INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

RED BOOK

VOLUME IV – FASCICLE IV.4

SPECIFICATIONS OF MEASURING EQUIPMENT

RECOMMENDATIONS OF THE O SERIES

VIII[TH] PLENARY ASSEMBLY
MALAGA-TORREMOLINOS, 8-19 OCTOBER 1984

Geneva 1985

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Part I – Series O Recommendations

Specifications of measuring equipment

PRELIMINARY NOTES

1 The Questions entrusted to each Study Group for the Study Period 1985-1988 can be found in Contribution No. 1 to that Study Group.

2 In this Volume, the expression "Administration" is used for shortness to indicate both a telecommunication Administration and a recognized private operating agency.

PART I

Series O Recommendations

SPECIFICATIONS OF MEASURING EQUIPMENT

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SECTION 1

SPECIFICATIONS FOR ANALOGUE-TYPE MEASUREMENT EQUIPMENT

Recommendation O.11

SPECIFICATIONS FOR MANUAL MAINTENANCE ACCESS LINES

1 General

1.1 *Introduction*

In order to more effectively carry out manual maintenance of international circuits in an automatic telephone network, the following international manual maintenance access lines are recommended:

a) a balanced quiet termination which initially returns a −10 dBm0 test tone;

b) a maintenance test position or console access line with multiple access codes for both voice communications and/or circuit testing;

c) a test line to terminate the Echo Suppressor Testing System (ESTS) (see Recommendation O.141) responder;

d) a loop test line with an initial tone/quiet termination interval;

e) a test line to terminate the echo canceller test responder.

These test lines should be provided as modular units so that each Administration may choose the number of each type it wishes to install at a given centre.

These test lines will not provide reliable test results for a circuit which is routed through a circuit multiplication system (CMS) employing interpolation techniques [this includes the case where a circuit is routed over time division multiple access/digital speech interpolation (TDMA/DSI) satellite channels] and therefore should not be used in this instance unless a permanent trunk-channel association in both directions of transmission can be made for the duration of the test sequence. The reason for this is that without such a trunk-channel association, circuit continuity may not be maintained within the CMS in the absence of a signal and during very low signal level conditions.

1.2 *Quiet termination test line*

The quiet termination test line is a dialable test line that initially returns a nominal 1020 Hz (or 820 Hz), −10 dBm0 tone for 13 to 15 seconds. After the initial tone period, the test line should present a balanced 600-ohm termination to simulate the nominal exchange impedance. This quiet termination should remain connected until the calling party disconnects. This dialable test line is intended to allow one-man manual 1-way loss, 1-way noise (or noise with tone) measurements and impulsive noise checks on any circuit from the distant switching centre.

1.3 *Test and/or communications access line*

The test and/or communications access line is a dialable access line intended to be located at the circuit maintenance test position or test console location associated with the international switching centres. These access lines are expected to be used for voice communications between the circuit maintenance personnel at the appropriate maintenance elements and as a test access point to make a variety of manual transmission tests. These access lines are potential facilities as a fault report point (circuit) or fault report point (network) and/or testing point (transmission).

Separate access codes will be allocated for each of the access line types described below. This is to ensure that if an Administration wishes to separate the various maintenance functions (i.e. transmission testing, switching testing and fault reports) it can do so. These allocations should not, however, stop those Administrations that wish to combine one or more of the functions, using a single access code.

1.3.1 *Transmission access test lines*

The transmission access test line is a dialable test line intended to be located at the circuit maintenance test position or test console location associated with the international switching centres. These test lines are expected to be used as a test access point to make a variety of manual transmission tests. They may also be used for voice communication purposes associated with the circuit testing.

The proposed dialling plan for these test lines enables a particular test position or console to be selected when the distant switching centre is equipped for this type of dialling access. If the normal test position number (access code) is busy, it is expected that the call should route to an idle test position number via a hunting group. Generally, the allocation of access codes should allow the digits 21 (see § 2.4.2) to cause the incoming test line call to route to the test position or maintenance console normally assigned to the particular circuit group over which the incoming call originated. Then the use of digits 22 to 29 (non CCITT No. 6 signalling) would allow the maintenance personnel to make a test line call to a specific test position or maintenance console at the distant location. This will allow both flexibility in assigning the test positions and consoles, and may also relieve the need for all test positions or consoles to be equipped with the same test equipment.

1.3.2 *Other test and/or communication lines*

A requirement exists for the provision of lines for manual switching and signalling tests and for the provision of facilities for a fault report point (circuit) or a fault report point (network). Codes will be allocated to these lines when the requirements are fully defined.

1.4 *Echo suppressor test line*

The echo suppressor test line is a dialable 4-wire test line intended to terminate the Echo Suppressor Testing System (ESTS) (see Recommendation O.141) responder on an international switching centre. This test line will allow the maintenance personnel at the distant switching centre using the ESTS director equipment to make one-man semiautomatic echo suppressor tests on the circuits between the two centres.

1.5 *Loop-around test line*

The loop-around test line is a dialable 4-wire test line that initially returns a nominal 1020 Hz (or 820 Hz), −10 dBm0 tone for 13 to 15 seconds. After the initial tone period, the test line should present a balanced 600-ohm termination to the "RETURN" direction for the next 13 to 15 seconds. The "GO" direction should also be terminated in a 600-ohm balanced termination during both these first two intervals.

After the second interval, the 600-ohm terminations should be disconnected. Finally, the "GO" and the "RETURN" directions should be connected (looped around) in the test responder at the correct level until released by the calling station.

The intent of this test facility is to provide a one-man manual means of performing fast transmission tests (level and noise) in both directions. It will also allow seizure and rapid testing by an automatic device at the calling station.

1.6 *Echo canceller test line*

The echo canceller test line is a dialable 4-wire test line intended to terminate the echo canceller test responder.

This test facility will allow maintenance personnel at the originating switching centre to make tests of the echo canceller(s) on the circuit under test. Whether the test will be made on both echo cancellers or just the echo canceller at the responder end of the circuit under test will depend on the type of directing equipment being used.

2 Method of access

2.1 In general, access arrangements should conform to the Recommendation cited in [1]).

2.2 Access to the test lines at the incoming international exchange will be gained via the normal exchange switching equipment on a 4-wire basis on all incoming and both-way circuits.

2.3 The wiring loss build-out arrangements for the test lines should conform to the Recommendation cited in [1].

2.4 *Address information*

2.4.1 *Address information sequence*

The following address information will be used to gain access to the maintenance access lines at the incoming international exchange:

i) *CCITT Signalling System No. 4*

- a) terminal seizing signal,
- b) code 13,
- c) code 12,
- d) digit 0,
- e) two digits associated with the particular international test line type to be accessed (see § 2.4.2 below),
- f) code 15.

ii) *CCITT Signalling System No. 5*

- a) KP1,
- b) digit 7 (nonallocated language digit),
- c) code 12,
- d) digit 0,
- e) two digits associated with the particular international test line type to be accessed (see § 2.4.2 below),
- f) ST.

iii) *CCITT Signalling System No. 6*

The initial address message format for access to testing devices is given in Recommendations Q.258 [2] and Q.259 [3]. The X digit allocation should be as follows:

- a) 3 (quiet termination test line),
- b) 4 (echo suppressor test line),
- c) 5 (loop-around test line),
- d) 6, 7 and 8 (transmission access test line),
- e) 9 (echo canceller test line).

In System No. 6, the bits of the access codes (bit pattern) sent on the line need not be identical with the actual access code number used by the maintenance staff. As System No. 6 will mainly be used together with SPC exchanges, it will be possible to translate any access code into an appropriate bit pattern.

iv) *CCITT Signalling System No. 7*

The initial address message format for access to testing devices is given in Recommendation Q.722 [4]. The two digits associated with the particular international test line to be accessed are given in § 2.4.2.

v) *CCITT Signalling System R1*

a) KP,

b) digits to be agreed upon between the Administrations concerned,

c) ST.

vi) *CCITT Signalling System R2*

a) test call indicator,

b) code I-13,

c) two digits associated with the particular international test line type to be accessed (see § 2.4.2 below),

d) code I-15 (on request).

2.4.2 *Test line codes for CCITT Signalling Systems Nos. 4, 5, 7 and R2*

i)	quiet termination	64
ii)	echo suppressor	65
iii)	loop-around	66
iv)	multiple address capability for transmission access test line	21-29
v)	echo canceller test line	67

3 Specifications for the test line apparatus

The following specifications apply to all test line types unless otherwise noted and apply over a temperature range of +5 °C to +50 °C.

3.1 *Tone source characteristics* (quiet termination and loop-around test lines)

a) The nominal tone source frequency should fall within either 804 to 820 Hz or 1004 or 1020 Hz. The tone source frequency including tone source stability and aging should remain within either 802 to 825 Hz or 1002 to 1025 Hz.

b) Purity of output: ratio of total output to unwanted signal at least 50 dB.

c) Long-term level stability: ± 0.03 dB.

3.2 *Transmitted level and timing intervals* (quiet termination and loop-around test lines)

a) The test tone level to be transmitted should be −10 dBm0 ± 0.1 dB.

b) Tone interval for quiet termination test line: 14 s ± 1.0 s. Tone and quiet termination intervals for the loop-around test line: 14 s ± 1.0 s.

3.3 *Impedance*

a) 600 ohms, balanced.

b) For all cases, longitudinal conversion loss (see Figure 1/O.121): at least 46 dB between 300 and 3400 Hz increasing below 300 Hz to at least 60 dB at 50 Hz.

3.4 *Return loss*

At least 30 dB between 300 and 3400 Hz.

3.5 *Frequency response*

a) ± 1 dB from 300 to 3000 Hz (quiet termination, echo suppressor, echo canceller and loop-around test lines).

b) ± 0.5 dB from 300 to 3000 Hz (transmission access test line).

3.6 *Loop-around test line level adjustment*

The loop-around test line equipment shall provide the proper buildout (loss or gain) in the loop-around measurement path to adjust its level to within ± 0.1 dB of the required nominal value. The required nominal value should be determined using Recommendation M.560 [5] and the reference level points at which the loop-around test line is employed.

4 Signalling system test line test sequence

4.1 *Circuit seizure*

When an outgoing circuit is to be seized and connected at the distant end to one of the international test lines, the appropriate address information is transmitted in accordance with the specification for the signalling system in use (see § 2.4 above).

4.2 *Test line answer*

When access is gained to the test line equipment, the answer signal (answer, no charge if System No. 6) will be transmitted. If the test line is occupied, a busy indication should be returned to the originating end in accordance with the normal signalling for the circuit and for the address concerned.

4.3 *Test line not equipped*

When a test line call is received at a switching centre not equipped to handle that type of test call, the called switching centre should respond with the standard "unallocated number" signal where available for the signalling system employed.

References

[1] CCITT Recommendation *Access points for international telephone circuits*, Vol. IV, Rec. M.565.

[2] CCITT Recommendation *Telephone signals*, Vol. VI, Rec. Q.258.

[3] CCITT Recommendation *Signalling-system-control signals*, Vol. VI, Rec. Q.259.

[4] CCITT Recommendation *General function of telephone messages and signals*, Vol. VI, Rec. Q.722.

[5] CCITT Recommendation *International telephone circuits – principles, definitions and relative transmission levels*, Vol. IV, Rec. M.560.

Recommendation O.21

CCITT AUTOMATIC TRANSMISSION MEASURING EQUIPMENT ATME No. 1 (FOR TELEPHONE-TYPE CIRCUITS)

The details of the specification for ATME No. 1 are given in Recommendation O.21 in Volume IV.1 of the *Green Book*, Geneva, 1973. ATME No. 1 was originally intended as an equipment for field trial purposes. This field trial has been completed and has led to the development of the specification for ATME No. 2 which is given in Recommendation O.22 of this fascicle.

Recommendation O.22 [1)]

SPECIFICATION FOR THE CCITT AUTOMATIC TRANSMISSION MEASURING AND SIGNALLING TESTING EQUIPMENT ATME No. 2

1 General

The CCITT automatic transmission measuring and signalling testing equipment (ATME No. 2) is intended to make transmission measurements and signalling system functional tests [2)] on all categories of international circuits terminating in exchanges with 4-wire switching.

1) The text of this Recommendation has been established under the responsibility of Study Groups IV and XI. Any modification to this text must be submitted for approval to these Study Groups.

2) The concept of *functional texts* excludes marginal testing.

The ATME No. 2 will consist of two parts, namely:

1) directing equipment at the outgoing end, and

2) responding equipment at the incoming end.

The responding equipment will be available in the following forms:

a) a signalling system functional testing *and* transmission measuring device (Type a),

b) a signalling system functional testing device (Type b)[3].

It is not possible for the signalling system functional testing devices as found in Types a and b to check the busy flash signal. For this purpose a separate test call must be established using an appropriate test code. Arrangements will therefore be provided to force the transmission of the busy flash signal over the circuit under test by the incoming international exchange equipment. This may be carried out by examination of the test code in the exchange equipment or by the provision of a separate responding equipment. The busy flash signal should be transmitted as the result of a simulation of exchange or circuit congestion. For the purposes of this specification, the equipment providing this busy test arrangement shall be referred to as responding equipment Type c.

Responding equipment Type a is always required. Type b is optional; when used in addition to Type a, it is expected to provide an economical means for making more frequent signalling tests without occupying the transmission measuring equipment. Type c responding equipment is required in cases when the signalling system used on the circuits to be tested provides a busy flash line signal.

For both-way circuits, directing and responding equipments are required at both ends for making signalling system functional tests. For transmission measurements over both-way circuits, the outgoing end is normally that which is the responsibility of the control station, and the incoming end is that which is the responsibility of the sub-control station. However, these may be interchanged by mutual agreement.

The equipment shall be of modular construction in order that only those features desired by the using Administrations need be included. The present specification already takes account of operating over circuits using CCITT Signalling Systems Nos. 3, 4, 5, 6, 7, R1 and R2.

Results of measurements shall be recorded only at the outgoing end, that is by the directing equipment. However, arrangements can be made by the Administrations or operating agencies involved to send the results of the measurements to the Administrations in charge of the incoming end and other points as desired, by mutually acceptable means. ATME 2 can be used on circuits incorporating circuit multiplication systems (CMSs) if the CMS concerned is so designed that a 2800 Hz can be used to hold the circuits during absence of the normally transmitted signals. TASI is an example of a CMS which accepts 2800 Hz as the holding tone.

2 Kinds of measurements and tests

Transmission measurements of the following kinds will be made in both directions of transmission:

a) absolute power level measurement at 800 (or 1000) Hz;

b) absolute power level measurement at 400, 800 (or 1000) and 2800 Hz (loss/frequency distortion);

c) noise measurements;

d) signal-to-total-distortion (including quantizing distortion) ratio measurements.

In addition to tests of the normal signalling functions required in the process of setting up the test call, line signals such as the following will also be tested:

- clear back,
- forward transfer,
- busy flash (this requires a separate test call).

The equipment will be designed in such a way that further measurements and tests can be incorporated at a later date.

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[3] The CCITT directs the attention of Administrations to the advantages of providing sufficient signalling system functional testing devices (Type b) to permit several signalling system functional tests to be conducted simultaneously and to permit signalling system functional tests to be conducted more frequently than transmission tests. (For the application of ATME No. 2, see Recommendation M.150 [1].)

3 Equipment for making transmission measurements and processing the results

The directing and responding equipments shall each be provided with features for making absolute power level, signal-to-total-distortion ratio and noise measurements, as described below. In addition, the directing equipment shall have the capability of receiving the results of the measurements made by both the directing and responding equipments, making the necessary adjustments to these results, as discussed below, and converting the results to the proper form for transmission to the output device. The output device is also considered to be part of the directing equipment.

3.1 *Absolute power level measurements*

3.1.1 *Sending end*

At the access point at the input to the path to be measured there will be connected a *sending equipment* which will send a tone of the appropriate frequency and level as specified in §§ 6.3 and 8.1 below.

3.1.2 *Measuring end*

At the access point at the output from the path to be measured there will be connected a measuring device whose specifications are given in §§ 6.3 and 8.1 below.

The measuring device shall provide results in the form of a deviation, expressed in dB, from the nominal absolute power level of the circuit at the virtual switching point at the receiving end. This assumes that for the responding equipment (see § 3.4 below), the relative level at the receiving end virtual switching point is -4 dBr. A level higher than nominal shall be indicated as positive " + " and a level lower than nominal shall be indicated as negative " − ". For the total distortion measurements, the results should give the signal-to-total-distortion ratio in dB. The transmission parameters of the switched access path between the virtual switching point and the measuring device shall be allowed for (see the Recommendation cited in [2]).

If the equipment is capable of detecting an interruption or a condition of instability experienced during a measurement (see § 10.5 below) the result shall be indicated as shown in Table 3/O.22.

3.2 *Noise measurements*

3.2.1 *Sending end*

At the access point at the input to the path to be measured there will be connected a 600-ohms terminating resistance or a CMS locking tone in accordance with §§ 6.4.19 or 6.4.20 and 8.3 below.

3.2.2 *Measuring end*

At the access point at the output from the path to be measured, there will be connected a noise measuring device whose specifications are given in § 8.2 below.

The noise measuring device shall provide results in terms of absolute power level with psophometric weighting referred to 0 level (dBm0p), assuming for the responding equipment that the relative level at the receiving end virtual switching point is -4 dBr (see § 3.4 below). The transmission parameters of the switched access path between the virtual switching point and the noise measuring device shall be allowed for (see the Recommendation cited in [2]).

3.3 *Signal-to-total-distortion ratio measurements*

3.3.1 *Sending end*

At the access point at the input to the path to be measured, there will be connected a sending equipment which will send a tone as specified in § 8.1 below.

3.3.2 *Measuring end*

The signal-to-total-distortion ratio measurements will be carried out in two steps.

Step 1

At the access point at the output from the path to be measured, there will be connected a noise measuring device connected with a 1000 to 1025 Hz signal rejection filter. The noise measuring device and the signal rejection filter are specified in § 8.2.

Step 2

At the access point at the output from the path to be measured there will be connected a measuring device whose specifications are given in §§ 6.3 and 8.1 below.

The measuring device shall provide results in the form of the signal-to-total-distortion ratio in dB. A bandwidth correction for the loss of effective noise bandwidth due to the rejection filter must be incorporated.

3.4 *Adjustment of results*

Circuits that may be used in international transit connections are operated with a nominal loss of 0.5 dB, that is, the relative level at the receiving virtual switching point is −4.0 dBr. However, circuits which are not intended to be used in international transit connections may be operated with nominal losses greater than 0.5 dB (see the Recommendation cited in [3]).

The results of measurement of absolute power level deviations and noise sent by the responding equipment to the directing end will assume a −4.0 dBr virtual switching point for all circuits. Thus, a measured value corresponding to −5.0 dBm at the virtual switching point will always be transmitted to the directing equipment as a deviation of −1.0 dB. Where a circuit is operated with a nominal loss greater than 0.5 dB, i.e. the actual relative level at the virtual switching point is more negative than −4.0 dBr, the directing equipment shall apply the appropriate correction to the results of the measurement of absolute power level deviation and noise received from the responding equipment. The signal-to-total-distortion measurment is not affected as the result is presented as the signal-to-total-distortion ratio in dB.

3.5 *Recording and presentation of output*

The output shall be recorded by suitable means, to be decided by the Administration concerned. For absolute power level measurements at 800 (or 1000) Hz the results shall be presented, with the appropriate algebraic sign, as deviations from the nominal absolute power level at the virtual switching point. The results of measurements at 400 and 2800 Hz shall be presented as deviations from the measured absolute power level at 800 (or 1000) Hz. Results of noise measurements shall be expressed in dBm referred to 0 level (dBm0p), and the signal-to-total-distortion measurements in the form of signal-to-total-distortion ratio expressed in dB.

An example is given in Table 1/O.22 below for measurements made by the responding equipment.

TABLE 1/O.22

Measurement	Frequencies (Hz)	Absolute power level at the receiving virtual switching point at responding equipment with −10 dBm0 sending level (dBm)	Deviation transmitted from responding equipment to directing equipment (a relative level of −4.0 dBr at the virtual switching point is assumed) (dB)	Presentation	
				For circuit with nominal loss of 0.5 dB (dB)	For circuit with nominal loss other than 0.5 dB, say 1.5 dB (dB)
Level	800 or 1000 400 2800	−13.7 −14.4 −14.6	+0.3 −0.4 −0.6	+0.3 −0.7 −0.9	+1.3 −0.7 −0.9
	Value at receiving virtual switching point at responding equipment		Value transmitted from responding equipment to directing equipment (a relative level of −4.0 dBr at the virtual switching point is assumed)		
Noise power (dBm0)	−50		−46	−46	−45
Signal-to-total-distorsion ratio (dB)	34 [a]		34	34	34

[a] With a sending level of −13.7 dBm.

Distinct indications will be given under the following conditions:

a) the absolute power level deviation exceeds the assigned maintenance limit;

b) the noise power value is outside the assigned maintenance limit;

c) the signal-to-total-distortion ratio is outside the assigned maintenance limit;

d) the absolute power level deviation is so great that the circuit is rendered unfit for service;

e) the noise power value is so great that the circuit is rendered unfit for service;

f) the signal-to-total-distortion ratio is so low that the circuit is rendered unfit for service;

g) failure to complete the test call;

h) failure to meet the requirements of the signalling tests.

In cases g) and h) the point in the programme at which a given failure occurs should be indicated.

The form that the output should take has not been specified, and international agreement on this point does not appear to be necessary, except concerning the following printout conventions (see Table 3/O.22 and § 10.5 below):

Results of the measurements out of range at the upper end . . . . + + +
(printout interpretation of three Code 11 signals)

Results of the measurements out of range at the lower end . . . . – – –
(printout interpretation of three Code 12 signals)

Interruption in measurement tone during absolute power level measurements . . . . . . 9XX or 7XX [4)]

Instability during absolute power level measurements . . . . 8XX or 6XX [4)]

It should be noted that when an interruption and instability are both detected during a power level measurement only the interruption will be recorded in the printout and no indication of the instability will be given (see § 10.5 below).

If directed by the input programme, the date and time (to the nearest minute) shall be recorded.

The possibility shall be included to provide a complete record of the results of all measurements and signalling tests and the identification of all circuits which could not be measured or tested because the circuit was occupied or because the responding equipment could not be reached. A different indication shall be given for each of the latter two categories.

In addition a shortened record should be obtainable which omits information concerning circuits which were within maintenance limits and on which no instability or interruption was indicated.

3.6 *Remeasurement and retest arrangements*

Arrangements are required to provide an input data record for circuits which were occupied on initial measurement or test and for circuits on which the responding equipment could not be reached. This input data record should be capable of expansion to include all circuits except those which are found to be within maintenance limits and on which no instability or interruption was indicated. The input data record shall be in such a form that it may be used to control the directing equipment so as to permit the reexamination of these circuits in any grouping as desired by the using Administration.

4 Method of access

4.1 In general, access arrangements will conform to the Recommendation cited in [2].

4.2 *Outgoing international exchange*

Access to the circuit for test at the outgoing international exchange will be on a 4-wire basis as shown in Figure 1/O.22 such that:

a) all line signalling equipment to be tested is included,

b) as much as possible of the international circuit will be measured, in accordance with Recommendation M.560 [4].

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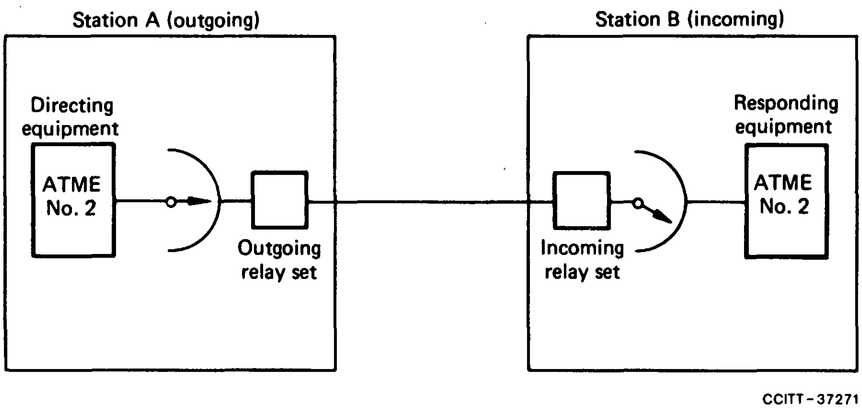
4) XX represents the results of the measurement.



Note – The connection between the directing equipment and the international circuit should be such that all line signalling equipment is included and allows as much as possible of the international circuit to be measured. The connection at the incoming international exchange between the international circuit and the responding equipment is made using the normal exchange switching equipment. It is recognized that there may be one or more switching stages involved at the outgoing and incoming international exchanges.

FIGURE 1/O.22

Recommended method of access for automatic transmission measurements and signalling tests

4.3 *Incoming international exchange*

Access to the responding equipments at the incoming international exchange will be gained via the normal exchange switching equipment on a 4-wire basis as shown in Figure 1/O.22.

4.4 *Address information*

The following address information will be used to gain access to the responding equipments at the incoming international exchange.

4.4.1 *Address information sequence*

4.4.1.1 *CCITT Signalling Systems Nos. 3 and 4*

a) terminal seizing signal,
b) code 13,
c) code 12,
d) digit 0,
e) two digits which will be associated with the particular testing or measuring device (see § 4.4.2 below),
f) code 15.

4.4.1.2 *CCITT Signalling System No. 5*

a) KP1,
b) digit 7 (non-allocated language digit),
c) code 12,
d) digit 0,
e) two digits which will be associated with the particular testing or measuring device (see § 4.4.2 below),
f) ST.

4.4.1.3 *CCITT Signalling System No. 6*

The initial address message format for access to testing devices is given in Recommendations Q.258 [5] and Q.295 [6].

The X digit allocation should be as follows:

a) signalling system testing and transmission measuring device (called Type a) 1

b) signalling system testing device (called Type b)[5] 2

4.4.1.4 *CCITT Signalling System No. 7*

The initial address message format for access to testing devices is given in Recommendation Q.722 [7]. The two digits associated with the particular international test line to be accessed are given in § 4.4.2 below.

4.4.1.5 *CCITT Signalling System R1*

a) KP,

b) digits to be agreed upon between the Administrations concerned,

c) ST.

4.4.1.6 *CCITT Signalling System R2*

a) test call indicator,

b) code I-13 (call to automatic test equipment),

c) two digits which will be associated with the particular testing or measuring device,

d) code I-15 (end-of-pulsing).

4.4.2 *Test codes for CCITT Signalling Systems Nos. 3, 4, 5, 7 and R2*

i) signalling system testing and transmission device, called Type a 61

ii) signalling system testing device, called Type b . . . . 62[5]

iii) signalling system *busy flash signal* testing, called Type c 63

(except in system R2).

5 Operating principles

It shall be possible to perform any one, two or more of the measurements and tests mentioned in § 2 above on the same circuit under the control of the directing equipment without releasing the connection except when the busy flash test is performed.

5.1 When the directing equipment has indicated to the responding equipment the kind of measurement to be made, the mesurement is first made at the directing equipment with the responding equipment sending a measurement tone or providing a 600-ohm termination. The directing equipment then sends the measurement tone or provides a 600-ohm termination while the responding equipment makes the measurement.

5.2 Directing equipment which has access to circuits equipped with echo suppressors and/or echo cancellers must be provided with arrangements to transmit the echo suppressor/canceller disabling tone specified in § 8.3 below. Arrangements must be included in the directing equipment to provide for the transmission of this tone only on circuits equipped with echo suppressors and/or echo cancellers. These features may be omitted in equipments which do not have access to such circuits, but provision must be made to add them when required.

5.3 Directing and responding equipment which has access to circuits on routes incorporating a CMS system, or to circuits equipped with echo suppressors and/or echo cancellers, must be provided with means for transmitting the CMS locking tone as specified in § 8.3 below. Means are required in the directing equipment to transmit this tone only on such routes or circuits. If these features are not provided initially, arrangements must be made so that they can be added when required.

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[5] If a Type b device is not provided in an exchange it should be possible to gain access to the Type a device using the code provided for the signalling system testing device Type b.

6 Signalling system testing and transmission measuring procedure

6.1 *Establishment of connection and signalling test sequence*

6.1.1 When the outgoing circuit is seized, the appropriate address information is transmitted in accordance with the specification for the signalling system in use (see § 4.4 above).

6.1.2 When access is gained to the responding equipment, the answer signal (answer, no charge in Signalling System No. 6) will be transmitted. If the responding equipment is occupied, a busy indication will be returned to the directing equipment in accordance with normal signalling arrangements for the circuit and for the access arrangements concerned. If the busy indication is received, this will be recorded by the directing equipment and the circuit released. (See § 3.4 above.)

6.1.3 If no signal is received by the directing equipment within 15 ± 5 seconds of transmission of the address information, then a fault will be recorded and the circuit released.

6.1.4 When the indication that the answer signal has been received is passed to the directing equipment and transmission measurements are desired with a responding equipment Type a, transmission measurement cycles may take place as described in § 6.4 below. These cycles will end with the *end of transmission measuring programme* signal (Code 15) transmitted by the directing equipment, followed by the acknowledgement signal (Code 13) transmitted by the responding equipment in accordance with the normal responding sequence.

6.1.5 When the indication that the answer signal has been received is passed to the directing equipment and transmission measurements are not desired, or if the responding equipment is of Type b, or if the transmission measurement cycles have been completed and a complete signalling functional test is required, the directing equipment will transmit the forward transfer signal, or if this signal is not provided, the Code 11 signal.

Where the forward transfer signal is part of the signalling system it should be used by the directing equipment to initiate the complete signalling function test[6].

a) *Forward transfer signal provided*

If transmission measurements have been made, a forward transfer signal will be initiated by the directing equipment 500 ± 100 ms after the end of the transmission measuring programme signal. If transmission measurements have not been made or if Type b equipment is used, the transmission of the forward transfer signal will be initiated by the directing equipment 500 ± 100 ms after the indication that the answer signal has been received is passed to the directing equipment[7]. These sequences apply to circuits fitted or not fitted with echo suppressors/cancellers.

b) *Forward transfer signal not provided*

If transmission measurements have been made the Code 11 signal will be transmitted after the end of the transmission measuring programme signal. The directing equipment will transmit the CMS locking tone between the Code 15 and Code 11 signals on circuits equipped with echo suppressors/cancellers to ensure that they remain disabled. When the acknowledgement to the Code 15 signal is recognized by the directing equipment the Code 15 command signal will be disconnected and the CMS locking tone will be connected within 60 ms. When the end of the command acknowledgement signal is recognized by the directing equipment the CMS locking tone will be removed and the Code 11 command signal will be connected 55 ± 5 ms after the disconnection of the CMS locking tone. If transmission measurements have not been made or if Type b equipment is used, the transmission of the Code 11 signal will be preceded by transmission of the echo suppressor/canceller disabling tone as specified in §§ 6.4.1 to 6.4.3 below. When the acknowledgement to the Code 11 signal (return of Code 13) is recognized by the directing equipment, the Code 11 command signal will be disconnected.

6.1.6 If shortened signalling functional tests alone are desired, the directing equipment will initiate a clear-forward signal on receipt of the answer signal if transmission measurements have not been made, or on receipt of the acknowledgement signal (Code 13) following the end of transmission measuring programme signal when transmission measurements have been made.

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6) It should be noted that although the forward transfer signal may be part of a signalling system, it may not be provided for in some international exchanges using such a signalling system. In these cases a complete signalling function test will not be possible, unless the use of Code 11 [see § 6.1.5, b)] is agreed on a bilateral basis.

7) The transmission of the line signals initiated by ATME 2 equipment on the international circuit is performed by exchange line signalling equipment in accordance with normal signalling procedures. Consequently, the actual times at which the various signals are transmitted and received depend upon the signalling system employed and the circuit propagation time in any particular case.

6.1.7 When a complete signalling functional test is carried out, the indication that a forward transfer signal has been received will cause the responding equipment to initiate a clear-back signal. For systems without a forward transfer signal (see § 6.1.5 above) the receipt of a Code 11 signal will initiate the transmission of a clear-back signal 500 ± 100 ms after the command acknowledgement signal.

The responding equipment will initiate a reanswer signal 500 ± 100 ms after the clear-back signal has been initiated[8)].

Note – It is possible that with a 500-ms gap between the initiation of the clear-back and reanswer signals a CMS circuit may release the CMS channel. This may also happen in other parts of the signalling test sequence.

If the clear-back signal is not received by the directing equipment within 5 to 10 seconds of sending the forward transfer signal or the Code 11 signal, or if the reanswer signal is not received 5 to 10 seconds after the receipt of the clear-back signal, a fault will be recorded and the circuit released.

When the reanswer signal is recognized, the directing equipment will initiate a clear-forward signal.

6.1.8 When the clear-forward signal is transmitted (in accordance with §§ 6.1.6 or 6.1.7 above), a check should be made that the outgoing circuit has been released and is available for future use. If the outgoing circuit is not fully released. within 5 to 10 seconds of the initiation of the clear-forward signal by the directing equipment, a fault will be recorded. It should be noted that the test for the release of the circuit may not be possible on certain designs of equipment.

6.2 *Busy flash test*

The busy flash signal may be tested by establishing a call using the address code specified in § 4.4 above, to force transmission of a busy flash signal by the incoming exchange equipment. On receipt of the busy flash signal the circuit will be released.

If the busy flash signal is not received within 10 to 20 seconds of transmission of the address information then a fault will be recorded and the circuit released.

Note – There is no need to make such a test in Signalling System No. 6 or in System R2.

6.3 *Transmission measuring procedure and exchange of information between directing and responding equipments*

The signalling sequence for each individual measurement cycle is specified in § 6.4 below and the frequencies and codes in Tables 2/O.22, 3/O.22 and 4/O.22. An example of the signalling sequence for a cycle involving the measurement of absolute power level is shown in Figure 2/O.22. The signalling scheme adopted for the command signals between directing and responding equipments consists of multi-frequency signals transmitted in compelled sequence; results are transmitted from the responding equipment to the directing equipment by means of multi-frequency pulse-type signals.

In the future it may be necessary to perform measurements with a tone level of -10 dBm0 in addition to the 0 dBm0 tone level now specified. In these circumstances a signal will be sent to inform the responding equipment of the measurement level to be used. (See Table 2/O.22 and § 8.1 below.) It should be noted that the sensitivity of the measuring equipment must be arranged to accommodate both levels.

The signal sender and signal receiver chosen are those specified for the CCITT interregister Signalling System No. 5 and the equipment used should be as specified in Recommendations Q.153 [8] and Q.154 [9]. (See the Annex to this Recommendation concerning the sensitivity of the signal receiver.)

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8) The transmission of the line signals initiated by ATME 2 equipment on the international circuit is performed by exchange line signalling equipment in accordance with normal signalling procedures. Consequently, the actual times at which the various signals are transmitted and received depend upon the signalling system employed and the circuit propagation time in any particular case.

TABLE 2/O.22

Command signals from directing equipment to responding equipment

Code No.	Interpretation
1	Measure absolute power level at 800 (or 1000) Hz (sent level 0 dBm0)
2	Measure absolute power level at 400 Hz } with a sent level indicated by the 800 (or 1000) Hz
3	Measure absolute power level at 2800 Hz } measurement command signal
4	Measure psophometric noise power (no CMS locking tone applied) [a]
5	Measure psophometric noise power (with CMS locking tone applied)
6	Measure absolute power level at 800 (or 1000) Hz and subsequent level measurements in the programme with a sent level of −10 dBm0
7	Measure total distortion
11	Used instead of forward transfer when this signal is not provided
13	Reverse the direction of measurement
14	(Reserved for national use)
15	End of transmission measurement programme

[a] Applies to circuits on routes which do not incorporate a CMS system and are not equipped with echo suppressors and/or cancellers.

TABLE 3/O.22

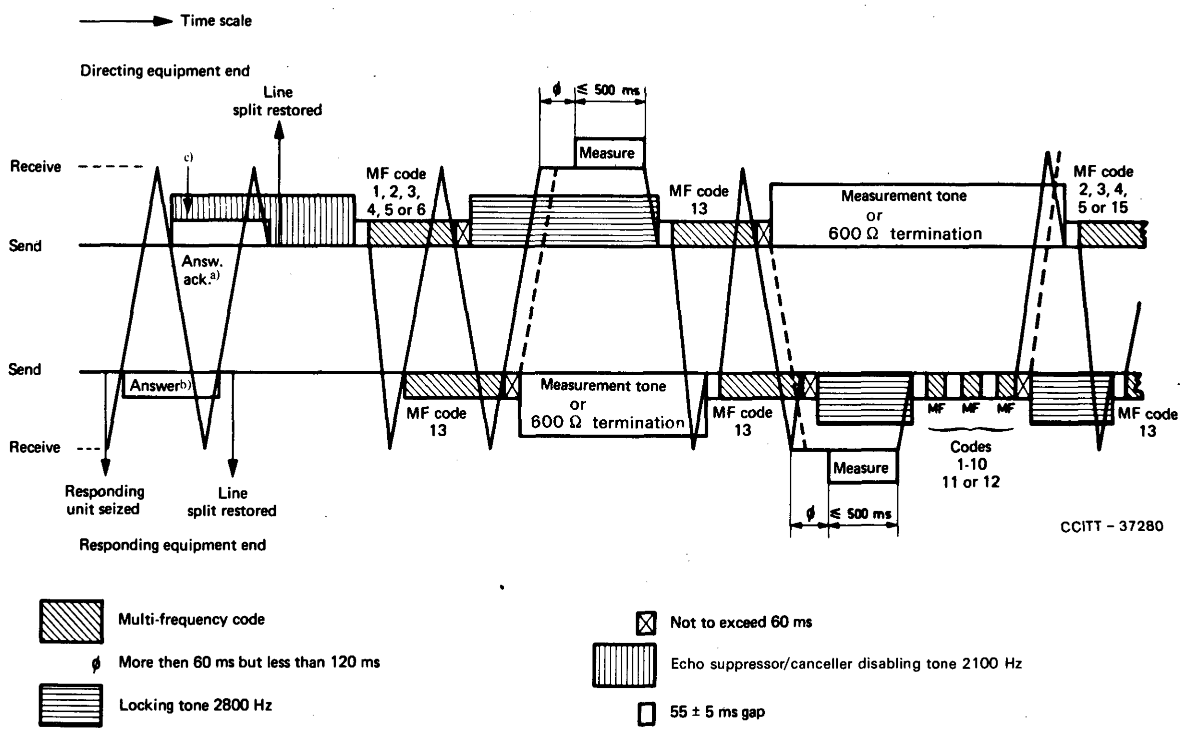
Signals from responding equipment to directing equipment

Code No.	Interpretation
1-10	Digits 1, ... 9, 0 (measurement results information)
11	+ (prefix for transmission measurements)
12	– (prefix for transmission measurements)
9	+ (prefix to indicate measurement tone interruption)
7	– (prefix to indicate measurement tone interruption)
8	+ (prefix to indicate measurement tone instability)
6	– (prefix to indicate measurement tone instability)
13	Command acknowledgement
11 (3-times)	(*out of range at the upper end* printed out as "+++")
12 (3-times)	(*out of range at the lower end* printed out as "– – –")
15	Recognition of faulty multi-frequency signal

TABLE 4/O.22

Frequency allocation and codes

Code No.	Frequencies (compound) Hz
1	700 + 900
2	700 + 1100
3	900 + 1100
4	700 + 1300
5	900 + 1300
6	1100 + 1300
7	700 + 1500
8	900 + 1500
9	1100 + 1500
10	1300 + 1500
11	700 + 1700
12	900 + 1700
13	1100 + 1700
14	1300 + 1700
15	1500 + 1700



Responding equipment end [a] CCITT No. 5 answer acknowledgement line signal.

[b] CCITT No. 4 and No. 5 answer line signal.

[c] In CCITT system No. 6 the sending of the echo suppressor/canceller disabling tone will start after reception of the answer signal (via the common signalling channel).

FIGURE 2/O.22

Typical ATME signalling sequence

6.4 *Description of transmission measuring cycles*

6.4.1 When the indication that the answer signal has been received is passed to the directing equipment, the echo suppressor/canceller disabling tone will be transmitted from the directing equipment for 2 seconds ± 250 ms.

Note 1 – This period takes into account the delay necessary for connection to a CMS channel, the time necessary for the assured disablement of the echo suppressor or echo canceller, the long propagation time likely to be experienced on satellite circuits and the delays attributable to the functioning of the signalling system. For circuits not using a line-signalling system involving an answer acknowledgement signal (such as Signalling Systems Nos. 3 and 4) it will be sufficient to send a disabling tone for at least 800 ms. If, however, the circuit to be tested is not equipped with echo suppressors/cancellers (see § 5 above), the procedure in § 6.4.1 will be omitted.

Note 2 – The specifications for the echo suppressor canceller disabling tone and the CMS locking tone are given in § 8.3 below.

6.4.2 When the echo suppressor/canceller disabling tone is removed, the directing equipment will transmit a multi-frequency command signal to the responding equipment. The interval between cessation of the tone and transmission of the command signal will be 55 ± 5 ms. If, however, the disabling tone has not been sent (see § 5 above) the multi-frequency command signal will be sent within 60 ms, following the indication that the answer signal has been received.

6.4.3 When the command signal is received by the responding equipment a multi-frequency command acknowledgement signal will be transmitted.

6.4.4 When the command acknowledgement signal is recognized by the directing equipment, the command signal will be disconnected and the CMS locking tone, if it is to be sent (see § 5 above), will be connected within 60 ms.

6.4.5 When the cessation of the command signal is recognized by the responding equipment the command acknowledgement signal is disconnected and the measurement tone is connected within 60 ms.

6.4.6 The time required for the directing equipment to detect the cessation of the command acknowledgement signal and connect the measuring equipment will not be less than 60 nor more than 120 ms. However, it should be as close to 60 ms as possible to reduce the probability of CMS switching during noise measurement.

6.4.7 The level measurement should be completed within 500 ms after connection of the measuring equipment. When the measurement is completed, the measuring equipment will be disconnected and the CMS locking tone mentioned in § 6.4.4 above, if present, will be disconnected.

6.4.8 Following disconnection of the CMS locking tone mentioned in § 6.4.7 above, a multi-frequency command signal will be connected. The interval between the tone and the signal will be 55 ± 5 ms. If, however, the CMS locking tone was not sent, the command signal will be connected 55 ± 5 ms after the measuring equipment has been disconnected.

6.4.9 When the multi-frequency command signal is recognized by the responding equipment, the measurement tone will be removed and a multi-frequency command acknowledgement signal will be transmitted. The interval between cessation of the measurement tone and the commencement of the multi-frequency command acknowledgement signal will be 55 ± 5 ms.

6.4.10 The recognition of the command acknowledgement signal by the directing equipment will cause the disconnection of the command signal and the connection of the measurement tone within 60 ms of the end of the command signal.

6.4.11 When the cessation of the multi-frequency command signal is detected by the responding equipment, the command acknowledgement signal will be disconnected and the CMS locking tone, if provided in the responding equipment, will be connected within 60 ms of the end of the command acknowledgement signal.

6.4.12 The time required for the responding equipment to detect the cessation of the command signal and connect the measuring equipment will not be less than 60 nor more than 120 ms. However, it should be as close to 60 ms as possible to reduce the probability of CMS switching during noise measurement.

6.4.13 The measurement should be completed within 500 ms after the connection of the measuring equipment. When the measurement is completed, the measuring equipment will be disconnected.

6.4.14 When the responding equipment is ready to transmit measurement results information to the directing equipment, the CMS locking tone mentioned in § 6.4.11 above will be disconnected if it has been sent. The first multi-frequency pulse to be used for the transmission of results will follow after an interval of 55 ± 5 ms from the disconnection of the CMS locking tone. If the locking tone was not sent, the first multi-frequency pulse will be sent within 60 ms after disconnection of the measuring equipment.

6.4.15 Measurement result information will be transmitted as three multi-frequency pulses in the form of a prefix followed by two digits of Codes 1 to 10 as appropriate (see Table 4/O.22). The last two digits will be sent in order of significance (most significant digit first). The pulse-length will be 55 ± 5 ms and the interval between pulses 55 ± 5 ms.

6.4.16 If the responding equipment is provided with a CMS locking tone this tone will be applied within 60 ms after the third multi-frequency pulse has been sent.

6.4.17 When the third multi-frequency pulse is recognized by the directing equipment, the measurement tone will be disconnected. A multi-frequency command signal will be sent by the directing equipment after an interval of 55 ± 5 ms from disconnection of the measurement tone. If the responding equipment has sent the CMS locking tone mentioned in § 6.4.16 above, this tone will be disconnected on recognition by the responding equipment of the multi-frequency command signal sent by the directing equipment. The responding equipment must send the command acknowledgement signal 55 ± 5 ms after cessation of the CMS locking tone. If the multi-frequency command signal sent by the directing equipment is the start of a new measurement cycle the new test sequence will proceed from the point described in § 6.4.4 above and will consist of a repetition of the sequence in §§ 6.4.4 to 6.4.17.

6.4.18 If the foregoing test sequence completes the transmission measuring programme, the multi-frequency command signal mentioned in § 6.4.17 above will be the *end of programme signal.*

6.4.19 In the case of all noise measurements, the measurement tone mentioned in §§ 6.4.5, 6.4.9, 6.4.10 and 6.4.17 above must be replaced by a 600-ohm terminating resistor.

6.4.20 In the case of noise measurements carried out on routes incorporating a CMS system or on circuits equipped with echo suppressors/cancellers, to ensure that the CMS locking tone is on in the direction which is not being measured, the CMS locking tone mentioned in §§ 6.4.4, 6.4.11 and 6.4.16 must be applied.

6.4.21 In the case of noise measurements, the responding equipment is informed of the necessity for the CMS locking tone mentioned in § 6.4.20 above by the multi-frequency command signal, *measure psophometric noise power (with CMS locking tone applied)* (see Table 2/O.22).

6.4.22 The signal-to-total-distortion measurement will be carried out in two steps:

a) detection of the total distortion measuring signal using the same method as for idle noise but with the 2800 Hz stop filter replaced by the 1000-1025 Hz rejection filter;

b) measuring of the level using the 1004-1020 Hz test signal.

6.4.23 When making total distortion measurements, the measurement tone mentioned in §§ 6.4.5, 6.4.9, 6.5.10 and 6.4.17 above must be replaced by the total distortion test signal.

6.5 *End-of-programme procedure*

When transmission measurement is complete, the remainder of the operations will be continued in accordance with §§ 6.1.4 through 6.1.8 above, insofar as they apply.

6.6 *System supervision*

6.6.1 Each multi-frequency signal must consist of two, and only two, frequencies. If one or more than two frequencies are received by the directing equipment, the measurement is recorded as faulty and the connection is released. If one or more than two frequencies are received by the responding equipment it shall be arranged to return Code 15 in place of the command acknowledgement signal Code 13. The directing equipment will then recognize the signal, record the measurements as a fault and release the connection.

6.6.2 In the transmission of measurement results, the code signals must comprise three, and only three, digits. When this is not the case, the measurement is recorded as faulty, and the connection is released.

6.6.3 Arrangements must be provided at the directing equipment to monitor the full duration of the programme. In addition to the time out requirements given in other parts of this specification, if at any time the programme fails to progress for a period of 20 to 40 seconds then the test is recorded as faulty and the connection is released. An alarm may be given to the maintenance staff.

7 **Programming**

The directing equipment will be programmed by manual means and by punched tape or cards or magnetic tape at the option of the using Administration or operating agency. Information to be supplied to the directing equipment will consist of the following:

1) the identification of the circuit to be tested;
2) the kind of circuit (CMS, echo suppressor/canceller equipped, etc.) and the kind of signalling system;
3) sufficient address information to identify the particular type of responding equipment at the incoming international exchange;
4) the transmission measurements to be made, the nominal values, and the assigned maintenance limits;
5) whether the results are to be recorded by the output equipment;
6) indication whether or not the date and time of the test should be recorded by the output equipment;
7) whether there should be a shortened record as described in § 3.4 above.

8 **Specifications for transmission measuring apparatus and for disabling tones and locking tones**

The following specifications apply over a temperature range of +5 °C to +50 °C.

8.1 *Absolute power level measuring device*

8.1.1 *Sending equipment*

Level measurements:

Frequencies: 400 ± 5 Hz, 800 ± 9 Hz (or 1000 ± 11 Hz[9]) and 2800 ± 14 Hz.

Absolute power level sent: 0 dBm0 ± 0.1 dB (or −10 dBm0 ± 0.1 dB, see § 6.3 above).

Purity of output: ratio of total output to unwanted signal at least 40 dB.

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[9] It is intended that only a single tone in the range 1004 to 1020 Hz will be required and that it can be used for both 1000 Hz level and total distortion measurements.

Total distortion test signal:

Frequency: The nominal frequency of the total distortion test signal shall be in the range 1004 to 1020 Hz. The frequency stability of the test signal shall be ± 2 Hz.

Absolute power level sent: −10 dBm0 ± 0.1 dB.

Purity of output: ratio of total output to unwanted signal at least 50 dB.

Impedance: 600 ohms balanced.

Longitudinal conversion loss (see Figure 1/O.121): At least 46 dB between 300 and 3400 Hz[10), 11)].

Return loss: at least 30 dB (at each of the above-mentioned frequencies).

8.1.2 *Receiving equipment*

Frequency range: 390-2820 Hz.

Impedance: 600 ohms balanced.

Balance with respect to earth: at least 46 dB between 300 and 3400 Hz, and below 300 Hz increasing such that at least 60 dB at 50 Hz is obtained[10), 11)].

Return loss: at least 30 dB at each of the above sending equipment frequencies.

Measuring range: from −9.9 dB to +5.1 dB relative to the nominal absolute power level of the −4.0 dBr receiving virtual switching point. It should be borne in mind that the nominal value of absolute power level at the receiving virtual switching point will depend on the absolute power level at the sending end which may be 0 dBm0 or −10 dBm0 (see § 6.3 above).

Accuracy (absolute): at 800 (or 1000) Hz, ± 0.2 dB; at 400 and 2800 Hz, ± 0.2 dB referred to the 800 (or 1000) Hz value.

Resolution (smallest measurement step): 0.1 dB.

8.2 *Noise and total distortion measuring apparatus*

Weighting: psophometric with requirements as specified in Recommendation O.41.

2800-Hz suppression: when noise measurements are made on circuits involving a CMS system or on circuits equipped with echo suppressors and/or echo cancellers, a stop filter for 2800 Hz must be inserted before carrying out the noise measurement. The requirements for the filter are given in Figure 4/O.22. When measuring white noise with psophometric weighting the insertion of the filter in the noise measuring circuit shall not cause a difference from the reading without the filter of more than 1 dB.

1000-1025 Hz suppression: when total distortion measurements are made, a test signal rejection filter[12)] for 1000 to 1025 Hz must be inserted before carrying out the total distortion signal measurement. The requirements for the filter are given in Figure 3/O.22. A bandwidth correction for the loss of effective noise bandwidth due to the rejection filter must be incorporated in the ATME No. 2 system.

Method of detection for idle noise: the method of detection shall be such that if white Gaussian noise, or a sine wave of any frequency between 390 and 2820 Hz is applied at the input in the absence of the 2800-Hz stop filter mentioned above, for a period of 375 ± 25 ms, the output indication will be the same in each case, within ± 1 dB, as that given by the CCITT psophometer when the same white Gaussian noise or sine wave is applied at its input for a period of 5 seconds.

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10) Pending the general adoption of a method for measuring the balance with respect to earth, the method to be used is left for agreement between the constructor of the equipment and the Administration or private operating agency concerned.

11) Any interface equipment provided to meet the signalling requirements of the exchange, or for purposes of controlling functions with the ATME No. 2, must be considered as part of the ATME No. 2 for the purpose of determining the balance to earth.

12) This is the same rejection filter characteristic as specified in Recommendation O.132.

Method of detection of the signal-to-total-distortion ratio: the method of detection of the total distortion signal shall be the same as that for idle noise as given above except with the 1000 to 1025 Hz rejection filter replacing the 2800 Hz stop filter. In addition, the level of the received 1004-1020 Hz test signal must be measured and compared with the total distortion signal to determine the signal-to-total-distortion ratio in dB.

Measuring interval: 375 ± 25 ms.

Impedance: 600 ohms balanced.

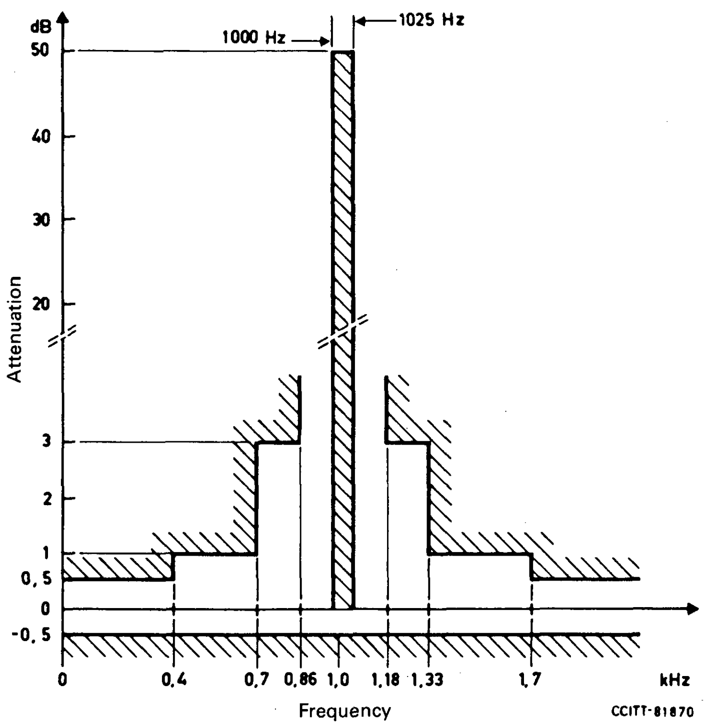
Input longitudinal interference loss (see Figure 5/O.121): at least 46 dB between 300 and 3400 Hz, and below 300 Hz increasing such that at least 60 dB and 50 Hz is obtained [13), 14)].

Return loss: at least 30 dB from 40 to 5000 Hz.

Measuring range: −30 to −65 dBm0p.

Accuracy: ± 1 dB at calibrating frequency from −30 to −55 dBm0p. Between −55 dBm0p and −65 dBm0p an accuracy of ± 2 dB is allowed, but ± 1 dB remains desirable.

Resolution (smallest measurement step): 1 dB.



The difference between the loss/frequency characteristic with the 1000 to 1025 Hz rejection filter inserted and the loss/frequency characteristic without the filter shall conform to the following limits:

30 Hz to 0.4 kHz and 1.7 kHz to 20 kHz	difference not greater than ±0.5 dB
0.4 kHz to 0.7 kHz and 1.33 kHz to 1.7 kHz	difference not greater than +1 dB or −0.5 dB
0.7 kHz to 0.86 kHz and 1.33 kHz to 1.18 kHz	difference not greater than +3 dB or −0.5 dB
1000 Hz to 1025 Hz	difference greater than 50 dB (rejection band)

(The characteristic with the filter inserted relative to the characteristic without the filter should not enter the hatched areas.)

FIGURE 3/O.22

Performance requirements for 1000-1025 Hz rejection filter

13) Pending the general adoption of a method for measuring the balance with respect to earth, the method to be used is left for agreement between the constructor of the equipment and the Administration or private operating agency concerned.

14) Any interface equipment provided to meet the signalling requirements of the exchange, or for purposes of controlling functions with the ATME No. 2, must be considered as part of the ATME No. 2 for the purpose of determining the balance to earth.

8.3 *Disabling and locking tones*

– Echo suppressor canceller disabling tone:

Frequency: 2100 Hz ± 15 Hz.
Level: -12 dBm0 ± 1 dB.

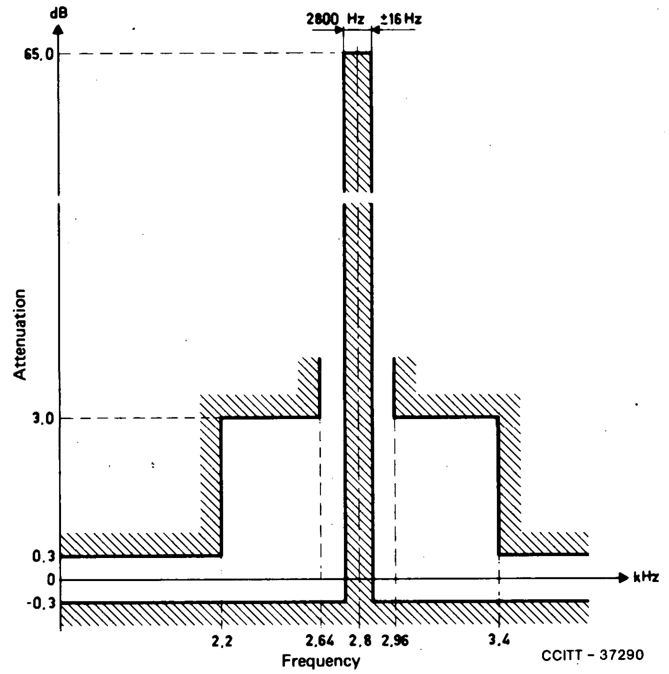
The 2100 Hz tone should be periodically interrupted every 450 ± 20 ms by a 180 ± 5 degree phase shift. The interruption interval may be asynchronous with the beginning of the tone-on interval.

– CMS locking tone:

Frequency: 2800 Hz ± 14 Hz.
Level: -10 dBm0 ± 1 dB.

– For the two tones:

Impedance: 600 ohms balanced.
Input longitudinal interference loss (see Figure 5/O.121): at least 46 dB between 300 and 3400 Hz[15), 16)].
Return loss: at least 30 dB from 300 to 3400 Hz.



The difference between the loss/frequency characteristic with the 2800-Hz stop-filter inserted and the loss/frequency characteristic without the filter shall conform to the following limits:

30 Hz to 2.2 kHz and 3.4 kHz to 20 kHz	difference not greater than ± 0.3 dB
2.2 kHz to 2.64 kHz 2.96 kHz to 3.4 kHz	difference not greater than +3.0 dB or −0.3 dB
2.8 kHz ± 16 Hz	difference greater than 65 dB

(The characteristic with the filter inserted relative to the characteristic without the filter should not enter the hatched areas.)

FIGURE 4/O.22

Performance requirements for 2800-Hz locking tone stop-filter

Figure 4/O.22, p.

15) Pending the general adoption of a method for measuring the balance with respect to earth, the method to be used is left for agreement between the constructor of the equipment and the Administration or private operating agency concerned.

16) Any interface equipment provided to meet the signalling requirements of the exchange, or for purposes of controlling functions with the ATME No. 2, must be considered as part of the ATME No. 2 for the purpose of determining the balance to earth.

9 Calibration

9.1 *Built-in calibration*

The accuracy desired from the ATME makes calibration equipment of laboratory-type accuracy necessary. Such accuracy is seldom provided by normal maintenance equipment available to repeater station staff. Hence, built-in calibration features should be provided. Due regard should be paid to the ease of maintenance, and adequate access facilities should be provided.

9.2 *Self-check*

The responding and directing equipments shall each incorporate a local self-checking facility on the transmission measuring unit which will bring in a local alarm and disable the unit when it is out of tolerance. This self-check should be applied at least daily. If they so wish, user Administrations or operating agencies may incorporate arrangements for making this self-check automatically.

10 Optional arrangements

10.1 *Automatic start*

In the long term, the operation of the ATME without any attention by technical personnel will be desirable. The addition of timed automatic start facilities to the ATME is required when unattended operation of the ATME is intended.

10.2 *Timed automatic selection of particular circuits or groups of circuits*

It may be desirable to select for test a particular circuit, or group of circuits, at specified times according to a prearranged programme, for example noise measurement during busy and non-busy hours.

10.3 *Automatic repeat attempt*

It may be desirable to incorporate an automatic repeat test facility for circuits which have been rejected as faulty. The arrangement should permit an *automatic repeat attempt* of the relevant test cycle immediately following the first test.

A test cycle is defined as a sequence of measurements commencing with Command Codes 1 to 7 and not Command Code 13.

10.4 *Switching pad test*

Administrations may use their ATME No. 2 directing equipment to test a pad-switching facility provided at the outgoing end of an international circuit.

Such testing must not involve any other Administration in making changes to their signalling, switching or ATME equipment or to their operating and maintenance procedures.

10.5 *Interruption and instability during level measurements*

It may be desirable to detect an interruption or a condition of instability during the level measuring interval at the directing and/or the responding equipments. If such indications are available they will always be recorded by the directing equipment (see § 3.5 above).

When an interruption and instability are both detected during a 500-ms measuring period only the indication of an interruption shall be transmitted and recorded.

10.6 *Nonavailability of responding equipment*

It may happen that, as a result of a failure at the responding end, all attempts made at the directing end to set up a call with a particular responding equipment will be unsuccessful – there may be no reply or the busy tone may be received. As this state of affairs could seriously affect the carrying out of a measurement programme as planned, it would appear to be desirable to ensure either:

- that this situation should give rise to an alarm signal if the directing equipment is operating under supervision;
- or that the directing equipment should be able automatically to select an alternative measurement programme if it is operating without supervision.

ANNEX A

(to Recommendation O.22)

Sensitivity of the signalling receiver

A.1 The multi-frequency signal sender and receiver specified for ATME No. 2 is given in Recommendations Q.153 [8] and Q.154 [9] respectively, as used in CCITT Signalling System No. 5.

The sending level per frequency = -7 ± 1 dBm0 and therefore the nominal receiving level at the -4.0 dBr virtual switching point = -11 dBm.

The operating limits of the multi-frequency receiver give a minimum margin of $\pm$ 7 dB on the nominal absolute level of each received signal (i.e. taken to mean per frequency).

Therefore the receiver minimum operate level range at the -4.0 dBr virtual switching point:

$$= -11 \text{ dBm} \pm 7 \text{ dB}$$

$$= -18 \text{ dBm to } -4 \text{ dBm}$$

A.2 The maximum circuit *loss* deviation from nominal over which the multi-frequency signals can be received is:

$$(-11 - 1) - (-18) = +6.0 \text{ dB}$$

and the minimum circuit *loss* deviation from nominal over which the multi-frequency signals can be received is:

$$(-11 + 1) - (-4) = -6.0 \text{ dB}$$

A.3 Therefore the circuit *loss* deviation limits between which multi-frequency signals can be received is $+6.0$ to -6.0 dB about the nominal loss, whereas ATME No. 2 is capable of measuring deviations greater than these values (see § 8.1 of this Recommendation).

A.4 Although the specification for the multi-frequency signal receiver (Recommendation Q.154 [9]) stipulates that a received signal may vary $\pm$ 7 dB about the nominal receive level of -7 dBm0, Recommendation Q.154 [9] also states that the receiver shall not operate to a signal 17 dB below the nominal received signal level, which means that in the range -14 to -24 dBm0 the receiver may or may not operate. It is to be expected therefore that somewhere within this range the receiver will cease to operate.

A.5 In practice multi-frequency receivers are set up to operate to a minimum signal level in this range of -14 to -24 dBm0. Therefore signalling would normally be possible over a circuit with a loss greater than that given in § A.3 above. In those cases where the multi-frequency receiver fails to operate the circuit test would still be recorded as mentioned in § 6.6.3 of this Recommendation.

References

[1] CCITT Recommendation *Routine maintenance schedule for international public telephony circuits*, Vol. IV, Rec. M.605.

[2] CCITT Recommendation *International telephone circuits – principles, definitions and relative transmission levels*, Vol. IV, Rec. M.560, § 2.

[3] CCITT Recommendation *Stability and echo*, Vol. III, Rec. G.131, § 2.1.

[4] CCITT Recommendation *International telephone circuits – principles, definitions and relative transmission levels*, Vol. IV, Rec. M.560.

[5] CCITT Recommendation *Telephone signals*, Vol. VI, Rec. Q.258.

[6] CCITT Recommendation *Overall tests of Signalling System No. 6*, Vol. VI, Rec. Q.295.

[7] CCITT Recommendation *General functions of messages and signals*, Vol. VI, Rec. Q.722.

[8] CCITT Recommendation *Multifrequency signal sender*, Green Book, Vol. VI-2, Rec. Q.153, ITU, Geneva, 1973.

[9] CCITT Recommendation *Multifrequency signal receiver*, Green Book, Vol. VI-2, Rec. Q.154, ITU, Geneva, 1973.

Recommendation O.31

SPECIFICATION FOR AN AUTOMATIC MEASURING EQUIPMENT FOR SOUND-PROGRAMME CIRCUITS

1 General

The CCITT automatic measuring equipment for sound-programme circuits is capable of rapidly measuring all relevant parameters necessary for checking the quality of such circuits. The measuring results are recorded by means of an analogue recorder and/or digital receiver. The results of the measurements are suitable for subsequent documentation and not only permit an immediate decision by the staff in the field on whether the sound-programme circuit or sound-programme connection respectively can be used for service, but they also provide the basis for later exact evaluation by the responsible transmission engineer.

The overall time for the measurements amounts to 136 seconds. It is thus short enough to check the quality also of international chains of sound-programme circuits interconnected on a short-term basis during the preparatory and lining-up period according to Recommendation N.4 [1]. Measurements for this purpose, made by the ISPCs involved in accordance with Recommendations N.12 [2] and N.13 [3], do not require any preceding agreement.

2 Quality criteria to be checked

With the CCITT automatic measuring equipment for sound-programme circuits the following quality criteria can be checked:

- a = deviation of the received absolute power level of the 0.8-kHz reference frequency from the nominal value;
- b = weighted and unweighted noise;
- c = nonlinear distortion measured selectively as harmonic distortion of the 2nd order (k_2) and 3rd order (k_3) and as a difference tone distortion of the 3rd order (d_3);
- d = compandor functioning test;
- e = loss/frequency distortion.

The complete measuring programme comprises three subroutines which can be chosen individually. The quality criteria to be checked are allotted to the subroutines in the following way:

Subroutine 1: $s + a$

Subroutine 2: $b + c + d$

Subroutine 3: e

where

in subroutine 1, s is the station coding of the sending unit.

Within the subroutine the timing of the programme in the sending unit and in the receiving unit is synchronized by means of a series of pulses provided by a generator within the equipment.

3 Specifications

3.1 *Sending unit*

3.1.1 *Start, stop and time base for synchronization and selection of measuring mode*

By means of a locking press-button in the sending unit the measuring programme for single or permanent mode of operation can be started. The timing of the measuring programme is controlled by a pulse generator. The smallest time base that can be programmed is fixed at 1.33 second. The synchronizing frequency related to this time base gives 0.75 Hz and has to be kept within ± 1%. A second press-button offers the possibility of stopping the measuring programme. By the activation of this press-button a means is provided whereby the locking mechanism of the start press-button for permanent operation is simultaneously released. Start, synchronization and stop of the receiving unit are triggered by coded pulses (1.3 kHz at −12 dBm0).

Every subroutine is preceded by coded pulses which serves as a start signal. By means of a special stop signal which is triggered by pressing the stop button, the progress of the measuring programme can be interrupted at any time and another programme, selected with the aid of a switch, can be started instead. Operating the stop button will also reset the time pulse generator to the starting condition.

The start and stop signals consist of four pulses whose duration can be fixed at 60 ms (value O) or 120 ms (value L) by means of digital coding. The time between the beginning of every pulse within the coded signal is 240 ms.

The coding of the pulses is as follows:

a) Start signals for:
   - Subroutine 1: OOOL
   - Subroutine 2: OOLO
   - Subroutine 3: OLOO

b) Stop signal: LLLL

The start signals are read from right to left, as is usual in the case of digital codes, and are transmitted in the same time sequence.

The sending of the coded signal (duration 960 ms) which is controlled by the time pulse generator must be delayed 370 ms (in order to comply with the time pulse duration of 1330 ms).

3.1.2 *Station coding*

The measuring programme is preceded by the code of the sending station using the Morse alphabet. For this purpose 19 timing intervals are allocated. The station code is sent by keying a 0.8-kHz tone between a level of −32 dBm0 and the reference test level. The duration of Morse dots and dashes shall be about 10% and 35% respectively, of one timing interval.

3.1.3 *Test level sent for the measurement of level at the reference frequency and level/frequency response* (quality criteria *s*, *a* and *e*)

The test level sent for loss measurements at the reference frequency (0.8 kHz) and for the measurement of level/frequency response should be −12 dBm0 (see Recommendation N.21 [4]). The measurements of level/frequency response are to be carried out with the aid of a sweep generator covering the frequency range from 0.03-16 kHz. Each octave – the first one beginning at 0.05 kHz – is marked by short pulses (1.3 kHz/−12 dBm0 from 50 to 100 ms duration). The speed of this sequence of operations for the frequency range from 30-16 000 Hz which covers 9.06 octaves should be 5 seconds/octave so that the recording device dealt with in § 3.2.7 below records one octave over 10 mm and 3.3 mm respectively.

3.1.4 *Test level sent for nonlinear distortion measurements*[1)]

The sent level of the test frequencies corresponds to the peak programme level (see the Recommendation cited in [5]), that is, the single tones for the nonlinear distortion measurements lead to the same peak loading as the double tone for the difference tone factor measurements (single tone of +9 dBm0 equivalent to 2.2 $V_{r.m.s.}$ = 3.1 V_{p0} and double tone each of +3 dBm0 equivalent to (because it is stuck to "2" in the Orange Book) 2 × 1.1 $V_{r.m.s.}$ = 2 × 1.55 V_{p0} referred to = 3.1 V_{p0} a zero relative level point). In order to avoid overload of carrier-frequency transmission systems, only frequencies below 2 kHz (with regard to circuits equipped with equipped with pre- and de-emphasis techniques) are applied and the duration of transmission is automatically reduced to the length of a single timing pulse[2)]. The following test frequencies should be used:

a) *For the measurement of nonlinear distortion in the lower audio-frequency range:*

c_1 = 0.09 kHz/+9 dBm0 for the k_2-measurement;

c_2 = 0.06 kHz/+9 dBm0 for the k_3-measurement.

b) *For the measurement of nonlinear distortion in the carrier-frequency range of a frequency division multiplex channel:*

c_3 = 0.8 kHz/+3 dBm0 and 1.42 kHz/+3 dBm0 for the d_3-measurement.

c) *For the measurement of nonlinear distortion in the medium audio-frequency range:*

c_4 = 0.8 kHz/+9 dBm0 for the k_2-measurement;

c_5 = 0.533 kHz/+9 dBm0 for the k_3-measurement.

3.1.5 *Signal sent for compandor functioning test* [3)] (quality criterion *d*)

In order to detect a noncomplementary behaviour of regulating amplifiers in compandors a 0.8-kHz signal is injected, the level of which is switched between the values +6, −6, +6 dBm0 for three consecutive timing intervals.

3.1.6 *Remote control of the sending unit*

Provision should be made for sending up to 16 command signals. These signals may be applied to the sending equipment in either binary code or by applying earth to 16 signal paths. In case of binary coding for starting the complete measuring programme the coded signal LOOL should be used in addition to the start signal given under § 3.1.1 above.

3.2 *Receiving unit*

3.2.1 *Start, stop and synchronization*

In the receiving unit the coded pulses must be detected and separated by means of a selective process. A guard circuit similar to the one normally used for signal receivers is required to protect against false operation. In combination with the above-mentioned guard circuit the 4-bit code chosen offers a highly reliable protection against the possibility that the starting mechanism might be activated by sound-programme signals. Thus, the receiving unit can remain continuously connected to a sound-programme circuit and can record the measuring programme without intervention by an operator.

The timing schedule must be in conformity with the requirements specified for the sending unit (see § 3.1.1 above).

The time pulse generator shall be triggered after the reception of the start signal. Reception of the stop signal shall cause the time pulse generator to be reset to the starting condition.

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1) It shall be possible for the signal sent for the measurement of nonlinearity distortion to be included in or omitted from the test cycle at will (for example, under control of a switch). Whether or not the nonlinearity distortion measurement is admissible must be determined for each circuit by the users of the equipment, and in a manner ensuring that the prescriptions of Recommendation N.21 [4] are respected.

2) Other methods are under study by the CCITT.

3) This test is intended for provisional use. A change will be necessary when, after further study, the CCITT issues Recommendations for compandors and appropriate methods of their testing.

3.2.2 *Measuring ranges*

The measuring device should have a logarithmic characteristic, and a linear measuring range of ± 10 dB referred to the respective centre-of-range should be provided.

For the particular measuring function the following centres-of-range should be provided:

– station coding, level measurement at 0.8 kHz and measure of level/frequency response (s, a, e)	−12 dBm0
– noise level weighted (b_1) and unweighted (b_2)	−51 dBm0
(signal/noise ratio, referred to +9 dBm0	60 dB)
– nonlinear distortion	
k_2- and k_3-measurements (c_1, c_2, c_4, c_5)	−31 dBm0
(ratio, referred to +9 dBm0	40 dB)
d_3-measurement (c_3)	−37 dBm0
(ratio, referred to +3 dBm0	40 dB)
– level step signal (d)	0 dBm0

The quality criteria a, c, d and e are expressed in terms of r.m.s. values.

3.2.3 *Noise measurements*

The quality criteria b_1 and b_2 (weighted and unweighted noise measurements) are measured in a quasi-peak mode. The dynamic properties of the rectifier circuitry and the network for weighted noise measurement (b_1) should meet the requirements of CCIR Recommendation 468-3 [6].

3.2.4 *Provision of filters and their characteristics*

Two bandpass filters should be provided for selecting the nonlinear distortion products, one for 0.18 kHz and the other for 1.6 kHz. They should be used as follows:

0.18-kHz filter

– for k_2-measurement of 0.09 kHz (c_1),
– for k_3-measurement of 0.06 kHz (c_2),
– for d_3-measurement of 0.8/1.42 kHz (c_3);

1.6-kHz filter

– for k_2-measurement of 0.8 kHz (c_4),
– for k_3-measurement of 0.533 kHz (c_5).

With the 0.18 kHz filter only the lower d_3-product (2 × 0.8 kHz − 1.42 kHz = 0.18 kHz) is measured. The measurement of the upper d_3-product at 2.04 kHz (= 2 × 1.42 kHz − 0.8 kHz) is not made. To compensate for this, two times the lower d_3-product at 0.18 kHz is taken.

The bandpass filters should meet the following selectivity requirements:

– passband defined by insertion loss values less than 1 dB:

$$\left.\begin{array}{l} 0.18 \text{ kHz filter: } \pm\ 3 \text{ Hz} \\ 1.6 \text{ kHz filter: } \pm\ 24 \text{ Hz} \end{array}\right\} \text{referred to the centre frequency}$$

– rejection frequency range defined by insertion loss values greater than 70 dB:

0.18 kHz filter: < 0.09 kHz and > 0.36 kHz
1.6 kHz filter: < 0.8 kHz and > 3.2 kHz

3.2.5 *Additional markers provided at digital receivers*

Additional markers can be generated in the digital receiver as required by making use of the octave markers received from the sending unit as a timing base.

3.2.6 *Programming of digital receivers*

Where a digital receiver is used it shall be possible to programme it so as to check that the circuits tested meet the required tolerances.

3.2.7 *Recording device*

The transient response time of the recording device should not exceed 200 ms. In connection with the rectifier circuitry of the receiving unit for noise measurements the requirements of CCIR Recommendation 468-3 [6] should be fulfilled.

Paper width and speed may be chosen according to national standards. The following values have proved to be practicable:

- paper width 100 mm;
- paper speed 2 mm/s and 2/3 mm/s.

  These paper speeds should be manually adjustable.

The above-mentioned values yield (on the 20-dB level range) a level scale of 2 dB/10 mm and (on the 136-seconds overall time) a record length of 272 mm and 90.7 mm respectively.

In addition to the recording device it would be desirable to provide appropriate access points for the use of an oscilloscope.

3.3 *Sequence of operations*

The sequence of operations of the measuring programme and the associated time units is shown in Annex A.

3.4 *Long-term measurements of noise*

3.4.1 *Automatic measurements*

After a period of 10 time intervals following the end of a complete measuring programme, and without receipt of a start signal, the receiver will automatically commence long-term noise measurements. Weighted noise will be measured over a period of 60 time intervals and unweighted noise over a period of 20 time intervals. The same centre-of-range as given in § 3.2.2 above for noise, weighted and unweighted will be used.

3.4.2 *Manual measurements*

In order to make measurements of weighted or unweighted noise continuously for unspecified periods of time, it must be possible to make the timing mechanism inoperative. Where an analogue receiver is used, a manually controlled switch should be provided, so that the centre-of-range can be changed by 10 dB in either direction.

3.5 *Matching characteristics*

According to the lining-up procedure for sound-programme circuits using the constant voltage method the following impedances are to be provided:

- output impedance of the sending unit < 10 ohms,
- input impedance of the receiving unit > 20 kohms.

Both values may be changed by internal switching to 600 ohms if, for the lining-up of the sound-programme circuit, the impedance matching method is applied. It should be possible to adjust the sending and receiving units by means of a switch to the following relative levels:

+6 dBr = nominal value at the repeater stations of Administrations;

0 dBr[4] = nominal value at the studios of broadcasting organizations.

3.6 *Accuracy of sending and receiving units*

3.6.1 *Sending unit*

a) *Individual frequency oscillators*

- level tolerance . . . . ± 0.2 dB
- frequency tolerance . . . . < 1.0%
- harmonic distortion at $2f$ and $3f$ . . . . < 0.1%

4) For certain purposes a level of −3 dBr or lower may be used.

b) *Sweep frequency oscillator*

- level tolerance at 0.8 kHz . . . . ± 0.2 dB
- level/frequency response referred to 0.8 kHz . . . . ± 0.2 dB

3.6.2 *Receiving unit*

Tolerances, including recording device:

- mid-scale value −12 dBm0 and 0 dBm0 . . . . ± 0.3 dB
- mid-scale value −51 dBm0 and −31 dBm0 . . . . ± 1.0 dB

Operational stability should be reached within 15 minutes after switching on. As far as the details of the division of the tolerances are concerned, reference is made to the values given in [7].

The tolerances may then be reduced by calibrating the sending and receiving units when interconnected on a loop basis (in order to compensate residual errors).

ANNEX A

(to Recommendation O.31)

TABLE A-1/O.31

Sequence of operations

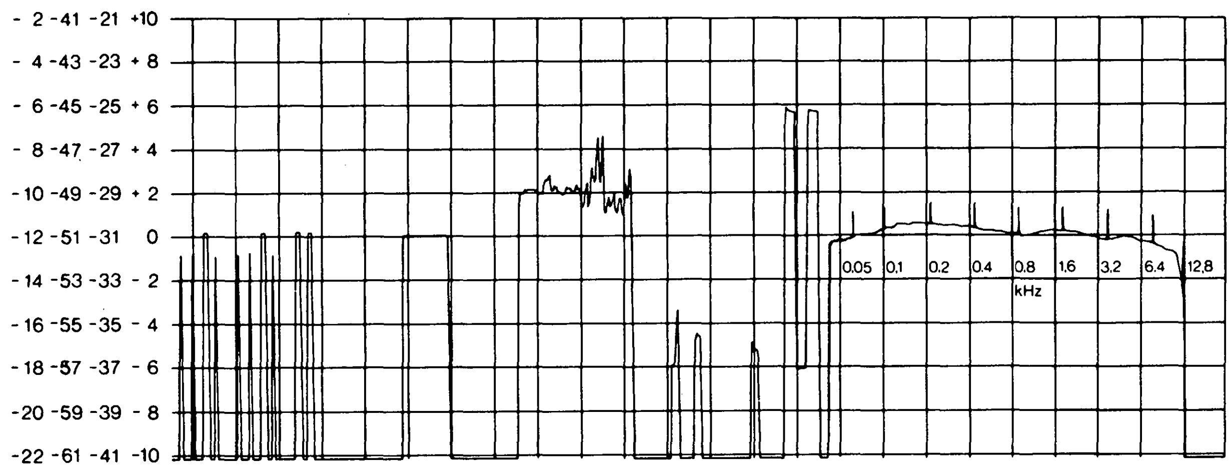
(See in the following appendix an example of the record of measurements made by a typical model of the automatic measuring equipment)

Time intervals	Sending unit		Receiving unit	
	Frequency kHz	Level dBm0	Measuring function	Centre of range dBm0
1	1.3	−12	Coded start signal No. 1	
1			Pause	
19	0.8 Morse	−32/−12 Code	Station coding using Morse alphabet	−12
1			Pause	
4	0.8	−12	Measurement of reference level	−12
2			Pause	
1	1.3	−12	Code start signal No. 2	
2			Pause	
5			Noise power weighted by psophometer filter	−51
5			Noise power unweighted	−51
2			Pause	
1	0.09	+9	k_2-level with 0.18 kHz filter	−31
1			Pause	
1	0.06	+9	k_3-level with 0.18 kHz filter	−31
2			Pause	
1	0.8 1.42	+3 +3	d_3-level with 0.18 kHz filter	−37
2			Pause	
1	0.8	+9	k_2-level with 1.6 kHz filter	−31
1			Pause	
1	0.533	+9	k_3-level with 1.6 kHz filter	−31
2			Pause	
3	0.8	+6/−6/+6	Compandor test	0
4			Pause with reserve	
1	1.3	−12	Coded start signal No. 3	
1			Pause	
35	0.03 ... 16 with frequency marks at each octave beginning at 0.05 kHz	−12	Level/frequency response	−12
2			Pause	
Total 102				

APPENDIX I

(to Recommendation O.31)

Example of the record of measurements made by a typical model of the automatic measuring equipment



dBm0				1	2	3	4	5 6 7 8 9	10	11
Scale				Measurement programme	Sending station	Receiving station	Circuit (Mono/Stereo)	Length	Remarks	
×				1 Station code						
×				2 0.8 kHz Line-up						
	×			3 Noise weighted						
	×			4 Noise unweighted						
		×		5 Non linear distortion at +9 dBm0 k_2 (0.09 kHz)						
		×		6 k_3 (0.06 kHz)						
		×		7 d_3 (0.8 + 1.42 kHz)	Date	Time				
		×		8 k_3 (0.8 kHz)						
		×		9 k_3 (0,533 kHz)						
			×	10 Compander test +6/−6/+6 dBm0						
×				11 Level/frequency distortion						

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References

[1] CCITT Recommendation *Definition and duration of the line-up period and the preparatory period,* Vol. IV, Rec. N.4.

[2] CCITT Recommendation *Measurements to be made during the line-up period that precedes a sound-programme transmission,* Vol. IV, Rec. N.12.

[3] CCITT Recommendation *Measurements to be made by the broadcasting organizations during the preparatory period,* Vol. IV, Rec. N.13.

[4] CCITT Recommendation *Limits and procedures for the lining-up of a sound-programme circuit,* Vol. IV, Rec. N.21.

[5] CCITT Recommendation *Measurements to be made by the broadcasting organizations during the preparatory period,* Vol. IV, Rec. N.13, Note.

[6] CCIR Recommendation *Measurement of audio-frequency noise in sound broadcasting,* Vol. X, Rec. 468-3, ITU, Geneva, 1982.

[7] *Measuring instrument requirements. Sinusoidal signal generators and level-measuring instruments,* Green Book, Vol. IV.2, Supplement No. 3.1, ITU, Geneva, 1973.

SPECIFICATION FOR AN AUTOMATIC MEASURING EQUIPMENT FOR STEREOPHONIC PAIRS OF SOUND-PROGRAMME CIRCUITS

1 General

An equipment designed in accordance with this Recommendation is intended for use on stereophonic pairs of sound-programme circuits. The equipment is very similar to the equipment specified in Recommendation O.31. The stereophonic and monophonic equipments are compatible for the testing of monophonic sound-programme circuits.

The differences between the monophonic and the stereophonic equipment are as follows:

The monophonic equipment (Recommendation O.31) measures 5 different parameters in 136 seconds; the stereophonic set measures the same 5 parameters in channels A and B of the stereophonic pair; in addition it measures the level and phase difference between channels A and B, and the crosstalk at three specified frequencies between the two channels. The overall time for the stereophonic measurements therefore amounts to approximately 371 seconds.

2 Quality criteria and measuring routines

2.1 *Quality criteria to be checked*

Table 1/O.32 gives the various quality criteria, designated by the letters *a* to *i*, including the criteria of Recommendation O.31.

2.2 *Main routines*

The measuring programmes for monophonic and for stereophonic circuits can be chosen as main routines, the monophonic programme being in accordance with the complete measuring programme of Recommendation O.31.

Each main routine consists of the subroutines shown in Table 2/O.32 which can be chosen individually (in subroutine 1, *s* is the station coding of the sending unit).

2.3 *Subroutines*

2.3.1 *Subroutine 1* (station coding and monophonic quality criterion *a*)

A station coding signal is sent in accordance with § 3.1.2 below followed by measurement of the level of channel A at the reference frequency.

2.3.2 *Subroutine 2* (monophonic criteria *b*, *c*, and *d*)

Subroutine 2 comprises three steps:

1) measurement of the weighted and unweighted noise level of channel A (b_1, and b_2);
2) nonlinear distortion of channel A measured selectively as harmonic distortion of the 2nd and 3rd order and as a difference tone distortion of the 3rd order ($c_1 \dots c_5$);
3) compandor functioning test of channel A (d).

2.3.3 *Subroutine 3* (monophonic criterion *e*)

Measurement of the level/frequency response of channel A.

2.3.4 *Subroutine 4* (monophonic quality criterion *a* and stereophonic quality criterion *f*)

Subroutine 4 comprises 3 steps: the first step checks received level at the reference frequency in channel B (monophonic criterion corresponding to subroutine 1). The second and third steps are used to determine the sum (f_1) and difference (f_2) levels of channels A and B. Both measured values serve for the polarity check and the approximate assessment of phase differences exceeding the range fixed in subroutine 8 (stereophonic criterion *h*). In the case of negligible level and phase differences between channels A and B, the resulting sum level must exceed the received level at the reference frequency on the individual channel by 6 dB and in this case the difference level is so small that it is not indicated. If the channels are of opposite polarity ($\Delta\Phi = 180°$), the sum level and the difference level behave inversely.

Large phase differences can be estimated from Table 3/O.32.

TABLE 1/O.32

Measurement of quality criteria *a* to *i*, sender and receiver requirements

	Quality criteria			Reference		Sender		Receiver	
				Sender	Receiver	Frequency (kHz)	Power level (dBm0)	Centre of range (dBm0)	Filter LP = Low Pass BP = Band Pass (kHz)
Monophonic measurement	*s*		Station coding	3.1.2		0.8	−32/−12	−12	−
	a		Level at the reference frequency	3.1.3	3.2.2	0.8	−12	−12	20 LP
	b	b_1 b_2	Noise level weighted unweighted		3.2.3	− −	− −	−51 −51	CCIR Rec. 468-3 [1] 20 LP
	c	c_1 c_2 c_3 c_4 c_5	Nonlinear distortion k_2 k_3 d_3 k_2 k_3	3.1.4	3.2.4	0.09 0.06 0.8 + 1.42 0.8 0.533	+9 +9 + 3 + 3 +9 +9	−31 −31 −37 −31 −31	0.18 BP 0.18 BP 0.18 BP 1.6 BP 1.6 BP
	d		Compandor test	3.1.5		0.8	+6/−6/+6	0	20 LP
	e		Level/frequency response	3.1.3		0.03 − 16	−12	−12	20 LP
Stereophonic measurement	*f*	f_1 f_2	Polarity check Level sum Level difference	3.1.3	2.3.4	0.8 0.8	−12 −12	−12 −12	20 LP 20 LP
	g		Level difference	3.1.3	2.3.7	0.03 − 16	−12	0 dB	20 LP
	h		Phase difference	3.1.3	3.2.5	0.03 − 16	−12	25°	
	i	i_1 i_2 i_3	Crosstalk at 180 Hz 1600 Hz 9000 Hz	3.1.6	3.2.6	0.18 1.6 9	−12 −12 −12	−52 −52 −52	0.18 BP 1.6 BP 9 BP

TABLE 2/O.32

		Subroutines								
Main routines	Monophonic	1	2	3						
	Stereophonic	1	2	3	4	5	6	7	8	9
Quality criteria		*s* *a*	*b* *c* *d*	*e*	*a* *f*	*b* *c* *d*	*e*	*g*	*h*	*i*

TABLE 3/O.32

Sum level Δn_S (dB)	Difference level Δn_D (dB)	Phase difference $\Delta\Phi$
+6.0	$-\infty$	0/360°
+5.7	−5.7	30/330°
+4.8	0	60/300°
+3.0	+3.0	90/270°
0	+4.8	120/240°
−5.7	+5.7	150/210°
$-\infty$	+6.0	180°

Note – The above table is derived from the following formulae:

$$\Delta n_S = 3 \text{ dB} + 10 \log [1 - \cos (180 - \Delta\Phi)]$$

$$\Delta n_D = 3 \text{ dB} + 10 \log (1 - \cos \Delta\Phi)$$

2.3.5 *Subroutine 5* (monophonic criteria *b*, *c* and *d*)

Measurement of weighted and unweighted noise levels and nonlinear distortion and compandor functioning test, as specified in subroutine 2, but for channel B.

2.3.6 *Subroutine 6* (monophonic criterion *e*)

Measurement of the level/frequency response of channel B. (Corresponds to subroutine 3 for channel A.)

2.3.7 *Subroutine 7* (stereophonic criterion *g*)

The level difference between channels A and B, determined as a function of the frequency.

2.3.8 *Subroutine 8* (stereophonic criterion *h*)

The phase difference between channels A and B, measured as a function of the frequency.

2.3.9 *Subroutine 9* (stereophonic criterion *i*)

The signal-to-crosstalk ratio between channels A and B at frequencies of 180, 1600 and 9000 Hz.

3 Specifications

The following specifications for carrying out the measurements of the monophonic quality criteria *a* to *e* are identical with those laid down in Recommendation O.31 for the monophonic version of such equipment.

3.1 *Sending unit*

3.1.1 *Start, stop and time base for synchronization and selection of measuring mode*

By means of a locking press-button in the sending unit the measuring programme for single or permanent mode of operation can be started. The timing of the measuring programme is controlled by a pulse generator. The smallest time base that can be programmed is fixed at 1.33 second. The synchronizing frequency related to this time base is 0.75 Hz and has to be kept within ± 1%. A second press-button offers the possibility of stopping the measuring programme. By the activation of this press-button a means is provided whereby the locking mechanism of the start press-button for permanent operation is simultaneously released. Start, synchronization and stop of the receiving unit are triggered by coded pulses (1.3 kHz at −12 dBm0).

Every subroutine is preceded by coded pulses which serve as a start signal. By means of a special stop signal which is triggered by pressing the stop button, the progress of the measuring programme can be interrupted at any time and another programme, selected with the aid of a switch, can be started instead. Operating the stop button will also reset the time pulse generator to the starting condition.

The start and stop signals consist of four pulses whose duration can be fixed at 60 ms (value O) or 120 ms (value L) by means of digital coding. The time between the beginning of every pulse within the coded signal is 240 ms.

The coding of the pulses is as follows:

a) Start signals for:
   - Subroutine 1: OOOL
   - Subroutine 2: OOLO
   - Subroutine 3: OLOO
   - Subroutine 4: LOOO
   - Subroutine 5: OOLL
   - Subroutine 6: OLLO
   - Subroutine 7: LLOO
   - Subroutine 8: OLOL
   - Subroutine 9: LOLO

b) Stop signal: LLLL

The start signals are read from right to left, as is usual in the case of digital codes, and are transmitted in the same time sequence.

The sending of the coded signal (duration 960 ms) which is controlled by the time pulse generator must be delayed 370 ms (in order to comply with the time pulse duration of 1330 ms).

3.1.2 *Station coding*

The measuring programme is preceded by the code of the sending station using the Morse alphabet. For this purpose, 19 timing intervals are allocated. The station code is sent by keying a 0.8-kHz tone between a level of -32 dBm0 and the reference test level. The duration of Morse dots and dashes shall be about 10% and 35% respectively, of one timing interval.

3.1.3 *Test level for the measurements of level at the reference frequency and level/frequency response*

The test level sent for level measurements at the reference frequency (0.8 kHz) and for the measurements of level/frequency response should be -12 dBm0 (see Recommendation N.21 [2]). The measurements of level/frequency response are to be carried out with the aid of a sweep generator comprising the frequency range from 0.03 to 16 kHz. Each octave – beginning at 0.05 kHz – is marked by short pulses (1.3 kHz/-12 dBm0 from 50 to 100 ms duration). The speed of this sequence of operations for the frequency range from 30-16 000 Hz which covers 9.06 octaves should be 5 seconds/octave so that the recording device dealt with in § 3.2.9 below records one octave over 10 mm and 3.3 mm respectively.

3.1.4 *Test level sent for nonlinear distortion measurements*[1)]

The sent level of the test frequencies corresponds to the peak programme level (see the Recommendation cited in [3]), that is, the single tones for the nonlinear distortion measurements lead to the same peak loading as the double tone for the difference tone factor measurements (single tone of $+9$ dBm0, equivalent to $2.2\ V_{r.m.s.} = 3.1\ V_{p0}$ and double tone each of $+3$ dBm0, equivalent to $2 \times 1.1\ V_{r.m.s.} = 2 \times 1.55\ V_{p0} = 3.1\ V_{p0}$ referred to

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1) It shall be possible for the signal sent for the measurement of nonlinearity distortion to be included in or omitted from the test cycle at will (for example, under control of a switch). Whether or not the nonlinearity distortion measurement is admissible must be determined for each circuit by the user of the equipment, and in a manner ensuring that the prescriptions of Recommendation N.21 [2] are respected.

a zero relative level point). In order to avoid overload of carrier-frequency transmission systems, only frequencies below 2 kHz (with regard to circuits equipped with pre- and de-emphasis techniques) are applied and the duration of transmission is automatically reduced to the length of a single timing pulse[2]. The following test frequencies should be used:

a) *For the measurement of nonlinear distortion in the lower audio-frequency range*

c_1 = 0.09 kHz/+9 dBm0 for the k_2-measurement,

c_2 = 0.06 kHz/+9 dBm0 for the k_3-measurement.

b) *For the measurement of nonlinear distortion in the carrier-frequency range of a frequency division multiplex channel*

c_3 = 0.8 kHz/+3 dBm0 and 1.42 kHz/+3 dBm0 for the d_3-measurement.

c) *For the measurement of nonlinear distortion in the medium audio-frequency range*

c_4 = 0.8 kHz/+9 dBm0 for the k_2-measurement,

c_5 = 0.533 kHz/+9 dBm0 for the k_3-measurement.

3.1.5 *Signal sent for compandor functioning test* [3]

In order to detect a noncomplementary behaviour of regulating amplifiers in compandors a 0.8-kHz signal is injected, the level of which is switched between the values +6, −6, +6 dBm0 for three consecutive timing intervals.

3.1.6 *Crosstalk between channels A and B*

The signal-to-crosstalk ratio between channels A and B is measured at the frequencies 180, 1600 and 9000 Hz. The sent level should be −12 dBm0.

3.1.7 *Remote control of the sending unit*

Provision should be made for sending up to 16 command signals. These signals may be applied to the sending equipment in either binary code or by applying earth to 16 signal paths. In the case of binary coding for starting the monophonic or stereophonic main routine, the coded signals LOOL or LLLO respectively should be used in addition to the start signals given under § 3.1.1 above.

3.2 *Receiving unit*

3.2.1 *Start, stop and synchronization*

In the receiving unit the coded pulses must be detected and separated by means of a selective process. A guard circuit similar to the one normally used for signal receivers is required to protect against false operation. In combination with the above-mentioned guard circuit the 4-bit code chosen offers a highly reliable protection against the possibility that the starting mechanism might be activated by sound-programme signals. Thus, the receiving unit can remain continuously connected to a sound-programme circuit and can record the measuring programme without intervention by an operator.

The timing schedule must be in conformity with the requirements specified for the sending unit (see § 3.1.1 above).

The time pulse generator shall be triggered after the reception of the start signal. Reception of the stop signal shall cause the time pulse generator to be reset to the starting condition.

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[2] Other methods are under study by the CMTT.

[3] This test is intended for provisional use. A change will be necessary when, after further study, the CCITT issues Recommendations for compandors and appropriate methods of their testing.

3.2.2 *Measuring ranges*

The measuring device should have a logarithmic characteristic, and a linear measuring range of ± 10 dB referred to the respective centre-of-range should be provided.

For the particular measuring function the centres-of-range as indicated in Table 1/O.32 should be provided.

3.2.3 *Noise measurements*

The quality criteria b_1 and b_2 (weighted and unweighted noise measurements) are measured in a quasi-peak mode. In this case, the dynamic properties of the rectifier circuitry and the network for weighted noise measurement (b_1) should meet the requirements of CCIR Recommendation 468-3 [1].

3.2.4 *Provision of filters and their characteristics*

Two bandpass filters should be provided for selecting the nonlinear distortion products, one for 0.18 kHz and the other for 1.6 kHz. They should be used as follows:

0.18-kHz filter

- for k_2-measurement of 0.09 kHz (c_1),
- for k_3-measurement of 0.06 kHz (c_2),
- for d_3-measurement of 0.8/1.42 kHz (c_3);

1.6-kHz filter

- for k_2-measurement of 0.8 kHz (c_4),
- for k_3-measurement of 0.533 kHz (c_5).

With the 0.18-kHz filter only the lower d_3-product (2 × 0.8 kHz − 1.42 kHz = 0.18 kHz) is measured. The measurement of the upper d_3-product at 2.04 kHz (= 2 × 1.42 kHz − 0.8 kHz) is not made. To compensate for this, two times the lower d_3-product at 0.18 kHz is taken.

The bandpass filters should meet the following selectivity requirements:

- passband defined by insertion loss values less than 1 dB:

  0.18 kHz filter: ± 3 Hz } referred to centre frequency;
  1.6 kHz filter: ± 24 Hz }

- rejection frequency range defined by insertion loss values greater than 70 dB:

  0.18 kHz filter: < 0.09 kHz and > 0.36 kHz,
  1.6 kHz filter: < 0.8 kHz and > 3.2 kHz.

3.2.5 *Measurement of the phase difference between channels A and B*

The phase difference between channels A and B is measured as a function of the frequency. For this purpose, a phase discriminator is required which is independent of the level difference between the two channels. Because of the chosen linear scale of 5°/cm and the recommended recording width, the measurement range is limited to 0-50°. Larger phase differences can be estimated from the stereophonic criterion f of subroutine 4.

3.2.6 *Measurement of crosstalk between channels A and B*

The crosstalk ratio between channels A and B at the measuring frequencies of 180, 1600 and 9000 Hz is measured selectively. The filters for the first two frequencies may be the same as those used for the nonlinearity measurements in subroutines 2 and 5.

One additional filter is required for 9 kHz.

This bandpass filter should meet the following selectivity requirements:

- passband defined by insertion loss values of < 1 dB: ± 0.8 kHz referred to the centre frequency;
- rejection frequency range defined by insertion loss values of > 14 dB: < 4.5 kHz and > 18 kHz referred to the centre frequency.

The measurable signal-to-crosstalk ratio is confined to the critical range between 30 and 50 dB.

3.2.7 *Additional markers provided at digital receivers*

Additional markers can be generated in the digital receiver as required, by making use of the octave markers received from the sending unit as a timing base.

3.2.8 *Programming of digital receivers*

Where a digit receiver is used, it shall be possible to programme it so as to check that the circuits tested meet the required tolerances.

3.2.9 *Recording device*

The transient response time of the recording device should not exceed 200 ms. In connection with the rectifier circuitry of the receiving unit for noise measurements the requirements of CCIR Recommendation 468-3 [1] should be fulfilled.

Paper width and speed may be chosen according to national standards. The following values have proved to be practicable:

- Paper width 100 mm.

  This value yields (on the 20-dB level range) a level scale of 2 dB/10 mm.

- Paper speed 2 mm/s and 2/3 mm/s.

  These paper speeds should be manually adjustable.

In addition to the recording device it would be desirable to provide appropriate access points for the use of an oscilloscope.

3.3 *Sequence of operations in the programme*

The sequence of operations of the stereophonic measuring programme including all subroutines is shown in Annex A. The first and second time pulse of each subroutine are provided for the start signal and a pause, respectively.

3.4 *Long-term measurements of noise*

3.4.1 *Automatic measurements*

After completion of the monophonic or stereophonic main routines, automatic long-term measurements of noise are performed on channel A and channel B respectively, without initiation or control by the sending unit. The sequence should be as follows:

time intervals	*receiver programme*	*channel*
10	pause	
60	weighted noise	A
20	unweighted noise	A
2	pause	
60	weighted noise	B
20	unweighted noise	B

3.4.2 *Manual measurements*

In order to make measurements of weighted or unweighted noise continuously for unspecified periods of time it must be possible to make the timing mechanism inoperative. Where an analogue receiver is used, a manually controlled switch should be provided, so that the centre-of-range can be changed by 10 dB in either direction.

3.5 *Matching characteristics*

According to the lining-up procedure for sound-programme circuits using the constant voltage method the following impedances are to be provided:

– output impedance of the sending unit < 10 ohms,

– input impedance of the receiving unit > 20 kohms.

Both values may be changed by internal switching to 600 ohms if, for the lining-up of the sound-programme circuit, the impedance matching method is applied. It should be possible to adjust the sending and receiving units by means of a switch to the following relative levels:

+6 dBr = nominal value at the repeater stations of Administrations;

0 dBr[4)] = nominal value at the studios of broadcasting organizations.

3.6 *Accuracy of sending and receiving units*

3.6.1 *Sending unit*

a) *Individual frequency oscillators*

–	level tolerance	± 0.2 dB
–	frequency tolerance	< 1.0%
–	harmonic distortion at $2f$ and $3f$	< 0.1%

b) *Sweep frequency oscillator*

–	level tolerance at 0.8 kHz	± 0.2 dB
–	level frequency response referred to 0.8 kHz	± 0.2 dB

3.6.2 *Receiving unit*

Tolerances, including recording device:

–	mid-scale value −12 dBm0 and 0 dBm0	± 0.3 dB
–	mid-scale value −51 dBm0 and −31 dBm0	± 1.0 dB

Operational stability should be reached within 15 minutes of switching on. As far as the details of the division of the tolerances are concerned, reference is made to the values given in [4].

The tolerances may then be reduced by calibrating the sending and receiving units when interconnected on a loop basis.

4) For certain purposes a level of −3 dBr or lower may be used.

ANNEX A

(to Recommendation O.32)

TABLE A-1/O.32

Sequence of operations of stereophonic main routine measuring programme

Sub-routine	Time intervals	Sending unit: Frequency (kHz)	Sending unit: Level (dBm0)	Sending unit: Loaded channel	Receiving unit: Measuring function	Receiving unit: Channel	Receiving unit: Centre of range (dBm0)
1	1	1.3	−12	A	Start signal No. 1	A	–
	1	–	–	–	Pause	–	–
	19	0.8	−32/−12	A	Station coding	A	−12
	1	–	–	–	Pause	–	–
	4	0.8	−12	A	Measurement of reference level	A	−12
	2	–	–	–	Pause	–	–
	28						
2	1	1.3	−12	A	Start signal No. 2	A	–
	2	–	–	–	Pause	–	–
	5	–	–	–	Weighted noise (psophometer filter)	A	−51
	5	–	–	–	Unweighted noise	A	−51
	2	–	–	–	Pause	–	–
	1	0.09	+9	A	k_2-level (0.18 kHz filter)	A	−31
	1	–	–	–	Pause	–	–
	1	0.06	+9	A	k_3-level (0.18 kHz filter)	A	−31
	2	–	–	–	Pause	–	–
	1	0.8/1.42	+3/+3	A	d_3-level (0.18 kHz filter)	A	−37
	2	–	–	–	Pause	–	–
	1	0.8	+9	A	k_2-level (1.6 kHz filter)	A	−31
	1	–	–	–	Pause	–	–
	1	0.533	+9	A	k_3-level (1.6 kHz filter)	A	−31
	2	–	–	–	Pause	–	–
	3	0.8	+6/−6/+6	A	Compandor test	A	0
	4	–	–	–	Pause with reserve	–	–
	35						
3	1	1.3	−12	A	Start signal No. 3	A	–
	1	–	–	–	Pause	–	–
	35	0.03 to 16	−12	A	Level/frequency response	A	−12
	2	–	–	–	Pause	–	–
	39						
4	1	1.3	−12	A	Start signal No. 4	A	–
	1	–	–	–	Pause	–	–
	2	0.8	−12	B	Measurement of reference level	B	−12
	1	–	–	–	Pause	–	–
	2	0.8	−12	A, B	Sum level	A, B	−12
	1	–	–	–	Pause	–	–
	2	0.8	−12	A, B	Difference level	A, B	−12
	2	–	–	–	Pause	–	–
	12						

TABLE A-1/O.32 - *(end)*

Sub-routine	Time intervals	Sending unit			Receiving unit		
		Frequency (kHz)	Level (dBm0)	Loaded channel	Measuring function	Channel	Centre of range (dBm0)
5	1	1.3	−12	A	Start signal No. 5	A	–
	2	–	–	–	Pause	–	–
	5	–	–	–	Weighted noise (psophometer filter)	B	−51
	5	–	–	–	Unweighted noise	B	−51
	2	–	–	–	Pause	–	–
	1	0.09	+9	B	k_2-level (0.18 kHz filter)	B	−31
	1	–	–	–	Pause	–	–
	1	0.06	+9	B	k_3-level (0.18 kHz filter)	B	−31
	2	–	–	–	Pause	–	–
	1	0.8/1.42	+3/+3	B	d_3-level (0.18 kHz filter)	B	−37
	2	–	–	–	Pause	–	–
	1	0.8	+9	B	k_2-level (1.6 kHz filter)	B	−31
	1	–	–	–	Pause	–	–
	1	0.533	+9	B	k_3-level (1.6 kHz filter)	B	−31
	2	–	–	–	Pause	–	–
	3	0.8	+6/−6/+6	B	Compandor test	B	0
	4	–	–	–	Pause with reserve	–	–
	35						
6	1	1.3	−12	A	Start signal No. 6	A	–
	1	–	–	–	Pause	–	–
	35	0.03 to 16	−12	B	Level/frequency response	B	−12
	2	–	–	–	Pause	–	–
	39						
7	1	1.3	−12	A	Start signal No. 7	A	–
	1	–	–	–	Pause	–	–
	35	0.03 to 16	−12	A, B	Level difference/ frequency response	A, B	0
	2	–	–	–	Pause	–	–
	39						
8	1	1.3	−12	A	Start signal No. 8	A	–
	1	–	–	–	Pause	–	–
	35	0.03 to 16	−12	A, B	Phase difference/ frequency response	A, B	25°
	2	–	–	–	Pause	–	–
	39						
9	1	1.3	−12	A	Start signal No. 9	A	–
	1	–	–	–	Pause	–	–
	2	0.18	−12	A	Crosstalk level (0.18 kHz filter)	B	−52
	1	–	–	–	Pause	–	–
	2	1.6	−12	A	Crosstalk level (1.6 kHz filter)	B	−52
	1	–	–	–	Pause	–	–
	2	9.0	−12	A	Crosstalk level (9 kHz filter)	B	−52
	2	–	–	–	Pause	–	–
	12						
1 to 9	278						

Duration of main routine measuring programme for stereophonic circuits: 278 time intervals × 1.33 sec/time interval ≈ 371 sec.

References

[1] CCIR Recommendation *Measurement of audio-frequency noise in sound broadcasting*, Vol. X, Rec. 468-3, ITU, Geneva, 1982.

[2] CCITT Recommendation *Limits and procedures for the lining-up of a sound-programme circuit*, Vol. IV, Rec. N.21.

[3] CCITT Recommendation *Measurements to be made by the broadcasting organizations during the preparatory period*, Vol. IV, Rec. N.13, Note.

[4] *Measuring instrument requirements. Sinusoidal signal generators and level-measuring instruments*, Green Book, Vol. IV.2, Supplement No. 3.1, ITU, Geneva, 1973.

Recommendation O.33

SPECIFICATION FOR AN AUTOMATIC EQUIPMENT FOR RAPIDLY MEASURING STEREOPHONIC PAIRS AND MONOPHONIC SOUND-PROGRAMME CIRCUITS, LINKS AND CONNECTIONS

1 General

An automatic measuring equipment for sound-programme circuits must be capable of rapidly measuring all relevant parameters necessary for checking the quality of such circuits. The parameters to be measured and the facilities that must be offered by the equipment are outlined in this specification but neither the measurement method nor the processing of the results are specified in detail. Manufacturers are thus free to adopt any appropriate design that will fulfil the requirements of this specification. However, it is evident that it would be advantageous to control the measurement sequence by stored programs. The use of different measuring sequences, each suited to the requirements of individual users and individual applications should be possible.

2 Basic design

The equipment shall consist of either two units, send and receive, or a combined sending and receiving unit of modular construction permitting a send-only or receive-only facility.

The measurement results should be made available by a direct display via a storage mechanism to permit a long-term display of any measured parameter.

The results of the measurements are not only to permit an immediate decision by the staff in the field, but also to provide the basis for later exact evaluation by the responsible transmission engineer. It is preferred that the results be available also as a 110- and 300-baud ISO-7 bit serial data output [1] at a standard RS 232-C [2] interface, selectable between 110 and 300 bauds, or optionally, at a standard IEEE 488/IEC 625 [3] interface.

In each case, the parameters measured must be clearly identified and the source code given (see § 2.1).

The equipment must be capable of measuring at least the following parameters:

a) received level (insertion gain);

b) frequency/attenuation distortion (frequency response);

c) harmonic distortion (nonlinear distortion);

d) signal-to-noise ratio unweighted, and weighted in accordance with CCIR Recommendation 468-3 [4];

e) compandor linearity;

f) programme modulated noise and expanded noise.

These parameters are further defined in § 4.

In addition, the equipment must be capable of measuring in channels A and B at least the following parameters:

g) interchannel difference in gain and phase;

h) interchannel crosstalk and circuit transposition.

The stereo parameters are further defined in § 5.

The physical design should preferably be such that this capability is provided by user conversion of the monophonic equipment by the addition of appropriate plug-in units and, possibly, minor internal wiring changes.

The equipment will be required to send audio test signals at amplitudes consistent with that required at the user's test point. Since the nominal working levels vary from broadcasting organization to broadcasting organization, and from PTT Administration to Administration, it is not desirable to specify absolute levels. "TEST" level has therefore been defined as the level 9 dB below the maximum permitted level at the point at which the measurement is made. TEST level corresponds to an absolute value of 0 dBm0 when measured at a point of zero relative level (0 dBr) [5]. Manufacturers of automatic measurement equipment should therefore choose to make TEST level equal to a convenient level (e.g. 0 dBm0).

At this fixed level, the send frequency amplitudes in the programme measurement sequences will conform to the definitions for permitted maximum level (+9 dBm0s), alignment level (0 dBm0s) and measuring level (−12 dBm0s) given in Recommendation N.15 [6].

Switching should be provided so that TEST level may be set to +6 dB, 0 dB, or −3 dB with respect to 0.775 V r.m.s. This switch must be protected, particularly for absolute values greater than 0 dBm0, against unintentional operation, e.g. by mounting it inside the instrument. Consideration should also be given to providing −20 dB with respect to 0.775 V r.m.s.

2.1 *Start/source/program identification*

The measurement sequence will be chosen to suit the requirements of individual applications. Defined measurement programs are annexed to this Recommendation. The sequence of operations of the measurement program together with the associated time units are shown.

The sequence of audio test signals is to be preceded by a start/source/program identification signal which will:

- instruct the receiving unit to start the measurement sequence;
- identify the source of the test signals;
- indicate which of the stored measurement programs is to be used.

The start/source/program identification signal using the ISO-7 [1] code with one even parity bit and two stop bits, is to be sent by frequency-shift keying with a mark frequency of 1650 Hz and a space frequency of 1850 Hz, at a transmission rate of 110 bauds.

The message structure of the identification signal is formed by the following order of characters:

- Start of heading (character "SOH");
- Source identification (four alphanumeric characters);
- Special signalling (one character);
- Start of text (character "STX");
- Measurement program identification (two numeric characters 00-99);
- End of text (character "ETX").

The mark frequency shall be transmitted for at least 18 ms (two bits) before the start bit of the SOH character.

The end of the second stop bit of the ETX character defines the start of the measurement sequence.

The start/source/program identification signal shall be set at 12 dB below TEST level.

2.2 *Modes of operation*

It shall be possible to operate the equipment in automatic or manual modes.

2.2.1 *Automatic mode*

In the automatic mode, the sending unit shall cycle once through a complete programmed test sequence on receipt of a start signal given either by a push-button on the sending unit or by the momentary closing of a remote pair of contacts. The receiver shall, on receipt of the identification signal from the sending unit, cycle once through the complete programmed measurement sequence, storing and/or printing the results for subsequent examination.

2.2.2 *Manual mode*

2.2.2.1 *Sending unit*

In the manual mode, it shall be possible to cycle the sending unit through the measuring sequence to any chosen test element, upon which the appropriate test signal will be sent continuously. This mode should thus permit the sending unit to operate with manual measuring equipment. It shall also be possible to manually adjust the output signal to any frequency within the range 40 to 15 000 Hz to a resolution of better than 5 Hz. The output shall be adjustable within the range −12 dB to +15 dB with respect to 0.775 V r.m.s. with a resolution of 0.2 dB. The instrument shall indicate the output frequency and level. A flashing warning light shall operate when the output level exceeds 0.775 V r.m.s.

2.2.2.2 *Receiving unit*

In the manual mode, it shall be possible to cycle the receiving unit through the measuring sequence to any chosen parameter measurement to permit the instrument to be used with manual sending equipment. It would be advantageous to display the frequency of the incoming signal.

2.2.3 *Remote control*

Both the sending and receiving units should optionally offer the possibility of remote control. This could be either the RS 232-C [2] or IEEE 488/IEC 625 [3] interface.

3 Design and construction

It should be noted that the group delay encountered on long circuits may lead to measurement error, particularly at low frequencies. The design of measurement circuits should therefore be such that measurements are made only after sufficient time has been allowed for the received waveform to stabilize.

In general, the design and construction of the equipment shall conform to national and international provisions, especially in relation to safety requirements and protection against electric shock [7].

4 Parameters

4.1 *Received level (insertion gain)*

1020 Hz is sent at TEST level; the received level shall be measured and the result expressed in dB with reference to TEST level.

4.2 *Frequency/attenuation distortion (frequency response)*

The received level shall be measured at a number of discrete frequencies. These frequencies are defined in the individual measurement program. The sending level shall be 12 dB below TEST level.

The results shall be displayed in dB relative to the received level at 1020 Hz sent at 12 dB below TEST level. It is not considered acceptable to use the level received from the parameter in § 4.1.

4.3 *Distortion*

Total harmonic distortion shall be measured at 60 Hz and 1020 Hz. Second harmonic distortion, k_2, shall be measured at 1020 Hz. Third harmonic distortion, k_3, shall be measured at 60 Hz.

The sending level shall be 9 dB above TEST level. The receiving instrument shall given an r.m.s. indication of the harmonic content and the results shall be expressed in dB with respect to the received levels of the fundamentals.

In order to avoid overload of carrier-frequency transmission systems, the sending of test frequencies at the maximum permitted level should be strictly in accordance with the prescriptions of Recommendation N.21 [8]. Programs which include distortion measurements should therefore limit the duration of transmission to a single time interval (1 s) and a pause of at least one interval must be allowed when successive distortion measurements are to be made.

It shall be possible to insert the test cycle, the measurement of nonlinearity distortion by either duplication of the stored programmes with and without this measurement or by the use of a non-locking switch.

Note – The frequency of 1020 Hz has been chosen to avoid using a sub-multiple of a digital sampling rate [9].

4.4 *Signal-to-noise ratio*

The sending unit shall suitably terminate the input to the circuit under test and the receiving unit shall measure the highest quasi-peak value, either weighted or unweighted, over a period of eight seconds, consistent with CCIR Recommendation 468-3 [4]. The results shall be given in dB with respect to the received TEST level at 1020 Hz or at maximum permitted level (+ 9 dBm0). Selection of the weighted or unweighted characteristic and the level reference shall be made by a manually operated switch on the receiving unit. The switch shall be protected against unintentional operation and its position shall be indicated in the results. The normal position will correspond to the weighted characteristic.

4.5 *Compandor linearity*

800 Hz tone is sent during three consecutive time intervals, at +6 dB, −6 dB and +6 dB with respect to TEST level.

The receiving unit shall indicate the levels as received.

4.6 *Expanded noise*

The time interval used for the measurement of distortion at 60 Hz may also be used for the measurement of expanded noise. A high-pass filter ($f_0 \leqslant 400$ Hz, and $\geqslant 60$ dB/60 Hz) is used to eliminate second and third order harmonics. The remaining noise will be measured, either weighted or unweighted, with a quasi-peak response.

5 Stereo parameters

5.1 *Interchannel difference in gain and phase*

When the stereo modules are used, the equipment shall measure simultaneously the difference in phase and level between the signals present at its two inputs A and B. Measurements shall be made at all frequencies specified for the measurement of frequency/attenuation distortion. The instrument shall preferably indicate the polarity of the error.

The results shall be expressed in dB and degrees, taking the A channel as reference.

Equipment not employing simultaneous measurement techniques may be acceptable if it can be established that they provide results equivalent to those obtained with simultaneous measurement. The caution given in Recommendation N.21, § 3.8 [8], on avoiding certain frequencies should be observed.

5.2 *Interchannel crosstalk and circuit transposition*

The transmitter shall send a tone at 2040 Hz at a level of 12 dB below TEST level first from output A and then from output B, the unused circuit being correctly terminated. The receiver shall measure the level of the unwanted signal in the terminated circuit.

The results shall be expressed in dB relative to the level in the used circuit.

The crosstalk test signal shall be used to test for circuit transposition and an indication shall be given if the channels are interchanged.

6 Equipment characteristics – sending unit

Output impedance [1]:	< 10 ohms
Level error:	< 0.2 dB
Frequency error:	$< 1\%$
Total harmonic distortion at maximum output level,	
(+21 dB): except 60 Hz and 1020 Hz	$< 0.5\%$
at 60 Hz and 1020 Hz	$< 0.1\%$
Weighted noise level output:	$\leqslant -80$ dBq0ps
Level difference between outputs A and B:	< 0.2 dB
Phase difference between outputs A and B:	$< 2°$

[1] Value does not take account of any transformer needed to comply with the requirements of Recommendation N.11 [10] in regard to impedance and balance with respect to earth.

7 Equipment characteristics – receiving unit

7.1 *Input impedance* [2]*:* > 20 kohms

7.2 *Minimum accuracy and range*

7.2.1 *Level measurements*

Range:

Signal: +20 dB to −45 dB
Noise: −20 dB to −70 dB
with respect to 0.775 V r.m.s.

Error:

≤ ± 0.2 dB over the range +15 to −20 dB
≤ ± 0.5 dB over the range −20 to −50 dB
≤ ± 1.0 dB over the range −50 to −60 dB
≤ ± 3.0 dB over the range −60 to −70 dB

Note – Noise measurements are band limited to comply with the frequency response given in Annex 1, CCIR Recommendation 468-3 [4].

Frequency range: 20 Hz-50 kHz

7.2.2 *Distortion measurement*

Range: down to 0.3% (−50 dB)
Error: (± 1 dB)

7.2.3 *Phase measurement*

Range: ± 180°
Error: ≤ +2° over whole range

8 Environmental performance

The characteristics specified in §§ 6 and 7 are to be maintained over a temperature range of +5 °C to +45 °C with a relative humidity of 45 to 75% and with mains supply variations of ± 10% from the nominal voltage. (These values are provisional and require further study.)

[2] Value does not take account of any transformer needed to comply with the requirements of Recommendation N.11 [10] in regard to impedance and balance with respect to earth.

ANNEX A

(to Recommendation O.33)

Measurement sequence for monophonic sound-programme circuits

Time interval (seconds)	Sending unit		Program number: 00
	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	Start/source/program identification
1	1 020	0	Received level
1	1 020	−12	Frequency response
1	40	−12	
1	80	−12	
1	200	−12	
1	500	−12	
1	820	−12	
1	2 000	−12	
1	3 000	−12	
1	5 000	−12	
1	6 300	−12	
1	9 500	−12	
1	11 500	−12	
1	13 500	−12	
1	15 000	−12	
1	1 020	+9	Total harmonic distortion
1 [a]	–	–	
1	60	+9	
1	800	+6	Compandor test
1	800	−6	
1	800	+6	
8	–	–	Signal-to-noise ratio

[a] Waiting interval.

ANNEX B

(to Recommendation O.33)

Measurement sequence for stereophonic pairs of sound-programme circuits

Time interval	Channel A Sending unit		Channel B Sending unit		Program number: 01
Seconds	Frequency (Hz)	Level (dBm0)	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	–	–	Start/source/program identification
1	1 020	0	1 020	0	Received level
1	1 020	−12	1 020	−12	Frequency response interchannel Gain and phase
1	40	−12	40	−12	
1	80	−12	80	−12	
1	200	−12	200	−12	
1	500	−12	500	−12	
1	820	−12	820	−12	
1	2 000	−12	2 000	−12	
1	3 000	−12	3 000	−12	
1	5 000	−12	5 000	−12	
1	6 300	−12	6 300	−12	
1	9 500	−12	9 500	−12	
1	11 500	−12	11 500	−12	
1	13 500	−12	13 500	−12	
1	15 000	−12	15 000	−12	
1	1 020	+9	1 020	+9	Total harmonic distortion
1 [a]	–	–	–	–	
1	60	+9	60	+9	
1	2 040	−12	–	–	Crosstalk and circuit transposition
1	–	–	2 040	−12	
1	800	+6	800	+6	Compandor test
1	800	−6	800	−6	
1	800	+6	800	+6	
8	–	–	–	–	Signal-to-noise ratio

[a] Waiting interval.

References

[1] CCITT Recommendation *International Alphabet No. 5*, Vol. VIII, Rec. T.50 and International Organization for Standardization *ISO 7-bit serial data output.*

[2] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment and data circuit terminating equipment*, Vol. VIII, Rec. V.24 and Electronic Industries Association (EIA) Standard RS-232-C *Interface between data terminal equipment and data communication equipment employing serial binary data interchange.*

[3] International Electrotechnical Commission *Interface system for programmable measuring instruments*, IEC Publications 625, 625-1 and 625-2.

[4] CCIR Recommendation *Measurement of audio-frequency noise in sound broadcasting*, Vol. X, Rec. 468-3, ITU, Geneva, 1982.

[5] CCITT Recommendation *Relative levels and impedances on an international sound-programme connection*, Vol. III, Rec. J.14.

[6] CCITT Recommendation *Maximum permissible power during an international sound-programme transmission*, Vol. IV, Rec. N.15.

[7] European Broadcasting Union (EBU) *Guiding principles for the design of electronic equipment*, Document TECH 3215.

[8] CCITT Recommendation *Limits and procedures for the lining-up of a sound-programme circuit*, Vol. IV, Rec. N.21.

[9] CCITT Supplement No. 3.5 to Volume IV *Test frequencies on circuits routed over PCM systems.*

[10] CCITT Recommendation *Essential transmission performance objectives for international sound-programme centres (ISPC)*, Vol. IV, Rec. N.11.

Recommendation O.41

SPECIFICATION FOR A PSOPHOMETER FOR USE ON TELEPHONE-TYPE CIRCUITS

1 Introduction

This specification provides basic requirements for psophometers to be used for the measurement of noise and other interfering signals on international telephone circuits and circuit sections.

2 General

To accomplish the measurements as stated above, a psophometer should have the following significant characteristics:

a) The relative sensitivity of the instrument, at various frequencies, should be as specified by the psophometric weighting characteristics.

b) The reference point for the sensitivity of the instrument should be 0 dBm (one milliwatt) at 800 Hz.

c) The r.m.s. (root mean square) value of the weighted noise signal should be detected and displayed.

d) The dynamics of the detector and display device should meet requirements given in § 3.

e) The overall accuracy of the instrument when being used in its normal range and environmental conditions should be ± 1.0 dB or better. Specific tests for accuracy of various aspects of the instrument are given in § 3.

The annex to this Recommendation provides a comparison of the CCITT psophometric and North American (C-message) noise weighting currently in use.

3 Specific requirements

The following provides a minimum set of requirements that should be met by an instrument used as a psophometer.

3.1 *Input impedance*

All given impedances are for a balanced (earth free) input. The impedance to ground at 800 Hz shall be > 200 kohms.

3.1.1 *Terminating mode*

When used in a terminating mode, the input impedance shall be 600 ohms with a return loss of $\geqslant$ 30 dB from 300 to 4000 Hz.

3.1.2 *Bridging mode*

When used in a bridging mode, the tapping loss across 300 ohms shall be $\leqslant$ 0.15 dB from 300 to 4000 Hz.

3.2 *Longitudinal losses*

Input longitudinal interference loss and longitudinal conversion loss shall be $\geqslant$ 110 dB at 50 Hz. This requirement decreases 20 dB per decade to 5000 Hz. (The impressed longitudinal voltage shall not exceed 42 volts r.m.s.)

3.3 *Measuring range*

The usable measuring range of the instrument shall be −90 to 0 dBm.

3.4 *Calibration accuracy at 800 Hz*

The output indication shall be 0 dBm ± 0.2 dB with an input signal of 0 dBm at 800 Hz. For other levels over the usable measuring range of the instrument, the measurement error limits shall be as follows:

Range	*Error limit*
0 to −60 dBm	± 0.5 dB
−60 to −90 dBm	± 1.0 dB

3.5 *Relative gain versus frequency (frequency weighting)*

The required frequency weighting coefficients and accuracy limits at various frequencies are given in Table 1/O.41. In addition, the equivalent noise bandwidth of the weighting network shall be 1823 ± 87 Hz.

Also, the unit may be provided with the 1004 to 1020 Hz test-signal reject filter, described in Table 1/O.132 of Recommendation O.132, for use with the characteristics described in Table 1/O.41. In this case, 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:

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

3.5.1 *Optional frequency characteristic*

If desired, the unit may provide the optional frequency response characteristic for unweighted measurements given in Figure 1/O.41 in addition to the psophometric weighting of Table 1/O.41.

As an additional option, a flat filter with an equivalent noise bandwidth of 3.1 kHz (bandwidth of a telephone channel) is considered desirable for unweighted measurements. Further details are under study.

TABLE 1/O.41

Telephone circuit psophometer weighting coefficients and limits

Frequency (Hz)	Relative weight (dB)	Limit (± dB)
16.66	−85.0	–
50	−63.0	2
100	−41.0	2
200	−21.0	2
300	−10.6	1
400	− 6.3	1
500	− 3.6	1
600	− 2.0	1
700	− 0.9	1
800	0.0	0.0 (Reference)
900	+ 0.6	1
1000	+ 1.0	1
1200	0.0	1
1400	− 0.9	1
1600	− 1.7	1
1800	− 2.4	1
2000	− 3.0	1
2500	− 4.2	1
3000	− 5.6	1
3500	− 8.5	2
4000	−15.0	3
4500	−25.0	3
5000	−36.0	3
6000	−43.0	–

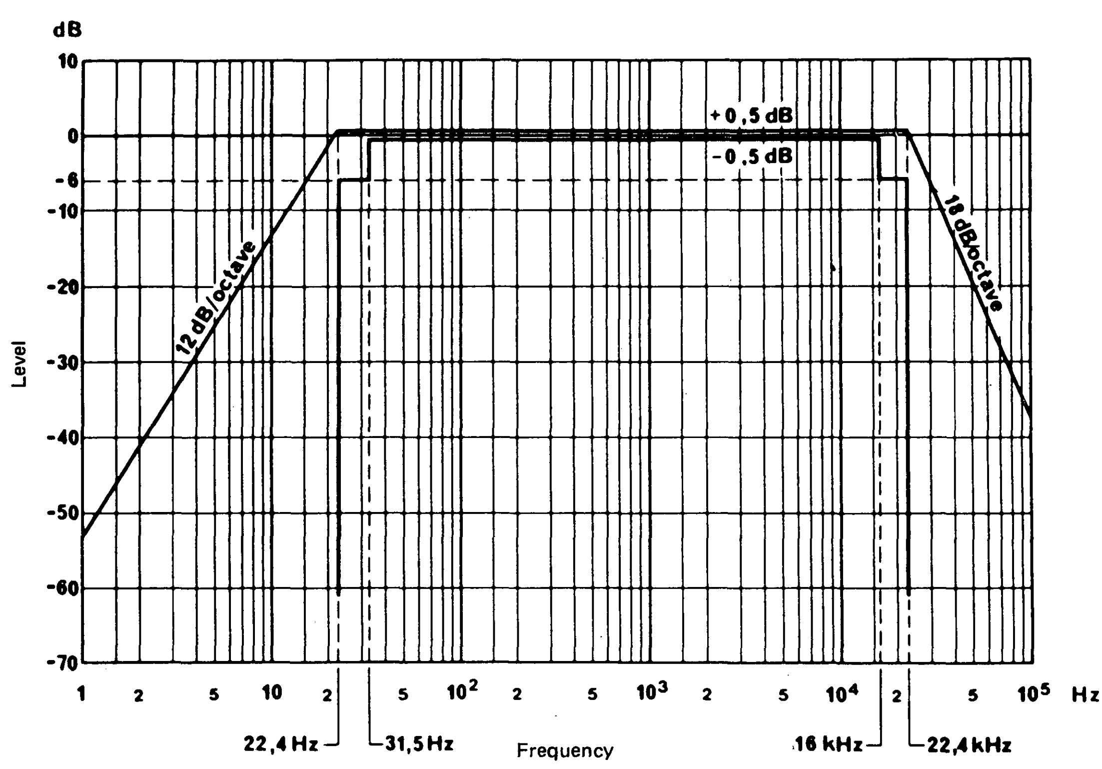

FIGURE 1/O.41

Frequency response characteristics for unweighted measurements

3.6 *Detector circuit characteristics*

The detector circuit should measure the r.m.s. value of the noise input. An approximate, or full-wave "quasi" r.m.s. detector may be used if its output does not differ from a true r.m.s. detector by more than ± 0.5 dB for the following signal waveforms:

a) Gaussian noise;

b) sinusoidal signals;

c) any periodic signal having a peak-to-r.m.s. ratio of 8 dB or less.

3.6.1 *Detector circuitry tests*

The following test is recommended to assure that the detector circuitry is functioning as prescribed.

a) Apply pulses of an 1800 Hz sinewave at a pulse rate of 80 Hz, with 20 percent of the cycle at full amplitude and 80 percent of the cycle 8.4 dB below full amplitude. The indicated r.m.s. value should be 5.0 ± 0.5 dB lower than the level of the ungated full amplitude sinewave.

Alternatively, psophometers manufactured to previous design specifications [1] shall meet the following test:

b) Successively apply two sinusoidal signals of different frequencies, which are not harmonically related and which provide the same output level on the output indicator. Then apply both these signals at the same levels simultaneously. The increase on the output indicator should be 3 dB ± 0.25 dB above the reading for the single frequency input. This condition should be fulfilled using different pairs of frequencies at different levels.

3.6.2 *Turnover*

Apply a rectangular waveform with a 20 percent duty cycle and a repetition rate of 600 pulses per second to the input of the instrument, and note the noise reading. Invert the input leads, the two readings shall agree within 1 dB. This test should be performed at several levels over the specified operating range of the set.

3.7 *Detector and display dynamics (measurement averaging time)*

The circuit design of the unit should be such that it is capable of passing the following test:

The application of an 800 Hz sinusoidal signal with a duration of 0.15 to 0.25 seconds should produce an output indication which is the same as that produced by the application of a continuous 800 Hz signal of the same amplitude. Applied signals of shorter duration should produce lower readings on the output indicator. (This test is provisional, further study is required to determine the adequacy of the test for determining averaging time.)

3.7.1 *Damped response*

Under study.

3.8 *Linearity*

The following test is recommended to assure that excessive error is not caused by overload in the presence of signals which have a large peak-to-r.m.s. ratio.

Apply a frequency of approximately 1000 Hz in 5 ms pulses separated by 20 ms at a r.m.s. level corresponding to the highest value within any selected range of the instrument. When the level is decreased over a range of 10 dB the psophometer reading shall be proportional to the applied level decrease with a tolerance of ± 0.5 dB, for all ranges of the instrument.

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[1] See the annex to this Recommendation.

3.9 *Output indicator*

If an analog meter is used, the spacing of the meter markings shall be one dB or less over the normally used portion of the meter scale.

If a digital display is used, the noise reading shall be displayed to the nearest 0.1 dB. The result shall be rounded rather than truncated. The update rate for a digital display shall be at least approximately once per second.

Optionally, instruments using digital displays may provide additional display characteristics to expand the application of the instrument. Such additional display characteristics shall be defined by the manufacturer to assist the user in interpreting the results.

3.10 *Operating environment*

The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75%. (These are provisional values and require further study.)

3.10.1 *Immunity to electromagnetic fields*

The unit should not be affected by the presence of electromagnetic fields (50 Hz). The test for this immunity is given below.

a) With the instrument in the weighted measurement mode, an electromagnetic field of 16 A/m at 50 Hz shall cause an output indication of less than −85 dBm.

b) With the instrument in an unweighted measurement mode (optional, § 3.5.1), an electromagnetic field of 0.8 A/m at 50 Hz shall cause an output indication of less than −85 dBm.

ANNEX A

(to Recommendation O.41)

Comparison of CCITT and North American weightings

Telephone circuit noise impairment is normally measured with "C-message" weighting within the North American domestic telephone networks. [1, 2] The frequency response of this weighting differs somewhat from the CCITT psophometric weighting specified in Recommendation O.41. As a consequence, the relationship between measurements made with the North American noise meter and the CCITT psophometer is dependent on the frequency spectrum of the noise being measured. In addition, it should be noted that measurements made with the North American noise meter are expressed in **dBrn** (decibels referred to −90 dBm or decibels above a reference power of 10^{-12} watts). For example, if one milliwatt of white noise in the 300 to 3400 Hz band is applied to both a CCITT psophometer and a North American noise meter, the following readings are obtained:

CCITT psophometer (1951 weighting)	−2.5 dBm
North American noise meter (C-message weighting)	88.0 dBrn.

Recognizing that the relationship of the output readings of the differently weighted instruments will change for other noise spectra, the following rounded conversion formula is proposed for practical comparison purposes:

Psophometer reading (in dBm) = C-message noise meter reading −90 (in dBrn)

This conversion includes the effect of the difference between the reference frequencies (800 Hz for psophometric weighting and 1000 Hz for C-message weighting) used in the two types of noise meters.

The C-message weighting coefficients and accuracy limits at various frequencies are given in Table A-1/O.41. A comparison between psophometric and C-message weighting is shown on Figure A-1/O.41.

TABLE A-1/O.41

C-message weighting coefficients and accuracy limits

Frequency (Hz)	Relative weight (dB)	Limit (± dB)
60	−55.7	2
100	−42.5	2
200	−25.1	2
300	−16.3	2
400	−11.2	1
500	− 7.7	1
600	− 5.0	1
700	− 2.8	1
800	− 1.3	1
900	− 0.3	1
1000	0.0	0.0 (Reference)
1200	− 0.4	1
1300	− 0.7	1
1500	− 1.2	1
1800	− 1.3	1
2000	− 1.1	1
2500	− 1.1	1
2800	− 2.0	1
3000	− 3.0	1
3300	− 5.1	2
3500	− 7.1	2
4000	−14.6	3
4500	−22.3	3
5000	−28.7	3

Note – The attenuation shall continue to increase above 5000 Hz at a rate of not less than 12 dB per octave until it reaches a value of −60 dB.

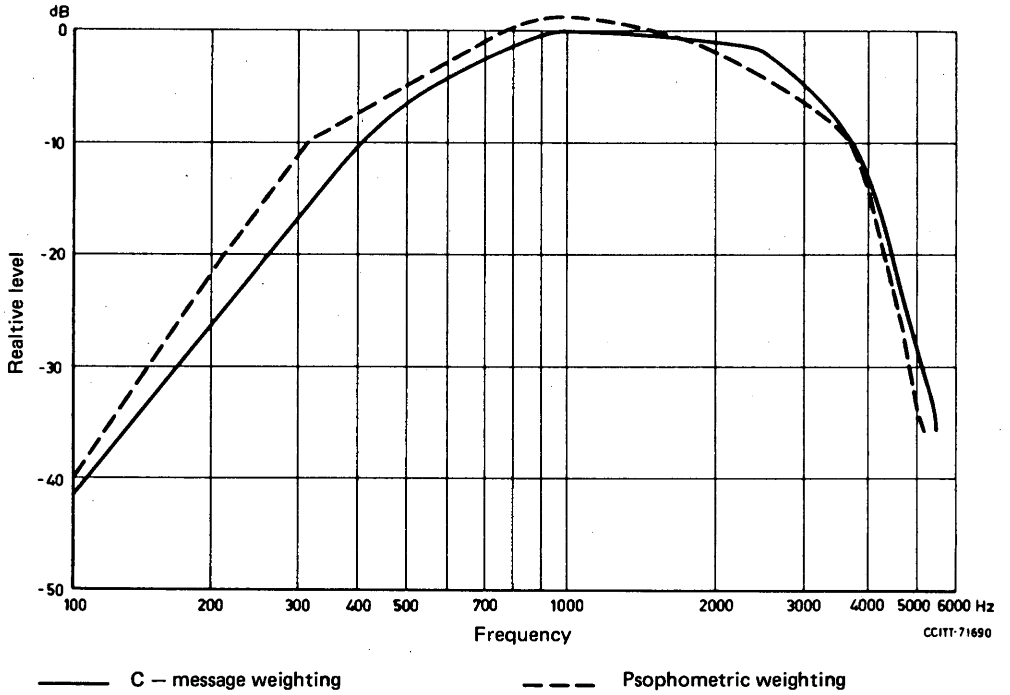

FIGURE A-1/O.41

Comparison between psophometric and C-message weighting

References

[1] IEEE Publication P743, *IEEE Standard Covering Methods and Equipment for Measuring the Transmission Characteristics of Analog Voice Frequency Circuits.*

[2] *Noise Measuring Instruments for Telecommunication Circuits*, CCITT Green Book, Vol. IV.2, Supplement 3.2, ITU, Geneva, 1973.

Recommendation O.42

SPECIFICATION FOR AN INSTRUMENT TO MEASURE NONLINEAR DISTORTION USING THE 4-TONE INTERMODULATION METHOD

1 Introduction

Nonlinear distortion impairments on analogue circuits are normally evaluated be measuring the harmonic frequency signals resulting from a sinusoidal test signal, or by measuring intermodulation frequency signals resulting from the interaction of a multitone test signal. Studies and experience have shown that the harmonic distortion method may severely underevaluate the amount of nonlinearity present on a circuit under certain circumstances. When multiple sources of nonlinearity are present on a circuit, harmonic products may tend to cancel each other, whereas the intermodulation products generated by a complex data signal may not cancel and may significantly impair the transmitted message. This effect has become increasingly important with the advent of higher bit rates and with multilevel/multiphase encoded data signals.

The following intermodulation method of testing for nonlinear distortion using a 4-tone test signal is recommended in order to achieve improved accuracy. This method measures certain 2nd and 3rd order distortion products resulting from the intermodulation of the tones in the prescribed test signal. The frequencies of the four test signal tones are selected to generate 2nd and 3rd order intermodulation products that occur in the passband of an analogue circuit and are easily separated from the applied test signal and measured. Four tones are used in order to achieve a test signal whose amplitude distribution is approximately Gaussian.

2 Principle of operation

Intermodulation distortion can be broadly defined as the modulation of the components of a complex wave with each other, as a result of which new components are produced that have frequencies equal to the sums and differences of integral multiples of those of the components of the original complex wave. Normally the 2nd and 3rd order intermodulation components are sufficient to evaluate the circuit nonlinearity.

A test signal is used which consists of four equal-level tones. Two of the tones are nominally 6 Hz apart centred at 860 Hz and the other two are nominally 16 Hz apart centred at 1380 Hz. To evaluate 3rd order distortion, the total power due to the six 3rd order intermodulation products in a narrow band centred at 1.9 kHz is measured and expressed in dB below the received signal. For 2nd order distortion, the power due to the four 2nd order intermodulation products in a narrow band centred at 520 Hz and the power nominally due to the four 2nd order intermodulation products in a narrow band centred at 2240 Hz are also measured. These two 2nd order distortion product powers are then averaged and the result expressed in dB below the received signal.

Second order intermodulation distortion is defined as follows:

$$\mathrm{Intermod}_{2nd} = 20 \log_{10} (V_{4T}/V_{2nd}) \text{ dB}$$

where:

V_{4T} is the r.m.s. voltage of the 4-tone signal, and

$$V_{2nd} = \sqrt{\frac{(V_5)^2 + (V_{22})^2}{2}}$$

where:

V_5 is the r.m.s. voltage in the frequency band centred at 520 Hz, and

V_{22} is the r.m.s. voltage in the frequency band centred at 2240 Hz.

Third order intermodulation distortion is defined as follows:

$$\text{Intermod}_{3rd} = 20 \log_{10} (V_{4T}/V_{19}) \text{ dB}$$

where:

V_{4T} is the r.m.s. voltage in the 4-tone signal, and

V_{19} is the r.m.s. voltage in the frequency band centred at 1900 Hz.

Depending on the relative levels of the intermodulation distortion products and noise on the circuit, the level of the signals measured in the receiver with the 4-tone test signal may be due in part or entirely to circuit noise. To determine the contribution of this noise, an additional measurement is made using a 2-tone signal consisting of the high pair or low pair of tones at the same power level as the 4-tone signal. The resulting signal-to-noise level readings are used to correct the observed distortion readings. The correction may be accomplished automatically in the test set or by the operator.

3 Specific requirements

The following provides a minimum set of requirements that should be met by an instrument used to measure nonlinear distortion using the "4-tone" intermodulation method.

3.1 *Transmitter*

3.1.1 *Level accuracy*

The r.m.s. signal output level error shall be less than ± 1 dB.

3.1.2 *Level range*

The output level range shall be at least 0 to −40 dBm. Calibrated attenuator increments of 1 dB or smaller shall be provided unless a level indicator is part of the test set, in which case a vernier control is acceptable.

3.1.3 *Spectrum*

The transmitted signal shall consist of four equal-level tones. Two of the tones shall be 6 ± 1 Hz apart centred at 860 ± 1 Hz and two of the tones shall be 16 ± 1 Hz apart centred at 1380 ± 1 Hz. The tones shall be of equal level within ± 0.25 dB.

3.1.4 *Harmonic distortion*

Any harmonic of any of the four tones shall be at least 35 dB below the tone.

3.1.5 *Background interference*

Any noise, distortion or interference falling within the distortion filter passbands as specified in § 3.2.4, shall be at least 80 dB below the signal.

3.1.6 *Probability density function*

The probability density function of the transmitted signal shall be approximately that of four independent sinusoidal oscillators even if the tones are synthesized from a single source.

3.1.7 *Signal-to-noise check signal*

It shall be possible to disable either the two tones centred at 1380 Hz or the two tones centred at 860 Hz and increase the other two tones by 3 ± 0.25 dB. This signal-to-noise check signal is used to determine the interference of the noise on the circuit under test to the measurement.

3.2 *Receiver*

3.2.1 *Accuracy*

The measurement error shall be less than ± 1 dB.

3.2.2 *Input level range*

The receiver shall meet the accuracy and measurement range requirements for an input level range of 0 to −40 dBm.

3.2.3 *Measurement and display range*

The test set shall be capable of measuring and displaying the ratio of the signal level to the 2nd and 3rd order distortion products over a range of 10 to 70 dB.

3.2.4 *Filter specifications*

The six 3rd order products to be measured fall in the range 1877 to 1923 Hz, the lower four 2nd order products in the range 503 to 537 Hz and the four upper 2nd order products in the range 2223 to 2257 Hz. (This allows for frequency shift in the channel and transmit signal frequency drift.)

Filters used to recover the products must be wide enough to measure the total power within the overall accuracy requirement of ± 1 dB and must be narrow enough to reject out-of-band noise. The filter bandwidths may be checked by adding a 3.5 kHz band-limited white noise signal at a level of −40 dBm to the input of the set in addition to the 4-tone signal at −10 dBm. The 2nd and 3rd order intermodulation levels displayed must each be at least 46 dB lower than the power of the −10 dBm tone signal.

Additionally with the 4-tone signal at −10 dBm applied to the input of the set, a test sinusoidal signal at a level of −25 dBm shall be added. The 3rd order distortion reading shall be at least 55 dB below the signal level for all test frequencies below 1600 Hz and above 2200 Hz. The 2nd order distortion reading shall be at least 55 dB below the signal level for all test frequencies below 220 Hz, between 820 and 1940 Hz, and above 2540 Hz. At 180 Hz and lower frequencies, the rejection must be at least 25 dB greater than the above requirement.

3.2.5 *Detectors*

The test signal and intermodulation distortion levels shall be measured with an average or an r.m.s. detector.

3.2.6 *Crosstalk with associated transmitter*

The receiver shall meet overall accuracy requirements when its associated transmitter (if provided) is set to its highest output level and terminated in 600 ohms, and a second transmitter, set 40 dB below this level, is used as a signal source for intermodulation measurement.

3.2.7 *Self-check capability*

A self-contained means should be provided to ensure that the receiver is calibrated within ± 1 dB for 2nd and 3rd order distortion measurements.

3.2.8 *Improper received signal level*

An indication shall be provided for received test signals that are not within the input level range of 0 to −40 dBm.

3.2.9 *Signal-to-noise check signal indicator*

An indication shall be provided to indicate the presence or absence of the signal-to-noise check signal.

3.2.10 *Correction for signal-to-noise*

Generally the correct signal-to-intermodulation distortion ratio is greater than the observed distortion reading due to the presence of circuit noise. The operating instructions shall include a suitable correction curve or correction table, unless the test set automatically makes the correction in the observed reading after the signal-to-noise check transmission.

3.2.11 *Spurious tone monitor*

A means should be provided to determine if a spurious tone or noise equal to or greater than the test tone is being received. Frequencies closer than ± 100 Hz about 860 Hz and 1380 Hz are excluded from this requirement.

3.3 *Input and output impedances*

All given impedances are for a balanced (earth free) connection.

3.3.1 *Terminating mode (transmit or receive)*

When used in a terminating mode, the input/output impedance shall be 600 ohms with a return loss of ⩾ 30 dB from 300 to 4000 Hz.

3.3.2 *Bridging mode (receive)*

When used in a bridging mode, the tapping loss across 300 Ω shall be ⩽ 0.15 dB from 300 to 4000 Hz.

3.4 *Longitudinal losses*

The transmitter/receiver inputs and outputs should meet the following requirements. Measurements should be made in accordance with Recommendation O.121.

3.4.1 *Longitudinal conversion loss*

The longitudinal conversion loss should be ⩾ 46 dB between 300 to 4000 Hz.

3.4.2 *Input longitudinal interference loss*

The input longitudinal interference loss should be ⩾ 110 dB at 50 Hz. This requirement decreases 20 dB per decade to 5000 Hz. The impressed longitudinal voltage shall not exceed 42 volts r.m.s.

3.5 *Output indicators*

3.5.1 *Analogue*

If an analogue meter is used, the spacing of the meter markings shall be 1 dB or less over the normally used portion of the meter scale.

3.5.2 *Digital*

If a digital indicator is used, the result shall be displayed to the nearest 1 dB. The result shall be rounded rather than truncated. The instrument shall indicate within 1 dB of the final reading within 10 seconds after application of a test signal. After this initial period, the display shall be updated at least once every 5 seconds on the basis of continuing measurements of both the received 4-tone level and the intermodulation products. An update period of two or three seconds is recommended.

3.6 *Operating environment*

The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75%. (These are provisional values and require further study.)

Recommendation O.51

VOLUME METERS

(For the text of this Recommendation see Recommendation P.52 of Volume V and for information on other volume indicators, see Supplement No. 3.3 of Volume IV.2 of the *Green Book*.)

Recommendation O.61

ESSENTIAL CLAUSES FOR A SIMPLE INSTRUMENT TO MEASURE INTERRUPTIONS ON TELEPHONE-TYPE CIRCUITS

The requirements for the characteristics of a simple interruption counter equipment capable of detecting short interruptions in transmission on audio channels are described below and must be adhered to in order to ensure compatibility between equipments standardized by the CCITT and produced by different manufacturers.

1 Definitions

1.1 interruption

For the purpose of this specification an interruption shall be regarded as a break in transmission or drop in the level of a test tone below a designated threshold.

1.2 dead time

The dead time is defined for the purpose of this specification as the time after which the counter is ready to record another interruption following the end of the preceding interruption.

2 The detector

2.1 *General*

All interruptions above 3.5 ms shall be detected. Interruptions of less than 2 ms shall not be recognized nor restoration of the signal for less than 2 ms. Interruptions separated by more than 4 ms shall be detected separately.

2.2 *Interruption detection threshold*

The instrument shall be capable of adjustment to threshold levels of 6 and 10 dB. The accuracy of the instrument at these threshold levels shall be ± 1 dB.

2.3 *Input conditions*

2.3.1 The detector shall respond to a test signal of 2000 Hz ± 100 Hz (see also § 5).

2.3.2 The instrument shall be capable of adjustment for input levels between +10 dBm and −30 dBm.

2.4 *Input impedance*

– balanced, earth free.

2.4.1 Signal balance ratio in the band 300 Hz to 6 kHz . . . . ≥ 50 dB

2.4.2 *Impedances*

2.4.2.1 Low impedance . . . . 600 ohms

Return loss at 2 kHz . . . . ≥ 30 dB

Return loss in the band 300 Hz to 6 kHz . . . . ≥ 25 dB

2.4.2.2 High impedance . . . . approx. 20 kohms

Tapping loss across 600 ohms . . . . ≤ 0.25 dB

2.5 *Dead time*

2.5.1 The dead time of an electronic instrument shall be 3 ms ± 1 ms.

2.5.2 The dead time of an instrument with mechanical counters shall be 125 ms ± 25 ms.

2.5.3 A switch shall be provided on the electronic instrument giving an optional 125 ms ± 25 ms dead time to enable comparable tests to be made with instruments using mechanical counters.

2.6 *Auxiliary logic output*

An auxiliary output from the detector shall be provided wired to a suitable socket giving a logic output for computer access or auxiliary equipment. The output from this socket shall be a two-state digital signal:

logic "0": signal level above the threshold;

logic "1": interruption, signal level below the threshold.

The output levels shall be as supplied by TTL (Transistor – Transistor Logic) integrated circuits. The output impedance shall be less than 2000 ohms, the precise value depending on the requirements of individual Administrations.

2.7 *Timing clock* (optional)

A timing clock shall be provided which shall limit the test duration to any period up to one hour. A manual position shall be provided on the clock for special testing purposes when test periods of greater than one hour are required.

3 The counter

3.1 *General*

All interruptions of greater than 3 ms shall be recorded. The interruptions shall be recorded on a single counter which shall have at least a three digit display. At the end of the testing period the counter display shall hold its accumulated total.

3.2 *Power failure*

In the event of a power failure the counter shall hold its accumulated total and resume the count when the power supply is restored. Should it prove impossible to meet this requirement a visual indication shall be provided to show that a power failure has taken place.

4 General

4.1 *Working conditions*

The instrument shall meet the above requirements under the following conditions:

- Temperature range: $+5\ °C$ to $+40\ °C$;
- Relative humidity: 45% to 75%.

(These values are provisional and require further study.)

5 Simultaneous measurements

The measurement of interruptions may be provided in an instrument which also makes measurements of other transient impairments, e.g., amplitude and phase hits. A test signal frequency of 1020 Hz ± 10 Hz may be used to facilitate the integration of several measurements of transient phenomena in such a combined instrument. In all other respects, the measurement of interruptions shall be in accordance with the principles of this Recommendation.

Recommendation O.62

ESSENTIAL CLAUSES FOR A SOPHISTICATED INSTRUMENT TO MEASURE INTERRUPTIONS ON TELEPHONE-TYPE CIRCUITS

The requirements for the characteristics of a sophisticated interruption counter equipment capable of detecting short interruptions in transmission on audio channels are described below and must be adhered to in order to ensure compatibility between equipments standardized by the CCITT and produced by different manufacturers.

1 Definitions

1.1 interruption

For the purpose of this specification an interruption shall be regarded as a break in transmission or drop in the level of a 2 kHz test tone below a designated threshold.

1.2 dead time

The dead time is defined for the purpose of this specification as the time after which the counter is ready to record another interruption following the end of the preceding interruption.

2 The detector

2.1 *General*

The detector shall be capable of recognizing an interruption having a nominal duration of 0.3 ms in accordance with the probability curve given in Figure 1/O.62.

This means that all interruptions exceeding 0.5 ms and 3 dB below the threshold to which the instrument is set are detected with 100% certainty whereas only 50% of these breaks occurring at 0.3 ms will be detected.

2.2 *Interruption detection threshold*

The threshold level selector shall be adjustable in steps to the values 3, 6, 10 and 20 dB below the normal test signal level at the input to detector.

The accuracy of the instrument at these threshold levels shall be as follows:

3, 6 and 10 dB: ± 1 dB

20 dB: ± 2 dB.

2.3 *Input conditions*

2.3.1 The detector shall respond to a test signal of 2000 Hz ± 100 Hz.

2.3.2 The instrument shall be capable of adjustment for input levels between +10 dBm and −30 dBm.

2.3.3 *Input impedance* (frequency range 300 Hz to 6 kHz)

– balanced, earth free.

2.3.3.1 Signal balance ratio . . . . ⩾ 50 dB

1) Low impedance . . . . 600 ohms
   Return loss . . . . ⩾ 30 dB

2) High impedance . . . . approx. 20 kohms
   Tapping loss across 600 ohms . . . . ⩽ 0.25 dB

2.4 *Auxiliary detector output*

A socket shall be provided permitting the connection of the detector logic output to an outside recording device such as a tape recorder or a computer. The output from this connector shall have a two-state digital signal:

logic “0”: signal level above the threshold;

logic “1”: interruption, signal level below the threshold.

The output levels shall be as supplied by TTL integrated circuits.

The output impedance shall be less than 2000 ohms, the precise value depending on the requirements of individual Administrations.

2.5 *Dead time*

The instrument shall have at least two dead times:

1) shortest possible, in accordance with the curve in Figure 1/O.62;
2) 125 ms ± 25 ms for special testing purposes.

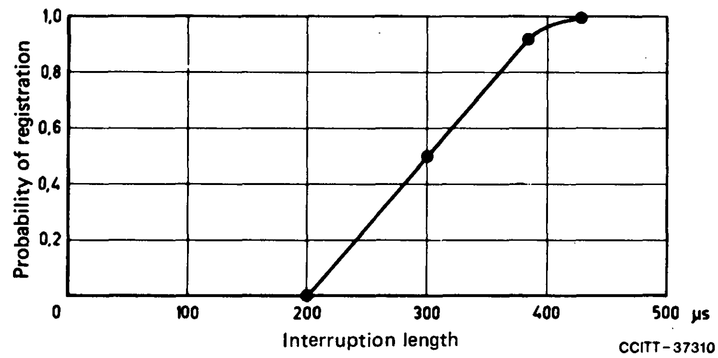

FIGURE 1/O.62

Probability curve for the detection of an interruption

2.6 *Visual indication*

A visual indication shall be provided showing the condition of *interruption.*

3 The counter

3.1 *General*

The detected interruptions shall be divided into the following time categories for recording purposes:

1) 0.3 ms-3 ms (optional),
2) 3 ms-30 ms,
3) 30 ms-300 ms,
4) 300 ms-1 min,
5) 1 min and over (optional).

Facility for adjusting to other time groupings may be provided at the option of the Administrations. The count shall be presented on a visual display.

3.2 *Power failure*

In the event of a power failure any loss of counting information should be clearly indicated on a display for later observation.

4 General

4.1 *Working conditions*

The instrument shall meet the above requirements under the following conditions:

- Temperature range: +5 °C to +40 °C;
- Relative humidity: 45% to 75%.

(These values are provisional and require further study.)

Recommendation O.71 [1)]

SPECIFICATION FOR AN IMPULSIVE NOISE MEASURING INSTRUMENT FOR TELEPHONE-TYPE CIRCUITS

The requirements for the characteristics of an instrument capable of assessing the impulsive noise performance of telephone-type circuits are described below and must be adhered to in order to ensure compatibility of results obtained by equipments standardized by the CCITT and produced by different manufacturers.

1 Principle of operation

The instrument will record the number of times that the instantaneous voltage of the input signal exceeds a predetermined threshold during the period of measurement. The maximum rate at which the instrument can record impulses exceeding the threshold is 8 ± 2 counts per second. The threshold level is calibrated in terms of the r.m.s. value of a sinusoidal input signal (dBm) whose peak value is just sufficient to cause the instrument to operate the counting mechanism.

2 Definition

2.1 dead time

For the purpose of this specification the dead time is defined as the time after which the counter is ready to register another pulse following the start of the preceding pulse.

3 Specification clauses

3.1 *Input impedance*

3.1.1 600 ohms balanced and earth free with a return loss of not less than 25 dB over the frequency range 200-3400 Hz, and

3.1.2 high impedance with a tapping loss not exceeding 0.1 dB over the frequency range 200-3400 Hz.

3.2 *Input balance*

With a pulse which is 60-dB higher than the threshold setting applied between the midpoint of the source impedance and the earth terminal of the instrument the counter shall not operate.

3.3 *Operate level range*

The minimum operate level range to which the instrument responds shall be from 0 to −50 dBm (i.e. 0 to −50 dB with respect to 1.1 V, which is the peak voltage of a sine wave having a power of 1 mW in 600 ohms). The threshold shall be adjustable in 3 dB steps (± 0.5 dB) and the thresholds for positive and negative polarities of input pulse shall not differ by more than 0.5 dB.

3.4 *Dead time*

Whatever values of dead time are included in a particular instrument, a value of 125 ± 25 ms shall be provided in all cases.

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1) The text of this Recommendation has been established under the responsibility of Study Groups IV, XVII and joint Study Group CMBD. Further elaboration of this Recommendation shall be the joint responsibility of these Study Groups.

3.5 *Attenuation/frequency characteristics*

3.5.1 *Flat bandwidth*

Response within the range ± 1 dB from 275 to 3250 Hz:

- 3 dB point ± 1 dB at 200 Hz;
- below 200 Hz, the attenuation shall rise at about 18 dB per octave; at 100 Hz, minimum attenuation 17 dB;
- above 3250 Hz, the rise in attenuation shall be compatible with the sensitivity requirement indicated in § 3.7 below.

3.5.2 *Optional bandwidths*

By means of additional filters the equipment may provide other optional bandwidths.

In any case it should be designed so that external filters can be added.

One of the filters shall have the following characteristics:

Flat within ± 1 dB from 750 Hz to 2300 Hz:

- 3 dB points at 600 Hz and 3000 Hz;
- below 600 Hz and above 3000 Hz the response shall fall off at about 18 dB per octave.

For measurements of impulsive noise in the 75 bit/s return channel, a filter with the following characteristics has been used:

- 3 dB points at 300 Hz and 500 Hz;
- below 300 Hz and above 500 Hz the response shall fall off at about 18 dB per octave.

3.6 *Calibration*

With the instrument switched to the *flat* condition, a continuous sinusoidal 1000 Hz signal applied to the input at a voltage equivalent to 0 dBm in 600 ohms, and with the operate level control set to 0 dBm the instrument shall be adjusted by means of a calibration control to register 8 ± 2 counts per second. When the input signal is reduced in level to −1 dBm the instrument shall not count.

When the input level is reduced to any value within the operate level range, the operate level setting at which the instrument just fails to count shall not differ from the actual input level by more than 1 dB.

3.7 *Sensitivity*

With the instrument calibrated in accordance with § 3.6 in the *flat* condition and the operate level set to 0 dBm, rectangular pulses of either polarity of 50 milliseconds duration having a peak amplitude of 1.21 V with an interval between pulses in excess of the dead time shall be applied to the instrument and cause the counter to operate at the correct rate. When the width of these pulses is gradually reduced, the counter shall count at the correct rate when the pulses have a duration of 50 microseconds but shall not count when the pulses are 20 microseconds.

3.8 *Counter*

Each event to be counted shall be recorded as one unit on a counter. The counter shall be able to register at least 999 events.

3.9 *Timer*

A built-in timer capable of switching off the instrument after a predetermined time shall be provided. This timer shall be adjustable from 5 to 60 minutes in steps of 1 minute.

Significant testing intervals will be 5, 15, 30 and 60 minutes.

4 Working conditions

The instrument shall meet the above requirements under the following conditions:

- Temperature range: +5 °C to +40 °C;
- Relative humidity: 45% to 75%.

(These values are provisional and require further study.)

Recommendation O.72

CHARACTERISTICS OF AN IMPULSIVE NOISE MEASURING INSTRUMENT FOR WIDEBAND DATA TRANSMISSIONS

(For the text of this Recommendation see Recommendation H.16 of Volume III.)

Recommendation O.81

SPECIFICATION FOR A GROUP-DELAY MEASURING SET FOR TELEPHONE-TYPE CIRCUITS

The requirements for the characteristics of a group-delay be measuring set for telephone-type circuits which are described below must adhered to in order to ensure compatibility between equipments standardized by the CCITT and produced by different manufacturers.

1 Measuring principle

In the case of group-delay distortion measurements over a line (straightaway measurements), a signal for phase demodulation is required on the receiving side whose frequency corresponds exactly to the modulation (split) frequency on the transmitting side and whose phase does not change during the measurement. With the proposed measuring principle, this frequency is generated in a split-frequency oscillator in the receiver whose frequency is controlled with the aid of a reference carrier having a fixed frequency of 1.8 kHz. The reference carrier is amplitude modulated with the same modulation frequency as the measuring carrier and is transmitted over the path to be measured in periodical alternation with the measuring carrier. During the changeover from measuring carrier to reference carrier no phase or amplitude surge must occur in the sending signal. For the sake of identification the reference carrier is furthermore amplitude modulated with an identifying signal.

If the path to be measured has different group delay and/or attenuation for the measuring carrier and the reference carrier, a phase and/or amplitude surge appears at the output of the path to be measured at the carrier changeover point within the receiver. This phase or amplitude surge is evaluated by the receiver of the measuring set. Thus, the receiver is provided with a phase measuring device for the purpose of group-delay measurements. This measuring device includes the above-mentioned frequency controlled split-frequency oscillator whose phase is automatically adjusted to the mean value derived from the phases of the split-frequencies transmitted with the measuring and the reference carriers. The split frequency voltage fed to the phase meter is taken from the output of an amplitude demodulator which can simultaneously be used for measuring amplitude variations. In order to recognize the actual measuring frequency on the receiving side – particularly during sweep measurements – a frequency discriminator may be provided.

If the frequency of the measuring carrier differs from the frequency of the reference carrier during the measurement and if the path to be measured has different group-delay and attenuation values for the two frequencies, a square-wave signal appears at the outputs of the phase meter, the amplitude demodulator and the frequency discriminator in the receiver, whose amplitudes are proportional to the respective measuring results – referred to the frequency of the reference carrier – and whose frequency corresponds to the carrier changeover frequency on the transmitting side. These three square-wave signals are subsequently evaluated with the aid of controlled rectifiers and allow indications, together with the correct signs, of differences in group-delay distortion, attenuation and measuring frequency between measuring and reference carrier frequencies.

2 Technical details

2.1 *Transmitter*

The modulation split frequency shall be 41.66 Hz (= 1000 Hz/24). With the aid of this signal the reference and measuring carriers are amplitude modulated to a modulation depth of 40%. Both sidebands are transmitted. The modulation distortion factor shall be smaller than 1%. The changeover from measuring carrier to reference carrier is carried out within a switching time of $\leqslant$ 100 microseconds. The changeover frequency is rigidly tied to the modulation frequency by binary frequency division and is 4.166 Hz (41.66 Hz/10). The carrier changeover occurs at the minimum of the modulation envelope. Deviations of $\leqslant \pm$ 0.2 milliseconds are admissible. The carrier frequency which is not transmitted in each case has to be suppressed by at least 60 dB referred to the sending signal.

The identifying signal which is required for identifying the reference carrier is also rigidly tied to the modulation (split) frequency. The assigned frequency 166.6 Hz is derived by multiplying the modulation (split) frequency by four or by dividing 1 kHz by six. The rectangular-shaped identifying signal derived from 1 kHz through frequency division can be used for direct modulation after having passed through an RC lowpass filter with a time constant of T = 0.43 milliseconds since a pure sinusoidal form is not required in this case. The modulation depth is 20%. The identifying signal is only transmitted during the last 24 milliseconds of the reference carrier sending time. The shape of the different signals on the transmitting side shown as a function of time and their respective forms can be seen from Figure 1/O.81.

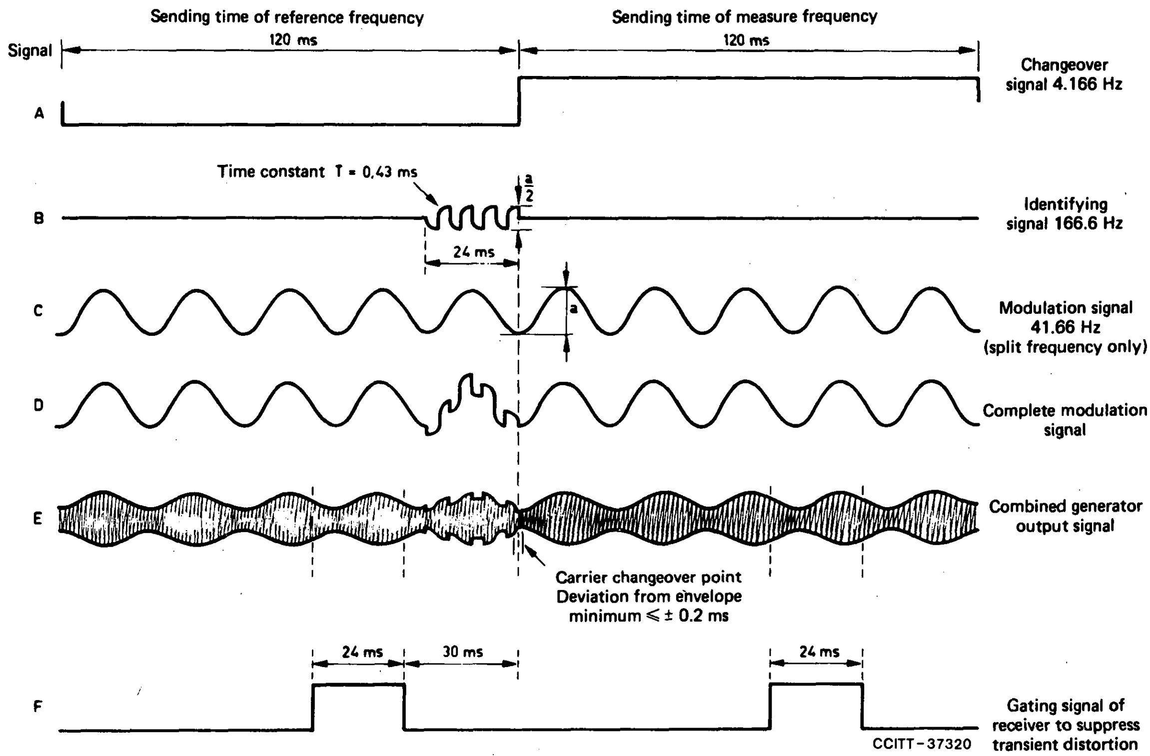


FIGURE 1/O.81

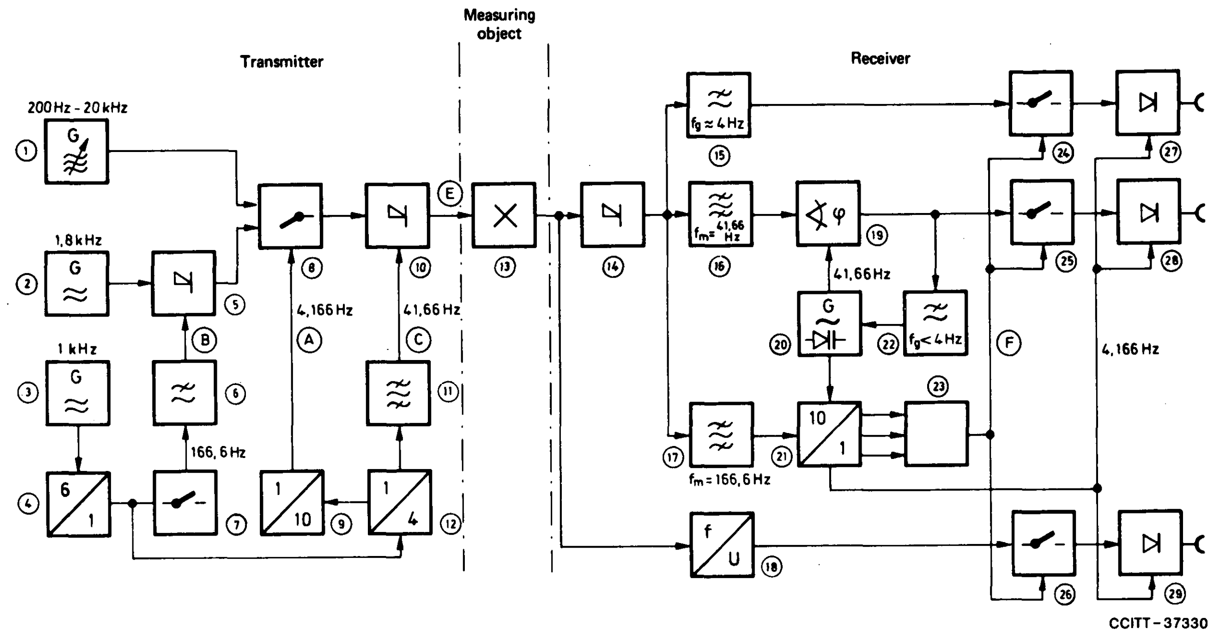
Timing of various signals of group-delay measuring set

2.2 *Receiver*

2.2.1 *Group-delay measurements* (see Figure 2/O.81)

The signal coming from the path to be measured is demodulated and the modulation frequency of 41.66 Hz so obtained is filtered out by a bandpass filter. This modulation voltage is rectangularly phase modulated, the frequency of the phase modulation being equivalent to the changeover frequency, 4.166 Hz. The phase deviation is proportional to the group-delay difference between the measuring carrier and the reference carrier. The phase demodulation is carried out in a phase meter whose second input is fed, for example, by a 1 kHz oscillator via a frequency divider 24/1. This oscillator forms a closed-phase control loop involving the phase meter and a lowpass filter which suppresses the changeover frequency. Thus, the modulation frequency generated in the receiver corresponds exactly to the modulation frequency coming from the transmitter.

At the output of the phase meter a 4.166-Hz square-wave voltage is obtained, whose amplitude is proportional to the measuring result. In order to enable a correct evaluation of this signal, a controlled rectification is required. The control voltage is derived from the modulation (split) frequency which is generated in the receiver by frequency division (10/1). The correct phase position with regard to the transmitting signal is enforced with the aid of the identifying signal 166.6 Hz. The controlled rectifier is connected both to an indicating instrument and to the direct current output.



1	oscillator, measure frequency
2	oscillator, reference frequency
3	oscillator, 1 kHz
4, 9, 12, 21	frequency dividers
5, 10	amplitude modulators
6, 15, 22	low pass filter
7	gate, identifying signal
8	carrier changeover switch
11, 16	bandpass filter, modulation frequency
13	measuring object
14	amplitude demodulator
17	bandpass filter, identifying frequency
18	frequency discriminator
19	phase meter
20	controlled oscillator
23	*And* circuit
24, 25, 26	gates
27, 28, 29	controlled rectifiers
A to F signals	see Figure 1/O.81

FIGURE 2/O.81

Principle of group-delay measuring set

2.2.2 *Amplitude measurements*

If the amplitude measurement is to be referred also to the reference carrier, the signal at the output of the amplitude demodulator (4.166-Hz square-wave proportional to Δa) can be subsequently evaluated as already described in the case of the group-delay measurements. Furthermore, it is possible to indicate the respective absolute carrier amplitude.

2.2.3 *Frequency measurements*

For sweep measurements it is necessary to generate in the receiver a voltage which is proportional to the measuring frequency. This can be achieved with the aid of a frequency discriminator which, in turn, supplies its output voltage to a controlled rectifier. The indicated measuring result is the frequency difference between the measuring carrier and the reference carrier. Optionally, only the measuring carrier frequency may be indicated.

2.2.4 *Blanking of transient distortion*

Due to the carrier changeover it may happen that transient distortions occur in the path to be measured as well as in the receiver. These interfering signals can effectively be blanked out by means of gate circuits. The gates will release the ensuing measuring devices only during those periods which are indicated in Figure 1/O.81.

3 General

The transmitter output and the receiver input must be earth free and balanced. It must be possible to apply a maximum direct current of approximately 100 mA to the connected measuring instruments for the purpose of loop holding.

4 Specifications for a group-delay measuring set for telephone-type circuits

4.1 *General*

4.1.1 Accuracy of group-delay measurements (see also § 4.2.1 below):

– 200 Hz to 400 Hz	$\leqslant \pm$ 100 microseconds	$\pm$ 3% of measuring range [1]
– 400 Hz to 600 Hz	$\leqslant \pm$ 30 microseconds	
– 600 Hz to 1 kHz	$\leqslant \pm$ 10 microseconds	
– 1 kHz to 20 kHz	$\leqslant \pm$ 5 microseconds	

Outside a temperature range of +15 °C to +35 °C the stated accuracy may be affected by variations of the modulation frequency, causing a measuring error of 4% instead of 3% (see § 4.1.4 below).

The additional error due to amplitude variations shall not exceed:

- variations up to 10 dB . . . . $\pm$ 5 microseconds
- variations up to 20 dB . . . . $\pm$ 10 microseconds
- variations up to 30 dB . . . . $\pm$ 20 microseconds

4.1.2 Measuring frequency . . . . 200 Hz to 20 kHz

4.1.2.1 Measuring frequency accuracy:

- in temperature range +15 °C to +35 °C $\leqslant \pm$ 1% of actual frequency reading $\pm$ 10 Hz
- in temperature range +5 °C to +50 °C $\leqslant \pm$ 2% of actual frequency reading $\pm$ 10 Hz

4.1.3 Reference frequency . . . . 1.8 kHz

(plus a vernier adjustment to avoid coincident interfering tones).

There should be an option to include two additional reference frequencies to increase accuracy at the edges of the band.

4.1.3.1 Reference frequency accuracy:

- in temperature range +15 °C to +35 °C . . . . $\leqslant \pm$ 1%
- in temperature range +5 °C to +50 °C . . . . $\leqslant \pm$ 3%

4.1.4 Modulation frequency (1 kHz : 24) [2]:

- in temperature range +15 °C to +35 °C . . . . 41.66 Hz $\pm$ 0.5%
- in temperature range +5 °C to +50 °C . . . . 41.66 Hz $\pm$ 1%

4.1.4.1 Modulation depth [2] . . . . $m = 0.4 \pm 0.05$

4.1.4.2 Modulation distortion factor [2, 3] . . . . $\leqslant$ 1%

4.1.5 Identifying frequency (1 kHz : 6) derived from modulation frequency [2] . . . . 166.6 Hz

4.1.5.1 Modulation depth [2] . . . . $m = 0.2 \pm 0.05$

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1) The measurement range is taken to be the indicated value at full-scale deflection on the range in use.

2) Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

3) The modulation distortion factor is taken to be:

$$\frac{\text{r.m.s. value of unwanted sidebands}}{\text{r.m.s. value of wanted sidebands}} \times 100\%.$$

4.1.5.2 Sending time of identifying signal[4)] . . . . 24 milliseconds terminating with the end of the sending time of the reference frequency

4.1.5.3 The commencement of the identifying signal shall cause a decrease in the amplitude of the carrier (as shown in Figure 1/O.81).

4.1.6 Changeover frequency (1 kHz : 240) derived from modulation frequency[4)] . . . . 4.166 Hz

4.1.6.1 Carrier changeover time[4)] . . . . Less than 100 microseconds

4.1.6.2 Deviation between carrier changeover point and envelope minimum[4)] . . . . $\leqslant \pm 0.2$ milliseconds

4.1.7 *Range of environmental conditions*[5)]

4.1.7.1 Power supply voltage variation . . . . +10 to −15%

4.1.7.2 Temperature range . . . . +5 °C to +50 °C

4.1.7.3 Relative humidity range . . . . 45% to 75%

4.1.8 *Additional requirements*

4.1.8.1 Speaker arrangements . . . . Optional

4.1.8.2 Internal check. Internal checking circuits shall be provided to verify the proper operation of the group-delay/frequency and attenuation/frequency distortion measurement functions, using appropriate outputs from the sender.

4.2 *Sender*

4.2.1 Error introduced by the sender in the overall accuracy of the group-delay measurement (as indicated in § 4.1.1 above) shall not exceed[4)]:

- 200 Hz to 400 Hz . . . . ± 10 microseconds
- 400 Hz to 600 Hz . . . . ± 3 microseconds
- 600 Hz to 20 kHz . . . . ± 1 microsecond

4.2.2 Range of send levels (average carrier power) (the maximum send level may be restricted as an option) . . . . −40 dBm to +10 dBm

4.2.2.1 Send level accuracy . . . . $\leqslant \pm 0.5$ dB
at the reference frequency . . . . $\leqslant \pm 0.3$ dB

4.2.3 Output impedance (frequency range 200 Hz to 20 kHz):

- balanced, earth free . . . . 600 ohms

4.2.3.1 Return loss . . . . $\geqslant 40$ dB

4.2.3.2 Signal balance ratio . . . . $\geqslant 46$ dB

4.2.4 Harmonic distortion of send signal . . . . $\leqslant 1\%$ (40 dB)

4.2.5 Spurious distortion of send signal . . . . $\leqslant 0.1\%$ (60 dB)

4.2.6 Frequency sweep rate . . . . Adjustable from 10 Hz/sec to 100 Hz/sec. At least four sweep rates shall be provided

4.2.7 Preventing possible response of dial tone receivers . . . . Optional

4.2.8 Provision for loop holding . . . . Yes

4.2.9 Arrangements shall be included in the sender so that when required, prior to measurement, the test and reference carrier frequencies can be measured to a resolution of 1 Hz. This may be achieved by providing suitable outputs at the sender for use with an external frequency counter.

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4) Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

5) These values are provisional and require further study.

4.3 *Receiver*

4.3.1 Input level range . . . . −40 dBm to +10 dBm

4.3.1.1 Dynamic range of receiver . . . . 30 dB

4.3.2 Input impedance (frequency range 200 Hz to 20 kHz):

– balanced, earth free . . . . 600 ohms

4.3.2.1 Return loss . . . . ⩾ 40 dB

4.3.2.2 Signal balance ratio . . . . ⩾ 46 dB

4.3.3 Range for measuring group-delay frequency distortion — 0 to ± 100, ± 200, ± 500 microseconds; 0 to ± 1, ± 2, ± 5, ± 10 milliseconds

4.3.3.1 Accuracy of group-delay measurements in accordance with §§ 4.1.1 and 4.2.1 above.

4.3.4 Measuring range for attenuation/frequency distortion measurements . . . . 0 ± 2, ± 5, ± 10, ± 20, ± 50 dB[6)]

4.3.4.1 Accuracy (+5 °C to +50 °C) . . . . ± 0.1 dB ± 3% of measuring range

4.3.5 Measuring range for input level measurements at the reference frequency . . +10 dBm to −20 dBm

4.3.5.1 Accuracy (+15 °C to +35 °C) . . . . ± 0.25 dB
(+5 °C to +50 °C) . . . . ± 1 dB

4.3.6 D.c. outputs shall be provided to drive an X-Y recorder.

4.3.7 Measuring ranges for frequency measurements . . . . 200 Hz to 4 kHz; 200 Hz to 20 kHz

4.3.7.1 Accuracy of frequency indications . . . . ± 2% ± 10 Hz

4.3.8 Provision for loop holding . . . . Yes

4.3.9 *Noise immunity*

4.3.9.1 There shall be an option to include a lowpass filter to reduce the effect of interfering frequencies above 4000 Hz, for example, metering pulses.

The group-delay/frequency distortion of the filter shall not exceed 5 microseconds at 2600 Hz and 30 microseconds at 2800 Hz relative to the group delay at 1000 Hz. The attenuation/frequency distortion shall not exceed 0.1 dB at 2600 Hz and 0.2 dB at 2800 Hz relative to the attenuation at 1000 Hz.

4.3.9.2 The r.m.s. value of the error in indication due to a white noise level at 26 dB per 4-kHz band below the mean carrier level of the received test signal shall not exceed 20 microseconds when the sweep rate does not exceed 25 Hz per second.

When testing an apparatus for its ability to meet this requirement, the group-delay/frequency distortion of the test object shall not vary at a rate exceeding 1.5 ms per 100 Hz.

4.3.9.3 The error in indication due to discrete tones ± 150 Hz around either test or reference signals shall not exceed ± 20 microseconds and for ± 200 Hz shall not exceed ± 2 microseconds when the level of such interfering frequency is 26 dB below the mean carrier level of the received test signal.

Bibliography

COENNING (F.): Progress in the Technique of Group Delay Measurements, *NTZ Communications Journal*, Vol. 5, pp. 256-264, 1966.

6) On the ± 50 dB range stated accuracy applies over the ± 30 dB range only (see § 4.3.1.1).

DESCRIPTION AND BASIC SPECIFICATION FOR A GROUP-DELAY MEASURING SET FOR THE RANGE 5 TO 600 kHz

The requirements for the characteristics of a group-delay measuring set for data circuits which are described below must be adhered to in order to ensure compatibility between equipments standardized by the CCITT, and produced by different manufacturers.

1 Measuring principle

In the case of group-delay distortion measurements over a line (straightaway measurements), a signal for phase demodulation is required on the receiving side whose frequency corresponds exactly to the modulation (split) frequency on the transmitting side and whose phase does not change during the measurement. With the proposed measuring principle, this frequency is generated in a split-frequency oscillator in the receiver whose frequency is controlled with the aid of a reference carrier. The reference carrier is amplitude modulated with the same modulation frequency as the measuring carrier and is transmitted over the path to be measured in periodical alternation with the measuring carrier. During the changeover from measuring carrier to reference carrier no phase or amplitude surge must occur in the sending signal. For the sake of identification the reference carrier is furthermore amplitude modulated with an identifying signal.

If the path to be measured has different group delay and/or attenuation for the measuring carrier and the reference carrier, a phase and/or amplitude surge appears at the output of the path to be measured at the carrier changeover point within the receiver. This phase or amplitude surge is evaluated by the receiver of the measuring set. Thus, the receiver is provided with a phase measuring device for the purpose of group-delay measurements. This measuring device includes the above-mentioned frequency controlled split-frequency oscillator whose phase is automatically adjusted to the mean value derived from the phases of the split frequencies transmitted with the measuring and the reference carriers. The split-frequency voltage fed to the phase meter is taken from the output of an amplitude demodulator which can simultaneously be used for measuring amplitude variations. In order to recognize the actual measuring frequency on the receiving side – particularly during sweep measurements – a frequency discriminator may be provided.

If the frequency of the measuring carrier differs from the frequency of the reference carrier during the measurement and if the path to be measured has different group-delay and attenuation values for the two frequencies, a square-wave signal appears at the outputs of the phase meter, the amplitude demodulator and the frequency discriminator in the receiver, whose amplitudes are proportional to the respective measuring results – referred to the frequency of the reference carrier – and whose frequency corresponds to the carrier changeover frequency on the transmitting side. These three square-wave signals are subsequently evaluated with the aid of controlled rectifiers and allow indications, together with the correct signs, of differences in group-delay distortion, attenuation and measuring frequency between measuring and reference carrier frequencies.

2 Technical details

2.1 *Transmitter*

The modulation split frequency shall be 416.66 Hz (= 10 000 Hz/24). With the aid of this signal the reference and measuring carriers are amplitude modulated to a modulation depth of 40%. Both sidebands are transmitted. The modulation distortion factor shall be smaller than 1%. The changeover from measuring carrier to reference carrier is carried out within a switching time of $\leq$ 100 microseconds. The changeover frequency is rigidly tied to the modulation frequency by binary frequency division and is 41.66 Hz (416.6 Hz/10). The carrier changeover occurs at the minimum of the modulation envelope. Deviations of $\leq \pm$ 20 microseconds are admissible. The carrier frequency which is not transmitted in each case has to be suppressed by at least 60 dB referred to the sending signal.

The identifying signal which is required for identifying the reference carrier is also rigidly tied to the modulation (split) frequency. The assigned frequency of 1666 Hz is derived by multiplying the modulation (split) frequency by four or by dividing 10 kHz by six. The rectangular-shaped identifying signal derived from 10 kHz through frequency division can be used for direct modulation after having passed through an RC lowpass filter with a time constant of T = 43 microseconds since a pure sinusoidal form is not required in this case. The modulation depth is 20%. The identifying signal is only transmitted during the last 2.4 milliseconds of the reference carrier sending time. The shape of the different signals on the transmitting side shown as a function of time and their respective forms can be seen from Figure 1/O.82.

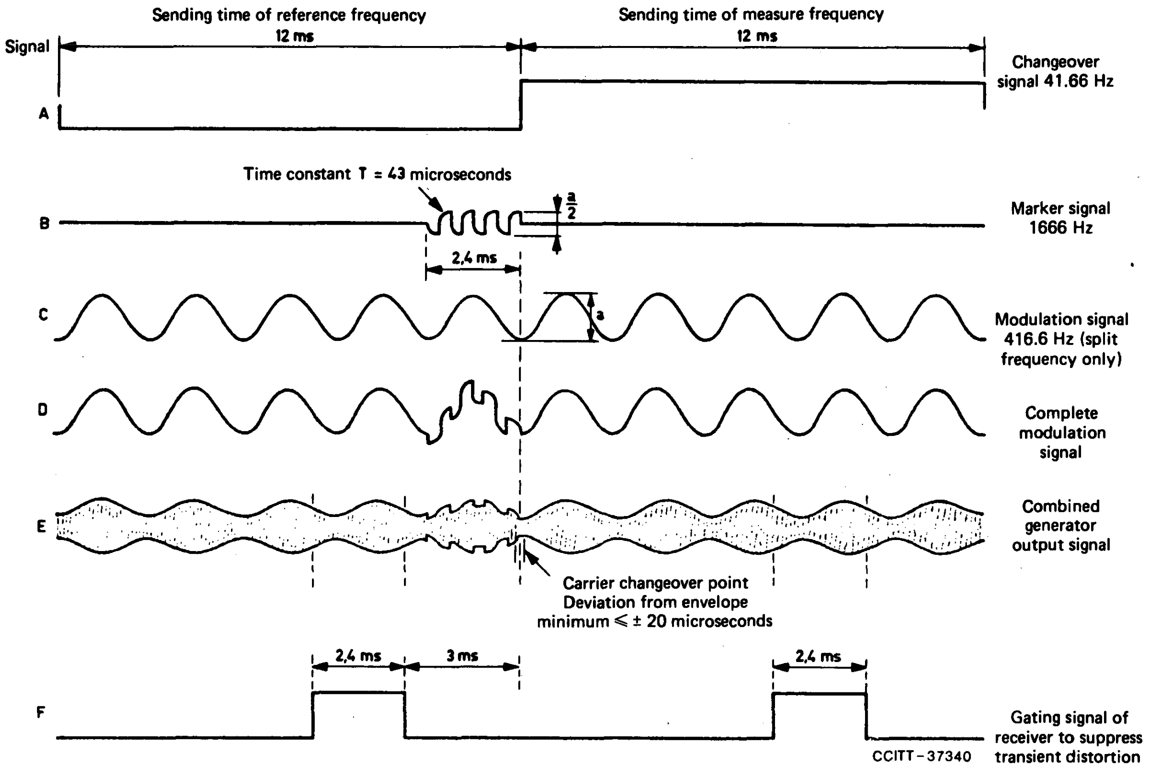


FIGURE 1/O.82

Timing of various signals of group-delay measuring set

2.2 *Receiver*

2.2.1 *Group-delay measurements* (see Figure 2/O.82)

The signal coming from the path to be measured is demodulated and the modulation frequency of 416.6 Hz so obtained is filtered out by a bandpass filter. This modulation voltage is rectangularly phase modulated, the frequency of the phase modulation being equivalent to the changeover frequency, 41.66 Hz. The phase deviation is proportional to the group-delay difference between the measuring carrier and the reference carrier. The phase demodulation is carried out in a phase meter whose second input is fed, for example, by a 10 kHz oscillator via a frequency divider 24/1. This oscillator forms a closed-phase control loop involving the phase meter and a lowpass filter which suppresses the changeover frequency. Thus, the modulation frequency generated in the receiver corresponds exactly to the modulation frequency coming from the transmitter.

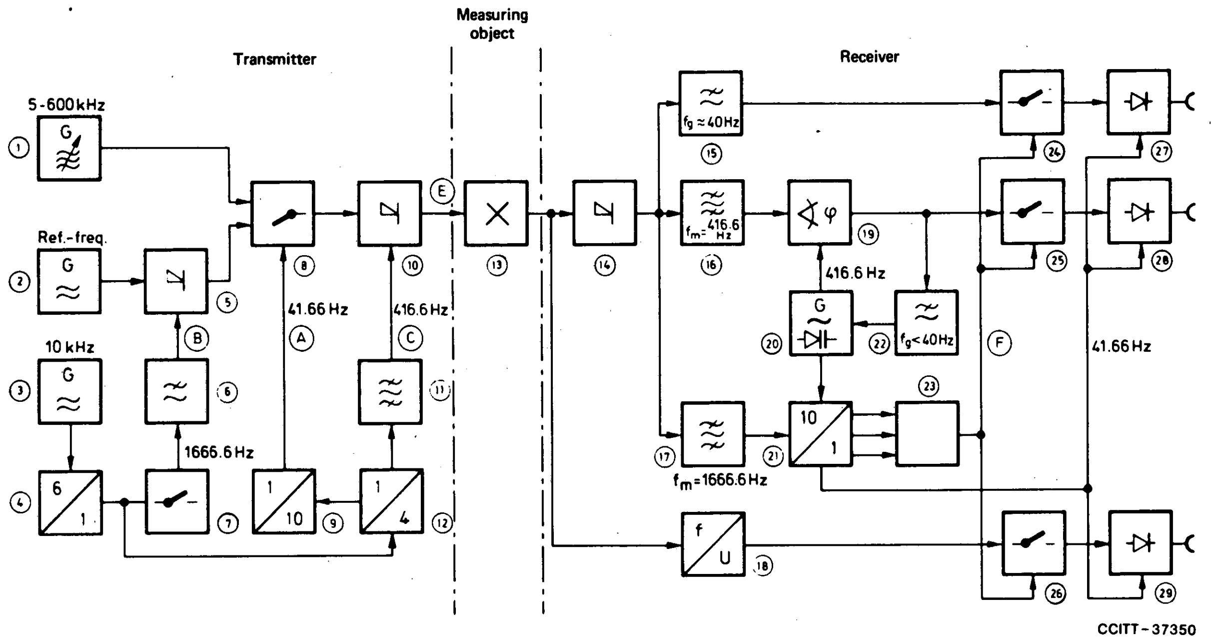
At the output of the phase meter a 41.66-Hz square-wave voltage is obtained, whose amplitude is proportional to the measuring result. In order to enable a correct evaluation of this signal, controlled rectification is required. The control voltage is derived from the modulation (split) frequency which is generated in the receiver by frequency division (10/1). The correct phase position with regard to the transmitting signal is enforced with the aid of the identifying signal 1666 Hz. The controlled rectifier is connected both to an indicating instrument and to the direct current output.

2.2.2 *Amplitude measurements*

If the amplitude measurement is to be referred also to the reference carrier, the signal at the output of the amplitude demodulator (41.66-Hz square-wave proportional to Δa) can be subsequently evaluated as already described in the case of the group-delay measurements. Furthermore, it is possible to indicate the respective absolute carrier amplitude.

2.2.3 *Frequency measurements*

For sweep measurements it is necessary to generate in the receiver a voltage which is proportional to the measuring frequency. This can be achieved with the aid of a frequency discriminator which, in turn, supplies its output voltage to a controlled rectifier. The indicated measuring result is the frequency difference between the measuring carrier and the reference carrier. Optionally, only the measuring carrier frequency may be indicated.



1	generator, measuring frequency	14	amplitude demodulator
2	generator, reference frequency	17	bandpass filter, marker frequency
3	oscillator, 10 kHz	18	frequency discriminator
4, 9, 12, 21	frequency dividers	19	phasemeter
5, 10	amplitude modulators	20	controlled oscillator
6, 15, 22	low-pass filter	23	*And* circuit
7	gate, marker signal	24, 25, 26	gates
8	carrier changeover switch	27, 28, 29	controlled rectifiers
11, 16	bandpass filter, modulation frequency	A to F signals	see Figure 1/O.82
13	measuring object		

FIGURE 2/O.82

Principle of group-delay measuring set

2.2.4 *Blanking of transient distortion*

Due to the carrier changeover it may happen that transient distortions occur in the path to be measured as well as in the receiver. These interfering signals can effectively be blanked out by means of gate circuits. The gates will release the ensuing measuring devices only during those periods which are indicated in Figure 1/O.82.

3 General

The transmitter output and the receiver input shall provide 135 and 150 ohms conditions which must be balanced and earth free. In addition, 75 ohms unbalanced conditions shall be provided.

4 Specifications for a group-delay measuring set for the range 5 to 600 Hz

4.1 *General*

4.1.1 Accuracy of group-delay measurements (see also § 4.2.1 below):

– 5 kHz to 10 kHz	$\leqslant \pm 5$	microseconds	± 3% of measuring range (see Note 1 at the end of this Recommendation)
– 10 kHz to 50 kHz	$\leqslant \pm 2$	microseconds	
– 50 kHz to 300 kHz	$\leqslant \pm 1$	microsecond	
– 300 kHz to 600 kHz	$\leqslant \pm 0.5$	microsecond	

Outside a temperature range of +5 °C to +40 °C the stated accuracy may be affected by variations of the modulation frequency, causing a measuring error of 4% instead of 3% (see § 4.1.4 below).

The additional error due to amplitude variations shall not exceed:

- variations up to 10 dB . . . . . ± 0.5 microsecond
- variations up to 20 dB . . . . . ± 1.0 microsecond
- variations up to 30 dB . . . . . ± 2.0 microseconds

4.1.2 Measuring frequency . . . . . 5 kHz to 600 kHz

4.1.2.1 Measuring frequency accuracy:

- in temperature range +5 °C to +40 °C . . . . . $\leqslant$ ± 1% ± 500 Hz of actual reading
- in temperature range +5 °C to +50 °C . . . . . $\leqslant$ ± 2% ± 500 Hz of actual reading

4.1.3 Reference frequency switchable . . . . . 25 kHz
(See Note 2 at the end of this Recommendation) 84 kHz
432 kHz

4.1.3.1 Reference frequency accuracy:

- in temperature range +5 °C to +40 °C . . . . . $\leqslant$ ± 1%
- in temperature range +5 °C to +50 °C . . . . . $\leqslant$ ± 3%

4.1.4 Modulation frequency accuracy [1]:

- in temperature range +5 °C to +40 °C . . . . . 416.66 Hz ± 0.5%
- in temperature range +5 °C to +50 °C . . . . . 416.66 Hz ± 1%

4.1.4.1 Modulation depth [1] . . . . . 0.4 ± 0.05

4.1.4.2 Modulation distortion factor [1] . . . . . $\leqslant$ 1%
(See Note 3 at the end of this Recommendation)

4.1.5 Identifying frequency [1] (derived from modulation frequency) . . . . . 1.666 kHz

4.1.5.1 Modulation depth [1] . . . . . 0.2 ± 0.05

4.1.5.2 Sending time of identifying signal [1] . . . . . 2.4 milliseconds terminating with the end of the sending time of the reference frequency

4.1.5.3 The identifying signal shall commence with an increase in the amplitude of the carrier as shown in Figure 1/O.82.

4.1.6 Changeover frequency [1] (derived from modulation frequency) . . . . . 41.66 Hz

4.1.6.1 Carrier changeover time [1] . . . . . less than 100 microseconds

4.1.6.2 Deviation between carrier changeover point and envelope minimum [1] . . . . . $\leqslant$ ± 0.02 millisecond

4.1.7 *Range of environmental conditions* [2]

4.1.7.1 Power supply voltage variation . . . . . ± 10%

4.1.7.2 Temperature range . . . . . +5 °C to +40 °C
Temperature range for storage and transport . . . . . –40 °C to +70 °C

4.1.7.3 Relative humidity . . . . . 45% to 75%

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[1] Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

[2] These values are provisional and require further study.

4.1.8 *Additional facilities*

4.1.8.1 Speaker facilities . . . . Optional

4.1.8.2 Internal checking circuit shall be provided to verify the proper operation of the group-delay and attenuation distortion measurement functions using appropriate outputs from the sender.

4.1.8.3 Facilities for fitting external filters to reduce interference from adjacent traffic bands . . . . Optional
(See Note 4 at the end of this Recommendation)

4.2 *Sender*

4.2.1 Error introduced by the sender in the overall accuracy of the group-delay measurements (as indicated in § 4.1.1 above) shall not exceed[3]:

- 5 kHz to 10 kHz . . . . ± 0.5 microsecond
- 10 kHz to 50 kHz . . . . ± 0.2 microsecond
- 50 kHz to 300 kHz . . . . ± 0.1 microsecond
- 300 kHz to 600 kHz . . . . ± 0.05 microsecond

4.2.2 Range of send levels (average carrier power) . . . . −40 dBm to +10 dBm
(The maximum send level may be restricted as an option.)

4.2.2.1 Send level accuracy . . . . ⩽ ± 0.5 dB
At the reference frequency . . . . ⩽ ± 0.3 dB

4.2.3 Output impedance (frequency range 5 to 600 kHz):

4.2.3.1 Balanced, earth free . . . . 135, 150 ohms
Return loss . . . . ⩾ 30 dB
Signal balance ratio . . . . ⩾ 40 dB

4.2.3.2 Unbalanced . . . . 75 ohms
Return loss . . . . ⩾ 40 dB

4.2.4 Harmonic distortion of send signal . . . . ⩽ 1% (40 dB)

4.2.5 Spurious distortion of send signal . . . . ⩽ 0.1% (60 dB)

4.2.6 Frequency sweep rate . . . . Adjustable from 0.2 kHz/sec to 10 kHz/sec. At least 6 sweep rates shall be provided

4.2.7 A facility shall be included in the sender so that, if required, prior to measurement the test and reference carrier frequencies can be measured to a resolution of 1 Hz. This may be achieved by providing suitable outputs at the sender for use with an external frequency counter.

4.3 *Receiver*

4.3.1 Input level range . . . . −40 dBm to +10 dBm

4.3.1.1 Dynamic range of receiver . . . . 30 dB

4.3.2 Input impedance (frequency range 5 to 600 kHz):

4.3.2.1 Balanced, earth free . . . . 135, 150 ohms
Return loss . . . . ⩾ 30 dB
Signal balance ratio . . . . ⩾ 40 dB

4.3.2.2 Unbalanced . . . . 75 ohms
Return loss . . . . ⩾ 40 dB

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[3] Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

4.3.3 Range for measuring group-delay/frequency distortion: 0 to ± 10, ± 20, ± 50, ± 100, ± 200, ± 500, ± 1000 microseconds.

4.3.3.1 Accuracy of group-delay measurements in accordance with §§ 4.1.1 and 4.2.1 above.

4.3.4 Measuring ranges for attenuation/frequency distortion measurement: 0 to ± 2, ± 5, ± 10, ± 20, ± 50 dB[4].

4.3.4.1 Accuracy (+5 °C to +50 °C) . . . . ± 0.1 dB ± 3% of measuring range

4.3.5 Measuring range for input level measurements at the reference frequency . . −20 dBm to +10 dBm

4.3.5.1 Accuracy (+5 °C to +40 °C) . . . . ± 0.25 dB
(+5 °C to +50 °C) . . . . ± 1 dB

4.3.6 D.c. outputs shall be provided to drive an X-Y recorder.

4.3.7 Measuring range for frequency measurements . . . . 5 to 60 kHz
50 to 150 kHz
150 to 600 kHz

4.3.7.1 Accuracy of frequency indication . . . . ± 2% ± 500 Hz

Note 1 – Measuring range – indicated value at full-scale deflection on the range in use.

Note 2 – It was originally proposed to use a fixed reference frequency of 1800 Hz. Due to the fact that the instrument for higher frequencies shall be applicable in three main frequency ranges (6 kHz to 54 kHz, 60 kHz to 108 kHz, 312 kHz to 552 kHz), three reference frequencies have to be provided which are in the middle of the respective frequency band.

Note 3 – Modulation distortion factor:

$$\frac{\text{r.m.s. value of unwanted sidebands}}{\text{r.m.s. value of wanted sidebands}} \times 100\%.$$

Note 4 – Administrations requiring to make measurements in the 60-108 kHz or 312-552 kHz ranges without removing traffic from adjacent groups or supergroups in their national section should add a clause:

"To minimize the effect of interference to measurements arising from traffic on adjacent groups or supergroups, the manufacturer shall provide a facility whereby an Administration can insert in the frequency discriminator path a zero-loss bandpass filter having a passband appropriate to the test being made and having an impedance of 75, 135 or 150 ohms."

Administrations should note that they will be responsible for a national instruction giving the relevant details of the filter and amplifier arrangement to be used, taking note of the manufacturer's information or the signal levels at this point.

Bibliography

COENNING (F.): Progress in the Technique of Group Delay Measurements, *NTZ Communications Journal*, Vol. 5, pp. 256-264, 1966.

Recommendation O.91

ESSENTIAL CLAUSES FOR AN INSTRUMENT TO MEASURE PHASE JITTER ON TELEPHONE-TYPE CIRCUITS

Introduction

The most commonly found single-frequency components of phase jitter on transmitted data signals are those of ringing current, commercial a.c. power and the second to fifth harmonics of these. Since the peak phase deviation caused by such components rarely exceeds 25° peak-to-peak (i.e. low index phase modulation) only one pair of significant sidebands is produced for each sinusoidal component. Hence the main phase jitter modulation usually exists within ± 300 Hz of a voice-frequency tone acting as a carrier.

[4] On the ± 50 dB range, the stated accuracy applies over ± 30 dB only (see § 4.3.1.1).

Since random noise can cause what would appear to be a significant amount of phase jitter, a message weighted noise measurement should always be made in conjunction with phase jitter measurements. Also, because quantizing noise can cause a significant phase jitter reading, care must be exercised in the choice of the carrier frequency and in the filtering to suppress the effect of noise on the measurement.

Whilst this Recommendation is concerned with measurements in the frequency bands 4-300 Hz, 4-20 Hz and 20-300 Hz, it is also applicable for measuring in the frequency band 3-300 Hz and 3-20 Hz.

The following specifications for phase jitter measuring equipment are proposed.

1 Measuring principle

A sinusoidal tone, free of phase jitter, is applied to the circuit under test at normal data transmission level. The phase jitter measuring receiver processes the received tone as follows:

1) band limit around carrier frequency;
2) amplify and amplitude-limit carrier to remove amplitude modulation;
3) detect the phase modulation (jitter);
4) display filtered jitter (up to about 300 Hz) on a peak-to-peak indicating meter or digital display.

2 Proposed specifications

2.1 *Measurement accuracy*

Objective is better than ± 5 per cent of the measured value plus ± 0.2 degrees.

2.2 *Transmitter*

a) Test signal frequency . . . . 1020 ± 10 Hz

b) Send level . . . . −30 dBm to 0 dBm

c) Output impedance (frequency range 300 Hz to 6 kHz)

   – balanced, earth free (other impedances optional) . . . . 600 ohms

   Return loss . . . . ⩾ 30 dB
   Signal balance ratio . . . . ⩾ 40 dB

d) Phase jitter at source . . . . ⩽ 0.1 degree peak-to-peak

2.3 *Receiver*

a) Measurement range

   At least as great as . . . . 0.2 to 30 degrees peak-to-peak

b) Sensitivity and frequency range

   The receiver should be capable of measuring the phase jitter of signals at input levels between −40 and +10 dBm and frequencies between 990 and 1030 Hz.

c) Input selectivity

   Power line hum protection: highpass filter with a nominal cutoff frequency of 400 Hz with at least 12 dB per octave slope.

   Protection for limiter against channel noise: lowpass filter with a nominal cutoff frequency of 1800 Hz with at least 24 dB per octave slope.

d) Input impedance (frequency range 300 Hz to 6 kHz)

   – balanced, earth free

   Signal balance ratio . . . . ⩾ 50 dB

   1) Low impedance . . . . 600 ohms
      (other impedances optional)
      Return loss . . . . ⩾ 30 dB

2) High impedance . . . . approx. 20 kohms
Tapping loss across 600 ohms . . . . $\leqslant$ 0.25 dB

Note – Definitions and measurement to be in accordance with Recommendation O.121.

2.4 *Modulation measurement weighting characteristics*

The phase jitter modulation is measured on a weighted basis defined as follows:

Three weighting characteristics are specified to measure phase jitter in the frequency bands 4 Hz to 20 Hz, 4 Hz to 300 Hz and 20 Hz to 300 Hz. Jitter components in these frequency bands are measured with full sensitivity and attenuated beyond the frequency bands.

The weighting characteristics may be measured by a 2-tone test as follows: if a pure[1] 1000 Hz, +10 dBm tone is applied to the input and a second pure tone 20 dB lower in level is added to this tone, values of phase jitter shall be observed according to the frequency of this added tone as shown in Table 1/O.91. Other weighting selections may be provided on a switchable basis.

TABLE 1/O.91

Frequency of the second tone (Hz)	Phase jitter (degrees)		
	Frequency band (Hz)		
	4 to 300	4 to 20	20 to 300
999.7 and 1000.3	< 1	< 1	xxx
999.25 and 1000.75	< 3	< 3	xxx
998.5 and 1001.5	< 8	< 8	xxx
998.0 and 1002.0	xxx	xxx	< 3
996.0 and 1004.0	10.7 ± 1.5	10.7 ± 1.5	xxx
994.0 and 1006.0	11.2 ± 1.0	11.2 ± 1.0	xxx
992.0 and 1008.0	11.5 ± 0.7	11.5 ± 0.7	xxx
988.0 and 1012.0			< 10
984.0 and 1016.0		11.5 ± 0.7	xxx
980.0 and 1020.0		11.1 ± 1.1	11.5 ± 0.7
967.0 and 1033.0		< 3	
953.0 and 1047.0		< 1	
760.0 and 1240.0	11.5 ± 0.7	xxx	11.5 ± 0.7
700.0 and 1300.0	11.1 ± 1.1	xxx	11.1 ± 1.1
500.0 and 1500.0	< 3	xxx	< 3
300.0 and 1700.0	< 1	xxx	< 1

xxx = Does not apply.

[1] A single frequency signal with a total nonlinear distortion at least 40 dB below the level of the fundamental signal.

2.5 *Amplitude-to-phase conversion*

With the second tone at 1100 Hz, an external attenuator is used to insert flat loss in 10 dB steps up to 50 dB between the sources of the tones and the receiver. The spread of the readings should not exceed 0.7 degrees. All of the requirements in Table 1/O.91 should also be met at any of the flat loss settings up to 50 dB. Also, a 10 per cent modulated (20 Hz-300 Hz) AM signal in the operating level range of the set applied in place of the above tones should cause less than 0.2 degrees jitter indication.

2.6 *Noise rejection*

A 3.5-kHz band-limited white-noise signal 30 dB below 1000 Hz sine-wave carrier should indicate less than 4 degrees peak-to-peak jitter.

2.7 *Test for peak detection*

The peak detector should measure white noise at the 2.58 σ (99%) point. This may be tested as follows:

a) Apply the two tones as described in § 2.4 above. For measurements in the frequency bands of 4 to 300 Hz and 20 to 300 Hz, the second tone should be approximately 1240 Hz. For measurements in the frequency band of 4 to 20 Hz the second tone should be at approximately 1010 Hz. Measure and record the r.m.s. value of the demodulated signal being fed to the peak detector. The signal from this point is normally provided as an output for spectrum analysis.

b) Remove only the second tone and apply a band limited (to at least 2 kHz) Gaussian noise signal along with the 1000-Hz carrier. Adjust the level of the Gaussian noise for the same 11.5-degree reading on the meter as in a). Measure the r.m.s. value of the demodulated signal being fed to the peak detector. This value shall lie between 52 and 58 per cent of the value recorded in a).

2.8 *Time to display correct reading*

It is desirable that the display be within 5% ± 0.2 degrees of its final value within 4 seconds of application of the test signal for the frequency band 20-300 Hz and within 30 seconds for the frequency band 4 - 20 Hz and 4-300 Hz.

2.9 *Operating environment*

The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75% (these values are provisional and require further study).

Recommendation O.95

SPECIFICATION FOR AN INSTRUMENT TO COUNT PHASE AND AMPLITUDE HITS ON TELEPHONE-TYPE CIRCUITS

1 General

This specification provides the outline requirements for an instrument to be used for counting phase and amplitude hits on telephone-type circuits. The instrument will independently count the number of phase hits and the number of amplitude hits that occur in a given period of time.

Phase or amplitude hits are defined as sudden positive or negative changes in phase or amplitude of an observed test signal which exceed a specified threshold and persist for a period of time greater than a specified duration.

The specifications given below for the transmitter and receiver input section shall correspond with §§ 2.2 b) to 2.2 d) and §§ 2.3 b) to 2.3 d) of Recommendation O.91 in order to facilitate the combination of this instrument with a phase jitter meter conforming to Recommendation O.91 in one set.

2 Transmitter

2.1 Test signal frequency . . . . 1020 ± 10 Hz

2.2 Send level . . . . −30 dBm to 0 dBm

2.3 *Output impedance* (frequency range 300 Hz to 6 kHz)

– balanced, earth free (other impedances optional) . . . . 600 ohms

Return loss . . . . ⩾ 30 dB
Signal balance ratio . . . . ⩾ 40 dB

2.4 Phase jitter at source . . . . ⩽ 0.1 degree peak-to-peak (see Recommendation O.91)

3 Receiver input section

3.1 *Sensitivity and frequency range*

The receiver should be capable of measuring with input levels between −40 and +10 dBm and frequencies between 990 and 1030 Hz.

3.2 *Selectivity*

Power line hum protection – high-pass filter with a nominal cutoff frequency of 400 Hz with at least 12 dB per octave slope.

If the filter is not located directly at the instrument input, hum voltages equal to or smaller than the test signal shall not result in measurement errors greater than those with the filter in front of the set.

Protection for limiter against channel noise – low-pass filter with a nominal cutoff frequency of 1800 Hz with at least 24 dB per octave slope.

3.3 *Input impedance* (frequency range 300 Hz to 6 kHz)

– balanced, earth free

Signal balance ratio . . . . ⩾ 50 dB

1) Low impedance (other impedance optional) . . . . 600 ohms
Return loss . . . . ⩾ 30 dB

2) High impedance . . . . approx. 20 kohms
Tapping loss across 600 ohms . . . . ⩽ 0.25 dB

4 Phase hit detection characteristics

4.1 *Threshold settings*

Settings from 5° to 45° in steps of 5° shall be provided with an accuracy of ± 0.5°, ± 10% referred to the selected threshold[1]. Additional settings may be optionally provided.

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[1] This specification should not preclude the use of existing instruments which have tolerances of ± 2° ± 5% on the accuracy of the threshold setting.

4.2 *Guard interval*

A guard interval shall be provided by electronic gating or other equivalent means to prevent the counter from registering phase hits shorter than 4 ms. The guard interval shall be tested as follows:

With a threshold setting of 20°, phase hits shall be counted correctly if the test signal is changed in phase by 25° for a duration of 5 ms or more. When the duration of the 25° phase changes is gradually reduced until the phase hit counter stops counting, the corresponding duration of the phase changes of the test signal shall be 4 ms ± 10%.

4.3 *Hit rate of change*

Slow phase changes shall not be counted. This characteristic shall be tested as follows:

With a threshold setting of 20°, a phase hit shall be counted when the phase of a test signal is linearly varied by 100° in a time interval of 20 ms or less. A phase hit shall not be counted when the phase of the test signal is linearly varied by 100° in a time interval of 50 ms or more. The same requirements shall be met with 100° changes of opposite polarity.

4.4 *Amplitude of phase conversion*

An 8 dB amplitude hit of either polarity shall not cause a phase hit to be counted at thresholds of 10° or more.

5 **Amplitude hit detection characteristics**

5.1 *Threshold settings*

Settings of 2, 3 and 6 dB shall be provided with an accuracy of ± 0.5 dB. Additional settings not exceeding 9 dB may be optionally provided.

5.2 *Guard interval*

A guard interval shall be provided by electronic gating or other equivalent means to prevent the counter from registering amplitude hits shorter than 4 ms. The guard interval shall be tested as follows:

With a threshold of 2 dB, amplitude hits shall be counted correctly if the test signal is changed in amplitude by 3 dB for a duration of 5 ms or more. When the duration of the 3-dB amplitude changes is gradually reduced until the amplitude hit counter stops counting, the corresponding duration of the amplitude changes of the test signal shall be 4 ms ± 10%.

5.3 *Hit rate of change*

Slow amplitude changes shall not be counted. This characteristic shall be tested as follows:

With a threshold setting of 2 dB, an amplitude hit shall be counted when the level of a test signal is linearly varied by 4 dB in a time interval of 200 ms or less. An amplitude hit shall not be counted when the amplitude of the test signal is linearly varied by 4 dB in a time interval of 600 ms or more. The same requirements shall be met with 4-dB changes of opposite polarity.

5.4 *Phase to amplitude conversion*

A 180 degree phase hit shall not cause an amplitude hit to be counted at any threshold.

6 Count capacity

The counting apparatus shall be equipped with independent phase and amplitude hit counters each having a register capacity of at least 9999 counts.

7 Counting rate and dead time

The maximum counting rate for either phase or amplitude hits shall be approximately 8 counts per second, which can be accomplished with a dead time of 125 ± 25 ms after each recognized phase or amplitude hit. For the purpose of this specification, the dead time is defined as the time interval that starts when a phase or amplitude hit exceeds the threshold, and ends when the phase or amplitude counter is ready to register another phase or amplitude hit. This characteristic shall be tested as follows:

With a threshold setting of 20°, phase hits having a duration of approximately 5 ms shall be counted correctly when the repetition rate is 5 hits per second or less. When the repetition rate is gradually increased until the phase hit counter fails to register all counts, the repetition rate shall be 8 hits per second ± 20%. The same requirement shall apply to the amplitude hit counter with a threshold of 2 dB when 3-dB amplitude hits having a duration of approximately 5 ms are applied.

8 Interruption of the test signal

If transmission of the signal is interrupted and the received test signal drops in level by 10 dB or more, the phase and amplitude hit detectors shall be blocked from counting until 1 ± 0.2 s after the test signal is restored. There shall be a maximum of 1 phase hit and 1 amplitude hit recorded with each interruption of the test signal.

9 Timer

A timer accurate to ± 5% shall be provided for the convenience of the operator. Periods of 5, 15 and 60 minutes and continuous operation should be provided under switch control if the timer is not continuously adjustable.

10 Auxiliary logic output

Auxiliary two-state logic outputs shall be provided from the phase and amplitude detectors for recording or computer processing of phase and amplitude hit activity. A logic "1" signal shall be output when the hit is present and a logic "0" signal at other times. The output levels shall be compatible with TTL (Transistor-Transistor Logic) integrated circuits. The output impedance shall be less than 2000 ohms or as specified by individual Administrations.

11 Operating environment

The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75%. (These values are provisional and require further study.)

12 Simultaneous measurements

The measurement of amplitude and phase hits may be provided in one instrument which also makes measurements of other transient impairments e.g. impulse noise, interruptions. Therefore, in order to facilitate the integration of several measurements of transient phenomena into one instrument, the measurement of interruptions in accordance with the principles of Recommendation O.61, but made with a test signal frequency of 1020 Hz ± 10 Hz could be included in such a combined instrument.

SPECIFICATION OF ESSENTIAL CLAUSES FOR AN INSTRUMENT TO MEASURE FREQUENCY SHIFT ON A CARRIER CHANNEL

1 General

The equipment described below is compatible with the measuring method described in [1].

2 Principle of operation

The instrument shall be capable of measuring the error in the reconstituted frequency of a carrier channel in the following modes:

Test 1: Measurement of frequency shift A → B (Δ Hz): transmitting from A and measuring at B (see Figure 1/O.111)

The sinusoidal test frequencies having a 2 : 1 harmonic relationship are transmitted simultaneously from A. At B these two test signals, each shifted in frequency by an amount Δ Hz, are modulated together in such a way as to detect Δ, the frequency shift in the AB direction.

Test 2: Measurement of loop frequency shift (Δ + Δ′ Hz) transmitting and measuring at A with the channels looped at B (see Figure 2/O.111)

This test is carried out in a similar manner to Test 1 and the loop frequency shift (Δ + Δ′ Hz) is detected.

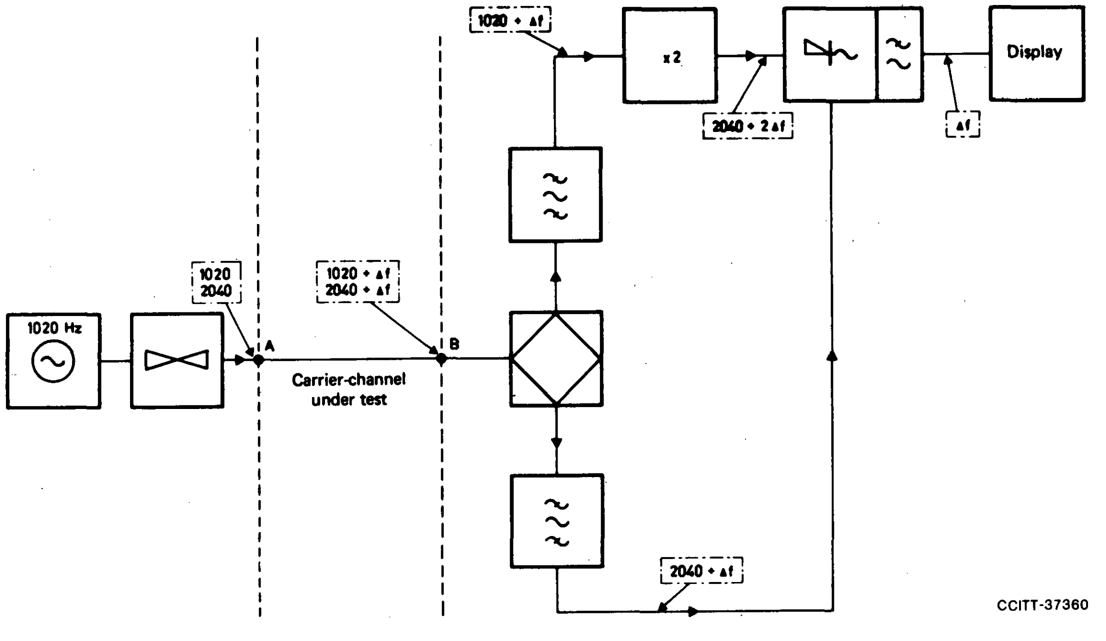


FIGURE 1/O.111

Measurement of frequency shift on a carrier channel A→B, transmitting from A and measuring at B

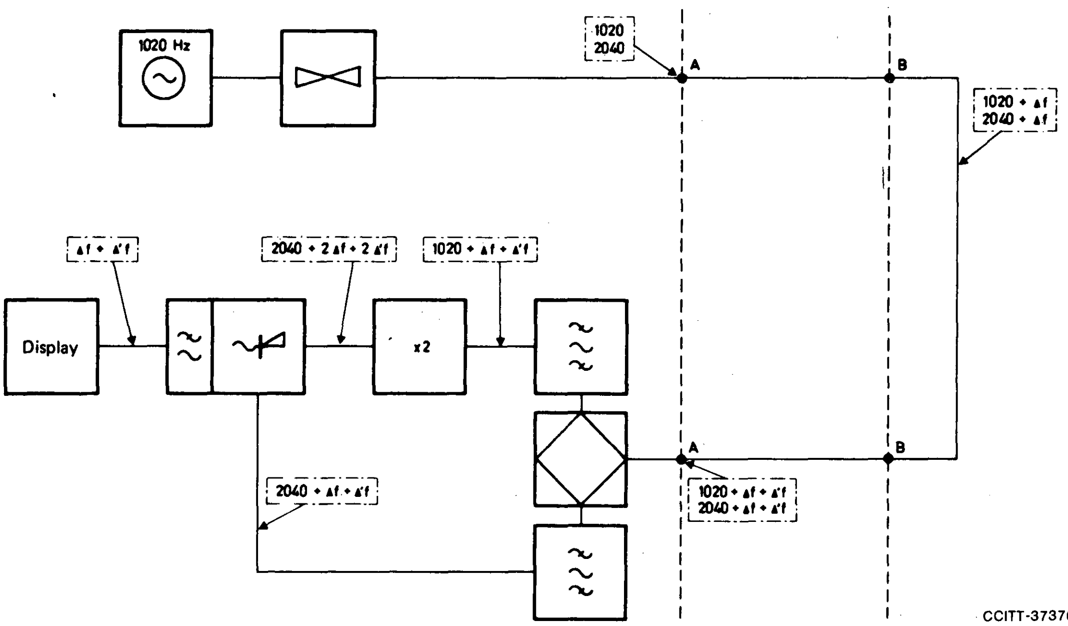


FIGURE 2/O.111

Measurement of loop frequency shift (A→B) + (B→A), transmitting and receiving at A with a direct loop at B

There may be a need to measure the frequency shift from B to A while the operator is still located at point A. This measurement can be accomplished in two ways:

Test 3a: Measurement of frequency shift B → A (Δ′ Hz) transmitting and measuring at A with B looped via a harmonic producing unit [see Part a) of Figure 3/O.111]

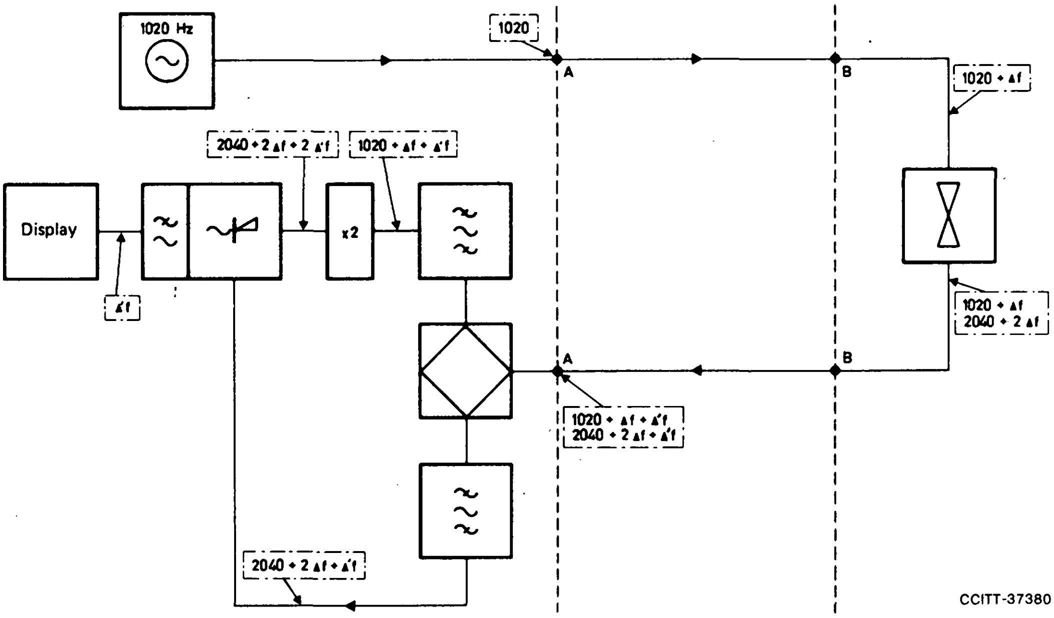
A sinusoidal test frequency is transmitted from A and received at B where it passes through a harmonic producing unit. This received signal and its second harmonic are then returned to A, both undergoing a frequency shift of Δ′ Hz where they are modulated together in such a way as to detect Δ′, the frequency shift in the B → A direction.

Test 3b: Measurement of frequency shift B → A, transmitting and measuring at A with an instrument at B, which sends out two test tones having harmonic relationship as in Test 1, initiated by receiving a single 1020-Hz tone from A [see Part *b)* of Figure 3/O.111].

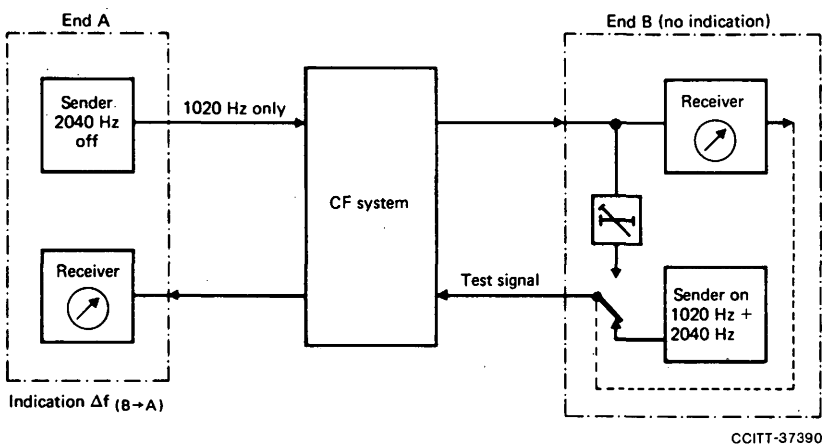
A sinusoidal test signal having a frequency of 1020 Hz is transmitted from A and received at B. If the receiver detects only a *single* tone at B, a generator producing 1020 Hz and 2040 Hz (harmonic relationship) is connected to line B → A, enabling the frequency shift measurement to be made in that direction.

If the receiver at B detects a measuring signal consisting of the *two* test tones 1020 Hz and 2040 Hz (level difference < 6 dB), the line is looped back at B automatically allowing the measurement described as Test 2 [see Part *c)* of Figure 3/O.111].

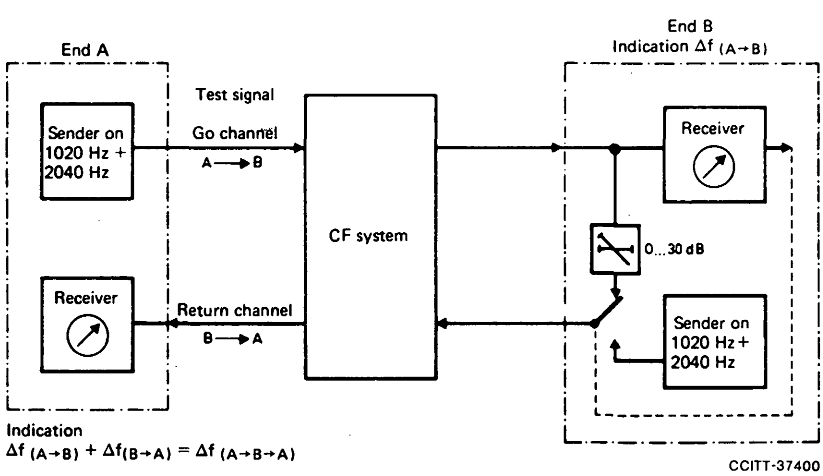
The use of the frequency shift measuring equipment for Tests 3a and 3b requires the transmission of a single 1020-Hz tone from A → B. Therefore this facility could be provided as an option for the instrument for this type of measurement. The specification of the equipment at B (harmonic producer or switched generator) should be left open for bilateral agreement between Administrations.



a) *Measurement of frequency shift on a carrier channel B→A, transmitting and measuring at A with B looped via an harmonic producing unit*



b) *Frequency shift of the return channel B→A*



c) *Frequency shift measurement of the loop (A→B B→A)*

FIGURE 3/O.111

Frequency shift measurement on a carrier channel transmitting and measuring at A

3 Transmitting equipment

The equipment shall transmit sinusoidal test signals as follows:

3.1 *Frequencies*

a) 1020 and 2040 Hz ± 2%. These two frequencies shall be in exact harmonic relationship.

Note – If this transmitting equipment is intended to be used in phase jitter measurements, an accuracy of ± 1% will be required.

b) optional additional output for Administrations wishing to cooperate Figure 3/O.111 type measurements . . . . 1020 Hz ± 2%.

3.2 *Level*

The r.m.s. total output power of the transmitted signal shall be adjustable in the range 0 dBm to −30 dBm. Where two frequencies are transmitted the difference between the two levels shall be less than 0.5 dB.

3.3 *Impedance* (frequency range 300 Hz to 6 kHz)

– balanced, earth free . . . . 600 ohms

3.3.1 Return loss . . . . ⩾ 30 dB

3.3.2 Signal balance ratio . . . . ⩾ 50 dB

4 Receiving equipment

The receiving equipment shall accept the two test tones and shall indicate the frequency shift on a meter or other suitable indicator.

4.1 *Measuring ranges*

Full-scale measuring ranges of 0-1 Hz and 0-10 Hz shall be provided. The algebraic sign of the shift shall also be indicated.

4.2 *Measuring accuracy*

– ± 0.05 Hz on 0-1 Hz range,

– ± 0.5 Hz on 0-10 Hz range.

4.3 The meter or indicator shall be such that frequency shifts down to ± 0.1 Hz shall be readable.

4.4 It shall be possible to determine frequency shifts of less than 0.1 Hz by a suitable additional visual facility.

4.5 *Input level*

The receiving equipment shall give the specified accuracy with test signals having levels in the range +10 dBm to −30 dBm (see, however, § 4.8 below). A device shall be provided to confirm that test signals are being received.

4.6 *Impedance* (frequency range 300 Hz to 6 kHz)

– balanced, earth free . . . . 600 ohms

4.6.1 Return loss . . . . ⩾ 30 dB

4.6.2 Signal balance ratio . . . . ⩾ 50 dB

4.7 *Input frequency*

The receiving equipment shall operate correctly with test signals up to ± 2% from nominal frequency as applied at the transmitting end and having experienced a frequency shift of up to ± 10 Hz in the transmission circuit concerned.

4.8 *Level difference*

When the two-frequency test signal is transmitted the receiving equipment shall operate correctly when, due to the insertion loss/frequency characteristic of the circuit, the two frequencies arrive at the input to the receiving equipment with a level difference of up to 6 dB.

4.9 *Recorder output*

A d.c. output for operating a recorder shall be provided.

4.10 *Noise immunity*

The r.m.s. value of the error in the indication due to a 300-3400 Hz band of white noise 26 dB below the level of the received test signal shall not exceed ± 0.05 Hz.

5 Working conditions

The instrument shall meet the above requirements under the following conditions:

- temperature range: +5 °C to +40 °C;
- relative humidity: 45% to 75%.

These values are provisional and require further study.

Reference

[1] *Method for measuring the frequency shift introduced by a carrier channel*, Green Book, Vol. IV.2, Supplement No. 2.10, ITU, Geneva, 1973.

Recommendation O.121

MEASURING ARRANGEMENTS TO ASSESS THE DEGREE OF UNBALANCE ABOUT EARTH

1 General

This Recommendation describes arrangements for measuring the following parameters:

- longitudinal conversion loss;
- transverse conversion loss;
- longitudinal conversion transfer loss;
- transverse conversion transfer loss;
- input longitudinal interference loss;
- common-mode rejection;
- output signal balance.

In practice, the above parameters are the seven most significant unbalance parameters. Limits for these parameters, special considerations for test terminations and the measurement frequencies to be used are given in the relevant Recommendation for the item under test.

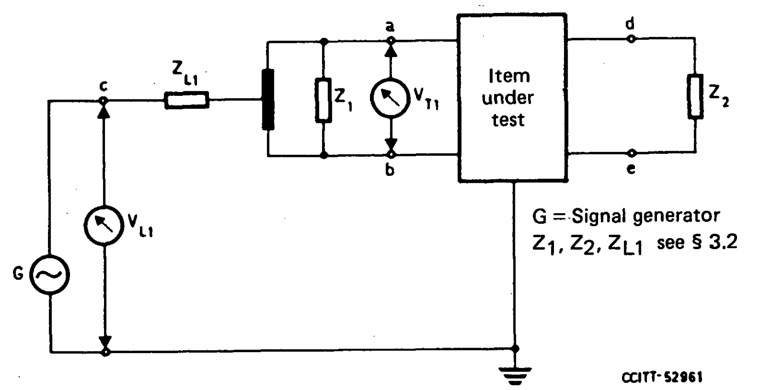
This Recommendation is in agreement with the principles, the nomenclature and the definitions, addressed in Recommendation G.117 [1], which considers the transmission aspects of unbalance about earth. References are made in the following sections, to the appropriate paragraphs/figures of Recommendation G.117.

In § 3, guidance is given regarding the construction of a test bridge along with values of the required components.

2 Measuring arrangements

2.1 *Longitudinal conversion loss (LCL)*

The LCL of a one- or two-port network is a measure (a ratio expressed in dB) of the degree of unwanted transverse signal produced at the terminals of the network due to the presence of a longitudinal signal on the connecting leads. It is measured as shown in Figure 1/O.121. This technique is applicable to either the input or output terminals, e.g., transpose terminals a and b with d and e respectively. (See § 4.1.3 of Recommendation G.117 [1].)



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

FIGURE 1/O.121

Measurement of longitudinal conversion loss

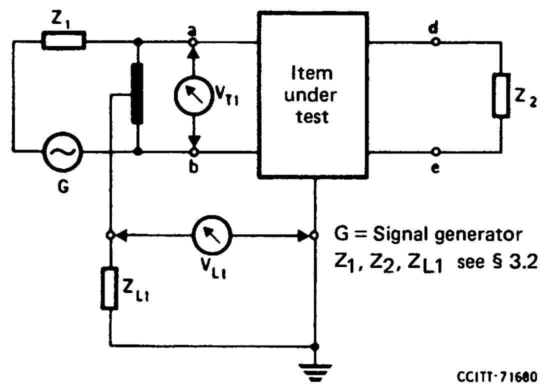
2.2 *Transverse conversion loss (TCL)*

The TCL of a one- or two-port network is a measure (a ratio expressed in dB) of the degree of unwanted longitudinal signal produced at the input (or output) of a network due to the presence of a transverse signal at the same port. TCL is measured as shown in Figure 2/O.121 (see § 4.1.2 of Recommendation G.117 [1]).

2.3 *Longitudinal conversion transfer loss (LCTL)*

The LCTL is a measure (a ratio expressed in dB) of an unwanted transverse signal produced at the output of a two-port network due to the presence of a longitudinal signal on the connecting leads of the input port. It is measured as shown in Figure 3/O.121 (see § 4.2.3 of Recommendation G.117 [1]).

If the item under test exhibits gain or loss between ports a/b and d/e, this must be taken into account when specifying LCTL. In addition to the general requirements of § 3, the measurement range of the test equipment must also take into account the gain or loss of the item under test. In addition, if the item under test performs a signal conversion (e.g., in FDM or TDM multiplexers) then the signal measured at V_{T2} may not be at the same frequency as that of the energizing signal designated V_{Li}. The signal at V_{T2} may even appear in coded form as a digital signal. Further study is required to define these signals and their relationships.

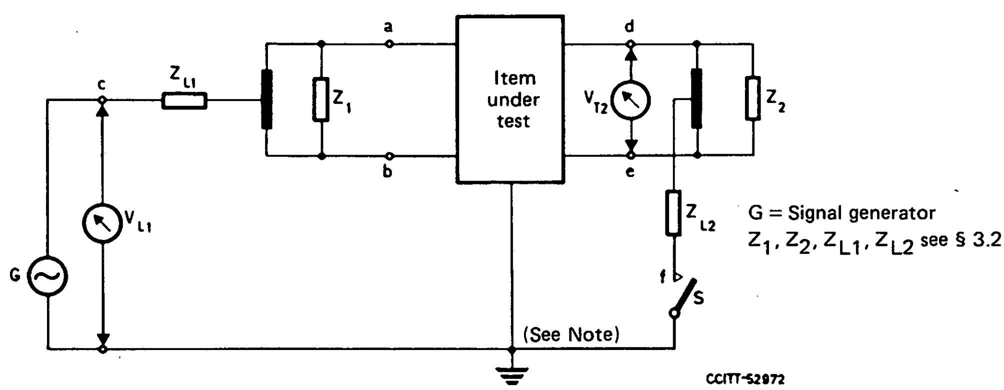


$$\text{Transverse conversion loss (TCL)} = 20 \log_{10} \left| \frac{V_{T1}}{V_{L1}} \right| \text{ dB}$$

Note – The transverse signal is expressed as the voltage at port a/b (or d/e). Any specification referring to the source voltage of the signal generator G will lead to the same result if the input (output) impedance of the item under test equals Z_1 (Z_2).

FIGURE 2/O.121

Measurement of transverse conversion loss



$$\text{Longitudinal conversion transfer loss (LCTL)} = 20 \log_{10} \left| \frac{V_{L1}}{V_{T2}} \right| \text{ dB}$$

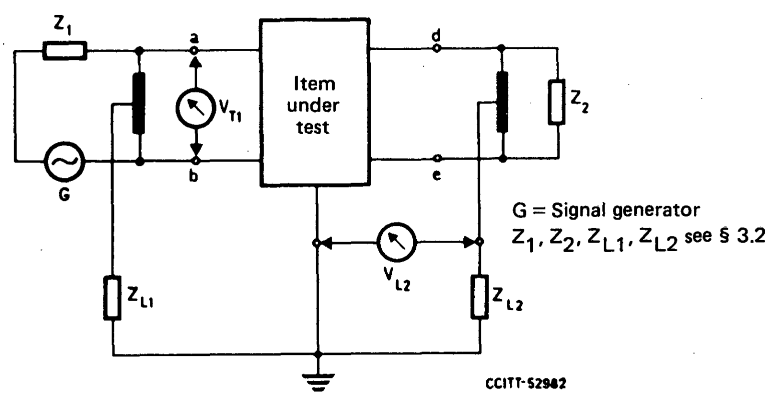
Note – Measurements are normally made, and limits specified, with switch S closed. However, for certain equipments, e.g. those described in Recommendation Q.45 [2], it may be necessary to specify limits for LCTL with switch S closed and with switch S open.

FIGURE 3/O.121

Measurement of longitudinal conversion transfer loss

2.4 *Transverse conversion transfer loss (TCTL)*

Transverse conversion transfer loss is a measure (a ratio expressed in dB) of an unwanted longitudinal signal produced at the output of a two-port circuit due to the presence of a transverse signal at the input port. It is measured as shown in Figure 4/O.121. If a signal conversion is performed by the item under test (e.g., in FDM or TDM multiplexers) then the signal measured at V_{L2} may not be at the same frequency as that of the energizing signal designated V_{T1}. The energizing signal may even be applied in coded form as a digital signal. Further study is required to define these signals and their relationships (see § 4.2.2 of Recommendation G.117 [1]).



$$\text{Transverse conversion transfer loss (TCTL)} = 20 \log_{10} \left| \frac{V_{T1}}{V_{L2}} \right| \text{ dB}$$

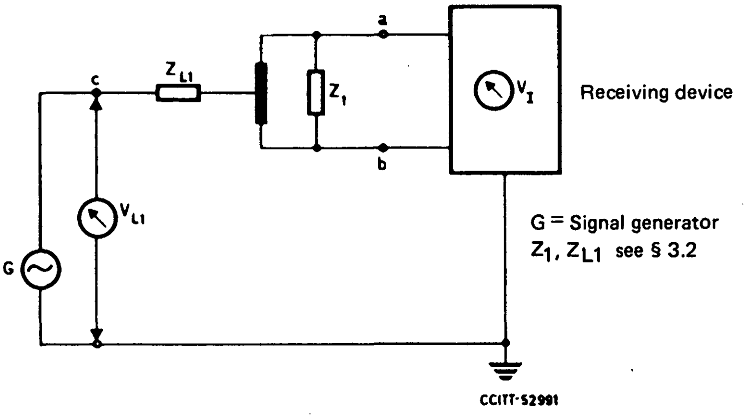
Note – The transverse signal is expressed as the voltage at port a/b. Any specification referring to the source voltage of the signal generator G will lead to the same result only if the input impedance of the item under test equals Z_1.

FIGURE 4/O.121

Measurement of transverse conversion transfer loss

2.5 *Input longitudinal interference loss (ILIL)*

The measurement of this parameter is applicable to receiving devices (e.g., level meters). ILIL is a measure (a ratio expressed in dB) of the sensitivity of a receiving device to longitudinal disturbances. It is measured as shown in Figure 5/O.121. In principle, it is identical to the longitudinal conversion transfer loss (LCTL) measurement. However, since, the item under test contains a built-in indicating device, the voltage V_I, which is equivalent to voltage V_{T2} in the LCTL measurement, can be observed directly without the need for an external indicator (see § 4.4.1 of Recommendation G.117 [1]).



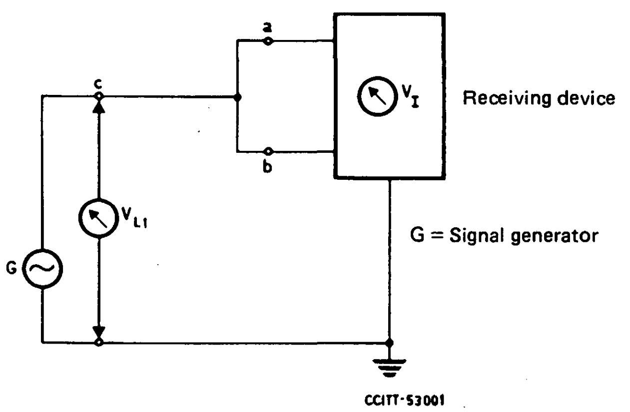
$$\text{Input longitudinal interference loss (ILIL)} = 20 \log_{10} \left| \frac{V_{L1}}{V_I} \right| \text{ dB}$$

FIGURE 5/O.121

Measurement of input longitudinal interference loss

2.6 *Common-mode rejection (CMR)*

Common-mode rejection is another measurement (a ratio expressed in dB) that is appropriate for receiving devices and is measured as shown in Figure 6/O.121. Note that in this arrangement the input terminals are short-circuited and then energized (see § 5.1 of Recommendation G.117 [1]).



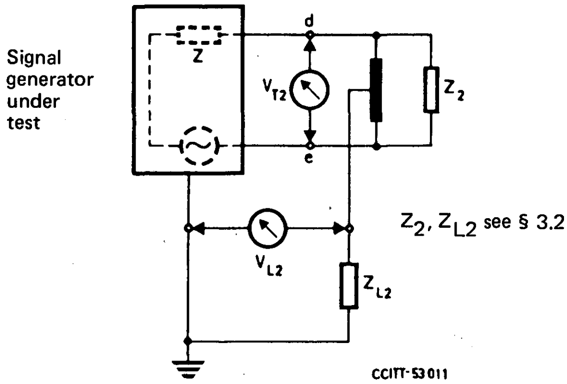
$$\text{Common mode rejection (CMR)} = 20 \log_{10} \left| \frac{V_{L1}}{V_I} \right| \text{ dB}$$

FIGURE 6/O.121

Measurement of common-mode rejection

2.7 *Output signal balance (OSB)*

This measurement (a ratio expressed in dB) is applicable to signal generators. OSB is a measure of unwanted longitudinal signals at the output of a generator. It is measured as shown in Figure 7/O.121 (see § 4.3.1 of Recommendation G.117 [1]).



$$\text{Output signal balance (OSB)} = 20 \log_{10} \left| \frac{V_{T2}}{V_{L2}} \right| \text{ dB}$$

FIGURE 7/O.121

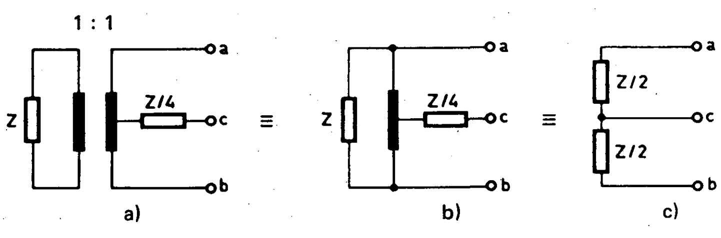
Measurement of the output signal balance

3 Requirements for the measuring arrangements

3.1 *Inherent balance*

The measuring arrangements shown in Figures 1/O.121 through 7/O.121 include two independent impedances and a centre-tapped inductor arranged as indicated to yield the equivalence of two matched impedances of the value $Z/2$. The coil should be iron-cored with an accurate centre-tapped connection, both the tightly coupled half windings being as symmetrical as possible. The circuits shown in Figure 8/O.121 are electrically equivalent and any one can be used to perform the measurements described in this Recommendation. It should be noted that in the case of option *c)* of Figure 8/O.121, the connection of point c to earth must be made via an impedance which is virtually zero. For very low frequencies, the arrangements *a)* and *b)* of Figure 8/O.121 may be unsuitable and it may be more convenient to use arrangement *c)* of Figure 8/O.121, with a small (e.g., 1 ohm) resistor being inserted in the longitudinal arm, so that a measure of longitudinal current can be obtained to derive the equivalent voltage across $Z/4$.

The inherent balance of any measuring arrangements must be determined and found to be sufficiently good before a measurement is made. This may be done by replacing the equipment being tested with a second test bridge. The inherent longitudinal conversion loss of the measuring arrangements should be 20 dB greater than the limit set for the item under test. This balance should also be obtained when the connections at a and b are reversed. This permits an accuracy in the order of ± 1 dB. An example of a practical test bridge is given in Recommendation G.117, Figure 21/G.117 [1].



Note – Impedance $Z = Z_1$ or Z_2

FIGURE 8/O.121

Electrical correspondence between centre-tapped coil configuration and centre-tapped resistors

3.2 *Impedances Z_1, Z_2, Z_{L1} and Z_{L2}*

Z_1 and Z_2 are the impedances connected in parallel to the input and/or output port respectively of the item under test. Z_1 and Z_2 are generally within ± 25% of the nominal impedance of the port to which they are connected. If measurements are made via high-impedance input ports, an additional impedance Z_1 should be connected between points a and b. The longitudinal impedances Z_{L1} and Z_{L2} are nominally equal to $Z_1/4$ or $Z_2/4$ respectively. Different values, however, may be used. This may be necessary to more properly simulate operating conditions of the item under test. In such cases the value of Z_{L1} and/or Z_{L2} shall be specified by the Recommendation convering the item under test.

3.3 *Measuring and generating the test signals*

The voltages V_L and V_T are measured with high-impedance voltmeters, and in such a way that the balance is not disturbed. The actual values of the internal impedance and e.m.f. of the generator G are irrelevant if V_{L1} is measured. The design of the item under test may impose a limit on the permissible magnitude of the longitudinal excitation.

When the equipment being tested as shown in Figure 1/O.121 is a signal generating device, V_{T1} must be measured selectively if it is required to measure the longitudinal conversion loss while the signal generator is active. Selective measurements are also preferable when high losses are to be measured.

3.4 *Other considerations*

It may be necessary in some measurements to make provisions for supplying a d.c. line holding current or a d.c. line current termination. In these cases the Recommendation covering the requirements for the item under test shall also specify the requirements for such d.c. line current treatment.

References

[1] CCITT Recommendation *Transmission aspects of unbalance about earth* Vol. III, Rec. G.117.

[2] CCITT Recommendation *Transmission characteristics of an international exchange* Vol. VI, Rec. Q.45.

Recommendation O.131

SPECIFICATION FOR A QUANTIZING DISTORTION MEASURING APPARATUS USING A PSEUDO-RANDOM NOISE STIMULUS

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 capable of interworking and give results of specified accuracy without the need for any special procedures or corrections to the measurement 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. Some information regarding procedures for interworking between different designs of measuring apparatus is given in Supplement No. 3.4 [1] to the Series O Recommendations.

2 Testing method proposed

The method proposed is that described in Method 1 of the Recommendation cited in [2]. 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 [1].

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

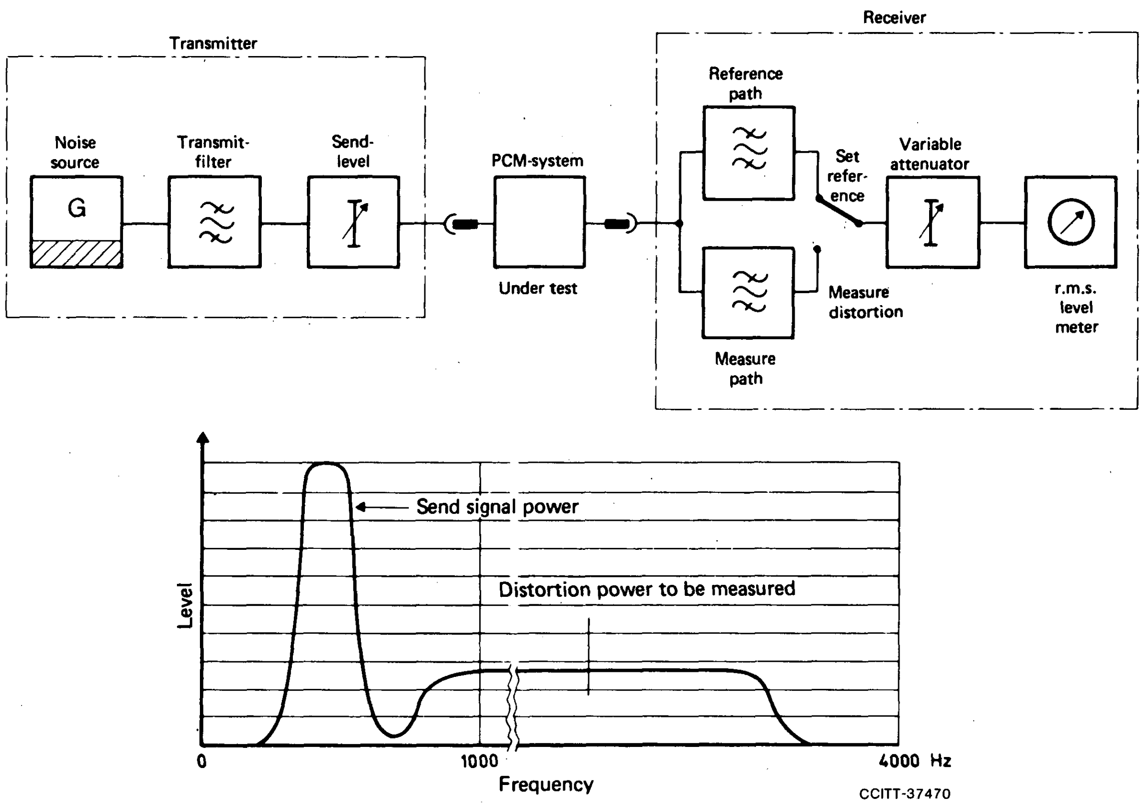


FIGURE 1/O.131

Principle of quantizing distortion measurement

1) 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 [2], 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.

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 ± 0.5 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 [3] with a setting accuracy of ± 0.5 dB.

3.1.7 *Output impedance*

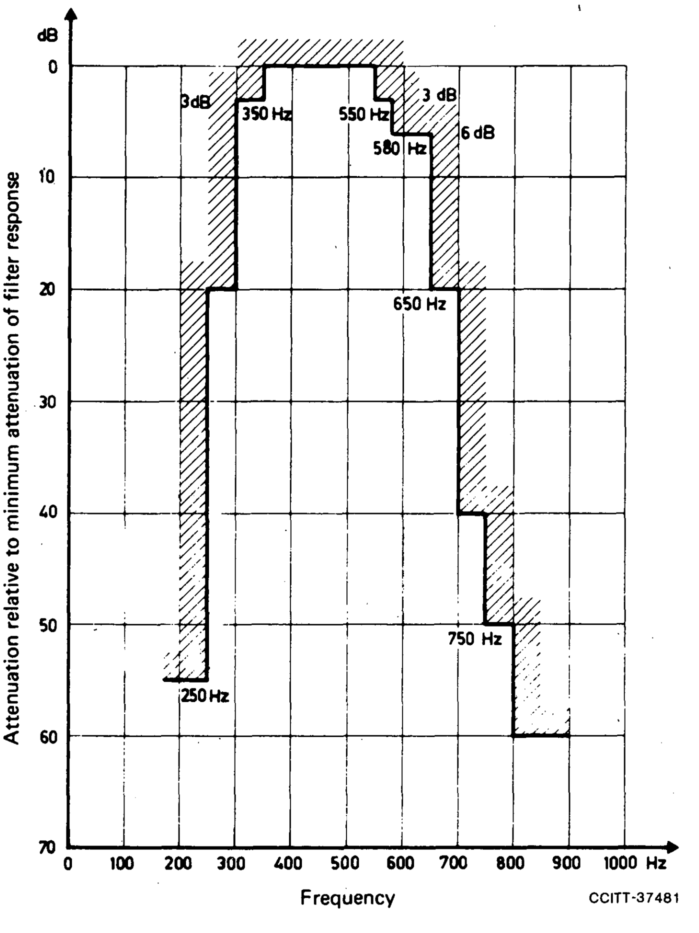
600 ohms balanced with a return loss of better than 30 dB over the frequency range 300-3400 Hz and a signal balance ratio (Recommendation O.121) better than 46 dB over the frequency range 300-4000 Hz. For frequencies below 300 Hz the signal balance ratio should be maintained at better than 46 dB and furthermore should be 60 dB or better at 40 Hz.

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.



Note – Refer to § 3.1.5 of this Recommendation, for bandpass characteristics.

FIGURE 2/O.131

Performance requirements for bandpass filter used in sending section of quantizing distortion measuring apparatus

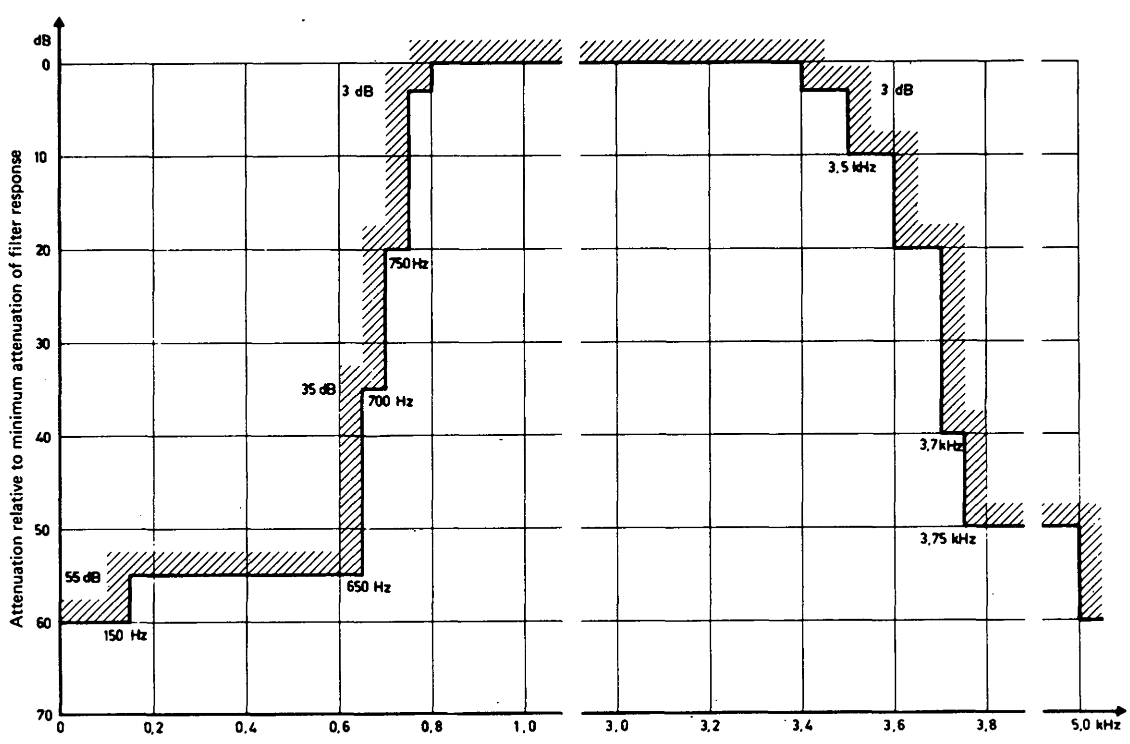
Note – The receive reference filter ideally restricts the bandwidth of the reference path to respond only to the spectrum of the received noise stimulus. However, the bandwidth of 350-550 Hz is chosen to allow for the need to interwork with test apparatus having a noise source bandwidth of up to 200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



Note – Refer to § 3.2.2 of this Recommendation, for bandpass characteristics.

FIGURE 3/O.131

Performance requirements for measuring path filter response used in receive section of quantizing distortion measuring apparatus

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:

$$10 \log_{10} \frac{3100}{y} \quad \text{(dB)}$$

where y is the effective noise bandwidth of the measuring filter in Hz.

3.2.4 *Receiver input impedance*

600 ohms balanced with return loss greater than 30 dB over the frequency range 300-3400 Hz and a signal-to-balance ratio exceeding 46 dB over the frequency range 300-4000 Hz. The signal balance ratio for frequencies below 300 Hz shall be maintained at better than 46 dB and shall be 60 dB or better at 40 Hz.

3.2.5 *Input reference level range*

0 dBm0 to at least −55 dBm0 for relative levels according to Recommendation G.232 [3].

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 ± 0.5 dB.
- Measuring range 0 dB to 10 dB: Accuracy ± 1.0 dB.

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

- Measuring range 20 dB to 40 dB: Accuracy ± 1.5 dB.
- Measuring range 0 dB to 20 dB: Accuracy ± 2.0 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.

References

[1] *Considerations of interworking between different designs of apparatus for measuring quantizing distortion*, Orange Book, Vol. IV.2, Supplement No. 3.4, ITU, Geneva, 1977.

[2] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Rec. G.712, § 9.

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

SPECIFICATION FOR A QUANTIZING DISTORTION MEASURING EQUIPMENT USING A SINUSOIDAL TEST SIGNAL

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. It is 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 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 Recommendation G.232 [2] with a setting accuracy of ± 0.2 dB.

3.2.2 *Output circuit characteristics* (over frequency range 300 to 3400 Hz)

Impedance balanced, earth-free . . . . 600 ohms

Return loss . . . . ⩾ 30 dB

Signal balance ratio . . . . ⩾ 40 dB

3.2.3 Distortion and spurious modulation ratio . . . . ⩾ 50 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 ± 1.0 dB.

3.3.2 *Input signal range*

At least −55 to +5 dBm0 for relative levels according to the Recommendation cited in [2].

3.3.3 *Input circuit characteristics* (over frequency range 300 to 3400 Hz)

Impedance balanced, earth-free . . . . 600 ohms

Return loss . . . . $\geqslant$ 30 dB

Signal balance ratio . . . . $\geqslant$ 46 dB

The signal balance ratio for frequencies below 300 Hz shall be maintained at better than 46 dB and shall be 60 dB or better at 40 Hz.

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.

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
1004 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

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:

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

4 Operating environment

The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75% (these values are provisional and require further study).

References

[1] CCITT Recommendation *Performance characteristics of PCM channels at audio frequencies*, Vol. III, Rec. G.712, § 9.

[2] CCITT Recommendation *12-channel terminal equipments*, Vol. III, Rec. G.232, § 11.

Recommendation O.133

SPECIFICATION FOR EQUIPMENT TO MEASURE THE PERFORMANCE OF PCM ENCODERS AND DECODERS

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 [1] [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 [1] [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.

---

1) The implications of the extended frame format at both 1544 k/bits and 2048 kbit/s are under study.

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*[2)]

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

3.1.1.2 Return loss from 200 Hz to 4 kHz: $\geq$ 36 dB.

3.1.1.3 Logitudinal conversion loss (frequency range 200 Hz to 4 kHz): $\geq$ 46 dB.

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 shall be provided:

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

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

2) Measurements at complex impedances are under study.

TABLE 1/O.133

Measurement capabilities

Parameter	Measuring configuration				Measurement facility
	A-D	D-A	A-A	D-D	
Gain (relationship between encoding law and audio level)	+	+	+	+ [b]	E
Stability	+	+	+	+	E
Return loss (at voice-frequency ports)	+	+	+	–	O
Longitudinal balance	+	+	+	–	O
Attenuation/frequency distortion	+	+	+	+	E
Envelope delay	Δ	Δ	Rec. O.81 and O.82 [a]		O
Envelope delay distortion	Δ	Δ			O
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) [b]	+	+	+	+	E
Crosstalk (measured with conventional telephone signal)	Δ	Δ	+	Δ	O
Interference from signalling [c]					O

[a] For measurements on transmultiplexers.

[b] Measurement to be performed while injecting an auxiliary signal in the disturbed channel.

[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.

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 $\sqrt{f}$.

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: ⩾ 20 dB
  - frequency range 20 kHz to 500 kHz at the output: ⩾ 14 dB
  - frequency range 500 kHz to 1.6 MHz at the output: ⩾ 16 dB

– 1544 kbit/s (without emphasis)
  - frequency range 20 kHz to 1.6 MHz at both input and output: ⩾ 20 dB

– 2048 kbit/s
  - frequency range 40 kHz to 2.5 MHz at both input and output: ⩾ 20 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, 400, 500, 600, 820, 1020, 2400, 2800, 3000, 3400 and 3600 Hz.

3.2.2.3 Deviation of transmitted frequency from indicated frequency: ± 2 Hz ± 0.1%.

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: ± 0.2 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 ± 1 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 ± 1 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.

3.4 *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, 3600 Hz.

3.4.1.3 Deviation of transmitted frequency from indicated frequency: $\pm$ 2 Hz $\pm$ 0.1%.

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: $\pm$ 0.2 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. To facilitate interworking, the sequence repetition rate (period) shall be fixed at 256 $\pm$ 1 ms (2048 samples).

Note – This requirement is also met by a period of 128 $\pm$ 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.

3.4.5 *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.

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

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

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

3.4.5.2.3 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.

3.4.6 *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 ± 127. 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 display*

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

3.5.7 *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, 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.

3.5.7.2 PCM multiplex to Recommendation G.733 [3]: loss of signal, loss of frame alignment, loss of multiframe alignment when channel associated signalling is in use, the state of bit 8 of each channel in the 6th and 12th frames, and the state of bit 1 in the 12th frame.

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).

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[3]. Examples are maximum load capacity, quantizing distortion ratio, variation 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_{AA}) and the analogue generator (E_{AG}) 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[3].

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

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[3] See Annex A to this Recommendation concerning the intrinsic errors in the PCM encoding process which may affect the interpretation of measured results.

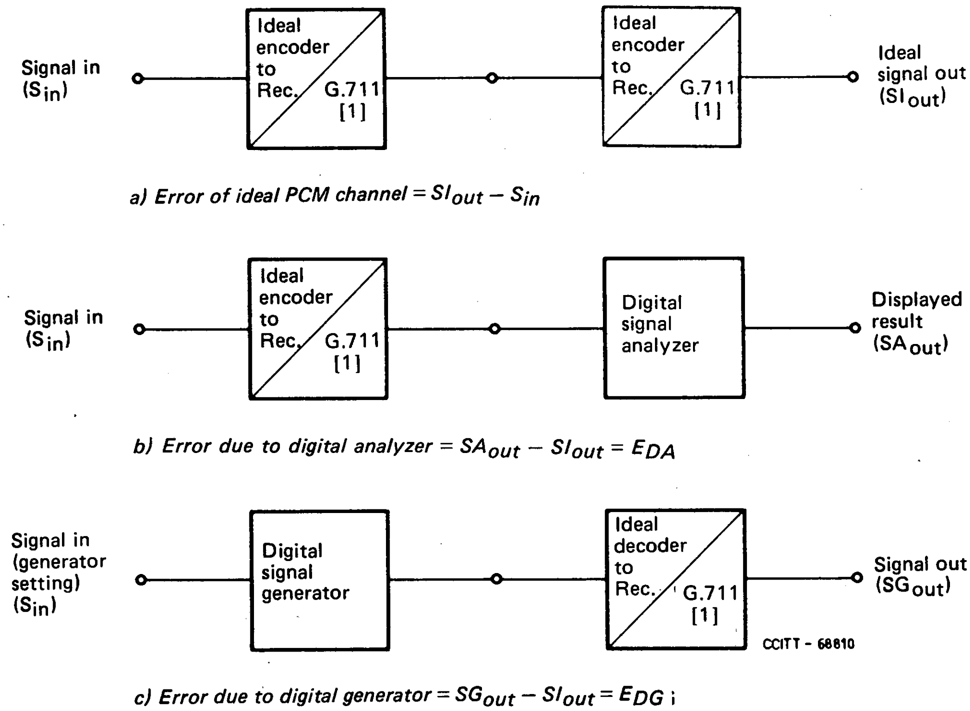


FIGURE 1/O.133

Error definitions for digital analyzer and generator

TABLE 2/O.133

Definition of total measuring error

Measuring configuration	Total measuring error
A-D	$E_{AG} + E_{DA}$
D-A	$E_{DG} + E_{AA}$
A-A	$E_{AG} + E_{AA}$
D-D	$E_{DG} + E_{DA}$

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 Supplement 3.5 of Volume IV.

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.

TABLE 3/O.133

Parameter	Error limits (dB)			
	A-D	D-A	A-A	D-D
Gain (relationship between encoding law and audio level) [a]	± 0.08	± 0.08	± 0.05	± 0.05

[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.* For further discussion and the theoretical location of the envelope, see Annex A to this Recommendation.

4.2.2 *Return loss* (optional)

See Table 4/O.133.

TABLE 4/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
Return loss [a]	0 to 30 dB	± 1	± 1	± 1	–
	30 to 40 dB	± 2	± 2	± 2	–

[a] Measured at a level $\geqslant -10$ dBm0.

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

See Table 5/O.133.

TABLE 5/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
LCL [a]	5 to 40 dB	± 1.5	–	± 1.5	–
	40 to 56 dB	± 2.5	–	± 2.5	–

[a] Measured at a level ⩾ −10 dBm0.

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

See Table 6/O.133.

TABLE 6/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
LCTL [a]	5 to 40 dB	± 1.5	–	± 1.5	–
	40 to 56 dB	± 2.5	–	± 2.5	–

[a] Measured at a level ⩾ −10 dBm0.

4.2.5 *Attenuation/frequency distortion*

See Table 7/O.133.

TABLE 7/O.133

Parameter	Frequency range	Error limits (dB)			
		A-D	D-A	A-A	D-D
Attenuation/frequency distortion [a]	200 to 300 Hz	± 0.08	± 0.08	± 0.08	± 0.08
	300 to 3000 Hz	± 0.05	± 0.05	± 0.05	± 0.05
	3000 to 3600 Hz	± 0.08	± 0.08	± 0.08	± 0.08

[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.

4.2.6 *Weighted noise*

See Table 8/O.133.

TABLE 8/O.133

Parameter	Indicated result	Error limits (dB)			
		A-D	D-A	A-A	D-D
Weighted noise [a]	-80 to -75 dBm0p -75 to -70 dBm0p -70 to -20 dBm0p	± 2.5 ± 1.5 ± 1	± 2.5 ± 1.5 ± 1	± 2.5 ± 1.5 ± 1	± 2.5 ± 1.5 ± 1

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

4.2.7 *Total distortion*

See Table 9/O.133.

TABLE 9/O.133

Parameter	Indicated result [a]	Error limits (dB) [a]			
		A-D	D-A	A-A	D-D
Total distortion (noise test signal)	0 to 40 dB	± 0.5	± 0.5	± 0.5	± 0.5
Total distortion (sinusoidal test signal)	0 to 40 dB	± 0.8	± 0.8	± 0.8	± 0.8

[a] With an absolute distortion signal not less than -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.* For further discussion and the theoretical location of the envelope, see Annex A to this Recommendation.

4.2.8 *Variation of gain with input level*

See Table 10/O.133.

TABLE 10/O.133

Parameter	Level range	Error limits (dB) [a]			
		A-D	D-A	A-A	D-D
Gain variation (noise test signal)	−10 to −40 dBm0 −40 to −50 dBm0 −50 to −55 dBm0	± 0.10 ± 0.15 ± 0.15	± 0.10 [b] ± 0.15 ± 0.15	± 0.15 [b] ± 0.20 ± 0.20	± 0.10 ± 0.10 ± 0.10
Gain variation (sinusoidal test signal at approx. 420, 820 or 1020 Hz)	+3 to −40 dBm0 −40 to −50 dBm0 −50 to −55 dBm0	± 0.10 [b] ± 0.20 ± 0.25	± 0.10 ± 0.15 ± 0.20	± 0.15 ± 0.20 ± 0.25	± 0.10 ± 0.15 ± 0.20

[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.* For further discussion and the theoretical location of the envelope, see Annex A to this Recommendation.

4.2.9 *Crosstalk measurement*

See Table 11/O.133.

TABLE 11/O.133

Parameter	Remarks	Error limits (dB)			
		A-D	D-A	A-A	D-D
Crosstalk	Sinusoidal test signal [a]	± 1	± 1	± 1	± 1
	Conventional telephone signal [b] (optional)	–	–	± 1.5	–

[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.

5 Operating environment

(Under study.)

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 ± 0.3 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 ± 0.04 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_{max} 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.

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	−0.023	−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-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-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-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		

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.

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.

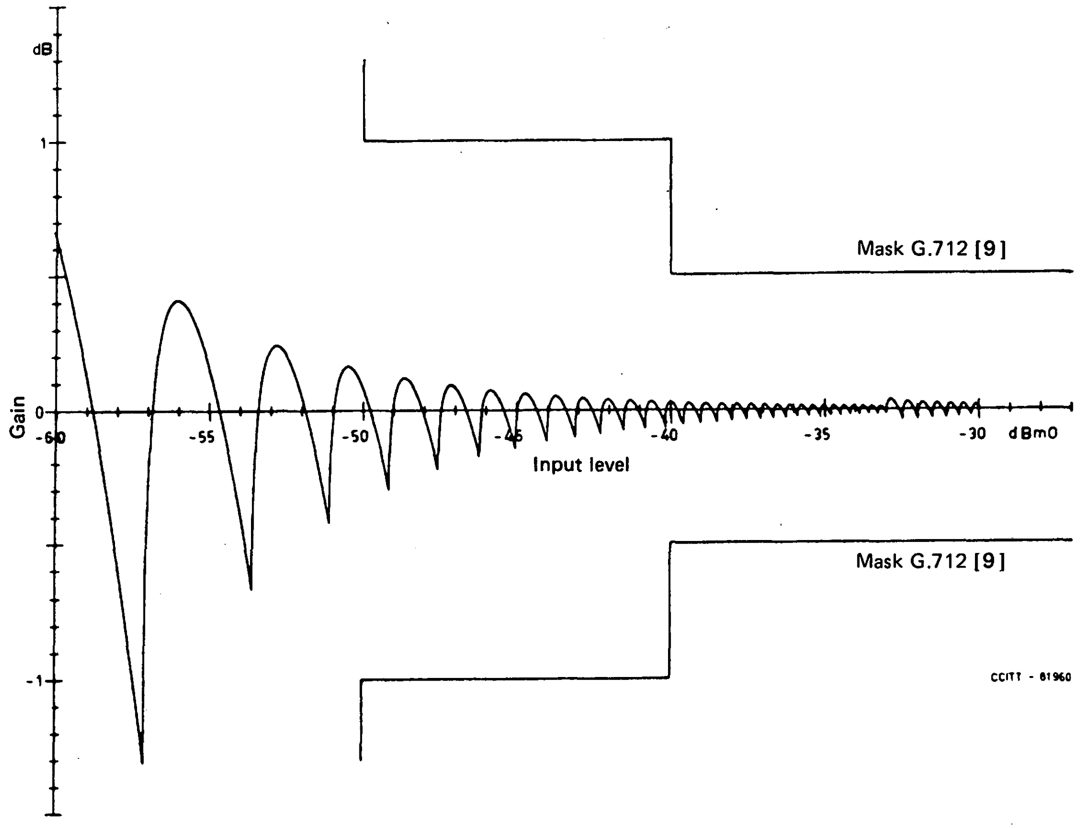


FIGURE A-1/O.133

Variation of gain with input level, A-law, selective measurement

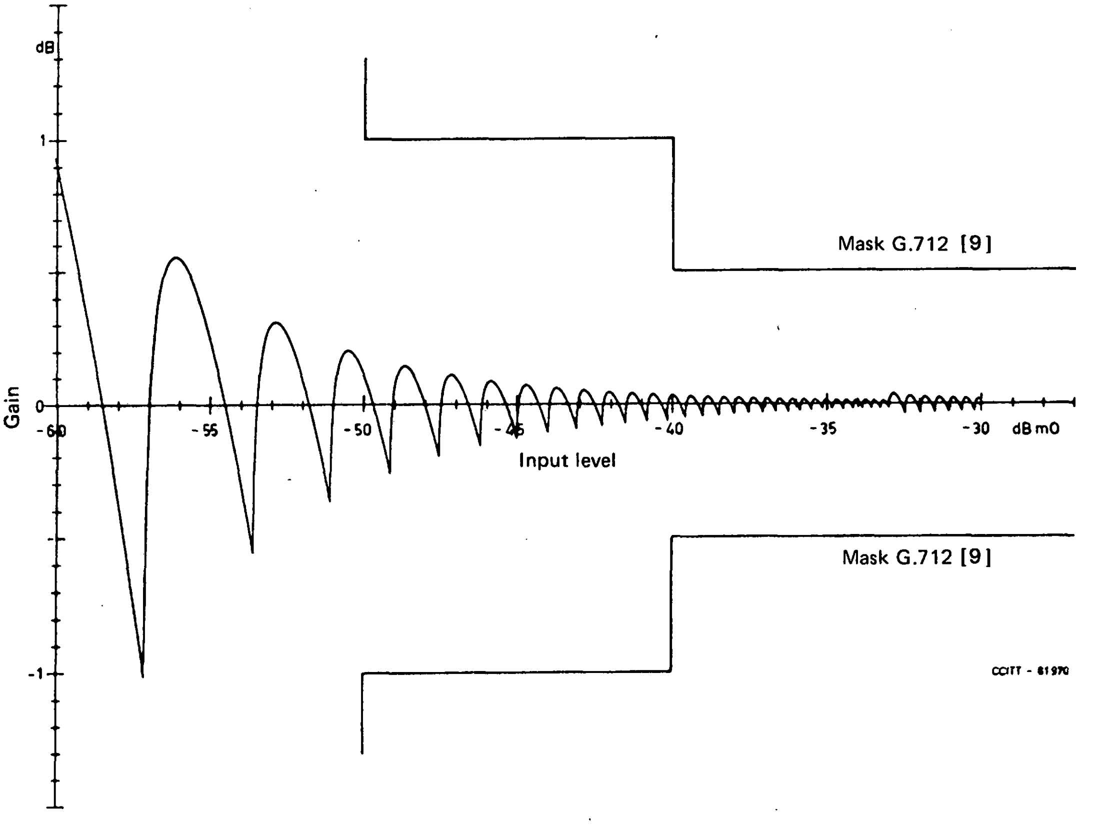


FIGURE A-2/O.133

Variation of gain with input level, A-law, wideband measurement

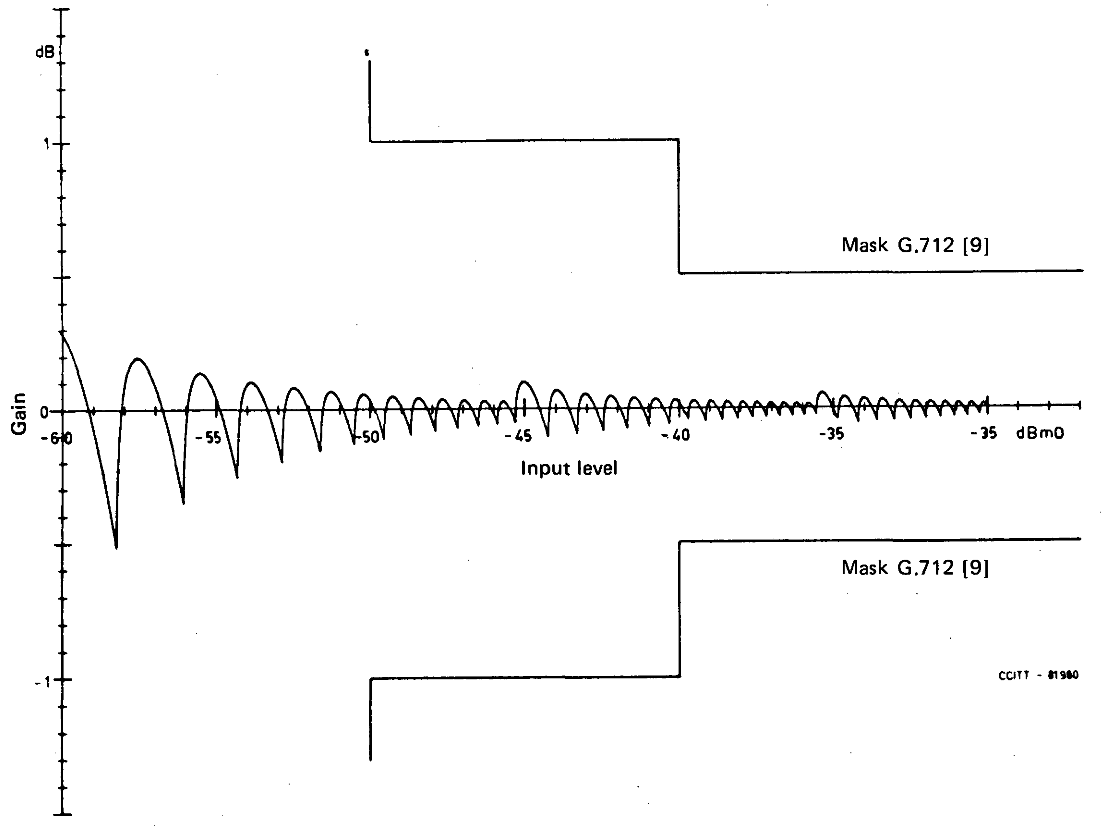


FIGURE A-3/O.133

Variation of gain with input level, μ-law, selective measurement

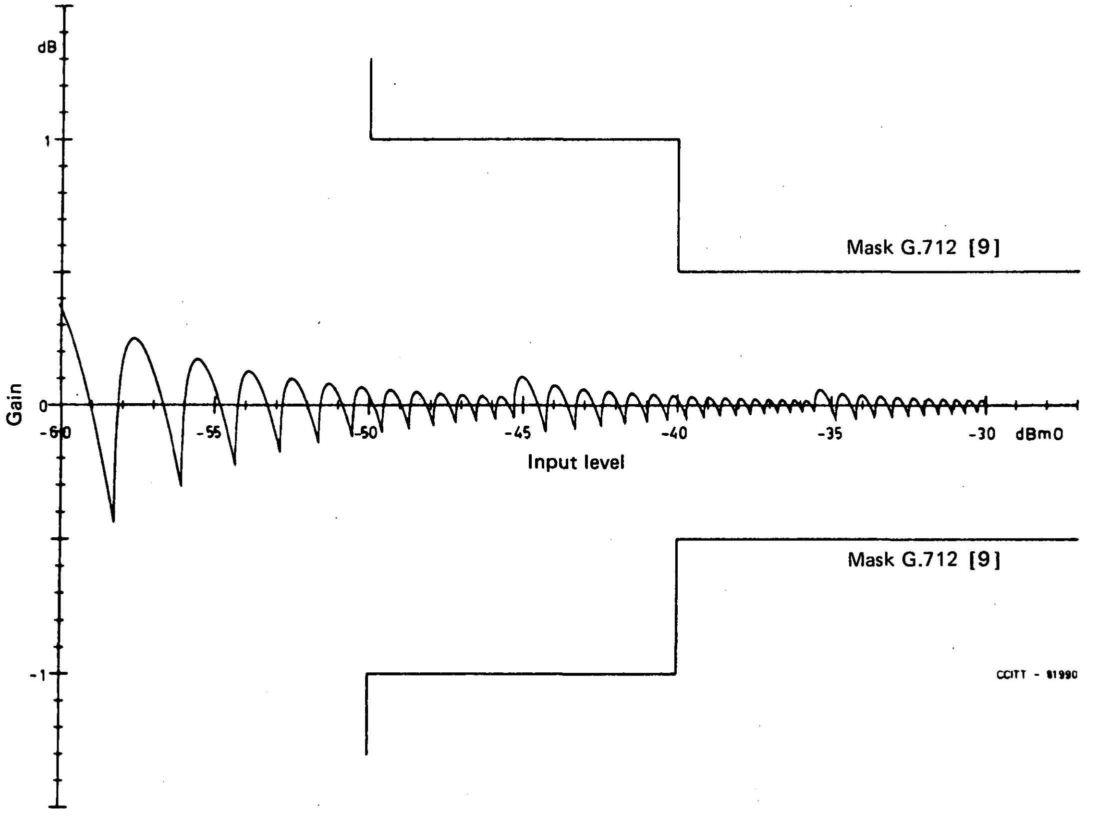
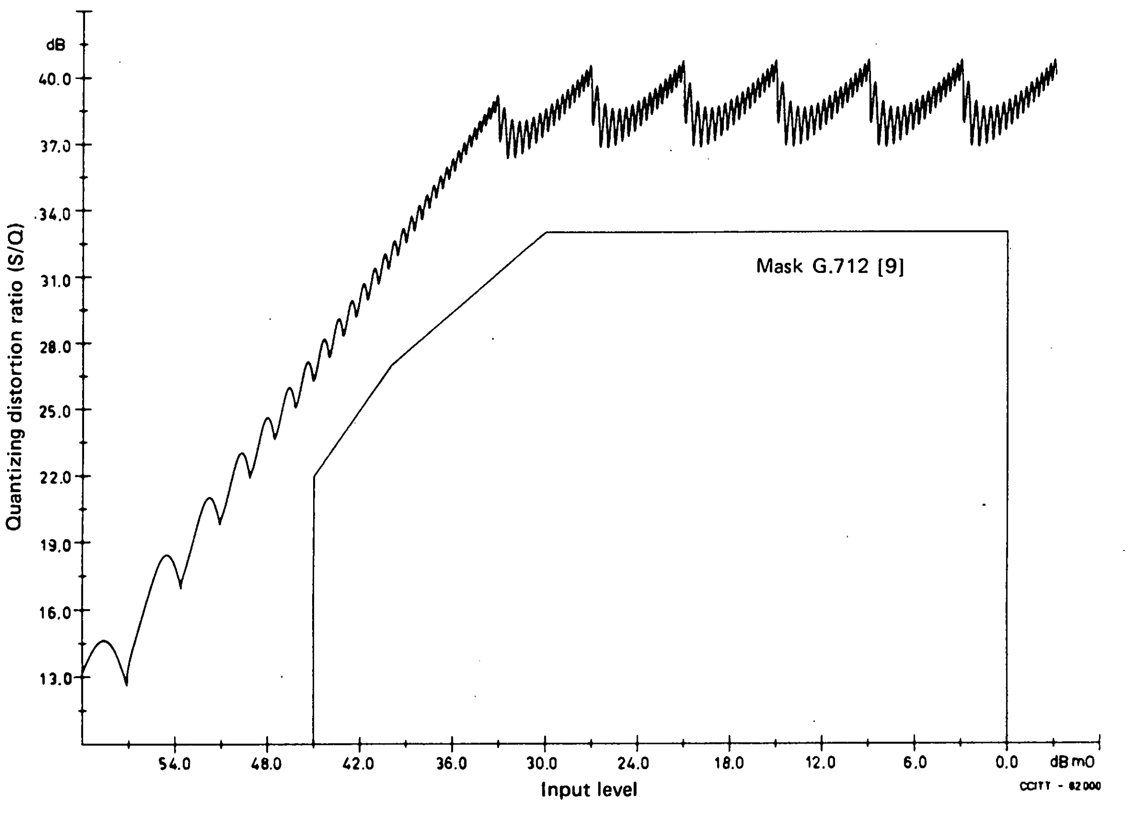


FIGURE A-4/O.133

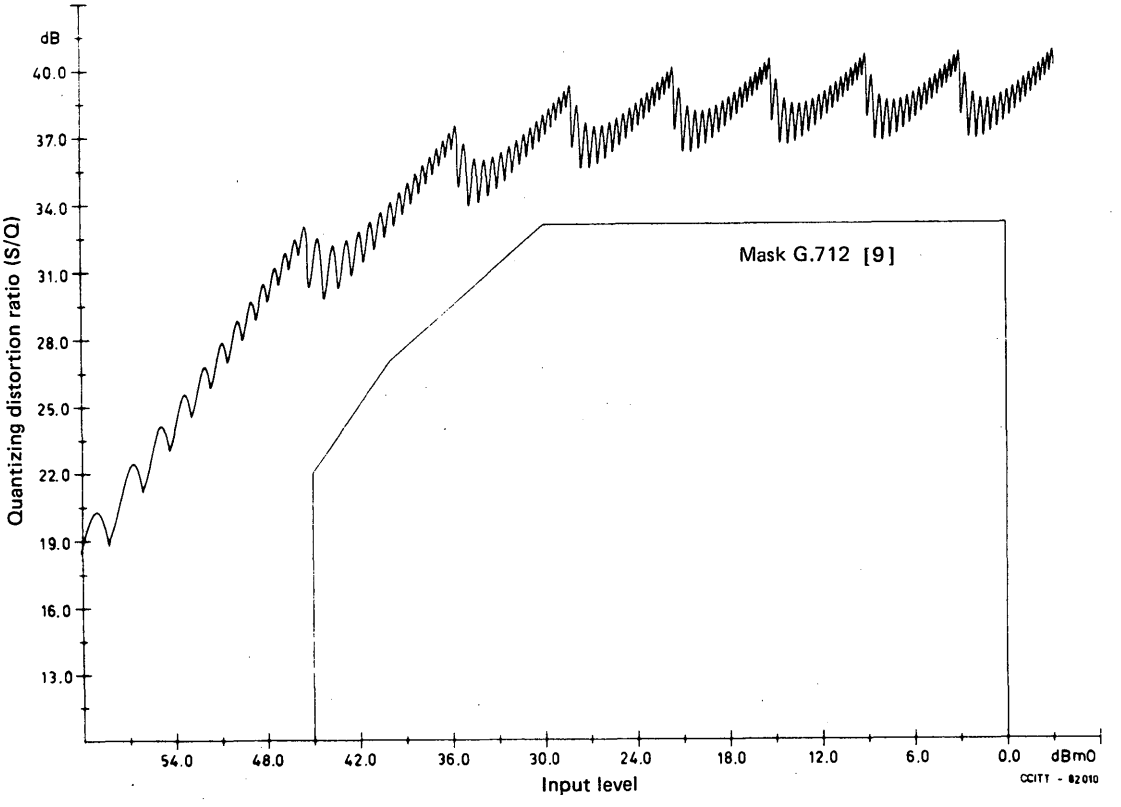
Variation of gain with input level, μ-law, wideband measurement



Note — The calculation simulates a selective measurement of the stimulus S at the output of the object under test.

FIGURE A-5/O.133

Quantizing distortion ratio, A-law



Note — The calculation simulates a selective measurement of the stimulus S at the output of the object under test.

FIGURE A-6/O.133

Quantizing distortion ratio, μ-law

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.

[3] CCITT Recommendation *Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s*, Vol. III, Rec. G.733.

[4] CCITT Recommendation *Characteristics of 60-channel transmultiplexing equipments*, Vol. III, Rec. G.793.

[5] CCITT Recommendation *Characteristics of 24-channel transmultiplexing equipments*, Vol. III, Rec. G.794.

[6] CCITT Recommendation *Transmission characteristics for transit exchanges*, Vol. VI, Rec. Q.517.

[7] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces*, Vol. III, Rec. G.703.

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

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

[10] CCITT Recommendation *Performance characteristics of PCM channels between 2-wire interfaces at voice frequencies*, Vol. III, Rec. G.713.

DESCRIPTION AND BASIC SPECIFICATION FOR A SEMIAUTOMATIC IN-CIRCUIT ECHO SUPPRESSOR TESTING SYSTEM (ESTS)

1 General

The CCITT semiautomatic *in-circuit* echo suppressor testing system (ESTS) is intended to test the sensitivity-related operational characteristics of echo suppressors assigned to all categories of international circuits.

The ESTS is suitable for testing echo suppressors complying with Recommendation G.161 [1] of the Orange Book. It may also be found suitable for certain applications on circuits employing echo suppressors complying with Recommendation G.164 [2].

The ESTS will consist of two parts: a) *directing equipment* at the outgoing end and b) *responding equipment* at the incoming end. The directing equipment will be manually connected to the circuit under test after a connection has been established to a responder at the incoming end. The responding equipment will be accessed via a test call over the circuit under test.

In order to simplify the test equipment design and its operation, quantitative measurement results will not be given. The two-way circuit loss, noise and the echo suppressor tests will be made and reported on a *pass/fail* basis. The test results shall be indicated only at the outgoing end by the directing equipment. The Administrations in charge of the incoming end need not be notified of the test results except as required to eliminate a deficiency evidenced by the test results.

The ESTS shall be capable of testing a full echo suppressor located at either the outgoing or incoming end as well as both echo suppressors when split echo suppressors are used. This equipment can be used on any circuit routed completely on terrestrial facilities, or any circuit routed on terrestrial facilities and not more than one satellite link.

This equipment will not provide reliable test results for a circuit which is routed through a circuit multiplication system (CMS) employing interpolation techniques [this includes the case where a circuit is routed over time division multiple access/digital speech interpolation (TDMA/DSI) satellite channels], and therefore should not be used in this instance unless a permanent trunk-channel association in both directions of transmission can be made for the duration of the test sequence. The reason for this is that without such a trunk-channel association, circuit continuity may not be maintained within the CMS in the absence of a signal and during very low signal level conditions.

2 Kinds of tests

A loss test will be made in both directions of transmission to ensure that the circuit loss is within ± 2.5 dB of nominal value.

A noise test will be made in both directions of transmission to determine if the circuit noise exceeds −40 dBm0p and is therefore likely to interfere with echo suppressor measurements.

The suppression and break-in sensitivities of the echo suppressor(s) are tested to ensure that they are within established limits.

3 Method of access

3.1 *Outgoing international exchange*

Access to the circuit under test at the outgoing international exchange will be on a 4-wire basis on the exchange side of the near-end echo suppressor.

The attachment of the directing equipment to the circuit under test will be done on a manual basis, such as at a testboard.

3.2 *Incoming international exchange*

Access to the responding equipment, by the circuit under test, at the incoming international exchange will be gained via the normal exchange switching equipment on a 4-wire basis.

3.3 *Address information*

The address information to be used to gain access to the responding equipment at the incoming international exchange is specified in Recommendation O.11, § 2.4.

4 Operating principles

4.1 After a switched connection has been established at the incoming end between the circuit under test and the responding equipment, the directing equipment is attached to the circuit at the outgoing end. It shall then be possible to make any number of circuit loss, circuit noise and echo suppressor tests without releasing the connection.

4.2 The tests shall be manually initiated at the outgoing end, which can either be accomplished on a test-by-test basis or the full overall test sequence can be programmed and initiated by a single control.

4.3 A fail or pass indication for each test shall be provided to the outgoing end. In order to avoid possible ambiguities in the interpretation of the test results, all suppressor tests [i.e. tests e) to l) in § 5.3.3 below] should be made during any test sequence.

4.4 The echo suppressor tests should be made only after the two-way loss tests are completed satisfactorily. A programmed test sequence should not continue beyond a failed loss test.

5 Testing procedure

5.1 *Establishment of connection*

5.1.1 When the outgoing circuit is seized, the appropriate address information is transmitted (see § 3.3 above).

5.1.2 When the access is gained to the responding equipment, the answer signal will be transmitted. If the responding equipment is occupied, a busy indication will be returned to the outgoing end in accordance with normal signalling arrangements for the circuit.

5.1.3 Upon receipt of the answer signal the directing equipment is manually attached to the circuit under test and the tests initiated as described in § 5.2 below.

5.1.4 The responding equipment will transmit a high level monitor tone at the time of access. This can be monitored at the outgoing end to assure that the responding equipment has been accessed and activated.

5.1.5 When the tests are completed the attachment of the directing equipment to the circuit under test is removed and the circuit is immediately released.

5.1.6 The responding equipment shall automatically time out and initiate a clear back if it has been accessed continuously for more than 15 minutes.

5.2 *Test initialization*

5.2.1 Each test is initiated by the sending of an associated multi-frequency command signal from the directing to the responding equipment. Before sending a multi-frequency command signal, the directing equipment shall assume a quiescent state so as to avoid interference with the proper detection of the command signal by the responding equipment.

5.2.2 Upon the detection of a valid multi-frequency (MF) command signal at any time, the responding equipment shall be returned to its quiescent state. Immediately after the cessation of the command signal the responding equipment will send a 610-Hz acknowledgement signal for a period of 500 ± 25 ms. The responding equipment will also begin sending a monitor tone and other test tones as required for the tests described below. The responding equipment shall time out and return to its quiescent state 10 seconds after the cessation of an MF command signal.

5.2.3 After sending an MF command signal the directing equipment shall be conditioned to detect the receipt of the acknowledgement signal for an interval of time up to 1400 ms. If acknowledgement is not received by the directing equipment during this interval a failure shall be indicated and the test should not proceed any further.

5.2.4 600 ± 30 ms after the cessation of the acknowledgement signal the directing equipment shall begin sending test and/or monitor tones for the various tests as described below.

5.3 *Test description*

5.3.1 Tone detection will be made by the directing equipment for the purpose of determining whether a test passed or failed during a 375 ± 25 ms test interval. This interval will begin 1000 ± 50 ms after the directing equipment begins sending test and/or monitor tones. This delay is required to permit the exchange of test and monitor tones on circuits with long delay (one satellite and long terrestrial facilities).

5.3.2 The responding equipment shall be designed to send a monitor tone whenever it is not receiving a monitor tone from the directing equipment, except during the near-to-far loss and noise tests. For the near-to-far loss and noise tests the responding equipment shall stop sending a monitor tone to indicate to the directing equipment a test failure condition.

5.3.3 Under the control of the directing equipment the ESTS will be capable of making 12 tests from the near end.

a) near-to-far loss,

b) far-to-near loss,

c) near-to-far noise,

d) far-to-near noise,

e) near-end suppressor non-operate,

f) near-end suppressor operate,

g) near-end break-in non-operate,

h) near-end break-in operate,

i) far-end suppressor non-operate,

j) far-end suppressor operate,

k) far-end break-in non-operate,

l) far-end break-in operate.

5.3.4 These tests are described below. The descriptions begin at the cessation of the acknowledgement signal as referred to in § 5.2.4 above. For all tests the responding equipment has started sending monitor and any required test tones as noted in § 5.2.2 above.

5.3.5 *Near-to-far loss test*

The responding equipment is silent. The directing equipment sends a −10 dBm0 test tone at 820 Hz for 100 ± 10 ms. If the test tone is within ± 2.5 dB of −10 dBm0 as measured at the far end, the responding equipment will send high level monitor tone. The detection of monitor tone by the directing equipment during the test interval will indicate that the test has passed.

5.3.6 *Far-to-near loss test*

The responding equipment is sending a −10 dBm0 test tone at 1020 Hz. The directing equipment measures the test tone during the test interval. If the test tone is within ± 2.5 dB of −10 dBm0, the test has passed.

5.3.7 *Near-to-far noise test*

The responding equipment is silent. The directing equipment terminates the transmit path in 600 ohms. Six hundred milliseconds after transmitting the acknowledgement signal, the responding equipment measures the noise during the following 375 ± 25 milliseconds. If the noise is below −40 dBm0p, the responding equipment will send a high level monitor tone. The detection of this monitor tone by the directing equipment during the test interval will indicate that the test has passed.

5.3.8 *Far-to-near noise test*

The responding equipment terminates its transmit path in 600 ohms. The directing equipment measures the noise during the test interval and if the noise is below −40 dBm0p the test has passed.

5.3.9 *Near-end suppressor non-operate test*

The responding equipment is sending a monitor tone and a −40 dBm0 test tone at 1020 Hz. The directing equipment starts sending a monitor tone. Upon detection of the monitor tone from the directing equipment, the responding equipment stops sending its monitor tone. The absence of the monitor tone received from the responding equipment during the test interval indicates to the directing equipment that the near-end suppressor has not operated and that the test has passed.

5.3.10 *Near-end suppressor operate test*

The responding equipment is sending a monitor tone and a −26 dBm0 test tone at 1020 Hz. The directing equipment starts sending a monitor tone. If the near-end suppressor has operated, the monitor tone from the directing equipment will not reach the responding equipment. The responding equipment will therefore continue sending a monitor tone and the detection of this monitor tone by the directing equipment during the test interval will indicate that the test has passed.

5.3.11 *Near-end break-in non-operate test*

The responding equipment is sending a monitor tone and a −15 dBm0 test tone at 1020 Hz. After the detection of the 1020-Hz test tone sent out by the responding equipment, the directing equipment starts sending a high level monitor tone and a −20 dBm0 test tone at 820 Hz. If break-in does not occur at the near-end suppressor, the monitor tone from the directing equipment will not reach the responding equipment. The responding equipment will therefore continue sending a monitor tone and the detection of this monitor tone by the direction equipment during the test interval will indicate that the test has passed.

5.3.12 *Near-end break-in operate test*

The responding equipment is sending a monitor tone and a −15 dBm0 test tone at 1020 Hz. After the detection of the 1020-Hz test tone sent out by the responding equipment the directing equipment starts sending a high-level monitor tone [see § 6.1.2 c) below] and a −10 dBm0 test tone at 820 Hz. If break-in does occur at the near-end suppressor, the monitor tone from the directing equipment will reach the responding equipment. The responding equipment, upon detection of the monitor tone from the directing equipment, will stop sending its monitor tone and this absence of monitor tone during the test interval will indicate to the directing equipment that the test has passed.

5.3.13 *Far-end suppressor non-operate test*

The responding equipment is sending a monitor tone. The directing equipment starts sending a −40 dBm0 test tone at 1020 Hz. If the far-end suppressor does not operate, the monitor tone from the responding equipment will continue to reach the directing equipment, and the detection of the monitor tone by the directing equipment during the test interval will indicate that the test has passed.

5.3.14 *Far-end suppressor operate test*

The responding equipment is sending a monitor tone. The directing equipment starts sending a −26 dBm0 test tone at 1020 Hz. If the far-end suppressor does operate, the monitor tone from the responding equipment will be prevented from reaching the directing equipment, and this absence of monitor tone during the test interval will indicate to the directing equipment that the test has passed.

5.3.15 *Far-end break-in non-operate test*

The responding equipment is silent. The directing equipment starts sending a −10 dBm0 test tone at 1020 Hz. Fifty milliseconds after detection of the 1020-Hz test tone from the directing equipment, the responding equipment starts sending a high level monitor tone and a −15 dBm0 test tone at 820 Hz. If break-in does not occur at the far-end suppressor, the monitor tone from the responding equipment will be prevented from reaching the directing equipment and this absence of monitor tone during the test interval will indicate to the directing equipment that the test has passed.

5.3.16 *Far-end break-in operate test*

The responding equipment is silent. The directing equipment starts sending a −20 dBm0 test tone at 1020 Hz. Fifty milliseconds after detection of the 1020-Hz test tone from the directing equipment, the responding equipment starts sending a high level monitor tone and a −15 dBm0 test tone at 820 Hz. If break-in does occur at the far-end suppressor, the monitor tone from the responding equipment reaches the directing equipment and detection of the monitor tone by the directing equipment during the test interval will indicate that the test has passed.

6 Specifications for transmission measuring equipment

The following specifications apply over a temperature range of +5 °C to +50 °C.

6.1 *Sending apparatus of the directing and responding equipment*

6.1.1 *Signal and tone frequencies*

a) test tones: 820 ± 9 Hz
1020 ± 11 Hz,

b) monitor tone: 510 ± 5.5 Hz,

c) acknowledgement signal: 610 ± 6.5 Hz.

6.1.2 *Signal and tone levels*

a) for loss measurements:
−10 ± 0.1 dBm0,

b) for test tones:
−10 ± 0.2 dBm0 (directing equipment only),
−15 ± 0.2 dBm0 (responding equipment only),
−20 ± 0.2 dBm0 (directing equipment only),
−26 ± 0.2 dBm0,
−40 ± 0.2 dBm0,

c) for monitor tone:
−42 ± 0.5 dBm0 (normal level),
−29 ± 0.5 dBm0 (high level),

d) for acknowledgement signal:
−29 ± 0.5 dBm0.

6.1.3 *Impedance*

600 ohms balanced with longitudinal conversion loss (see Figure 1/O.121) of at least 46 dB between 300 and 3400 Hz. Return loss of at least 20 dB between 300 and 3400 Hz.

6.1.4 *Distortion and spurious-modulation supression*

Better than 25 dB.

6.2 *Receiving apparatus of the directing and responding equipment*

6.2.1 *Measuring ranges*

a) for loss measurement:
from −7.5 ± 0.2 dBm0 to −12.5 ± 0.2 dBm0,

b) for noise measurement:
test threshold −40 ± 1.0 dBm0p measured with psophometric weighting as specified in Recommendation P.51 [3],

c) for monitor tone and acknowledgement signal detection:
test threshold of −54 ± 2.0 dBm0 measured with selective receivers having sufficient discrimination to reject other tones and noise that may be present on the circuit under test.

6.2.2 *Test interval*

375 ± 25 ms.

6.2.3 *Impedance*

600 ohms balanced with input longitudinal interference loss (see Figure 4/O.121) of at least 46 dB between 300 and 3400 Hz. Return loss of at least 30 dB between 300 and 3400 Hz.

7 Command signals from the directing equipment to the responding equipment

Each test shall be initiated by the sending of a unique multi-frequency (MF) command signal from the directing equipment to the responding equipment.

The signal sender and signal receiver are those specified for the CCITT No. 5 Interregister Signalling System and the equipment used should be as specified in Recommendations Q.153 [4] and Q.154 [5], except that the MF command signals will be sent for 500 ± 100 ms and that the MF receiver shall respond to MF command signals between −26 dBm0 and −3 dBm0.

CODE No.	FREQUENCY (Hz)	TEST
1	700 + 900	Near-to-far loss
2	700 + 1100	Far-to-near loss
3	900 + 1100	Near-to-far noise
4	700 + 1300	Far-to-near noise
5	900 + 1300	Near-end suppressor non-operate
6	1100 + 1300	Near-end suppressor operate
7	700 + 1500	Near-end break-in non-operate
8	900 + 1500	Near-end break-in operate
9	1100 + 1500	Far-end suppressor non-operate
10	1300 + 1500	Far-end suppressor operate
11	700 + 1700	Far-end break-in non-operate
12	900 + 1700	Far-end break-in operate

References

[1] CCITT Recommendation *Echo-suppressor suitable for circuits having either short or long propagation times*, Orange Book, Vol. III-1, Rec. G.161, ITU, Geneva, 1977.

[2] CCITT Recommendation *Echo suppressors*, Vol. III, Rec. G.164.

[3] CCITT Recommendation *Artificial voices, artificial mouths, artificial ears*, Vol. V, Rec. P.51.

[4] CCITT Recommendation *Multifrequency signal sender*, Green Book, Vol. VI.2, Rec. Q.153, ITU, Geneva, 1973.

[5] CCITT Recommendation *Multifrequency signal receiver*, Green Book, Vol. VI.2, Rec. Q.154, ITU, Geneva, 1973.

SECTION 2

SPECIFICATIONS FOR DIGITAL-TYPE MEASUREMENT EQUIPMENT

Recommendation O.151

SPECIFICATION FOR INSTRUMENTATION TO MEASURE ERROR PERFORMANCE ON DIGITAL SYSTEMS[1)]

The requirements for the characteristics of bit-error ratio instrumentation which are described below must be adhered to in order to ensure compatibility between equipments standardized by the CCITT, and produced by different manufacturers.

1 General

The instrumentation is designed to measure the bit-error ratio of digital transmission systems by the direct comparison of a pseudorandom test pattern with an identical locally generated test pattern. In addition the capability to measure errored time intervals is provided.

2 Test patterns

2.1 *Pseudorandom pattern for systems using a $2^{15} - 1$ pattern length*

This pattern is to be produced by means of a shift register incorporating appropriate feedback (see Figure 1/O.151 and Table 1/O.151):

Number of shift register stages 15

Pattern length . . . . $2^{15} - 1 = 32\,767$ bits

Feedback . . . . taken from the 14th and 15th stage via an exclusive-OR-gate to the first stage

Longest sequence of zeros zeros . . . . 15 (inverted signal)

2.2 *Pseudorandom pattern for systems using $2^{23} - 1$ pattern length*

This pattern is to be produced by means of a shift register incorporating appropriate feedback (see Figure 2/O.151):

Number of shift register stages 23

Pattern length . . . . $2^{23} - 1 = 8\,388\,607$ bits

Feedback . . . . taken from the 18th and 23rd stages via an exclusive-OR-gate to the first stage

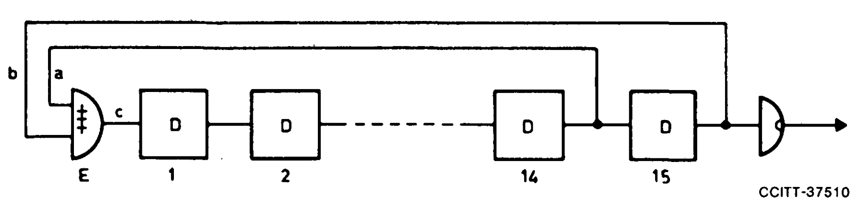
Longest sequence of zeros . . . . 23 (inverted signal)

1) This Recommendation is the joint responsibility of Study Groups IV, XVII and XVIII.

TABLE 1/O.151

Status of the shift register stages during the transmission of the first 47 bits

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
2	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0
3	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	0
⋮																0 ⋮ 0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
16	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
17	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
⋮																1 ⋮ 1
29	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
30	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
31	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
32	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1
⋮																1 ⋮ 1
43	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1
44	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0
45	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
46	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
47	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1
																1 ⋮



Note – The clock pulse connection is not shown.

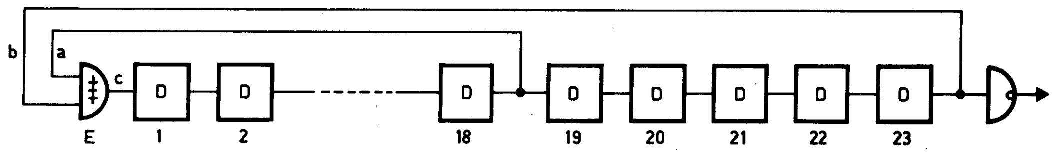
a	b	c
1	0	1
0	1	1
0	0	0
1	1	0

Truth table for exclusive OR-gate (E):

a and b: gate inputs
c: gate output

FIGURE 1/O.151

Circuit example for a 15-stage shift register with D-flipflops and an exclusive-OR-gate



Note – The clock pulse connection is not shown.

CCITT-39300

a	b	c
1	0	1
0	1	1
0	0	0
1	1	0

Truth table for exclusive OR-gate (E):

a and b: gate inputs
c: gate output

FIGURE 2/O.151

Circuit example for a 23-stage shift register with D-flipflops and an exclusive-OR gate

2.3 *Fixed patterns (optional)*

Fixed patterns of all ones and alternating ones and zeros may be provided.

3 Bit rate

The bit rates in accordance with CCITT Recommendations are indicated in Table 2/O.151.

TABLE 2/O.151

Bit rates, pertinent Recommendations and pseudo randon test patterns

Bit rate (kbit/s)	Recommendation corresponding to multiplex system	Recommendation corresponding to digital line section/line system	Bit rate tolerance	Test pattern
1544	G.733 [1]	G.911 [8], G.951 [9], G.955 [10]	$\pm 50 \cdot 10^{-6}$	$2^{15}-1$
2048	G.732 [2]	G.921 [11], G.952 [12], G.956 [13]	$\pm 50 \cdot 10^{-6}$	
6312	G.743 [3]	G.912 [14], G.951 [9], G.955 [10]	$\pm 30 \cdot 10^{-6}$	
8448	G.742 [4], G.745 [5]	G.921 [11], G.952 [12], G.956 [13]	$\pm 30 \cdot 10^{-6}$	
32 064	G.752 [6]	G.913 [15], G.953 [16], G.955 [10]	$\pm 10 \cdot 10^{-6}$	$2^{15}-1$
34 368	G.751 [7]	G.921 [11], G.954 [17], G.956 [13]	$\pm 20 \cdot 10^{-6}$	$2^{23}-1$
44 736	G.752 [6]	G.914 [18], G.953 [16], G.955 [10]	$\pm 20 \cdot 10^{-6}$	$2^{15}-1$
139 264	G.751 [7]	G.921 [11], G.954 [17], G.956 [13]	$\pm 15 \cdot 10^{-6}$	$2^{23}-1$

Note – Normally only the appropriate combination of bit rates – either 2048 kbit/s, 8448 kbit/s, etc. or 1544 kbit/s, 6312 kbit/s, etc. – will be provided in a given instrumentation.

4 Interfaces

The interface characteristics (impedances, levels, codes, etc.) should be in accordance with Recommendation G.703 [19].

In addition to providing for terminated measurements the instrumentation shall also be capable of monitoring 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.

5 Error-ratio measuring range

The receiving equipment of the instrumentation should be capable of measuring bit-error ratios in the range 10^{-3} to 10^{-8}. In addition, it should be possible to measure bit-error ratios of 10^{-9} and 10^{-10}; this can be achieved by providing the capability to count cumulative errors.

6 Mode of operation

The mode of operation should be such that the signal to be tested is first converted into a unipolar (binary) signal in the error measuring instrument and subsequently the bit comparison is made also with a reference signal in binary form.

Facilities may *optionally* be provided to allow the direct comparison at line code (e.g. AMI or HDB-3) with correspondingly coded reference signals. In the case of such measurements polarity distinction is possible, so that errors caused by the injection or omission of positive or negative pulses can be determined separately.

7 Measurement of errored time intervals

The instrument shall be capable of detecting errored seconds and other errored or error-free time intervals as defined by Recommendation G.821 [20]. The number of errored or error-free time intervals in a selectable observation period from 1 minute to 24 hours, or continuous, shall be counted and displayed.

For this measurement the error detection circuits of the instrument shall be controlled by an internal timer which sets intervals of equal length and which operates independently of the occurrence of errors.

References

[1] CCITT Recommendation *Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s*, Vol. III, Rec. G.733.

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

[3] CCITT Recommendation *Second-order digital multiplex equipment operating at 6312 kbit/s and using positive justification*, Vol. III, Rec. G.743.

[4] CCITT Recommendation *Second-order digital multiplex equipment operating at 8448 kbit/s and using positive justification*, Vol. III, Rec. G.742.

[5] CCITT Recommendation *Second-order digital multiplex equipment operating at 8448 kbit/s and using positive/zero/negative justification*, Vol. III, Rec. G.745.

[6] CCITT Recommendation *Characteristics of digital multiplex equipments based on a second-order bit rate of 6312 kbit/s and using positive justification*, Vol. III, Rec. G.752.

[7] CCITT Recommendation *Digital multiplex equipments operating at the third-order bit rate of 34 368 kbit/s and the fourth-order bit rate of 139 264 kbit/s and using positive justification*, Vol. III, Rec. G.751.

[8] CCITT Recommendation *Digital line sections at 1544 kbit/s*, Vol. III, Rec. G.911.

[9] CCITT Recommendation *Digital line systems based on the 1544 kbit/s hierarchy on symmetric pair cables*, Vol. III, Rec. G.951.

[10] CCITT Recommendation *Digital line systems based on the 1544 kbit/s hierarchy on optical fibre cables*, Vol. III, Rec. G.955.

[11] CCITT Recommendation *Digital sections based on the 2048 kbit/s hierarchy*, Vol. III, Rec. G.921.

[12] CCITT Recommendation *Digital line systems based on the 2048 kbit/s hierarchy on symmetric pair cables*, Vol. III, Rec. G.952.

[13] CCITT Recommendation *Digital line systems based on the 2048 kbit/s hierarchy on optical fibre cables*, Vol. III, Rec. G.956.

[14] CCITT Recommendation *Digital line sections at 6312 kbit/s*, Vol. III, Rec. G.912.

[15] CCITT Recommendation *Digital line sections at 32 064 kbit/s*, Vol. III, Rec. G.913.

[16] CCITT Recommendation *Digital line systems based on the 1544 kbit/s hierarchy on coaxial pair cables*, Vol. III, Rec. G.953.

[17] CCITT Recommendation *Digital line systems based on the 2048 kbit/s hierarchy on coaxial pair cables*, Vol. III, Rec. G.954.

[18] CCITT Recommendation *Digital line sections at 44 736 kbit/s*, Vol. III, Rec. G.914.

[19] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces*, Vol. III, Rec. G.703.

[20] CCITT Recommendation *Error performance on an international digital connection forming part of an integrated services digital network*, Vol. III, Rec. G.821.

Recommendation O.152

SPECIFICATION FOR AN INSTRUMENT TO MEASURE THE ERROR PERFORMANCE ON 64 KBIT/S PATHS

The requirements for the characteristics of a bit-error ratio measuring set which are described below must be adhered to in order to ensure compatibility between equipments standardized by the CCITT, and produced by different manufacturers.

1 General

The set is designed to measure the bit-error ratio of digital paths (operating at 64 kbit/s) by the direct comparison of a pseudorandom test pattern with an identical locally generated test pattern.

2 Test patterns

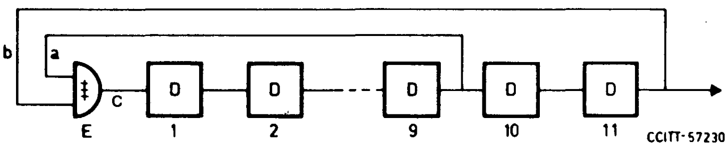
2.1 *Pseudorandom pattern*

This pattern is to be produced by means of a shift register incorporating appropriate feedback (see Figure 1/O.152):

Number of shift register stages	11
Pattern length	$2^{11} - 1 = 2047$ bits
Feedback	taken from the outputs of the 9th and 11th stage via an exclusive-OR-gate to the first stage
Longest sequence of zeros	10 (non-inverted signal)

Note 1 – In the case of international testing where the measurement includes systems based on 1544 kbit/s it is necessary to modify the test sequence in such a way that more than seven consecutive "0"-bits are avoided. This is achieved by forcing the output signal to "1" whenever the next 7 bits of the sequence are all zeros.

Note 2 – It is recommended to use the test pattern of 2047 bit length also at other bit rates in the range 48 kbit/s to 168 kbit/s.



Note – The clock pulse connection is not shown.

a	b	c
1	0	1
0	1	1
0	0	0
1	1	0

Truth table for exclusive OR-gate (E):

a and b: gate inputs
c: gate output

FIGURE 1/O.152

Circuit example for an 11-stage shift register with D-flipflops and an exclusive-OR-gate

2.2 *Fixed patterns (optional)*

Fixed patterns of all ones (. . . 1111 . . .) and alternating ones and zeros (. . . 1010 . . .) may be provided.

3 Bit rate

Bit rate in accordance with CCITT Recommendations G.703, § 1 [1] and V.36 [2] of 64 kbit/s:

a) bit rate tolerance (Recommendation G.703 [1]): $\pm$ 100 $\cdot$ 10^{-6},

b) bit rate tolerance (Recommendation V.36 [2]), optional: $\pm$ 50 $\cdot$ 10^{-6}.

4 Interfaces

The interface characteristics (impedances, levels, codes, etc.) should be in accordance with Recommendations G.703 [1] and V.11 [3] (optional).

In addition to providing for terminated measurements the measuring set shall also be capable of monitoring at protected test points on digital equipment. Therefore, a high impedance and/or additional gain must be provided to compensate for the loss at monitoring points already provided on some equipments.

4.1 *Interfaces corresponding to Recommendation G.703* [1]

Three interfaces shall be provided:

a) a codirectional interface in accordance with Recommendation G.703, § 1.2.1 [1],

b) a centralized clock interface in accordance with Recommendation G.703, § 1.2.2 [1],

c) a contradirectional interface in accordance with Recommendation G.703, § 1.2.3 [1].

4.2 *Method of clock synchronization*

The following modes of synchronization shall be selectable:

a) Lock the digital generator clock rate to that at the input of the receive side of the measuring set (for the codirectional interface).

b) Allow the generator clock to free run within the overall allowed frequency tolerances.

c) Lock the digital generator clock rate to an external clock signal. (Configuration of input for external clock in accordance with Recommendation G.703 [1].)

4.3 *Interface corresponding to Recommendation V.11* [3]

As an option an interface in accordance with Recommendation V.11 [3] shall be provided.

5 Bit-error-ratio measuring range

The receiving equipment of the set should be capable of measuring bit-error ratios in the range 10^{-2} to 10^{-7}. The measurement time should be sufficiently long to achieve accurate measurements. In addition, it should be possible to measure bit-error ratios smaller than 10^{-7}; this can be achieved by providing the capability to count cumulative errors.

6 Block-error ratio measurements

Optionally, the instrument should be capable to perform block-error measurements in addition to the bit-error measurements. If provided it should be possible to measure block-error ratios in the range 10^{-0} to 10^{-5} when using the pseudorandom test pattern with a block length of 2047 bits.

7 Mode of operation

The mode of operation should be such that the signal to be tested is first converted into a unipolar (binary) signal in the error measuring instrument and subsequently the bit comparison is made also with a reference signal in binary form.

8 Error evaluation

8.1 *Measurement of errored time intervals*

The instrument shall be capable of detecting errored seconds and other errored or error-free time intervals as defined by Recommendation G.821 [4]. The number of errored or error-free time intervals in a selectable observation period from 1 minute to 24 hours, or continuous, shall be counted and displayed.

For this measurement the error detection circuits of the instrument shall be controlled by an internal timer which sets intervals of equal length and which operates independently of the occurrence of errors.

8.2 *Measurement of short-term mean error ratio*

8.2.1 It shall be possible to record the time intervals as defined in Recommendation G.821 [4], during which the bit-error ratio is less than $1 \cdot 10^{-6}$.

8.2.2 It shall be possible to record the one-second intervals during which the bit-error ratio is less than $1 \cdot 10^{-3}$.

9 Recording of measurement results

As an option an interface shall be provided which allows connecting external equipment for further processing the measuring results.

The interface shall comply with Recommendation V.24 [5] or the interface bus according to IEC Publication 625 [6].

10 Operating environment

The electrical performance requirements shall be met when operating at temperatures within the range +5 °C to +40 °C and relative humidity of 45% to 75%. (These values are provisional and require further study.)

References

[1] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces,* Vol. III, Rec. G.703.

[2] CCITT Recommendation *Modems for synchronous data transmission using 60-108 kHz group band circuits,* Vol. VIII, Rec. V.36.

[3] CCITT Recommendation *Electrical characteristics for balanced double-current interchange circuits for general use with integrated circuit equipment in the field of data communications,* Vol. VIII, Rec. V.11.

[4] CCITT Recommendation *Error performance on an international digital connection forming part of an integrated services digital network*, Vol. III, Rec. G.821.

[5] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment and data circuit-terminating equipment*, Vol. VIII, Rec. V.24.

[6] IEC Publication 625.

Recommendation O.161

SPECIFICATION FOR AN IN-SERVICE CODE VIOLATION MONITOR FOR DIGITAL TRANSMISSION SYSTEMS

1 General

This specification describes an in-service code violation monitor for the first and second level in the digital transmission hierarchy.

The pseudoternary codes to be monitored are alternate mark inversion (AMI), high density bipolar with a maximum of 3 consecutive zeros (HDB3), B6ZS and B8ZS.

2 Definition of code violation [1)]

2.1 *AMI*

Two consecutive marks of the same polarity. This may not be the absolute number of errors.

2.2 *HDB3*

Two consecutive bipolar violations of the same polarity. This may not be the absolute number of errors.

2.3 *B6ZS*

Two consecutive marks of the same polarity excluding violations caused by the zero substitution code. This may not be the absolute number of errors.

2.4 *B8ZS*

Two consecutive marks of the same polarity excluding violations caused by the zero substitution code. This may not be the absolute number or errors.

3 Input signal

3.1 *Interface*

The code violation monitor shall be capable of operating at the following bit rates and corresponding interface characteristics as described in the appropriate paragraphs of Recommendation G.703 [1]:

a) 1544 kbit/s;

b) 6312 kbit/s;

c) 2048 kbit/s;

d) 8448 kbit/s.

1) According to the definitions of code violations in this Recommendation it should be taken into account that the code violation monitor will not detect zero sequences which violate the relevant coding rules.

3.2 *Instrument operation*

3.2.1 The instrument may be equipped to monitor only one or two of the listed codes and operate at the appropriate bit rates for those codes.

3.3 *Input sensitivity*

3.3.1 The instrument is required to operate satisfactorily under the following input conditions.

3.3.1.1 Input impedances and levels in accordance with Recommendation G.703 [1].

3.3.1.2 The instrument shall also be capable of monitoring at protected test points on digital equipment. Therefore, a high impedance input and/or additional gain of 30 dB (40 dB – see Note) shall be provided to compensate for the loss at the monitoring points already provided on some equipment.

Note – As an option for instruments operating at an interface of 1544 kbit/s corresponding to the Recommendation cited in [1], the additional gain, where provided, shall be 40 dB.

3.3.1.3 Additionally, the instrument is required to operate satisfactorily, in both the terminated and monitor mode, when connected to an interface output in accordance with Recommendation G.703 [1] via a length of cable which can have an insertion loss of 0 dB to 6 dB at the half bit rate of the signal. The insertion loss of the cable at other frequencies will be proportional to $\sqrt{f}$.

3.4 *Input impedance*

3.4.1 The instrument shall have a return loss better than 20 dB under the conditions listed in Table 1/O.161.

TABLE 1/O.161

Instrument operating at kbit/s	Test conditions	
1544	100 ohm, nonreactive	20 kHz to 1.6 MHz
2048	75/120/130 ohm, nonreactive	40 kHz to 2.5 MHz
6312	75/110 ohm, nonreactive	100 kHz to 6.5 MHz
8448	75 ohm, nonreactive	100 kHz to 10.0 MHz

3.5 *Signal input gating*

3.5.1 The instrument shall incorporate a sampling circuit, operated from the incoming digital signal, such that the instrument senses only the voltages which are present during a short gating period at the midpoint of each digit time slot.

3.6 *Input jitter tolerance*

3.6.1 The instrument shall be able to tolerate the lower limit of maximum tolerable input jitter specified in the appropriate paragraph of Recommendation G.703 [1].

4 **Display**

4.1 The instrument shall incorporate an indicator to show the presence of a digital signal of correct amplitude and bit rate.

4.2 The code violation rate shall be indicated in the range 1 in 10^3 to at least 1 in 10^6. Indication of code violations, occurring in the input signal and detected as defined in § 2 above, shall be determined by counting the number of code violations that occur during the period of at least 10^6 digit time slots.

4.3 It shall be possible to indicate the sum of the code violations. This facility will not be required at the same time as the code violation rate is being counted and displayed.

4.4 The count capacity shall be 99 999 and a separate indicator shall be given if the count exceeds this figure.

4.5 The counting sequence shall be started by operating a "start" control and shall be stopped by a "stop" control.

4.6 The counter, and its display, shall be capable of being reset.

5 Instrument check

5.1 A check facility shall be provided. This facility is to enable a check to be made of the display, counter and recorder output and optionally of the instrument input circuits.

5.2 Where the optional check of the input circuits is provided, the method of introducing code violations into the input digital signal shall be agreed. The violations shall be as defined in § 2 above.

6 Recorder output

6.1 An output signal may optionally be provided by the instrument to enable the status of the digital signal to be recorded externally in analogue and/or digital form.

6.2 For the analogue output, the signal shall vary corresponding to the measured result.

6.3 If the instrument has an analogue output, appropriate means for calibrating the external recorder shall be provided.

6.4 A possible arrangement relating the status of the digital input signal to the d.c. output signal is given in Table 2/O.161. The actual arrangement will depend upon the count period specified for the instrument (see § 4.2 above).

TABLE 2/O.161

Status	Deflection (mA or volts)	Tolerance (mA or volts)
No signal	0	
Valid signal	5	± 0.2
Violation rate $\geqslant 1 \times 10^{-3}$	2	± 0.2
Violation rate $\geqslant 1 \times 10^{-4}$	2.5	± 0.2
Violation rate $\geqslant 1 \times 10^{-5}$	3	± 0.2
Violation rate $\geqslant 1 \times 10^{-6}$	3.5	± 0.2
Single code violations	4	± 0.2

6.5 For the digital output of the measurement result, where provided, a parallel signal in binary coded decimal (BCD) form with transistor-transistor logic (TTL) levels shall be used.

7 Operating environment

7.1 The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75%. (These values are provisional and require further study.)

Reference

[1] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces,* Vol. III, Rec. G.703.

SPECIFICATION FOR AN INSTRUMENT TO MONITOR THE FRAME ALIGNMENT SIGNAL OF FRAME STRUCTURES (FRAME ALIGNMENT SIGNAL MONITOR)

1 General

1.1 This specification describes an in-service frame alignment signal monitor for frame structures that are in accordance with Recommendation G.704 [1].

1.2 The instrument is required to monitor a 2048-kbit/s HDB3 encoded signal, display any inherent alarm condition in the signal and be capable of counting errors in the frame alignment signal.

1.3 The instrument may also, if so desired, count and display HDB3 code violations as a separate facility.

1.4 *HDB3 decoding strategy*

When necessary, the received digital signal shall be decoded by the instrument in a manner such that, when sampling the signal, on recognition of 2 consecutive zeros (spaces) followed by a bipolar violation, the decoder shall substitute 4 consecutive zeros in place of the bipolar violation and the 3 preceding digits.

2 Input signal

2.1 *Interface*

The instrument shall be capable of operating with the interface at 2048 kbit/s corresponding to Recommendation G.703 [2], § 6.

2.2 *Input sensitivity*

2.2.1 The instrument is required to operate satisfactorily under the following input conditions.

2.2.1.1 Input impedances and levels in accordance with Recommendation G.703 [2].

2.2.1.2 The instrument shall also be capable of monitoring at protected test points on digital equipment. Therefore, a high impedance input and/or additional gain of 30 dB shall be provided to compensate for the loss at the monitoring points already provided on some equipment.

2.2.1.3 Additionally the instrument is required to operate satisfactorily, in both the terminated and monitor mode, when connected to an interface output in accordance with Recommendation G.703 [2] via a length of cable which can have an insertion loss of 0 dB to 6 dB at the half bit rate of the signal. The insertion loss of the cable at other frequencies will be proportional to $\sqrt{f}$.

2.3 *Input impedance*

2.3.1 The instrument shall have a return loss of better than 20 dB against a nonreactive 75/120/130-ohm resistor over a frequency range of 40 kHz to 2500 kHz.

2.4 *Signal input gating*

2.4.1 The instrument shall incorporate a timing recovery circuit, operated from the incoming digital signal, such that the instrument senses only the voltages which are present during a short gating period at the midpoint of each digit time slot.

2.5 *Input jitter tolerance*

2.5.1 The instrument shall be able to tolerate the lower limit of maximum tolerable input jitter specified in Recommendation G.823 [3].

3 Facilities

3.1 The instrument shall incorporate fault indications to meet the alarm strategies of equipments meeting Recommendation G.732 [4].

3.2 A possible fault indication plan is illustrated in § 3.3 below. All fault indicators are normally extinguished.

3.3 *Fault indication plan*

3.3.1 *Input signal failure*

A fault indication shall be given if more than 10 consecutive zeros are detected.

3.3.2 *Alarm indication signal (AIS)*

The instrument shall recognize a signal containing less than 3 zeros in a 2-frame period (512 bits) as a valid AIS signal and the appropriate indicator shall be lit.

The strategy for the detection of the presence of an AIS shall be such that the AIS is detectable even in the presence of a code violation rate of 1 in 10^3. However, a signal with all bits in the 1s state, except the frame alignment signal (FAS), shall not be mistaken for a valid AIS.

3.3.3 *Frame*

3.3.3.1 In the event of a loss of frame alignment, as defined in Recommendation G.732 [4], § 3, the instrument shall recognize the loss and the appropriate indicator shall be lit.

3.3.3.2 In the event of recovery of frame alignment, as defined in Recommendation G.732 [4], § 3, the indicator shall be extinguished.

3.3.4 *Errors in the frame alignment signal*

3.3.4.1 The instrument shall have a means of indicating error rates, e.g. 1×10^{-3}, 1×10^{-4}, 1×10^{-5} and illuminate the appropriate indicator.

The indication of error rates occurring in the received decoded signal and detected as incorrect frame alignment signals shall comply with the limits given in Table 1/O.162. The requirements in the table shall apply on the assumption that the average error rates are present for the whole of the counter measurement period.

TABLE 1/O.162

Error rate indication	Average error rates in decoded signal	Probability of indication illuminating or extinguishing within the periods stated below	
		Illuminate	Extinguish
1×10^{-3}	1×10^{-3} 5×10^{-4} 1×10^{-4}	50% within 0.3 s 5% within 0.3 s –	5% within 0.3 s – 95% within 0.3 s
1×10^{-4}	1×10^{-4} 5×10^{-5} 1×10^{-5}	50% within 3 s 5% within 3 s –	5% within 3 s – 95% within 3 s
1×10^{-5}	1×10^{-5} 5×10^{-6} 1×10^{-6}	50% within 30 s 5% within 30 s –	5% within 30 s – 95% within 30 s

3.3.4.2 It shall also be possible to count the sum of the errors indicated. The count capacity shall be 99 999. A separate indication shall be given if the count exceeds this figure.

3.3.5 *Multiframe*

3.3.5.1 In the event of a loss of multiframe alignment, as defined in Recommendation G.732 [4], § 5.2, the instrument shall recognize the loss and the appropriate indicator shall be lit.

3.3.5.2 In the event of recovery of multiframe alignment, as defined in Recommendation G.732 [4], § 5.2, the indicators shall be extinguished.

3.3.5.3 If time slot 16 is used for common channel signalling, the multiframe alignment signal is not present in a nominal input signal to the instrument. In this case it shall be possible to inhibit the loss of multiframe indicator in order to prevent false alarm indications.

3.3.6 *Distant alarm*

The instrument shall recognize the distant alarm condition as defined in Recommendation G.732 [4] (bit 3 of time slot 0 in frames alternate to those containing the frame alignment signal for at least 2 consecutive occasions and recognized within 4 consecutive occasions) and the appropriate indicator shall be lit.

3.3.7 *Distant multiframe alarm*

3.3.7.1 The instrument shall recognize the distant multiframe alarm condition as defined in Recommendation G.732 [4] (bit 6 of time slot 16, frame 0 for at least 2 consecutive occasions and recognized within 3 consecutive occasions) and the appropriate indicator shall be lit.

3.3.7.2 If time slot 16 is used for common channel signalling, bit 6 will be continuously in state 1. In this case it shall be possible to inhibit the distant multiframe alarm in order to prevent false alarm indications.

3.4 *Code violation detection*

3.4.1 *Definition of an HDB3 code violation*

Two consecutive bipolar violations of the same polarity. This may not be the absolute number of errors.

3.4.2 When used as an HDB3 code violation detector the instrument shall incorporate an indicator to indicate the presence of a digital signal of correct amplitude and bit rate.

3.4.3 The code violation rate shall be indicated in the range 1 in 10^3 to at least 1 in 10^6. Indications of code violations occurring in the input signal and detected as defined in § 3.4.1 above, shall be determined by counting the number of code violations that occur during the period of at least 10^6 time slots.

3.4.4 It shall be possible to indicate the sum of the code violations. This facility will not be required at the same time as the code violation rate is being counted and displayed.

3.4.5 The count capacity shall be 99 999 and a separate indication shall be given if the count exceeds this figure.

3.5 *Lamp lock – Lamp auto reset*

3.5.1 A facility shall be provided whereby the fault indication lamps either clear automatically when the fault condition clears or remain lit until a manual reset is operated.

4 Display

4.1 The counting sequence shall be started by operating a "start" control and shall be stopped by a "stop" control.

4.2 The counter, and its display, shall be capable of being reset.

5 Alarm function check

5.1 A method of introducing fault conditions into the incoming digital signal, in order to check the correct functioning of the instrument, shall be considered.

6 Recorder output

6.1 An output signal may optionally be provided by the instrument to enable the status of the digital signal to be recorded externally in analogue and/or digital form.

6.2 For the analogue output, the signal shall vary corresponding to the measured result.

6.3 If the instrument has an analogue output, appropriate means for calibrating the external recorder shall be provided.

6.4 A possible arrangement relating the status of the digital input signal to the d.c. output signal is given in Table 2/O.162. This is appropriate to the first order multiplex when the instrument is used to monitor the frame alignment signal. When used as a code violation monitor (§ 3.4) the instrument shall give a d.c. output signal as proposed in Table 3/O.162. The actual arrangement will depend upon the count period specified for the instrument (see § 3.4.3).

6.5 For the digital output of the measurement result, where provided, a parallel signal in binary coded decimal (BCD) form with transistor-transistor logic (TTL) levels shall be used.

TABLE 2/O.162

Status	Deflection (mA or volts)	Tolerance (mA or volts)
Input signal fail	0	
Valid signal	5	± 0.2
AIS	1	± 0.2
Frame	1.5	± 0.2
Errors ⩾ 1 in 10^3	2	± 0.2
Errors ⩾ 1 in 10^4	2.5	± 0.2
Errors ⩾ 1 in 10^5	3	± 0.2
Multiframe alarm	3.5	± 0.2
Distant alarm	4	± 0.2
Distant multiframe alarm	4.5	± 0.2

TABLE 3/O.162

Status	Deflection (mA or volts)	Tolerance (mA or volts)
No signal	0	
Valid signal	5	± 0.2
Violation rate ⩾ 1 in 10^3	2	± 0.2
Violation rate ⩾ 1 in 10^4	2.5	± 0.2
Violation rate ⩾ 1 in 10^5	3	± 0.2
Violation rate ⩾ 1 in 10^6	3.5	± 0.2
Single code violations	4	± 0.2

7 Operating environment

7.1 The electrical performance requirements shall be met when operating at temperatures within the range of +5 °C to +40 °C and relative humidity of 45% to 75%. (These values are provisional and require further study.)

References

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

[2] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces,* Vol. III, Rec. G.703.

[3] CCITT Recommendation *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy* Vol. III, Rec. G.823.

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

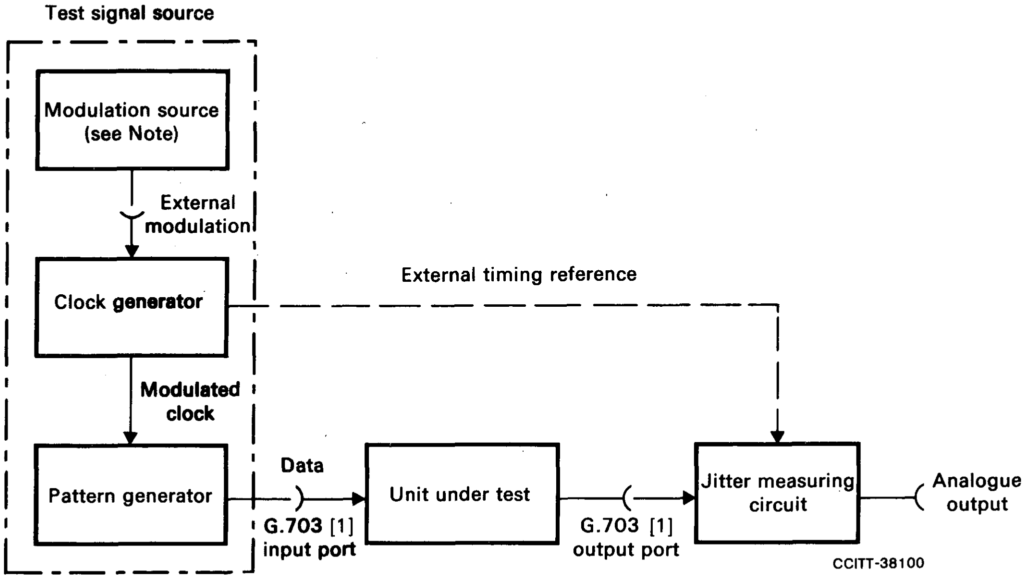
Recommendation O.171

SPECIFICATION FOR INSTRUMENTATION TO MEASURE TIMING JITTER ON DIGITAL EQUIPMENT

1 Introduction

1.1 *General*

1.1.1 The instrumentation specified below will be used to measure timing jitter on digital equipment. This instrumentation, which consists of a jitter measuring circuit and a test signal source, is shown in a general form in Figure 1/O.171. While essential requirements are given for the instrumentation, the realization of the equipment configuration is not covered and should be given careful consideration by the designer and user. An error-ratio meter may also be required for certain types of measurements.



Note – The modulation source, to test to the series G.700 Recommendations, may be provided within the clock generator and/or the pattern generator, or it may be provided separately.

FIGURE 1/O.171

Simplified block diagram for measuring timing jitter

1.1.2 Certain requirements in this specification are provisional and are still under study. These are individually indicated.

1.1.3 It is recommended that Recommendation G.823 [2] be read in conjunction with this Recommendation.

1.2 *Interfaces*

1.2.1 The instrumentation shall be capable of operating at one or more of the following bit rates and corresponding interface characteristics as described in the appropriate paragraphs of Recommendation G.703 [1]. However, for all bit rates the signal applied to the input of the jitter measuring circuit should be a nominal rectangular pulse. Other signal shapes may produce intersymbol interference thus affecting measurement accuracy.

a) 64 kbits, [1)]
b) 1544 kbit/s,
c) 6312 kbit/s,
d) 2048 kbit/s,
e) 8448 kbit/s,
f) 32 064 kbit/s,
g) 44 736 kbit/s,
h) 34 368 kbit/s,
i) 139 264 kbit/s.

1.2.2 As an option the jitter measuring circuit shall be capable of measuring jitter at a clock output port when such an access is provided on digital equipment.

1.3 *Interface impedances*

1.3.1 The jitter measuring circuit and signal source shall have a return loss better than 20 dB [2)] under the conditions listed in Table 1/O.171.

TABLE 1/O.171

Return loss test conditions

Bit rate (kbit/s)	Test conditions	
64	120 ohm nonreactive	1 kHz to 70 kHz
1544	100 ohm nonreactive	20 kHz to 1.6 MHz
2048	75/120/130 ohm nonreactive	40 kHz to 2.5 MHz
6312	75/110 ohm nonreactive	100 kHz to 6.5 MHz
8448	75 ohm nonreactive	100 kHz to 10 MHz
32 064	75 ohm nonreactive	500 kHz to 40 MHz
34 368	75 ohm nonreactive	500 kHz to 40 MHz
44 736	75 ohm nonreactive	500 kHz to 50 MHz
139 264	75 ohm nonreactive	7 MHz to 210 MHz

1) References to 64 kbit/s relate to the codirectional interface. Limits for other 64 kbit/s interfaces are under study.

2) In the case of 1544 kbit/s, the signal source shall have the following return loss: 20 kHz to 500 kHz ⩾ 14 dB and 500 kHz to 1.6 MHz ⩾ 16 dB.

2 Test signal source

Tests of digital equipment may be made with either a jittered or a non-jittered digital signal. This will require the pattern generator, clock generator and modulation source shown in Figure 1/O.171.

2.1 *Modulation source*

The modulation source, testing in conformance with the Series G.700 Recommendations, may be provided within the clock generator and/or pattern generator or it may be provided separately.

2.2 *Clock generator*

2.2.1 It shall be possible to phase modulate the clock generator from the modulation source and to indicate the peak-to-peak phase deviation of the modulated signal.

The generated peak-to-peak jitter and the modulating frequencies shall meet the requirements of Figure 2/O.171 and Table 2/O.171.

2.2.2 The modulating input sensitivity of the clock generator shall be at least:

a) 2 volts peak-to-peak into 600 ohms for bit rates up to and including 8448 kbit/s,

b) 1 volt peak-to-peak into 75 ohms for bit rates up to and including 139 264 kbit/s.

2.2.3 The minimum output of the modulated clock signal and the external timing reference signal shall be 1 volt peak-to-peak into 75 ohms.

2.2.4 *Accuracy of the clock generator*

Accuracy requirements are still under study.

2.3 *Pattern generator*

The jitter measuring circuit will normally be used with any suitable pattern generator providing the following facilities.

Note – When test signals are applied to the input of a digital demultiplexer, they must contain the frame alignment signal and justitication control bits. Other measurement techniques are available which do not require the addition of the frame alignment signal or justification control bits.

2.3.1 *Patterns*

The pattern generator shall be capable of providing the following patterns:

Note – Longer pseudorandom patterns may be necessary for jitter measurements on digital line systems and digital line sections [1].

2.3.1.1 For use at digit rates of 64 kbit/s, a pseudorandom pattern of $2^{11} - 1$ bit length corresponding to Recommendation O.152. Encoding in accordance with Recommendation G.703 [1], § 1.2.1.

2.3.1.2 For use at digit rates of 1544 kbit/s, 2048 kbit/s, 6312 kbit/s, 8448 kbit/s, 32 064 kbit/s and 44 736 kbit/s, a pseudorandom pattern of $2^{15} - 1$ bit length corresponding to Recommendation O.151, § 2.1.

2.3.1.3 For use at digit rates of 34 368 kbit/s and 139 264 kbit/s, a pseudorandom pattern of $2^{23} - 1$ bit length corresponding to Recommendation O.151, § 2.2.

2.3.1.4 For use at all digit rates, a 1000 1000 repetitive pattern.

2.3.1.5 As an option and for use at all digit rates:

a) two freely programmable 8-bit patterns capable of being alternated at a low rate (e.g. from 10 Hz to 100 Hz),

b) a freely programmable 16-bit pattern.

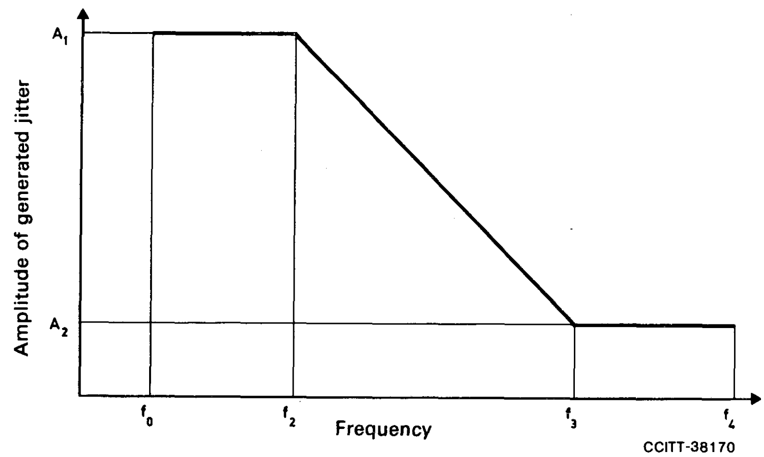


FIGURE 2/O.171

Generated jitter amplitude versus jitter frequency

TABLE 2/O.171

Generated jitter amplitude versus jitter frequency

Bit rate (kbit/s)	A_1 = Minimum value of generated jitter from f_0 to f_2	A_2 = Minimum value of generated jitter from f_3 to f_4
64	5.0 UI from 2 Hz to 600 Hz	0.5 UI from 6 kHz to 10 kHz
1544	10.0 UI from 2 Hz to 200 Hz	0.5 UI from 4 kHz to 40 kHz
2048	10.0 UI from 2 Hz to 2400 Hz	0.5 UI from 45 kHz to 100 kHz
6312	10.0 UI from 2 Hz to 1600 Hz	0.5 UI from 32 kHz to 160 kHz
8448	10.0 UI from 2 Hz to 400 Hz	0.5 UI from 8.5 kHz to 400 kHz
32 064	10.0 UI from 2 Hz to 1600 Hz	0.5 UI from 32 kHz to 800 kHz
34 368	10.0 UI from 2 Hz to 1000 Hz	0.5 UI from 20 kHz to 800 kHz
44 736	16.0 UI from 2 Hz to 3200 Hz	0.5 UI from 100 kHz to 4500 kHz
139 264	10.0 UI from 2 Hz to 500 Hz	0.5 UI from 10 kHz to 3500 kHz
8448 (low Q)	10.0 UI from 2 Hz to 10.7 kHz	0.5 UI from 200 kHz to 400 kHz

Note 1 to Figure 2/O.171 and Table 2/O.171 – Amplitude of jitter specified as peak-to-peak value in unit intervals (UI).

Note 2 to Figure 2/O.171 and Table 2/O.171 – f_1 lies between f_0 and f_2 (see Figure 3/O.171 and Table 3/O.171). It is not defined here since it is not significant in the context of the requirements of the clock generator.

Note 3 to Figure 2/O.171 and Table 2/O.171 — For testing at a 64 kbit/s codirectional interface, a figure of 20 kHz may be necessary for f_4 (under study).

2.3.2 *Generation errors*

The detailed specification of pattern generator parameters, to be compatible with the jitter measuring circuit specification, is under study.

3 Jitter measuring circuit

3.1 *Input sensitivity*

The jitter measuring circuit is required to operate satisfactorily under the following input conditions:

a) The specification for equipment output ports listed in Recommendation G.703 [1].

b) The jitter measuring circuit shall also be capable of measuring at protected test points on digital equipment. Therefore, an additional gain of 30 dB (40 dB) shall be provided to compensate for the flat loss at the monitoring points already provided on some equipment.

Note 1 – As an option for instrumentation operating at an interface of 1544 kbit/s the additional gain, where provided, shall be 40 dB.

Note 2 – The influence of the additional gain of 40 dB and of frequency dependent cable loss on the measurement accuracy is under study.

3.2 *Measurement ranges*

3.2.1 The jitter measuring circuit shall be capable of measuring peak-to-peak jitter. The measurement ranges to be provided are to be optional but for reasons of compatibility the jitter amplitude/jitter frequency response of the jitter measuring circuit shall meet the requirements of Figure 3/O.171 and Table 3/O.171 where f_1 to f_4 are the frequencies defining the jitter frequencies to be measured.

3.2.2 When measuring peak-to-peak jitter it shall also be possible to count the number of occasions and the period of time for which a given selectable threshold of jitter is exceeded. It shall be possible to record these events by means of an external counter, or an internal counter as an option.

3.2.3 It shall be possible to set the threshold of § 3.2.2 at any selected measurement value within the measuring range of the jitter measuring circuit.

3.2.4 As an option, the jitter measuring circuit shall be capable of measuring r.m.s. jitter. In such cases it shall be possible to measure 3.0 unit intervals (UI) at jitter frequencies up to f_2, and 0.15 UI at jitter frequencies from f_3 to f_4 of Figure 3/O.171 and Table 3/O.171, the measurement ranges being optional.

3.2.5 Where the option in § 3.2.4 is not provided, the analogue output can be used to make r.m.s. measurements with an external meter.

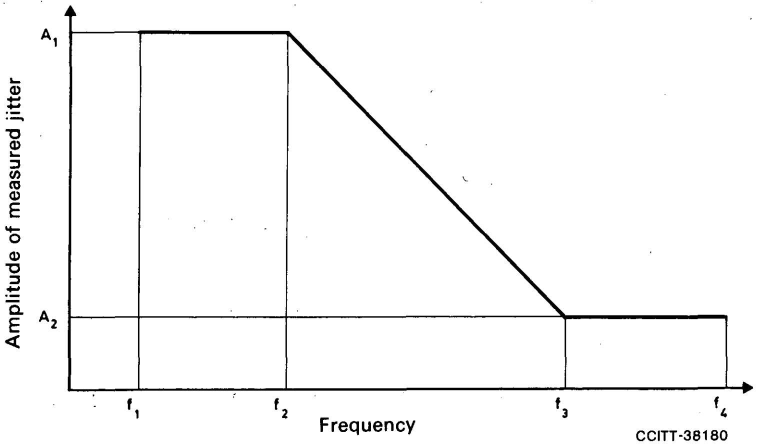


FIGURE 3/O.171

Measured jitter amplitude versus jitter frequency

TABLE 3/O.171

Measured jitter amplitude versus jitter frequency

Bit rate (kbit/s)	A_1 = Maximum value of jitter to be measured from f_1 to f_2	A_2 = Maximum value of jitter to be measured from f_3 to f_4
64	5.0 UI from 20 Hz to 600 Hz	0.5 UI from 6 kHz to 10 kHz
1544	10.0 UI from 10 Hz to 200 Hz	0.3 UI from 7 kHz to 40 kHz
2048	10.0 UI from 20 Hz to 2400 Hz	0.5 UI from 45 kHz to 100 kHz
6312	10.0 UI from 10 Hz to 1600 Hz	0.5 UI from 32 kHz to 160 kHz
8448	10.0 UI from 20 Hz to 400 Hz	0.5 UI from 8.5 kHz to 400 kHz
32 064	10.0 UI from 60 Hz to 1600 Hz	0.5 UI from 32 kHz to 800 kHz
34 368	10.0 UI from 100 Hz to 1000 Hz	0.5 UI from 20 kHz to 800 kHz
44 736	16.0 UI from 10 Hz to 3200 Hz	0.5 UI from 100 kHz to 4500 kHz
139 264	10.0 UI from 200 Hz to 500 Hz	0.5 UI from 10 kHz to 3500 kHz
8448 (low Q)	10.0 UI from 20 Hz to 10.7 kHz	0.5 UI from 200 kHz to 400 kHz

Note 1 to Figure 3/O.171 and Table 3/O.171 — Amplitude of jitter specified as peak-to-peak value in unit intervals (UI).

Note 2 to Figure 3/O.171 and Table 3/O.171 — For testing at a 64 kbit/s codirectional interface, a figure of 20 kHz may be necessary for f_4 (under study).

3.3 *Measurement bandwidths*

3.3.1 The basic jitter measuring circuit shall contain filters to limit the band of the jitter frequencies to be measured at the various bit rates. Additional filters shall be provided to further limit the bandwidth for the measurement of specified jitter spectra as defined in the Series G.700 Recommendations and for other uses. These additional filters may be either internal or external to the jitter measuring circuit. The filters are to be connected between the phase detector and the measuring device. The bandwidth of the jitter measuring circuit and the filters shall be in accordance with Table 4/O.171.

3.3.2 *Frequency response of jitter measuring circuit and filters*

The response of all filters within the passband shall be such that the accuracy requirements of the jitter measuring circuit are met.

At frequencies below the lower 3-dB point, the attenuation of the highpass filtration shall rise with a value greater than, or equal to, 20 dB per decade.

At frequencies above the upper 3-dB point the attenuation of the lowpass filtration shall rise with a value greater than, or equal to, 60 dB per decade.

However, the maximum attenuation of the filters shall be at least 60 dB.

Note — The effect of nonsinusoidal jitter on the requirements for the filters is still under study.

TABLE 4/O.171

Jitter measurement bandwidths and highpass filter cutoff frequencies

Bit rate (kbit/s)	Jitter measurement bandwidth					
	f_0 (lower 3 dB point) (Hz)	f_1 (Hz)	f_4 (kHz)	f_5 (upper 3 dB point) (kHz)	Highpass filter No. 1	Highpass filter No. 2
64	2	20	10	⩽ 20	20 Hz	3 kHz
1554	2	10	40	⩽ 80	10 Hz	8 kHz
2048	2	20	100	⩽ 200	20 Hz	700 Hz 18 kHz
6312	2	10	160	⩽ 320	10 Hz 60 Hz	24 kHz 32 kHz
8448	2	20	400	⩽ 800	20 Hz	3 kHz 80 kHz
32 064	2	60	800	⩽ 1600	60 Hz	160 kHz
34 368	2	100	800	⩽ 1600	100 Hz	10 kHz
44 736	2	10	4500	⩽ 9000	10 Hz	900 kHz
139 264	2	200	3500	⩽ 7000	200 Hz	10 kHz

Note 1 – The accuracy of the instrument is specified between frequencies f_1 and f_4.

Note 2 – Two values are specified for highpass filter No. 1 at 6312 kbit/s and highpass filter No. 2 at 2048 kbit/s, 6312 kbit/s and 8448 kbit/s.

3.4 *Measurement accuracy*

3.4.1 *General*

The measuring accuracy of the jitter measuring circuit is dependent upon several factors such as fixed intrinsic error, frequency response and pattern-depending error of the internal reference timing circuits. In addition there is an error which is a function of the actual reading.

The total error at 1-kHz jitter frequency (excluding the error due to frequency response) shall be less than

$$\pm 5\% \text{ of reading } \pm X \pm Y$$

where X is the fixed error of Table 5/O.171 and Y an error of 0.01 UI p-p (0.002 UI $_{\text{r.m.s.}}$) which applies if internal timing extraction is used.

3.4.2 *Fixed error*

For the system bit rates and for the indicated test sequences the fixed error of the jitter measuring circuit shall be as listed in Table 5/O.171 when measured at any jitter frequency between f_1 and f_4 of Figure 3/O.171.

3.4.3 *Error at other frequencies*

At jitter frequencies between f_1 and f_4 other than 1 kHz, the error additional to that defined in § 3.4.1 above shall be as listed in Table 6/O.171.

Note – The limits of measuring accuracy of the jitter measuring circuit given in § 3.4 are provisional and are still under study.

TABLE 5/O.171

Fixed error in jitter measurements

Bit rate (kbit/s)	Jitter in UI for given patterns					
	1000 1000		Pseudorandom[a)]		All ones or clock input	
	p-p	r.m.s.	p-p	r.m.s.	p-p	r.m.s.
64	0.005	0.002	0.025	0.004	0.004	0.001
1544	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
2048	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
6312	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
8448	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
32 064	Under study					
34 368	< 0.025	< 0.01	< 0.055	< 0.015	< 0.02	< 0.01
44 736	Under study					
139 264	< 0.03	< 0.015	< 0.085	< 0.02	< 0.025	< 0.015

a) See § 2.3.1.

TABLE 6/O.171

Frequency response error

Bit rate (kbit/s)	Measurement bandwidth		Additional error referring to error at 1 kHz
	f_1 (Hz)	f_4 (kHz)	
64	20	10	± 2% 20 Hz to 600 Hz ± 3% 600 Hz to 10 kHz
1544	10	40	± 4% f_1 to 1 kHz; ± 2% to f_4
2048	20	100	± 2% f_1 to f_4
6312	10	160	± 4% f_1 to 1 kHz; ± 2% to f_4
8448	20	400	± 2% f_1 to 300 kHz ± 3% 300 kHz to f_4
32 064	60	800	± 2% 60 Hz to 300 kHz ± 3% 300 kHz to f_4
34 368	100	800	
44 736	10	4500	± 4% 10 Hz to 200 Hz ± 2% 200 Hz to 300 kHz ± 3% 300 kHz to 1 MHz ± 5% 1 MHz to 3 MHz ± 10% > 3 MHz
139 264	200	3500	

3.5 *Additional facilities*

3.5.1 *Analogue output*

The jitter measuring circuit shall provide an analogue output signal to enable measurements to be made externally to the jitter measuring circuit.

3.5.2 *Reference timing signal*

A reference timing signal for the phase detector is required. For end-to-end measurements it may be derived in the jitter measuring circuit from any input pattern. For loop-measurements it may be derived from a suitable clock source.

4 Operating environment

The electrical performance requirements shall be met when operating at temperatures within the range +5 °C to +40 °C and relative humidity of 45% to 75%. (These values are provisional and required further study.)

References

[1] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces,* Vol. III, Rec. G.703.

[2] CCITT Recommendation *The control of jitter and wander within digital networks which are based on the 2048 kbit/s hierarchy,* Vol. III, Rec. G.823.

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PART II

SUPPLEMENTS TO SERIES O RECOMMENDATIONS

(Section 3 of the Supplements to Series M, N and O Recommendations)

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3 Measuring equipment specifications

Supplement No. 3.1

MEASURING INSTRUMENT REQUIREMENTS.
SINUSOIDAL SIGNAL GENERATORS AND LEVEL-MEASURING INSTRUMENTS

(For this Supplement, see page 530, Volume IV.2 of the *Green Book*)

Supplement No. 3.2

NOISE MEASURING INSTRUMENTS FOR TELECOMMUNICATION CIRCUITS

(For this Supplement, see page 534, Volume IV.2 of the *Green Book*)

Supplement No. 3.3

PRINCIPAL CHARACTERISTICS OF VOLUME INDICATORS

(For this Supplement, see page 548, Volume IV.2 of the *Green Book*)

Supplement No. 3.4

CONSIDERATION OF INTERWORKING BETWEEN DIFFERENT
DESIGNS OF APPARATUS FOR MEASURING QUANTIFYING DISTORTION

(For this Supplement, see page 85, Volume IV.2 of the *Orange Book*)

Supplement No. 3.5

TEST FREQUENCIES ON CIRCUITS ROUTED OVER PCM SYSTEMS

1 Introduction

It should be noted that small errors in level measurement can arise on circuits routed over PCM systems where the test frequency is a submultiple of the PCM sampling rate. The magnitude of this error has a theoretical maximum of ± 0.15 dB at 800 Hz on systems with a sampling rate of 8000 Hz employing 8-bit coding[1]. The error at 1000 Hz will be slightly greater since the error increases as the test frequency approaches the PCM sampling rate.

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[1] It should be noted that some PCM systems used by Administrations in the international network (e.g. Recommendation M.675 [1], SPADE) employ 7-bit coding. In this case the theoretical maximum error will be ± 0.3 dB.

Studies within Study Group IV during the Study Period 1973-1976 confirmed that no significant problems in maintenance had been encountered due to this effect and therefore any retrospective action to modify existing tests or test equipment was unnecessary.

However, Study Group IV felt that in the future it would be prudent, where possible, to avoid submultiples of the PCM sampling rate for any new tests or test equipment to be included in the CCITT Recommendations and expressed a preference for the choice of an offset of 20 Hz (i.e., reference test frequencies of 820 or 1020 Hz). The studies revealed that some Administrations already employed reference test frequencies offset from the nominal 800 or 1000 Hz by varying amounts but within the ranges 804-860 Hz and 1004-1020 Hz.

2 Considerations for new measuring equipment specifications

The following should be considered for new measuring equipment specifications in the Series O Recommendations:

i) Measuring circuits or instruments which utilize the reference test frequencies should provide, if possible, for measurement of any frequencies within the nominal ranges 800-860 Hz and/or 1000-1020 Hz.

ii) The nominal values of 820 Hz and/or 1020 Hz are preferred for test frequency generating circuits or instruments that provide reference test frequencies. The specified frequency tolerance should be established bearing in mind the needs of the particular test concerned and so as to avoid submultiples of the PCM sampling rate.

Reference

[1] CCITT Recommendation *Lining up and maintaining international demand assignment circuits (SPADE)*, Vol. IV, Rec. M.675.

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