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SECTION 5

EQUIPMENT FOR THE MEASUREMENT OF

DIGITAL AND ANALOGUE/DIGITAL PARAMETERS

Recommendation O.131

QUANTIZING DISTORSION MEASURING EQUIPMENT USING

A PSEUDO-RANDOM NOISE TEST SIGNAL

(Geneva, 1976; amended at Geneva, 1980, and at Melbourne, 1988)

1 Preamble

It is important that the characteristics of quantizing distortion measuring apparatus are specified with sufficient precision to ensure that all future designs of measuring apparatus conforming to the recommended specification shall be compatible with one another, i.e., they shall be capacble of interworking and give results of specified accuracy without the need for any special procedures or corrections to the measurements results. It is considered equally important that all designs of measuring apparatus conforming to the recommended specification shall be capable of interworking with existing designs of measuring apparatus already in use by various Administrations, who will thus not be placed at any economic disadvantage. The following specification is based on the proposals studied by Study Group XVIII and is specifically aimed at the foregoing compatibility objectives.

Note — The question of interworking between existing designs of quantizing distortion measuring apparatus is not, in itself, directly relevant to this specification, but it is worth recording that this topic has been studied by the Federal Republic of Germany and the United Kingdom Post Office. Satisfactory rules have been established to facilitate interworking between the different existing types of measuring apparatus which use a band-limited pseudo-random noise source.

2 Testing method proposed

The method proposed is that described in Method 1 in § 9 of Recommendation G.712 [1]. The proposed noise source is band-limited pseudo-random noise having a probability density distribution of amplitudes which is substantially near to a Gaussian distribution

The signal-to-total distortion power, including quantizing distortion, is measured as the ratio of the power of received stimulus in the reference band, to the noise power in the measured band. A correction is included to relate the measurement to the full PCM speech channel bandwidth

The receive measuring apparatus specified in § 3.2 may also be used to measure quantizing distortion using a sinusoidal test signal in the frequency range 350-550 Hz (preferably at 420 ± 20 Hz) instead of the pseudo-random noise stimulus. It should be noted, however, that while the measurement is similar to Method 2 described in Recommendation G.712 [1], the obtained measurement results are related to a bandwidth of 3.1 kHz and that no noise weighting is provided. It should also be noted that results given by the pseudo-random noise and sinusoidal methods may not be the same.

The principle of the measurement is illustrated in Figure 1/O.131.

Figure 1/O.131, p.

3 Basic specification clauses

3.1 *Send*

The sending signal is a band-limited pseudo-random noise having the following characteristics:

3.1.1 *Band limited noise stimulus*

Approximately Gaussian distribution of the amplitudes within the bandwidth of the send filter. The bandwidth can have any value from 100 Hz to 200 Hz between the 3-dB points (see §§ 3.1.4 and 3.1.5 below).

3.1.2 *Number of spectral lines*

Not less than 25 spectral lines with a spacing not greater than 8 Hz measured at the output of the send filter.

3.1.3 *Peak-to-r.m.s. ratio*

10.5 dB. Tolerance ± | .5 dB.

Note 1 — The requirements according to §§ 3.1.1 to 3.1.3 above may be accomplished by a noise stimulus derived from the output of a 17-stage shift register with exclusive OR gating with the outputs of stages 3 and 17 returned to the input of stage 1. The shift register produces a maximally long sequence of $(2^{17} — 1)$ bits.

The shift register is driven at a clock frequency f_c Hz such that the spectral line spacing f_s Hz of the output signal is less than or equal to 8 Hz.

In order to meet the specified limits of the peak-to-r.m.s. ratio of the sent signal as given in § 3.1.3 above, the clock frequency can be adjusted to:

$$f_c = f_s \,(2^{17} — 1) \text{ Hz}$$

To keep the peak factor within the specified limits, a stability of the clock frequency f_c on the order of 1% is required.

Note 2 — Instead of using a shift register to generate the noise signal, other principles may be adopted as long as the generated signal has the characteristics recommended in §§ 3.1.1 and 3.1.3 above.

3.1.4 *Frequency position of sent signal*

Between 350 and 550 Hz.

3.1.5 *Sending filter characteristics*

The attenuation of the bandpass filter with reference to minimum attenuations should be as follows:

not lower than 350 Hz	3 dB point at lower frequency
not exceeding 550 Hz	3 dB point at upper frequency
below 250 Hz	greater than 55 dB
at 300 Hz	greater than 20 dB
at 580 Hz	greater than 6 dB
at 650 Hz	greater than 20 dB
at 700 Hz	greater than 40 dB
at 750 Hz	greater than 50 dB
at and above 800 Hz	greater than 60 dB

The response characteristic of a filter designed to these limits should give a bandwidth between 3-dB points of at least 100 Hz.

The performance requirements for the sending filter characteristics conforming to the above limits is given in Figure 2/O.131.

3.1.6 *Sending reference level range*

0 dBm0 to at least —55 dBm0 for relative levels according to Recommendation G.232, § 11 [2] with a setting accuracy of ± | .5 dB.

3.1.7 *Output impedance* | frequency range 300 Hz to 4 kHz)

— Balanced, earth free (other impedances optional) 600 ohms — Return loss ≥" 30 dB — Output signal balance ≥" 40 dB

3.2 *Receive*

3.2.1 *Receive reference filter*

Nominal bandwidth of reference path 350-550 Hz. (See Note below).

The characteristic of the filter is chosen to prevent inaccuracy in the measurement of the received noise stimulus in the presence of quantizing distortion and other system noise conditions. The filter should not diminish the power of a noise band between 350 Hz and 550 Hz by more than 0.25 dB.

Figure 2/O.131, p.

Note — The receive reference filter ideally restricts the bandwidth of the reference path to respond only to the spectrum of the received noise stimulus. However, the bandwidth of 350-550 Hz is chosen to allow for the need to interwork with test apparatus having a noise source bandwidth of up to 200 Hz.

3.2.2 *Bandwidth of measuring path*

At least 2.4 kHz (with a loss variation of less than 2 dB). The required bandpass characteristic of the filters for measurement of distortion products is indicated below and is such that received noise stimulus does not affect measurements. Attenuation with reference to the minimum attenuation:

150 Hz and below	greater than 60 dB
650 Hz	greater than 55 dB
700 Hz	greater than 35 dB
750 Hz	greater than 20 dB
800 Hz	3 dB or greater
3.4 kHz	3 dB or greater
3.5 kHz	greater than 10 dB
3.6 kHz	greater than 20 dB
3.7 kHz	greater than 40 dB
3.75 kHz	greater than 50 dB
5.0 kHz and above	greater than 60 dB

The performance requirements for the measurement filter characteristic conforming to the above limits is given in Figure 3/O.131.

Figure 3/O.131, p.

3.2.3 *Bandwidth correction*

The calibration of the test apparatus shall include a correction factor of appropriate value to relate the signal to total distortion power measured to the total distortion power present in the full PCM channel bandwidth of 3100 Hz. The correction factor is given by the following expression, which assumes a uniform distribution of distortion power over the channel bandwidth:

$$10 \log_{10} \frac{100}{f I y} \text{ (dB)}$$

where *y* | s the effective noise bandwidth of the measuring filter in Hz.

3.2.4 *Input impedance*

— Balanced, earth free (other impedances optional) 600 ohms — Return loss ≥" 30 dB — Input longitudinal interference loss (below 4 kHz) ≥" 46 dB — Input longitudinal interference loss (at 40 Hz) ≥" 60 dB 3.2.5 *Input reference level range*

0 dBm0 to at least —55 dBm0 for relative levels according to Recommendation G.232 [2].

3.2.6 *Accuracy of the signal-to-total distortion ratio indication*

For reference levels in the range —6 dBm0 to —55 dBm0 and an absolute distortion signal not less than —72 dBm0:

— Measuring range 10 dB to 40 dB: Accuracy ± | .5 dB.

— Measuring range 0 dB to 10 dB: Accuracy ± | .0 dB.

For reference levels in the range 0 dBm0 to —6 dBm0:

— Measuring range 20 dB to 40 dB: Accuracy ± | .5 dB.

— Measuring range 0 dB to 20 dB: Accuracy ± | .0 dB.

Note 1 — These limits include the inaccuracies which are caused by:

— the effective bandwidth of the measuring filter,

— the receive reference filter,

— the attenuator in the measuring path,

— the characteristics of the indicating circuit.

Note 2 — For reference level ranges 0 dBm0 to —6 dBm0, the wider tolerances are not only required by the measuring apparatus but reflect also the characteristics of PCM coders and decoders when operated near the overload point.

4 Operating environment

The electrical performance requirements shall be met when operating at the climatic conditions as specified in Recommendation O.3, § 2.1.

References

[1] CCITT Recommendation *Performance characteristics of PCM channels between 4-wire interfaces at voice frequencies* , Vol. III, Rec. G.712.

[2] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232.

Recommendation O.132

QUANTIZING DISTORTION MEASURING EQUIPMENT USING A SINUSOIDAL TEST SIGNAL

(Geneva, 1980; amended at Melbourne, 1988)

1 Introduction

This specification gives basic clauses describing the essential features to be provided in test equipment using a sinusoidal test signal for quantizing distortion measurements on PCM channels important that the characteristics of quantizing distortion measuring apparatus of this type are sufficiently specified to ensure that they are capable of interworking and that they will give results of sufficient accuracy. This specification is based on a general statement of the method described as Method 2 in § 9 of Recommendation G.712 [1].

2 Testing method

The testing method consists of applying a sine-wave signal to the input port of a PCM channel and measuring the ratio of the received signal to distortion power, using the proper noise weighting (see § 3.3.4 below). The method also requires the use of a narrow-band rejection filter in the receiver equipment to block the sinusoidal test signal from the distortion measuring circuits so that the distortion power may be measured.

3 Specifications

3.1 *Test signal frequencies*

A test signal in either of two frequency bands may be required depending on the test-signal rejection filter being used to make the measurement. The preferred test frequencies are either 820 Hz or 1020 Hz. However, other frequencies in the rejection band of the test-signal rejection filter (such as 804 Hz or 850 Hz) may be used.

3.2 *Characteristics of the signal source*

3.2.1 *Signal level range*

At least —45 to +5 dBm0 for relative levels according to § 11 of Recommendation G.232 [2] with a setting accuracy of ± | .2 dB.

3.2.2 *Output impedance* | frequency range 300 Hz to 4 kHz)

— Balanced, earth free (other impedances optional) 600 ohms — Return loss ≥" 30 dB — Output signal balance ≥" 40 dB

3.2.3 Distortion and spurious modulation ratio ≥" | 0 dB 3.2.4 *Frequency accuracy and stability*

The accuracy and stability of the test signal frequency shall be appropriate to the frequency used and its position with respect to the rejection band of the filter concerned. The accuracy and stability must in any case be such that the frequency is never a submultiple of the PCM sampling rate.

3.3 *Characteristics of the measuring instrument*

3.3.1 *Measuring range and accuracy*

10 to 40 dB signal-to-distortion ratio with an accuracy of ± | .0 dB.

3.3.2 *Input signal range*

At least —55 to +5 dBm0 for relative levels according to § 11 of Recommendation G.232 [2].

3.3.3 *Input impedance* | frequency range 300 Hz to 4 kHz)

— Balanced, earth free (other impedances optional) 600 ohms — Return loss ≥" 30 dB — Input longitudinal interference loss (below 4 kHz) ≥" 46 dB — Input longitudinal interference loss (at 40 Hz) ≥" 60 dB 3.3.4 *Measuring filter*

The value of the distortion signal shall be weighted by the standard CCITT noise weighting filter for telephony (see Recommendation O.41). Alternatively, C-message weighting may be used (see Annex A to Recommendation O.41). A calibration correction factor may be necessary when C-message weighting is used. The manufacturing tolerances on the characteristics of these filters may have to be less than is permitted in their respective specifications, in order to achieve the measuring accuracy in § 3.3.1.

3.3.5 *Test-signal reject filter*

Either of two test-signal rejection filters may be provided, with characteristics as given in Table 1/O.132.

H.T. [T1.132]

TABLE 1/O.132

Test-signal reject filter characteristics

{ 804 to 850 Hz test-signal reject filter }	
Frequency	Loss
< 325 Hz	< 0.5 dB
< 570 Hz	< 1.0 dB
< 690 Hz	< 3.0 dB
800 to 855 Hz	> 50 dB (rejection band)
> 1000 Hz	< 3.0 dB
> 1105 Hz	< 1.0 dB
> 1360 Hz	< 0.5 dB
{ 100 to 1020 Hz test-signal reject filter }	
Frequency	Loss
< 400 Hz	< 0.5 dB
< 700 Hz	< 1.0 dB
< 860 Hz	< 3.0 dB
1000 to 1025 Hz	> 50 dB (rejection band)
> 1180 Hz	< 3.0 dB
> 1330 Hz	< 1.0 dB
> 1700 Hz	< 0.5 dB

Table 1/O.132 [T1.132], p.

3.3.6 *Detector characteristics*

An r.m.s. or quasi-r.m.s. detector having sufficient accuracy to meet the accuracy objective must be used for measuring the distortion signal.

3.3.7 *Bandwidth correction*

The calibration of the measuring instrument shall include a correction factor of appropriate value to account for the loss in effective noise bandwidth due to the test-signal reject filter. The correction factor assumes a uniform distribution of distortion power over the frequency range involved and is of the following form:

$$\text{Correction (dB)} = 10 \log_{10} \frac{ffective\ bandwidth\ of\ standard\ noise\ weighting}{ffective\ bandwidth\ of\ the\ measuring\ instrument}$$

4 Operating environment

The electrical performance requirements shall be met when operating at the climatic conditions as specified in Recommendation O.3, § 2.1.

References

[1] CCITT Recommendation *Performance characteristics of PCM channels between 4-wire interfaces at voice frequencies* , Vol. III, Rec. G.712.

[2] CCITT Recommendation *12-channel terminal equipments* , Vol. III, Rec. G.232.

Recommendation O.133

EQUIPMENT FOR MEASURING THE PERFORMANCE OF PCM ENCODERS AND DECODERS

(Geneva, 1984; amended at Melbourne, 1988)

1 Introduction

1.1 Encoders and decoders conforming to Recommendation G.711 [1] for converting voice-frequency signals to digital (PCM) signals and vice versa are contained in various equipments described by relevant CCITT Recommendations. Examples of these equipments are:

— PCM multiplexers (Recommendations G.732 [2] and G.733 [3]);

— transmultiplexers (Recommendations G.793 [4] and G.794 [5]);

— subsystems of digital exchanges (e.g., Recommendation Q.517 [6]).

To ensure that the overall performance limits specified in the CCITT Recommendations are always met where the PCM equipments are interconnected, it is necessary to separately specify and measure the analogue-digital (A-D) and digital-analogue (D-A) performance of the equipments. In addition, analogue-analogue (A-A) and digital-digital (D-D) measurements have to be carried out.

1.2 The measuring instrumentation described below allows these measurements to be made on PCM equipments operating at 2048 kbit/s and/or 1544 kbit/s as specified in Recommendations G.732 [2], G.733 [3], G.793 [4], G.794 [5] and relevant Series Q Recommendations.

2 General

2.1 *Measuring functions and physical configuration*

The instrumentation described in this Recommendation consists of the following functional units.

2.1.1 An analogue signal generator to apply voice-frequency signals to the analogue input ports of the equipment under test.

2.1.2 An analogue signal analyzer to process voice-frequency signals received from the analogue output ports of the equipment under test.

2.1.3 A digital signal generator to apply test signals to the digital input ports of the equipment under test.

2.1.4 A digital signal analyzer to process signals received from the digital output ports of the equipment under test.

2.1.5 The four units mentioned in §§ 2.1.1 to 2.1.4 may be provided in any convenient physical arrangement as determined by the supplier.

2.1.6 The functions described in §§ 2.1.3 and 2.1.4 may be realized using either conventional analogue-to-digital and digital-to-analogue conversion techniques, or by direct digital processing techniques.

2.2 *Measuring accuracy and compatibility objectives*

2.2.1 As a general objective, the accuracy of the measuring instrumentation should be an order of magnitude better than the relevant performance limits of the equipment under test. Due to technical and cost limitations, however, it may not always be possible to meet this objective.

2.2.2 In addition errors may increase if instrumentation of different design is interworking or if the input and output parts of the equipment under test are not accessible at the same location (end-to-end measurements).

2.2.3 Where the test methods of Recommendations such as O.131 or O.132 are referenced below, it should be noted that some of the design requirements of such Recommendations may be insufficient to guarantee the accuracy called for in this Recommendation. Even when observing the specifications of this and other relevant Recommendations (e.g. O.131, O.132), compatibility problems may arise especially when pseudorandom noise signals are used as stimuli leading to reduced measuring accuracy and/or fluctuating results indications.

2.2.4 In order to facilitate interworking of instrumentation of different design, it is recommended to provide pseudorandom noise signals having a specified periodicity (see §§ 3.2.3.1 and 3.4.2.1).

2.3 *Measurement capabilities*

Table 1/O.133 contains a list of parameters which can be measured on the various equipments. In addition, the required measuring configuration is indicated. It should be noted, however, that not all the listed parameters can be measured with the instrumentation specified in this Recommendation. Where applicable, reference is made to other pertinent Recommendations.

3 **Instrument specifications**

In this section the minimum requirements to be met by the four functional units of the instrumentation are described. The measuring accuracy is covered in § 4 below.

3.1 *Interfaces*

3.1.1 *Analogue interfaces*

3.1.1.1 Output and input impedances, balanced earth free: 600 and/or 900 ohms.

Measurements at complex impedances are under study.

3.1.1.2 Return loss from 200 Hz to 4 kHz: ≥" | 6 dB.

3.1.1.3 Logitudinal conversion loss (frequency range 200 Hz to 4 kHz): ≥" | 6 dB.

H.T. [T1.133]

TABLE 1/O.133

Measurement capabilities

Parameter	Measuring configuration A-D	D-A	A-A	D-D	Measurement facility
{ Gain (relationship between encoding law and audio level) }	+	+	+	+ | ua)	E
{ Variation of gain (loss) with time | ub) }	+	+	+	+	E
{ Return loss (at voice-frequency ports) }	+	+	+	—	O
Longitudinal balance	+	+	+	—	O
{ Attenuation/frequency distortion }	+	+	+	+	E
Weighted noise	+	+	+	+	E
{ Discrimination against out-of-band input signals }	Δ"	Δ"	Δ"	Δ"	O
{ Spurious out-of-band output signals }	Δ"	Δ"	Δ"	Δ"	O
Single frequency noise	Δ"	Δ"	Δ"	Δ"	O
{ Total distortion (including quantizing distortion) }	+	+	+	+	E
{ Variation of gain with input level }	+	+	+	+	E
{ Crosstalk (measured with sinewave signals) | ua) }	+	+	+	+	E
{ Crosstalk (measured with conventional telephone signal) }	Δ"	Δ"	+	Δ"	O
{ Interference from signalling | uc) }					O
{ Frequency of repetitive signal }	+	+	+	+	0

a) Measurement to be performed while injecting an auxiliary signal in the disturbed channel.

b) This parameter is called ‘‘stability’’ in Recommendations G.712 [9], G.714 [12] and G.792 [13].

c) Stimulus for signalling channel is not specified.

E Essential Δ" Capability not provided O Optional + Yes — Not applicable

Note — Where no symbol is shown, the need for the measurement is under study.

Tableau 1/O.133 [T1.133], p. 5

3.1.2 *Digital interfaces*

3.1.2.1 *Level conditions and frame format*

The instrumentation is required to operate satisfactorily with interface levels in accordance with Recommendation G.703 [7].

One or both of the following conditions of interface and frame formats, including extended frame formats and cyclic redundancy check (CRC) procedures, shall be provided:

At 1544 kbit/s Recommendation G.703 [7], § 2, and Recommendations G.733 [3] and G.704 [11].

At 2048 kbit/s Recommendation G.703 [7], § 6, and Recommendations G.732 [2] and G.704 [11].

Additionally the digital analyzer is required to operate satisfactorily when connected via a length of cable which has an insertion loss of 6 dB at the half bit rate of the signal. The insertion loss of the cable at other frequencies will be proportional to $\sqrt{fIf\ |}$.

In addition to providing for terminated measurements the instrumentation may also be required to monitor at protected test points on digital equipment. Therefore a high impedance and/or additional gain should be provided to compensate for the loss at monitoring points already provided on some equipments.

3.1.2.2 *Impedances of digital interfaces*

The impedances at the digital outputs and inputs shall conform to Recommendation G.703 [7], §§ 2 or 6.

The return loss measured against the nominal impedance shall be:

— 1544 kbit/s (with pre-emphasis)

frequency range 20 kHz to 1.6 MHz at the input: ≥" | 0 dB

frequency range 20 kHz to 500 kHz at the output: ≥" | 4 dB

frequency range 500 kHz to 1.6 MHz at the output: ≥" | 6 dB

— 1544 kbit/s (without emphasis)

frequency range 20 kHz to 1.6 MHz at both input and output: ≥" | 0 dB

— 2048 kbit/s

frequency range 40 kHz to 2.5 MHz at both input and output: ≥" | 0 dB

3.1.2.3 *Longitudinal conversion loss*

(Under study.)

3.2 *Analogue signal generator*

The following minimum functions shall be provided:

3.2.1 *Relative levels*

See Recommendation G.232 [8].

3.2.1.1 Relative levels (minimum range): —16 dBr to 0 dBr.

3.2.2 *Sinusoidal test signals*

3.2.2.1 At levels of 0 and —10 dBm0, the generator shall produce test signals in the frequency range 200 to 3600 Hz. The frequencies of § 3.2.2.2 below, comprising the reference and break points of the relevant masks, shall be provided as a minimum. See § 4.1.4 for a note on the choice of test frequencies.

3.2.2.2 Test signal frequencies (approximately): 200, 300, 420, 500, 600, 820, 1020, 2400, 2800, 3000, 3400 and 3600 Hz.

3.2.2.3 Deviation of transmitted frequency from indicated frequency: ± | Hz ± | .1%.

3.2.2.4 For at least one frequency (preferably approximately 820 or 1020 Hz), it shall be possible to adjust the level of the signal between +3 dBm0 and —55 dBm0. The levels of § 3.2.2.5 comprising the reference and break points of the relevant masks shall be provided as a minimum. See § 4.1.4 for a note on the choice of test frequencies.

3.2.2.5 Test signal levels: —55, —50, —45, —40, —30, —20, —10, 0 +3 dBm0.

3.2.2.6 Deviation of transmitted level from indicated level over the operating range of the instrument: ± | .2 dB. Means shall nevertheless be provided to make relative measurements as defined in § 4.2 within the specified tolerances.

Note — This tolerance is specified to facilitate interworking. Deviations in measurement results due to errors in test levels must be considered when reading the measuring accuracies quoted in this Recommendation.

3.2.2.7 Total distortion referred to a measurement bandwidth of 20 kHz is to be at least 20 dB better than the limits given in the diagram of Figure 4/G.712 [9].

3.2.3 *Pseudorandom test signal*

3.2.3.1 A pseudorandom test signal in accordance with Recommendation O.131 shall be provided. To facilitate interworking, the sequence repetition rate (period) shall be fixed at 256 ms (2048 samples) derived, where possible, from the sampling rate of the encoder under test. Otherwise, the tolerance shall be ± | ms.

Note — This requirement is also met by a period of 128 ± 0.5 ms (1024 samples).

3.2.3.2 The level of the pseudorandom test signal shall be adjustable between —3 dBm0 and —55 dBm0. The levels of § 3.2.3.3 below, comprising the reference and break points of the relevant masks, shall be provided as a minimum.

3.2.3.3 Test signal levels: —55, —50, —40, —34, —27, —10, —6, —3 dBm0.

3.2.4 *Auxiliary signal*

3.2.4.1 In order to increase the accuracy when performing crosstalk measurements, an auxiliary (activating) signal for injection into the disturbed channel shall be provided.

3.2.4.2 Band-limited noise located between 350 and 550 Hz similar to that specified in Recommendation O.131, and having a level in the range —50 to —60 dBm0, may be used as an auxiliary signal. At frequencies below 250 Hz and in the range 700 Hz to 4 kHz, the spurious signal shall be at least 40 dB smaller than the auxiliary signal.

3.2.4.3 As an alternative, a sinusoidal signal having a level in the range —33 to —40 dBm0 may be employed. Harmonic components of the sinusoidal signal shall be at least 40 dB below the fundamental.

3.3 *Analogue signal analyzer*

The following minimum functions shall be provided.

3.3.1 *Relative levels*

(See Recommendation G.232 [8].)

3.3.1.1 Relative levels (minimum range): —5 dBr to +7 dBr.

3.3.2 *Level*

3.3.2.1 Level measuring range: —60 to +5 dBm0.

3.3.3 *Return loss* | optional)

3.3.3.1 Return loss measuring range: 0 to 40 dB over the frequency range 200 to 3600 Hz.

3.3.4 *Longitudinal balance in accordance with Recommendation O.121* | optional)

3.3.4.1 Longitudinal conversion loss measuring range: 5 to 56 dB, over the frequency range 200 to 3600 Hz.

3.3.4.2 Longitudinal conversion transfer loss measuring range: 5 to 56 dB, over the frequency range 200 to 3600 Hz.

3.3.5 *Weighted noise in accordance with Recommendation O.41*

3.3.5.1 Noise measuring range: —80 to —20 dBm0p.

3.3.6 *Total distortion in accordance with Recommendations O.131 and/or O.132*

Note — To facilitate interworking, the observation time for Recommendation O.131 shall be 256 ms or a multiple thereof, derived, where possible, from the sample rate of the decoder under test. Otherwise the tolerance shall be ± | ms.

3.3.6.1 Total distortion measuring range: 0 to 40 dB.

3.3.7 *Crosstalk*

3.3.7.1 Level measuring range: —75 to —20 dBm0.

3.3.8 *Frequency of a repetitive signal*

As an option it shall be possible to measure and display the frequency of any repetitive signal in the frequency range 200 and 4000 Hz applied to the input of the instrument at any level in the range defined in § 3.3.2. The result shall be displayed to a resolution of 1 Hz. The measurement shall be made to an accuracy of at least 50×10^{D}lF261^{6}.

3.4 *Digital signal generator*

The following facilities shall be provided by the digital signal generator.

3.4.1 *Digitally encoded sine wave signals*

3.4.1.1 At levels of 0 and —10 dBm0, digitally encoded sine waves with frequencies in the range 200 Hz to 3600 Hz are to be provided. The frequencies of § 3.4.1.2 comprising the reference and break points of the relevant masks, shall be provided as a minimum. See § 4.1.4 for a note on the choice of test frequencies.

3.4.1.2 Test signal frequencies (approximately): 200, 300, 420, 500, 600, 820, 1020, 2400, 2800, 3000, 3400 and 3600 Hz.

3.4.1.3 Deviation of transmitted frequency from indicated frequency: ± | Hz ± | .1%.

3.4.1.4 For at least one frequency (preferably approximately 820 or 1020 Hz), it shall be possible to adjust the level of the signal between +3 dBm0 and —55 dBm0. The levels of § 3.4.1.5 below, comprising the reference and break points of the relevant masks, shall be provided as a minimum. See § 4.1.4 for a note on the choice of test frequencies.

3.4.1.5 Test signal levels: —55, —50, —45, —40, —30, —20, —10, 0, +3 dBm0.

3.4.1.6 Deviation of transmitted level from indicated level: ± | .2 dB.

Note — This tolerance is specified to facilitate interworking. Deviations in measurement results due to errors in test levels should be included in measuring accuracy specifications.

3.4.1.7 *Digital reference sequence*

The digital signal generator shall be capable of generating the periodic sequences of character signals detailed in Table 5/G.711 [1] and/or Table 6/G.711 [1], equivalent to a 1 kHz sine wave at a nominal level of 0 dBm0.

3.4.2 *Digitally encoded pseudorandom noise signal*

3.4.2.1 The noise source shall have the same characteristics, in terms of frequency spectrum and amplitude distribution, as a signal that would result from applying a band-limited pseudorandom noise source , conforming to Recommendation O.131, to a perfect transmit channel be fixed at 256 ± | ms (2048 samples).

Note — This requirement is also met by a period of 128 ± 0.5 ms (1024 samples).

3.4.2.2 The level of the digitally encoded pseudorandom noise signal shall be adjustable between —3 dBm0 and —55 dBm0. The levels of § 3.4.2.3 below, comprising the reference and break points of the relevant masks, shall be provided as a minimum.

3.4.2.3 Test signal levels: —55, —50, —40, —34, —27, —10, —6, —3 dBm0.

3.4.3 *Additional digital signals*

In addition to the signals specified in §§ 3.4.1 and 3.4.2, it shall be possible to manually select any 8-bit repetitive pattern.

3.4.4 *Time slot assignment*

3.4.4.1 It shall be possible to apply the signals described in §§ 3.4.1, 3.4.2 and 3.4.3 to:

a) any selected speech time slot,

b) as an option, to all speech time slots.

Speech time slots not containing the signals described in §§ 3.4.1 and 3.4.2 shall be provided with the digital signals of § 3.4.3.

3.4.4.2 As an option, an interface shall be provided to enable an externally generated digital signal to be applied to any selected speech time slot. The interface shall meet the requirements of a co-directional interface as defined in Recommendation G.703 [7].

3.4.5 *Test of PCM multiplex alarm unit*

3.4.5.1 *2048 kbit/s PCM multiplexers* | (e.g. Recommendation G.732 [2])

3.4.5.1.1 It shall be possible to modify any bit of the digital signal in time slot 0 of the frames containing the frame alignment signal and of the frames not containing the frame alignment signal in order to fully test the multiplex alarm unit

3.4.5.1.2 It shall be possible to modify any bit of the digital signal in time slot 16 of frame 0.

3.4.5.1.3 As an option during the tests described in §§ 3.4.5.1.1 and 3.4.5.1.2, a digitally encoded sine wave signal of approximately 820 Hz at a level of 0 dBm0 shall be applied to all speech time slots. This is to provide a means of checking speech highway suppression when the multiplex alarm unit operates.

3.4.5.1.4 As an option it shall be possible to modify any bit of the digital signal in time slot 16 of frames 1 to 15 of a multiframe when channel associated signalling is in use. All 30 signalling channels may be provided with the same pattern.

3.4.5.1.5 The instrument shall be capable of generating frame formats including CRC multiframes and CRC check bits, in accordance with Recommendation G.704, § 2.3 [11].

3.4.5.1.6 Where a CRC multiframe is being generated, it shall be possible to modify any bit of the CRC multiframe alignment signal.

3.4.5.1.7 As an option, an interface shall be provided to allow the signalling bits associated with any selected speech time slot to be controlled from an external source when channel associated signalling is in use.

3.4.5.2 *1544 kbit/s PCM multiplexes* | e.g. Recommendation G.733 [3])

3.4.5.2.1 The instrument shall be capable of generating frame formats including CRC multiframes, in accordance with Recommendation G.704, § 3.1 [11].

3.4.5.2.2 It shall be possible to modify the first bit of each frame containing the frame alignment signal.

3.4.5.2.3 It shall be possible to modify the first bit of frame 12.

3.4.5.2.4 Where the 12-frame multiframe is being generated, it shall be possible to modify the eighth bit of each channel time slot in frames 6 and 12 when channel associated signalling is in use. All signalling channels may be provided with the same pattern.

3.4.5.2.5 Where the 24-frame multiframe is being generated, it shall be possible to modify the eighth bit of each channel time slot in frame 6, 12, 18 and 24 when channel associated signalling is in use. All signalling channels may be provided with the same pattern.

3.4.5.2.6 As an option, an interface shall be provided to allow the signalling bits associated with any selected speech time slot to be controlled from an external source when channel associated signalling is in use.

3.4.6 *Selectable synchronization*

It shall be possible to either:

a) lock the digital generator clock rate to that at the input of the digital analyzer, or

b) allow the generator and analyzer clocks to free run within the overall allowed frequency tolerances,

c) as an option, lock the digital generator clock rate to an external clock.

3.5 *Digital signal analyzer*

The digital signal analyzer shall be capable of measuring the following parameters by extracting the digital signal from any selectable time slot of the PCM multiplex stream, and treating it, where appropriate, as an encoded audio signal.

3.5.1 *Level*

3.5.1.1 Level measuring range: —60 to +5 dBm0.

3.5.2 *Weighted noise in accordance with Recommendation O.41*

3.5.2.1 Noise measuring range: —80 to —20 dBm0p.

Note — If the digital analyzer is receiving a digital signal corresponding to the decoder output value number 1 for the A-law or decoder output value number 0 for the μ-law and the polarity bit is kept in a fixed position, the indicated noise level shall not exceed —85 dBm0p.

3.5.3 *Total distortion in accordance with Recommendations O.131 and/or O.132*

Note — To facilitate interworking, the observation time for Recommendation O.131 shall be 256 ms or a multiple thereof, derived, where possible, from the sample rate of the encoder under test. Otherwise the tolerance shall be ± 1 ms.

3.5.3.1 Total distortion measuring range: 0 to 40 dB.

3.5.4 *Crosstalk*

3.5.4.1 Level measuring range: —75 to —20 dBm0.

3.5.5 *Peak code detection and display*

It shall be possible to display the positive and/or negative peak code present in an observation period of at least 800 frames, or in automatically selected repetitive periods of at least 800 frames. This code may have any integer value in the range 0 to ± | 27. As an alternative option the peak code can be indicated by a display of the equivalent tone level in dBm0.

3.5.6 *Signalling bits*

3.5.6.1 As an option, the signalling bits associated with any speech time slot shall be selectable for display when channel associated signalling is in use.

3.5.6.2 An an option, an interface shall be provided to enable the signalling bits associated with any selectable speech time slot to be monitored by an externally connected instrument when channel associated signalling is in use.

3.5.7 *Alarm detection and display* (optional)

The digital analyzer shall be capable of monitoring the digital output of a PCM multiplex and recognizing and displaying the following alarm conditions and bit states.

3.5.7.1 PCM multiplex to Recommendation G.732 [2]: loss of signal, loss of frame alignment, loss of multiframe alignment where channel associated signalling is in use, loss of CRC multiframe alignment, state of bit 1 of time slot 0 of frame containing frame alignment signal, state of bits 1 and 3 to 8 of time slot 0 of frame not containing frame alignment signal, state of bit 6 of time slot 16 of frame 0, and display of information conveyed via the CRC procedure as defined in Recommendation G.704 [11].

3.5.7.2 PCM multiplex to Recommendation G.733 [3].

3.5.7.2.1 Loss of signal, loss of frame alignment, loss of multiframe alignment when channel associated signalling is in use.

3.5.7.2.2 When a 12-frame multiframe is being monitored, the state of bit 8 of each channel in the 6th and 12th frames and the state of bit 1 of the 12th frame.

3.5.7.2.3 When a 24-frame multiframe is being monitored, the state of bit 8 of each channel in the 6th, 12th, 18th and 24th frames, the state of bit 1 of the 12th frame, and the display of information conveyed via the CRC procedure as defined in Recommendation G.704 [11].

3.5.8 *Frequency of a repetitive signal*

As an option, it shall be possible to measure and display the frequency of any repetitive signal in the frequency range 200 Hz to 4000 Hz applied at a level in the range defined in § 3.5.1. The result shall be displayed to a resolution of 1 Hz. The measurement shall be made to an accuracy of at least 50 **|** (mu | 0^{D}lF261^{6}.

3.5.9 *External speech time-slot interface*

As an option, an interface shall be provided to enable the digital signal contained in a selected speech time slot to be extracted and applied to a separate instrument. The interface shall meet the requirements of a co-directional interface as defined in Recommendation G.703 [7].

4 Measuring accuracy

4.1 *Definition of the error limits of the measuring instrumentation*

4.1.1 The error limits stated in this Recommendation refer always to a complete measuring configuration and therefore include errors of the generator as well as of the analyzer side (if applicable).

See Annex A to this Recommendation concerning the intrinsic errors in the PCM encoding process which may affect the interpretation of measured results.
4.1.2 Even ideal encoder/decoder pairs conforming to the requirements of Recommendation G.711 [1] exhibit intrinsic limitations to the PCM process which cannot be avoided of gain with input level and limited audio frequency range.

The measuring instrumentation described here has the same general characteristics and limitations as an ideal encoder/decoder conforming to Recommendation G.711 [1]. For the purposes of this Recommendation the differences between an ideal encoder/decoder conforming to Recommendation G.711 [1] and the measuring instrument are defined as measuring errors. Figure 1/O.133 illustrates the relationship of these errors to the errors exhibited by the digital signal generator and digital signal analyzer.

4.1.3 When stating the total measuring error, the errors contributed by the analogue analyzer ($E_{A\backslash dA}$) and the analogue generator ($E_{A\backslash dG}$) must also be considered. Because of the limited level accuracy of the analogue signal generator, variations in measurement result will arise due to quantizing gain effects in the PCM channel under test

The total measuring error applicable to the four measuring configurations can be calculated as shown in Table 2/O.133.

Figure 1/O.133, p.

H.T. [T2.133]

TABLE 2/O.133 { **Definition of total measuring error** }	
Measuring configuration	Total measuring error
A-D	*E* + *E*
D-A	*E* + *E*
A-A	*E* + *E*
D-D	*E* + *E*

Table 2/O.133 [T2.133], p.

4.1.4 *Choice of test frequencies*

When specifying the accuracy of measurements on sinusoidal signals, the tone presented to the ideal encoder in Figure 1/O.133 is assumed to have a frequency unrelated to the sampling rate, and the measurement time is assumed to be long enough to eliminate averaging error.

Intrinsic errors in tone measurements depend on the highest common factor of the test signal frequency and the PCM sampling rate. Simple submultiples of the sampling rate, and their harmonics, should be avoided. The instrumentation should use a large number of independent samples and the measuring accuracy should be specified relative to a minimum number of samples. A figure of at least 400 is recommended. Restrictions on the use of other frequencies should be stated. The choice of test frequency shall be made in accordance with Recommendation O.6.

4.1.5 *Intrinsic distortion of test signals*

To facilitate interworking on total distortion measurements, certain variable-level, digitally-encoded signals, if provided, should be specified for intrinsic total distortion over the range of selectable levels, measured as follows:

— Pseudorandom noise, sinusoidal signal, 420 Hz: by the method of Recommendation O.131.

— Sinusoidal signal, 820 Hz or 1020 Hz: by the method of Recommendation O.132.

4.1.6 *Measurement bandwidth for tone measurements*

The design of filters for tone measurements is not specified. However, measurement errors should be calculated relative to the results obtained by ideal selective measurement.

4.2 *Summary of total measuring errors*

Full 8-bit coding is assumed as specified in Recommendation G.711 [1].

4.2.1 *Gain (relationship between encoding law and audio level)*

See Table 3/O.133.

H.T. [T3.133]
TABLE 3/O.133

Parameter	Error limits (dB)			
	A-D	D-A	A-A	D-D
{ Gain (relationship between encoding law and audio level) | ua) }	± | .08	± | .08	± | .05	± | .05

a) Measured at one frequency, approximately 820 Hz or 1020 Hz at a level of 0 dBm0.

Note — If a sinusoidal test signal is used, uncertainties in the absolute level position of the companding law characteristic of a practical encoder require special interpretation of the error limits specified in modes A-D, A-A and (if the signal passes via an analogue point) D-D. In these modes, the figures represent the accuracy with which the *envelope* of the characteristic can be located, rather than the accuracy of any *single result* Annex A to this Recommendation.

Table 3/O.133 [T3.133], p.

4.2.2 *Return loss* | optional)

See Table 4/O.133.

H.T. [T4.133]
TABLE 4/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
Return loss | ua)	0 to 30 dB	± |	± |	± |	—
	30 to 40 dB	± |	± |	± |	—

a) Measured at a level ≥" —10 dBm0.

Table 4/O.133 [T4.133], p.

4.2.3 *Longitudinal conversion loss (LCL)* | optional)

See Table 5/O.133.

H.T. [T5.133]

TABLE 5/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
LCL | ua)	5 to 40 dB	± | .5	—	± | .5	—
	40 to 56 dB	± | .5	—	± | .5	—

a) Measured at a level ≥" —10 dBm0.

Table 5/O.133 [T5.133], p.

4.2.4 *Longitudinal conversion transfer loss (LCTL)* | optional)

See Table 6/O.133.

H.T. [T6.133]

TABLE 6/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
LCTL | ua)	5 to 40 dB	± | .5	—	± | .5	—
	40 to 56 dB	± | .5	—	± | .5	—

a) Measured at a level ≥" —10 dBm0.

Table 6/O.133 [T6.133], p.

4.2.5 *Attenuation/frequency distortion*

See Table 7/O.133.

H.T. [T7.133]

TABLE 7/O.133

Parameter	Frequency range	Error limits (dB) A-D	D-A	A-A	D-D

{
Attenuation/frequency distortion | ua)
} {
200 to 300 Hz
300 to 3000 Hz
3000 to 3600 Hz
} {
± | .08
± | .05
± | .08
} {
± | .08
± | .05
± | .08
} {
± | .08
± | .05
± | .08
} {
± | .08
± | .05
± | .08
}

a) Measured at a level of 0 or —10 dBm0. Error referred to measurement at approximately 820 Hz/1020 Hz. The specified measurement error is applicable if the measured attenuation/frequency distortion does not exceed 6 dB.

Table 7/O.133 [T7.133], p.

4.2.6 *noise* See Table 8/O.133. **H.T. [T8.133]** TABLE 8/O.133 center box; cw(48p) | cw(48p) | cw(24p) sw(24p) sw(24p) sw(24p) , ˆ | ˆ | c | c | c | c. Parameter result Error limits (dB)	*Weighted* Indicated		A-D	D-A	A-A	D-D
Weighted noise | ua) { —80 to —75 dBm0p —75 to —70 dBm0p —70 to —20 dBm0p } { ± | .5 ± | .5 ± | | } { ± | .5 ± | .5 ± | | } { ± | .5 ± | .5 ± | | } { ± | .5 ± | .5 ± | | }						

a) Measurement error includes tolerances of the weighting filter given in Recommendation O.41.

Table 8/O.133 [T8.133], p.

4.2.7 *Total distortion*

See Table 9/O.133.

H.T. [T9.133]

TABLE 9/O.133

Parameter	Indicated result | ua)	Error limits (dB) | ua)			
		A-D	D-A	A-A	D-D
{ Total distortion (noise test signal) }	0 to 40 dB	± | .5	± | .5	± | .5	± | .5
{ Total distortion (sinusoidal test signal) } ± | .8	**0 to 40 dB**	**± | .8**	**± | .8**	**± | .8**	**{**
a) With an absolut[text mangled] —72 dBm0.					

Note — If a sinusoidal test signal is used, uncertainties in the absolute level position of the companding law characteristic of a practical encoder require special interpretation of the error limits specified in modes A-D, A-A and (if the signal passes via an analogue point) D-D. In these modes, the figures represent the accuracy with which the *envelope* of the characteristic can be located, rather than the accuracy of any *single result* Annex A to this Recommendation.

Table 9/O.133 [T9.133], p.

BLANC

4.2.8 *Variation of gain with input level*

See Table 10/O.133.

H.T. [T10.133]

TABLE 10/O.133

<table>
<tr><th rowspan="2">Parameter</th><th rowspan="2">Level range</th><th colspan="4">Error limits (dB) | ua)</th></tr>
<tr><th>A-D</th><th>D-A</th><th>A-A</th><th>D-D</th></tr>
<tr><td>{
Gain variation (noise test signal)
}
—10 to —40 dBm0
—40 to —50 dBm0
—50 to —55 dBm0
}
± | .10
± | .15
± | .15
}
± | .10 | ub)
± | .15
| ub)
± | .15
| ub)
}
± | .15 | ub)
± | .20
| ub)
± | .20
| ub)
}
± | .10
± | .10
± | .10
}</td><td>{
{
{
{
{</td><td></td><td></td><td></td><td></td></tr>
<tr><td>{
Gain variation (sinusoidal test signal at approx. 420, 820 or 1020 Hz)
}
+3 to —40 dBm0
—40 to —50 dBm0
—50 to —55 dBm0
}
± | .10 | ub)
± | .20
| ub)
± | .25
| ub)
}
± | .10
± | .15
± | .20
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± | .15
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± | .25
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± | .10
± | .15
± | .20
}</td><td>{
{
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{</td><td></td><td></td><td></td><td></td></tr>
</table>

a) Error referred to measurement of —10 dBm0.

b) Provisional value, to be studied further.

Note — If a sinusoidal test signal is used, uncertainties in the absolute level position of the companding law characteristic of a practical encoder require special interpretation of the error limits specified in modes A-D, A-A and (if the signal passes via an analogue point) D-D. In these modes, the figures represent the accuracy with which the *envelope* of the characteristic can be located, rather than the accuracy of any *single result* Annex A to this Recommendation.

Table 10/O.133 [T10.133], p.

4.2.9 *Crosstalk measurement*

See Table 11/O.133.

H.T. [T11.133]

TABLE 11/O.133

Parameter	Remarks	Error limits (dB)			
		A-D	D-A	A-A	D-D
Crosstalk	{ ±| {	±|	±| |	±|	
	—	—	±|.5	—	

a) Measurement to be performed while injecting an auxiliary signal in the disturbed channel. Appropriate auxiliary signals are defined in § 3.2.4. Error includes effect of finite rejection of the auxiliary signal by the measurement filter and of quantizing distortion in the measurement bandwidth.

b) Measurement error includes tolerances of the weighting filter given in Recommendation O.41.

Table 11/O.133 [T11.133], p.

5 Operating environment

The electrical performance requirements shall be met when operating at the climatic conditions as specified in Recommendation O.3, § 2.1.

ANNEX A

(to Recommendation O.133)

Intrinsic errors in the PCM encoding process

which may affect the interpretation of measured results

A.1 *Introduction*

Pulse Code Modulation (PCM) has some inherent limitations which affect measurements on PCM encoders. This pertains especially to the measurement of the variation of gain with input level and of the quantizing distortion ratio. Due to the limited number of quantizing steps available for encoding an analogue signal, the output signal of a PCM decoder is not a replica of the input signal to the encoder. Depending on the actual amplitude of the signal samples to be encoded, as compared with the quantizing thresholds, the output values at the decoder are sometimes greater and

sometimes smaller than would occur in a linear system. The differences are called quantizing errors, and exist even for an ideal PCM encoder/decoder pair conforming to a practical encoding law. A test signal will experience the average effect of the quantizing errors in all its samples, which depends on the amplitude distribution of the signal. For Gaussian noise, the errors tend to average out, and no measurement problems arise. However, this is not the case for sinusoidal signals, and measurement results for gain linearity and quantizing distortion ratio must be interpreted with care.

A.2 *Measurement of gain and variation of gain with input level*

As mentioned in the introduction, the signal at the output of a PCM decoder may differ from what would occur at the output of a linear system. This means that a PCM channel may appear to have unexpected gain when measured with a sinusoidal signal. This ‘‘quantizing gain’’ is sometimes positive and sometimes negative and varies with input level. In the case of linear encoding, the more quantizing steps available for encoding the analogue input signal, the smaller the quantizing errors and hence the gain variations. With a truly logarithmic encoding characteristic the quantizing error would be independent of the input level.

The encoding laws used in practice (A- and μ-law) approximate the logarithmic characteristic by a segmented curve. For the A-law, this results in a gain variation which follows the same rules for the segments No. 7 to No. 2 and which increases with decreasing input level for segment No. 1. Because the values at the segment end points of the μ-law characteristic are not multiples of 2 (as with the A-law), the gain variations for the corresponding segment portions are similar but not identical.

Figures A-1/O.133 to A-4/O.133 show the (calculated) variation of gain with input level when measuring a PCM channel with an asynchronous sinusoidal signal. Because the gain variation in the upper segments is always between +0.043 dB and —0.048 dB, only the level range below —30 dBm0 is shown. The gain has a sharp minimum each time the peak of the sinusoid passes through a decision value. As the input amplitude is increased, the gain rises quickly to a maximum before falling again. In the vicinity of the minima, the gain can vary substantially when the input level is varied only by small amounts. With the A-law, for example, the gain changes by approximately 0.8 dB (selective measurements) when the input level is varied between —57.00 dB and —57.066 dB.

In this case the ratio of level-to-gain variation is 1:11.8. For greater input levels and for the μ-law, the variation of gain with input level is smaller but still not negligible.

For signal levels above —60 dBm0, the maximum excursions are within a range of approximately —1.3 to +0.65 dB (—1.0 to +0.9 dB) for the A-law, and approximately 0.5 to 0.3 dB (—0.45 to 0.35 dB) for the μ-law depending on the measurement mode selective or (wideband).

When measuring the gain variation of a PCM channel with a sinusoidal stimulus, the theoretical considerations described above must be taken into account. Because the relative level at the encoder input need only be set within a limit of ± | .3 dB (Recommendation G.713 [10]), and because the analogue signal generator used for the measurement has some uncertainty in the send level setting, it is not possible to exactly predict the actual position on the encoding characteristic or even to avoid the minima. For this reason, any single measurement result must be treated as relative to the envelope of the gain variation characteristic. Additionally, it has to be

considered that Figures A-1/O.133 to A-4/O.133 represent theoretical values with ideal encoders having no quantizing threshold errors. In practice, deviations from the ideal characteristics due to encoder threshold offset must be expected.

This limitation also applies to measurements of gain, although at high levels the error is small — of the order of ± | .04 dB.

To simplify the interpretation of measurement results, Tables A-1/O.133 to A-4/O.133 list the extreme values of the gain variation with input level for the A- and μ-law for selective and wideband measurements. The tables have 64 lines (multiple of 16), so one line contains the values of corresponding segment portions. For the A-law the corresponding gain values in the first three columns are identical.

A.3 *Quantizing distortion measurements*

The quantizing error results in quantizing distortion which varies as function of input level. Figures A-5/O.133 and A-6/O.133 illustrate the (calculated) quantizing distortion characteristics for the A- and μ-law when measuring a PCM-channel with a sinusoidal stimulus. As with gain measurements, the quantizing distortion ratio can vary substantially as a result of small variations of the input signal. The variation ratio reaches its maximum at the segment end points.

For the same reason as described above, one can again only refer to the envelope of the variation of the quantizing distortion ratio when interpreting individual measurement results. The warning with respect to quantizing threshold errors in a non-ideal encoder applies to quantizing distortion ratio measurements as well.

Tables A-5/O.133 and A-6/O.133 contain the extreme values of the quantizing distortion ratio of an ideal encoder when measured with a sinusoidal signal. In the tables, ''level'' is the input level; S/Q is the ratio of the corresponding level (at the output) of the stimulus, measured selectively, to the quantizing noise, measured flat and with a fixed correction to normalize the noise bandwidth to 3.1 kHz.

Note — Tables A-5/O.133 and A-6/O.133 and their accompanying graphs are mainly indicative, since:

1) the calculations (flat S/Q) do not compare with the weighted ratio $(S+Q)/Q$ result of the method of Recommendation O.132. They are more similar to the use of a tone stimulus with the filters of Recommendation O.131;

2) the correction to the 3.1 kHz bandwidth assumes the quantizing noise spectrum is flat, whereas it is non-flat and level-dependent (so that no fixed correction will compensate for the lost bandwidth of the stimulus rejection filter).

A.4 *General notes to tables and graphs*

The input levels are stated based on values of $T_{m\backslash da\backslash dx}$ of exactly 3.14 dBm0 for the A-law and 3.17 dBm0 for the μ-law. (On this basis, the selective levels of 1 kHz sequences of Recommendation G.711 [1] are —0.0016 dBm0 for a the A-law and —0.0024 dBm0 for the μ-law.)

The envelope of a characteristic is a pair of smooth curves tangential to the characteristic at or near all its extreme values.

H.T. [T12.133]

TABLE A-1/O.133

Variation of gain with input level, A-law.

Gain calculation based on a selective measurement of the stimulus

Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)
2.948	0.009	—9.093	0.009	—21.135	0.009	—33.176	0.008
2.864	0.018	—9.177	—0.018	—21.218	—0.018	—33.259	—0.019
2.666	0.009	—9.375	0.009	—21.417	0.009	—33.458	0.009
2.579	—0.019	—9.462	—0.019	—21.503	—0.019	—33.544	—0.020
2.374	0.010	—9.667	0.010	—21.708	0.010	—33.749	0.009
—2.285	—0.020	—9.756	—0.020	—21.797	—0.020	—33.839	—0.021
2.073	0.010	—9.969	0.010	—22.010	0.010	—34.051	0.010
1.980	—0.021	—10.061	—0.021	—22.102	—0.021	—34.143	—0.022
1.760	0.011	—10.281	0.011	—22.322	0.011	—34.363	0.010
1.664	—0.022	—10.377	—0.022	—22.418	—0.022	—34.459	—0.023
1.436	0.012	—10.605	0.012	—22.647	0.012	—34.688	0.011
1.336	—0.024	—10.705	—0.024	—22.746	—0.024	—34.787	—0.025
1.099	0.012	—10.942	0.012	—22.983	0.012	—35.024	0.011
0.996	—0.025	—11.045	—0.025	—23.087	—0.025	—35.128	—0.026
0.749	0.013	—11.293	0.013	—23.334	0.013	—35.375	0.012
0.641	—0.027	—11.400	—0.027	—23.441	—0.027	—35.482	—0.028
0.383	0.014	—11.658	0.014	—23.699	0.014	—35.740	0.013
0.272	—0.028	—11.770	—0.028	—23.811	—0.028	—35.852	—0.030
0.002	0.015	—12.039	0.015	—24.080	0.015	—36.121	0.014
—0.115	—0.030	—12.156	—0.030	—24.197	—0.030	—36.238	—0.032
—0.396	0.017	—12.438	0.017	—24.479	0.017	—36.520	0.015
—0.519	—0.032	—12.560	—0.032	—24.601	—0.032	—36.642	—0.034
—0.814	0.018	—12.856	0.018	—24.897	0.018	—36.937	0.016
—0.942	—0.034	—12.984	—0.034	—25.025	—0.034	—37.066	—0.036
—1.254	0.020	—13.295	0.020	—25.336	0.020	—37.376	0.017
—1.388	—0.036	—13.429	—0.036	—25.470	—0.036	—37.512	—0.039
—1.716	0.023	—13.758	0.023	—25.799	0.023	—37.838	0.019
—1.858	—0.038	—13.899	—0.038	—25.940	—0.038	—37.981	—0.043
—2.206	0.026	—14.248	0.026	—26.289	0.026	—38.327	0.020
—2.354	—0.040	—14.395	—0.040	—26.436	—0.040	—38.478	—0.047
—2.741	0.035	—14.782	0.035	—26.824	0.035	—38.844	0.022
—2.881	—0.018	—14.922	—0.018	—26.963	—0.018	—39.004	—0.051
—3.073	0.009	—15.114	0.009	—27.155	0.009	—39.394	0.024
—3.156	—0.018	—15.198	—0.018	—27.239	—0.018	—39.565	—0.056
—3.355	0.009	—15.396	0.009	—27.437	0.009	—39.982	0.027
—3.441	—0.019	—15.482	—0.019	—27.524	—0.019	—40.164	—0.062
—3.646	0.010	—15.688	0.010	—27.729	0.010	—40.612	0.030
—3.736	—0.020	—15.777	—0.020	—27.818	—0.020	—40.808	—0.070
—3.948	0.010	—15.989	0.010	—28.030	0.010	—41.291	0.034
—4.040	—0.021	—16.082	—0.021	—28.123	—0.021	—41.503	—0.079
—4.261	0.011	—16.302	0.011	—28.343	0.011	—42.029	0.038
—4.356	—0.022	—16.398	—0.022	—28.439	—0.022	—42.259	—0.090
—4.585	0.012	—16.626	0.012	—28.667	0.012	—42.834	0.044
—4.684	—0.024	—16.725	—0.024	—28.767	—0.024	—43.087	—0.104
—4.922	0.012	—16.963	0.012	—29.004	0.012	—43.723	0.051
—5.025	—0.025	—17.066	—0.025	—29.107	—0.025	—44.002	—0.122
—5.272	0.013	—17.313	0.013	—29.354	0.013	—44.713	0.061
—5.379	—0.027	—17.421	—0.027	—29.462	—0.027	—45.025	—0.146
—5.637	0.014	—17.678	0.014	—27.719	0.014	—45.831	0.074
—5.749	—0.028	—17.790	—0.028	—29.831	—0.028	—46.185	—0.178
—6.018	0.015	—18.059	0.015	—30.101	0.015	—47.114	0.092
—6.135	—0.030	—18.176	—0.030	—30.218	—0.030	—47.524	—0.226
—6.417	0.017	—18.458	0.017	—30.499	0.017	—48.623	0.119
—6.539	—0.032	—18.580	—0.032	—30.622	—0.032	—49.107	—0.299
—6.835	0.018	—18.876	0.018	—30.917	0.018	—50.451	0.162
—6.963	—0.034	—19.004	—0.034	—31.045	—0.034	—51.045	—0.423
—7.274	0.020	—19.315	0.020	—31.356	0.020	—52.775	0.240
—7.409	—0.036	—19.450	—0.036	—31.491	—0.036	—53.544	—0.668
—7.737	0.023	—19.778	0.023	—31.819	0.022	—55.976	0.408
—7.878	—0.038	—19.919	—0.038	—31.961	—0.039	—57.066	—1.312
—8.227	0.026	—20.268	0.026	—32.309	0.026		

—8.375	—0.040	—20.416	—0.040	—32.457	—0.040		
—8.762	0.035	—20.803	0.035	—32.844	0.035		
—8.901	—0.018	—20.942	—0.018	—32.984	—0.018		

Table A-1/O.133 [T12.133], p.

H.T. [T13.133]
TABLE A-2/O.133
Variation of gain with input level, A-law.

Gain calculation based on a wideband measurement of the stimulus

Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)
2.947	0.009	—9.094	0.009	—21.135	0.009	—33.176	0.009
2.864	—0.018	—9.177	—0.018	—21.218	—0.018	—33.259	—0.018
2.665	0.010	—9.376	0.010	—21.417	0.010	—33.458	0.010
2.579	—0.019	—9.462	—0.019	—21.503	—0.019	—33.544	—0.019
2.374	0.010	—9.668	0.010	—21.709	0.010	—33.750	0.010
2.285	—0.020	—9.756	—0.020	—21.797	—0.020	—33.839	—0.020
2.072	0.011	—9.969	0.011	—22.010	0.011	—34.052	0.011
1.980	—0.021	—10.061	—0.021	—22.102	—0.021	—34.143	—0.021
1.759	0.012	—10.282	0.012	—22.323	0.012	—34.364	0.011
1.664	—0.022	—10.377	—0.022	—22.418	—0.022	—34.459	—0.022
1.435	0.012	—10.606	0.012	—22.647	0.012	—34.688	0.012
1.336	—0.023	—10.705	—0.023	—22.746	—0.023	—34.787	—0.023
1.098	0.013	—10.943	0.013	—22.984	0.013	—35.025	0.013
0.996	—0.024	—11.045	—0.024	—23.087	—0.024	—35.128	—0.025
0.748	0.014	—11.293	0.014	—23.334	0.014	—35.376	0.013
0.641	—0.026	—11.400	—0.026	—23.441	—0.026	—35.482	—0.026
0.383	0.015	—11.658	0.015	—23.700	0.015	—35.741	0.014
0.272	—0.027	—11.770	—0.027	—23.811	—0.027	—35.852	—0.028
0.001	0.016	—12.040	0.016	—24.081	0.016	—36.122	0.015
—0.115	—0.029	—12.156	—0.029	—24.197	—0.029	—36.238	—0.030
—0.397	0.018	—12.439	0.018	—24.480	0.018	—36.521	0.016
—0.519	—0.031	—12.560	—0.031	—24.601	—0.031	—36.642	—0.032
—0.815	0.019	—12.857	0.019	—24.898	0.019	—36.938	0.018
—0.942	—0.033	—12.984	—0.033	—25.025	—0.033	—37.066	—0.034
—1.255	0.021	—13.296	0.021	—25.337	0.021	—37.378	0.019
—1.388	—0.035	—13.429	—0.035	—25.470	—0.035	—37.512	—0.037
—1.718	0.024	—13.759	0.024	—25.800	0.024	—37.840	0.021
—1.858	—0.037	—13.899	—0.037	—25.940	—0.037	—37.981	—0.040
—2.208	0.027	—14.249	0.027	—26.290	0.027	—38.328	0.023
—2.354	—0.038	—14.395	—0.038	—26.436	—0.038	—38.478	—0.044
—2.742	0.036	—14.783	0.036	—26.825	0.036	—38.846	0.025
—2.881	—0.017	—14.922	—0.017	—26.963	—0.017	—39.004	—0.048
—3.073	0.009	—15.114	0.009	—27.156	0.009	—39.396	0.028
—3.156	—0.018	—15.198	—0.018	—27.239	—0.018	—39.565	—0.053
—3.355	0.010	—15.397	0.010	—27.438	0.010	—39.984	0.031
—3.441	—0.019	—15.482	—0.019	—27.524	—0.019	—40.164	—0.058
—3.647	0.010	—15.688	0.010	—27.729	0.010	—40.615	0.034
—3.736	—0.020	—15.777	—0.020	—27.818	—0.020	—40.808	—0.065
—3.949	0.011	—15.990	0.011	—28.031	0.011	—41.295	0.039
—4.040	—0.021	—16.082	—0.021	—28.123	—0.021	—41.503	—0.073
—4.261	0.012	—16.302	0.012	—28.344	0.012	—42.033	0.044
—4.356	—0.022	—16.398	—0.022	—28.439	—0.022	—42.259	—0.083
—4.585	0.012	—16.627	0.012	—28.668	0.012	—42.839	0.051
—4.684	—0.023	—16.725	—0.023	—28.767	—0.023	—43.087	—0.095
—4.922	0.013	—16.963	0.013	—29.005	0.013	—43.729	0.060
—5.025	—0.024	—17.066	—0.024	—29.107	—0.024	—44.002	—0.111
—5.273	0.014	—17.314	0.014	—29.355	0.014	—44.720	0.072
—5.379	—0.026	—17.421	—0.026	—29.462	—0.026	—45.025	—0.132
—5.638	0.015	—17.679	0.015	—29.720	0.015	—45.840	0.088
—5.749	—0.027	—17.790	—0.027	—29.831	—0.027	—46.185	—0.161
—6.019	0.016	—18.060	0.016	—30.102	0.016	—47.128	0.111
—6.135	—0.029	—18.176	—0.029	—30.218	—0.029	—47.524	—0.202
—6.418	0.018	—18.459	0.018	—30.500	0.018	—48.642	0.146
—6.539	—0.031	—18.580	—0.031	—30.622	—0.031	—49.107	—0.263
—6.836	0.019	—18.877	0.019	—30.918	0.019	—50.480	0.203
—6.963	—0.033	—19.004	—0.033	—31.045	—0.033	—51.045	—0.365
—7.275	0.021	—19.316	0.021	—31.358	0.021	—52.827	0.310
—7.409	—0.035	—19.450	—0.035	—31.491	—0.035	—53.544	—0.556
—7.738	0.024	—19.779	0.024	—31.821	0.023	—56.086	0.554
—7.878	—0.037	—19.919	—0.037	—31.961	—0.037	—57.066	—1.015
—8.228	0.027	—20.269	0.027	—32.311	0.027		

—8.375	—0.038	—20.416	—0.038	—32.457	—0.039		
—8.763	0.036	—20.804	0.036	—32.845	0.036		
—8.901	—0.017	—20.942	—0.017	—32.984	—0.017		

Table A-2/O.133 [T13.133], p.

H.T. [T14.133]

TABLE A-3/O.133

Variation of gain with input level, μ-law.

Gain calculation based on a selective measurement of the stimulus

Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)
2.977	0.009	—9.173	0.009	—21.662	0.010	—35.769	0.014
2.893	—0.018	—9.258	—0.019	—21.751	—0.020	—35.882	—0.030
2.694	0.009	—9.459	0.010	—21.964	0.010	—36.154	0.015
2.607	—0.019	—9.547	—0.020	—22.057	—0.021	—36.272	—0.032
2.401	0.010	—9.756	0.010	—22.277	0.011	—36.557	0.016
2.311	—0.020	—9.847	—0.021	—22.373	—0.023	—36.681	—0.034
2.098	0.010	—10.063	0.011	—22.602	0.012	—36.980	0.017
2.005	—0.021	—10.157	—0.022	—22.702	—0.024	—37.110	—0.036
1.784	0.011	—10.382	0.011	—22.940	0.012	—37.425	0.018
1.668	—0.023	—10.479	—0.023	—23.043	—0.025	—37.562	—0.039
1.458	0.012	—10.712	0.012	—23.291	0.013	—37.893	0.020
1.358	—0.024	—10.814	—0.024	—23.399	—0.027	—38.038	—0.043
1.120	0.013	—11.056	0.013	—23.657	0.014	—38.388	0.022
1.016	—0.025	—11.161	—0.026	—23.769	—0.029	—38.541	—0.046
0.767	0.013	—11.414	0.014	—24.039	0.015	—38.914	0.024
0.660	—0.027	—11.524	—0.027	—24.157	—0.030	—37.076	—0.051
0.400	0.014	—11.787	0.015	—23.439	0.016	—39.473	0.027
0.288	—0.028	—11.902	—0.029	—25.562	—0.032	—39.646	—0.056
0.017	0.016	—12.177	0.016	—24.858	0.018	—40.071	0.030
—0.101	—0.030	—12.297	—0.031	—24.987	—0.035	—40.255	—0.062
—0.384	0.017	—12.585	0.017	—25.299	0.019	—40.713	0.034
—0.507	—0.032	—12.711	—0.033	—25.434	—0.037	—40.911	—0.069
—0.805	0.018	—13.014	0.019	—25.763	0.021	—41.406	0.039
—0.934	—0.034	—13.145	—0.035	—25.905	—0.040	—41.621	—0.077
—1.247	0.020	—13.465	0.021	—26.253	0.024	—42.160	0.045
—1.382	—0.036	—13.603	—0.038	—26.403	—0.043	—42.393	—0.087
—1.713	0.023	—13.941	0.024	—26.773	0.027	—42.986	0.054
—1.855	—0.039	—14.086	—0.040	—26.932	—0.046	—43.241	—0.098
—2.206	0.026	—14.446	0.027	—27.327	0.032	—43.902	0.067
—2.355	—0.040	—14.598	—0.041	—27.495	—0.048	—44.181	—0.110
—2.745	0.036	—14.997	0.037	—27.938	0.043	—44.959	0.099
—2.886	—0.018	—15.141	—0.018	—28.097	—0.022	—45.236	—0.054
—3.080	0.009	—15.340	0.009	—28.318	0.011	—45.639	0.026
—3.164	—0.019	—15.426	—0.019	—28.414	—0.023	—45.815	—0.059
—3.364	0.009	—15.632	0.010	—28.643	0.011	—46.247	0.028
—3.451	—0.020	—15.721	—0.020	—28.743	—0.024	—46.435	—0.066
—3.658	0.010	—15.934	0.010	—28.982	0.012	—46.901	0.032
—3.748	—0.021	—16.026	—0.021	—29.086	—0.026	—47.104	—0.074
—3.963	0.010	—16.247	0.011	—29.334	0.013	—47.608	0.036
—4.056	—0.022	—16.343	—0.023	—29.442	—0.027	—47.828	—0.084
—4.278	0.011	—16.571	0.012	—29.701	0.014	—43.378	0.041
—4.375	—0.023	—16.671	—0.024	—29.814	—0.029	—48.618	—0.096
—4.605	0.012	—16.908	0.012	—30.084	0.015	—49.223	0.047
—4.706	—0.024	—17.012	—0.025	—30.202	—0.031	—49.488	—0.112
—4.946	0.013	—17.259	0.013	—30.485	0.016	—50.159	0.056
—5.050	—0.025	—17.367	—0.027	—30.608	—0.033	—50.454	—0.133
—5.300	0.014	—17.625	0.014	—30.906	0.017	—51.209	0.067
—5.408	—0.027	—17.737	—0.028	—31.035	—0.035	—51.541	—0.161
—5.669	0.015	—18.007	0.015	—31.347	0.019	—52.404	0.082
—5.782	—0.029	—18.124	—0.030	—31.483	—0.038	—52.784	—0.200
—6.054	0.016	—18.406	0.017	—31.813	0.021	—53.791	0.104
—6.172	—0.030	—18.528	—0.032	—31.956	—0.041	—54.235	—0.258
—6.458	0.017	—18.824	0.018	—32.305	0.023	—55.444	0.138
—6.581	—0.032	—18.953	—0.034	—32.456	—0.044	—55.978	—0.352
—6.881	0.019	—19.264	0.020	—32.826	0.025	—57.490	0.195
—7.011	—0.035	—19.399	—0.037	—32.987	—0.048	—58.161	—0.522
—7.326	0.021	—19.727	0.022	—33.381	0.029		
—7.462	—0.037	—19.869	—0.039	—33.552	—0.053		
—7.795	0.023	—20.217	0.025	—33.975	0.053		
—7.938	—0.039	—20.367	—0.042	—34.156	—0.057		
—8.292	0.027	—20.737	0.029	—34.613	0.039		

—8.442	—0.040	—20.894	—0.044	—34.806	—0.060		
—8.836	0.036	—21.307	0.039	—35.323	0.054		
—8.977	—0.018	—21.456	—0.019	—35.508	—0.028		

Table A-3/O.133 [T14.133], p.

H.T. [T15.133]

TABLE A-4/O.133

Variation of gain with input level, μ-law.

Gain calculation based on a wideband measurement of the stimulus

Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)	Input level (dBm0)	Gain (dB)
2.977	0.009	—9.173	0.010	—21.662	0.010	—35.769	0.015
2.893	—0.018	—9.258	—0.018	—21.751	—0.020	—35.882	—0.028
2.693	0.010	—9.460	0.010	—21.965	0.011	—36.155	0.016
2.607	—0.019	—9.547	—0.019	—22.057	—0.021	—36.272	—0.030
2.400	0.010	—9.757	0.011	—22.278	0.012	—36.558	0.017
2.311	—0.020	—9.847	—0.020	—22.373	—0.022	—36.681	—0.032
2.097	0.011	—10.064	0.011	—22.603	0.012	—36.981	0.018
2.005	—0.021	—10.157	—0.021	—22.702	—0.023	—37.110	—0.035
1.783	0.012	—10.382	0.012	—22.940	0.013	—37.426	0.020
1.668	—0.022	—10.479	—0.022	—23.043	—0.024	—37.562	—0.037
1.458	0.012	—10.713	0.013	—23.292	0.014	—37.895	0.022
1.358	—0.023	—10.814	—0.024	—23.399	—0.026	—38.038	—0.041
1.119	0.013	—11.057	0.014	—23.658	0.015	—38.390	0.024
1.016	—0.024	—11.161	—0.025	—23.769	—0.028	—38.541	—0.044
0.767	0.014	—11.415	0.015	—23.040	0.016	—38.916	0.026
0.660	—0.026	—11.524	—0.026	—24.157	—0.029	—37.096	—0.048
0.400	0.015	—11.788	0.016	—24.440	0.017	—39.475	0.029
0.288	—0.027	—11.902	—0.028	—24.562	—0.031	—39.646	—0.053
0.016	0.016	—12.178	0.017	—24.859	0.019	—40.073	0.033
—0.101	—0.029	—12.297	—0.030	—24.987	—0.034	—40.255	—0.058
—0.385	0.018	—12.586	0.018	—25.300	0.021	—40.715	0.037
—0.507	—0.031	—12.711	—0.032	—25.434	—0.036	—40.911	—0.065
—0.806	0.019	—13.015	0.020	—25.764	0.023	—41.409	0.042
—0.934	—0.033	—13.145	—0.034	—25.905	—0.039	—41.621	—0.073
—1.248	0.021	—13.466	0.022	—26.254	0.025	—42.163	0.049
—1.382	—0.035	—13.603	—0.036	—26.403	—0.042	—42.393	—0.082
—1.714	0.024	—13.942	0.025	—26.775	0.028	—42.990	0.058
—1.855	—0.038	—14.086	—0.039	—26.932	—0.045	—43.241	—0.093
—2.208	0.027	—14.447	0.028	—27.329	0.033	—43.907	0.072
—2.355	—0.039	—14.598	—0.040	—27.495	—0.047	—44.181	—0.104
—2.746	0.036	—14.998	0.038	—27.939	0.044	—44.963	0.104
—2.886	—0.017	—15.141	—0.018	—28.097	—0.021	—45.236	—0.050
—3.080	0.009	—15.340	0.010	—28.318	0.012	—45.641	0.029
—3.164	—0.018	—15.426	—0.019	—28.414	—0.022	—45.815	—0.055
—3.365	0.010	—15.632	0.010	—28.644	0.012	—46.249	0.032
—3.451	—0.019	—15.721	—0.020	—28.743	—0.023	—46.435	—0.061
—3.659	0.011	—15.934	0.011	—28.983	0.013	—46.904	0.036
—3.748	—0.020	—16.026	—0.021	—29.086	—0.025	—47.104	—0.069
—3.963	0.011	—16.247	0.012	—29.335	0.014	—47.611	0.041
—4.056	—0.021	—16.343	—0.022	—29.442	—0.026	—47.828	—0.078
—4.279	0.012	—16.572	0.012	—29.702	0.015	—48.382	0.047
—4.375	—0.022	—16.671	—0.023	—29.814	—0.028	—48.618	—0.089
—4.606	0.013	—16.909	0.013	—30.085	0.016	—49.228	0.055
—4.706	—0.023	—17.012	—0.024	—30.202	—0.030	—49.488	—0.103
—4.946	0.013	—17.260	0.014	—30.486	0.017	—50.166	0.065
—5.050	—0.025	—17.367	—0.026	—30.608	—0.032	—50.454	—0.121
—5.300	0.014	—17.626	0.015	—30.907	0.019	—51.218	0.079
—5.408	—0.026	—17.737	—0.027	—31.035	—0.034	—51.541	—0.145
—5.670	0.015	—18.007	0.016	—31.349	0.020	—52.416	0.098
—5.782	—0.028	—18.124	—0.029	—31.483	—0.037	—52.784	—0.179
—6.055	0.017	—18.407	0.018	—31.814	0.022	—53.807	0.126
—6.172	—0.029	—18.528	—0.031	—31.956	—0.039	—54.235	—0.229
—6.459	0.018	—18.825	0.019	—32.306	0.024	—55.467	0.170
—6.581	—0.031	—18.953	—0.033	—32.456	—0.043	—55.978	—0.307
—6.882	0.020	—19.265	0.021	—32.828	0.027	—57.529	0.247
—7.011	—0.033	—19.399	—0.036	—32.987	—0.046	—58.161	—0.444
—7.327	0.022	—19.729	0.023	—33.383	0.030		
—7.462	—0.036	—19.869	—0.038	—33.552	—0.050		
—7.796	0.024	—20.219	0.026	—33.976	0.035		
—7.938	—0.038	—20.367	—0.041	—34.156	—0.055		
—8.294	0.028	—20.739	0.030	—34.615	0.041		

—8.442	—0.039	—20.894	—0.042	—34.806	—0.058		
—8.837	0.037	—21.309	0.040	—35.325	0.056		
—8.977	—0.017	—21.456	—0.019	—35.508	—0.027		

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H.T. [T16.133]

TABLE A-5/O.133

Quantizing distortion ratio, A-law

Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)
3.050	40.768	—8.991	40.767	—21.032	40.739	—33.070	39.178
2.879	39.769	—9.162	39.769	—21.203	39.745	—33.246	38.390
2.771	40.565	—9.270	40.565	—21.311	40.535	—33.348	38.904
2.595	39.537	—9.446	39.537	—21.488	39.512	—33.531	38.100
2.483	40.361	—9.558	40.361	—21.599	40.329	—33.636	38.621
2.301	39.301	—9.740	39.301	—21.781	39.275	—33.825	37.800
2.185	40.156	—9.856	40.155	—21.897	40.122	—33.934	38.328
1.997	39.061	—10.044	39.061	—22.086	39.033	—34.130	37.490
1.877	39.950	—10.165	39.949	—22.206	39.914	—34.242	38.025
1.682	38.817	—10.360	38.817	—22.401	38.788	—34.445	37.168
1.557	39.744	—10.485	39.744	—22.526	39.706	—34.561	37.711
1.354	38.570	—10.687	38.569	—22.728	38.539	—34.773	36.834
1.224	39.541	—10.817	39.541	—22.858	39.501	—34.893	37.386
1.014	38.320	—11.027	38.320	—23.068	38.287	—35.113	36.487
0.879	39.343	—11.162	39.342	—23.204	39.299	—35.238	37.047
0.661	38.070	—11.380	38.069	—23.422	38.034	—35.467	36.126
0.519	39.153	—11.522	39.152	—23.563	39.105	—35.597	36.694
0.292	37.820	—11.749	37.819	—23.790	37.782	—35.836	35.749
0.143	38.976	—11.898	38.975	—23.939	38.924	—35.971	36.327
—0.093	37.575	—12.134	37.574	—24.175	37.534	—36.222	35.355
—0.250	38.819	—12.291	38.819	—24.332	38.762	—36.362	35.943
—0.496	37.339	—12.537	37.339	—24.578	37.295	—36.626	34.942
—0.661	38.697	—12.702	38.696	—24.743	38.633	—36.772	35.541
—0.918	37.122	—12.959	37.122	—25.000	37.073	—37.049	34.509
—1.094	38.631	—13.135	38.630	—25.176	38.558	—37.202	35.119
—1.361	36.941	—13.403	36.940	—25.444	36.887	—37.494	34.054
—1.549	38.665	—13.591	38.664	—25.632	38.579	—37.655	34.676
—1.828	36.831	—13.870	36.831	—25.911	36.767	—37.963	33.574
—2.032	38.907	—14.073	38.906	—26.114	38.800	—38.132	34.208
—2.320	36.893	—14.362	36.891	—26.403	36.817	—38.460	33.066
—2.552	39.774	—14.593	39.771	—26.634	39.618	—38.638	33.714
—2.811	37.910	—14.852	37.908	—26.894	37.798	—38.986	32.526
—2.971	40.768	—15.012	40.764	—27.053	40.542	—39.174	33.189
—3.141	39.769	—15.183	39.766	—27.224	39.578	—39.546	31.952
—3.249	40.565	—15.291	40.562	—27.331	40.328	—39.746	32.631
—3.426	39.537	—15.467	39.534	—27.508	39.337	—40.145	31.337
—3.537	40.361	—15.579	40.357	—27.619	40.111	—40.357	32.033
—3.720	39.301	—15.761	39.298	—27.802	39.091	—40.789	30.676
—3.835	40.156	—15.877	40.151	—27.917	39.891	—41.016	31.391
—4.024	39.061	—16.065	39.058	—28.107	38.841	—41.485	29.960
—4.144	39.950	—16.185	39.945	—28.226	39.669	—41.728	30.697
—4.339	38.817	—16.380	38.814	—28.422	38.585	—42.251	29.183
—4.464	39.744	—16.505	39.740	—28.546	39.446	—42.504	29.941
—4.666	38.570	—16.707	38.566	—28.749	38.324	—43.075	28.326
—4.796	39.541	—16.837	39.536	—28.878	39.223	—43.356	29.113
—5.006	38.320	—17.047	38.316	—29.089	38.059	—44.002	27.353
—5.142	39.343	—17.183	39.338	—29.223	39.000	—44.301	28.195
—5.360	38.070	—17.401	38.065	—29.443	37.792	—45.025	26.277
—5.502	39.153	—17.543	39.147	—29.583	38.782	—45.361	27.168
—5.729	37.820	—17.770	37.815	—29.811	37.522	—46.185	25.051
—5.877	38.976	—17.919	38.969	—29.959	38.571	—46.569	25.999
—6.113	37.575	—18.155	37.570	—30.197	37.253	—47.524	23.623
—6.270	38.819	—18.311	38.812	—30.351	38.374	—47.973	24.645
—6.516	37.339	—18.557	37.334	—30.599	36.990	—49.108	21.914
—6.682	38.697	—18.723	38.689	—30.763	38.200	—49.649	23.034
—6.938	37.122	—18.980	37.116	—31.022	36.738	—51.046	19.779
—7.114	38.631	—19.155	38.622	—31.195	38.065	—51.729	21.045
—7.382	36.941	—19.423	36.934	—31.465	36.513	—53.545	16.935
—7.570	38.665	—19.611	38.655	—31.651	38.004	—54.477	18.438
—7.849	36.831	—19.890	36.824	—31.933	36.343	—57.066	12.603
—8.053	38.907	—20.094	38.894	—32.133	38.093	—58.554	14.638

—8.341	36.892	—20.382	36.883	—32.425	36.309		
—8.572	39.774	—20.613	39.754	—32.652	38.628		
—8.832	37.910	—20.873	37.896	—32.916	37.064		

Note — The stimulus *S* is measured selectively at the output of the test object. The quantizing products *Q* are measured with an effective noise bandwidth of 3.1 kHz.

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TABLE A-6/O.133

Quantizing distortion ratio, μ-law

Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)	Input level (dBm0)	S/Q (dB)
3.080	40.722	—9.069	40.585	—21.552	40.016	—35.627	37.431
2.908	39.723	—9.242	39.583	—21.735	39.006	—35.864	36.366
2.800	40.519	—9.352	40.376	—21.850	39.789	—36.006	37.104
2.623	39.490	—9.532	39.345	—22.040	38.748	—36.254	36.003
2.510	40.313	—9.645	40.166	—22.159	39.558	—36.402	36.764
2.327	39.252	—9.831	39.301	—22.356	38.485	—36.662	35.625
2.211	40.106	—9.948	39.953	—22.480	39.324	—36.817	36.413
2.022	39.010	—10.141	38.856	—22.684	38.215	—37.090	35.232
1.901	39.898	—10.263	39.740	—22.813	39.087	—37.253	36.049
1.705	38.764	—10.462	38.604	—23.025	37.939	—37.541	34.821
1.580	39.691	—10.589	39.527	—23.159	38.849	—37.712	35.671
1.376	38.515	—10.796	38.349	—23.380	37.657	—38.016	34.391
1.246	39.486	—10.928	39.316	—23.520	38.610	—38.197	35.279
1.035	38.263	—11.142	38.090	—23.750	37.370	—38.519	33.941
0.898	39.825	—11.281	39.109	—23.896	38.373	—38.711	34.873
0.679	38.010	—11.504	37.830	—24.136	37.079	—35.052	33.469
0.536	39.092	—11.649	38.908	—24.290	38.141	—39.257	34.454
0.308	37.758	—11.881	37.570	—24.540	36.786	—39.621	32.975
0.159	38.912	—12.033	38.720	—24.702	37.918	—39.840	34.023
—0.079	37.510	—12.275	37.314	—24.964	36.492	—40.229	32.457
—0.236	38.753	—12.435	38.553	—25.135	37.711	—40.465	33.582
—0.484	37.272	—12.687	37.066	—25.409	36.204	—40.883	31.914
—0.650	38.628	—12.857	38.417	—25.591	37.533	—41.139	33.141
—0.909	37.051	—13.120	36.836	—25.879	35.928	—41.590	31.351
—1.086	38.558	—13.300	38.337	—26.073	37.405	—41.871	32.713
—1.355	36.867	—13.576	36.640	—26.375	35.682	—42.360	30.775
—1.545	38.589	—13.769	38.355	—25.584	37.371	—42.671	32.335
—1.826	36.753	—14.056	36.513	—26.900	35.500	—43.203	30.212
—2.031	38.826	—14.266	38.579	—27.128	37.534	—43.557	32.102
—2.321	36.809	—14.563	36.556	—27.458	35.480	—44.134	29.751
—2.554	39.688	—14.801	39.425	—27.719	38.307	—44.559	32.424
—2.816	37.822	—15.070	37.554	—28.018	36.411	—45.106	30.244
—2.976	40.677	—15.234	40.398	—28.199	39.212	—45.411	32.915
—3.149	39.677	—15.411	39.394	—28.398	38.188	—45.796	31.650
—3.258	40.471	—15.522	40.184	—28.520	38.956	—46.002	32.337
—3.436	39.442	—15.705	39.150	—28.726	37.901	—46.417	31.013
—3.548	40.264	—15.821	39.967	—28.854	38.695	—46.636	31.718
—3.732	39.203	—16.010	38.901	—29.068	37.605	—47.086	30.325
—3.849	40.055	—16.129	39.747	—29.201	38.428	—47.320	31.051
—4.039	38.959	—16.326	38.646	—29.424	37.301	—47.811	29.580
—4.160	39.846	—16.450	39.527	—29.562	38.155	—48.063	30.327
—4.357	38.711	—16.653	38.387	—29.795	36.987	—48.611	28.765
—4.483	39.636	—16.782	39.306	—29.939	37.878	—48.875	29.537
—4.668	38.460	—16.993	38.123	—30.182	36.665	—49.488	27.845
—4.819	39.429	—17.128	39.086	—30.334	37.598	—49.771	28.666
—5.031	38.206	—17.348	37.856	—30.588	36.334	—50.454	26.831
—5.168	39.226	—17.489	38.869	—30.747	37.315	—50.770	27.697
—5.388	37.951	—17.717	37.586	—31.013	35.994	—51.541	25.684
—5.532	39.031	—17.865	38.658	—31.181	37.032	—51.900	26.603
—5.761	37.696	—18.103	37.315	—31.460	35.647	—52.784	24.365
—5.912	38.849	—18.258	38.459	—31.638	36.753	—53.198	25.349
—6.151	37.445	—18.506	37.047	—31.932	35.295	—54.235	22.808
—6.309	38.687	—18.670	38.279	—32.120	36.485	—54.726	23.878
—6.558	37.204	—18.929	36.786	—32.430	34.941	—55.978	20.910
—6.726	38.558	—19.102	38.130	—32.631	36.239	—56.582	22.098
—6.986	36.980	—19.374	36.541	—32.959	34.593	—58.161	18.473
—7.164	38.485	—19.558	38.035	—33.175	36.034	—58.949	19.842
—7.435	36.792	—19.842	36.330	—33.521	34.265		
—7.626	38.512	—20.040	38.037	—33.756	35.913		
—7.909	36.674	—20.336	36.186	—34.122	33.991		
—8.116	38.745	—20.552	38.241	—34.381	35.978		

—8.408	36.725	—20.859	36.208	—34.766	33.865		
—8.643	39.601	—21.104	39.064	—35.065	36.635		
—8.907	37.733	—21.382	37.185	—35.418	33.687		

Note — The stimulus *S* is measured selectively at the output of the test object. The quantizing products *Q* are measured with an effective noise bandwidth of 3.1 kHz.

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Figure A-6/O.133, p. 28

References

[1] CCITT Recommendation *Pulse code modulation (PCM) of voice frequencies* , Vol. III, Rec. G.711.

[2] CCITT Recommendation *Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s* , Vol. III, Rec. G.732.

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[11] CCITT Recommendation *Functional characteristics of interface associated with network nodes* , Vol. III, Rec. G.704.

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