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SECTION 4

**TRANSMISSION CHARACTERISTICS**

**Recommendation Q.551**

TRANSMISSION CHARACTERISTICS OF DIGITAL EXCHANGES

## 1 Introduction

### 1.1 *General*

The field of application of this Recommendation is found in Recommendation Q.500.

*Note* — A high percentage of international calls will have a digital PABX included in the connection. Therefore, Recommendations Q.551-Q.554 are applicable also for digital PABXs with regard to those specific transmission parameters affecting the transmission quality of an international call, for instance Loudness Ratings, noise, talker’s and listener’s sidetone, echo and stability. These Recommendations primarily concern digital PABXs connected digitally to the international network. However, Administrations may find some of the specification details useful for digital PABXs connected by analogue means to the international network.

The signals taken into consideration are passed through the following interfaces as described in Recommendations Q.511 and Q.512 and Figures 1/Q.551 and 2/Q.551.

— Interface A is for primary digital signals at 2048 kbit/s or 1544 kbit/s.

— Interface B is for secondary digital signals at 8448 kbit/s or 6312 kbit/s.

— Interface C comprises both 4-wire and 2-wire analogue trunk interfaces. Interfaces $C_1$ 4-wire and $C_2$ 2-wire represent possible applications of interface C in Figure 1/Q.511.

Interface $C_1$ represents a 4-wire and interface $C_2$ a 2-wire analogue trunk interface. For practical reasons, $C_1$ and $C_2$ are further sub-divided into $C_{1\d1}$, $C_{1\d2}$, $C_{1\d3}$, $C_{2\d1}$ and $C_{2\d2}$.

$C_{1\d1}$ interfaces channel translating equipment. $C_{1\d2}$ and $C_{1\d3}$ interface 4-wire analogue exchanges; $C_{1\d2}$ via the relay sets, $C_{1\d3}$ directly to the switching stages.

$C_{2\d1}$ is an interface applicable when a 2-wire circuit connects a digital transit exchange with a local exchange, analogue or digital. $C_{2\d2}$ is an interface applicable when a 2-wire circuit connects local exchanges, analogue and/or digital.

See Figures 1/Q.551 and 2/Q.551 for illustration of the principles.

— Interface type V is for digital subscriber line access.

— Interface type Z is for analogue subscriber line access.

*Note 1* — Remote analogue exchange concentrators and analogue PABXs may use interface Z for access to a digital exchange.

*Note 2* — In the future, differences in circuit configurations with respect to transmission parameters may cause a sub-division of the Z interface.

**Figure 1/Q.551, p.**

**Figure 2/Q.551, p.**

Also for ports other than those designated Z, there can exist types whose transmission characteristics have not been defined, even though they may be recognized as being in practical operation. This may be due to CCITT not having considered their international standardization justified, e.g., because of their limited use, or because their function is to coordinate with pre-existing national standards. However, later additions to recommended interfaces are not ruled out (e.g., 4-wire subscriber interface).

Interface types V and Z may appear remote from the exchange through the use of digital transmission facilities. When this occurs, there should be no impact on transmission parameters other than delay. Transmission parameters associated with interface Z include the effects of the equipment provided for interfacing the analogue subscriber line to the digital switching network of the exchange.

Multislot channels are not considered in this Recommendation. This requires further study.

It is necessary to ensure that representative feeding currents are flowing during the measurements of all of these transmission parameters. These feeding currents can contribute to noise, distortion, crosstalk, variation of gain with input level, etc. Therefore, appropriate allowances for this must be made. In some cases, where indicated, the permissible limits quoted include these allowances.

Detailed transmission characteristics for these interfaces are provided in the following Recommendations:

— Recommendation Q.552 for 2-wire analogue interfaces

— Recommendation Q.553 for 4-wire analogue interfaces

— Recommendation Q.554 for digital interfaces.

In the present Recommendations, values given for transmission characteristics relate to the path from an exchange test point to an exchange interface and vice-versa; the overall characteristics for connections involving two interfaces can in most cases be obtained by suitably combining these values (see Recommendation Q.551, § 3).

In the future, other interfaces may be defined.

At this time these Recommendations consider analogue signals which are encoded in accordance with Recommendation G.711. Other coding laws may be defined in the future and these Recommendations will need to take them into account.

The transmission characteristics of voice-frequency (VF) connections through a digital transit exchange should in principle provide performance in accordance with Recommendations G.712, G.713 and, where applicable, Q.45 | fIbis (see also Recommendation G.142).

The principles of Recommendation G.142 and the limits of Recommendations G.714 and G.715 have been used as a basis for establishing the transmission characteristics for analogue voice frequency connections specified in §§ 2 and 3 of Recommendations Q.552 and Q.553, respectively. The limit values are not necessarily identical with those specified in the G-Series, since in the case of a connection through the exchange, additional allowances generally have been made for cabling (see § 2). The principles of Recommendations G.714 and G.715 have been used for the analogue/digital test connections referred to in §§ 2 and 3 of Recommendations Q.552 and Q.553, respectively.

The values given are to be considered as either ‘‘design’’ or ‘‘performance objectives’’ according to the explanations of the terms given in Recommendation G.102 (Transmission performance and objectives and recommendations) and the particular context.

The specification clauses in this Recommendation exclude the effects of auxiliary functions such as echo suppression, echo cancellation or transmission to the subscriber of metering impulses, or of non-telephony functions such as telemetering over the subscriber pair.

1.2 *Definitions*

1.2.1 *Exchange test points, exchange input and output and half-connections*

1.2.1.1 **exchange test points**

The exchange test points shown in Figure 1/Q.551 are defined for specification purposes. They may not physically exist in an exchange but may be accessed via the digital switching network. In this case, some or all of the switching network will be included in the path from the exchange interface to the access points.

The transmission parameters affected by this means of access are the absolute group delay and possibly jitter and wander and bit error ratio. For most other parameters, either the exchange test points or the access points are located such that end-to-end performance can be determined by suitably combining performances between each interface and either the exchange test points or the access points.

1.2.1.2 **exchange input and output**

The exchange input and output for a connection through a digital exchange are located at the interfaces identified in § 1.1 and shown in Figures 1/Q.551 and 2/Q.551.

The exact position of each of these points depends on national practice, and it is not necessary for the CCITT to define it.

However, the applicability of recommended values to points arbitrarily located is subject to certain restrictions:

— for analogue interfaces, as referred to in § 2 of this Recommendation (maximum length of exchange cabling between exchange equipment ports and the interface);

— for digital interfaces, as also mentioned in § 2 (maximum loss between exchange interfaces and connected equipment, e.g., digital line or higher order multiplex equipment).

1.2.1.3 *Half-connections*

**input connection** — A unidirectional path from an interface of a digital exchange to an exchange test point.

**output connection** — A unidirectional path from an exchange test point to an interface of a digital exchange.

**half connection** — A bidirectional path comprised of an input connection and an output connection, both having the same exchange interface.

*Note 1* — These terms may be qualified by the words analogue or digital, the qualification signifying the property of the exchange interface.

*Note 2* — An analogue input (output) (half) connection may be further qualified by the words 2-wire or 4-wire.

*Note 3* — Refer to Recommendation Q.9 for additional information.

1.2.2 *Relative levels*

1.2.2.1 *Exchange test points*

The nominal relative level at the input and output exchange test points is assigned the value 0 dBr.

1.2.2.2 *Analogue interfaces*

The nominal relative level at the exchange input point is designated $L_i$.

The nominal relative level at the exchange output point is designated $L_o$.

1.2.2.3 *Digital interfaces*

The relative level to be associated with a point in a digital path carrying a digital bit stream generated by a coder lined-up in accordance with the principles of Recommendation G.101 is determined by the value of the digital loss or gain between the output of the coder and the point considered.

If there is no such loss or gain the relative levels at the exchange input and output points (i.e., digital interfaces V, A and B) are by convention said to be 0 dBr. For further information, see Recommendation G.101, § 5.3.2.4.

*Note* — The digital level may be established using measuring equipment in accordance with Recommendation O.133.

Relative level has no meaning for digital bit streams that are not derived from real or simulated analogue sources.

### 1.2.3 *Measurement conditions*

#### 1.2.3.1 *Common measurement conditions*

All digital signal processing devices which affect bit integrity of the 64 kbit/s path (e.g., digital loss pads, code converters, digital echo control devices, digital speech interpolation apparatus or all-zero suppressors) must be rendered inoperative when measuring the transmission parameters of this Recommendation. However, if the nominal transmission loss, NL, for speech connections is implemented by a digital loss pad, the loss pad must *not* be inoperative for the output connection when measuring parameters dependent on NL.

Where measuring transmission parameters between 2-wire ports is considered necessary, the opposite direction of transmission must be interrupted in order to avoid disturbing effects due to reflections at hybrids.

In addition, 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 should be applied to the exchange test point.

*Note* — These patterns are slightly different from the idle code produced by an exchange (see e.g., Recommendation Q.522, § 2.12).

#### 1.2.3.2 *Reference frequency*

For the reference frequency, Recommendation O.6 applies:

— A reference test frequency of 1020 Hz is recommended for test frequency generating circuits or instruments that provide reference test frequencies. The specified frequency tolerance should be +2 to —7 Hz.

#### 1.2.3.3 *Impedance*

Unless otherwise specified, measurements at analogue interfaces shall be made under nominally matched conditions.

*Note* — The preferred interpretation of this statement should be that the nominal exchange impedance should be used as the internal impedance of the analogue test generator and the analogue level meter. However, under some circumstances it may be preferable to use a low impedance generator and a high impedance meter which corresponds to an exact matching to the actual exchange impedance. (Losses measured according to the two methods will only differ by a small amount, in the same order of magnitude as the loss of a very short subscriber cable.)

#### 1.2.3.4 *Test levels at analogue interfaces*

At the reference frequency, test levels are defined in terms of the apparent power relative to 1 mW.

Where no value is given, the test level should be —10 dBm0.

At frequencies different from the reference frequency, test levels are defined as having the same voltage as the test level at the reference frequency. Measurements are based on the use of a test generator with a frequency-independent EMF.

The above considerations are primarily concerned with measurements at discrete frequencies. Their impact on the measurement at interfaces with complex impedances of broadband signals (e.g., random or quasi-random noise with defined spectral intensity) and *vice versa* needs further study.

### 1.2.4 *Transmission loss*

#### 1.2.4.1 *Nominal transmission loss*

A connection through the exchange (see Figure 1/Q.551) is established by connecting in both directions an input located at one interface to an output located at another interface.

The **nominal transmission loss for a connection through an exchange** is equal to the difference of the relative levels at the input and the output.

$$NL = (L_i - L_o) \text{ dB}$$

The **nominal transmission loss between the input at an analogue interface and the exchange test point** is defined as:

$$NL_i = L_i$$

The **nominal transmission loss between the exchange test point and the output of an analogue interface** is defined as:

$NL_o = —L_o$.bp

This is equal to the nominal ‘‘composite loss’’ (see definition in Blue Book, Fascicle I.3) at the reference frequency. See also Recommendation G.101, § 5.3 and Supplement No. 1 in Fascicle VI.5 of the CCITT Blue Book.

*Note 1* — The nominal transmission loss, NL, may be implemented by an analogue loss pad. It may also be implemented by a digital loss pad. In the latter case, the digital loss pad may be on the incoming side of the digital switching network, or on the outgoing side of the digital switching network or both.

As a general principle, the use of digital loss pads should be avoided because bit integrity is lost for digital services and additional transmission impairments are introduced for analogue services.

However, it is recognized that during the transition stage to a completely digital network, existing national transmission plans may require digital pads to be inserted for speech.

In addition, connections in a future ISDN used for voice can be expected to contain other devices which destroy bit integrity of the 64 kbit/s path (e.g., code converters, digital echo control devices, digital speech interpolation apparatus, or all-zero-suppressors). Provision must be made to render all such devices inoperative when necessary. See Recommendation Q.521, § 4.3.7.

*Note 2* — The nominal transmission loss of the exchange may be different in the two directions.

1.2.5 *Attenuation frequency distortion*

The attenuation frequency distortion (loss distortion) is the logarithmic ratio of output voltage at the reference frequency (nominally 1020 Hz), $U$ (1020 Hz), divided by its value at frequency $f$, $U(f)$:

$$LD = 20 \log \frac{U(1020\ \mathrm{Hz})}{U(f)}$$

See Recommendation G.101, § 5.3 and Supplement No. 1 in Fascicle VI.5 of the CCITT Blue Book.

1.2.6 *Digital parameters*

1.2.6.1 **bit integrity**

The property of a digital half connection of a digital exchange in which the binary values and the sequence of the bits in an octet at the input of the half connection are reproduced exactly at the output.

*Note* — Digital processing devices such as A/μ law converters, echo suppressors and digital pads must be disabled to provide bit integrity.

## 2 Characteristics of interfaces

The interfaces taken into account are those of Figures 1/Q.511 and 1/Q.551. For voice-frequency interfaces (C and Z), the electrical parameters refer to the appropriate distribution frame (DF), on the assumption that the length of the cabling between the DF and the actual exchange does not exceed 100 m (exchange cables). In this respect, Recommendation Q.45 | fIbis § 3 applies. For corresponding limitations on the location of digital interfaces, see Recommendation G.703.

### 2.1 *Two-wire analogue interfaces*

Detailed transmission characteristics of 2-wire analogue interfaces are provided in Recommendation Q.552.

#### 2.1.1 *Interface Z*

The interface Z provides for the connection of analogue subscriber lines and will carry signals such as speech, voice-band analogue data and multi-frequency push button signals, etc. In addition, the interface Z must provide for DC feeding the subscriber set and ordinary functions such as DC signalling, ringing, metering, etc., where appropriate.

Other extraordinary (supplementary) functions, as mentioned in § 1.1 above, are not considered as forming part of the exchange but rather of the line, i.e. included on the exchange side. Since the interface Z ordinarily terminates the subscriber line, it is necessary to control the impedance and unbalance about earth. (While this will also be true of equipment providing supplementary functions, its specification is not dealt with here.)

When the Z interface is used as an extension line interface of a digitally connected digital PABX, additional functions may be required to provide special features of the PABX. If the extension line is entirely contained within a building some attributes of the PABX such as longitudinal conversion loss, may no longer need to be specified and others may take special values.

### 2.1.2 *Interface $C_2$*

The interface $C_2$ provides for the connection of 2-wire analogue circuits to other exchanges.

The interface $C_{2\backslash d1}$ provides the termination of outgoing and incoming international long-distance connections and possibly national connections also with the exchange acting as a transit switch (see Figure 2/Q.551).

The interface $C_{2\backslash d2}$ provides for the connection of a 2-wire trunk line. Typical is the interconnection of a Z interface with a $C_{2\backslash d2}$ interface in a local exchange for routings through the existing 2-wire analogue trunk network. A $C_{2\backslash d2}$ interface cannot be part of the international 4-wire chain.

## 2.2 *Four-wire analogue interfaces*

Detailed transmission characteristics of 4-wire analogue interfaces are provided in Recommendation Q.553.

### 2.2.1 *Interface $C_1$*

The interface $C_1$ provides for the connection of 4-wire analogue circuits to other exchanges.

According to Figure 1/Q.551, the interface $C_{1\backslash d1}$ of a digital exchange is intended for connection to the channel translating equipment of an FDM system.

According to Figure 1/Q.551, the interface $C_{1\backslash d2}$ of a digital exchange is intended for connection to the incoming and outgoing relay set of an analogue 4-wire exchange (see Figure 1/Q.45 | fIbis ).

According to Figure 1/Q.551, the interface $C_{1\backslash d3}$ of a digital exchange is intended for connection to a 4-wire analogue switching stage (see Figure 1/G.142, case 5.)

## 2.3 *Digital interfaces*

Detailed transmission characteristics of digital interfaces are provided in Recommendation Q.554.

### 2.3.1 *Interface A*

The interface A operating at a rate of 1544 kbit/s or 2048 kbit/s provides for the digital connection of circuits to other exchanges.

### 2.3.2 *Interface B*

The interface B operating at a rate of 6312 kbit/s or 8448 kbit/s provides for the digital connection of circuits to other exchanges.

### 2.3.3 *V-type interfaces*

V-type interfaces provide for digital subscriber line access.

V-type interfaces allow the connection to the exchange of a digital subscriber line capable of providing digital subscriber side access for ISDN. The different variants, $V_2$, $V_3$ etc., are described in Recommendation Q.512 § 3. It will be seen that the differences lie essentially in multiplexing and in the associated signalling facilities, the transmission requirements being substantially identical, i.e., providing 64 kbit/s B channels, with bit integrity assumed unless the transmission plan specifically requires otherwise. See also Recommendation Q.554, § 2.5.

*Note* — The designation ''$V_1$'' is applied to a reference point which is connected to a basic access digital section.

## 3 Voice frequency parameters of a connection between two interfaces of the same exchange

### 3.1 *General*

This section of Recommendation Q.551 provides guidance on obtaining the overall characteristics for connections between two interfaces of the same exchange. For overall connections involving one or more digital interfaces, the results may be interpreted by assuming that ideal send and receive sides (see Recommendations G.714 and Q.715) are connected to the digital inputs and outputs, respectively.

In this section, transmission parameters relating to the path from an exchange interface to an exchange test point will be referred to as input parameters. Transmission parameters relating to the path from an exchange test point to an exchange interface will be referred to as output parameters.

### 3.2 *Transmission loss through the exchange*

The transmission loss through the exchange is equal to the algebraic sum of the input transmission loss and the output transmission loss.

The overall characteristic for the following parameters can be obtained the same way.

— short-term variation of loss with time;

— attenuation/frequency distortion;

— variation of gain with input level.

### 3.3 *Group delay*

#### 3.3.1 *Absolute group delay*

‘‘Absolute group delay’’ refers to the minimum group delay measured in the frequency band 500-2800 Hz.

The absolute group delay through an exchange will very much depend on the exchange architecture and the types of connections involved. Table 1/Q.551 gives estimated mean and 0.95 probability of not exceeding values of round trip delay between interfaces exemplified in Figure 3/Q.551. These values may not be applicable to digital PABXs.

The absolute group delay includes delay due to electronic devices such as frame aligners and time stages of the switching matrix but does not include delays due to ancillary functions, such as echo suppression or echo cancellation.

**H.T. [T1.551]**

TABLE 1/Q.551

**Round trip delay between interfaces as depicted in Figure 3/Q.551**

| Figure 0.95 probability of not exceeding μs } | Mean μs | { |
|---|---|---|
| a) | 900 | 1500 |
| b) | 1950 | 2700 |
| c) | 1650 | 2500 |
| d) | 3000 | 3900 |
| e) | 2700 | 3700 |
| f) | 2400 | 3500 |

*Note 1* — These values for the absolute group delays are applicable under reference load A conditions as defined in Recommendation Q.543.

*Note 2* — These values do not include the propagation delay associated with transmission across the link between the main part and any remotely located parts of a digital local exchange.

**Table 1/Q.551 [T1.551], p.**

**Figure 3/Q.551, p.**

3.3.2 *Group delay distortion*

The total group delay distortion is equal to the sum of the input and the output group delay distortions.

3.4 *Noise and total distortion*

When evaluating the exchange noise characteristics, it is necessary to consider two components of noise. One of these arises from the PCM translating process, the other from analogue sources e.g., signalling circuits, exchange power supply, line power feeding on both sides of a connection between two interfaces through the same exchange.

The noise arising from the PCM translating process is limited by Recommendation G.712, the noise from analogue sources by Recommendation G.123. This applies to both weighted noise and total distortion. The requirements for weighted noise and total distortion for connections between the same interfaces and through the same exchange are of value for test purposes.

In real connections through the network, usually several connections between different exchanges with different levels and different interfaces apply. This would result in very complex calculations for the overall noise contribution and cannot be handled in a simple way. Consideration of the contribution of noise and total distortion for each individual half connection as specified in Recommendations Q.552 and Q.553 for the case in question should be preferred.

3.4.1 *Weighted noise*

The total psophometric noise power allowed at a Z interface contributed by a whole connection through the exchange Z-Z is approximated by the formula:

respective the total noise level

where

$P_{T\backslash dN}$ | Total weighted noise power of a whole connection through the local digital exchange Z-Z.

$P_{A\backslash dN}$ | Weighted noise power caused by analogue functions according to Recommendation G.123, Annex A, i.e., 200 pWp.

$L_o$ | Output relative level at the Z interface.

$L_i$ | Input relative level at the Z interface of the same exchange.

$L_{I\backslash dN}$ | Weighted noise (idle channel noise) for PCM translating equipment according to Recommendation G.712, i.e., —65 dBm0p

$L_{T\backslash dN}$ | Total weighted noise level of a whole connection through the local digital exchange Z-Z.

Alternatively the same $P_{T\backslash dN}$ and $L_{T\backslash dN}$ can be obtained by adding the relevant values for input and output connections at Z interfaces according to Recommendation Q.552, § 3.3.2.1, observing that the values for $L_{I\backslash dN\backslash di}$ and $L_{I\backslash dN\backslash do}$ are different from $L_{I\backslash dN}$.

However, a small difference in the numerical results occurs due to approximation errors between $L_{I\backslash dN}$ on the one hand compared with $L_{I\backslash dN\backslash di}$ and $L_{I\backslash dN\backslash do}$ on the other.

For the $C_2$ interfaces, similar considerations can be made to obtain the allowed psophometric noise power.

Either calculating the idle channel noise according to Recommendation G.712 (to be maximum —65 dBm0p) together with the analogue noise according to Recommendation G.123 (to be maximum —67 dBm0p) which results in approximately —63 dBm0p. Alternatively, the allowed values for the input and output connections according to Recommendation Q.553, § 3.2.2.1 for equipment with signalling on the speech wires can be combined, giving again approximately —63 dBm0p.

### 3.4.2 *Total distortion including quantizing distortion*

The method shown below uses the sinusoidal test signal with the reference frequency of 1020 Hz as specified in Recommendation O.132. The ratio of signal-to-total-distortion power for a whole connection through the exchange is given by the formula:

where

$S/N_T$ | resulting signal-to-total distortion ratio for a whole connection through a digital exchange.

$L_S$ | signal level of the measuring signal in dBm0.

$L_o$ | output relative level of the local exchange in dBr.

$S/N$ | signal-to-total distortion ratio for PCM translating equipment in Recommendation G.712 (whole connection).

$L_N$ | Weighted noise caused by analogue functions according to Recommendation G.123, Annex A, i.e., —67 dBmp.

*Note* — No band limiting effect on the noise by the encoding process was taken into account to compensate for overall effects. Thus the calculation above is assumed to give the worst case requirements.

This calculation of $S/N_T$ applies to both Z and $C_2$ interfaces.

Total distortion including quantizing distortion using the noise method as specified in Recommendation O.131 will be the subject of further study.

### 3.5 *Crosstalk*

Where measurement of the signal to crosstalk ratio between any two complete connections (analogue to analogue) through the exchange is considered necessary, a sine wave test signal at the reference frequency of 1020 Hz and at a level of 0 dBm0 is applied to the analogue 2-wire or 4-wire interface of one connection. An auxiliary low level activation signal, for example a band limited noise signal (see Recommendation O.131) at a level in the range —50 to —60 dBm0 is injected into the input of the connection to be measured. The level produced in any other connection should not exceed —65 dBm0 (value to be further studied).

Care must be taken on the choice of frequency and the filtering characteristics of the selective measuring equipment, in order to avoid that the activating signal and noise affects the accuracy of the crosstalk measurement. This measurement arrangement is shown in Figure 4/Q.551.

*Note 1* — The go to return crosstalk of 4-wire connections is covered by Recommendation Q.553 §§ 3.1.4.1.2 and 3.1.4.2.2.

*Note 2* — Measurement of NEXT is not required, as it is the same as in a half-connection.

*Note 3* — If it is not possible without considerable difficulty to break the return path of the 4-wire loop, reflection should be minimized by making the terminating impedance and the balance impedance equal.

*Note 4* — Further study is required to determine whether MORE STRINGENT LIMITS or measurements at additional frequencies should be specified.

### 3.6 *Discrimination against out-of-band signals applied to the input interface*

The values for these parameters for a complete connection through an exchange are identical to the corresponding values for a half connection. See Recommendation Q.552, § 3.1.6 and Recommendation Q.553, § 3.1.6.

**Figure 4/Q.551, p.**

3.7 *Spurious out-of-band signals received at the output interface*

The values for these parameters for a complete connection through an exchange are identical to the corresponding values for a half connection. See Recommendation Q.552, § 3.1.7 and Recommendation Q.553, § 3.1.7.

3.8 *Echo and stability*

When a complete connection, comprised of a 2-wire analogue half connection and a 4-wire half connection, terminates the international chain, the total stability loss of the national extension is provided by the 2-wire analogue half connection. See Recommendation Q.552, § 3.1.8.

If in a digital exchange (including PABXs), 2-wire half connections (Z or $C_2$ interfaces) cooperate in such a way that an additional 2-wire—4-wire—2-wire is included as part of an international connection, then Recommendation G.122 concerning echo, stability and especially effects of listener echo has to be fulfilled.

The effects of listener echo depend on the maximum total number of loops in a complete connection. Listener echo signals:

— can lead to objectionable ‘‘hollowness’’ in voice communications, and

— can impair the bit error ratio of received voice-band data signals.

## 4 Exchange transfer function - jitter and wander

The exchange transfer function relates wander at the output of the exchange to wander at the inputs used for synchronization purposes. It is recognized that the approach of using the exchange transfer function to specify the performance of an exchange is not applicable to all implementations (e.g., when mutual synchronization methods are used). The exchange transfer mask is similar to that of a low pass filter with a maximum gain of 0.2 dB, a break point at 0.1 Hz and slope of 6 dB/octave as shown in Figure 5/Q.551.

The higher frequency (jitter) portion of the mask is undefined, but must provide significant attenuation above 100 Hz.

**Figure 5/Q.551, p.**

# Recommendation Q.552

## TRANSMISSION CHARACTERISTICS AT 2-WIRE ANALOGUE INTERFACES

## OF DIGITAL EXCHANGE

## 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 $C_{2\backslash d1}$ and $C_{2\backslash d2}$ interface specifications. The interface $C_{2\backslash d1}$ provides the termination of outgoing and incoming international long distance connections and possible national connections, with the exchange acting as transit switch. The interface $C_{2\backslash d2}$ provides for the

connection of a 2-wire trunk line. A typical example is the interconnection of a Z interface with a $C_{2\backslash d2}$ interface in a local exchange for routing through the 2-wire analogue trunk network. A $C_{2\backslash d2}$ 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 $C_2$ interface against the test network for the exchange impedance should comply with the limits given in Figure 1/Q.552.

**Figure 1/Q.552, p.**

### 2.1.2 *Impedance unbalance about earth*

The longitudinal conversion loss (LCL), defined in Recommendation G.117, § 4.1.3, should exceed the minimum values of Figure 2/Q.552 with the equipment under test in the normal talking state, in accordance with Recommendation K.10.

*Note 1* — An Administration 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 Recommendation G.117, § 4.1.2, 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, p.**

*Test method*

Longitudinal conversion loss should be measured in accordance with the principles given in Recommendation O.121, §§ 2.1 and 3. Figure 3/Q.552 shows an example of the basic measuring arrangement for digital exchanges.

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

**Figure 3/Q.552, p.**

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* $C_{2\d1}$

$C_{2\d1}$ 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* $C_{2\d2}$

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 $C_{2\d2}$ 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 of Recommendation G.121 (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 Recommendation G.715, § 2.1.

### 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 Recommendation Q.551, § 2.1.1

#### 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 voice band 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/Q.552.

**H.T. [T1.552]**

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 | 1000 | 220 n |
| New Zealand | 370 | 620 | |
| 310 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.

*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, 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.

*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.

**Table 1/Q.552 [T1.552], p.**

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 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/Q.552.

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/Q.552 for guidance.

**H.T. [T2.552]**
TABLE 2/Q.552
**Examples of limit values of return loss against the exchange impedance**

| | |
|---|---|
| FRG<br>14 dB at 300 Hz, rising (log *f*<br>scale) to 18 dB at 500 Hz remaining<br>at 18 dB to 2000 Hz and then falling (log *f*<br>scale) to 14 dB at<br>3400 Hz.<br>} | { |
| NTT | 22 dB: 300-3400 Hz. |
| BT<br>18 dB: 200-800 Hz; 20 dB: 800-2000 Hz; 24 dB: 2000-4000 Hz.<br>} | { |
| USA<br>20 dB: 200-500 Hz; 26 dB: 500-3400 Hz.<br>} | { |
| Austria<br>14.5 dB at 300 Hz, rising (log *f*<br>scale) to 18 dB at<br>500 Hz remaining at 18 dB to 2500 Hz and then falling (log *f*<br>scale) to<br>14.5 dB at 3400 Hz.<br>} | { |

*Note* — The 12 dB spread in values stems from the difference in telephone set sensitivities.

**Table 2/Q.552 [T2.552], p.**

2.2.2 *Impedance unbalance about earth*

The longitudinal conversion loss (LCL) of the Z interface should meet the values given in § 2.1.2 and Figure 2/Q.552, measured in accordance with the test method given in Figure 3/Q.552.

2.2.3 *Longitudinal interference threshold levels*

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/Q.552.

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:

$L_{E\backslash dN} = Y_1$ pWp using sinusoidal longitudinal test signal with $X_1$ volts rms;

$L_{E\backslash dN} = Y_2$ 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 of this Recommendation.

*Note 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.)

*Note 2* — The value of the induced noise power $L_{E\backslash dN}$ needs further study. (Attention is drawn to § 3.1.6.2 of this Recommendation and to § 1 of Recommendation G.123.)

*Test method*

**Figure 4/Q.552, p.**

The exact definition of the harmonic content and the coupling network is for further study.
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 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 RPOA reported an impedance of —j 1.17 kohm at 60 Hz for each capacitor indicated in Figure 4/Q.552.)

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

*Note 1* — Annex A gives an example of a CN applicable to the measuring arrangement of Figure 4/Q.552, the application of which needs further study.

*Note 2* — The measuring arrangement in Figure 4/Q.552 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.

2.2.4 *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 Recommendation G.113, 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 Recommendation G.121, § 6.4 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 ± | 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 $L_i$ — $L_o$ ≥" 6 dB and if adequate balance networks are used (e.g., § 3.1.8 and Figure 11/Q.552), the requirements of Recommendation G.121, § 6 (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 to Recommendation 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 1* — Recommendation G.101, § 5.3.2.3 indicates that if the minimum nominal send loudness rating (SLR) of the local system under the same conditions is not less than —1.5 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 ≥" —1.5 dB.

*Note 2* — The values given above are in conformity with current national practices and with the existing text of Recommendation G.101. However, the latter is itself partly based on a very old investigation (which Study Group XII has been asked to review) of the relationship between loudness ratings and speech levels. This may, in the near future, lead to amending the basis of objectives, so that it may be useful to allow wider design margins.

2.2.4.1.2 *Output relative level*

According to Annex C to Recommendation 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.

If the connection type can always be detected, the nominal output relative levels for local or national connections can take other values in accordance with national transmission planning. According to Annex C to Recommendation 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 Recommendation G.715, § 2.1.

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).

If values of $L'_i$ | and $L'_o$ | are chosen as indicated, the loss difference with respect to the conditions given in § 2.2.4.1 will be left unchanged.

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 $C_{2\backslash d1}$ 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 Recommendation Q.551, § 2.1.1.

*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 Recommendation Q.551, § 1.2.3.1.)

### 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 Recommendation Q.551, § 1.2.4.1 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 ± | .2 dB during any 10-minute interval of typical operation under the steady state condition 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 5/Q.552.

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, p.**

3.1.1.5 *Loss distortion with frequency*

The loss distortion with frequency of any input or output connection according to Recommendation Q.551, § 1.2.5 should lie within the limits shown in the mask of Figure 6/Q.552 | ) or 6/Q.552 | ) 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.

**Figure 6/Q.552, p.**

3.1.2 *Group delay*

‘‘Group delay’’ is defined in the Yellow Book, Fascicle X.1.

3.1.2.1 *Absolute group delay*

See Recommendation Q.551, § 3.3.1.

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 2500 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/Q.552. Group delay distortion is measured in accordance with Recommendation O.81.

**Figure 7/Q.552, p.**

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

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.

*Note* — See Recommendation Q.551, § 1.2.3.1.

3.1.4 *Crosstalk*

For crosstalk measurements, auxiliary signals are injected as indicated in Figures 8/Q.552 and 9/Q.552. These signals are:

— the quiet code (see Recommendation Q.551, § 1.2.3.1);

— a low level activating signal. Suitable activating signals are, for example, a band limited noise signal (see Recommendation O.131), at a level in the range —50 to —60 dBm0 or a sine-wave signal 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 *Input crosstalk*

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/Q.552).

**Figure 8/Q.552, p.**

3.1.4.2 *Output crosstalk*

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/Q.552).

**Figure 9/Q.552, p.**

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/Q.552 and 14/Q.552 for interface $C_2$ and § 3.3.3, Figure 15/Q.552 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. 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:

where

$Z_o$ exchange impedance of a 2-wire equipment port

$Z_b$ impedance of the balance network presented at a 2-wire equipment port

$Z_t$ impedance of the balance test network

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

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 $a_{i\backslash do}$ | 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 port and between the 2-wire equipment port and the exchange test point $T_o$, respectively.

TBRL can thus be determined by measurement of $a_{i\backslash do}$ | 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:

$$\text{TBRL} = = a_{i\backslash do} — (NL_o + NL_i)$$

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

$$\text{TBRL} = a_{i\backslash do} — (AL_o + AL_i)$$

c) the loss $a_{i\backslash do}$ | is measured with the 2-wire equipment port open- and short-circuited, giving losses $a'_{i\backslash do}$y and $a''_{i\backslash do}$ respectively.

TBRL = $a_{i\backslash do}$ — [Unable to Convert Formula]

Method b) provides the most accurate results.

**Figure 10/Q.552, p.**

Using the arrangement of Figure 10/Q.552 and sinusoidal test signals, the measured TBRL should exceed the limits shown in Figure 11/Q.552.

**Figure 11/Q.552, p.**

Figure 12/Q.552 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.

**Figure 12/Q.552, p.**

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 (Figure 10/Q.552) 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 $_o$ measured as $a_{i\backslash do}$ should be:

Stability Loss = $a_{i\backslash do}$ ≥" 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.

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. A 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 (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:

$C_{2\d1}$ 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

$C_{2\d2}$ interfaces

$NL_i$ = 3.0 to —7.0 dB for all types of connections $NL_o$ = 8.0 to —1.0 dB

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 arises from the quiet decoder, the other from analogue sources, such as signalling equipment. The first component is limited by Recommendation G.714, § 10 as receiving equipment noise to —75 dBm0p; the other component by Recommendation G.123, § 3 to —(67+3) dBm0p = —70 dBm0p for one 2-wire analogue interface. This results in the maximum value for the overall weighted noise in the talking state at the $C_2$ interface of a digital exchange of:

—68.8 dBm0p for equipment with signalling on the speech wires,

—75.0 dBm0p for equipment with signalling on separate wires.

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, e.g. signalling equipment. The first component is limited by Recommendation G.714, § 9 as idle channel noise to —66 dBm0p; the other component by Recommendation G.123, § 3 to —(67+3) dBm0p = —70 dBm0p for one 2-wire analogue interface. This results in the maximum value for the overall weighted noise in the talking state at the exchange test point $T_o$ of a digital exchange of:

—64.5 dBm0p for equipment with signalling on the speech wires,

—66.0 dBm0p for equipment with signalling on separate wires.

3.2.2.2 *Unweighted noise*

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

*Note* — The need for and value of this parameter are both under study. Recommendations Q.45 **|** fIbis , § 2.5.2 and G.123, § 3 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 are under study. Pending the results of this study, Recommendation Q.45 | fIbis , § 2.5.3 may give some guidance on the subject of controlling impulsive noise with low frequency content.

*Note 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.

*Note 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. This latter case, involving impulsive noise with high frequency content, is not presently covered by the measurement procedure of Recommendation Q.45 | fIbis .

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/Q.552 for equipment with signalling on separate wires, and in Figure 14/Q.552 for equipment with signalling on the speech wires both measured in the talking state.

**Figure 13/Q.552, p.**

**Figure 14/Q.552, p.**

The values of Figure 14/Q.552 include the limits for the encoding process given in Figure 4/G.714 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 Recommendation G.123, § 3.

### 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, e.g. noise arising from the decoding process, is dependent upon the output relative level. The other, e.g. power supply noise from the feeding bridge, is independent of the output relative level. The first component is limited by Recommendation G.714, § 10 as receiving equipment noise to —75 dBm0p; the other component is assumed by Recommendation G.123, Annex A to be 200 pWp (—67 dBmp). This can be caused by the main DC power supply and auxiliary DC-DC converters.

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).

The total psophometric power allowed at a Z interface with a relative output level of $L_o$ dB may be approximated by the formula:

The total noise level is given by:

where

$P_{T\backslash dN\backslash do}$ | total weighted noise power for the output connection of the local digital exchange;

$P_{A\backslash dN}$ | weighted noise power caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. 200 pWp;

$L_{I\backslash dN\backslash do}$ | receiving equipment noise (weighted) for PCM translating equipment according to Recommendation G.714, § 10, i.e., —75 dBm0p;

$L_o$ | output relative level of a half-channel of a local digital exchange according to § 2.2.4.1.2, e.g., 0 to —8.0 dBr;

$L_{T\backslash dN\backslash do}$ | total weighted noise level for the output connection of the local digital exchange.

For the range of output relative levels according to § 2.2.4.1.2 the resulting total psophometric powers and the total noise levels for the output connection are:

**H.T. [T3.552]**

| | | | | | | |
|---|---|---|---|---|---|---|
| *L* | *= 0* | *—5.0* | *—6.0* | *—7.0* | *—8.0* | *dBr* |
| *P* | *= \| 31* | *\| 10* | *\| 08* | *\| 06* | *\| 05* | *pWp* |
| *L* | *= —66.4* | *—66.8* | *—66.8* | *—66.9* | *—66.9* | *dBmp* |

**Table [T3.552], p.**

3.3.2.1.2 *Input connection*

Two components of noise must be considered. One of these, e.g. noise arising from the encoding process, is dependent upon the output relative level. The other, e.g. power supply noise from the feeding bridge, must be corrected by the input relative level for calculation at the exchange test point $T_o$. The first component is limited by Recommendation G.714, § 9 as idle channel noise to —66 dBm0p; the other component is assumed by Recommendation G.123, Annex A to be 200 pWp (—67 dBmp) 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 a relative input level of $L_i$ dB may be approximated by the formula:

and the total noise level by

where

$P_{T\backslash dN\backslash di}$ | total weighted noise power for the input connection of the local digital exchange;

$P_{A\backslash dN}$ | weighted noise power caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. 200 pWp;

$L_{I\backslash dN\backslash di}$ | idle channel noise (weighted) for the input connection of a digital local exchange according to Recommendation G.714, § 9 i.e., —66 dBm0p;

$L_i$ | input relative level of a half-channel of a local digital exchange according to § 2.2.4.1.1, e.g. 0 and +1 dBr;

$L_{T\backslash dN\backslash di}$ | total weighted noise level for the input connection of the local exchange.

For the relative levels according to § 2.2.4.1.1, the resulting psophometric power and the total noise levels for the input connection are:

**H.T. [T4.552]**

| | | | | |
|---|---|---|---|---|
| *L* | = 0 | +1.0 | +2.0 | *dBr* |
| *P* | = \| 51 | \| 10 | \| 77 | *pW0p* |
| *L* | = —63.5 | —63.9 | —64.2 | *dBm0p* |

**Table [T4.552], p.**

*Note* — The calculation above is intended to account for the worst case. No band limiting effect of the encoder on the noise was taken into account.

3.3.2.2 *Unweighted noise*

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

*Note* — The need for and value of this parameter are both under study. Recommendation G.123, § 3 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 are under study.

*Note 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.

*Note 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. This latter case, involving impulsive noise with high frequency content, is not presently covered by the measurement procedure of Recommendation Q.45 | fIbis .

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.

The signal-to-total distortion ratio required for a half connection may be approximated by the formula:

where

*fIN* $\frac{\text{f IS}}{\text{f IT}}$ resulting signal-to-total distortion ratio for input or output connections in digital local –v'6p' exchanges;

$L_s$ | signal level of the measuring signal in dBm0;

$L_r$ | for input connections, input relative level $L_i$ in dBr for output connections, output relative level $L_o$ in dBr;

*S* /*N* | signal-to-total distortion ratio for PCM translating equipment in Recommendation G.714;

$L_N$ | weighted noise caused by analogue functions according to Recommendation G.123, Annex A for local exchanges, i.e. —67 dBmp at the Z interface.

One resulting template for the signal-to-total distortion ratio of input and output connections in a local exchange is shown in Figure 15/Q.552 | ) and b) as an example.

The values of Figure 15/Q.552 include the limits for the coding process given in Figure 5/G.714 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 Recommendation G.123, Annex A. As an example, the mean relative levels according to § 2.2.4.1 are assumed to be $L_i$ = 0 dBr and $L_o$ = —7 dBr.

*Note* — For an input connection the calculation above is assumed to be the worst case. No band limiting effect of the encoder on the noise was taken into account.

**Figure 15)/Q.552, p.**

ANNEX A
(to Recommendation Q.552)

**Example of a
longitudinal interference coupling network**

The component should be chosen with small absolute tolerances (at least resistors and capacitors with 1% and the inductance with less than 5%) and matched to 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 symetrically applied to each port should be used.

**Figure A-1/Q.552, p.**

**H.T. [T5.552]**
TABLE A-1/Q.552
**Components list**

| Quantity | Type | | |
|---|---|---|---|
| Metallized resistors | | | |
| 1 | 10 | R1 \| \| \| \| 10: \| 00 | ohm 1%, 1.1 W |
| 2 | 4 | R11 \| \| \| \| 14: 49.9 | ohm 1%, 1.1 W |
| 3 | 12 | R15 \| \| \| \| 26: \| 33 | ohm 1%, 0.35 W |
| 4 | 12 | R27 \| \| \| \| 38: 32.4 | ohm 1%, 0.35 W |
| 5 | 2 | R39 \| \| \| \| 40: 24.9 | ohm 1%, 0.35 W |
| 6 | 4 | R41 \| \| \| \| 44: \| 00 | kohm 1%, 0.35 W |
| Styroflex foil capacitors | | | |
| 1 | 4 | C1 \| \| \| \| 4: \| 15 | nF 1%, 160 V |
| 2 | 8 | C5 \| \| \| \| 12: 7.5 | nF 1%, 160 V |
| 3 | 4 | C13 \| \| \| \| 16: \| 8 | nF 1%, 160 V |
| 4 | 2 | C17 \| \| \| \| 18: 24.3 | nF 1%, 160 V |
| 5 | 2 | C19 \| \| \| \| 20: \| 0 | nF 1%, 160 V |
| 6 | 2 | C21 \| \| \| \| 22: \| 99 | pF 1%, 160 V |
| 7 | 12 | C23 \| \| \| \| 34: 60.4 | nF 1%, 63 V |
| HF-chokes, ferrite rod | | | |
| 1 L1 \| \| \| \| 2: 47 μH 5%, R o 1.1 ohm } | 2 | { | |

**Tableau A-1/Q.552 [T5.552], p.37**

**MONTAGE: RECOMMANDATION Q.553 SUR LE RESTE DE CETTE PAGE**