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DIGITAL EXCHANGES

TRANSMISSION CHARACTERISTICS AT 2-WIRE ANALOGUE INTERFACES OF DIGITAL EXCHANGES

ITU-T Recommendation Q.552

(Previously "CCITT Recommendation")

FOREWORD

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

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

The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation Q.552 was revised by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 20th of January 1994.

NOTE

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

CONTENTS

TRANSMISSION CHARACTERISTICS AT 2-WIRE ANALOGUE INTERFACES OF DIGITAL EXCHANGES

(*revised 1994*)

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 Recommendation 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. Administrations 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 equipment port against the test network for the exchange impedance should comply with the limits given in Figure 1.

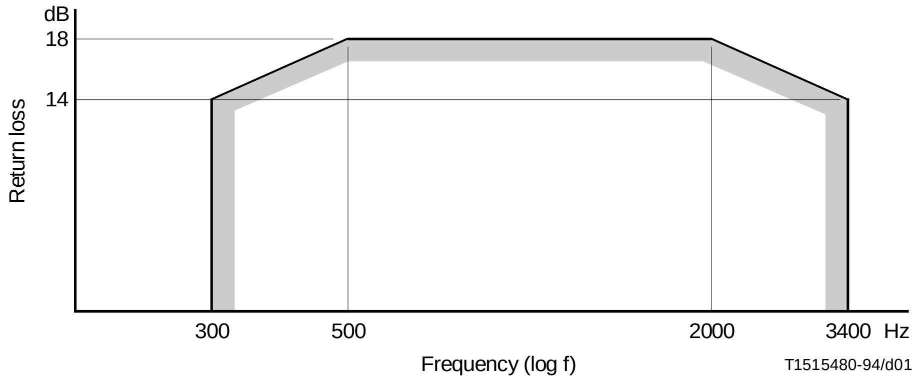


FIGURE 1/Q.552

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 equipment post, defined in 2.1/O.9, should exceed the minimum values of Figure 2 with the equipment under test in the normal talking state, in accordance with Recommendation K.10.

NOTES

1 An Administration may adopt other values and in some cases a wider bandwidth, depending on actual conditions in its telephone network.

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.

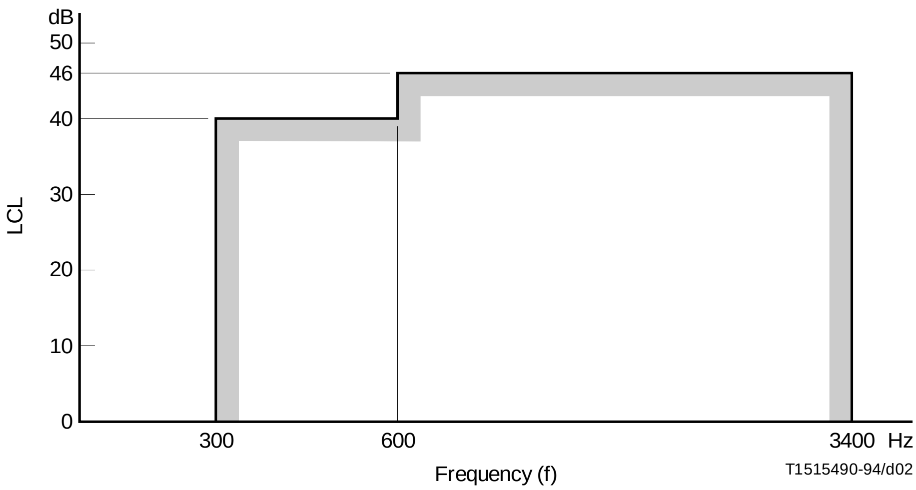


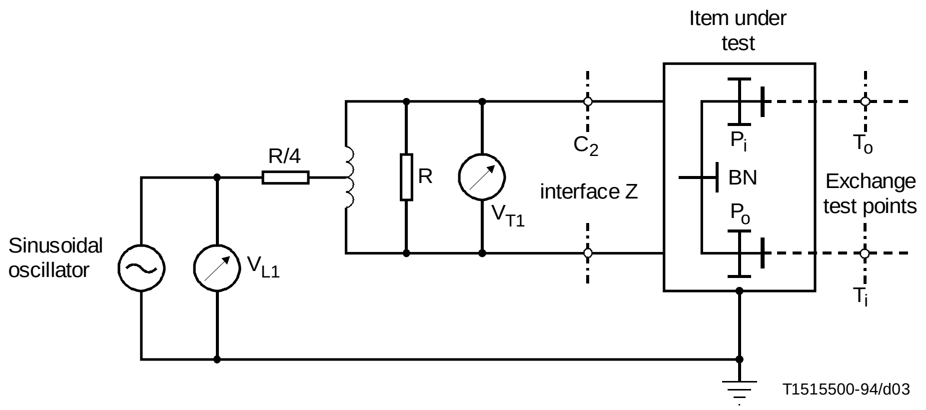
FIGURE 2/Q.552

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

Test method

Longitudinal conversion loss at the equipment post should be measured in accordance with the principles given in 2.1/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 clause 3/O.9).

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



BN Balance network

R should be in the range of 600-900 Ω

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

NOTES

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

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

FIGURE 3/Q.552

Arrangement for measuring LCL

2.1.3 Longitudinal interference threshold level

Under study.

2.1.4 Relative levels

2.1.4.1 Nominal levels

2.1.4.1.1 Interface C_{21}

C_{21} interfaces should meet the recommended values for Z interfaces in 2.2.4.1 if no loss compensation comparable to 2.2.4.3 is provided.

2.1.4.1.2 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 2.1.4.1.1 and 2.2.4.1, the following ranges encompass the requirements for C_{22} interfaces of a large number of Administrations:

– 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.

According to Annex E/G.121 (see column 2 of Table E.1/G.121), the range of transmission loss from 1.0 to 8.0 dB for the digital transmission section encompasses the requirements of a large number of Administrations.

In order to compensate loss on long toll or junction lines, an Administration 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 require 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.

2.1.4.2 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

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 Supplement No. 2, Fascicle VI.5 of the CCITT *Blue Book* and Recommendations G.111 and 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 Administrations, examples of nominal values chosen by some Administrations are given in Table 1.

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

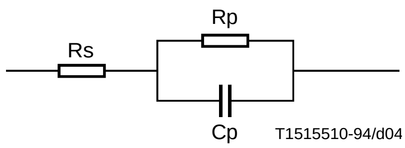
2.2.2 Impedance unbalance about earth

The longitudinal conversion loss (LCL) at the equipment postof 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.

TABLE 1/Q.552

Test networks for exchange impedances being considered

	Rs (ohms)	Rp (ohms)	Cp (farads)
NTT	600	infinity	1 µ
Austria, FRG	220	820	115 n
USA	900	infinity	2.16 µ
BT	300	1 000	220 n
New Zealand	370	620	310 n
European PABX	275	850	150 n



NOTES

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.

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, Administrations 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.

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.

TABLE 2/Q.552

Examples of limit values of return loss against the exchange impedance

FRG	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.
BT	18 dB: 200-800 Hz; 20 dB: 800-2000 Hz; 24 dB: 2000-4000 Hz.
USA	20 dB: 200-500 Hz; 26 dB: 500-3400 Hz.
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.

2.2.3 **Longitudinal interference threshold levels** (under study)

The signalling and transmission performance of the Z interface can be degraded when the subscriber line is exposed to an electromagnetic field of sufficiently high intensity. The value of induced interference energy causing performance degradation may be below a level which would cause permanent damage or operate protective devices. Longitudinal interference may come from power or traction lines or radio-frequency sources.

Radio-frequency interference tests at the Z interface should be in accordance with Recommendations of the K-Series (intended by Study Group V).

Longitudinal interference tests relative to power and traction line sources should be performed according to Figure 4.

Interference up to the interference threshold level should not affect signalling and transmission more than the limits stated below. Measurements should be performed using quiet code at the exchange test point T_i.

There are two groups of parameters to be observed while performing the tests:

i) signalling related parameters;

ii) transmission related parameters, i.e. noise parameters.

For group i) the performance of the signalling parameters mentioned in Recommendation Q.543 should be tested in a go-no-go procedure under normal operating conditions.

For group ii) two test steps should be performed under normal operating conditions, the first step without and the second one with the longitudinal test generator connected to the coupling network. The additional noise in the second test step should not contribute more than:

$L_{EN} = Y_1$ pWp using sinusoidal longitudinal test signal with X_1 volts rms;

$L_{EN} = Y_2$ pWp using longitudinal EMF test signal with defined harmonic content (e.g. triangular waveform with X_2 volts zero to peak).

The values Y_1 and Y_2 of the noise power must be specified depending on the interface the noise measuring set is connected to, i.e. the analogue interface at the termination T representing subscriber apparatus or the digital interface at the exchange test point T_o. The noise measuring set should be provided with a notch filter to exclude the activating signal at the nominal reference frequency.

The associated noise level limit results from the use of the equations given in 3.3.2.1 and 3.3.3.

NOTES

1 The values of X_1 and X_2 need further study. (Some Administrations reported an X_1 value of 15 volts and an X_2 value of 25 volts.)

2 The value of the induced noise power L_{EN} needs further study. (Attention is drawn to 3.1.6.2 and to 1/G.123.)

The longitudinal interference test generator should provide the longitudinal interference EMF with the fundamental frequency of the interference source (as appropriate to national conditions, i.e. 16 2/3 Hz, 50 Hz or 60 Hz) with a sinusoidal waveshape, and additionally with a waveshape having a certain amount of harmonic content, e.g. a triangular waveshape.

The coupling network CN[1)] should represent a typical subscriber line (length, type of cable) exposed to power or traction line interference. The impedance of the coupling path within the network should be primarily capacitive. (One ROA reported an impedance of –*j* 1.17 kohm at 60 Hz for each capacitor indicated in Figure 4.)

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1) The exact definition of the harmonic content and the coupling network is for further study.

Test Method

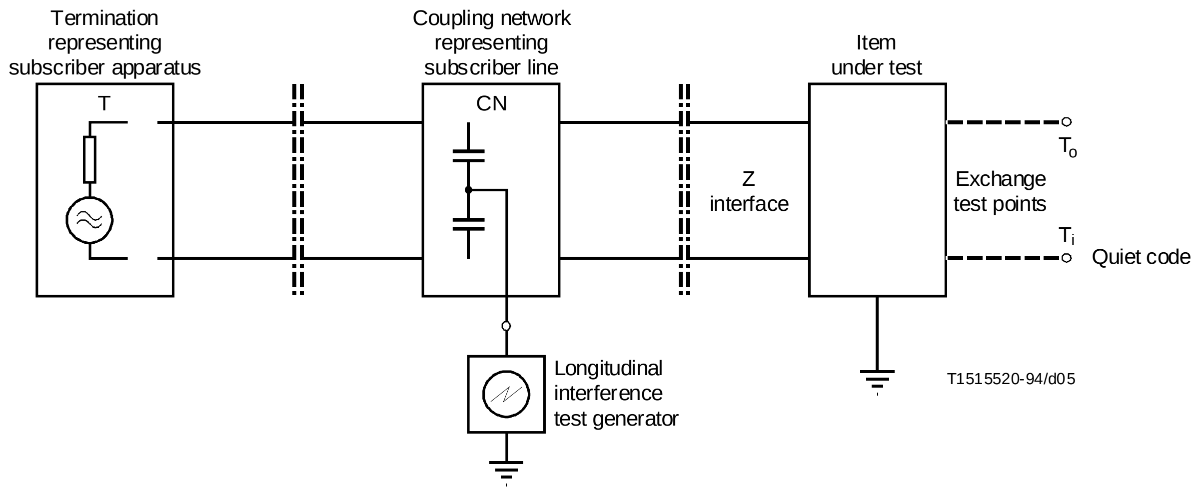


FIGURE 4/Q.552

Arrangement for measuring longitudinal interference threshold level

The termination T representing subscriber apparatus should provide for an appropriate loop current and the requested internal impedance of the reference frequency signal generator.

NOTES

1 The measuring arrangement in Figure 4 covers the general use of subscriber equipment, as recommended in Recommendation K.4, without low impedance to earth, especially without signalling using earth return. National deviations from this general case need to be considered for each special type of subscriber circuit.

2 Annex A gives an example of a CN applicable to the measuring arrangement of Figure 4, the application of which needs further study.

3 Annex B gives an example of a simplified CN applicable to measurements in the voiceband or below (as appropriate to national conditions), the application of which needs further study.

2.2.4 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 6.4/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 2.2.4.1.1 and 2.2.4.1.2, 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 11), the requirements of clause 6/G.121 (Incorporation of PCM digital processes in national extensions) as well as for Recommendation G.122 (Stability and echo loss) will be satisfied.

2.2.4.1 Nominal levels

2.2.4.1.1 Input relative level

According to Annex C/G.121 (columns 1, 2 and 3 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 Administrations.

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

NOTE – Subclause 2.6/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 (this value is under study), 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.

2.2.4.1.2 Output relative level

According to Annex C/G.121 (column 3 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 Administrations:

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

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 1 and 2 of Table C.1/G.121) the following range encompasses the requirements of a large number of Administrations:

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

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

2.2.4.2 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.

2.2.4.3 Consideration of short and long subscriber lines

In order to compensate for the loss of short or long subscriber lines, an Administration 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 2.1.4.2 and 2.2.4.2 should lie within the following range:

–0.3 to +0.7 dB

These differences may arise, for example, from design tolerances, cabling (between analogue equipment ports 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 *Ti* 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 5.

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.

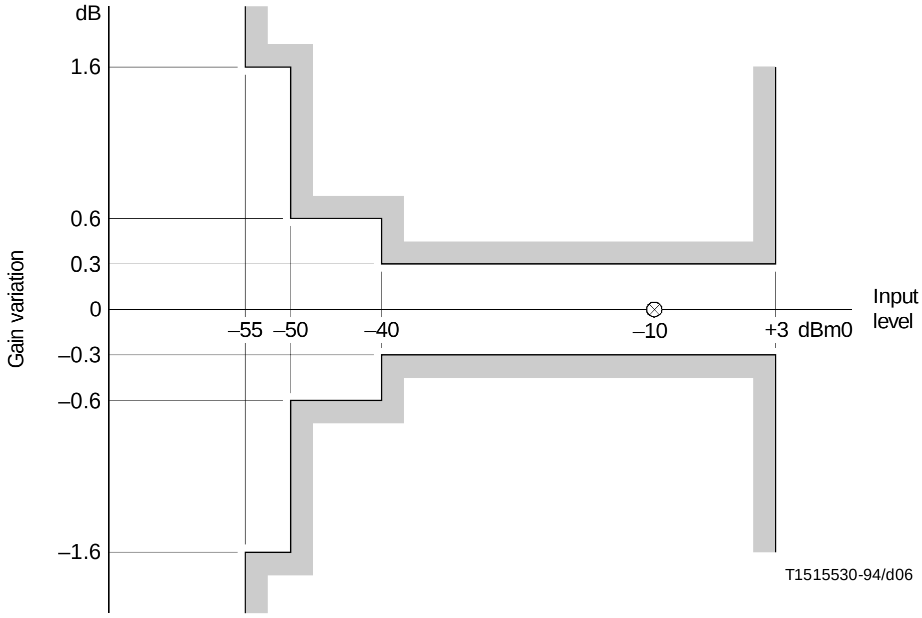


FIGURE 5/Q.552

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 6a) or 6b) 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 distortion in the subscriber line.

3.1.2 Group delay

"Group delay" is defined in the *Blue Book*, Fascicle I.3.

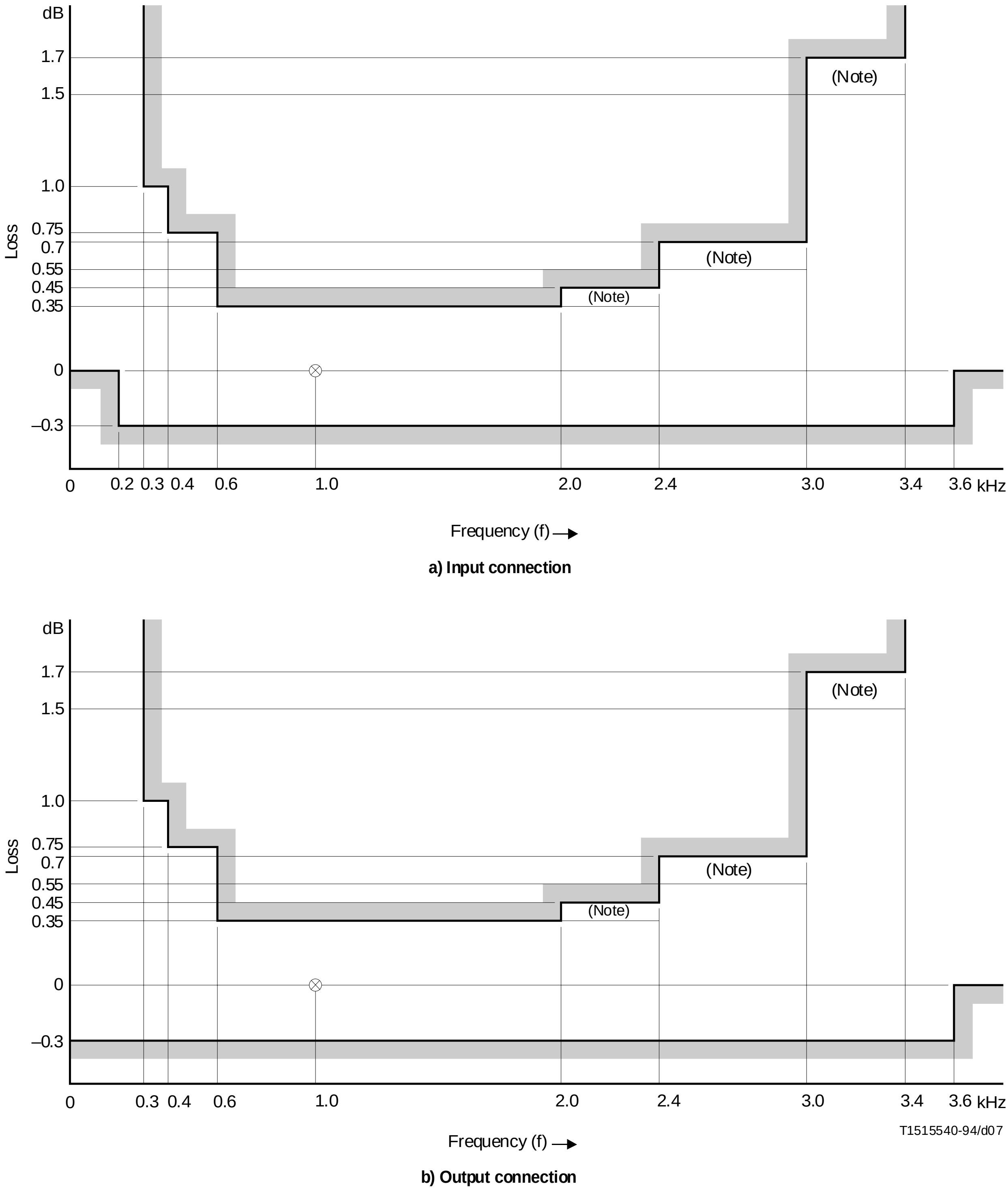
3.1.2.1 Absolute group delay

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 7. Group delay distortion is measured in accordance with Recommendation O.81.

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



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 6/Q.552

Loss distortion with frequency

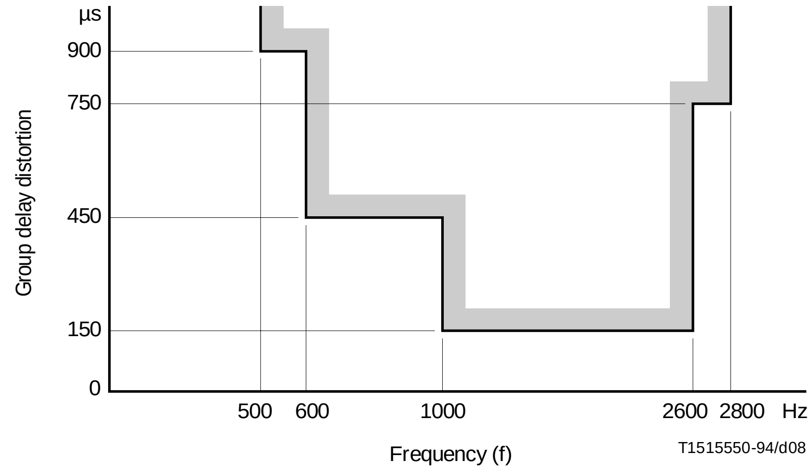


FIGURE 7/Q.552

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 8 and 9. 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 8).

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 9).

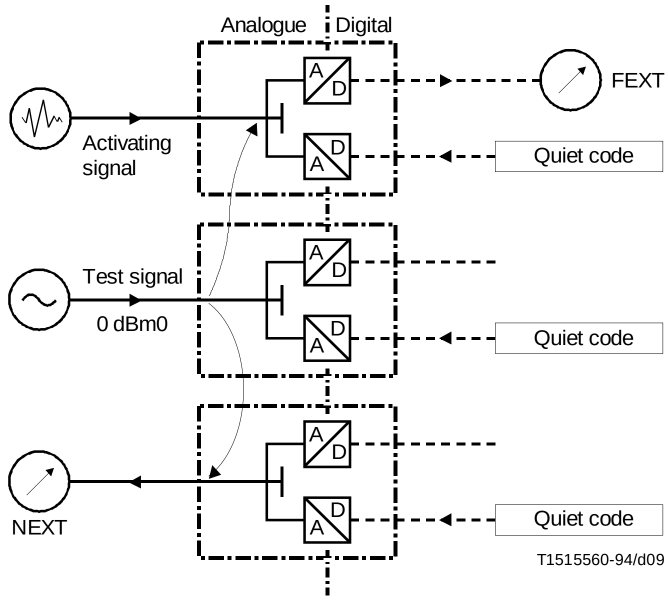


FIGURE 8/Q.552

FEXT and NEXT measurements with analogue test signal

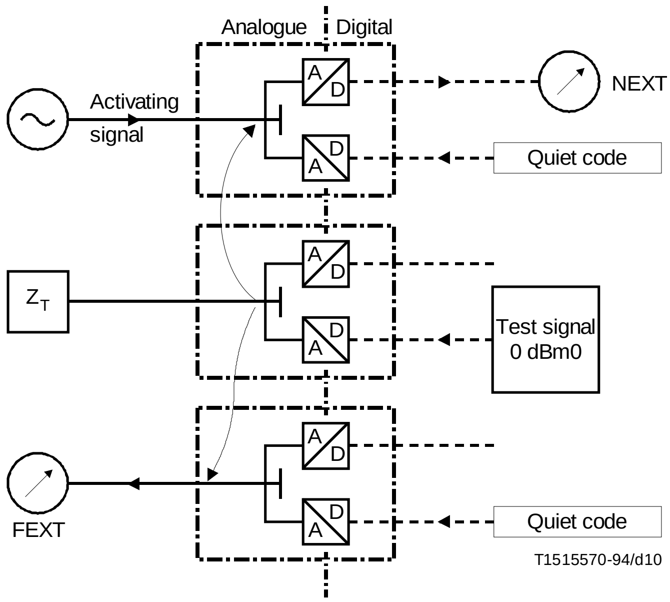


FIGURE 9/Q.552

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 Recommendation 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 4/G.223) should lie above the limits given in 3.2.3, Figures 13 and 14 for interface C_2 and 3.3.3, Figure 15 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 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 300-3400 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 Recommendation G.122 with respect to echo and stability. The TBRL of an equipment port is measured in the talking state as in an established connection through a digital exchange.

The parameter “Stability Loss”, as defined in Recommendation 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 equipment port.

The expression for TBRL is:

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

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 equipment port.

Some Administrations 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

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

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:

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

where a_o and a_i are the losses between the exchange test point T_i and the 2-wire equipment port and between the 2-wire equipment port 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:

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

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:

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

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

$$\text{TBRL} = a_{io} \left| \frac{a'_{io} + a''_{io}}{2} \right|$$

Method b) provides the most accurate results.

Using the arrangement of Figure 10 and sinusoidal test signals, the measured TBRL should exceed the limits shown in Figure 11.

Figure 12 gives examples of balance test networks adopted by some Administrations for unloaded subscriber lines. These examples may provide guidance for other Administrations in order to minimize the diversity of types of test networks.

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

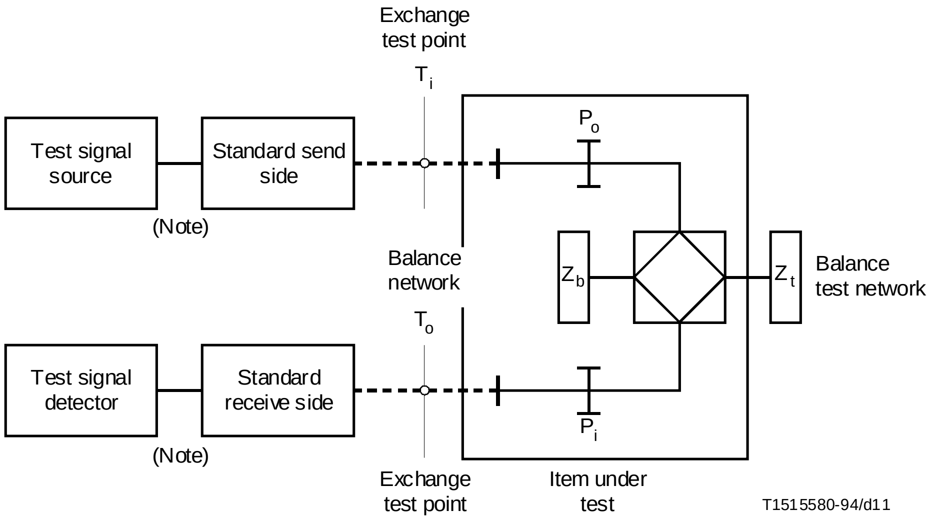
3.1.8.2 Stability loss

The stability loss should be measured between the exchange test points T_i and T_o of a half-connection (see Figure 10) by terminating the 2-wire interface with stability test networks representing the "worst terminating condition encountered in normal operation". Some Administrations may find that open- and short-circuit terminations are sufficiently representative of worst-case conditions. Other Administrations may need to specify, for example, an inductive termination to represent the worst-case condition.

With worst-case terminating conditions on the 2-wire interface of a half-connection, the stability loss T_i to T_o measured as a_{io} should be:

Stability Loss $= a_{io} \geq x$

where x is under study for sinusoidal signals at all frequencies between 200 Hz and 3600 Hz. This frequency band is determined by the filters used in the interface designs.



NOTE – This equipment may be all digital, with equivalent functions (see Recommendation O.133). The test signal source and the test signal detector may be as shown in Figure A.1/G.122.

FIGURE 10/Q.552

Arrangement for measuring the loss a_{io}

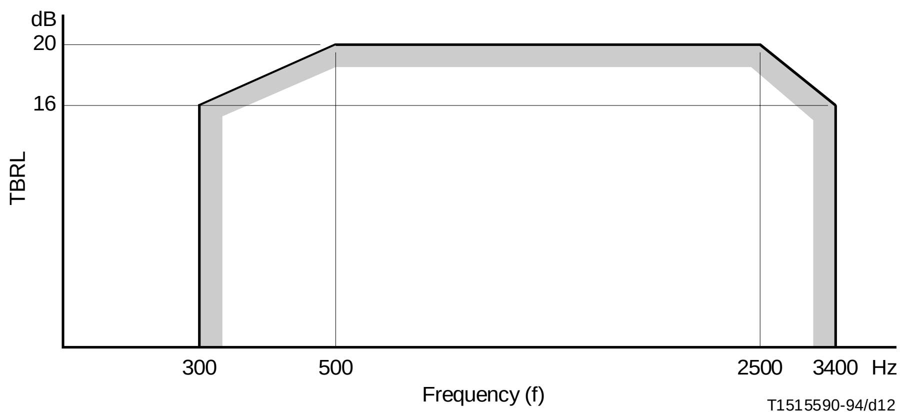


FIGURE 11/Q.552

Limits for TBRL

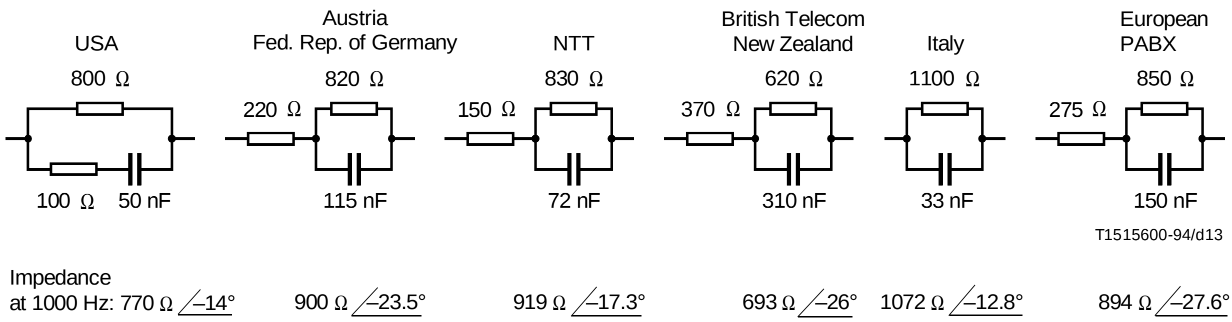


FIGURE 12/Q.552

Examples of test networks to be used by some administrations
(applicable to unloaded subscriber lines)

The need for requirements outside this frequency band is also under study.

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 Recommendation G.122 are met. An SL value of 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 (see *Red Book* 1984) but further study is required to provide guidance in this area. One Administration 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 2.1.4.1, 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 to 2.0 dB for all types of connections

NL_o = 0 to 8.0 dB for international connections

0 to 8.0 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 2.1.4.1.2 or 2.2.4.3.

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 was not taken into account. For a more exact calculation further study is necessary.

3.2.2.1.1 Output connection

Two components of noise must be considered. One of these, namely noise arising from the quiet decoder, the other 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 + 3) dBm0p = –70 dBm0p for one 2-wire analogue interface in accordance with clause 3/G.123.

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;

  –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 2.1.4.1 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 + 3) dBm0p = –70 dBm0p for one 2-wire analogue interface including circuit noise in accordance with clause 3/G.123.

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.

NOTE – The need for and value of this parameter are both under study. Subclause 2.5.2/Q.45 *bis* and clause 3/G.123 must also be considered.

3.2.2.3 Impulsive noise

It will be necessary to place limits on impulsive noise arising from sources within the exchange; these limits and measurement conditions are under study.

NOTES

1 The sources of impulsive noise are often associated with signalling functions (or in some cases the power supply) and may produce either transverse or longitudinal voltage at C_2 interfaces.

2 The disturbances to be considered are those to speech or modem data at audio frequencies, and also those causing bit errors on parallel digital lines carried in the same cable.

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 13 for equipment with signalling on separate wires, and in Figure 14 for equipment with signalling on the speech wires both measured in the talking state.

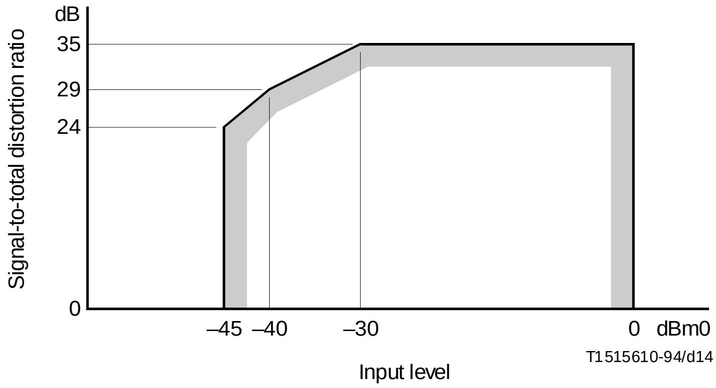


FIGURE 13/Q.552

Limits for signal-to-total distortion ratio as a function of input level; input or output connection with signalling on separate wires

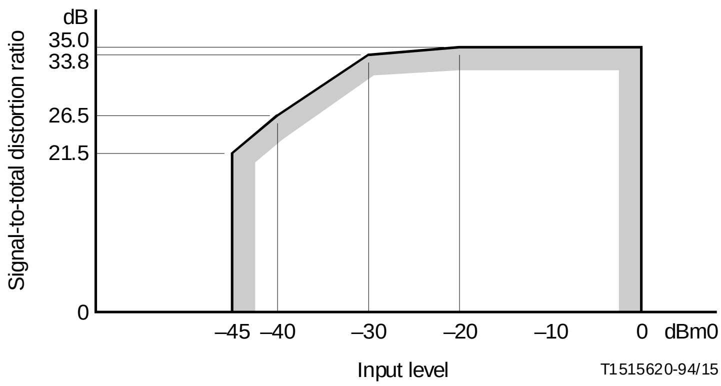


FIGURE 14/Q.552

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 14 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 + 3) dBm0p = –70 dBm0p for one C_2 analogue interface by clause 3/G.123.

3.3 Characteristics of interface Z

3.3.1 Nominal value of transmission loss

According to the relative levels defined in 2.2.4.1, 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 2.2.4.3.

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. For a more exact calculation further study is necessary.

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, e.g. 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.123. 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.

Information about the subject of noise on the DC power supply is given in Supplement No. 13 to the G-Series Recommendations (*Orange Book*, Volume III-3).

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

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

Values for other output relative levels cited in 2.2.4.1.2 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 at test point T_o. One of these, namely noise arising from the encoding process is independent to the input relative level. The other, e.g. power supply noise from the feeding bridge and the circuit noise, is dependent upon the input relative level and must therefore be corrected by the input relative level if referred to the exchange test point T_o. 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.123, which results in –67 dBmp $-L_i$ at the exchange test point T_o.

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

$$PTN_i = PAN \cdot 10^{\frac{-L_i}{10}} + 10^{\left(\frac{90+LIN_i}{10}\right)} \text{ pWp}$$

and the total noise level is:

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

Values for other input relative levels cited in 2.2.4.1.1 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.

NOTE – The need for and value of this parameter are both under study. Clause 3/G.123 must also be considered.

3.3.2.3 Impulsive noise

It will be necessary to place limits on impulsive noise arising from sources within the exchange; these limits and measurement conditions are under study.

NOTES

1 The sources of impulsive noise are often associated with signalling functions (or in some cases the power supply and the ringing voltage) and may produce either transverse or longitudinal voltages at Z interfaces.

2 The disturbances to be considered are those to speech or modem data at audio frequencies, and also those causing bit errors on parallel digital subscriber lines carried in the same cable.

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 15 a) and 15 b) as an example where L_i = 0 dBr and L_o = –7 dBr respectively.

Values for other relative levels cited in 2.2.4.1 can be calculated by using the formula given in 3.4.2/Q.551.

The values of Figure 15 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 for a Z interface (with feeding) by Annex A/G.123.

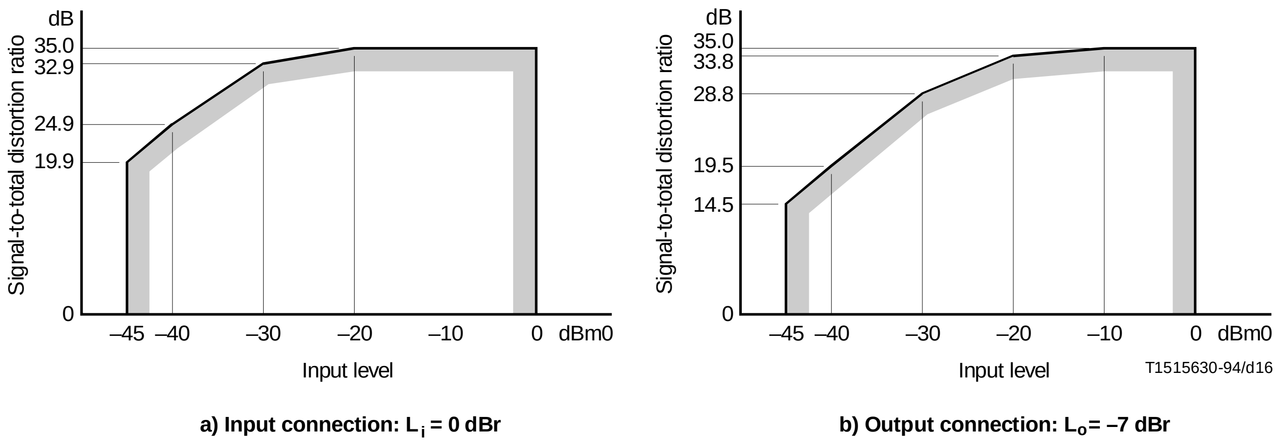


FIGURE 15/Q.552

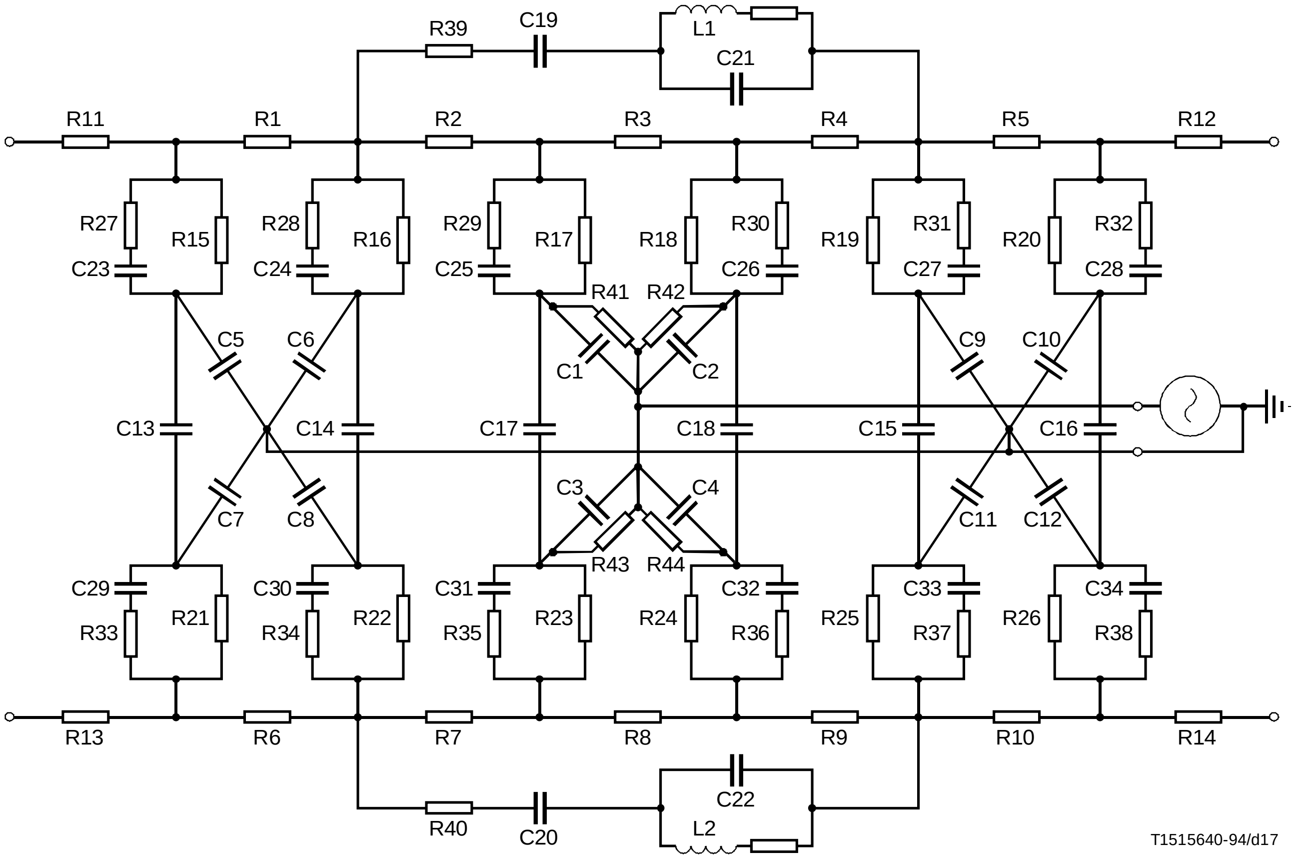
Limits for signal-to-total distortion ratio as a function of input level including analogue noise

Annex A

Example of a longitudinal interference coupling network

(This annex forms an integral part of this Recommendation)

The components should be chosen with small absolute tolerances (at least resistors and capacitors within 1% and the inductances with less than 5%) and matched pairs where relevant to achieve a longitudinal conversion loss better than 60 dB at 1000 Hz. For this LCL measurement, a terminating resistance of 600 ohms symmetrically applied to each port shall be used. See Figure A.1.



NOTE – The component values given in Table A.1 are applicable to 4 km of 0.4 mm cable with a mutual capacitance of 47 nF/km and a capacitance to earth of 15 nF/km.

FIGURE A.1/Q.552

An example of a longitudinal interference coupling network (CN)

TABLE A.1/Q.522

Components list

	Quantity	Type
		Metallized resistors
1	10	R1 ... R10: 100 ohms 1%, 1.1 W
2	4	R11 ... R14: 49.9 ohms 1%, 1.1 W
3	12	R15 ... R26: 133 ohms 1%, 0.35 W
4	12	R27 ... R38: 32.4 ohms 1%, 0.35 W
5	2	R39 ... R40: 24.0 ohms 1%, 0.35 W
6	4	R41 ... R44: 200 kohms 1%, 0.35 W
		Styroflex foil capacitors
1	4	C1 ... C4: 15 nF 1%, 160 V
2	8	C5 ... C12: 7.5 nF 1%, 160 V
3	4	C13 ... C16: 28 nF 1%, 160 V
4	2	C17 ... C18: 24.3 nF 1%, 160 V
5	2	C19 ... C20: 20 nF 1%, 160 V
6	2	C21 ... C22: 499 pF 1%, 160 V
7	12	C23 ... C34: 60.4 nF 1%, 63 V
		HF-chokes, ferrite rod
1	2	L1 ... L2: 47 μH 5%, R_0 1.1 ohms

Annex B

Example of a test method for measuring longitudinal interference threshold level

(This annex forms an integral part of this Recommendation)

B.1 Possible types of degradations

There are several types of transmission degradations which may occur due to induced longitudinal voltages:

1) mis-operation of the subscriber loop interface circuit;

2) transmission impairment due to saturation of the electronic subscriber loop interface (i.e. the transistor circuit);

3) increase of quantizing distortion;

4) increase of noise due to the harmonic components of the induced voltage;

5) hum modulation, in amplitude and/or phase, of transversal signals passing the line circuit.

The longitudinal voltage interference tests should be laid out accordingly.

Some of the listed degradations may be evaluated using a sinusoidal test voltage. However, items 4 and 5 require a signal with a defined harmonic content and the preferred method here is to use a triangular wave form.

B.2 Test circuits

The first step for an Administration is to decide upon a realistic "worst case" to base the longitudinal interference testing upon. This amounts to stating the "worst case" length of subscriber line and the value of the interference voltage.

Depending on the signalling system, for interference tests on signalling related parameters special test circuits may be needed which physically (as well as electrically) closely simulate the actual subscriber lines, including capacitances to earth and possible ground start arrangements.

For testing transmission related parameters, the physical resemblance is not critical, provided the test circuit has good electrical equivalence regarding both the transversal and the longitudinal circuit.

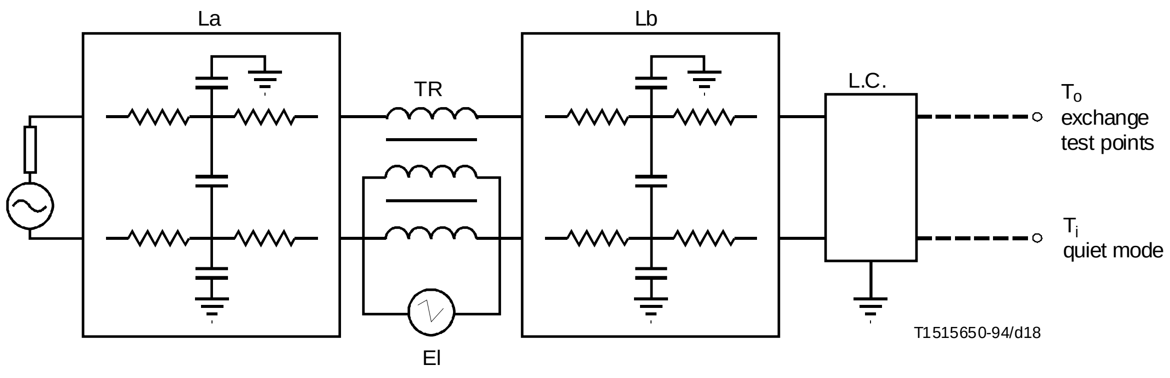
Figure B.1 shows an interference test circuit representing a close physical and electrical simulation of the subscriber line. The interference voltage is introduced by a series connected low-impedance transformer at a typical distance from the circuit interface. Note that all elements in the test circuit have to be very well balanced to earth, especially if transmission parameters are to be measured.

Figure B.2 depicts a simpler test circuit which suffices when the longitudinal interference on transmission parameters is to be determined in the voiceband. (On this type of circuit it may be easier to obtain good balance to earth.)

Note that in Figure B.2:

1) the artificial line L only needs to reproduce the transversal line transmission characteristics (Its main purpose is to present a realistic 2-wire impedance to the Z interface.);

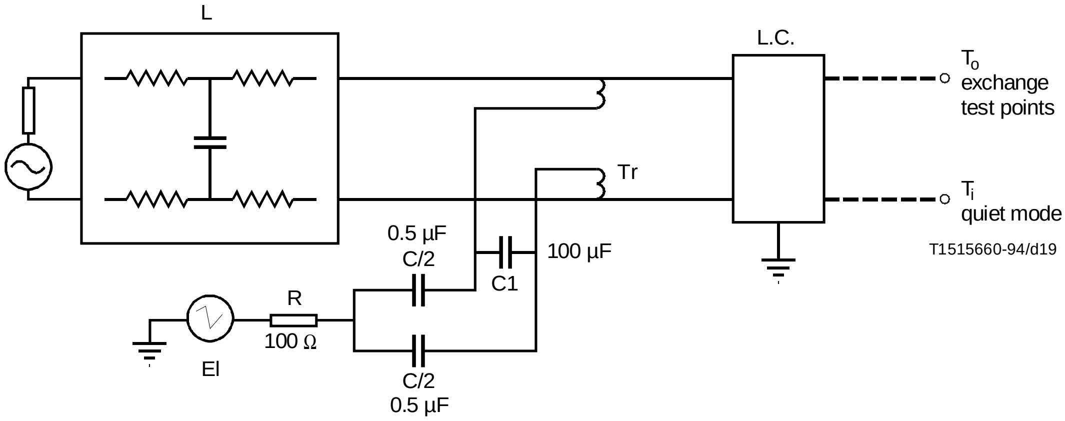
2) the equivalent longitudinal line parameters are accurately represented by the R-C circuit at the longitudinal interference frequency and its harmonics.



La, Lb Artificial lines, including the distributed capacitances to earth
TR Current transformer

FIGURE B.1/Q.552

Test circuit for physically simulating the longitudinal interference mechanism



L	Conventional artificial line
Tr	Centre tapped choke
C1	Large capacitor
C/2+C/2+R	Chosen “worst case” longitudinal impedance. For the given length of the cables
C	Capacity to earth of a cable pair
R	1/12 of the loop reistance of a pair

FIGURE B.2/Q.552

Test circuit for electrically simulating the equivalent longitudinal mechanism

It is worth mentioning that other simple test configurations may function equally well for determining transmission degradations due to longitudinal interference. The criteria are:

a) the introduced test voltage shall produce the aimed for “worst case” longitudinal voltage at the input of the line circuit;

b) the longitudinal impedance presented to the line circuit shall correspond to the “worst case” line length, i.e. being approximately equal to a capacitance of 120 nF/km and a series resistance equal to 1/12 of the transversal pair resistance;

c) the transversal circuit shall represent normal operating conditions and not be affected in a detrimental way by the longitudinal circuit. Likewise, the transversal circuit must not destroy the balance to earth.

B.3 Test values

Numerical values for the longitudinal interference parameters are for further study. (Some Administrations report using a sinusoidal voltage of 15 volts r.m.s. and a triangular test voltage of 25 volts peak-to-peak.)

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