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# G.712

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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,  
DIGITAL SYSTEMS AND NETWORKS

Digital transmission systems – Terminal equipments –  
Coding of analogue signals by pulse code modulation

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## **Transmission performance characteristics of pulse code modulation channels**

ITU-T Recommendation G.712

(Previously CCITT Recommendation)

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## **ITU-T RECOMMENDATION G.712**

### **TRANSMISSION PERFORMANCE CHARACTERISTICS OF PULSE CODE MODULATION CHANNELS**

#### **Summary**

This Recommendation deals with the transmission performance characteristics of PCM channels of 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. 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.

#### **Source**

ITU-T Recommendation G.712 was revised by ITU-T Study Group 15 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 8th of November 1996.

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## **Recommendation G.712<sup>1</sup>**

### **TRANSMISSION PERFORMANCE CHARACTERISTICS OF PULSE CODE MODULATION CHANNELS**

*(revised in 1996)*

#### **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).

Line current is not normally to be expected at the ports of the PCM equipment. If "line current" is nevertheless present, as the case when Signalling takes place on the two wires, any noise it contributes should meet requirements at the appropriate interface as described in the Q.550-Series of Recommendations. The limits should be met when any Signalling function is in the normal speaking condition, but excluding any dynamic Signalling conditions, e.g. metering.

##### **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 subclauses, the concepts of a "standard digital generator" and "a standard digital analyser" should be assumed and these are defined as follows.

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<sup>1</sup> 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 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.

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  $\mu$ -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.

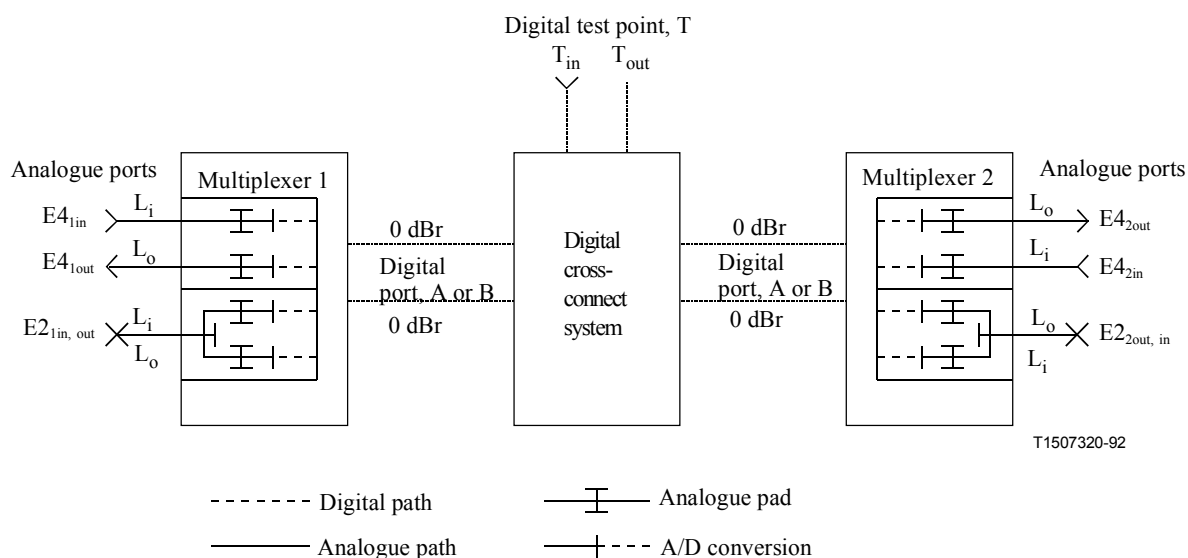
Figure 1 shows two PCM equipments connected via a digital cross-connect (DXC) system. Each PCM equipment is shown to have a 4-wire analogue voice-frequency port, E4, and a 2-wire analogue voice-frequency port, E2. Each of the PCM equipment is connected to the DXC by digital ports A or B, which consists 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 ( $E2_{in}$  to  $E2_{out}$  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 is similar to Figure 1/Q.551, which identifies interfaces, 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<sup>2</sup>.



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 <sub>1</sub> to E4 <sub>2</sub> channels)	G.712
2-wire analogue to 2-wire analogue (E2 <sub>1</sub> to E2 <sub>2</sub> 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

### 1.3 Abbreviations

This Recommendation uses the following abbreviations:

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

<sup>2</sup> References to specific clauses of other Recommendations are valid for their *Blue Book* editions.

## **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 clause 11/G.232.

### **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 subclause are different from the requirements in 2.1.4/Q.552.

## **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  $0 \text{ dBm0} \pm 0.3 \text{ dB}$  for 4-wire ports ( $T_{in}$  to  $E4_{out}$ ) or an output level of  $0 \text{ dBm0} \pm 0.4 \text{ dB}$  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  $0 \text{ dBm0} \pm 0.3 \text{ dB}$  for 4-wire ports ( $E4_{in}$  to  $T_{out}$ ) or an output level of  $0 \text{ dBm0} \pm 0.4 \text{ dB}$  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 the maximum value of  $T_{out}$  ( $=T_{outmax}$ ), 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.  $T_{outmax}$  is taken as being 0.3 dB greater than the measured input level.

This method allows  $T_{outmax}$  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.  $+3.14 \text{ dBm0}$  for the A-law or  $+3.17 \text{ dBm0}$  for the  $\mu$ -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 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 ( $E_{4in}$ to $E_{4out}$ )	$\pm 0.2$ dB	$\pm 0.5$ dB	
2-wire to 2-wire ( $E_{2in}$ to $E_{2out}$ )	$\pm 0.2$	$\pm 0.6$	
4-wire to digital ( $E_{4in}$ to $T_{out}$ )	$\pm 0.1$	$\pm 0.3$	
Digital to 4-wire ( $T_{in}$ to $E_{4out}$ )	$\pm 0.1$	$\pm 0.3$	(Note)
2-wire to digital ( $E_{2in}$ to $T_{out}$ )	$\pm 0.1$	$\pm 0.3$	
Digital to 2-wire ( $T_{in}$ to $E_{2out}$ )	$\pm 0.1$	$\pm 0.3$	(Note)
NOTE – The 0 dBm0 sequence of 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,  $E_{4in}$  and  $E_{4out}$ , should be  $600\ \Omega$ , balanced.

For 2-wire voice frequency ports,  $E_2$ , no single value of impedance is recommended. The following values can be found in practice:

- $600\ \Omega$  resistive, balanced;
- $900\ \Omega$  resistive, balanced;
- $600\ \Omega + 2.16\ \mu\text{F}$ , balanced;
- $900\ \Omega + 2.16\ \mu\text{F}$ , balanced.

NOTE 1 – Some examples of complex impedances used in connection with subscriber lines can be found in 2.2.1/Q.592.

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

### 5.2 Return loss

The return loss, measured against the nominal impedance, should meet the return loss requirements shown in Table 3 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 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 clause 5/G.121.)			

## 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). The value of  $Z$  in the driving test circuit should be within  $\pm 20\%$  of the values shown in Tables 4 and 5. The termination at the other port shall be the nominal characteristic impedance.

### 6.1 Longitudinal conversion loss

The longitudinal conversion loss (see 2.1/0.9) should not be less than the limits in Table 4.

**Table 4/G.712 – Longitudinal conversion loss requirements for E4 and E2 ports**

Measured port	$Z$ ( $\Omega$ )	Longitudinal conversion loss requirement			Notes
		300 Hz to 600 Hz	600 Hz to 2400 Hz	2400 Hz to 3400 Hz	
4-wire, E4 <sub>in</sub>	600	> 46 dB	> 46 dB	> 41 dB	1, 2
4-wire, E4 <sub>out</sub>	600	> 46	> 46	> 41	1, 2
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 clause 3/O.9, 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 – For frequencies below 300 Hz, in particular at 50 Hz or 60 Hz, 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.					

## 6.2 Longitudinal conversion transfer loss

The difference between the longitudinal conversion transfer loss (see 2.3/O.9) at the specified frequencies and the insertion loss at the same frequencies should not be less than the limits in Table 5 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	<i>Z</i> (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 <sub>1in</sub> to E4 <sub>2out</sub>	600	>46 dB	>46 dB	>41 dB	1, 2
2-wire, E2 <sub>1in</sub> to E2 <sub>2out</sub>	600	>40	>46	>41	1, 2, 3, 4
NOTE – See Notes to Table 4.					

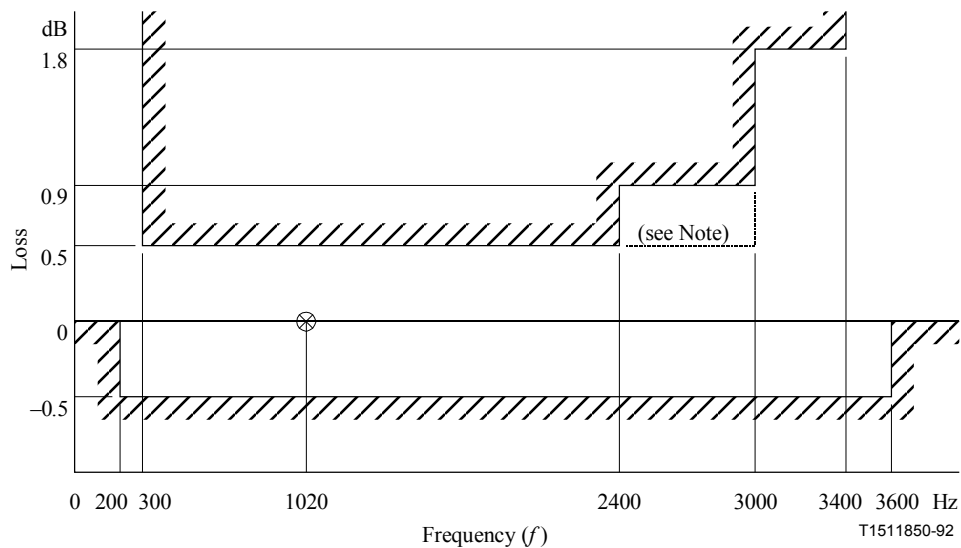
## 7 Attenuation/frequency distortion

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

The nominal reference frequency is 1020 Hz.

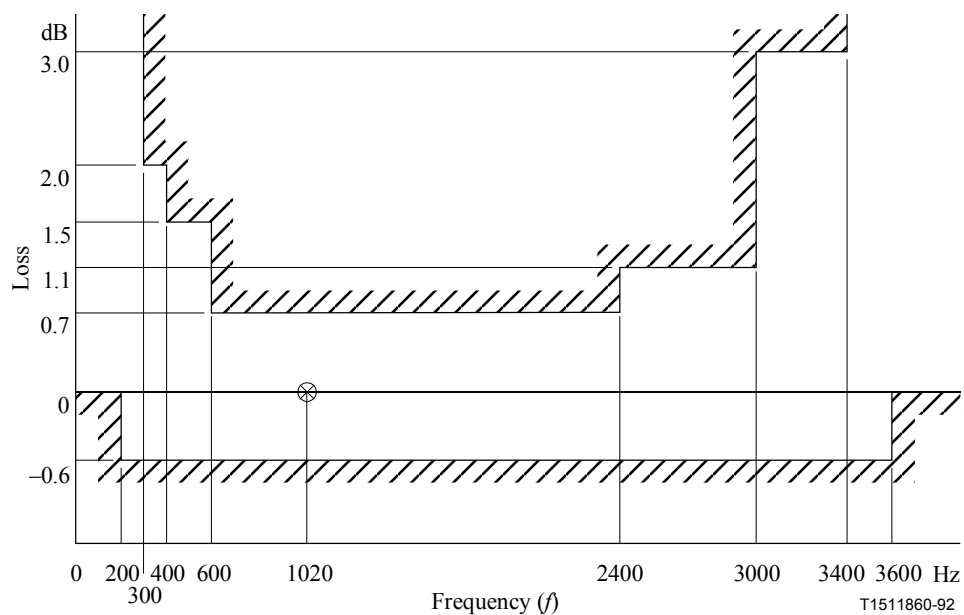
The preferred input power level is –10 dBm<sub>0</sub>, in accordance with Recommendation O.6. As an alternative, a level of 0 dBm<sub>0</sub> may be used. If complex nominal impedances are used at 2-wire analogue ports, the attenuation/frequency distortion is the logarithmic ratio of output voltage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

$$\text{Attenuation/frequency distortion} = 20 \log (U(1020 \text{ Hz}) / U(f)).$$



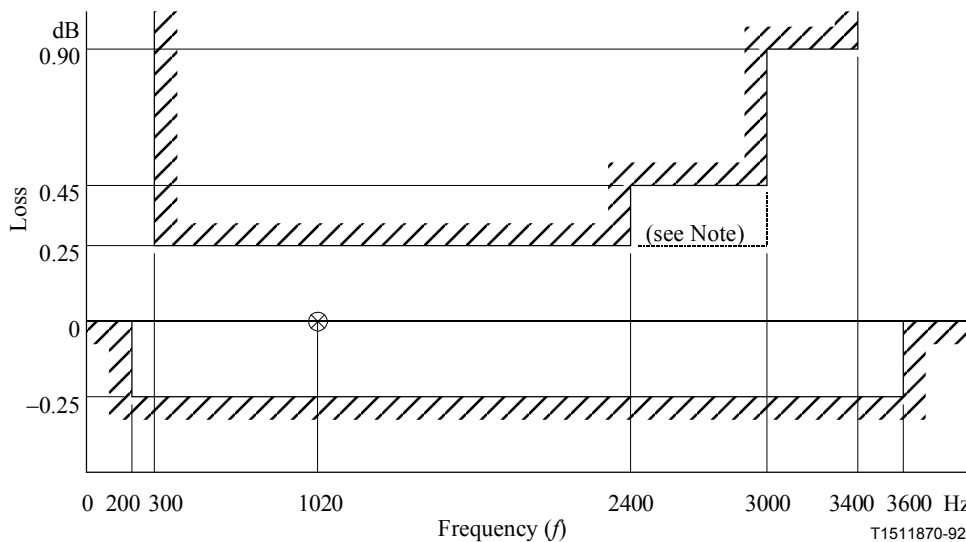
NOTE – In some applications in which several PCM channels may be connected in tandem, it may be necessary to extend the +0.5 dB limit from 2400 Hz to 3000 Hz.

**Figure 2/G.712 – Attenuation/frequency distortion for analogue-to-analogue channels between 4-wire ports ( $E4_{1in}$  to  $E4_{2out}$ )**



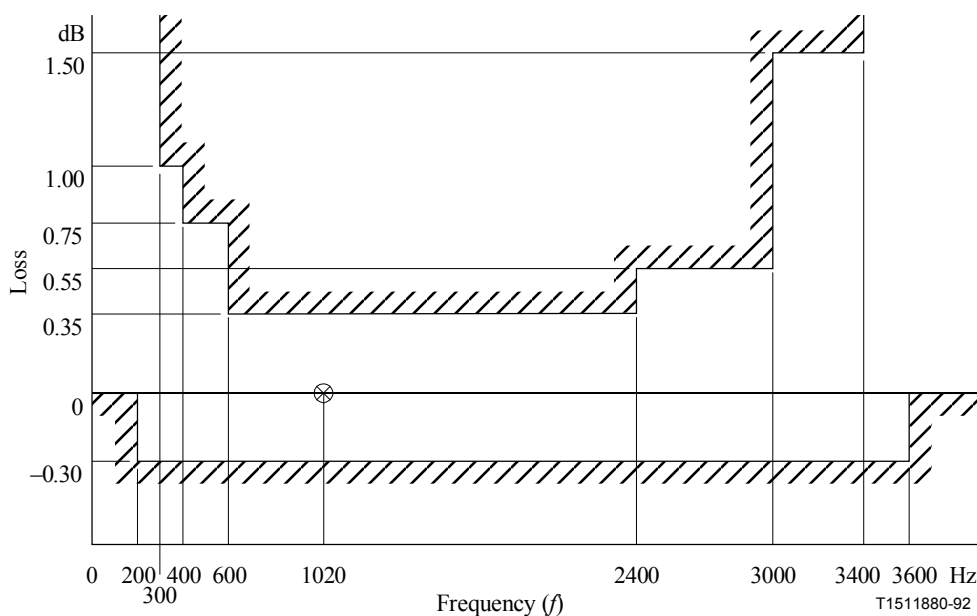
NOTE – Some Administrations apply a limit of 1 dB maximum loss for the frequency range 300 Hz to 3000 Hz.

**Figure 3/G.712 – Attenuation/frequency distortion for analogue-to-analogue channels between 2-wire ports ( $E2_{1in}$  to  $E2_{2out}$ )**



NOTE – In some applications in which several PCM channels may be connected in tandem, it may be necessary to extend the +0.25 dB limit from 2400 Hz to 3000 Hz.

**Figure 4/G.712 – Attenuation/frequency distortion for 4-wire analogue-to-digital channels ( $E4_{in}$  to  $T_{out}$  or  $T_{in}$  to  $E4_{out}$ )**



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 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.

## 8.1 Absolute group delay

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

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.

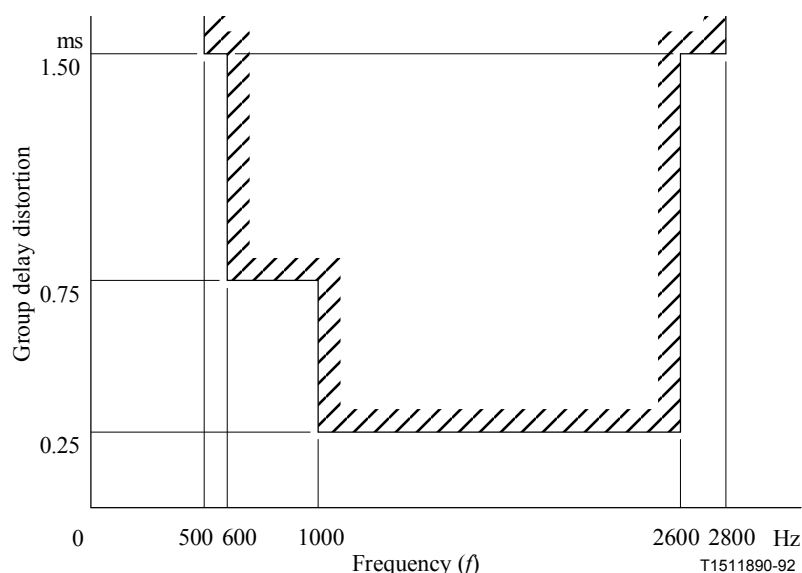
**Table 6/G.712 – Requirements for absolute group delay**

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 $A_{out}$ or $B_{out}$ )	< 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

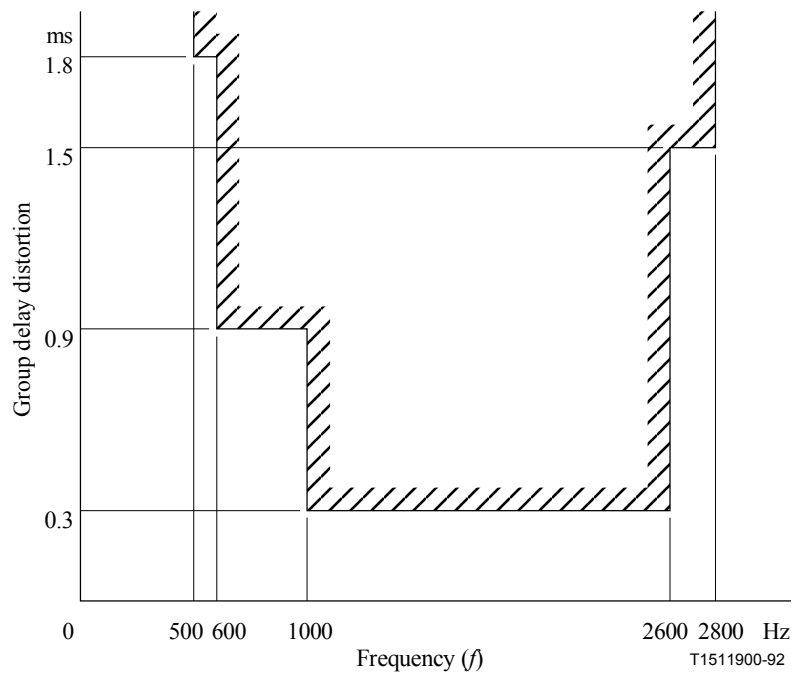
The group delay distortion should lie within the limits shown in the mask of Figures 6, 7, 8, or 9.

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

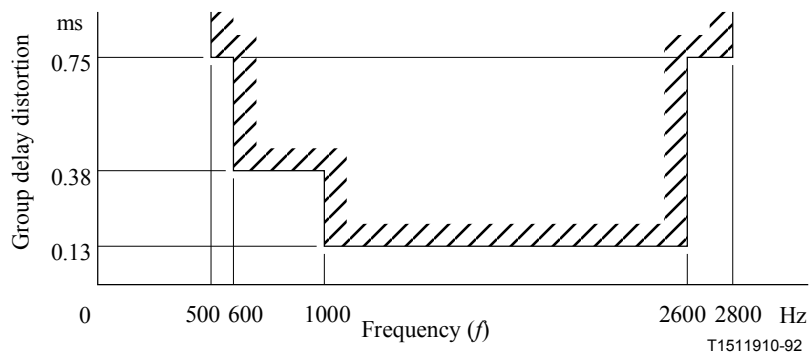


**Figure 6/G.712 – Group delay distortion with frequency for analogue-to-analogue channels between 4-wire ports ( $E4_{1in}$  to  $E4_{2out}$ )**

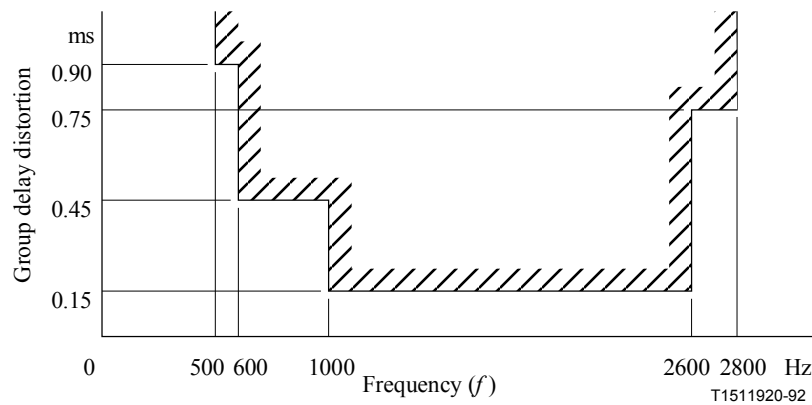




**Figure 7/G.712 – Group delay distortion with frequency for analogue-to-analogue channels between 2-wire ports ( $E2_{1in}$  to  $E2_{2out}$ )**



**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.

**Table 7/G.712 – Requirements for weighted idle channel noise**

Port terminated	Port measured	Weighted noise limit	Notes
4-wire analogue, $E4_{lin}$	4-wire analogue, $E4_{2out}$	$< -65$ dBm0p	
2-wire analogue, $E2_{lin}$	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. 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  $\mu$ -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/G.100).

## **9.2 Single frequency interference**

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.

## **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.

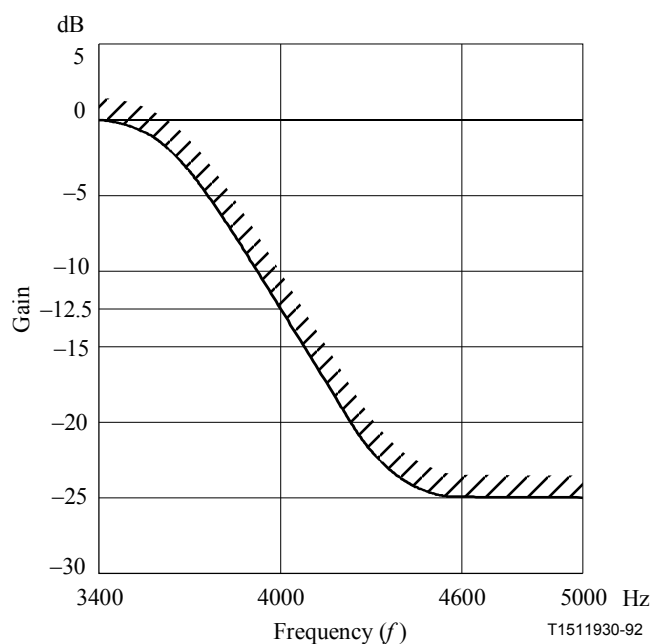
NOTE 2 – Overall rejection of longitudinal interference can be achieved by a combination of good longitudinal balancing (see clause 6) and high pass filtering.

### **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 10.1 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 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:

$$G = 12.5 \left[ \sin \frac{\pi(400 - f)}{1200} - 1 \right] \text{ dB}$$

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 dBm<sub>0</sub> 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 dBm<sub>0</sub>.

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 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 dBm<sub>0</sub> 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 11.1.1 should be met.

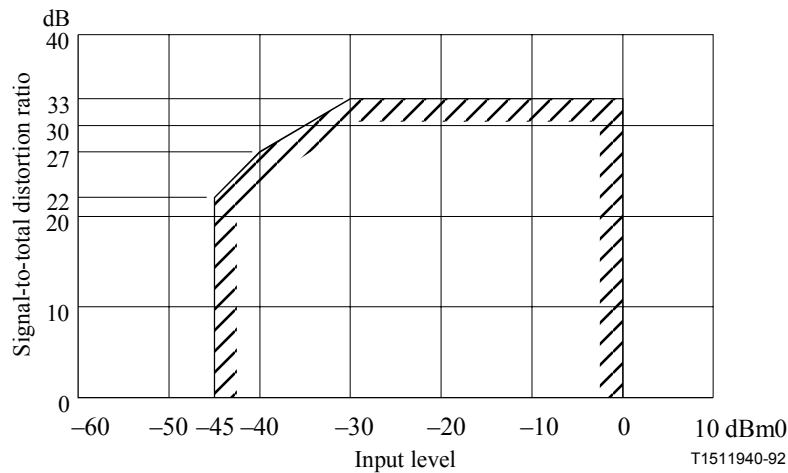
## 11.2 Spurious in-band signals at the channel output port

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 ( $E_{4\text{in}}$  or  $E_{2\text{in}}$ ), 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 ( $E_{4\text{out}}$  or  $E_{2\text{out}}$ ), should be less than – 40 dBm0.

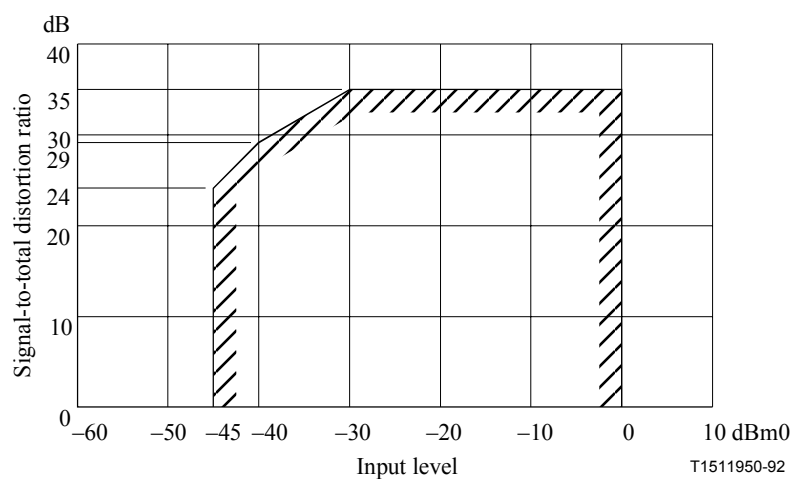
## 12 Total distortion, including quantizing distortion

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 and 12.

NOTE – A method based on a noise test signal is in use. This method, which is described in Appendix I, 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 ( $E_{4\text{in}}$  to  $E_{4\text{out}}$  and  $E_{2\text{in}}$  to  $E_{2\text{out}}$ )**

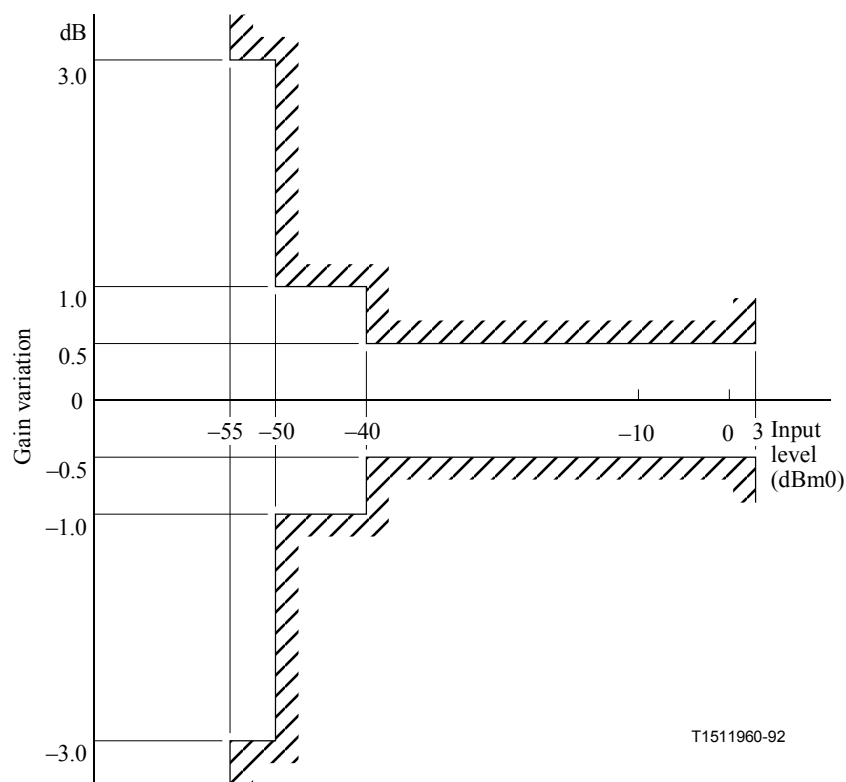


**Figure 12/G.712 – Signal-to-total distortion ratio as a function of input level  
for analogue-to-digital channels  
( $E_{4in}$  to  $T_{out}$ ,  $T_{in}$  to  $E_{4out}$ ,  $E_{2in}$  to  $T_{out}$  and  $T_{in}$  to  $E_{2out}$ )**

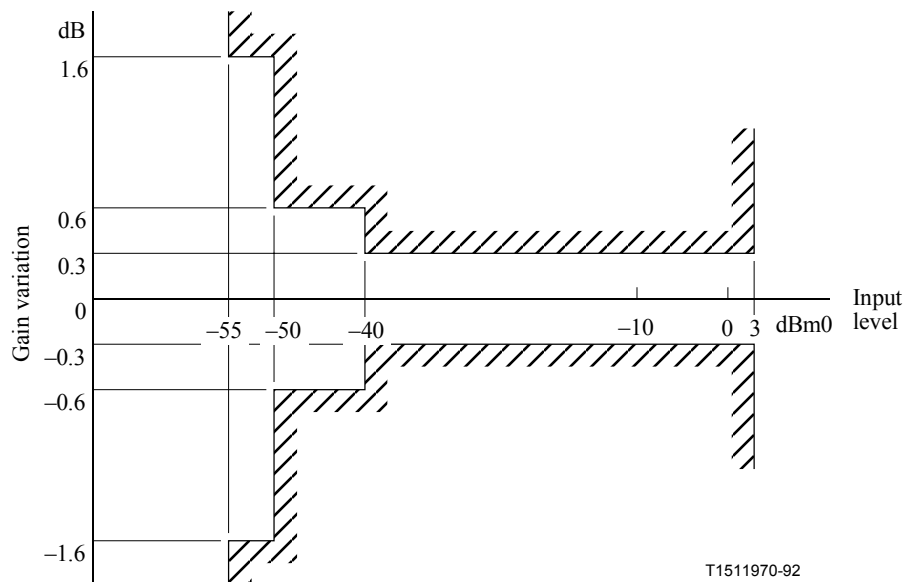
### 13 Variation of gain with input level

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 or 14.

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



**Figure 13/G.712 – Variation of gain with input level for analogue  
4-wire to 4-wire and 2-wire to 2-wire channels  
( $E_{4in}$  to  $E_{4out}$  and  $E_{2in}$  to  $E_{2out}$ )**



**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 to 21. These signals are:

- the quiet code, i.e. a PCM signal corresponding to decoder output value number 0 ( $\mu$ -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

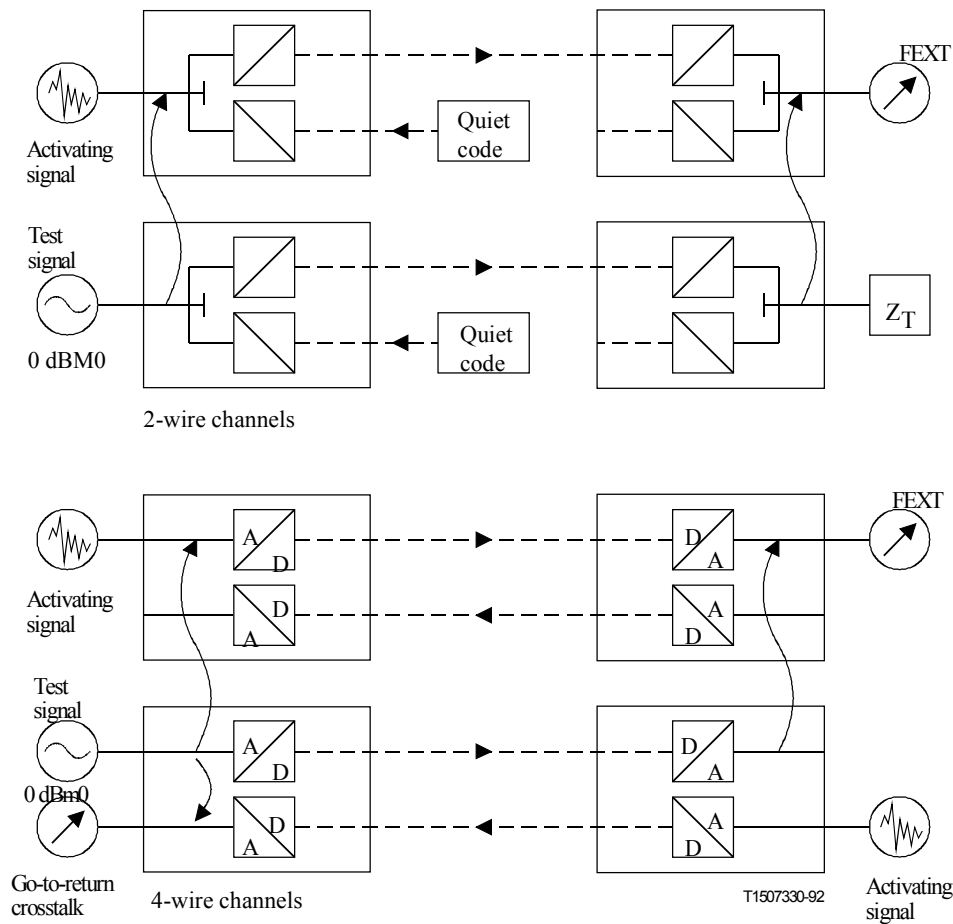
#### 14.2.1 Far-end crosstalk measured with analogue test signal

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 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.



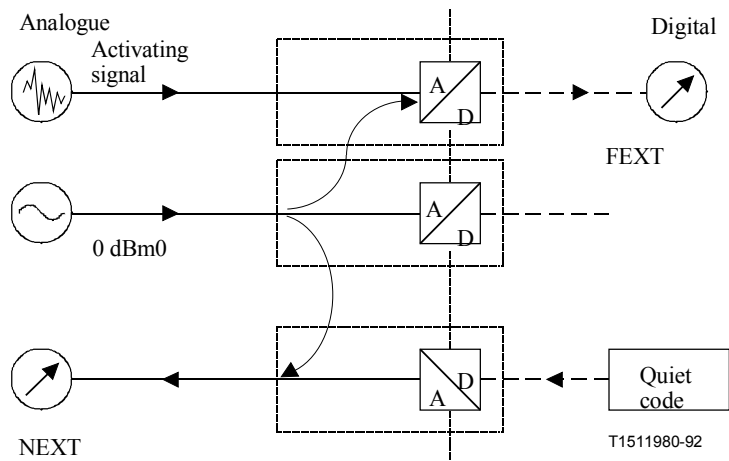


**Figure 15/G.712 – Measurement of crosstalk between two channels**

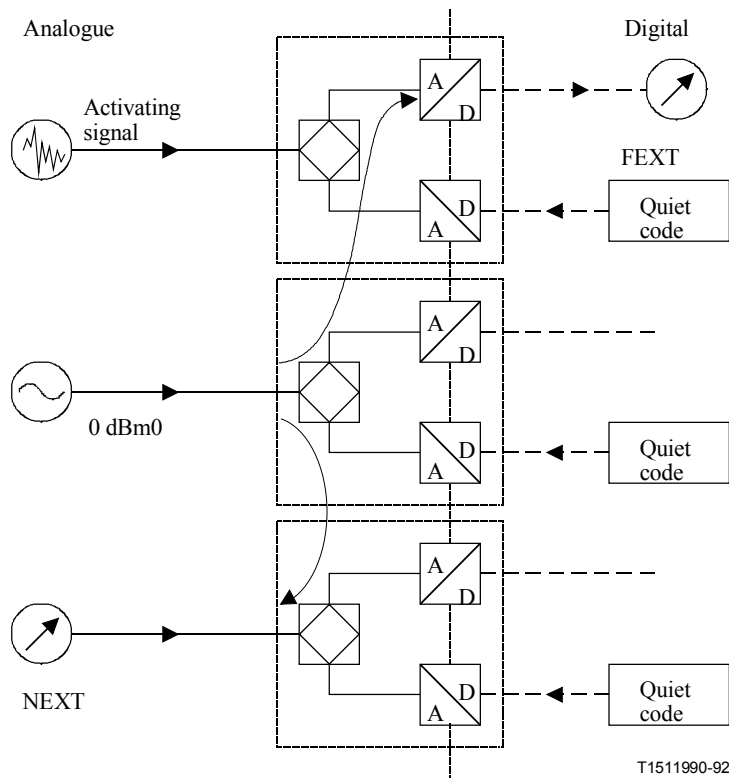
### 14.3 Crosstalk measurements of individual primary multiplexers

#### 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 Figures 16 and 17 for measurements of 4-wire and 2-wire channels respectively.



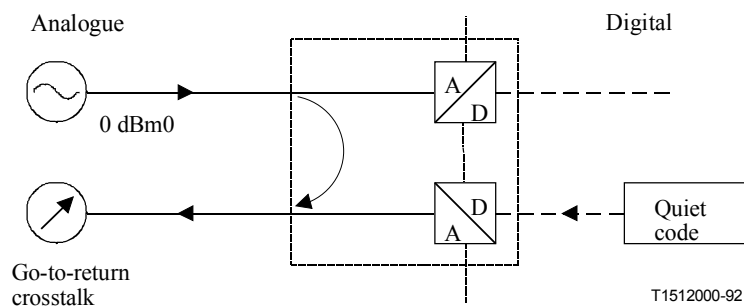
**Figure 16/G.712 – FEXT and NEXT measurements with analogue test signal for channels with 4-wire (E4) ports**



**Figure 17/G.712 – FEXT and NEXT measurements with analogue test signal for channels with 2-wire (E2) ports**

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

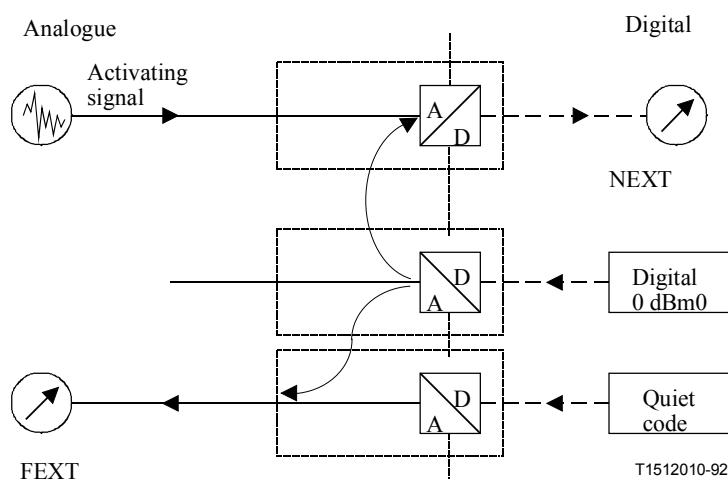
The crosstalk between a channel and its associated return channel should be such that with a sine-wave signal at any frequency in the range 300 Hz to 3400 Hz and at a level of 0 dBm0 applied to an input port, the crosstalk level measured at the output of the corresponding return channel should not exceed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



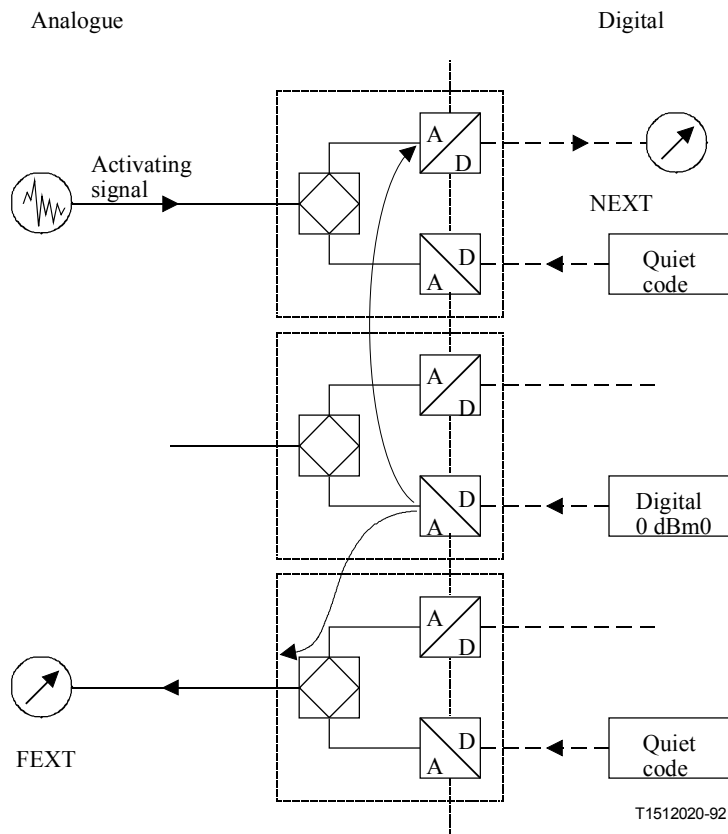
**Figure 18/G.712 – Go-to-return crosstalk measurements on 4-wire (E4) ports with analogue test signal**

### 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 for Far-End crosstalk (FEXT). See Figures 19 and 20 for measurements of 4-wire and 2-wire channels respectively.



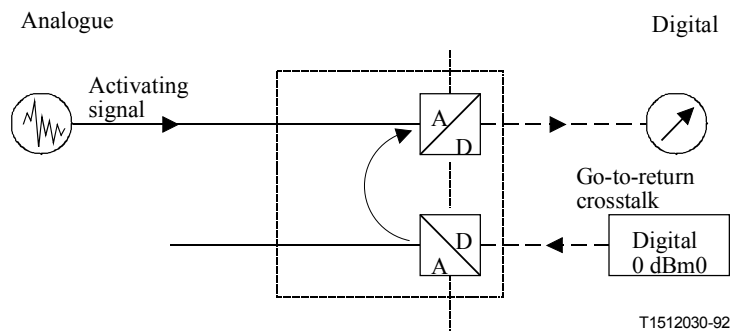
**Figure 19/G.712 – Measurements on 4-wire (E4) ports with digital test signal between different channels**



**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.



**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

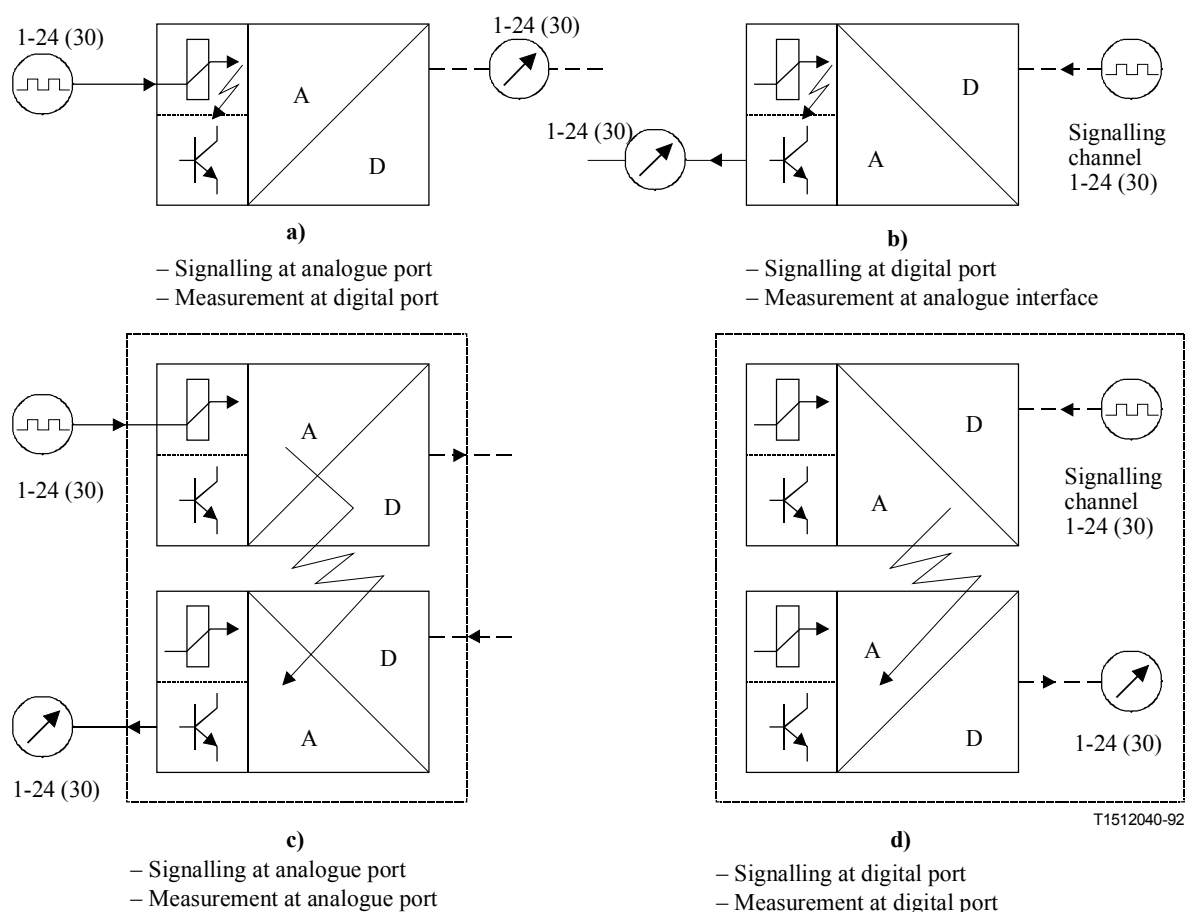
The maximum level of any interference into a channel should not exceed  $-60$  dBm<sub>0p</sub> when signalling (10 Hz signal with a 50/50 duty ratio to simulate dial pulsing) is active simultaneously on all other channels.

### 15.2 2-wire analogue to 2-wire analogue channels

The maximum level of any interference into a channel should not exceed  $-50$  dBm<sub>0p</sub> when signalling (10 Hz signal with a 50/50 duty ratio to simulate dial pulsing) 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). In each case, the maximum level of interference in one channel should not exceed  $-63$  dBm<sub>0p</sub> when signalling (10 Hz signal with a 50/50 duty ratio to simulate dial pulsing) 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, configurations **a**) and **b**)]. In each case, the maximum level of interference in one channel should not exceed  $-53$  dBm0p when signalling (10 Hz signal with a 50/50 duty ratio to simulate dial pulsing) is active simultaneously on all other channels.

## 16 Echo and stability at 2-wire ports, E2

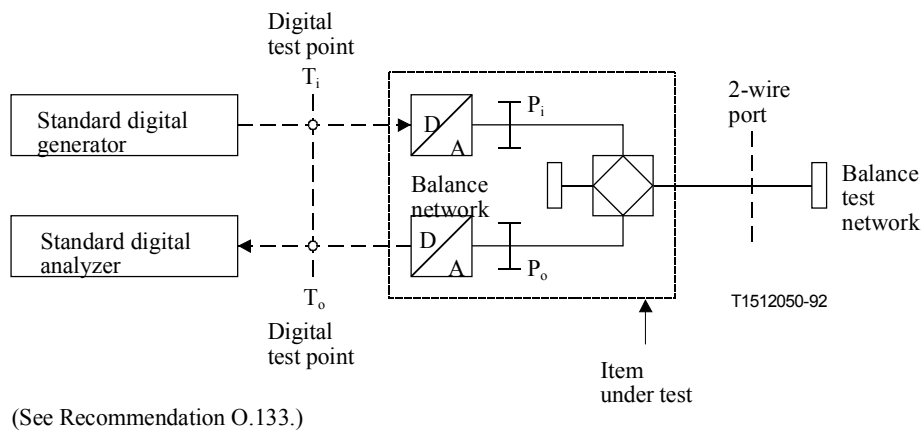
### 16.1 Terminal Balance Return Loss (TBRL)

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 3.1.8.1/Q.552) 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) as follows:

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

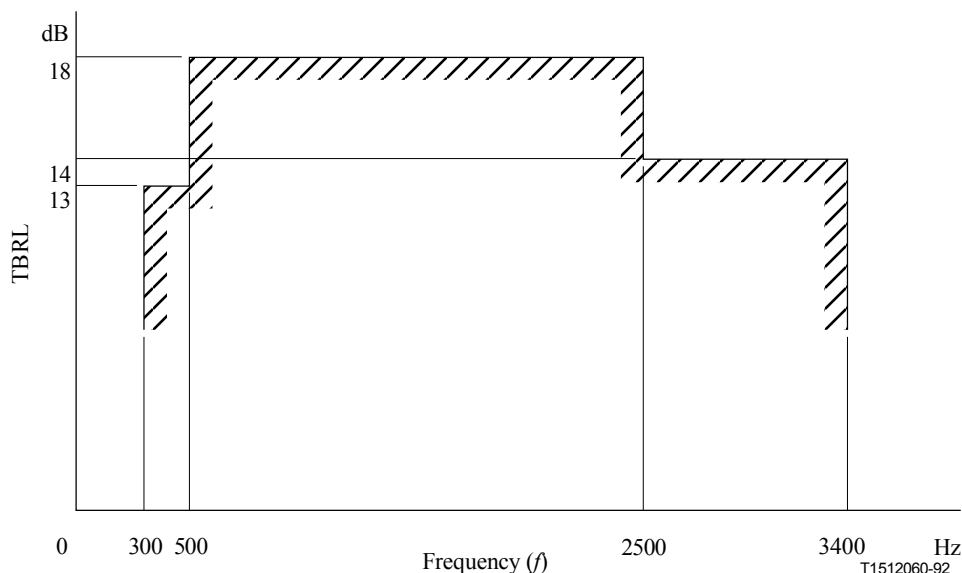
where  $P_i$  and  $P_o$  are the measured values of loss in the equivalent circuit of Figure 23 which represent all loss between the digital test point and the 2-wire point, or conversely, at the measurement frequency.

The TBRL should be measured in the arrangement of Figure 23 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 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  $a_{i0}$  measured in the arrangement of Figure 23. 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, an inductive termination to represent that worst case condition.

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

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

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.

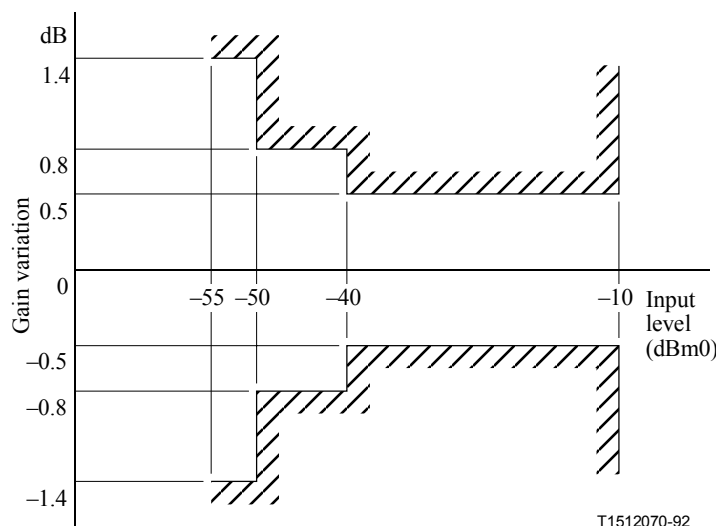
Administrations should choose the nominal values of  $P_i$  and  $P_o$  taking account of the value of  $X$  for their particular operating conditions and of national and international transmission plans for overall network stability (see Recommendation G.122).

## APPENDIX I

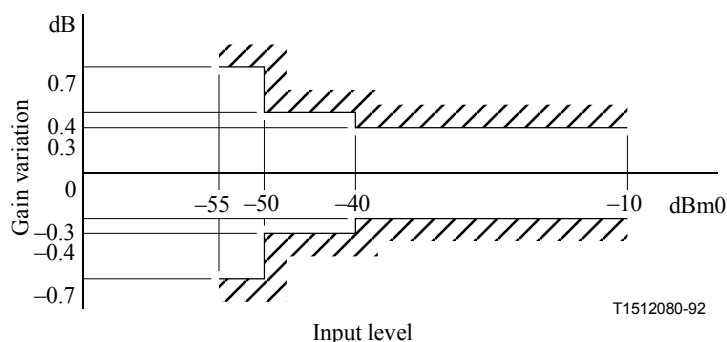
### Alternative measurements using band limited noise signals

#### I.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 I.1 or Figure I.2. The measurement should be limited to the frequency band 350 Hz to 550 Hz in accordance with the filter characteristic defined in 3.2.1/O.131.



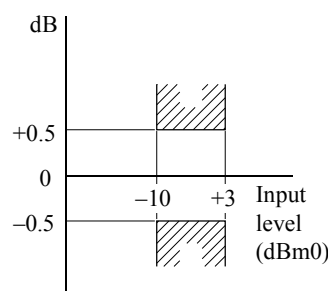
**Figure I.1/G.712 – Variation gain with input level for analogue-to-analogue channels between 4-wire ports ( $E4_{in}$  to  $E4_{out}$ ) or 2-wire ports ( $E2_{in}$  to  $E2_{out}$ )**



**Figure I.2/G.712 – Variation 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  $E2_{out}$ )**

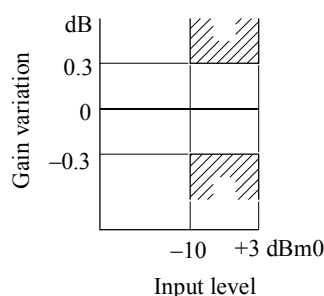
Furthermore, with a sine-wave signal at the nominal frequency of 1020 Hz applied to the input port of any channel at a level between  $-10$  dBm0 and  $+3$  dBm0, the gain variation of that channel relative to the gain at an input level of  $-10$  dBm0, should be within the limits of Figure I.3 or Figure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





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**Figure I.3/G.712 – Variation of gain with input level for analogue-to-analygue channels between 4-wire ports ( $E4_{in}$  to  $E4_{out}$ ) or 2-wire ports ( $E2_{in}$  to  $E2_{out}$ )**



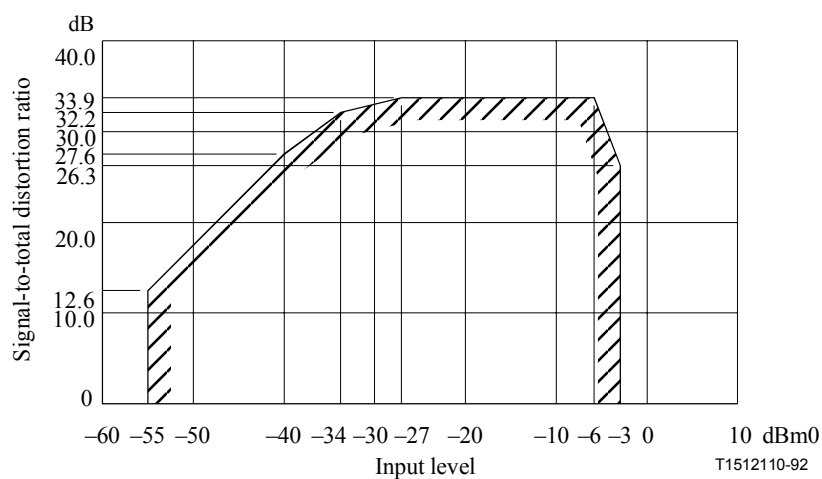
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**Figure I.4/G.712 – Variation of gain with input level for analogue-to-digital channels ( $E4_{in}$  to  $T_{out}$ ,  $T_{in}$  to  $E4_{out}$ ,  $E2_{in}$  to  $T_{out}$ , or  $T_{in}$  to  $E2_{out}$ )**

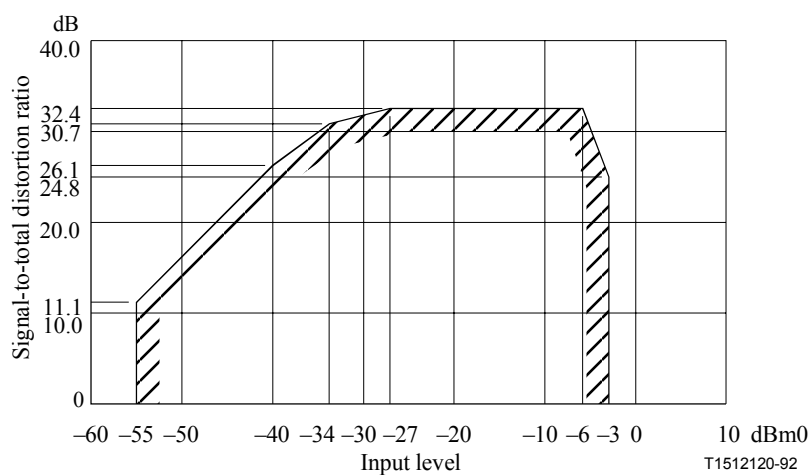
## I.2 Total distortion, including quantizing distortion

NOTE – Compared with the sine-wave test method recommended in clause 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.

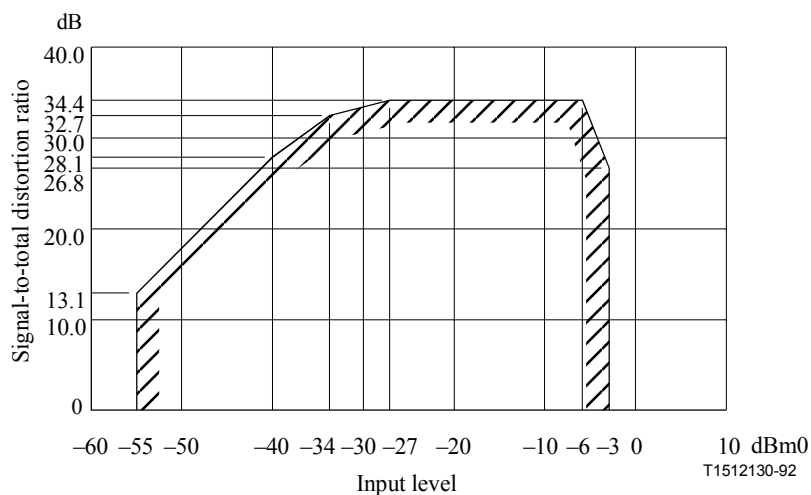
With a noise signal corresponding to Recommendation O.131 applied to the input port of a channel, the ratio of signal-to-total distortion power should lie above the limits shown in Figures I.5 through I.10.



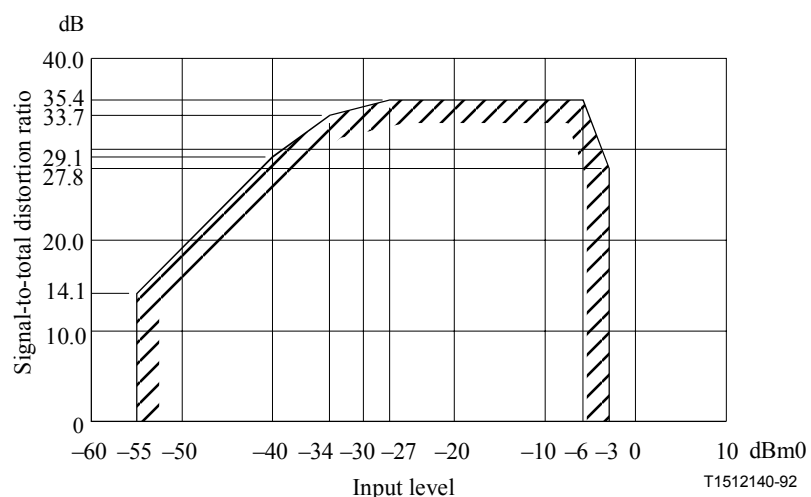
**Figure I.5/G.712 – Signal-to-total distortion ratio as a function of input level for 4-wire analogue-to-analogue connections (E4<sub>1in</sub> to E4<sub>2out</sub>)**



**Figure I.6/G.712 – Signal-to-total distortion ratio as a function of input level for 2-wire analogue-to-analogue connections (E2<sub>1in</sub> to E2<sub>2out</sub>)**

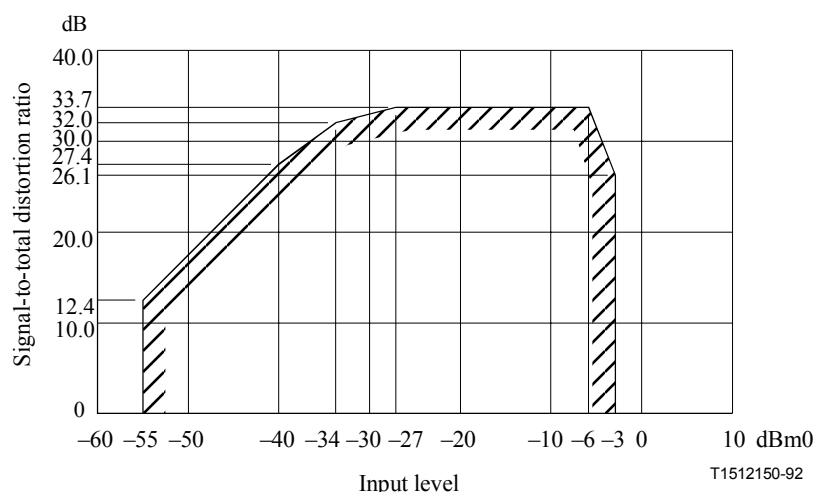


**Figure I.7/G.712 – Signal-to-total distortion ratio as a function of input level for 4-wire analogue-to-digital encoding side ( $E_{4in}$  to  $T_{out}$ )**

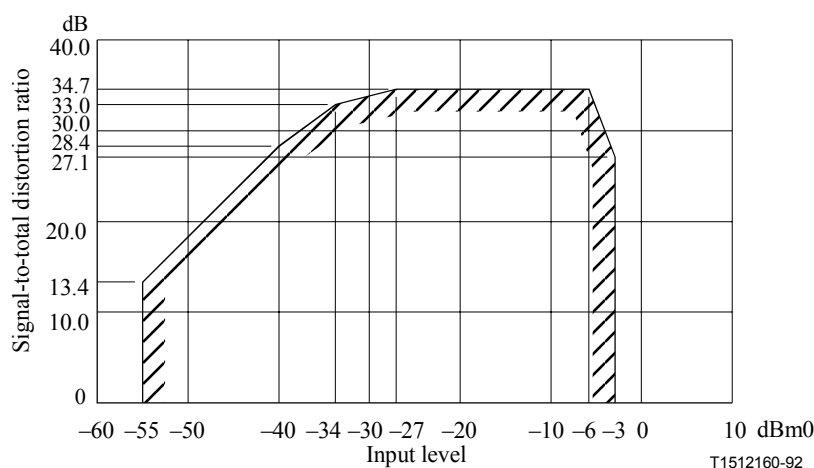


NOTE – The values in the mask include the distortion power of an ideal encoder.

**Figure I.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  $E_{4out}$ )**



**Figure I.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 I.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  $E2_{out}$ )**

## APPENDIX II

### 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  $\sigma_v^2$ , the total output variance may be

determined as  $\sigma_u^2$  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 distortion 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 of Figure I.5, 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 I.5.)



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