INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

G.712

(09/92)

GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS;

TERMINAL EQUIPMENTS

TRANSMISSION PERFORMANCE CHARACTERISTICS OF PULSE CODE MODULATION

Recommendation G.712

FOREWORD

The CCITT (the International Telegraph and Telephone Consultative Committee) is a permanent organ of the International Telecommunication Union (ITU). CCITT 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 Plenary Assembly of CCITT which meets every four years, establishes the topics for study and approves Recommendations prepared by its Study Groups. The approval of Recommendations by the members of CCITT between Plenary Assemblies is covered by the procedure laid down in CCITT Resolution No. 2 (Melbourne, 1988).

Recommendation G.712 was revised by Study Group XV and was approved under the Resolution No. 2 procedure on the 1st of September 1992.

CCITT NOTES

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

2) A list of abbreviations used in this Recommendation can be found in Annex C.

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Recommendation G.712[1)]

TRANSMISSION PERFORMANCE CHARACTERISTICS OF PULSE CODE MODULATION CHANNELS

(revised 1992)

0 Scope

This Recommendation deals with the transmission performance characteristics of PCM channels transmitted via digital transmission equipment. Requirements to be met between 4-wire and 2-wire analogue ports are given as well as requirements for analogue to digital and digital to analogue connections.

1 General

Performance characteristics which follow should be met between voice-frequency ports or between the voice-frequency and digital ports of PCM channels coded in accordance with Recommendation G.711.

Equipment which meets the analogue-to-analogue requirements, but not the analogue-to-digital requirements, may only be used as permanently connected pairs of equipment.

The parameters and values specified in this Recommendation apply to the use of PCM equipment connected to analogue trunks or to analogue and digital exchanges. When PCM equipment is connected directly to analogue subscriber lines, different values for some of the parameters may be required. Recommendation Q.552 contains those values. The requirements in this Recommendation may also be applied if the PCM equipment is directly connected to an analogue local exchange that is virtually transparent with regard to the impedances connected to its ports and the subscriber lines are short (e.g. less than 500 metres).

In deriving the limits, an allowance has been included for the effect of possible signalling functions and/or line current feeding on the transmission performance. The limits should be met when any signalling function is in the normal speaking condition, but excluding any dynamic signalling conditions, e.g. metering.

The limits do not, in general, have any allowance for the effects of line current noise. The permissible amount of line current noise and the need for allowances are under study.

1.1 *Measurement considerations*

When a nominal reference frequency of 1020 Hz is indicated (e.g. measurement of attenuation/frequency distortion and adjustment of relative levels), the actual frequency should be 1020 Hz, +2 Hz, –7 Hz in accordance with Recommendation O.6. For an interim period Administrations may, for practical reasons, need to use a reference frequency of nominally 800 Hz. To avoid level errors produced as a result of the use of test frequencies which are sub-multiples of the PCM sampling rate, the use of integer sub-multiples of 8 kHz should be avoided.

In the following sections, the concepts of a "standard digital generator" and "a standard digital analyser" should be assumed and these are defined as follows:

A **standard digital generator** is a hypothetical device which is absolutely ideal, i.e. a perfect analogue-to-digital converter preceded by an ideal low pass filter (assumed to have no attenuation/frequency distortion and no group delay distortion), and which may be simulated by a digital processor.

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1) This Recommendation replaces Recommendations G.712, G.713, G.714 and G.715 of the CCITT *Blue Book* Volume III, Fascicle III.4.

A **standard digital analyser** is a hypothetical device which is absolutely ideal, i.e. a perfect digital-to-analogue converter followed by an ideal low pass filter (assumed to have no attenuation/frequency distortion and no group delay distortion), and which may be simulated by a digital processor.

Recommendation O.133 contains information about test equipment based on these concepts. Account should be taken of the measurement accuracy provided by test equipment designed in accordance with that Recommendation.

A PCM quiet signal is defined to be an idle character signal corresponding to decoder output value number 0 for μ-law or decoder output value number 1 for A-law with the sign bit in a fixed state.

The following specifications are based on ideal measuring equipment. Therefore, they do not include any margin for measurement errors.

1.2 *Port definitions*

The term port in this Recommendation is defined as a functional unit (e. g. a connector) of the PCM equipment through which signals can enter or leave the unit under test. The measurements are made at the equipment, and the requirements do not include an allowance for wiring to a distribution frame.

Figure 1/G.712 shows two PCM equipments connected via a digital cross-connect (DXC) system. Each PCM equipment is shown to have a 4-wire analogue voice-frequency port, E4, and a 2-wire analogue voice-frequency port, E2. Each of the PCM equipment is connected to the DXC by digital ports A or B, which consists of transparent 64 kbit/s PCM channels within a higher order digital signal conforming to applicable Recommendations. The DXC implements transparent 64 kbit/s cross connections between its own A or B ports, or to the digital test point, T. The T point consists of a 64 kbit/s channel within a digital signal suitable for connection to the standard digital generator and analyser. Since the connections provided by the DXC are 64 kbit/s transparent, the paths within the DXC are assumed not to affect the recommended transmission performance characteristics except for absolute delay. The test points T are defined for specification purposes. They may not physically exist in a DXC but may be accessed via the DXC network.

Unless stated otherwise, measurements between two-wire ports ($E2_{1in}$ to $E2_{2out}$ connections) should be made with the 4-wire loop opened in such a way that the impedances presented to the 4-wire port of the 2-wire/4-wire terminating unit are representative of those that will occur in normal operation. This condition may be achieved by interrupting the digital signal in the opposite direction to the direction of measurement and injecting a PCM quiet signal into the appropriate channel. It should be noted that the opening of the 4-wire loop is considered necessary to determine the intrinsic performance of the equipment. In normal operation, where the loop is not opened, account needs to be taken of the impact on overall performance of the terminating impedances connected to the 2-wire ports.

Figure 1/G.712 is similar to Figure 1/Q.551, which identifies ports, transmission levels and test points at a digital exchange.

Recommendations in the CCITT *Blue Book*, Volume III, Fascicle III.4 specified performance characteristics between ports as shown in Table 1/G.712[2)].

2 Relative levels at voice-frequency ports

2.1 *Relative levels at 4-wire ports (E4)*

When attenuation pads are set to zero loss, L_o at $E4_{2out}$ and L_i at $E4_{1in}$ must have one of the following two series of nominal values: Maximum L_o = +4 dBr and minimum L_i = –14 dBr; or maximum L_o = + 7 dBr and minimum L_i = –16 dBr. See Recommendation G.232, § 11.

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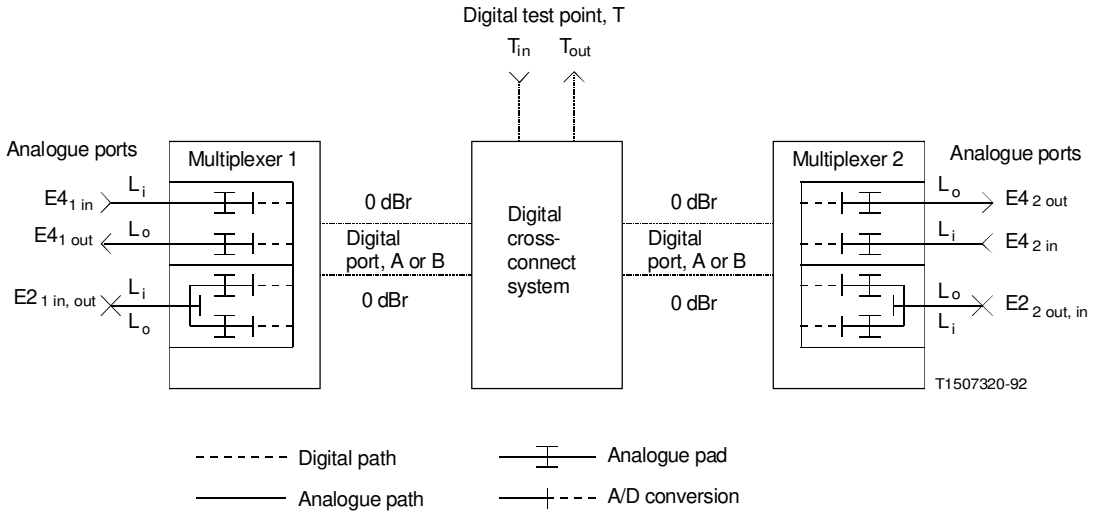
2) References to specific sections of other Recommendations are valid for their *Blue Book* editions.



Note – Numbers 1 or 2 in the subscript indicate multiplexers 1 or 2.

FIGURE 1/G.712

PCM equipment and test ports

TABLE 1/G.712

Equivalence between previous Recommendations and connections specified in this Recommendation

Channel	Recommendation
4-wire analogue to 4-wire analogue ($E4_1$ to $E4_2$ channels)	G.712
2-wire analogue to 2-wire analogue ($E2_1$ to $E2_2$ channels)	G.713
4-wire analogue to digital (E4 to A or B for a primary multiplexer)	G.714
2-wire analogue to digital (E2 to A or B for a primary multiplexer)	G.715

2.2 *Relative levels at 2-wire ports (E2)*

Due to differences in network transmission plans and equipment utilization, Administrations have differing requirements for the range of relative levels to be provided. The following ranges would encompass the requirements of a large number of Administrations:

– input level (L_i encoding side) 0 to –5 dBr in 0.5 dB steps;

– output level (L_o decoding side) –2 to –7.5 dBr in 0.5 dB steps.

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

Note – The requirements in this section are different from the requirements in Recommendation Q.552, § 2.1.4.

3 Adjustment of actual relative levels

3.1 *Adjustment of the decoding side (T_{in} to E_{out})*

The gain of the decoding side should be adjusted by connecting T_{in} to a standard digital generator and applying a 1020 Hz sinusoidal test signal at a level of 0 dBm0. The adjustment should result in an output level of 0 dBm0 ± 0.3 dB for 4-wire ports (T_{in} to $E4_{out}$) or an output level of 0 dBm0 ± 0.4 dB for 2-wire ports (T_{in} to $E2_{out}$) and should be made under typical conditions of power supply voltage, humidity and temperature.

3.2 *Adjustment of the encoding side (E_{in} to T_{out})*

The gain of the encoding side should be adjusted by connecting T_{out} to a standard digital analyser and applying a 1020 Hz test signal at a level of 0 dBm0 to E_{in}. The adjustment should result in an output level of 0 dBm0 ± 0.3 dB for 4-wire ports ($E4_{in}$ to T_{out}) or an output level of 0 dBm0 ± 0.4 dB for 2-wire ports ($E2_{in}$ to T_{out}) and should be made under typical conditions of power supply voltage, humidity and temperature.

3.3 *Load capacity (overload point)*

The load capacity of the encoding side may be checked by applying a 1020 Hz sinusoidal test signal at E_{in}. The level of this signal should be initially well below T_{max}, and should then be slowly increased. The input level should be measured at which the first occurrence is observed of the character signal corresponding to the extreme quantizing interval for both positive and negative values. T_{max} is taken as being 0.3 dB greater than the measured input level.

This method allows T_{max} to be checked for both positive and negative amplitudes, and the values thus obtained should be within 0.4 dB of the theoretical load capacity (i.e. +3.14 dBm0 for the A-law or +3.17 dBm0 for the μ-law).

4 Short- and long-term variation of loss with time

When a 1020 Hz sinusoidal test signal at a level of –10 dBm0 (preferred value: however, a level of 0 dBm0 may be used) is applied to any voice-frequency input, the level measured at the corresponding output should not vary by more than the limits shown in Table 2/G.712 during any 10-minute interval of typical operation, nor by more than the limits shown during any one year under the permitted variations in the power supply voltage and temperature.

TABLE 2/G.712

Requirements for short- and long-term variation of level with time

Measurement configurations	Maximum permitted variation		
	10-minute interval	One-year interval	
4-wire to 4-wire ($E4_{1in}$ to $E4_{2out}$)	±0.2 dB	±0.5 dB	
2-wire to 2-wire ($E2_{1in}$ to $E2_{2out}$)	±0.2	±0.6	
4-wire to digital ($E4_{in}$ to T_{out})	±0.1	±0.3	
Digital to 4-wire (T_{in} to $E4_{out}$)	±0.1	±0.3	(Note)
2-wire to digital ($E2_{in}$ to T_{out})	±0.1	±0.3	
Digital to 2-wire (T_{in} to $E2_{out}$)	±0.1	±0.3	(Note)

Note – The 0 dBm0 sequence of Recommendation G.711, Tables 5/G.711 and 6/G.711 may be used.

5 Nominal impedance and return loss of voice frequency ports

5.1 *Nominal impedance*

The nominal impedance at the 4-wire voice frequency input and output ports, $E4_{in}$ and $E4_{out}$, should be 600 Ω, balanced.

For 2-wire voice frequency ports, E2, no single value of impedance is recommended. The following values can be found in practice:

- 600 Ω resistive, balanced
- 900 Ω resistive, balanced
- 600 Ω + 2.16 μF, balanced
- 900 Ω + 2.16 μF, balanced.

Note 1 – Some examples of complex impedances used in connection with subscriber lines can be found in Recommendation Q.552, § 2.2.1.

Note 2 – Measurements at ports with complex impedances shall follow the definitions and conventions given in Recommendation G.100, Annex A.

5.2 *Return loss*

The return loss, measured against the nominal impedance, should meet the return loss requirements shown in Table 3/G.712 over the frequency range 300 Hz to 3400 Hz.

TABLE 3/G.712

Return loss requirements for E4 and E2 ports

Analogue port	Frequency range		Notes
	From 300 Hz to 600 Hz	From 600 Hz to 3400 Hz	
4-wire, E4	> 20 dB return loss	> 20 dB return loss	1
2-wire, E2	> 12 dB return loss	> 15 dB return loss	2

Note 1 – The return loss limit should be met when the adjusting pads are set to 0 dB (see Recommendation G.232, Figure 5/G.232).

Note 2 – Reflections due to impedance mismatches at 2-wire/4-wire ports may cause severe sidetone and echo problems in the network. Administrations need to adopt a suitable impedance strategy, including tolerances, to ensure an adequate transmission quality. (For further information, see Recommendation G.121, § 5.)

6 Impedance unbalance about earth

The longitudinal conversion loss parameters referred to below are defined in Recommendation O.9, which also gives some information about the requirements of test circuits (see Note 1 of Table 4/G.712). The value of Z in the driving test circuit should be within ± 20% of the values shown in Tables 4/G.712 and 5/G.712. The termination at the other port shall be the nominal characteristic impedance.

6.1 *Longitudinal conversion loss*

The longitudinal conversion loss (see Recommendation O.9, § 2.1) should not be less than the limits in Table 4/G.712.

TABLE 4/G.712

Longitudinal conversion loss requirements for E4 and E2 ports

Measured port	*Z* (Ω)	Longitudinal conversion loss requirement			Notes
		300 Hz to 600 Hz	600 Hz to 2400 Hz	2400 Hz to 3400 Hz	
4-wire, $E4_{in}$	600	> 46 dB	> 46 dB	> 41 dB	1, 2, 5
4-wire, $E4_{out}$	600	> 46	> 46	> 41	1, 2, 5
2-wire, E2	600	> 40	> 46	> 41	1, 2, 3, 4
2-wire, E2	750	> 40	> 46	> 41	1, 2, 3, 4

Note 1 – Attention is drawn to Recommendation O.9, § 3, which shows the equivalence between a number of different test driving circuits and also includes information concerning the inherent balance requirements of the test bridge.

Note 2 – Attention is drawn to the fact that these values represent minimum requirements. The magnitude of potential longitudinal signal voltages depends, for example, on system use, the system environment, the location of hybrid transformers and attenuators, and may therefore vary for different Administrations. Some Administrations have found it necessary to specify higher values for longitudinal conversion loss and longitudinal conversion transfer loss to ensure that transverse voltages caused by possible longitudinal signal voltages are sufficiently small.

Note 3 – The possible need to introduce limits for frequencies below 300 Hz, in particular at 50 Hz or 60 Hz, is under study. Overall rejection of longitudinal interference can be achieved by a combination of good longitudinal balancing and high pass filtering (see § 10.2).

Note 4 – The measurements should be made selectively.

Note 5 – The need to include other balance parameters is under study.

6.2 *Longitudinal conversion transfer loss*

The difference between the longitudinal conversion transfer loss (see Recommendation O.9, § 2.3) at the specified frequencies and the insertion loss at the same frequencies should not be less than the limits in Table 5/G.712 as specified from input to output ports. The measurement is only applicable to the configuration where the driving test circuit is applied to one of the voice-frequency ports and a measurement made at the other voice-frequency port. The measurement should be made with the switch S (see Figure 3/O.9), closed.

TABLE 5/G.712

Longitudinal conversion transfer loss requirements for 4-wire and 2-wire analogue-to-analogue channels

Connected channel of two primary multiplexers	*Z* (Ω)	Requirements on the difference between the longitudinal conversion transfer loss and the insertion loss			Notes
		300 Hz to 600 Hz	600 Hz to 2400 Hz	2400 Hz to 3400 Hz	
4-wire, $E4_{1in}$ to $E4_{2out}$	600	> 46 dB	> 46 dB	> 41 dB	1, 2
2-wire, $E2_{1in}$ to $E2_{2out}$	600	> 40	> 46	> 41	1, 2, 3, 4

Note – See Notes to Table 4/G.712.

7 Attenuation/frequency distortion

The variations with frequency of the attenuation of any channel should lie within the limits shown in the masks of Figure 2/G.712, Figure 3/G.712, Figure 4/G.712 or Figure 5/G.712.

The nominal reference frequency is 1020 Hz.

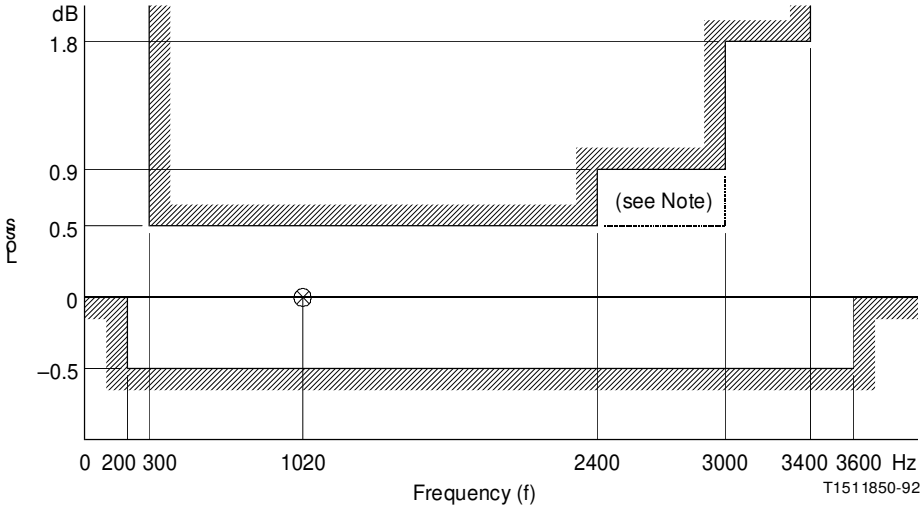
The preferred input power level is –10 dBm0, in accordance with Recommendation O.6. As an alternative, a level of 0 dBm0 may be used. If complex nominal impedances are used at 2-wire analogue ports, the attenuation/frequency distortion is the logarithmic ratio of output voltage at the reference frequency (nominally 1020 Hz), U(1020 Hz), divided by its value at frequency f, $U(f)$:

Attenuation/frequency distortion = 20 log (U(1020 Hz) / $U(f)$).

8 Group delay

Specifications of absolute group delay and group delay distortion between analogue and digital ports are design objectives only.

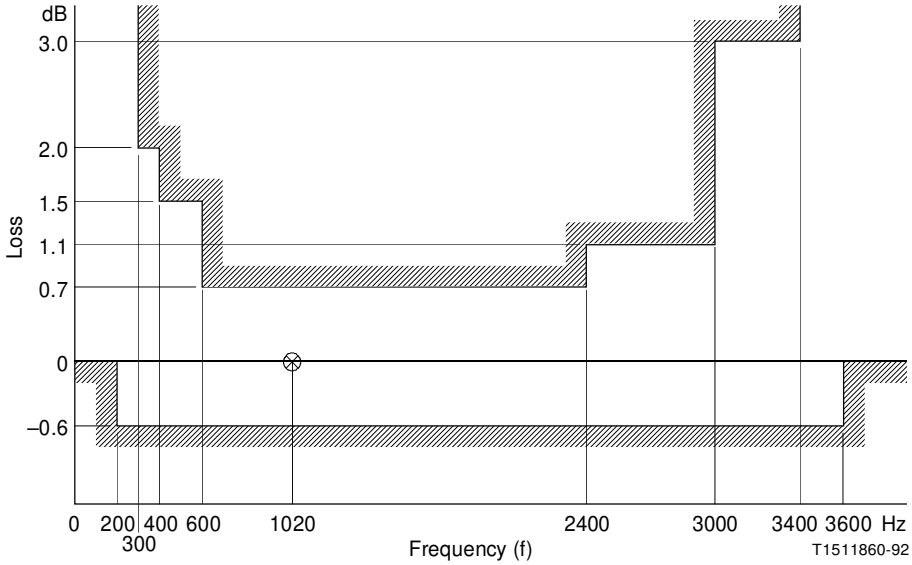
The requirements on absolute group delay and group delay distortion should be met at an input power level of –10 dBm0 (preferred value). As an alternative, a level of 0 dBm0 may be used.



Note – In some applications in which several PCM channels may be connected in tandem, it may be necessary to extend the +0.5 dB limit from 2400 Hz to 3000 Hz.

FIGURE 2/G.712

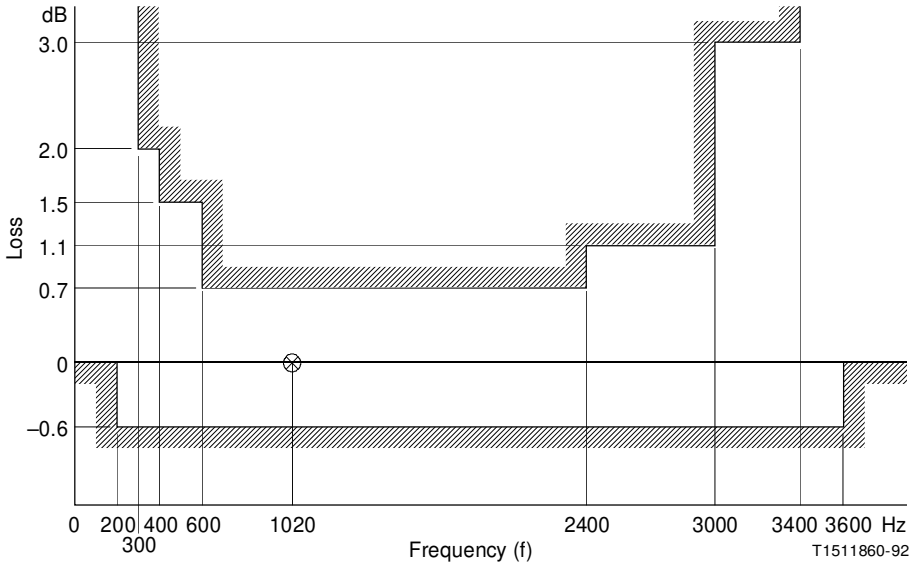
Attenuation/frequency distortion for analogue-to-analogue channels between 4-wire ports ($E4_{1in}$ to $E4_{2out}$)



Note – Some Administration apply a limit of 1 dB maximum loss for the frequency range 300 Hz to 3000 Hz.

FIGURE 3/G.712

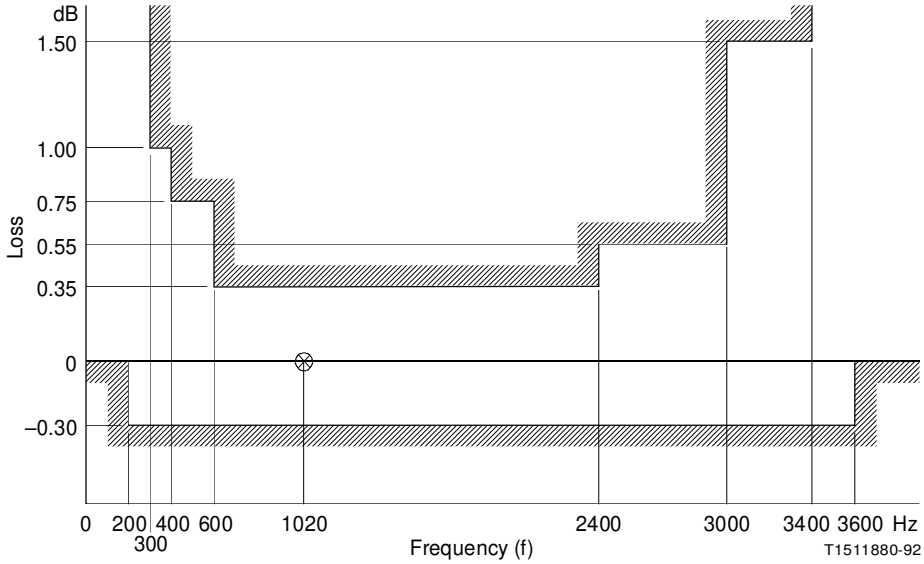
Attenuation/frequency distortion for analogue-to-analogue channels between 2-wire ports ($E2_{1in}$ to $E2_{2out}$)



Note – Some Administration apply a limit of 1 dB maximum loss for the frequency range 300 Hz to 3000 Hz.

FIGURE 3/G.712

Attenuation/frequency distortion for analogue-to-analogue channels between 2-wire ports ($E2_{1in}$ to $E2_{2out}$)



Note – Some Administrations apply a limit of 0.5 dB maximum loss for the frequency range 300 Hz to 3000 Hz.

FIGURE 5/G.712

Attenuation/frequency distortion for 2-wire analogue-to-digital channels ($E2_{in}$ to T_{out} or T_{in} to $E2_{out}$)

8.1 *Absolute group delay*

The absolute group delay at the frequency of minimum group delay should not exceed the limit in Table 6/G.712.

Note that absolute delay is specified to the A or B port, since the digital cross-connect system will contribute additional delay. These are design objectives only.

TABLE 6/G.712

Requirements for absolute group delay

Measurement configuration	Absolute group delay
4-wire analogue-to-analogue channel ($E4_{1in}$ to $E4_{2out}$)	< 600 microseconds
2-wire analogue-to-analogue ($E2_{1in}$ to $E2_{2out}$)	< 750
4-wire analogue-to-digital ($E4_{in}$ to A_{out} to B_{out})	< 360
Digital to 4-wire analogue (A_{in} or B_{in} to $E4_{out}$)	< 240
2-wire analogue-to-digital ($E2_{in}$ to A_{out} or B_{out})	< 450
Digital to 2-wire analogue (A_{in} or B_{in} to $E2_{out}$)	< 300

8.2 *Group delay distortion with frequency*

The group delay distortion should lie within the limits shown in the mask of Figure 6/G.712, Figure 7/G.712, Figure 8/G.712, or Figure 9/G.712.

The minimum value of absolute group delay is taken as the reference for the group delay distortion.

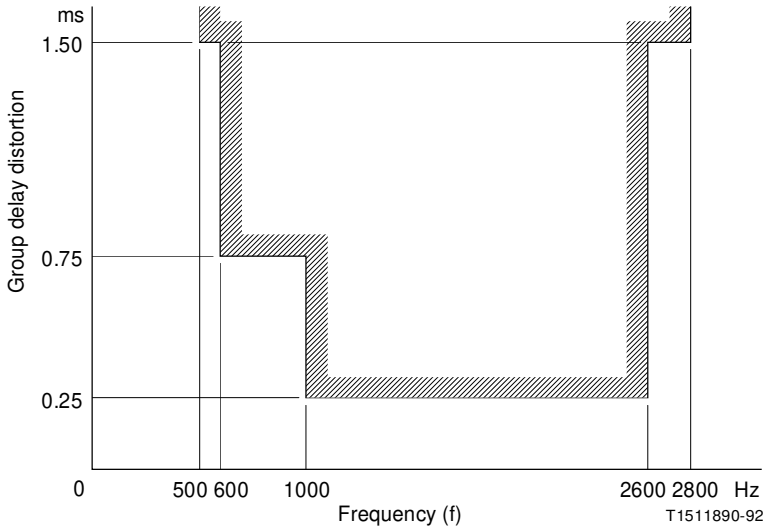


FIGURE 6/G.712

Group delay distortion with frequency for analogue-to-analogue channels between 4-wire ports (E4 $_{1in}$ to E4 $_{2out}$)

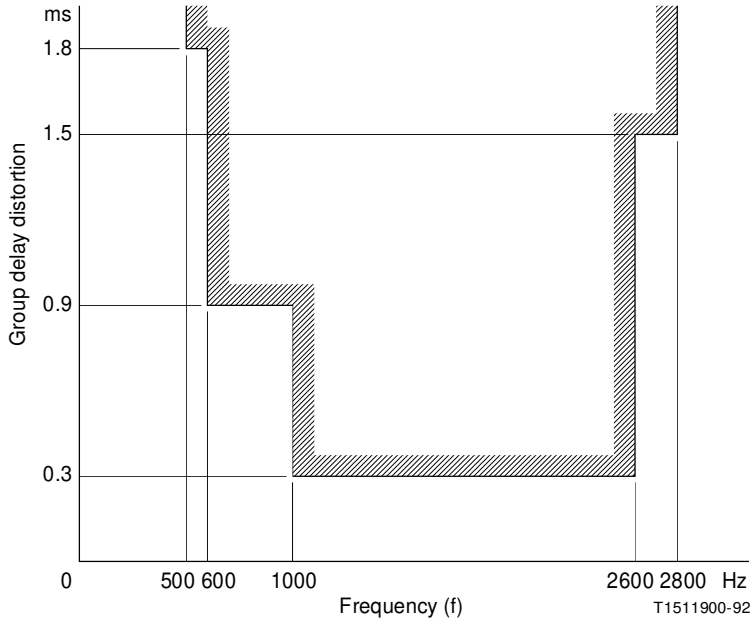


FIGURE 7/G.712

Group delay distortion with frequency for analogue-to-analogue channels between 2-wire ports (E2 $_{1in}$ to E2 $_{2out}$)

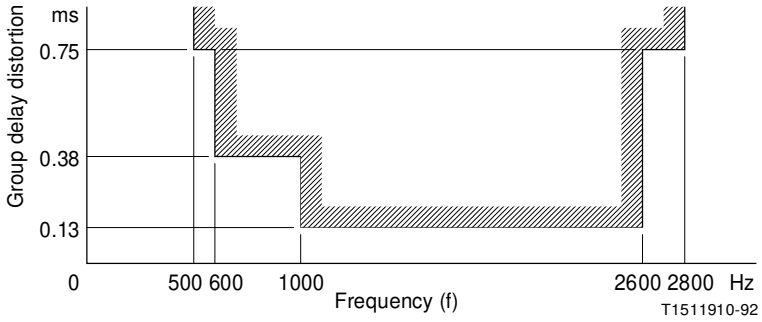


FIGURE 8/G.712
Group delay distortion with frequency for 4-wire analogue-to-digital channels ($E4_{in}$ to T_{out} or T_{in} to $E4_{out}$)

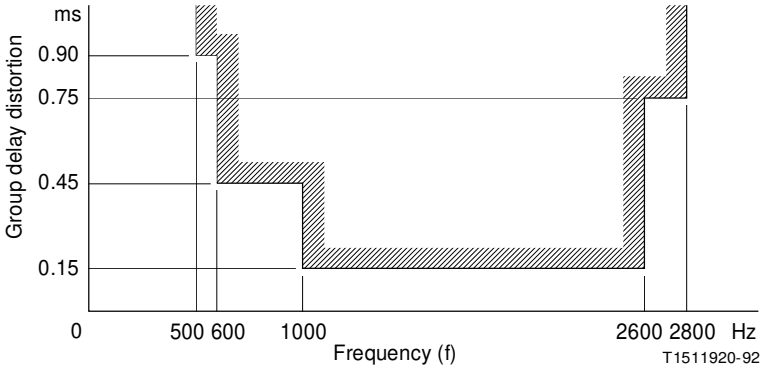


FIGURE 9/G.712
Group delay distortion with frequency for 2-wire analogue-to-digital channels ($E2_{in}$ to T_{out} or T_{in} to $E2_{out}$)

9 Idle channel noise

9.1 *Weighted noise*

With the input and output ports of the channel terminated in the nominal impedance, the idle channel noise should not exceed the limits of Table 7/G.712.

9.2 *Single frequency noise*

The level of any single frequency measured selectively (in particular the sampling frequency and its multiples at the 4-wire analogue, $E4_{out}$, and 2-wire analogue, $E2_{out}$ ports) should not exceed –50 dBm0. Between 300 Hz 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.

TABLE 7/G.712

Requirements for weighted idle channel noise

Port terminated	Port measured	Weighted noise limit	Notes
4-wire analogue, $E4_{1in}$	4-wire analogue, $E4_{2out}$	< –65 dBm0p	
2-wire analogue, $E2_{1in}$	2-wire analogue, $E2_{2out}$	< –65	1, 4
4-wire analogue, $E4_{in}$	Digital, T_{out}	< –67	2
Digital, T_{in}	4-wire analogue, $E4_{out}$	< –70	3
2-wire analogue, $E2_{in}$	Digital, T_{out}	< –67	2
Digital, T_{in}	2-wire analogue, $E2_{out}$	< –70	3, 5

Note 1 – This limit does not include any allowance for additional noise which might be present when signalling takes place on the two wires. The derivation of limits for this case, taking account of the philosophy adopted in Recommendation Q.551, is under study. Due to the effects of quantization, it is not necessarily the case that noise powers can be added.

Note 2 – Weighted noise measured at the encoding side.

Note 3 – Noise measured at the decoding side. The digital port is driven by a PCM signal (quiet code) corresponding to the decoder output value number 0 for the μ-law or decoder output value number 1 for the A-law.

Note 4 – Below –5 dBr and –8 dBr the noise limit is –64 dBm0p.

Note 5 – Below –5 dBr the noise limit is –75 dBmp.

Note 6 – Psophometric measurements of composite signals at ports with complex impedances should be performed with a psophometer having an input impedance equal to the nominal complex impedance specified for that port. The psophometer has to be calibrated accordingly (see also Recommendation O.41 and Annex A to Recommendation G.100).

10 Discrimination against out-of-band signals

10.1 *Input signals above 4600 Hz at analogue ports E4 and E2*

With any sine-wave signal in the range from 4600 Hz to 72 kHz applied to the input voice frequency port of the channel at a suitable level, the level of any image frequency produced at an output E or T port should, as a minimum requirement, be at least 25 dB below the level of the test signal.

Note – It has been found that a suitable test level is –25 dBm0.

10.2 *Input signals below 300 Hz at 2-wire analogue port E2*

No particular value is recommended.

Note 1 – While some Administrations have no particular requirement in this respect, some other Administrations have found it necessary to provide at least 20 to 26 dB rejection at the encoding side at frequencies across the band 15 Hz to 60 Hz.

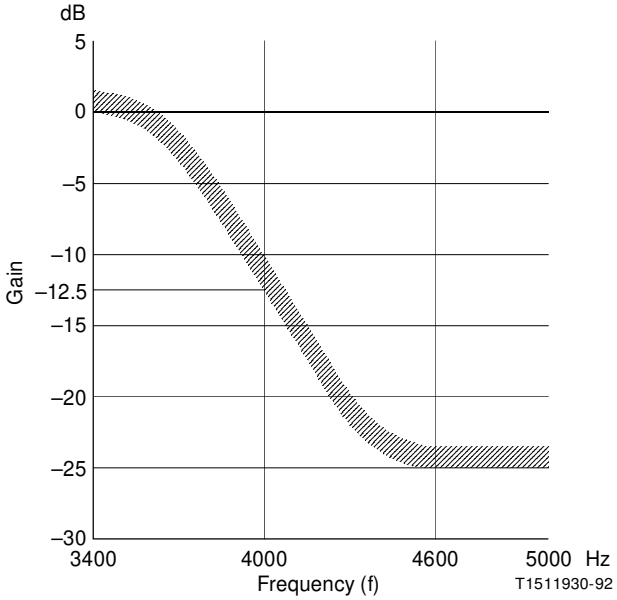
Note 2 – Overall rejection of longitudinal interference can be achieved by a combination of good longitudinal balancing (see § 6) and high pass filtering.

10.3 *Overall requirement (4-wire only)*

Under the most adverse conditions encountered in a national network, the 4-wire PCM channel ($E4_{in}$ to $E4_{out}$ or $E4_{in}$ to T_{out}) should not contribute more than 100 pW0p of additional noise in the band 10 Hz to 4 kHz at the channel output, as a result of the presence of out-of-band signals at the 4-wire analogue channel input.

Note 1 – The discrimination required depends on the performance of frequency division multiplex (FDM) channel equipments and telephone instruments in national networks, and individual Administrations should carefully consider the requirements they should specify taking into account the comments above and the requirement of § 10.1 above. In all cases at least the minimum requirement of this section should be met.

Note 2 – Attention is drawn to the importance of the attenuation characteristic in the range 3400 Hz to 4600 Hz. Although other attenuation characteristics can satisfy the following requirements, the filter template of Figure 10/G.712 gives adequate protection against the out-of-band signals at 4-wire and 2-wire analogue channel inputs.



Note – The curved portion of the graph conforms to the equation:

$$G = 12.5 \left[\sin \frac{\pi (4000 - f)}{1200} - 1\right] \text{dB}$$

for the range $3400 \leq f \leq 4600$.

FIGURE 10/G.712
Gain relative to gain at 1020 Hz

11 Spurious signals at the channel output port

11.1 *Spurious out-of-band signals at the channel output port*

11.1.1 *In-band input signal*

With any sine-wave test signal in the frequency range 300 Hz to 3400 Hz and at a level of 0 dBm0 applied to the digital or analogue input port of a channel (T_{in} or a connected $E4_{in}$ or $E2_{in}$), the level of spurious out-of-band image signals measured selectively at the 4-wire or 2-wire analogue output port ($E4_{out}$ or $E2_{out}$) should be lower than –25 dBm0.

Note – Attention is drawn to the importance of the attenuation characteristic in the range 3400 Hz to 4600 Hz. Although other attenuation characteristics can satisfy the above requirement, the filter template of Figure 10/G.712 gives adequate protection against the out-of-band signal.

11.1.2 *Overall requirement*

The spurious out-of-band signals should not give rise to unacceptable interference in equipment connected to the PCM channel. In particular, the intelligible or unintelligible crosstalk in a connected FDM channel should not exceed a level of –65 dBm0 as a consequence of the spurious out-of-band signals at the PCM channel output.

Note – The discrimination required depends on the performance of FDM channel equipment and telephone instruments in national networks and individual Administrations should carefully consider the requirements they should specify, taking into account the comments above and the requirement of § 11.1.1 above. In all cases at least the minimum requirement of this section should be met.

11.2 *Spurious in-band signals at the channel output port*

With any sine-wave test signal in the frequency range 700 Hz to 1100 Hz and at a level of 0 dBm0 applied to the analogue input port of a channel ($E4_{1in}$ or $E2_{1in}$), the output level at any frequency other than the frequency of the test signal, measured selectively in the frequency band 300 Hz to 3400 Hz at the 4-wire or 2-wire analogue output port ($E4_{2out}$ or $E2_{2out}$), should be less than –40 dBm0.

12 Total distortion, including quantizing distortion

With a sine-wave test signal at the nominal reference frequency of 1020 Hz applied to the input port of a channel, the ratio of signal-to-total distortion power measured with the proper noise weighting (see Table 4/G.223) at the output port should lie above the limits shown in Figures 11/G.712 and 12/G.712.

Note – A method based on a noise test signal is in use. This method, which is described in Annex A, is not exactly equivalent to the sine-wave test method.

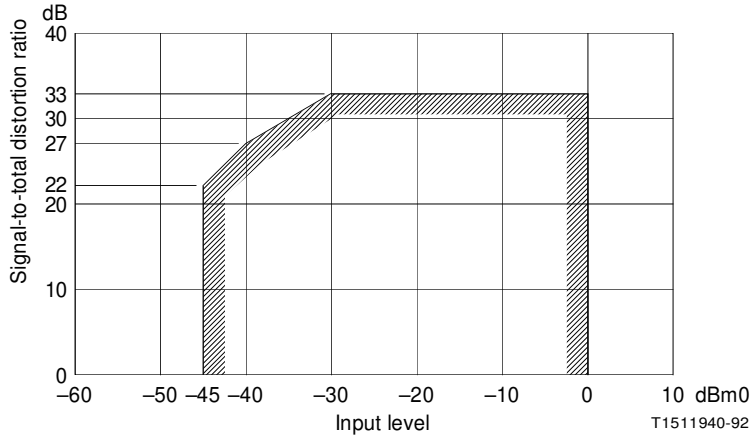


FIGURE 11/G.712

Signal-to-total distortion ratio as a function of input level for analogue 4-wire to 4-wire and 2-wire to 2-wire channels ($E4_{1in}$ to $E4_{2out}$ and $E2_{1in}$ to $E2_{2out}$)

13 Variation of gain with input level

With a sine-wave test signal at the nominal reference frequency of 1020 Hz applied to the input port of any channel at a level between –55 dBm0 and +3 dBm0, the gain variation of that channel relative to the gain at an input level of –10 dBm0, should be within the limits of Figures 13/G.712 or 14/G.712.

Note – A method based on a noise test signal is in use. This method, which is described in Annex A, is not exactly equivalent to the sine-wave test method.

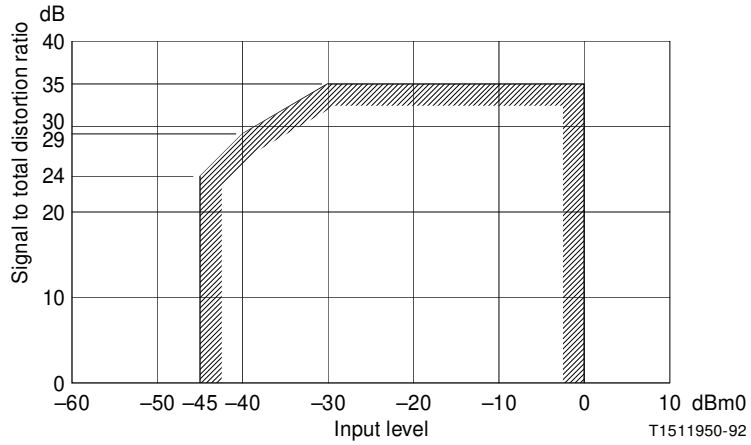


FIGURE 12/G.712

Signal-to-total distortion ratio as a function of input level for analogue-to-digital channels ($E4_{in}$ to T_{out}, T_{in} to $E4_{out}$, $E2_{in}$ to T_{out} and T_{in} to $E2_{out}$)

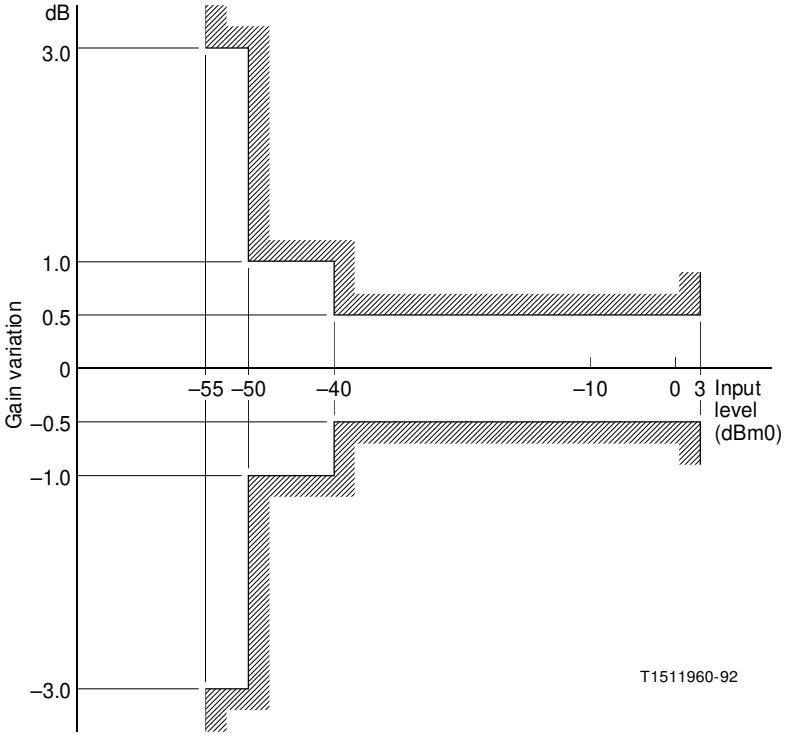


FIGURE 13/G.712

Variation of gain with input level for analogue 4-wire to 4-wire and 2-wire to 2-wire channels ($E4_{1in}$ to $E4_{2out}$ and $E2_{1in}$ to $E2_{2out}$)

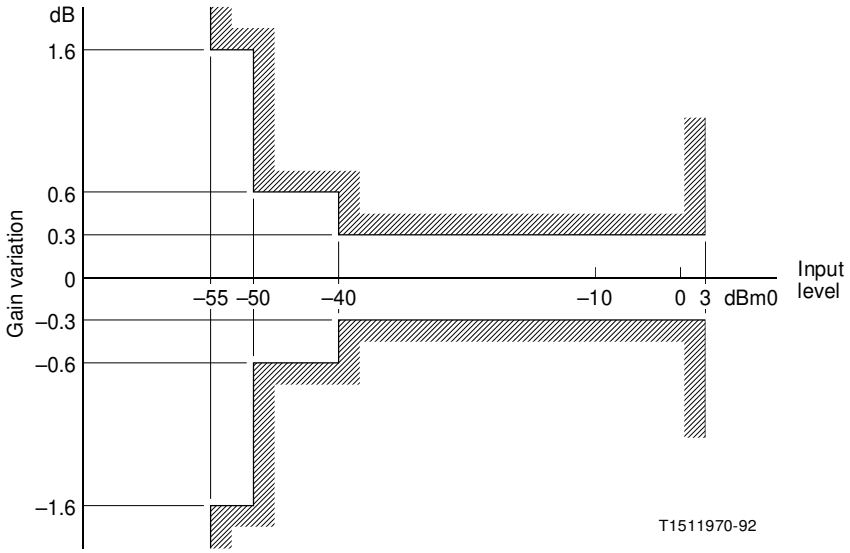


FIGURE 14/G.712

Variation of gain with input level for analogue-to-digital channels ($E4_{in}$ to T_{out}, T_{in} to $E4_{out}$, $E2_{in}$ to T_{out}, and T_{in} to $E2_{out}$)

14 Crosstalk

14.1 *General*

For the crosstalk measurements, auxiliary signals are injected as indicated in Figures 15/G.712 to 21/G.712. These signals are:

– the quiet code, i e. a PCM signal corresponding to decoder output value number 0 (μ-law) or output value number 1 (A-law) (with the sign bit in a fixed state);

– a low level activating signal, a sine-wave at a level in the range –33 dBm0 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.

14.2 *Interchannel crosstalk, analogue-to-analogue channels*

14.2.1 *Far-end crosstalk measured with analogue test signal*

The crosstalk between individual transmission paths of a PCM equipment should be such that with a sine-wave signal at the nominal reference frequency of 1020 Hz and at a level of 0 dBm0 applied to a 4-wire or 2-wire analogue input port ($E4_{1in}$ or $E2_{1in}$), the crosstalk level received at the 4-wire or 2-wire analogue output of any other transmission path ($E4_{2out}$ or $E2_{2out}$) should not exceed –65 dBm0 far-end crosstalk (FEXT). See Figure 15/G.712 for measurements of 4-wire and 2-wire channels.

14.2.2 *Go-to-return crosstalk for 4-wire to 4-wire analogue channels*

The crosstalk between a channel and its associated return channel should be such that with a sine-wave signal at any frequency in the range 300 Hz to 3400 Hz and at a level of 0 dBm0 applied to a 4-wire analogue input port $E4_{1in}$ or $E4_{2in}$, the crosstalk level measured at the 4-wire analogue output port $E4_{1out}$ or $E4_{2out}$ respectively of the same channel of the same primary multiplexer should not exceed –60 dBm0 when the channel is connected through to another primary multiplexer. See Figure 15/G.712.

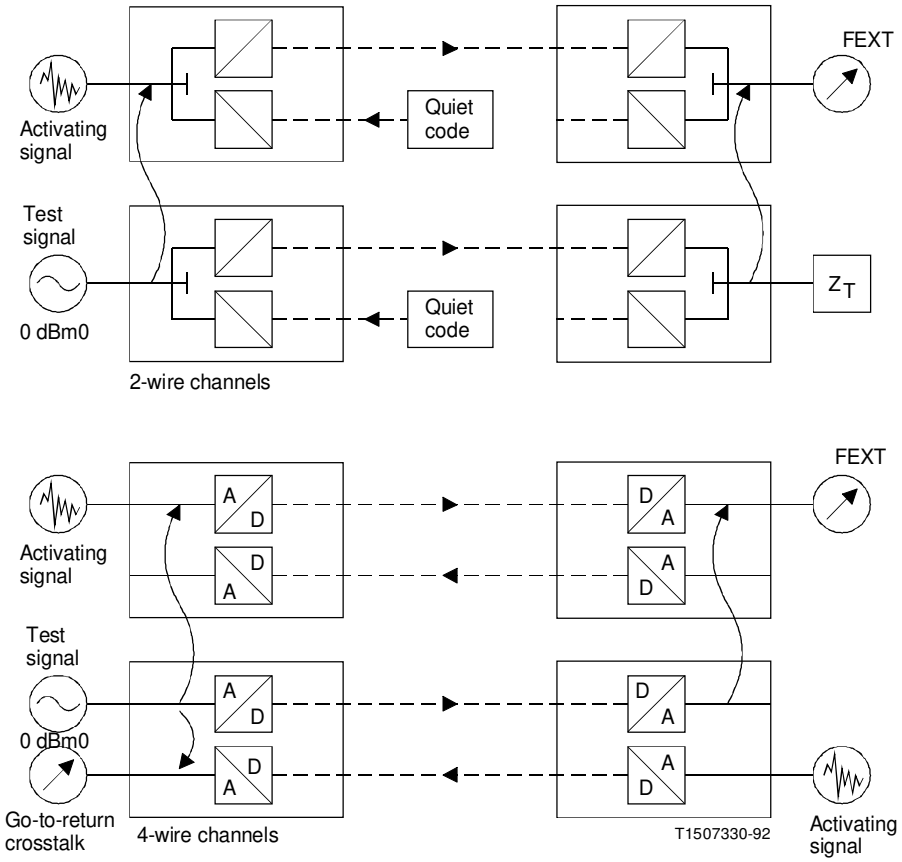


FIGURE 15/G.712

Measurement of crosstalk between two channels

14.3 *Crosstalk measurements of individual primary multiplexers*

14.3.1 *Far-end and near-end crosstalk measured with analogue test signal*

The crosstalk between individual channels of a multiplex should be such that with a sine-wave signal at the nominal reference frequency of 1020 Hz and at a level of 0 dBm0 applied to a voice-frequency input port, the crosstalk level produced in any other channel should not exceed –73 dBm0 for near-end crosstalk (NEXT) and –70 dBm0 for far-end crosstalk (FEXT). See Figure 16/G.712 and Figure 17/G.712 for measurements of 4-wire and 2-wire channels respectively.

14.3.2 *Go-to-return crosstalk measured with analogue test signal*

The crosstalk between a channel and its associated return channel should be such that with a sine-wave signal at any frequency in the range 300 Hz to 3400 Hz and at a level of 0 dBm0 applied to an input port, the crosstalk level measured at the output of the corresponding return channel should not exceed –66 dBm0. See Figure 18/G.712.

14.3.3 *Far-end and near-end crosstalk measured with digital test signal*

The crosstalk between individual channels of a multiplex should be such that with a digitally simulated sine-wave signal at the nominal reference frequency of 1020 Hz and at a level of 0 dBm0 applied to the digital input, the crosstalk level received in any other channel should not exceed –70 dBm0 for near-end crosstalk (NEXT) and **Error! Bookmark not defined.** for far-end crosstalk (FEXT). See Figure 19/G.712 and Figure 20/G.712 for measurements of 4-wire and 2-wire channels respectively.

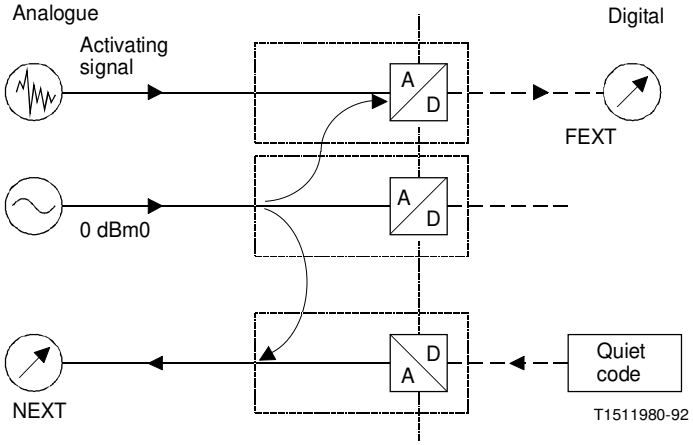


FIGURE 16/G.712

Measurements on 4-wire (E4) ports with analogue test signal between different channels

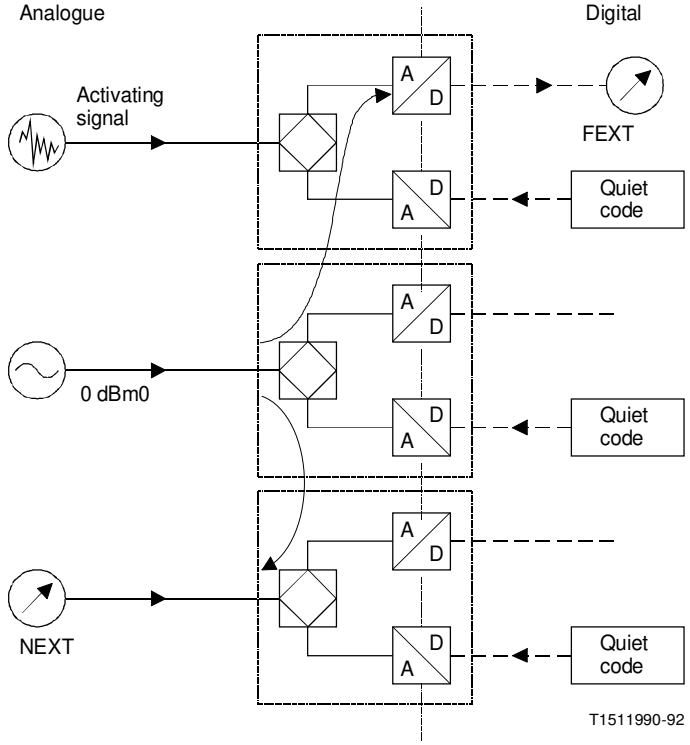


FIGURE 17/G.712

Measurements on 2-wire (E2) ports with analogue test signal between different channels

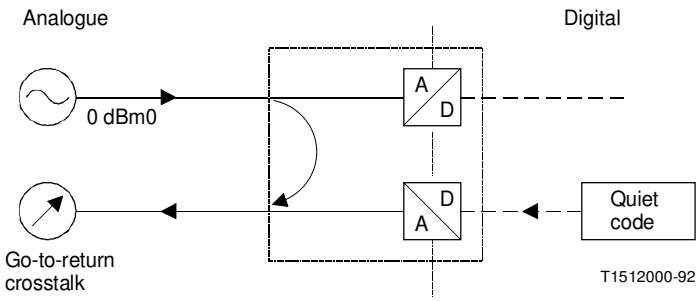


FIGURE 18/G.712

Measurements on 4-wire port (E4) with analogue test signal between go and return directions of the same channel

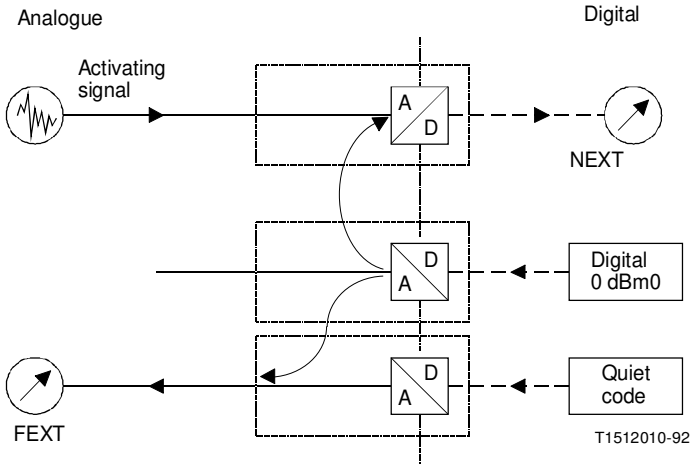


FIGURE 19/G.712

Measurements on 4-wire (E4) ports with digital test signal between different channels

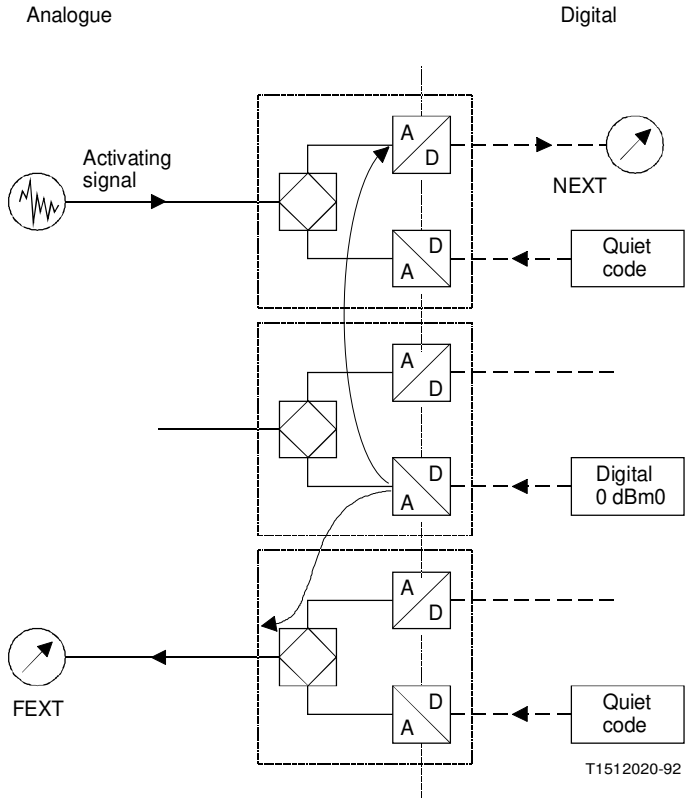


FIGURE 20/G.712
Measurements on 2-wire (E2) ports with digital test signal between different channels

14.3.4 *Go-to-return crosstalk measured with digital test signal*

The crosstalk between a channel and its associated return channel should be such that with a digitally simulated sine-wave signal at any frequency in the range 300 Hz to 3400 Hz and at a level of 0 dBm0 applied to a digital input port, the crosstalk level measured at the digital output of the corresponding return channel should not exceed –66 dBm0. See Figure 21/G.712.

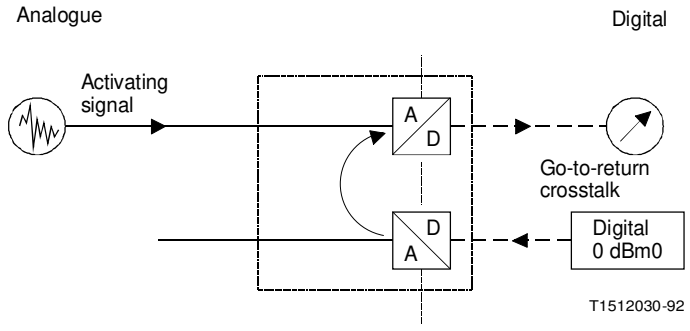


FIGURE 21/G.712
Measurements on 4-wire port (E4) with digital test signal between go and return directions of the same channel

15 Interference from signalling

15.1 *4-wire analogue to 4-wire analogue channels*

The maximum level of any interference into a channel should not exceed –60 dBm0p when signalling (10 Hz signal with a 50/50 duty ratio) is active simultaneously on all other channels.

15.2 *2-wire analogue to 2-wire analogue channels*

The maximum level of any interference into a channel should not exceed –50 dBm0p when signalling (10 Hz signal with a 50/50 duty ratio) is active simultaneously on all other channels.

15.3 *4-wire analogue-to-digital channels*

The characterization of such interference by separate measurements requires four different types of measurement for crosstalk (see Figure 22/G.712). In each case the maximum level of interference in one channel should not exceed –63 dBm0p when signalling (10 Hz with 50/50 duty ratio) is active simultaneously on all other channels.

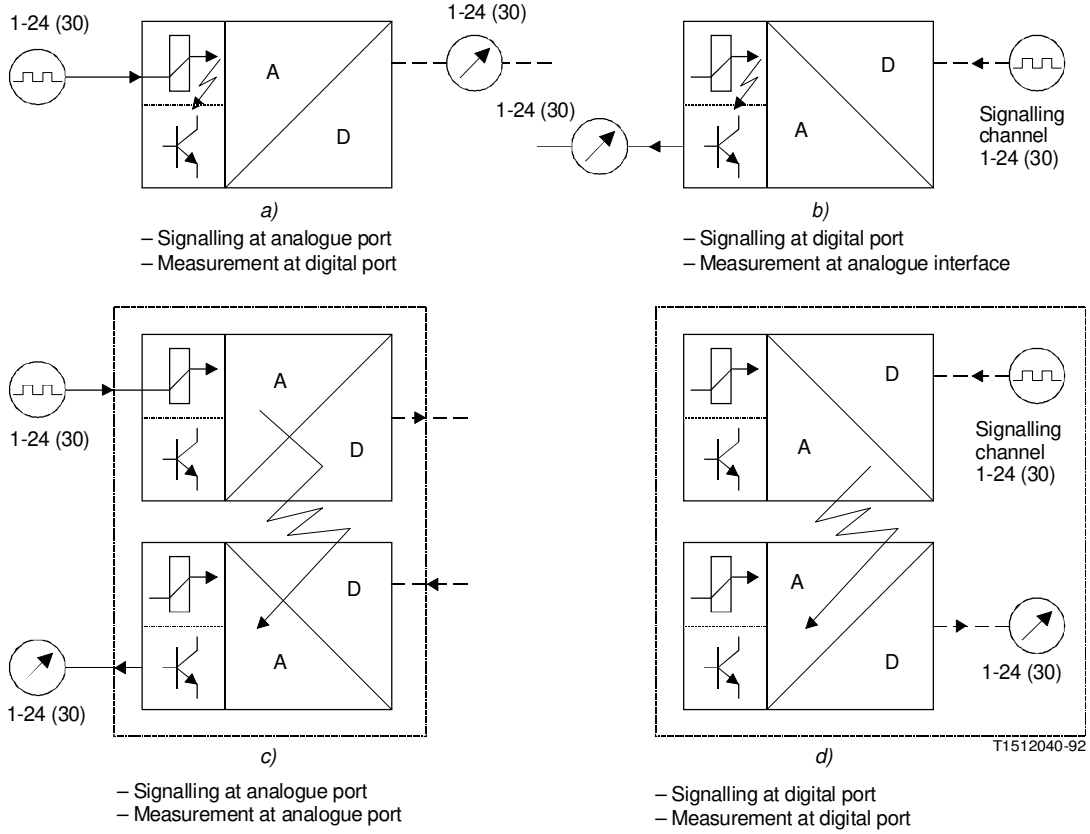


FIGURE 22/G.712

Measurement of signalling interference contributions

15.4 *2-wire analogue-to-digital channels*

The characterization of such interference by separate measurements requires two different types of measurement for crosstalk [see Figure 22/G.712, configurations a) and b)]. In each case the maximum level of interference in one channel should not exceed *X* dBm0p when signalling (10 Hz with 50/50 duty ratio) is active simultaneously on all other channels.

Note – The value of *X* is under study.

16 Echo and stability at 2-wire ports, E2

16.1 *Terminal balance return loss (TBRL)*

This quantity characterizes the equipment performance required to comply with the network performance objective of Recommendation G.122 in respect of echo. The terminal balance return loss (TBRL) is defined as the balance return loss (see definition in Recommendation Q.552, § 3.1.8.1) measured against a balance test network. It is related to the loss between the digital test input point, T_i and the digital test output point, T_o (see Figure 23/G.712) as follows:

$$a_{io} = T_i \text{ to } T_o \text{ loss} = P_i + P_o + TBRL \qquad \text{(dB)}$$

where P_i and P_o are the measured values of loss in the equivalent circuit of Figure 23/G.712 which represent all loss between the digital test point and the 2-wire point, or conversely, at the measurement frequency.

The TBRL should be measured in the arrangement of Figure 23/G.712 with a sinusoidal test signal at frequencies across the telephone band covering the bandwidth 300 Hz to 3400 Hz.

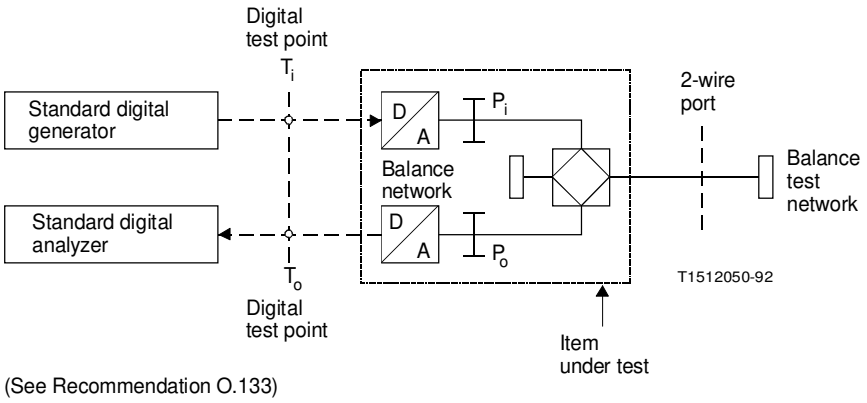


FIGURE 23/G.712

Arrangement for measuring half-loop loss

Values for the nominal balance impedance and for the maximum deviation of this impedance from the nominal value, differ from one Administration to another. The range of impedances presented at the 2-wire port during normal operation also varies considerably. Administrations will need to establish their own requirements for TBRL, taking account of national or international transmission plans. As a minimum requirement, the TBRL limits in Figure 24/G.712 should be met when the 2-wire port is terminated with a balance test network which is representative of the impedance conditions expected in the speaking condition from a population of 2-wire trunks connected to the PCM equipment. The limits are provisional.

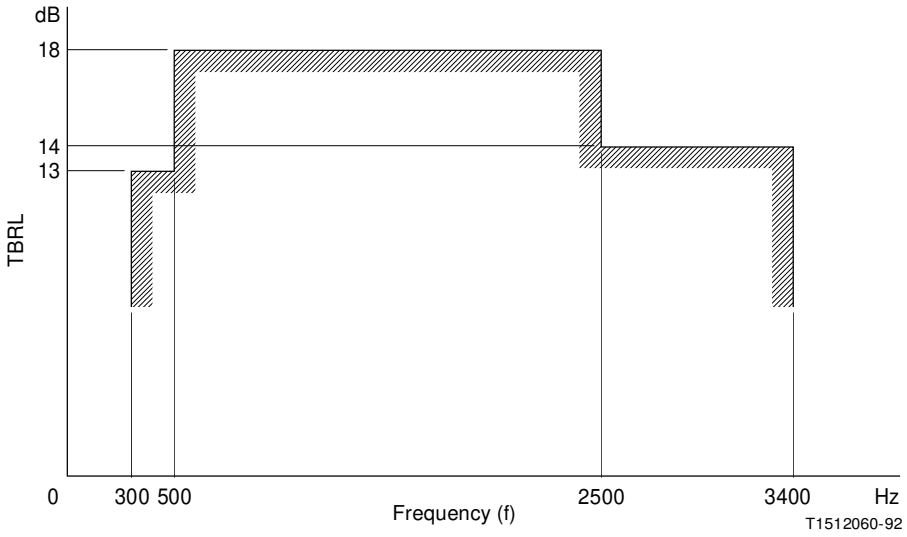


FIGURE 24/G.712

Minimum values of terminal balance return loss (provisional)

16.2 *Stability loss (SL)*

The stability loss (SL) is defined as the minimum value of the loss a_{io} measured in the arrangement of Figure 23/G.712. The stability loss should be measured between T_i and T_o by terminating the 2-wire port with stability test networks representing the worst case terminating condition encountered in normal operation. Some Administrations may find that open circuit and short circuit terminations are sufficiently representative of worst case conditions. Other Administrations may need to specify, for example, and inductive termination to represent that worst case condition.

The stability loss at any frequency can be expressed as follows:

$$SL \geq P_i + P_o - X \qquad \text{(dB)}$$

where P_i and P_o are measured values of loss, at the measurement frequency, under normal terminating conditions at the 2-wire port. X has a value dependent on the interaction between the 2-wire input impedance, the 2-wire balance impedance and the impedance actually applied at the 2-wire port. X can be computed or measured by the method described in Recommendation Q.552.

The 2-wire input and balance impedances at a 2-wire/4-wire port usually have to be optimized by Administrations with regard to echo and sidetone. The worst case terminations depend on the actual network conditions. Thus, the value of X is fully determined by network conditions and the impedance strategy. Values between 0 and 3 dB have been observed in practice.

Administrations should choose the nominal values of P_i and P_o taking account of the value of X for their particular operating conditions and of national and international transmission plans for overall network stability (see Recommendation G.122).

ANNEX A

(to Recommendation G.712)

Alternative measurements using band limited noise signals

A.1 *Variation of gain with input level*

With a band limited noise signal, as defined in Recommendation O.131, applied to the input port of any channel at a level between –55 dBm0 and –10 dBm0, the gain variation of that channel relative to the gain at an input level of –10 dBm0, should be within the limits of Figure A-1/G.712 or Figure A-2/G.712. The measurement should be limited to the frequency band 350 Hz to 550 Hz in accordance with the filter characteristic defined in Recommendation O.131, § 3.2.1.

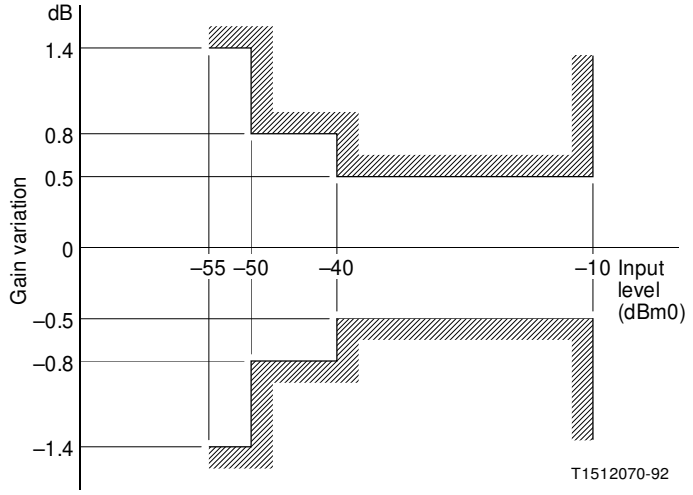


FIGURE A-1/G.712

Variation of gain with input level for analogue-to-analogue channels between 4-wire ports (E4 $_{1in}$ to E4 $_{2out}$) or 2-wire ports (E2 $_{1in}$ to E2 $_{2out}$)

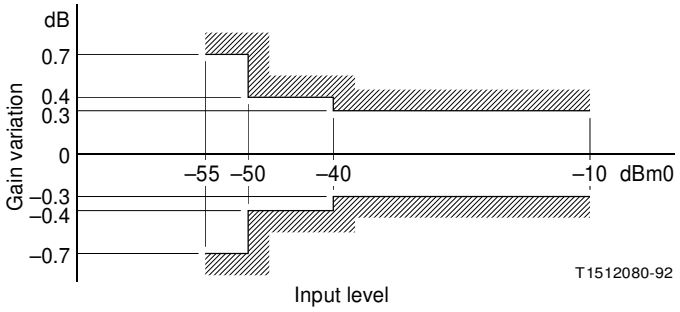


FIGURE A-2/G.712

Variation of gain with input level for analogue-to-digital channels (E4$_{in}$ to T$_{out}$, T $_{in}$ to E4 $_{out}$, E2 $_{in}$ to T $_{out}$, or T $_{in}$ to E2 $_{out}$)

Furthermore, with a sine-wave signal at the nominal frequency of 1020 Hz applied to the input port of any channel at a level between –10 dBm0 and +3 dBm0, the gain variation of that channel relative to the gain at an input level of –10 dBm0, should be within the limits of Figure A-3/G.712 or Figure A-4/G.712.

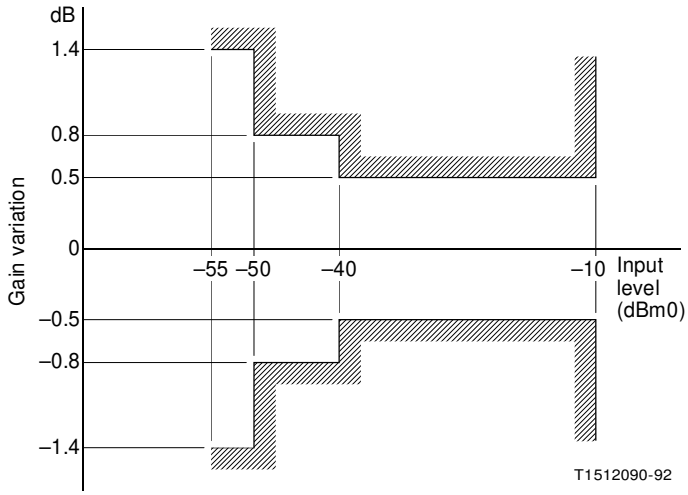


FIGURE A-3/G.712

Variation of gain with input level for analogue-to-analogue channels between 4-wire ports (E4 $_{1in}$ to E4 $_{2out}$) or 2-wire ports (E2 $_{1in}$ to E2 $_{2out}$)

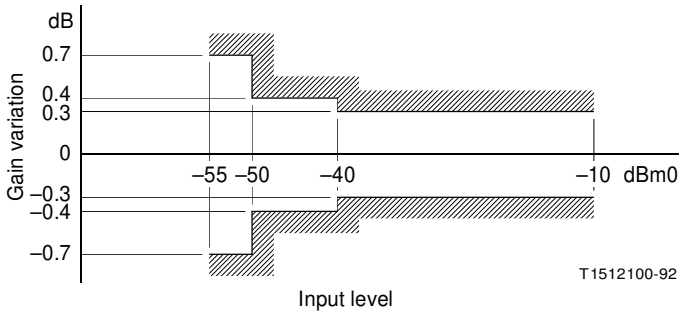


FIGURE A-4/G.712

Variation of gain with input level for analogue-to-digital channels (E4 $_{in}$ to T_{out} , T_{in} to E4 $_{out}$, E2 $_{in}$ to T $_{out}$, or T $_{in}$ to E2 $_{out}$)

A.2 *Total distortion, including quantizing distortion*

Note – Compared with the sine-wave test method recommended in § 12, the noise test method here gives fairly smooth curves, not very dependent upon input signal level. The sine-wave method can be more sensitive in identifying possible localized codec imperfections. Thus, this method responds to practical codec impairments in slightly different ways. The noise test method is about 1.5 dB more stringent than the sine-wave test method.

With a noise signal corresponding to Recommendation O.131 applied to the input port of a channel, the ratio of signal-to-total distortion power should lie above the limits shown in Figures A-5/G.712 through A-10/G.712.

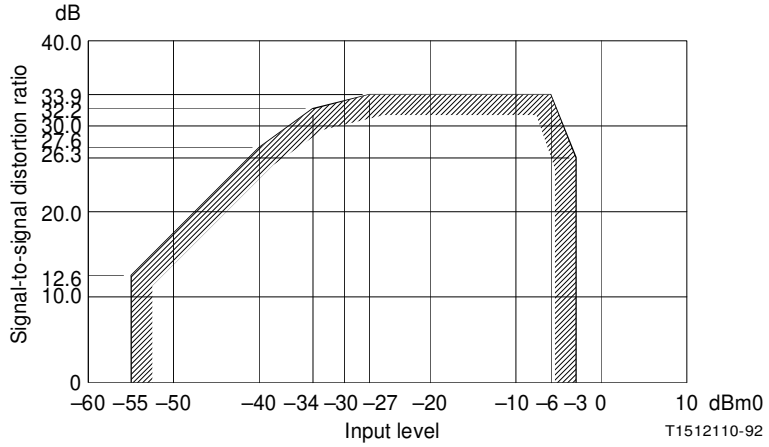


FIGURE A-5/G.712

Signal-to-total distortion ratio as a function of input level for 4-wire analogue-to-analogue connections ($E4_{1in}$ to $E4_{2out}$)

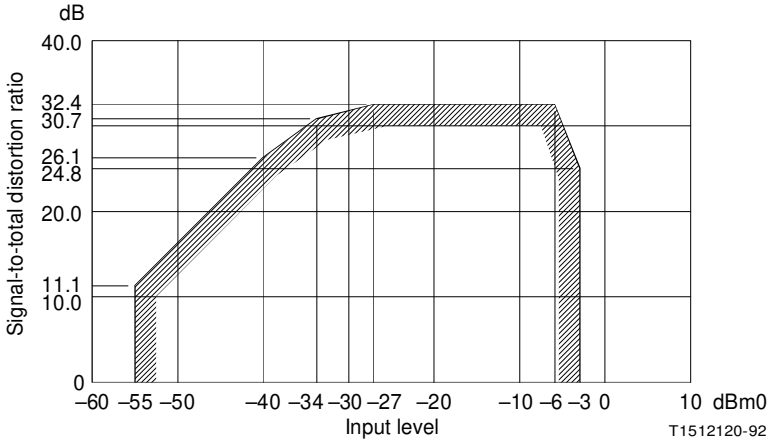


FIGURE A-6/G.712

Signal-to-total distortion ratio as a function of input level for 2-wire analogue-to-analogue connections ($E2_{1in}$ to $E2_{2out}$)

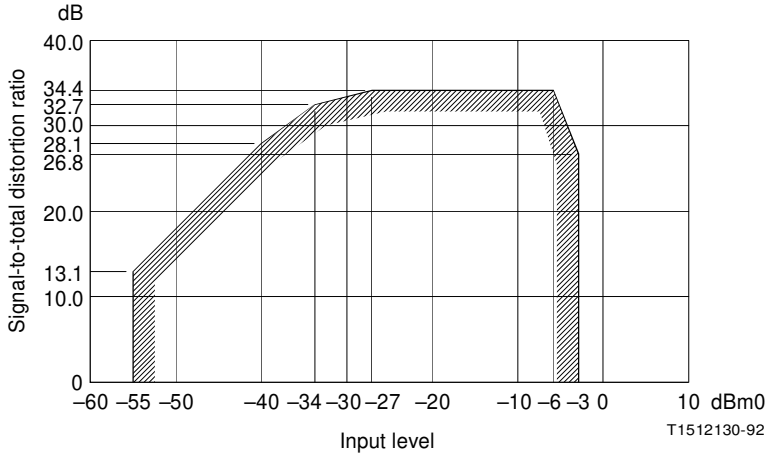
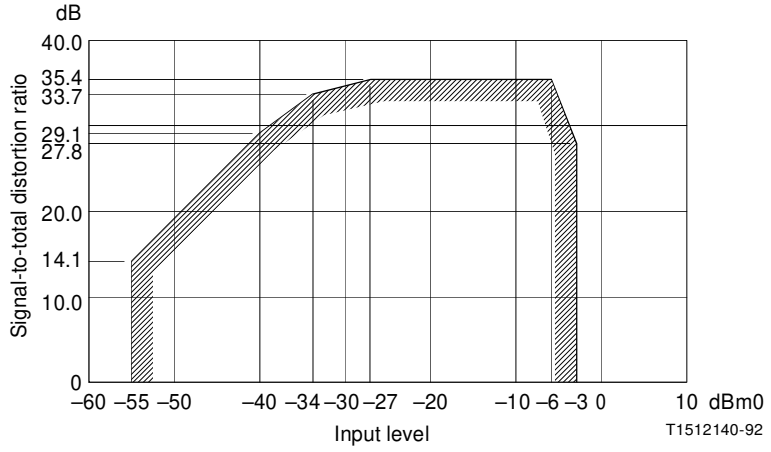


FIGURE A-7/G.712

Signal-to-total distortion ratio as a function of input level for 4-wire analogue-to-digital encoding side (E4 $_{in}$ to T $_{out}$)



Note – The values in the mask include the distortion power of an ideal encoder.

FIGURE A-8/G.712

Signal-to-total distortion ratio as a function of input level for 4-wire analogue-to-digital decoding side (T $_{in}$ to E4 $_{out}$)

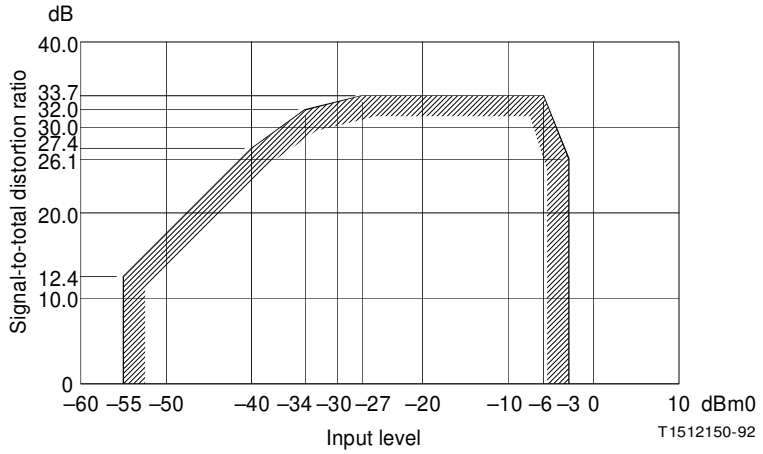
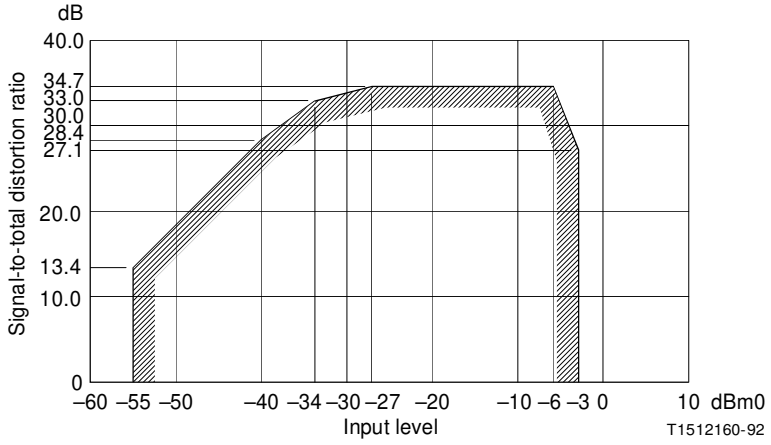


FIGURE A-9/G.712

Signal-to-total distortion ratio as a function of input level for 2-wire analogue-to-digital encoding side (E2 $_{in}$ to T $_{out}$)



Note – The values in the mask include the distortion power of an ideal encoder.

FIGURE A-10/G.712

Signal-to-total distortion ratio as a function of input level for 2-wire analogue-to-digital decoding side (T_{in} to E2 $_{out}$)

ANNEX B

(to Recommendation G.712)

Method of derivation of the signal-to-total distortion ratio for the A-law

The signal-to-quantizing distortion ratio produced by PCM systems can be obtained analytically in a number of different ways. The method adopted here is a special case of a more general analysis which enables the calculated results to be compared directly with those obtained by practical measurements of the systems.

The compression characteristic of the system is assumed to be "ideal", i.e. to meet precisely the theoretical segmented law, with the system a.c. zero coincident with the centre decision amplitude. The input signal is assumed to be symmetrical about a.c. zero, and to have a Gaussian distribution of instantaneous amplitudes. For a given input, of variance σ_v^2, the total output variance may be determined as σ_u^2 and the variance of the signal content in the output, by linear regression, as $m^2\,\sigma_v^2$ where m is the slope of the regression line of output on input.

The variance of the distorsion components is then $\sigma_\varepsilon^2 = \sigma_u^2 - m^2\,\sigma_v^2$, and the signal-to-quantizing distortion ratio in dB is:

$$10 \log_{10} \frac{m^2\ \sigma_v^2}{\sigma_\varepsilon^2}$$

The limits Figure A-5/G.712, which refer to *total* distortion, have been derived from the theoretical values of signal-to-*quantizing* distortion for A-law coding by subtracting 4.5 dB. In this way, practical imperfections of codecs as well as a certain amount of noise are taken into account. (Actually, the subtraction of 4.5 dB was applied to the break-points of the tolerance scheme in Figure A-5/G.712.)

ANNEX C

(to Recommendation G.712)

Alphabetical list of abbreviations used in this Recommendation

DXC Digital cross-connect

FDM Frequency division multiplex

FEXT Far-end crosstalk

NEXT Near-end crosstalk

PCM Pulse code modulation

SL Stability loss

TBRL Terminal balance return loss