable capacitance. Therefore, it is not possible to find one unique nominal impedance to match exactly all the types of cables that usually are found in the network of a service provider. Moreover, many analogue networks contain equipment with an impedance of nominally 600 Ω resistive. For the determination of a compromise nominal impedance Z_T these impedances must also be considered. An overview of the problems and discussion of the methodology is given in [1] and [2].

Some calculated curves will be presented as an illustration for a typical unloaded 0.5 mm-Cu-subscriber cable with:

$$R' = 168\frac{\Omega}{\text{km}}, L' = 0.7\frac{\text{mH}}{\text{km}}, G' = 1\frac{\mu S}{\text{km}}, C' = 50\frac{\text{nF}}{\text{km}}, 300\,\text{Hz} \le f \le 3.4\,\text{kHz} \text{ (data see [3])}$$

I.8.1 Cable input impedance Z_2 and hybrid input impedance Z_T

The cable input impedance Z_2 is calculated for a terminating impedance:

- Z_T = 600 Ω resistive termination, representing the nominal impedance of many existing telephone sets;
- $Z_T = Z_{ETSI}$ = 270 Ω + (750 Ω || 150 nF), representing the nominal impedance of future telephone sets.

The ETSI-impedance is a compromise which has been recommended to be used both as the nominal input impedance of equipment in the 2-wire network (exchanges and terminals) and as balance impedance in exchanges.

NOTE – The input impedance of telephone sets has a rather wide tolerance, some sets are often slightly inductive.

Figure I.5 shows the input impedance of a cable with length variation 0 km ≤ ℓ ≤ 4 km and terminated with 600 Ω resistive, and similarly Figure I.6 for the ETSI-impedance Z_{ETSI} as termination.

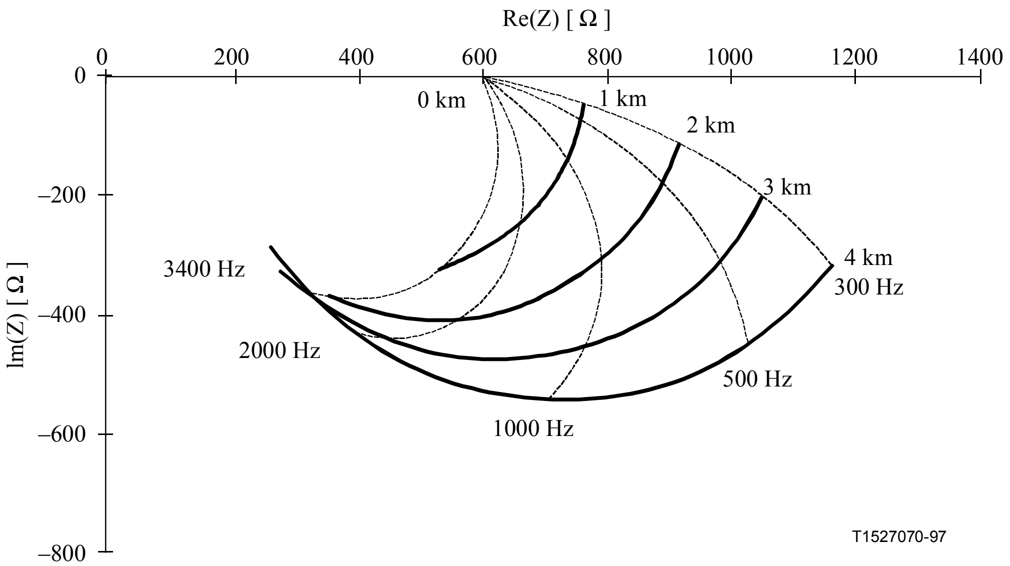
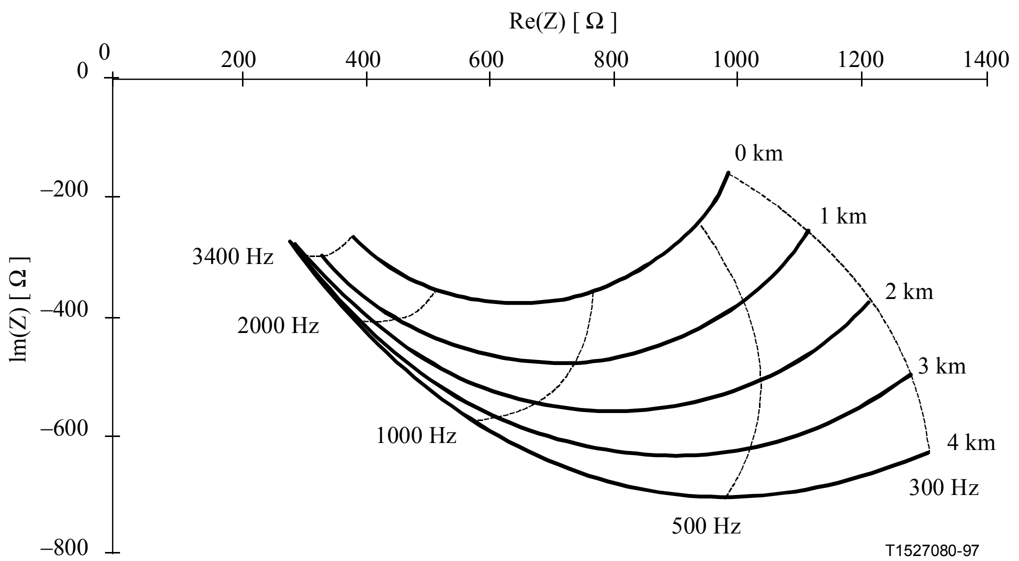


Figure I.5/Q.552 – Input impedance Z_2 of a 0.5 mm cable with different lengths terminated by Z_T = 600 Ω resistive load



NOTE – The dotted lines connect points of the same frequency but different cable length.

Figure I.6/Q.552 – Input impedance Z_2 of a 0.5 mm cable with different lengths terminated by $Z_T = Z_{ETSI} = 270\ \Omega + (750\ \Omega \parallel 150\ nF)$

To compare the effect of different cable terminations, Figure I.7 shows the range of the magnitude of the reflection coefficient versus the frequency with the cable length as parameter (calculated with equation I-7). A general aim is to have a reflection coefficient of "Zero" all over the frequency- and length-range under consideration.

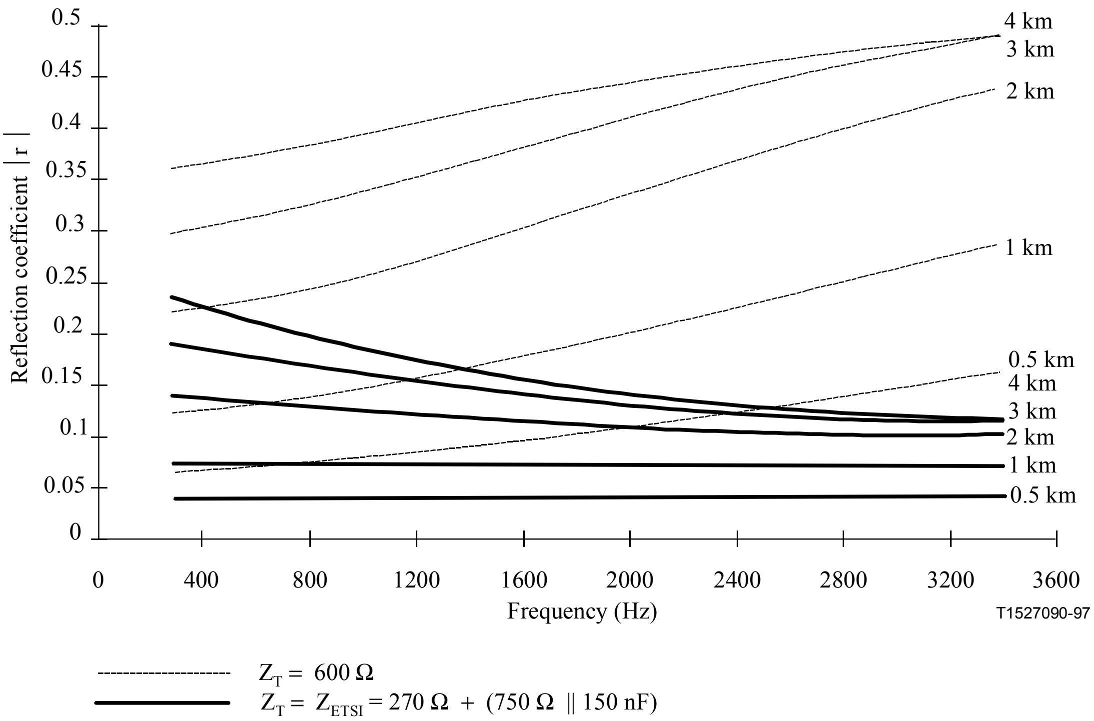


Figure I.7/Q.552 – Reflection coefficient: Impedance Z_T compared to cable input impedance Z_2 (cable terminated by the impedance Z_T) versus frequency

I.8.2 Balance impedance Z_B

If only terminals with the ETSI input impedance are used, it is possible to obtain a better average balance return loss by choosing a Z_B that differs from Z_{ETSI}.

A three-element balance network $Z_{B_{calc}}$ was found by an iterative calculation process with the following preconditions regarding the echo loss L_e:

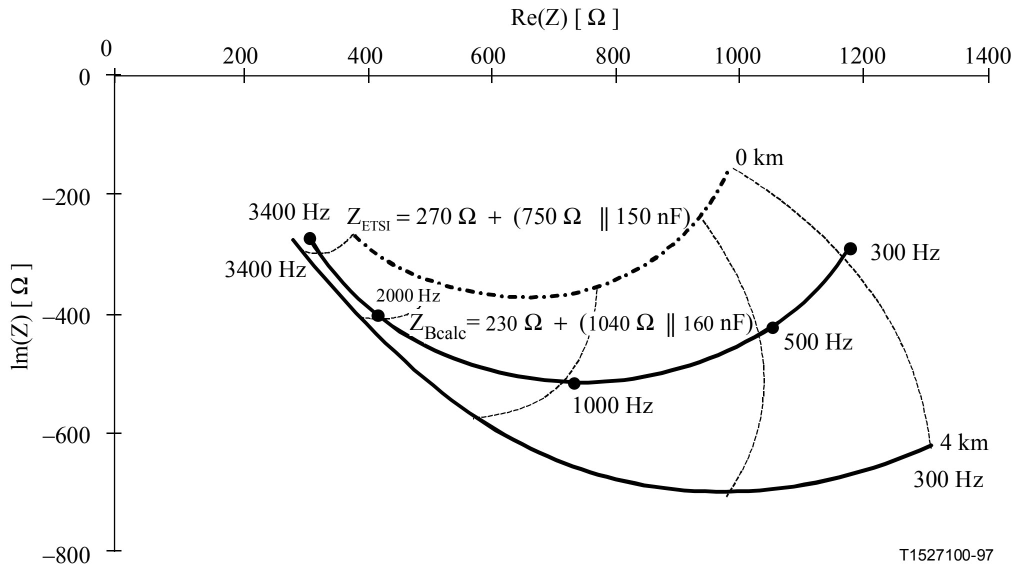
- cable lengths and type: 0 km ≤ l ≤ 4 km, 0.5 mm-Cu;
- cable termination impedance $Z_T = Z_{ETSI}$ = 270 Ω + (750 Ω || 150 nF);
- L_e should be a maximum in the range of the average length (resulting of the cumulative length-distribution of a network; in this example an average length of 1.7 km is assumed);
- for l = 0 km and l = 4 km: L_e should be a minimum but the value should be as high as possible and nearly the same.

The result of the calculation is:

$$Z_{B_{calc}} = 230\Omega + (1040\Omega \| 160 \text{ nF})$$

NOTE – For low frequencies $\left|Z_{B_{calc}}\right| \approx \left|Z_{ETSI}\right| + (1.7 \text{ km} \cdot R')$.

Figure 1.8 shows the locus of the balance impedance $Z_{B_{calc}}$ in comparison with the ETSI-impedance Z_{ETSI}.



NOTE – The area shown represents the input impedance range of the cable terminated by Z_{ETSI} (see Figure I.6).

Figure I.8/Q.552 – Loci of $Z_{B_{calc}}$ = 230 Ω + (1040 Ω || 160 nF) and Z_{ETSI} = 270 Ω + (750 Ω || 150 nF)

I.8.3 Application of the special impedance diagram

Figures I.9 and I.10 show the same input impedance curves as depicted in Figures I.5 and I.6; however, in the special impedance diagram mentioned above, the same type of cable is terminated with Z_{ETSI} and 600 Ω respectively.

Also depicted are two examples of balance impedances, namely Z_{ETSI} and $Z_{B_{calc}}$. As can be seen directly, $Z_{B_{calc}}$ is more optimal if the Z_{ETSI}-termination is the only one allowed. However, if only 600 Ω-termination have to be considered, Z_{ETSI} is the better choice. It is also apparent that a complex impedance termination results in much less impedance deviations so that better balancing with a single 3-element-impedance-network is possible.

Note that the ETSI-impedance was obtained from more data than just 0.5 mm Cu-cables.

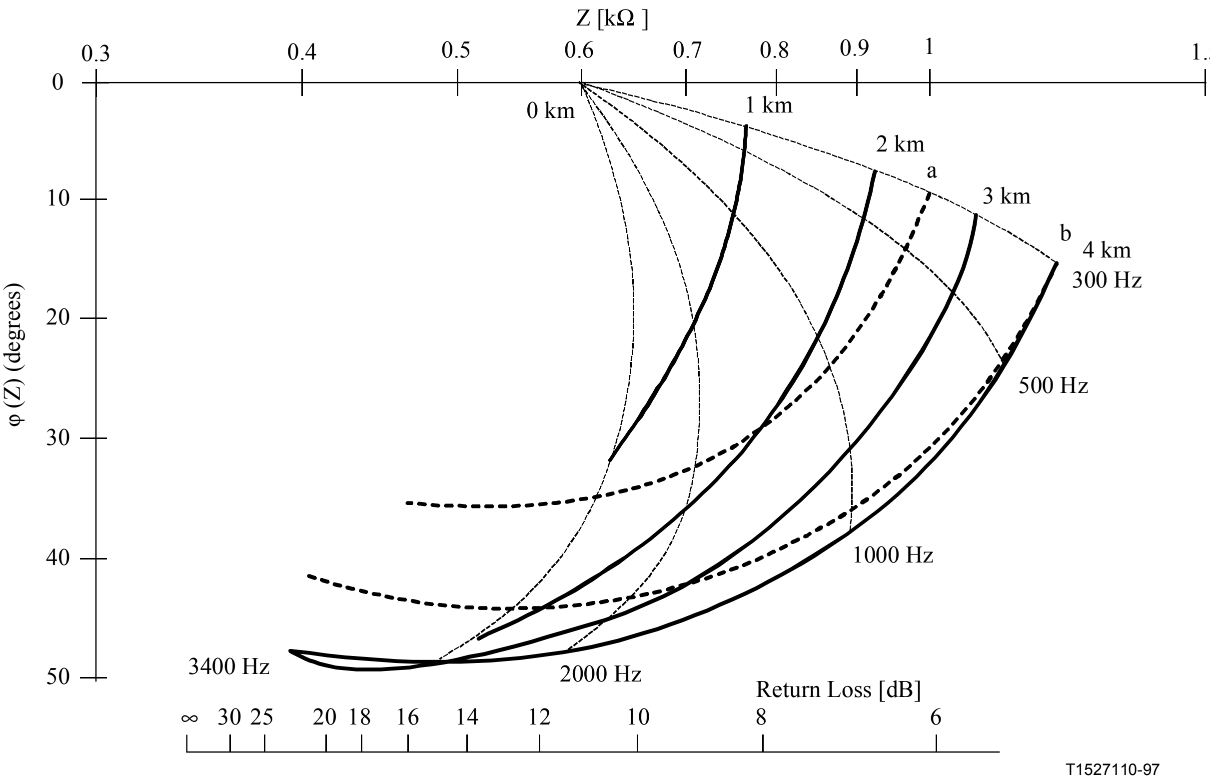
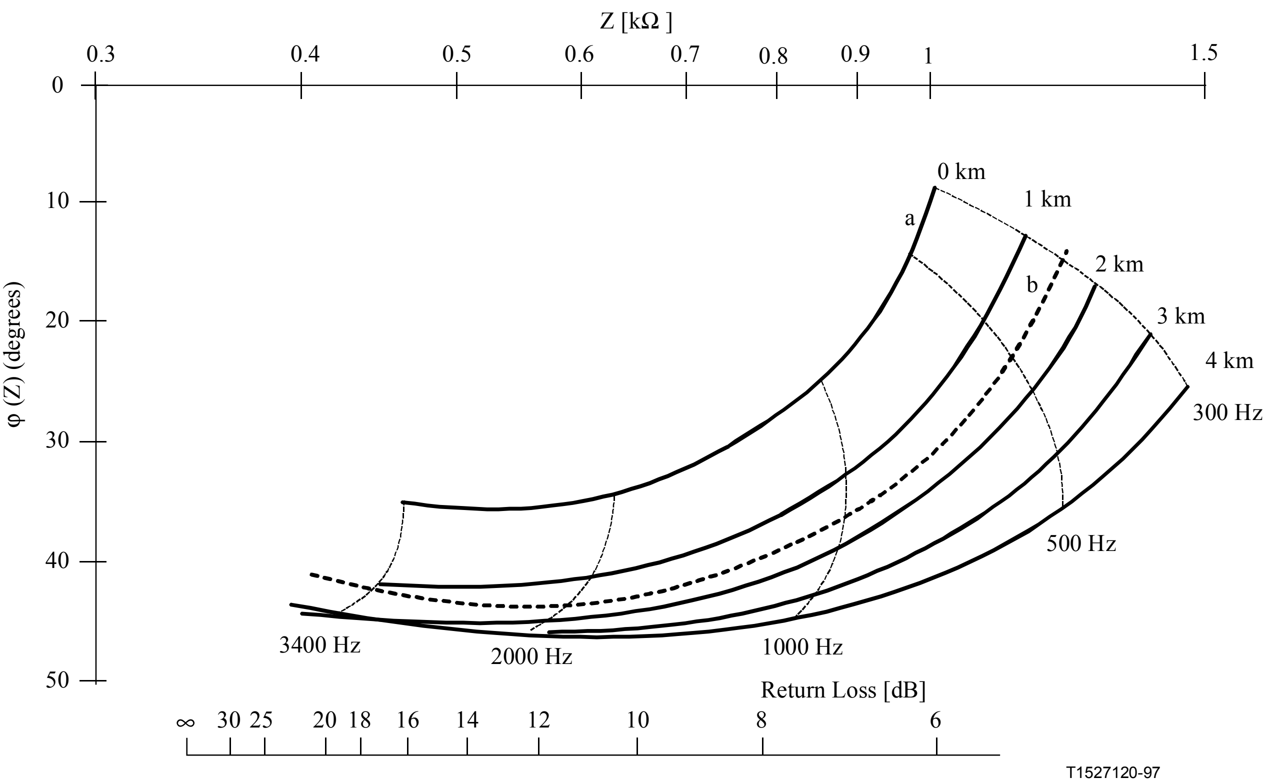


Figure I.9/Q.552 – Input impedance Z_2 of a 0.5 mm cable with different lengths terminated by Z_0 = 600 Ω resistive load in comparison to Z_{ETSI} (a) and $Z_{B_{calc}}$ (b)



NOTE – The dotted lines for different frequency marks in Figures I.9 and I.10 refer only to the input impedance Z_2 curves.

Figure I.10/Q.552 – Input impedance Z_2 of a 0.5 mm cable with different lengths terminated by $Z_0 = Z_{ETSI}$ = 270 Ω + (750 Ω || 150 nF) in comparison to Z_{ETSI} (a) and $Z_{B_{calc}}$ (b)

The Z_{ETSI} and $Z_{B_{calc}}$ impedance curve results of the same frequency range 300 Hz ≤ f ≤ 3400 Hz; however, due to a better representation the frequencies 500 Hz, 1000 Hz and 2000 Hz are not marked for Z_{ETSI} and $Z_{B_{calc}}$ in Figure I.9 and for $Z_{B_{calc}}$ in Figure I.10 (the deviation can be seen in Figure I.8).

I.8.4 Echo considerations

I.8.4.1 Echo loss L_e

The echo loss L_e is the weighted average of $L_{TR} = L_T + L_{br} + L_R$ (see equation I-1).

Figure I.11 shows the echo loss at the listener's exchange for different combinations of impedances. At the exchange line circuit, the losses $L_T = 0$ dB and $L_R = 7$ dB are assumed.

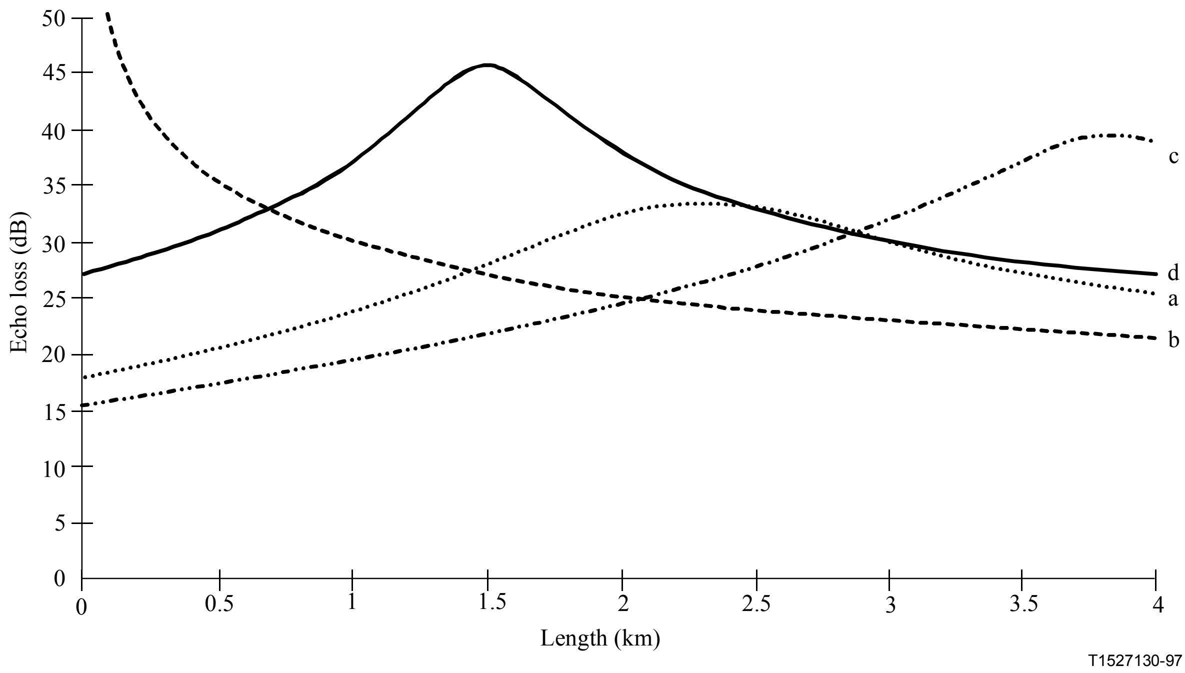


Figure I.11/Q.552 – Echo loss in a network versus different cable length with different hybrid impedances as parameter:

curve a)	$Z_{T_{set}} = 600\ \Omega$	$Z_{B_{ex}} = Z_{ETSI}$
curve b)	$Z_{T_{set}} = Z_{ETSI}$	$Z_{B_{ex}} = Z_{ETSI}$
curve c)	$Z_{T_{set}} = 600\ \Omega$	$Z_{B_{ex}} = Z_{B_{calc}}$
curve d)	$Z_{T_{set}} = Z_{ETSI}$	$Z_{B_{ex}} = Z_{B_{calc}}$

I.8.4.2 Sidetone loss L_{st}

The sidetone loss L_{st} is the weighted average of $L_{TR} = L_T + L_{br} + L_R$ (see equation I-1). Figure I.12 shows the sidetone loss at the hybrid of a telephone set for different balance networks. At the telephone set, the losses $L_T = L_R = 0$ dB are assumed.

The sidetone loss L_{st} can be transformed into a STMR value for the set in the following way. Referred to the 0 dBr point of the exchange, the "target value" is (SLR + RLR) = 10 dB. The sum of the T and R-pads usually is (T + R) = 7 dB. Suppose the line attenuation is 3 dB, then for the set itself {SLR(set) + RLR(set)} = 10 dB – 7 dB – 2 × 3 dB = –3 dB. Thus, using equation (I-9): STMR = L_{st} – 4. Judging from the L_{st} – values of Figure I.8, there is no problem with a too loud sidetone.

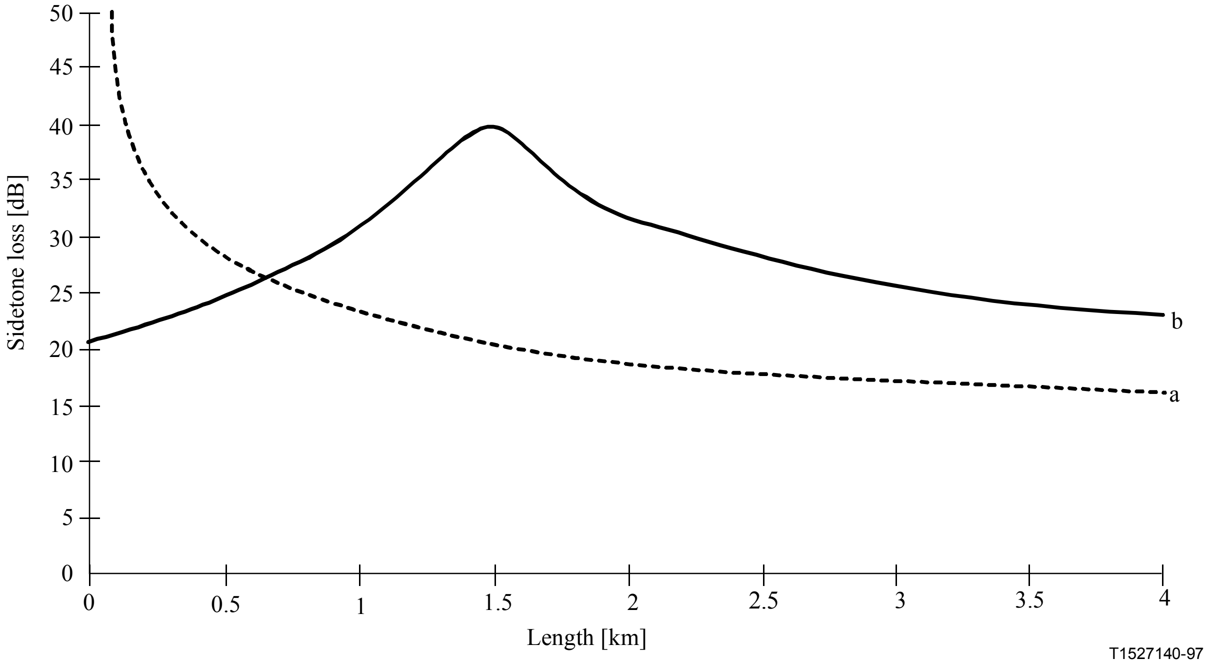


Figure I.12/Q.552 – Sidetone loss for different balance networks in the telephone set

curve a) $Z_{T_{ex}} = Z_{ETSI}$ $Z_{B_{set}} = Z_{ETSI}$

curve b) $Z_{T_{ex}} = Z_{ETSI}$ $Z_{B_{set}} = Z_{B_{calc}}$

Bibliography

[1] ITU-T G.100-series Supplement 31 (1993), *Principles of determining an impedance strategy for the local network.*

[2] ADLER (K.), RAHMIG (G.): Unterdrückung des Sprecherechos in gemischt analog/digitalen Netzen Frequenz, Band 46, pp. 210-216, July-August 1992.

[3] ETSI ETR 004 (1990), *Overall transmission plan aspects of a private branch network for voice connections with access to the public network.*

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of 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	Cable networks and 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, 2002