INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

BLUE BOOK

VOLUME IV – FASCICLE IV.4

SPECIFICATIONS FOR MEASURING EQUIPMENT

SERIES O RECOMMENDATIONS

IXTH PLENARY ASSEMBLY
MELBOURNE, 14-25 NOVEMBER 1988

Geneva 1989

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(Section 3 of the Supplements to the Series M, N and O Recommendations)

3 Measuring equipment specifications

MODIFICATIONS TO THE SERIES O RECOMMENDATIONS

Reorganization within Volume IV of the CCITT Book

Due to certain rearrangements within Volume IV of the CCITT *Red Book*, some existing Recommendations have been moved (or renumbered) and appear now in other sections of the Volume.

For the convenience of the reader of Volume IV of the CCITT *Blue Book*, these changes are listed below:

CCITT Red Book (Malaga-Torremolinos, 1984)	*CCITT Blue Book* (Melbourne, 1988)
O.121	O.9
O.141	O.25

PRELIMINARY NOTES

1 The list of Supplements in the Contents includes some which are not published in the Blue Book. Reference information for these Supplements can be found on the page indicated in the Contents.

2 The Questions entrusted to each Study Group for the Study Period 1989-1992 can be found in Contribution No. 1 to that Study Group.

3 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 FOR MEASURING EQUIPMENT

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SECTION 1

GENERAL

Recommendation O.1

SCOPE AND APPLICATION OF SERIES O RECOMMENDATIONS

(Melbourne, 1988)

1 Scope of Series O Recommendations

The CCITT establishes various Recommendations covering:

a) essential specifications for telecommunications equipments, and

b) operational matters, e.g. procedures for bringing circuits into service and routing checks of performance.

The type of tests for checking compliance with these two categories of Recommendations are essentially different, and this often leads to a different choice of test equipment.

Category a) tests will normally be more comprehensive. Their purpose (often based upon measurements of sample or prototype equipments) is to certify compliance with design objectives and they may therefore be a prerequisite to equipment being accepted for installation in an Administration's network. Such tests are unlikely to be employed routinely and in general CCITT does not produce Recommendations for test equipment intended specifically for this purpose.

Category b) tests, however, are used systematically and repetitively and their widespread application may necessitate additional considerations, in particular the need for:

1) conformity of results when tests may be performed using test equipment supplied by more than one manufacturer, and

2) a common measurement technique to ensure compatibility when a test requires test equipment at both ends of an international circuit.

It is primarily for these circumstances that CCITT issues the Series O Recommendations.

The above remarks apply quality to analogue and digital techniques.

2 Application of measuring equipment for use on digital transmission systems

This section is presented as an aid to selecting and applying specifications in the Series O Recommendations concerning test and measuring equipment for use on primary PCM and data multiplexers and digital transmission systems.

Applications are divided into two categories:

a) measurements and indications on primary PCM multiplexers;

b) measurements and indications on digital transmission systems including digital line systems, digital circuits and digital multiplexers.

Figures 1/O.1 and 2/O.1 illustrate the range of test and measurement capabilities applicable to primary PCM multiplexers, in the send and receive directions, respectively.

Tables 1/O.1 and 2/O.1 illustrate the range of test and measurement capabilities applicable to digital transmission systems.

The figures indicate the relevant Series O Recommendations to be applied for each test and measurement parameter, and also show the connection interface for the test instrument.

Example:

To measure quantising distortion on a primary PCM multiplexer:

Figure 1/O.1 shows that instruments conforming to Recommendations O.131 and O.132 can be employed, connected to the audio input interface of the send encoder.

Figure 2/O.1 shows that similar instruments are connected to the audio output interface of the receive decoder to complete the measurement path.

Signal generation: Parameter	Signal generation: Rec.	Signal measurement: Rec.
Attenuation/frequency distortion	O.133	O.133
Code violations		O.161
Crosstalk	O.133	O.133
Frame alignment signal monitor 2 Mbit/s		O.162
Gain	O.133	O.133
Quantizing distortion	O.131 O.132	
Variation of gain (loss) with time	O.133	O.133
Total distortion (including quantizing distortion)	O.133	O.133
Variation of gain with input level	O.133	O.133
Weighted noise	O.133	O.133
Non-linear distortion (4-tone intermodulation method)	O.42	
Degree of unbalance about earth	O.9	O.9

Audio input → PCM multiplex → First order output 1.544/2.048 Mbit/s

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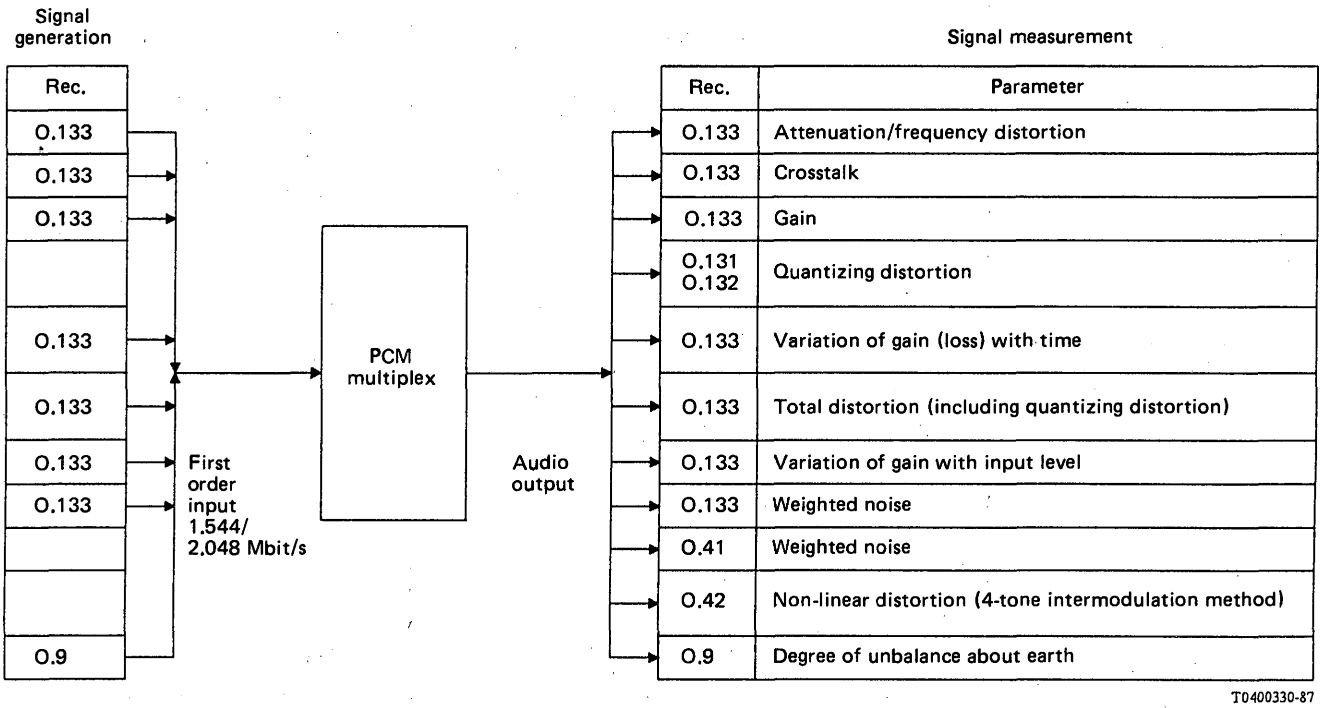
Note — Measurements performed via the digital interface of a primary PCM multiplexer are generally applicable also to transmultiplexers conforming to Recommendations G.793 [1] and G.794 [2]. Where relevant, a suitable analogue test signal generator is assumed.

FIGURE 1/O.1

List of tests and measurements applicable to primary PCM multiplexers in the send direction



Note – Measurements performed via the digital interface of a primary PCM multiplexer are generally applicable also to transmultiplexers conforming to Recommendations G.793 [1] and G.794 [2]. Where relevant, a suitable analogue test signal measurement capability is assumed.

FIGURE 2/O.1

List of tests and measurements applicable to primary PCM multiplexers in the receive direction

TABLE 1/O.1

List of tests and measurements applicable to digital transmission systems in the send direction

System hierarchical level		First order	Second order	Third order	Fourth order
Bit rate	64 kbit/s	1544 2048 kbit/s	6312 8448 kbit/s	32 064 34 368 44 736 kbit/s	139.264 Mbit/s
Parameter	Recommendation				
Error performance	O.152	O.151	O.151	O.151	O.151
Timing jitter	O.171	O.171	O.171	O.171	O.171

TABLE 2/O.1

List of tests and measurements applicable to digital transmission systems in the receive direction

System hierarchical level		First order	Second order	Third order	Fourth order
Bit rate	64 kbit/s	1544 2048 kbit/s	6312 8448 kbit/s	32 064 34 368 44 736 kbit/s	139.264 Mbit/s
Parameter	Recommendation				
Error performance	O.152	O.151	O.151	O.151	O.151
Code violations		O.161	O.161		
Frame alignment Signal monitor		O.162 (2 Mbit/s)			
Timing jitter	O.171	O.171	O.171	O.171	O.171

3 Application of measuring equipment for use on analogue transmission systems

Under study.

References

[1] CCITT Recommendation *Characteristics of 60-channel transmultiplexing equipments*, Vol. III, Rec. G.793.

[2] CCITT Recommendation *Characteristics of 24-channel transmultiplexing equipments*, Vol. III, Rec. G.794.

Recommendation O.3

CLIMATIC CONDITIONS AND RELEVANT TESTS FOR MEASURING EQUIPMENT

(Melbourne, 1988)

1 General

The Recommendations of the Series O specify measuring equipment for a wide range of applications. Reliable test equipment is an important prerequisite when maintaining telecommunication equipment and telecommunication networks. The reliability of measuring equipment can be affected by the environmental conditions to which the equipment is exposed to during its use.

This Recommendation gives a range of climatic conditions for the operation of measuring equipment specified in the Series O Recommendations. In addition, climatic conditions for transportation and storage of measuring equipment are defined.

In order to be able to prove that the requirements of this Recommendation are fulfilled, test conditions simulating the various environmental parameters are specified.

Where possible, this Recommendation is based on standards produced by other bodies such as the international electrotechnical commission (IEC) [1]; (CEPT) [2].

2 Climatic conditions for the operation of measuring equipment

2.1 *Operation in indoor rooms*

Considering that measuring equipment will be used in most of the cases in weather-protected locations, the normal operating conditions specified in Figure 1/O.3 define the range of climatic conditions under which the equipment specifications shall be met. These conditions may be found in normal working areas, offices, telecommunication centres or storage rooms for sensitive products, etc.

The normal operating conditions are maintained by heating, cooling and, where necessary, by forced ventilation. Humidity may normally not be controlled.

Figure 1/O.3 implies that the measuring equipment is usually operated at a temperature of approximately 25° C at a relative humidity of 45%.

The dotted field in the centre of the climatogram of Figure 1/O.3 specifies the climatic conditions which will be experienced during 90% of the time.

The exceptional operating conditions shown in Figure 1/O.3 may exist, e.g. following failure of the climate controlling system. Under these conditions the measuring equipment shall still operate without irreversible faults. However, the measurement may be less accurate.

In some instances the measuring equipment may be exposed to solar radiation and to heat radiation from other sources (e.g. from room heating). Direct solar radiation should be avoided and the temperature in the vicinity of the equipment shall not exceed the limits of Figure 1/O.3

The equipment may also be exposed to movements of the surrounding air due to draughts in buildings (e.g. through open windows). It shall not be subjected to condensation or precipitation.

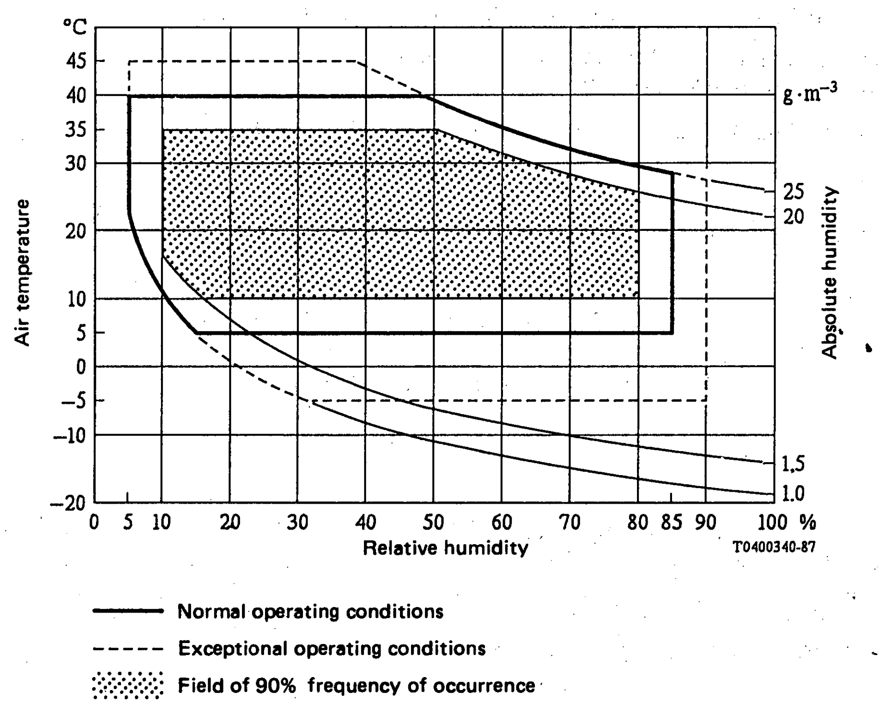


FIGURE 1/O.3

Temperature-humidity-chart for the operation of measuring equipment (weather-protected locations)

2.2 *Operation of measuring equipment in other environments*

Under study.

3 Transportation and storage

During transportation and storage the measuring equipment shall tolerate temperatures between $-40\,^{\circ}C$ and $+70\,^{\circ}C$ without irreversible failure. For relative humidities higher than 45% and temperatures higher than $25\,^{\circ}C$ the limits of the climatogram of Figure 1/O.3 shall not be exceeded for any humidity/temperature combination. In this case the (uninterrupted) exposure time is limited to 2 months.

Note 1 – It is assumed that the measuring equipment is packed in its usual shipping container and that the ambient conditions mentioned above are those outside the package.

Note 2 – This requirement is provisional and requires further study.

4 Test conditions

4.1 *Testing conditions for indoor climates*

It is assumed that the measuring equipment meets the requirements of § 2.1 if it tolerates the basic environmental testing procedures in accordance with IEC Publication 68-2-3 [3].

During these testing procedures, the mesuring equipment shall be placed in the testing chamber for 4 days. After a recovery time of 2 hours the test specimen shall properly function and the specified error limits shall not be exceeded.

Note – This requirement is provisional and requires further study.

4.2 *Testing conditions for other environments*

Under study.

References

[1] IEC Publication 731-3 *Classification of Groups of Environmental Parameters and their Severities.*

IEC-Publication 721-3-3 *Stationary Use at Weather-Protected Locations.*

[2] CEPT Recommendation T/TRw, Part B-3 *Environmental Conditions and Environmental Tests for Telecommunications Equipment.* (October 1987).

[3] IEC-Publication 68-2-3 *Basic Environmental Testing Procedures. Part 2: Test Ca: Damp heat, steady state.*

Recommendation O.6

1020 Hz REFERENCE TEST FREQUENCY

(Melbourne, 1988)

1 Introduction

The intent of this Recommendation is to specify a single nominal reference frequeny of 1020 Hz in order to provide guidance to manufacturers and Administrations in the design and operation of new equipment and systems. This Recommendation is not intended to have an effect on existing equipment or systems except where modifications are required to allow for interworking. For instance, an older analogue exchange would need to be provided with new reference frequency capability if circuits were provided between it and digital exchanges.

2 Test frequencies on circuits routed over PCM systems

The selection of a suitable test frequency is a major consideration when testing circuits routed over PCM systems. An error in level measurement can arise on circuits routed over PCM systems if the test frequency is a sub-multiple of the PCM sampling rate. This error can be nearly as great as ± 0.15 dB at 800 Hz and ± 0.20 dB at 1000 Hz with a sampling rate of 8000 Hz employing 8-bit coding. In addition, errors in other parameters, such as total distortion, may be even more significant.

Therefore, it is recommended that the use of a reference test frequency that is a sub-multiple of the PCM sampling rate should be avoided. Studies within CCITT reveal that some Administrations have employed nominal reference test frequencies offset from 800 Hz or 1000 Hz by varying amount but within the ranges 804-860 Hz or 1004-1020 Hz. These studies have confirmed that where interworking is not required, no significant problems in maintenance have been encountered by Administrations and existing test procedures and equipment may continue to be used.

In the case of interworking and for new equipment and systems, the Administrations expressed a strong preference for the selection of a reference test frequency of 1020 Hz.

3 Considerations for new measuring equipment specifications

The following should be considered for new measuring equipment specifications in the Series O Recommendations:

i) A reference test frequency of 1020 Hz is recommended for test frequency generating circuits or instruments that provide reference test frequencies. The specified frequency tolerance should be +2 to −7 Hz[1]).

ii) The nominal level of the reference test frequency when used on in-service equipment should not be greater that −10 dBm0 ± 0.1 dB.

iii) Measuring circuits or instruments which utilize the reference test frequencies should provide, if possible, for measurements of any frequencies within the nominal range of 1000 to 1025 Hz.

By agreement between the Administrations concerned, in the absence of the required sending or measuring apparatus, the use of a measuring frequency in the range of 800 to 860 Hz is admissible. Other considerations about the deployment and use of reference test frequencies are given in Recommendation M.20 [1].

References

[1] CCITT Recommendation *Maintenance philosophy for analogue, digital and mixed networks*, Volume IV, Recommendation M.20.

Recommendation O.9

MEASURING ARRANGEMENTS TO ASSESS THE DEGREE OF UNBALANCE ABOUT EARTH

(Geneva, 1972; amended at Malaga-Torremolinos, 1984, and at Melbourne, 1988)

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.

1) The negative tolerance of 7 Hz is intended to allow the use of digitally generated test signals that are generated by a sufficiently high number of samples to achieve the measurement accuracy specified in certain Series O Recommendations (e.g. Recommendation O.133).

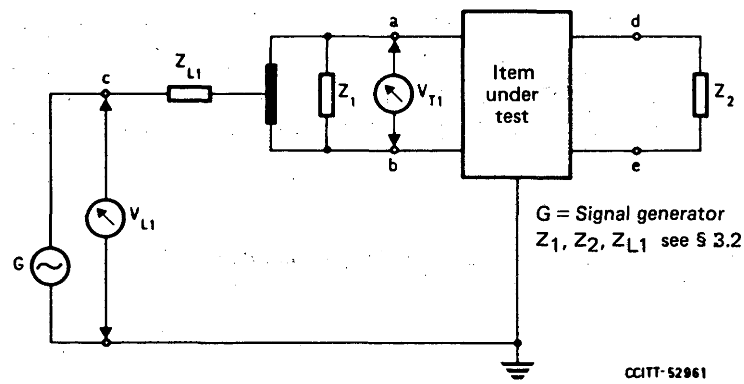
This Recommendation is in agreement with the principles, the nomenclature and the definitions, addressed in Recommendation G.117 [1], which considers the transmission aspects of unbalance about earth. References are made in the following sections, to the appropriate paragraphs/figures of Recommendation G.117 [1].

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.9. 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.9

Measurement of longitudinal conversion loss

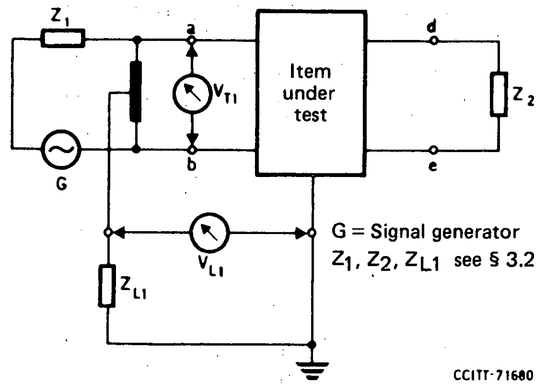
2.2 *Transverse conversion loss (TCL)*

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.9 (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.9 (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_{L1}. 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.

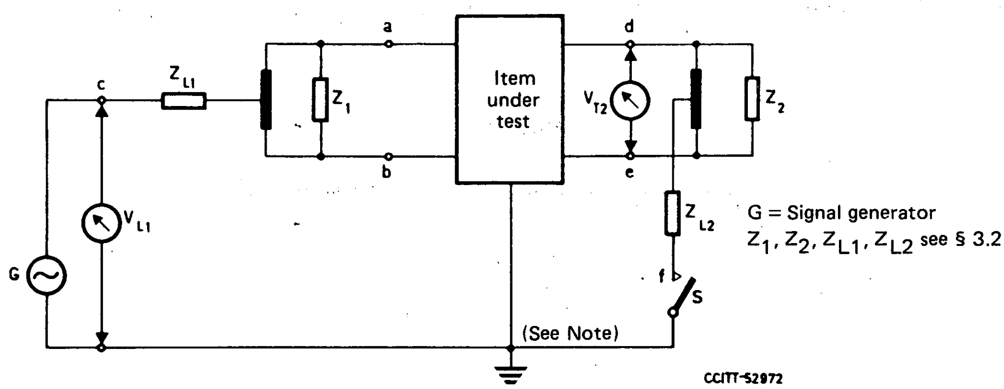


Transverse conversion loss (TCL) $= 20 \log_{10} \left| \frac{V_{T1}}{V_{L1}} \right|$ dB

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.9

Measurement of transverse conversion loss



Longitudinal conversion transfer loss (LCTL) $= 20 \log_{10} \left| \frac{V_{L1}}{V_{T2}} \right|$ dB

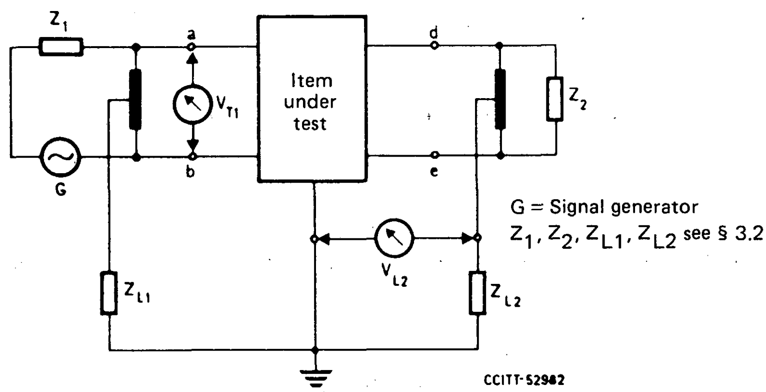
Note – Measurements are normally made, and limits specified, with switch S closed. However, for certain equipments, e.g. those described in Recommendation Q.45 [2], it may be necessary to specify limits for LCTL with switch S closed and with switch S open.

FIGURE 3/O.9

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.9. 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.

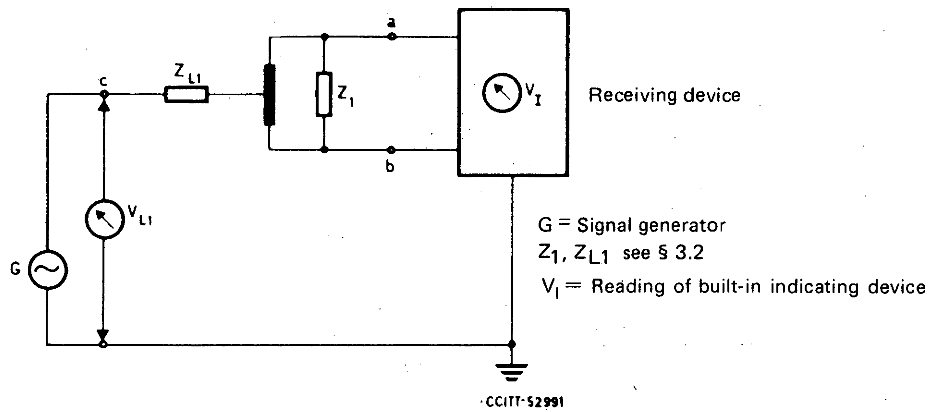
FIGURE 4/O.9

Measurement of transverse conversion transfer loss

2.5 *Input longitudinal interference loss (ILIL)*

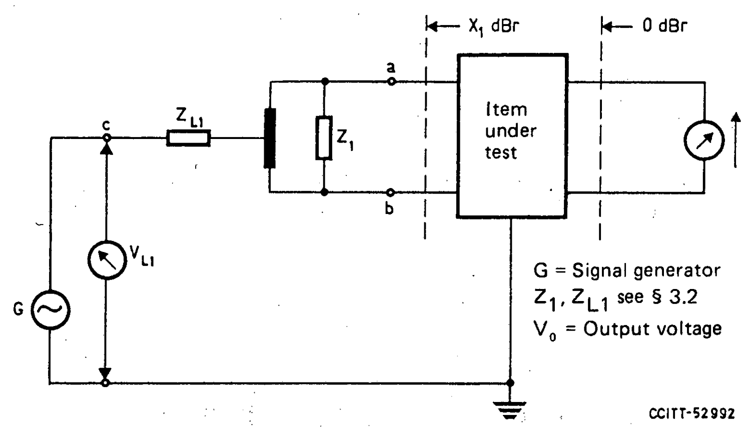
The measurement of this parameter is applicable to receiving devices (e.g., amplifiers, level meters, etc.). ILIL is a measure (a ratio expressed in dB) of the sensitivity of a receiving device to longitudinal disturbances. It is measured as shown in Figure 5a/O.9 and 5b/O.9. In principle, it is similar to the longitudinal conversion loss (LCL) measurement. However, since the measurement is performed internally (using a built-in indicating device) or at the output of the item under test, not only the impedance balance at port a/b, but also the effect of common-mode rejection is measured. (See § 4.4.1 of Recommendation G.117 [1].)

Measurements in accordance with Figure 5b/O.9 are also applicable to devices which perform a signal conversion (e.g. VF/CF side of channel translating equipment, A/D side of PCM multiplex equipment, etc. See § 2, item f of Recommendation G.117 [1]). In this case the measurement at the output of the device under test requires an appropriate analyzer, namely a selective level meter for measurements at channel translators or a digital analyzer (see Recommendation O.133) for measurements at PCM-multiplexers. In the equation in Figure 5b/O.9 it is assumed that V_0 is measured at a 0-dBr point. The quantity X_1 is the relative level at port a/b.



$$\text{Input longitudinal interference loss (ILIL)} = 20 \log_{10} \left| \frac{V_{L1}}{V_I} \right| \text{ dB}$$

a) Measurement of input longitudinal interference loss with item under test containing built-in indicating device



$$\text{Input longitudinal interference loss (ILIL)} = 20 \log_{10} \left| \frac{V_{L1}}{V_0} \right| \text{ dB}$$

Note – Values of X_1 differing from 0 dBr must be taken into account when calculating ILIL.

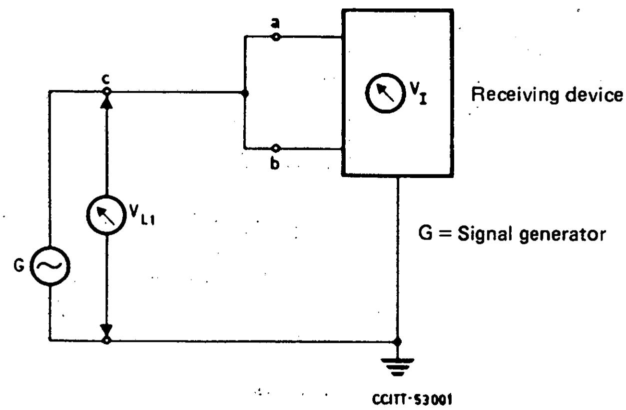
b) Measurement of input longitudinal interference loss with item under test having external indicating device

FIGURE 5/O.9

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.9. Note that in this arrangement the input terminals are short-circuited and then energized (see § 5.1 of Recommendation G.117 [1]).



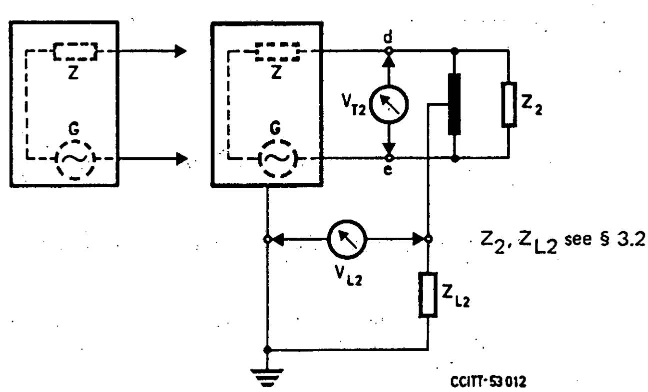
$$\text{Common mode rejection (CMR)} = 20 \log_{10} \left| \frac{V_{L1}}{V_I} \right| \text{ dB}$$

FIGURE 6/O.9

Measurement of common-mode rejection

2.7 *Output signal balance (OSB)*

This measurement (a ratio expressed in dB) is applicable to signal outputs. OSB is a measure of unwanted longitudinal signals at the output of a device. It is measured as shown in Figure 7/O.9 (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.9

Measurement of output signal balance

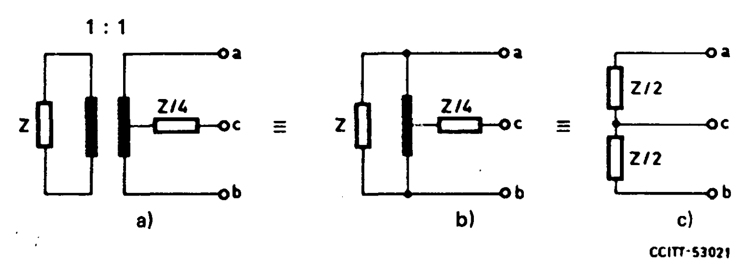
The signal source G shown in Figure 7/O.9 can be internal or external to the device under test. OSB measurements are also applicable to devices which perform a signal conversion (e.g. CF/VF side of channel translating equipment. D/A side of PCM multiplex equipment, etc. See § 2, item f of Recommendation G.117 [1]). In this case an appropriate external signal source, namely a signal generator for measurements at channel translators or a digital signal generator (see Recommendation O.133) for measurements at PCM-multiplexers is required.

3 Requirements for the measuring arrangements

3.1 *Inherent balance*

The measuring arrangements shown in Figures 1/O.9 through 7/O.9 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.9 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.9, 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.9 may be unsuitable and it may be more convenient to use arrangement *c)* of Figure 8/O.9, 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.9

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.9 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 analogue exchange* Vol. VI, Rec. Q.45.

SECTION 2

MAINTENANCE ACCESS

Recommendation O.11

MAINTENANCE ACCESS LINES

(Geneva, 1972; amended at Malaga-Torremolinos, 1984, and at Melbourne, 1988)

1 General

1.1 *Introduction*

In order to more effectively carry out manual and automatic maintenance of international circuits in an automatic telephone network, the following international 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.25) responder;

d) a loopback test line (analogue or digital);

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

f) a test line to terminate the signalling system functional testing and transmission measuring responder (type a) for use with ATME No. 2 (Recommendation O.22);

g) a test line which returns a busy flash signal for use with ATME No. 2 (also referred to as type c responding equipment, see Recommendation O.22).

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

The test lines listed in a) to e) above 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[1] −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.25) 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 semi-automatic echo suppressor tests on the circuits between the two centres.

[1] For further information about the choice of the test reference frequency refer to Recommendation O.6.

1.5 *Loopback test line*

1.5.1 *Analogue loopback test line*

The loopback test line is a dialable 4-wire test line that initially returns a nominal 1020 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.

1.5.2 *Digital loopback test line*

The digital loopback test line provides a dialable 4-wire test line capability intended both for use in measuring the error performance of international digital circuits and as a quick method of verifying the continuity of wholly digital, non-PCM encoded and mixed analogue/digital circuits. It consists of circuitry that accepts and loops back on a digital basis the signal from a circuit. The test signal may be any arbitrary digital test pattern or analogue test signal.

Once the tester has accessed the test line at a remote location, the tester may transmit the desired analogue test signals or digital test patterns. The tester may examine the returning signal for the received power (or continuity) of the analogue test signals or the error performance (or continuity) of the digital test patterns.

The proposed dialling plan for this test line enables a particular line to be selected when the distant switching centre is equipped for this type of dialling access. If the normal test line number (access code) is busy, it is expected that the call should route to a busy indication.

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.

1.7 *ATME No. 2 test lines*

The ATME No. 2 test lines are dialable 4-wire test lines intended to terminate the ATME No. 2 responders (see Recommendation O.22). The responding equipment is available in two forms:

a) a signalling system functional testing and transmission measuring device (type *a*);

b) a signalling system function testing device (type *b*).

The ATME No. 2 equipment, consisting of directing equipment at the outgoing end and responding equipment at the incoming end, is intended to make automatic transmission measurements and signalling system functional tests on all categories of international circuits terminating in exchange with 4-wire switching.

1.8 *Busy flash signal test line*

The busy flash test line is a dialable 4-wire test line intended for use with the ATME No. 2 directing equipment (see Recommendation O.22). This test line, which is also referred to as type *c* responding equipment in Recommendation O.22, is required in cases when the signalling system used on the circuits to be tested provides a busy flash signal. This test line functionality may be provided within the exchange equipment or by separate responding equipment.

2 Method of access

2.1 In general, access arrangements should conform to the Recommendation M.565 [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 M.565.

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 (non-allocated 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) 1 (ATME No. 2 responding equipment type *a* for signalling tests and transmission measurements),
   - b) 2 (ATME No. 2 responding equipment type *b* for signalling tests only),
   - c) 3 (quiet termination test line),
   - d) 4 (echo suppressor test line),
   - e) 5 (loopback test line),
   - f) 6, 7 and 8 (transmission access test line). (See Note),
   - g) 9 (echo canceller test line),
   - h) 10 (digital loopback test line).

   Note – The allocation of the X digit is under the responsibility of Study Group XI. In Signalling 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 Signalling 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 No. 4, 5, 7 and R2*

i)	ATME No. 2 responding equipment type a	61
ii)	ATME No. 2 responding equipment type b	62
iii)	Busy flash signal	63
iv)	quiet termination	64
v)	echo suppressor	65
vi)	analogue loopback	66
vii)	digital loopback	68
viii)	multiple address capability for transmission access test line	21-29
ix)	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 the range of climatic conditions specified in Recommendation O.3.

3.1 *Tone source characteristics (quiet termination and loopback test lines)*

a) The nominal tone source frequency should fall within 1004 to 1020 Hz. The tone source frequency including tone source stability and aging should remain within 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 loopback 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 loopback 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.9): 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 46 dB at 1020 Hz, and 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 loopback test lines).

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

3.6 *Loopback test line level adjustment*

The loopback test line equipment shall provide the proper buildout (loss or gain) in the loopback 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 loopback test line is employed.

3.7 *Digital loopback test*

The digital loopback test line provides a dialable, 4-wire test line capability; this type of test line accepts and loops back received octets from a digital circuit. The octets when looped back, are retransmitted so that the positions of the bits within the octet are preserved; that is, the most significant bit of the retransmitted octet corresponds to the most significant bit of the received octet, and so forth.

The loopbacks may be integrated into the switching network of the digital switching machine, or may be provided in a stand-alone mode, having an external 4-wire 64 kbit/s appearance on the switching machine, similar to existing test lines.

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).

4.2 *Test line answer*

When access is gained to the test line equipment, the answer signal (answer, no charge if Signalling 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.

SECTION 3

AUTOMATIC AND SEMI-AUTOMATIC MEASURING SYSTEMS

Recommendation O.22 [1)]

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

(Geneva, 1972; amended Geneva, 1980, Malaga-Torremolinos, 1984 and Melbourne, 1988)

1 General

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

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.

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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.

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.605 [1].)

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 to 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 No. 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 with Type a responders:

a) absolute power level measurement at 1020 Hz[4];

b) absolute power level measurement at 400, 1020 and 2800 Hz (loss/frequency distortion);

c) noise measurements;

d) signal-to-total-distortion (including quantizing distortion) ratio measurements at values of holding tone (i.e. −10 and −25 dBm0);

e) an in-circuit echo canceller testing system (ECTS) sequence, intended to test both near-end and far-end cancellers on a circuit under test. The ECTS is suitable for testing echo cancellers complying with Recommendation G.165 [2];

f) on wholly digital circuits between digital exchanges, measurements by the director of a director generated digital test pattern looped back by a Type a responder.

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 to a separate test line, see Rec. O.11).

In addition to the transmission measurements made between directors and responders it shall also be possible to make measurements from a director to a digital loopback test line as described in Recommendation O.11

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

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, digital test pattern tests, echo canceller tests, signal-to-total-distortion ratio and noise measurements, as described below. In addition, the directing equipment shall have the capability, where required, 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.

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[4] For further information about the choice of the test signal frequency refer to Recommendation O.6

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 9.1.

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 9.1.

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 § 3.6), 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 decibel. The transmission parameters of the switched access path between the virtual switching point and the measuring device shall be allowed for (see Recommendation M.560 [3]).

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

3.2 *Noise measurements*

Note – When ATME No. 2 is implemented using digital signal processing techniques, noise measurement is inherently limited to 4 kHz when using an 8 kHz sampling frequency.

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 9.3.

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 § 9.2 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 −4.0 dBr (see § 3.6). The transmission parameters of the switched access path between the virtual switching point and the noise measuring device shall be allowed for (see Recommendation M.560 [3]).

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 tones at two different levels (−10 and −25 dBm0) as specified in § 9.1.

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 § 9.2.

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 9.1.

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

3.4 *Echo canceller testing system (ECTS)*

As part of the ECTS, the directing and responding equipments shall each be provided with features for making absolute power level, echo performance 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.

3.4.1 *Absolute power level measurements*

3.4.1.1 *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 §§ 5.2 and 9.4.

3.4.1.2 *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 §§ 6.7 and 9.1.

The measuring device shall provide results in the form of a deviation, expressed in decibel, 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 § 3.6), the relative level at the receiving end virtual switching point is −4.0 dBr. A level higher than nominal shall be indicated as positive "+" and a level lower than nominal shall be indicated as negative "−". The transmission parameters of the switched access path between the virtual switching point and the measuring device shall be allowed for (see Recommendation M.560 [3]).

If the equipment is capable of detecting an interruption or a condition of instability experienced during a measurement (see § 11.5), the result shall be indicated as described in § 3.6.

3.4.2 *Noise measurements*

(To determine echo noise floor in step 1 of echo performance test.)

3.4.2.1 *Sending end*

At the access point at the input to path to be measured, there will be connected a 600-ohms terminating resistance in accordance with §§ 6.7 and 9.4.3.

3.4.2.2 *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 § 9.5.1.

The noise measuring device shall provide results as noise ratios which are the relative power level with psophometric weighting referred to the −10 (dBm0p) sending level, assuming for the responding equipment that the relative level at the receiving end virtual switching point is −4.0 dBr (see § 3.6).

Note − This noise level is referred to −10 dBm0p rather than 0 dBm0p to make it represent the minimum measurable noise ratio in steps 2 and 3 of the echo performance tests in § 3.4.3. The transmission parameters of the switched access path between the virtual switching point and the noise measuring device shall be allowed for (see Recommendation M.560 [3]).

3.4.3 *Echo performance ratio measurements*

(Steps 2 and 3 of echo performance tests)

3.4.3.1 *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 −10 dBm0 noise test signal as specified in § 9.4.1e).

3.4.3.2 *Measuring end*

At the access point at the ouput form the path to be measured, there will be connected an echo performance (noise) measuring device whose specifications are given in § 9.5.1.

The measuring device shall provide results in terms of relative power level ratio with psophometric weighting referred to the −10 dBm0 noise test signal in § 3.4.3.1, assuming for the responding equipment that the relative level at the receiving end virtual switching point is −4.0 dBr (see § 3.6). The transmission parameters of the switched access path between the virtual switching point and the noise measuring device shall be allowed for (see Recommendation M.560 [3]).

3.5 *Digital loopback tests*

3.5.1 *Digital test pattern tests to a digital loopback test line*

3.5.1.1 *Sending end*

At the access point at the input to the path to be measured, there will be connected a sending equipment which will provide a pseudo-random digital test pattern as specified in Recommendation O.152, § 2.

3.5.1.2 *Measuring end*

At the access point at the output from the path to be measured, there will be connected a receiving equipment as specified in Recommendation O.152. This measuring equipment should be capable of measuring bit-error ratio, block-error ratio, and errored time intervals as defined in Recommendation G.821 [4].

3.5.2 *Transmission tests to a digital loopback test line*

3.5.2.1 *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 tones of the appropriate frequency and level as specified in §§ 6.3, 9.1, 9.2 and 9.3.

3.5.2.2 *Measuring end*

At the access point at the output from the path to be measured there will be connected measuring equipment provided with features for making absolute power level, noise, and signal-to-total-distortion ratio measurements and as specified in §§ 3.1.2, 3.2.2 and 3.3.2 respectively.

It should be noted that measurements made through the digital loopback test line will experience twice the circuit distance and delay characteristics experienced by a far end measurement device. Therefore, measurement results must be compared to circuit maintenance limits which are modified to reflect a doubling of circuit distance and quantizing distortion units (QDUs).

3.6 *Adjustment 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 Recommendation G.131 [5]).

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 and the echo performance measurements are not affected as the results are presented as signal-to-total-distortion ratio in dB or noise signal to echo signal ratio in dB.

3.7 *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 1020 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 1020 Hz. Results of noise measurements shall be expressed in dBm referred to 0 level (dBm0p). The signal-to-total-distortion measurements are in the form of signal-to-total-distortion ratios expressed in dB. The echo performance measurements are in the form of noise signal to echo signal ratios expressed in dB.

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

TABLE 1/O.22

Example of measurements made by the responder

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)	Presentation: For circuit with nominal loss other than 0.5 dB, say 1.5 dB (dB)
Level	1020 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-distortion ratio [a] or noise ratio (dB)	34 [a]		+34	34	34

[a] With a received total distortion test signal level of −13.7 dBm and a total distortion power of −48 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) the echo performance ratio is outside the assigned maintenance limits for any dely value at either end. (When this happens, the noise floor value measured in step 1 of the test must also be recorded);

h) digital error performance values greater than the assigned maintenance limit;

i) failure to complete the test call;

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

In cases i) and j) 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 § 11.5):

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[5)]

Instability during absolute power level measurements . . . . 8XX or 6XX[5)]

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 § 11.5).

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.

3.8 *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 Recommendation M.560 [3].

4.2 *Outgoing international exchange*

Access to the circuit for test at the outgoing international exchange shall conform to Recommendation M.565 [6].

4.3 *Incoming international exchange*

Access to the responding equipment at the incoming international exchange will be gained via a maintenance access line associated with the normal switching equipment. The address information to be used to gain access to either Type a or Type b responding equipment or to a digital loopback test line at the incoming exchange is specified in § 2.4 of Recommendation O.11.

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5) XX represents the results of the measurement.

5 Operating principles

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

5.1 When the directing equipment has indicated to the responding equipment the kind of measurement to be made, the measurement 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 § 9.3. 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 § 9.3. 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.

5.4 Initially Echo canceller testing system (ECTS) signals will be sent by the directing equipment to disable or lock-up any echo suppressor or circuit multiplication equipment that is present on the circuit under test.

Next, loss tests will be made in both directions of transmission to ensure that the circuit loss is within nominal values.

Then a series of echo performance (noise ratio) measurements will be made toward an echo canceller at the distant end of a circuit corresponding to each of three circuit conditions provided by its terminating equipment:

a) quiet termination of both directions of transmission,

b) 2 dB gain loop with prescribed amount of delay to test each stage (cascaded delay section) of the canceller, and

c) 10 dB loss loop with prescribed amount of delay.

The process will then be reversed so as to test both the far-end and near-end echo cancellers with one access of the circuit under test.

6 Signalling system testing and transmission measuring procedure – director to responder

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.

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 § 3.7.)

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. 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. When the acknowledgement of 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.

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) 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[7].

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] 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 No. 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.

6.1.8 When the clear-forward signal is transmitted (in accordance with §§ 6.1.6 or 6.1.7), 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 § 2.4 of Recommendation O.11, 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 Systems Nos. 6 and 7 or in Systems R1 and R2.

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

Individual measurement cycles are specified in two groups known as "Layer 1" and "Layer 2". One code in Layer 1 has been designated to indicate that a measurement cycle in Layer 2 is being requested.

6.3.1 *Layer 1 procedures*

The signalling sequence for each Layer 1 individual measurement cycle is specified in § 6.4 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 1/O.22. The signalling scheme adopted for the command signals between directing and responding equipments consists of multi-frequency (MF) signals transmitted in compelled sequence; results are transmitted from the responding equipment to the directing equipment by means of multi-frequency pulse-type signals.

All transmission measurements should be performed with a tone level of −10 dBm0 (total distortion measurements may also use a −25 dBm0 level). Certain older responding equipment may be equipped to test with two tone levels, i.e. 0 dBm0 and −10 dBm0. 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 § 9.1.) 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 [7] and Q.154 [8] (see Annex A to this Recommendation concerning the sensitivity of the signalling receiver.)

6.3.2 *Layer 2 procedures*

The signalling sequence for each Layer 2 individual measurement cycle is specified in § 6.6 and the frequencies and codes in Tables 4/O.22 and 5/O.22. Multi-frequency pulse-type signals are used in Layer 2 both for command signals between directing and responding equipments and for transmitting results from the responding equipment to the directing equipment. When a Layer 2 procedure has been completed, a designated multi-frequency pulse-type signal command returns the dialogue to Layer 1.

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), 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 § 9.3.

TABLE 2/O.22

Command signals from directing equipment to responding equipment

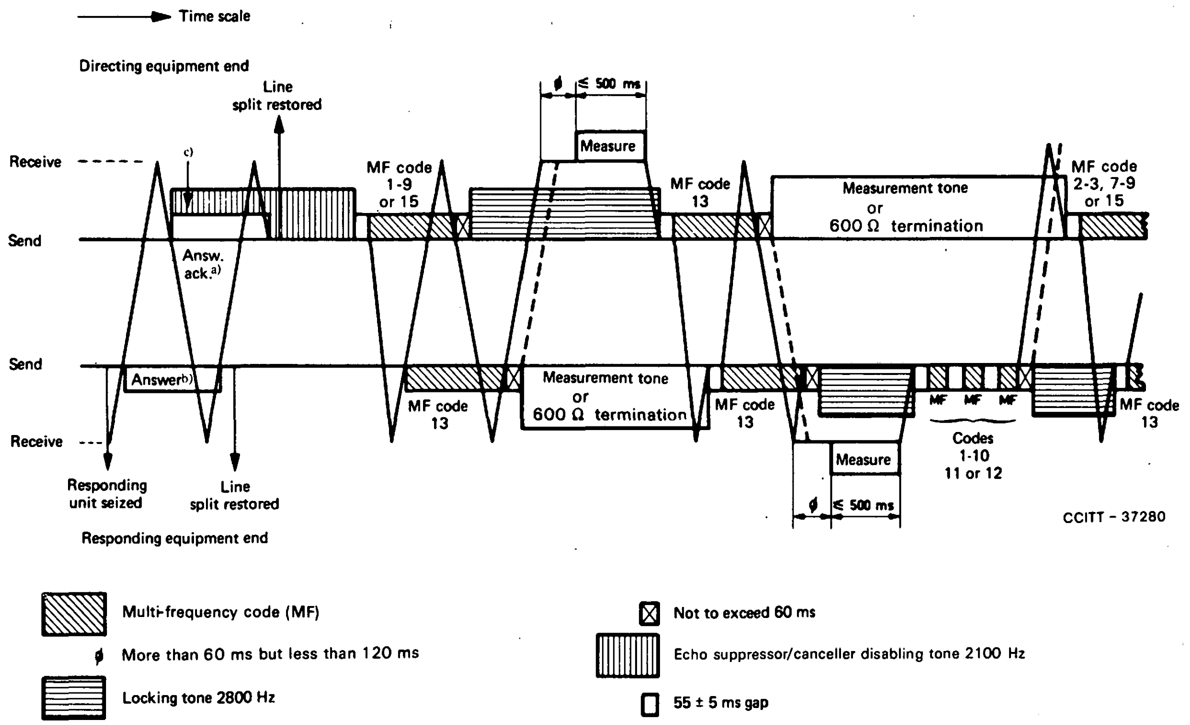
Code No.	Interpretation
1	Measure absolute power level at 1020 Hz (sent level 0 dBm0)
2	Measure absolute power level at 400 Hz } with a sent level indicated by the 1020 Hz measurement command signal
3	Measure absolute power level at 2800 Hz } with a sent level indicated by the 1020 Hz measurement command 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 1020 Hz and subsequent level measurements in the programme with a sent level of -10 dBm0
7	Measure total distortion with -10 dBm0 signal
8	Measure total distortion with -25 dBm0 signal
9	Shift to Layer 2
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



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 1/O.22

Typical ATME signalling sequence

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

TABLE 5/O.22

Layer 2 command signals from directing equipment to responding equipment

Code No.	Layer 2 Interpretation
1	Echo canceller test system – automatic
2	Reserved
3	Loop-around test – digital
5	Return to Layer 1

6.4.2 When the echo suppressor/canceller disabling tone is removed, the directing equipment will transmit a multi-frequency (MF) 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) the MF 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 MF 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), 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, if present, will be disconnected.

6.4.8 Following disconnection of the CMS locking tone mentioned in § 6.4.7, a MF 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 MF 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 MF 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 MF 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 will be disconnected if it has been sent. The first MF 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 MF pulse will be sent within 60 ms after disconnection of the measuring equipment.

6.4.15 Measurement result information will be transmitted as three MF 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. The digit zero is represented by Code 10.

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 MF pulse has been sent.

6.4.17 When the third MF pulse is recognized by the directing equipment, the measurement tone will be disconnected. A MF 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, this tone will be disconnected on recognition by the responding equipment of the MF 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 MF 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 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 MF command signal mentioned in § 6.4.17 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 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 by the MF 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 at either −10 or −25 dBm0 depending on the requested test.

6.4.23 When making total distortion measurements, the measurement tone mentioned in §§ 6.4.5, 6.4.9, 6.4.10 and 6.4.17 must be replaced by the proper level total distortion test signal (either −10 or −25 dBm0).

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, insofar as they apply.

6.6 *Description of Layer 2 transmission measuring cycles*

After a compelled MF Code 9 has been used in Layer 1 to enter Layer 2 and MP command acknowledgement has been detected (not waiting for it to cease), a MF pulse-type signal is used to select a measurement cycle (see Table 5/Q.22). Some Layer 2 measurement cycles contain no-signal intervals of a length sufficient to cause a CMS circuit to switch the CMS connecting channel.

The directing equipment may exit a Layer 2 measurement cycle by sending a pulse-type MF Code 5. If required as specified in § 6.4.1, the directing equipment will then send the echo suppressor/canceller disable tone. This assures that echo suppressors and/or cancellers will not interfere with the compelled MF commands used in Layer 1.

6.7 *Description of echo canceller testing cycles*

6.7.1 The test descriptions in this section follow the test sequence shown in Figures 2/O.22 and 3/O.22. All gaps between the MF pulse bursts and other actions shall be 80 ± 5 ms unless otherwise specified Timing and other error conditions are covered in § 6.8.

6.7.2 The director sends a Code 9 MF command to indicate that a Layer 2 cycle is being specified.

6.7.3 When the command signal is received by the responding equipment a MF command acknowledgement signal will be transmitted.

6.7.4 When the command acknowledgement signal is recognized by the directing equipment the command signal will be disconnected and a pulsed MF command sent (§ 6.7.6).

6.7.5 When the cessation of the command signal is recognized by the responding equipment the command acknowledgement signal is disconnected.

6.7.6 The directing equipment begins the test sequence by transmitting to the responder an MF priming burst which specifies a 1020 Hz test tone and automatic test timing (see §§ 6.3 and 6.4 and Table 5/O.22).

6.7.7 Following the initial MF priming burst, the director pauses for 500 ms to ensure that echo cancellers are enabled. It then sends an 800 ms period of 2100 Hz tone, if required, which disables any echo suppressors which may be on the circuit under test and provides lockup for any circuit multiplication equipment employed on the circuit.

6.7.8 Next the director sends test tone (1020 Hz) at −10 dBm0 to the responder while it waits for the responder to measure the received level of the tone and return a measurement result.

6.7.9 The responder detects the presence of the test tone, measures the level, and returns the results of the measurement as pulsed MF digits. It then applies test tone (1020 Hz) at −10 dBm0 toward the director.

6.7.10 Upon receipt of the measurement result from the responder, the director removes test tone and waits for receipt of test tone from the responder upon which it makes a level measurement.

6.7.11 The director next sends MF priming bursts to specify the test sequence for the far-end echo canceller (at the responder end) or for the near-end echo canceller (at the director end). The following steps test the far-end echo canceller.

6.7.12 After sending the priming digit specifying a far-end echo canceller test, the director applies a noise test signal and waits for an MF confirmation burst from the responder.

6.7.13 Upon receiving the priming burst indicating a far-end echo canceller test, the responder removes the test tone it had been sending, returns an MF confirmation burst, and provides a quiet termination on both transmit and receive paths of the circuit under test as the step 1 condition.

6.7.14 Upon receiving the step 1 confirmation MF burst, the director continues the noise signal for 500 ms to allow the far-end echo canceller to zero its internal registers on receipt of the noise signal, and then the director makes a noise ratio measurement which is an indication of the far-to-near circuit noise. (This measurement is only an indication of the noise performance of the circuit under test but is intended to assure that excessive circuit noise problems are not distorting the canceller tests.) The director then sends an MF priming burst to advance the responder to step 2 conditions and indicates, using two more MF priming bursts, the amount of delay to be provided in the 2 dB gain loop. The requested value of delay in the loop should be continuously variable from 0 to 75 ms in steps of 1 ms. After the priming is completed, it then resumes sending the noise signal toward the responder.

6.7.15 Upon receiving the step 2 priming from the director, the responder removes the step 1 terminations, provides a 2 dB gain loop with the specified delay, and returns the step 2 priming confirmation MF burst.

6.7.16 The director receives the step 2 confirmation MF, continues the noise signal for 500 ms to allow the far-end canceller to adjust to the two-talker state, and then makes a noise ratio measurement of the looped-back signal. It then sends an MF priming burst to advance the responder to the step 3 condition which is a 10 dB loss loop with the same delay and applies the noise signal toward the responder.

6.7.17 Upon receiving the step 3 priming MF burst from the director, the responder applies the step 3 conditions and returns a confirmation MF burst.

6.7.18 The director receives the step 3 confirmation MF burst, continues the noise signal for 500 ms to allow the far-end echo canceller to attempt to cancel the looped noise, and then makes a noise ratio measurement of the returned signal.

6.7.19 If the far-end canceller has additional delay stages to be tested, the director may repeat the step 2 and step 3 sequences with the appropriate values of delay for testing each stage.

6.7.20 If there are no additional far-end echo canceller delay stages to test and there is no near-end echo canceller to be tested, and if no completed tests are to be repeated, nor has a test of the far-end canceller disabler been requested, the director sends an MF priming burst instructing the responder to return to Layer 1.

a) If there is no near-end canceller to be tested and the disabler function of the far-end canceller is to be tested, that test is performed at this time. (Note that if there is also a near-end canceller, testing of the far-end canceller disabler function is done after the near-end canceller has been tested.)

b) To test the operation of the far-end echo canceller disabler, it is assumed that the previously described sequence has been applied to the far-end canceller and exited with the 10 dB loss loop still applied by the responder while it awaits additional commands.

c) The director removes the noise signal used for the 10 dB loss loop measurement and sends for 800 ms an echo canceller disable signal consisting of a 2100 Hz burst with phase reversed 180° pediodically (see § 9.4.1 c). Upon receipt of this signal, the disabler in the echo canceller should operate, thus disabling the canceller action.

d) The director removes the disable signal, sends an MF priming burst, and applies the noise signal upon which the far-end canceller should now take no action. Upon receiving the MF burst, the responder removes the 10 dB loss loop with delay, returns an MF confirmation burst, and applies a 10 dB loss loop with no delay. Upon receipt of the MF confirmation burst from the responder, the director continues the noise signal for 500 ms and then makes a noise ratio measurement of the returned signal (which should differ from the previous 10 dB loss loop measurement because the canceller has been disabled).

e) The director then removes the noise signal and sends an MF priming burst instructing the responder to return to Layer 1.

6.7.21 If there is a near-end echo canceller to be tested, the director sends an MF priming burst which instructs the responder to assume the control function and indicates the number of stages to be tested in the near-end canceller. The director then applies test tone toward the responder (see Figure 3/O.22).

6.7.22 Upon receipt of the command to assume test control, the responder sends a step 1 priming MF burst to the director. The responder then applies a noise signal and awaits a step 1 confirmation MF burst from the director. The 3-step sequence proceeds as for the far-end canceller except that the responder returns by MF bursts the results of the previous step's measurement immediately after sending the MF priming burst requesting the next step conditions.

6.7.23 When testing of the near-end canceller is completed, the responder sends an MF burst indicating return of control to the director and applies test tone.

a) If testing only the near-end canceller disabler function has been requested, the director sends an MF priming instructing the responder to perform a series of operations while the director applies a quiet termination.

b) Upon receipt of the disabler test MF priming burst, the responder removes the test tone and applies for 800 ms the echo canceller disable signal (see § 9.4.1 c)). The responder then sends an MF priming burst and applies the noise test signal. Upon receipt of the MF priming burst, the director returns an MF confirmation burst and applies a 10 dB loss loop with no delay. Upon receipt of the MF confirmation burst, the responder continues the noise signal for 500 ms upon which the disabled near end canceller should take no action. The responder next makes a noise ratio measurement of the returned signal. The responder returns the result as MF bursts, preceded by an MF burst indicating return of control to the director, and awaits the next command. Upon receipt of these MF bursts, the director removes the 10 dB loss loop and pauses 500 ms to allow the canceller to become enabled.

c) If testing both near-end and far-end disablers has been requested, the sequence described in b) proceeds to the point where the 10 dB noise ratio value, measured with the near-end canceller disabled, has been returned by the responder. Since the far-end disabler is also to be tested, the responder returns test tone (with no pause) and awaits further director command.

d) Upon receiving the near-end disabler test result, the director removes the 10 dB loss loop (no delay) test condition, sends an MF burst requesting the 10 dB loop and applies the noise signal.

e) Upon receiving the command, the responder removes the test tone, provides a 10 dB loss loop (no delay), and returns a confirmation MF burst.

f) Upon receipt of the confirmation MF burst, the director continues the noise signal for 500 ms upon which the disabled far-end canceller should now take no action. The director then makes a noise ratio measurement of the returned signal (which should indicate no cancellation).

g) After making the measurement, the director pauses 500 ms to allow the canceller(s) to become enabled.

6.7.24 The director sends an MF priming burst instructing the responder to return to Layer 1. Note, at this point any CMS on the circuit may have been released during the 500 ms pause. (See Figures 2/O.22 and 3/O.22).

6.8 *Echo canceller test timing and error considerations*

6.8.1 *Automatic testing – director function*

6.8.1.1 If no response is received from the responder within 5 seconds of a prompt, send a return to Layer 1 MF command to the responder and report timeout.

6.8.1.2 If an MF burst is received that is out of sequence, undefined, or bad (e.g., more than two MF frequencies received) record an MF digit error condition, remain at current position in the test sequence, and restart the timeout timer. If correct MF is not received by the next timeout, report "MF error" and return to Layer 1. If correct MF is received, continue with normal sequence.

6.8.1.3 If an MF error report is received from the responder indicating that it has perceived receipt of an undefined, out-of-sequence, or bad MF digit, report that disposition, send a return to Layer 1 MF to the responder, and return to Layer 1.

6.8.2 *Automatic testing – responder function*

If an MF burst is out of sequence, undefined, or bad, send a "bad MF" report MF (Code 13) to the director and remain at current position in test sequence.

6.9 *Responder digital loopback test*

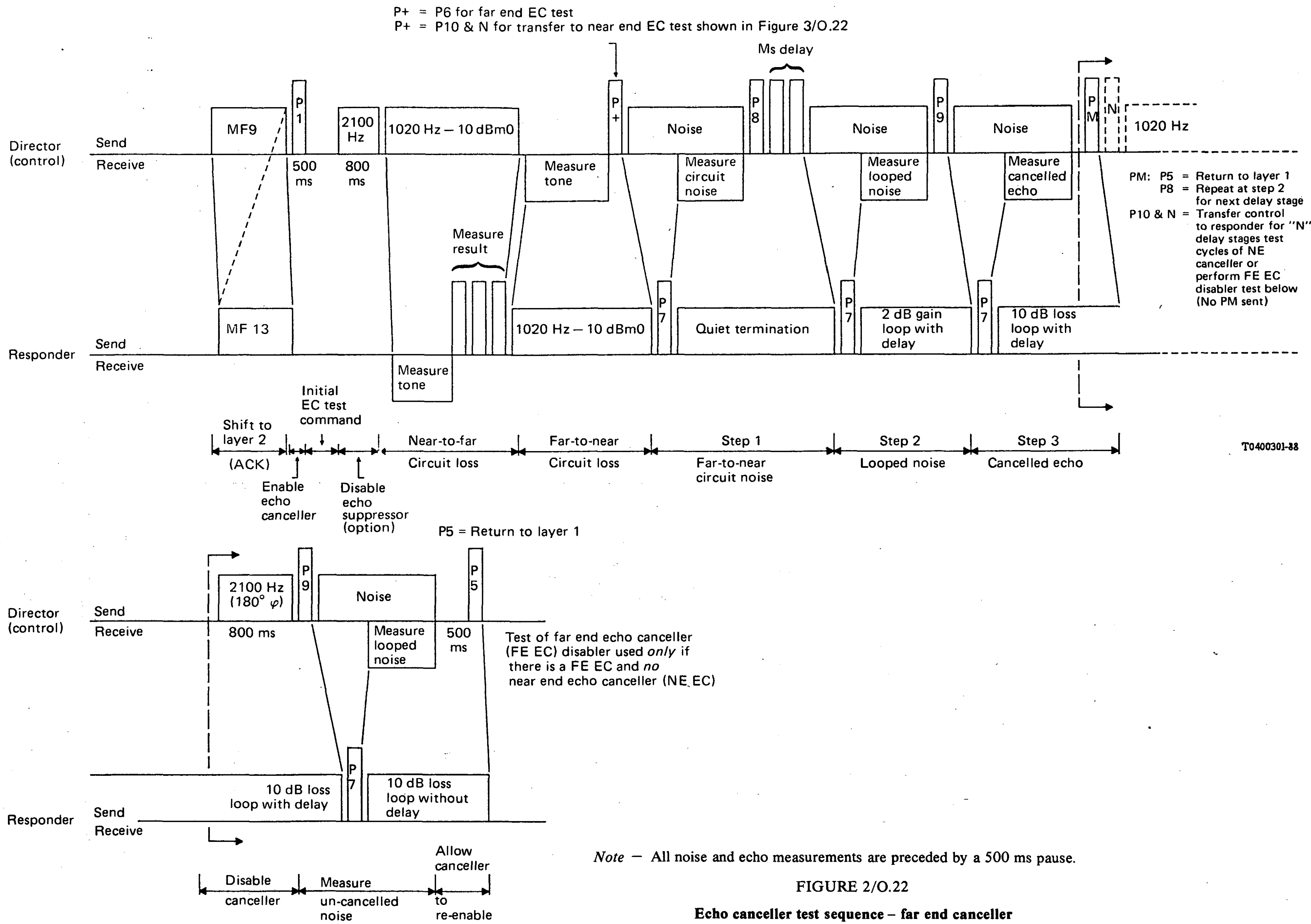
6.9.1 The director sends a Code 9 MF command to indicate that a Layer 2 cycle is being specified.

6.9.2 When the command signal is received by the responding equipment an MF command acknowledgement signal will be transmitted.

6.9.3 When the command acknowledgement signal is recognized by the directing equipment the command signal will be disconnected and a pulsed Code 3 MF command sent.

6.9.4 When the cessation of the command signal is recognized by the responding equipment the command acknowledgement signal is disconnected and the digital loopback is applied in response to the Code 3.

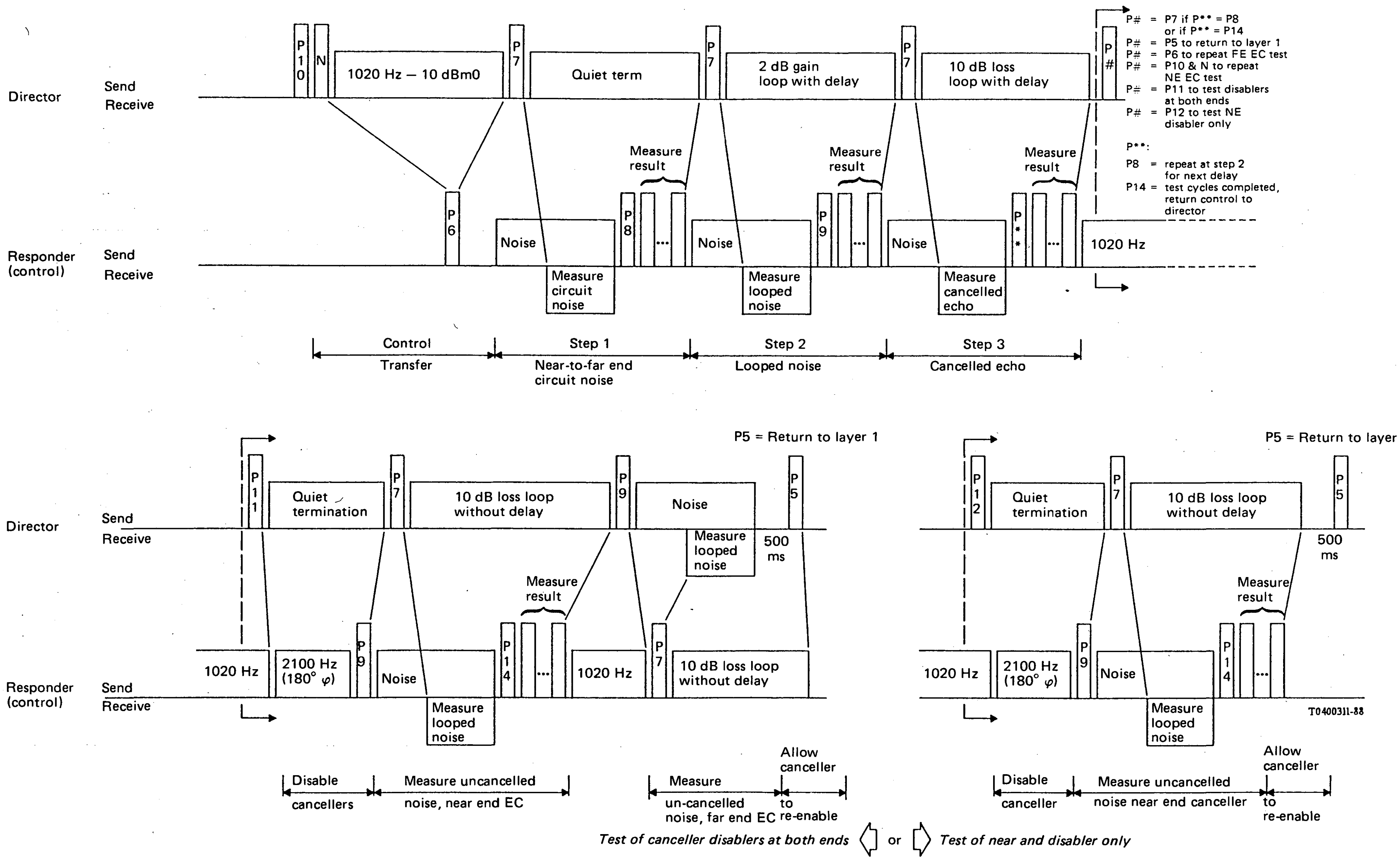
6.9.5 The directing equipment begins the test sequence by transmitting the digital test pattern and analyzing the looped return signal.



Note – All noise and echo measurements are preceded by a 500 ms pause.

FIGURE 2/O.22

Echo canceller test sequence – far end canceller



Note – All noise and echo measurements are preceded by a 500 ms pause.

FIGURE 3/O.22

Echo canceller test sequence – near end canceller

6.9.6 At the conclusion of the test, the director removes the test pattern and sends a Code 5 pulsed multi-frequency command instructing the responder to return to Layer 1. If a Code 5 is not received within 30 seconds of the application of the digital loopback, the responder will remove the digital loopback and return to Layer 1. However, the director may begin a new 30 second test interval by sending a pulsed multi-frequency Code 3 command instead of a Code 5 before the current 30 second interval has expired.

6.10 *System supervision*

6.10.1 Each MF 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.

6.10.2 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.

6.10.3 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 Description of tests to digital loopback test lines

7.1 The directing equipment shall be capable of making the following tests of measurements to a digital loopback test line as specified in Recommendation O.11. The type of test to be made will depend on the type of circuit under test. For all tests it is assumed that any echo suppressors or cancellers have been disabled before the start of the tests using the appropriate disabling tone and/or CMS locking tone (see § 6.4).

7.2 *Analogue tests on all circuit types*

The following tests can be made on analogue, composite digital/analogue and wholly digital circuits.

a) Looped received power at 1020 Hz

b) Looped received noise with and without the CMS locking tone

c) Looped signal-to-total distortion ratio with 1020 Hz test signal at -10 or -25 dBm0 depending on the requested test.

Note – Looped 400 and 2800 Hz measurements are not being specified.

7.3 *Digital tests on wholly digital circuits*

The directing equipment shall be capable of implementing bit integrity tests per Recommendation O.152 to a digital loopback test line for wholly digital circuits between digital exchanges. The interval between removal of the echo canceller/suppressor disabling tone and/or CMS locking tone is removed and application of the test tone or digital test pattern shall be 55 $\pm$ 5 ms. The results shall be capable of being expressed in terms of estimated percent error free seconds and of estimated bit error ratio. The length of test intervals shall be specified in seconds from 10 to 600 as an input parameter.

8 Programming

The directing equipment will be programmed by manual or automatic means 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) the location on the circuit of the echo cancellers: near-end, far-end or both ends;
4) sufficient address to identify the particular type of responding equipment at the incoming international exchange;
5) the measurements to be made, the nominal values, the assigned maintenance limits, and whether the canceller disabler tests are to be performed;

6) whether the results are to be recorded by the output equipment;

7) whether or not the date and time of the test should be recorded by the output equipment;

8) whether there should be a shortened record as described in § 3.7.

9 Specifications for transmission measuring apparatus and for disabling tones and locking tones

The equipment shall perform under the climatic conditions as shown in Recommendation O.3.

9.1 *Absolute power level measuring device*

9.1.1 *Sending equipment*

Level measurements:

Frequencies: 400 ± 5 Hz, 1020 +2, −7 Hz and 2800 ± 14 Hz.

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

Purity of output: ratio of total output to unwanted signal at least 36 dB.

Total distortion test signal:

Frequency: The nominal frequency of the total distortion test signal shall be 1020 Hz.[8] The frequency stability of the test signal shall be ± 2 Hz.

Absolute power level sent: −10 dBm0 ± 0.1 dB and −25 dBm0 ± 0.1 dB.

Purity of output: ratio of total output to unwanted signal at least 36 dB.

Impedance: 600 ohms balanced - earth free.

Longitudinal conversion loss (see Figure 1/O.9): At least 46 dB between 300 and 3400 Hz[9], [10].

Return loss:[11] greater than 46 dB at 1020 Hz and greater than 30 dB between 200 and 4000 Hz.

9.1.2 *Receiving equipment*

Frequency range: 390-2820 Hz.

Impedance: 600 ohms balanced - earth free.

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[9], [10].

Return loss:[11] greater than 46 dB at 1020 Hz and greater than 30 dB between 200 and 4000 Hz.

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, −10 dBm0 or −25 dBm0 (see § 6.3).

Accuracy (absolute): at 1020 Hz, ± 0.2 dB; at 400 and 2800 Hz, ± 0.2 dB referred to the 1020 Hz value.

Resolution (smallest measurement step): 0.1 dB.

9.2 *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

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[8] It is intended that only a single tone in the range 1020 +2, −7 Hz will be required and that it can be used for both 1020 Hz level and total distortion measurements.

[9] 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 concerned.

[10] 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.

[11] Return loss requirement for older equipment should conform to greater than 30 dB at each of the above sending equipment frequencies.

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 5/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.

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.9): 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:[15] greater that 46 dB at 1020 Hz and greater that 30 dB between 200 and 4000 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.

9.3 *Disabling and locking tones*

– Echo suppressor/canceller disabling tone: (CMS lock-up or CMS locking tone).

  Frequency: 2100 Hz ± 8 Hz.

  Level: −12 dBm0 ± 1 dB.

  The 2100 Hz tone should be periodically interrupted every 450 ± 25 ms by a 180 ± 5 degree phase shift. The interruption interval may be asynchronous with the beginning of the tone-on interval.

– CMS holding tone:

  Frequency: 2800 Hz ± 14 Hz.

  Level: −10 dBm0 ± 1 dB.

– For the two tones:

  Impedance: 600 ohms balanced - earth free.

  Input longitudinal interference loss (see Figure 5/O.9): at least 46 dB between 300 and 3400 Hz.[13), 14)]

  Return loss: greater than 46 dB at 1020 Hz and greater than 30 dB and 4000 Hz.

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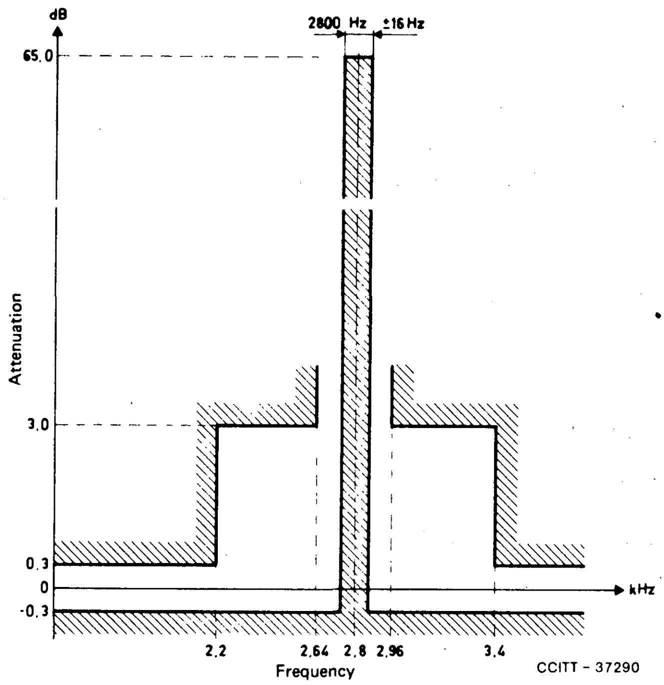
12) This is the same rejection filter characteristic as specified in Recommendation O.132.

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 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.

15) Return loss requirement for older equipment should conform to greater than 30 dB at each of the above sending equipment frequencies.



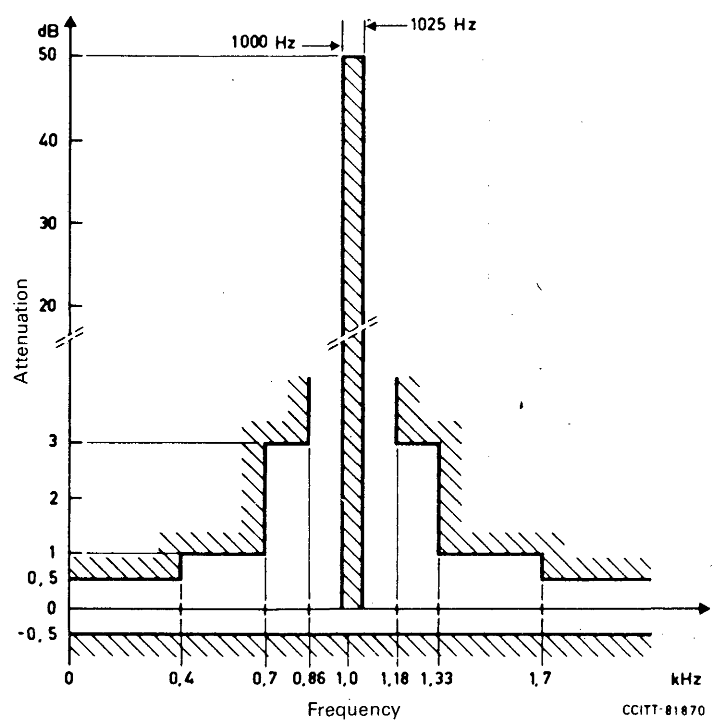
The difference between the loss/frequency characteristic with the 2800-Hz stop-filter inserted and the loss/frequency characteristic without the filter shall conform to the following limits:

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



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 5/O.22

Performance requirements for 1000-1025 Hz rejection filter

9.4 *ECTS sending apparatus of the directing and responding equipment*

9.4.1 *Signal and tone frequencies*

a) test tone: 1020 +2, −7 Hz

b) disable tone: 2100 Hz ± 8 Hz (echo suppressors and CMS)

c) disable tone for echo canceller: 2100 Hz ± 8 Hz. The 2100 Hz tone should be periodically interrupted every 450 ± 25 ms by a 180 ± 5 degree phase shift. The interruption interval may be asynchronous with the beginning of the tone-on interval.

d) CMS holding tone: 2800 Hz ± 14 Hz

e) noise signal: the noise test signal is obtained by passing a wideband quasi random noise source signal through a bandpass filter network meeting the requirements given in Table 6/O.22.

TABLE 6/O.22

Filter response

Frequency (Hz)	Loss [a] (dB)	Tolerance (dB)
⩽ 200	⩾ 30	–
300	21.8	± 2.3
560	3	± 0.4
750	0.2	± 0.2
1000	0	± 0.1
1500	0.1	± 0.2
1965	3	± 0.4
2400	10.9	± 1.2
3000	22.9	± 3.0
4000	42.6	± 5.0
⩾ 5000	⩽ 45	–

[a] Excluding any flat insertion loss.

9.4.2 *Signal and tone levels*

a) for loss measurements: −10 ± 0.1 dBm0

b) disable tone: −12 ± 1 dBm0

c) CMS holding tone: −10 ± dBm0

d) noise signal: −10 ± 5 dBm0

9.4.3 *Impedance*

600 ohms balanced with longitudinal conversion [16), 17)] loss (see Figure 1/O.9) of at least 46 dB between 300 and 3400 Hz. Return loss [18)] greater than 46 dB at 1020 Hz and greater than 30 dB between 200 and 4000 Hz.

[16)] 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 concerned.

[17)] 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.

[18)] Return loss requirement for older equipment should conform to greater than 30 dB at each of the above sending equipment frequencies.

9.4.4 *Purity of tone output*

Better than 30 dB.

9.4.5 *Loop characteristics*

a) value of loop delay, 0 to 75 ms ± 0.2 ms

b) loop gain 2.0 dB ± 0.1 dB

c) loop loss 10.0 dB ± 0.1 dB

9.5 *ECTS receiving apparatus of the directing and responding equipment*

9.5.1 *Measuring ranges*

a) for loss measurement: from 0 ± 0.1 dBm to −40 ± 0.1 dBm

b) for echo performance and noise measurement: from 0 to −65 dBm (± 1 dB to −55 dBm, ± 2 dB to −65 dBm) using a detector with response per Recommendation O.41, Table 1/O.41.

9.5.2 *Measuring interval*

500 ± 25 ms.

9.5.3 *Impedance*

600 ohms balanced with input longitudinal interference loss [19), 20)] (see Figure 5/O.9) of at least 46 dB between 300 and 3400 Hz. Return loss [21)] greater than 46 dB at 1020 Hz and greater than 30 dB between 200 and 4000 Hz.

9.6 *ECTS command signals exchanged between the directing equipment and the responding equipment*

Test sequence commands and responses exchanged between the directing and responding equipment will be pulse-type multifrequency (MF) signals. The signal sender and signal receiver are those specified for the CCITT No. 5 Interregister Signalling System per CCITT Recommendation Q.153 [7] and Q.154 [8]. The frequencies and the meaning of the codes are given in Table 7/O.22.

9.7 *Digital pattern generator and detector*

9.7.1 *Test pattern generator*

The test pattern generator shall utilize the pseudorandom test pattern specified in Recommendation O.152, § 2.

9.8 *Test pattern detector*

The detector is designed to measure the error performance of the 64 kbit/s digital path by the direct comparison of the received pseudorandom test pattern with an identical locally generated pseudorandom test pattern as specified in Recommendation O.152.

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19) 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 concerned.

20) 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.

21) Return loss requirement for older equipment should conform to greater than 30 dB at each of the above sending equipment frequencies.

TABLE 7/O.22

ECTS command signals between director and responder

Code No.	Frequency (Hz)	Meaning
1	700 + 900	Automatic test
2	700 + 1100	Reserved
3	900 + 1100	Spare
4	700 + 1300	Spare
5	900 + 1300	Return to Layer 1
6	1100 + 1300	Step 1 priming MF
7	700 + 1500	Request confirmation
8	900 + 1500	Step 2 priming MF
9	1100 + 1500	Step 3 priming MF
10	1300 + 1500	Request responder assume control
11	700 + 1700	Test disablers at both ends
12	900 + 1700	Test near-end disabler only
13	1100 + 1700	MF error condition
14	1300 + 1700	Control returned to director
15	1500 + 1700	Spare

10 Calibration

10.1 *Built-in calibration*

The accuracy desired from the ATME No. 2 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.

10.2 *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 may incorporate arrangements for making this self-check automatically.

11 Optional arrangements

11.1 *Automatic start*

In the long term, the operation of the ATME No. 2 without any attention by technical personnel will be desirable. The addition of timed automatic start facilities to the ATME No. 2 is required when unattended operation of the ATME No. 2 is intended.

11.2 *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.

11.3 *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 9 and not command Code 13.

11.4 *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 No. 2 equipment or to their operating and maintenance procedures.

11.5 *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 § 3.7).

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.

11.6 *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 [7] and Q.154 [8] respectively, as used in CCITT Signalling System No. 5.

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

The operating limits of the multi-frequency receiver give a minimum margin of ± 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:

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

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 dB about the nominal loss, whereas ATME No. 2 is capable of measuring deviations greater than these values (see § 9.1 of this Recommendation).

A.4 Although the specification for the multi-frequency signal receiver (Recommendation Q.154 [8]) stipulates that a received signal may vary ± 7 dB about the nominal receive level of −7 dBm0, Recommendation Q.154 [8] 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. In those cases where the multi-frequency receiver fails to operate the circuit test would still be recorded as mentioned in § 6.10.3 of this Recommendation.

References

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

[2] CCITT Recommendation *Echo Cancellers* Vol. III, Rec. G.165

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

[4] CCITT Recommendation *Error performance of an international digital connection forming part of an integrated services digital network,* Vol. III, Rec. G.821.

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

[6] CCITT Recommendation *Access points for International Telephone Circuits* Vol. IV, Rec. M.565.

[7] CCITT Recommendation *Multifrequency signal sender,* Vol. VI, Rec. Q.153.

[8] CCITT Recommendation *Multifrequency signal receiver,* Vol. VI, Rec. Q.154.

Recommendation O.25

SEMIAUTOMATIC IN-CIRCUIT ECHO SUPPRESSOR TESTING SYSTEM (ESTS)

(Geneva, 1976; amended Melbourne, 1988)

1 General

The CCITT semiautomatic *in-circuit* echo suppressor testing system 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 $\pm$ 10 ms. If the test tone is within $\pm$ 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 $\pm$ 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 $\pm$ 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 *Output impedance* (frequency range 300 Hz to 4 kHz)

– Balanced, earth free . . . . 600 ohms
– Return loss . . . . ⩾ 30 dB
– Output signal balance . . . . ⩾ 40 dB

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 *Input impedance* (frequency range 300 Hz to 4 kHz)

– Balanced, earth free . . . . 600 ohms
– Return loss . . . . ⩾ 30 dB
– Input longitudinal interference loss . . . . ⩾ 46 dB

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 ear and artificial mouth*, 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.

IN-STATION ECHO CANCELLER TEST EQUIPMENT

(Melbourne, 1988)

1 General

The in-station echo canceller test equipment (ISET) is intended to test type C and D echo cancellers including tone disablers as specified in Recommendation G.165 [1]. Two test modes are provided as described below. The tests performed in each test mode are listed in Table 1/O.27.

2 Test modes

2.1 *Routine test mode*

In this test mode, ISET provides 7 simplified tests of echo canceller performance under normal circuit conditions with the adaptation and non-linear processing logic activated. Access to the echo canceller being tested is on a 4-wire basis, and these simple performance tests are made by applying test signals to the receive-in (R_{in}) and the send-in (S_{in}) ports of the echo canceller. Test results are measured at the send-out (S_{out}) port. A functional block diagram of the test arrangement is shown in Figure 1/O.27.

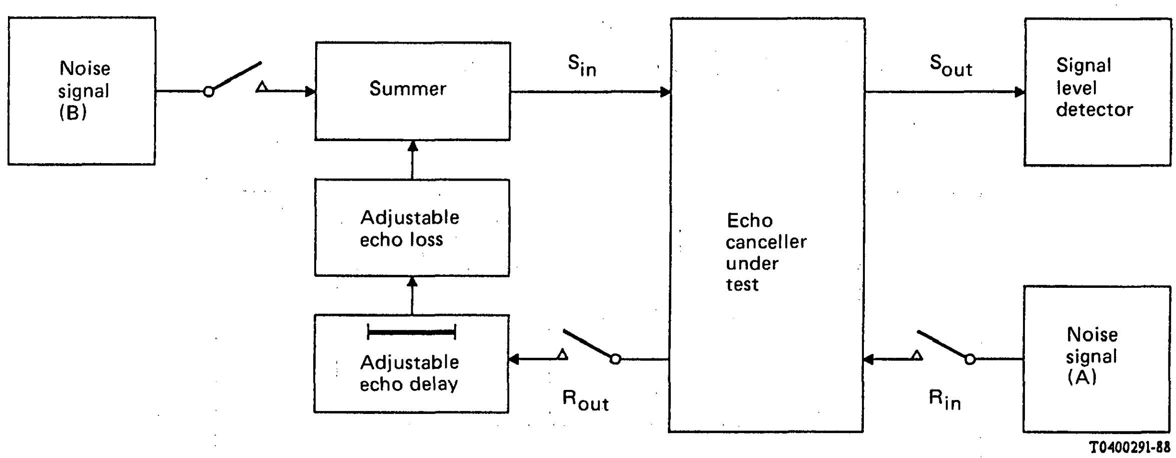

FIGURE 1/O.27

Functional block diagram of test arrangement

2.2 *Diagnostic test mode*

In this mode, all performance tests are made according to procedures specified in Recommendation G.165 [1]. The adaptation and non-linear processing logic is disabled when necessary by controlling the echo canceller that is being tested.

3 Operating principles

3.1 *Method of access*

When an echo canceller to be tested is fitted to a particular circuit, a reserved echo canceller should be substituted so that the tests can be made without causing any disturbance to the circuit. If no reserved echo canceller is available, the circuit should be blocked from service while the tests are being performed.

ISET may be connected to an echo canceller under test either manually at local access points or remotely by access arrangements through a switching system. Administrations may wish to provide remote access capability to echo cancellers for routine tests as shown in Figure 2/O.27. Local access as shown in Figure 3/O.27 is for diagnostic tests where the use of control signals to inhibit the H register, adaptation and center clipper logic are needed.

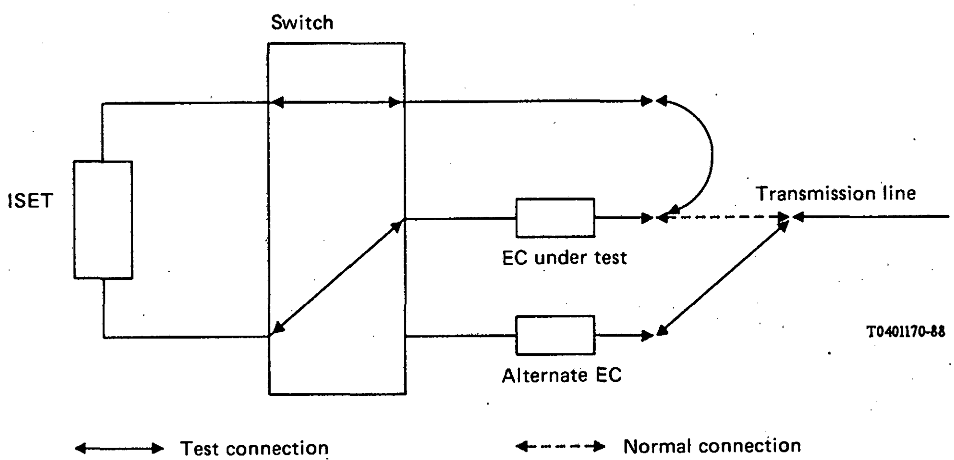

FIGURE 2/O.27

Configuration for routine test mode

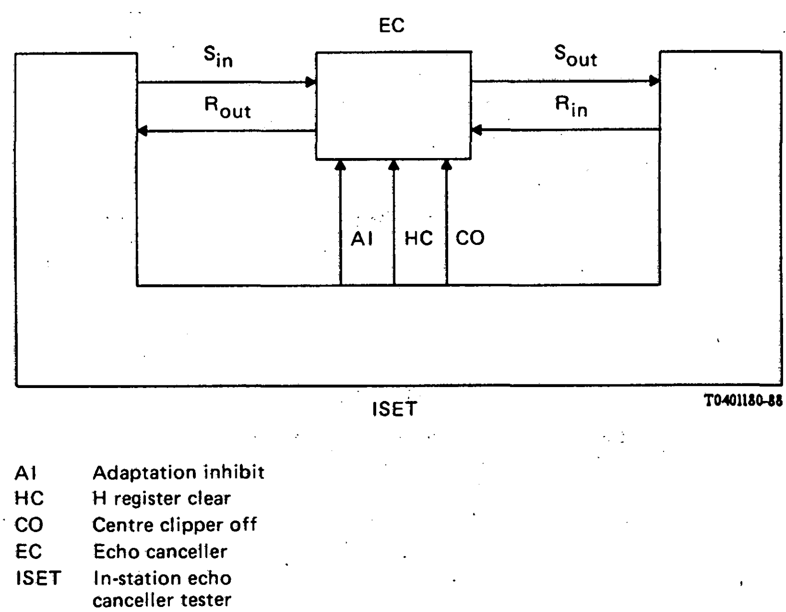

FIGURE 3/O.27

Configuration for diagnostic test mode

3.2 *Testing sequences*

When access has been established, a series of tests is performed manually or automatically. The tests to be performed in the routine and diagnostic test modes are given in Table 1/O.27. Measurement results for each test shall be provided to the maintenance personel by a visual display or printed message.

If an echo canceller fails any of the routine tests, it should be completely tested in the diagnostic test mode.

TABLE 1/O.27

Test Procedures

No.	Type of Test	G.165 [1] Reference	Test modes	
			Routine	Diagnostic
1	Steady state residual and returned echo level test	3.4.2.1	0	0
2	Convergence test	3.4.2.2	0	0
3	Double talk detection oversensitivity test	3.4.2.3.1	0	0
4	Double talk detection undersensitivity test	3.4.2.3.2	0	0
5	Leak rate test	3.4.2.4		0
6	Infinite return loss convergence test	3.4.2.5	0	0
7	Tone disabler send side sensitivity test	4.2	0	0
8	Tone disabler receive side sensitivity test	4.2	0	0
9	Tone disabler guard band test	4.3		0
10	Tone disabler holding band test	4.4		0
11	Tone disabler operate time test	4.5		0
12	Tone disabler release time test	4.8		0
13	External disabler control test	3.3		0

4 Test procedures and test requirements

4.1 *Routine test mode*

Figure 1/O.27 shows a functional arrangement for the routine test mode. The following seven tests should be repeated with an appropriate echo path delay Δ ms[1)] set in the adjustable echo delay unit.

At the beginning of each of the seven tests, a conditioning tone is applied for 1 second to the R_{in} port for initialization of the echo canceller to be tested. The conditioning tone is a 2100 Hz signal of -10 dBm0 with periodic phase reversals occurring every 0.45 seconds and is also used to disable echo cancellers. During this initialization period the H register of the canceller is cleared. After the conditioning tone is disconnected, no signal is applied to the canceller for at least 0.4 seconds to allow it to return to an enabled state. Further information on the characteristics of echo canceller tone disablers may be found in § 4 and Annex B of Recommendation G.165 [1].

4.1.1 *Check of steady state residual and returned echo level*

Step 1: A random noise signal (A) of -10 dBm0 is applied to the R_{in} port. With the echo path loss set at 10 dB, an echo appears at the S_{in} port.

Step 2: After 2 seconds the returned echo level at the S_{out} port is measured.

Requirement: The returned echo level must be less than -65 dBm0.

4.1.2 *Check of convergence*

Step 1: A random noise signal (A) of -10 dBm0 is applied to the R_{in} port. With the echo path loss set at 6 dB, an echo is appears at the S_{in} port.

Step 2: A second random noise signal (B) of -10 dBm0 is applied to the S_{in} port as shown in Figure 1/O.27.

Step 3: After 0.5 seconds noise signal (B) is disconnected, and 0.5 seconds later the returned signal level at the S_{out} port is measured.

Requirement: The signal level must be less than -37 dBm0.

4.1.3 *Check of double talk detection oversensibility*

Step 1: A random noise signal (A) of -10 dBm0 is applied to the R_{in} port. With the echo path loss set as 6 dB, an echo appears at the S_{in} port.

Step 2: After 0.5 seconds, a second random noise signal (B) of -25 dBm0 is applied to the S_{in} port.

Step 3: One second later noise signal (B) is disconnected and the returned echo level at the S_{out} port is measured.

Requirement: The returned echo level must be less than -25 dBm0.

4.1.4 *Check of double talk detection undersensitivity*

Step 1: With the echo path loss set at 10 dB, a random noise signal (A) of -10 dBm0 is applied to the R_{in} port.

Step 2: After 1 second the noise signal (A) at the R_{in} port is disconnected.

Step 3: After an interval of 0.5 seconds, the noise signal (A) is reapplied to the R_{in} port. Simultaneously a second noise signal (B) of 0 dBm0 is applied to the S_{in} port.

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1) Different echo cancellers may be designed to work satisfactorily for different echo path delays depending on their application in various networks. Thus Δ represents the echo path delay for which the echo canceller is designed. Each Administration may choose a delay value of Δ appropriate for their equipment.

Step 4: 0.5 seconds later the noise signal (B) is disconnected and the residual echo level at the S_{out} port is measured.

Requirement: The returned echo level must be less than -26 dBm0.

4.1.5 *Check of infinite return loss convergence*

Step 1: With the echo path loss set at 6 dB, a random noise signal (A) of -10 dBm0 is applied to the R_{in} port.

Step 2: After 1 second the echo path between R_{out} and S_{in} is disconnected while noise signal (A) remains connected to the R_{in} port.

Step 3: 0.5 seconds later the returned echo level at the S_{out} port is measured.

Requirement: The returned echo level must be less than -37 dBm0.

4.1.6 *Check of tone disabler send-side sensitivity*

There are two parts to this test to ensure that the disabler tone detection circuit on the send side is not oversensitive or undersensitive.

Step 1: A 2100 Hz signal of -36.5 dBm0 with periodic phase reversals every 0.45 seconds is applied for one second to the S_{in} port.

Step 2: A random noise signal (A) of -10 dBm0 is applied to the R_{in} port.

Step 3: After 0.5 seconds the returned echo level at the S_{out} port is measured.

Requirement: The returned echo level must be less than -32 dBm0 to show that the disabler is not operated.

Step 4: The conditioning tone is reapplied for one second to the R_{in} port. After at least 0.4 seconds, the 2100 Hz signal with periodic phase reversals every 0.45 seconds is reapplied to the S_{in} port at a level of -29.5 dBm0 for one second.

Step 5: Then the random noise signal (A) of -10 dBm0 is reapplied to the R_{in} port with the echo path loss set at 10 dB.

Step 6: After 0.5 seconds the returned echol level at the S_{out} port is measured.

Requirement: The returned echo level must be between -29.5 dBm0 and -26.5 dBm0 to show that the disabler is operated.

4.1.7 *Check of tone disabler receive-side sensitivity*

There are also two parts to this test to ensure that the disabler tone detection on the receive side is not oversensitive or undersensitive.

Step 1: A 2100 Hz signal of -36.5 dBm0 with period periodic phase reversals every 0.45 seconds is applied for one second to the R_{in} port.

Step 2: A random noise signal (A) of -10 dBm0 is applied to the R_{in} port. With the echo path loss set at 10 dB, an echo appears at the S_{in} port.

Step 3: After 0.5 seconds the returned echo level at the S_{out} port is measured.

Requirement: The returned level must be less than -32 dBm0 to show that the disabler is not operated.

Step 4: The conditioning tone is reapplied for one second to the R_{in} port. After at least 0.4 seconds, the 2100 Hz signal with periodic phase reversals every 0.45 seconds is reapplied to the S_{in} port at a level of -29.5 dBm0 for one second.

Step 5: Then the random noise signal (A) of -10 dBm0 is reapplied to the R_{in} port with the echo path loss set at 10 dB.

Step 6: After 0.5 seconds the returned echo level at the S_{out} port is measured.

Requirement: The returned echo level must be between -29.5 dBm0 and -26.5 dBm0 to show that the disabler is operated.

4.2 *Diagnostic test mode*

In this mode diagnostic tests are performed as specified in Recommendation G.165. § 3.3.2 and § 4 [1].

5 Specifications for transmission measuring equipment

The following specifications apply for climatic conditions specified in Recommendation O.3.

5.1 *Signal generator*

5.1.1 *Range of frequency*

0.3 to 3.4 kHz in 0.01 kHz steps.

5.1.2 *Range of level*

−40 tò 0 dBm0 in 0.1 dB steps.

5.1.3 *Accuracy*

Frequency	± 0.01 kHz
Level	± 0.1 dB.

5.2 *Level meter*

5.2.1 *Range of measurement*

−70 to + 3.2 dBm0.

5.2.2 *Accuracy*

± 0.1 dB (above −40 dBm0).

5.2.3 *Dynamic response time*

Under study [2)].

5.3 *Random noise source*

5.3.1 *Level*

−40 to + 0 dBm0.

5.3.2 *Noise signal*

The noise test signal is a band-limited white noise (300-3400 Hz).

5.4 *Echo path*

5.4.1 *Echo loss*

0 dB to 40 dB in 0.1 dB steps.

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2) A meter with a rapid response time will be needed to meet the timing requirements of some of the tests specified above.

5.4.2 *Echo delay*

0 to Δ ms[3] in 1 ms steps.

5.4.3 *Bandwidth*

0.3 to 3.4 kHz.

6 Calibration

6.1 *Calibration of measuring equipment*

Calibration features should be provided to check that the accuracy requirements are met.

6.2 *Self-check of operational function*

A local self-checking facility should be provided to make sure that the testing functions are operating properly.

7 Optional arrangements

7.1 *Automatic test function*

A function to perform tests in sequence automatically according to the predetermined procedure, may be provided.

7.2 *Automatic start function*

A timed automatic start function which enables the unattended operations, may be provided.

References

[1] CCITT Recommendation *Echo Cancellers*, Vol. III, Rec. G.165.

[3] Different echo cancellers may be designed to work satisfactorily for different echo path delays depending on their application in various networks. Thus Δ represents the echo path delay for which the echo canceller is designed. Each Administration may choose a delay value of Δ appropriate for their equipment.

AUTOMATIC MEASURING EQUIPMENT FOR SOUND-PROGRAMME CIRCUITS

(Geneva, 1972; amended at Geneva, 1976)

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.

---

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 [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:

  0.18 kHz filter: ± 3 Hz
  1.6 kHz filter: ± 24 Hz
  } 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 [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 Supplement No. 3.1 at the end of this fascicle.

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

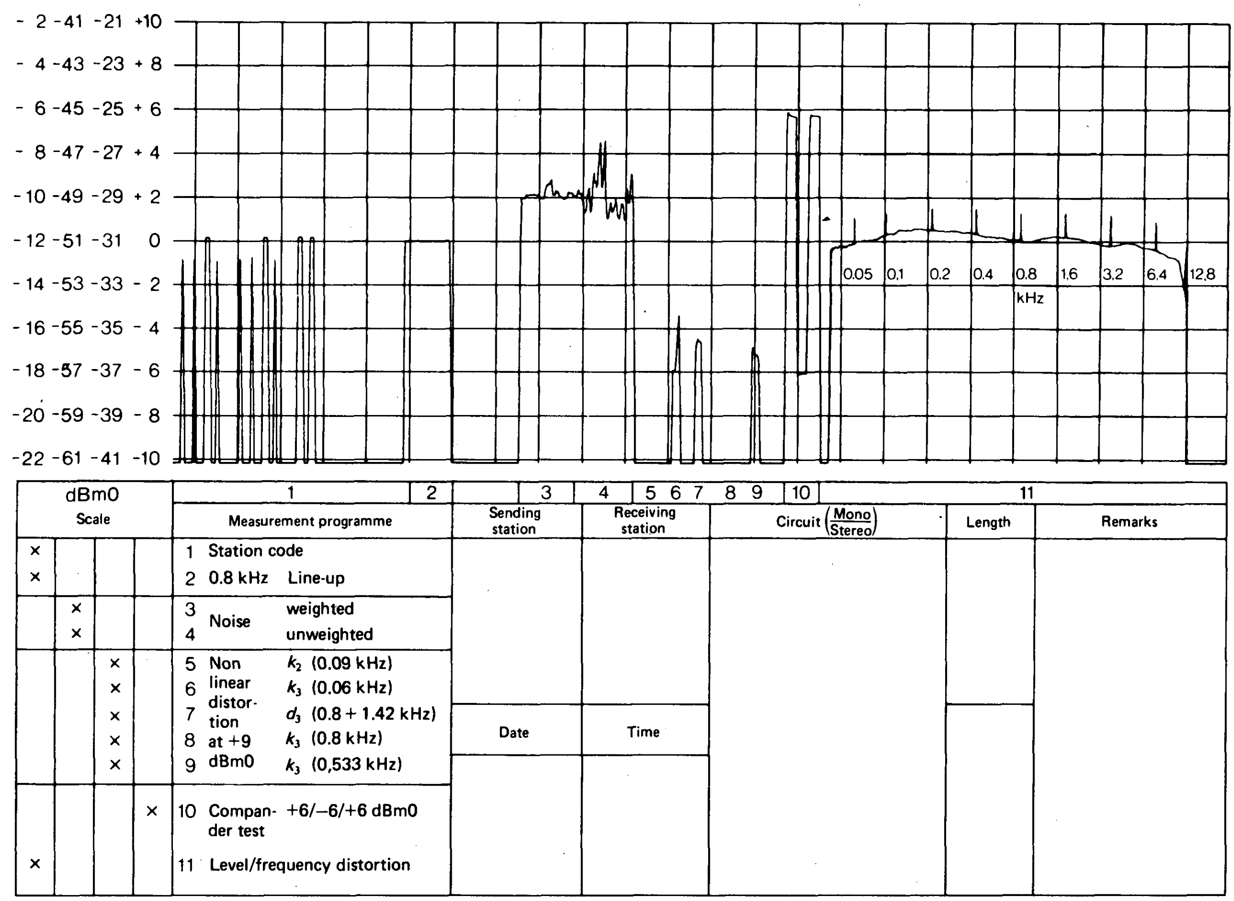
(See in the following appendix an example of the record of measurements made by a typical model of the automatic measuring equipment)

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



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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, ITU, Geneva, 1986.

AUTOMATIC MEASURING EQUIPMENT FOR STEREOPHONIC PAIRS OF SOUND-PROGRAMME CIRCUITS

(Geneva, 1972)

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 [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								
Mains 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

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).

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 [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 ($= 2 \times 1.42$ 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:

  $\left.\begin{array}{l}\text{0.18 kHz filter: } \pm\ 3 \text{ Hz} \\ \text{1.6 kHz filter: } \pm\ 24 \text{ Hz}\end{array}\right\}$ referred to 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 *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 [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 Supplement No. 3.1 at the end of this fascicle.

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			Receiving unit		
		Frequency (kHz)	Level (dBm0)	Loaded channel	Measuring function	Channel	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: Frequency (kHz)	Sending unit: Level (dBm0)	Sending unit: Loaded channel	Receiving unit: Measuring function	Receiving unit: Channel	Receiving unit: 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, ITU, Geneva, 1986.

[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.

Recommendation O.33

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

(Malaga-Torremolinos, 1984; amended at Melbourne, 1988)

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.

It should be noted that the equipment will meet the requirements of Recommendations N.12 [1] and N.13 [2]. However, measurement of every parameter specified in Recommendations N.10 [3], N.21 [4] and N.23 [5] is not possible, e.g., group delay/frequency response.

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 [6] at a standard RS 232-C [7] interface, selectable between 110 and 300 bauds, or optionally, at a standard IEEE 488/IEC 625 [8] 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 [9];

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) [10]. 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 [11].

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 [6] 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 [7] or IEEE 488/IEC 625 [8] 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 [12].

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 [4]. 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.

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 [9]. 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*

820 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 [4], 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:	⩽ −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 [13] 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 [9].

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 Operating equipment

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

[2] Value does not take account of any transformer needed to comply with the requirements of Recommendation N.11 [13] 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		Programme number: 00
	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	Start/source/programme 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	1 900	−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	820	+6	Compandor test
1	820	−6	
1	820	+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		Programme number: 01
Seconds	Frequency (Hz)	Level (dBm0)	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	–	–	Start/source/programme 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	1 900	−12	1 900	−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	
1 [a]	–	–	–	–	Total harmonic distortion
1	60	+9	60	+9	
1	2 040	−12	–	–	Crosstalk and circuit transposition
1	–	–	2 040	−12	
1	820	+6	820	+6	
1	820	−6	820	−6	Compandor test
1	820	+6	820	+6	
8	–	–	–	–	Signal-to-noise ratio

[a] Waiting interval.

ANNEX C

(to Recommendation O.33)

Measurement sequence for medium band sound-programme circuits

Time interval (Secs.)	Sending unit		Programme number: 02
	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	Start/source/programme identification
1	1 020	0	Received level
1	1 020	−12	Frequency response
1	40	−12	
1	80	−12	
1	200	−12	
1	300	−12	
1	500	−12	
1	820	−12	
1	1 400	−12	
1	3 000	−12	
1	5 000	−12	
1	6 300	−12	
1	7 400	−12	
1	8 020	−12	
1	10 000	−12	
1	1 020	+9	Total harmonic distortion
1	–	–	
1	60	+9	
1	820	+6	Compandor test
1	820	−6	
1	820	+6	
8	–	–	Signal-to-noise ratio

ANNEX D

(to Recommendation O.33)

Measurement sequence for narrow-band (telephone type) circuits

Time interval (Secs.)	Sending unit		Programme number: 03
	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	Start/source/programme identification
1	1 020	0	Received level
1	1 020	−10	Frequency response
1	200	−10	
1	300	−10	
1	400	−10	
1	600	−10	
1	820	−10	
1	1 400	−10	
1	1 900	−10	
1	2 400	−10	
1	2 700	−10	
1	2 900	−10	
1	3 000	−10	
1	3 100	−10	
1	3 400	−10	
1	1 020	+9	Total harmonic distortion
8	–	–	Signal-to-noise ratio

ANNEX E

(to Recommendation O.33)

Measurement sequence for narrow-band (telephone-type) circuits used for sound-programme transmissions which are fitted with compandors

Time interval (Secs.)	Sending unit		Programme number: 04
	Frequency (Hz)	Level (dBm0)	Measuring function
1	1650/1850	−12	Start/source/programme identification
1	1 020	0	Received level
1	1 020	−10	Frequency response
1	200	−10	
1	300	−10	
1	400	−10	
1	600	−10	
1	820	−10	
1	1 400	−10	
1	1 900	−10	
1	2 400	−10	
1	2 700	−10	
1	2 900	−10	
1	3 000	−10	
1	3 100	−10	
1	3 400	−10	
1	1 020	+9	Total harmonic distortion
1	820	+6	Compandor test
1	820	−6	
1	820	+6	
8	–	–	Signal-to-noise ratio

ANNEX F

(to Recommendation O.33)

Measurement sequence for the CMTT three-level test signals (without station announcement) for the alignment of international sound-programme connections

Time interval	Channel A sending unit		Channel B sending unit		Programme number: 05
Seconds	Frequency (Hz)	Level (dBm0)	Frequency (Hz)	Level (dBm0)	Measuring Function
1	1650/1850	−12	–	–	Start/Source/Programme identification
1	–	–	–	–	Pause
1	1 020	−12	1 020	−12	Measurement level (ML)
1	1 020	−12	1 020	−12	
1	1 020	0	1 020	0	Alignment level (AL)
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0	1 020	0	
1	1 020	0 [a]	–	–	Permitted maximum [a] level (PML)
1	1 020	0 [a]	–	–	
1	–	–	–	–	Pause
1	–	–	–	–	
1	–	–	–	–	
1	–	–	1 020	0 [a]	Permitted maximum [a] level (PML)
1	–	–	1 020	0 [a]	

[a] Provisionally 0 dBm0 level is to be used. The resulting two-level test signal is required until all transmission systems are capable of carrying sinusoidal signals at +9 dBm0s without producing excessive channel loading or crosstalk into other channels. The active incorporation of the +9 dBm0 level into this sequence will need to be confirmed by CMTT and CCITT.

References

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

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

[3] CCITT Recommendation *Limits for the lining-up of international sound-programme links and connections*, Vol. IV, Rec. N.10.

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

[5] CCITT Recommendation *Maintenance measurements to be made on international sound-programme circuits*, Vol. IV, Rec. N.23.

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

[7] 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.*

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

[9] CCIR Recommendation *Measurement of audio-frequency noise in sound broadcasting*, Vol. X, Rec. 468, ITU, Geneva, 1986.

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

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

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

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

SECTION 4

EQUIPMENT FOR THE MEASUREMENT OF ANALOGUE PARAMETERS

Recommendation O.41

PSOPHOMETER FOR USE ON TELEPHONE-TYPE CIRCUITS

(Geneva, 1972; amended at Malaga-Torremolinos, 1984, and at Melbourne, 1988)

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.

Annex A 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 ≥ 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 $\pm$ 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	$\pm$ 0.5 dB
-60 to -90 dBm	$\pm$ 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 $\pm$ 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. If provided, this filter shall have the characteristics of Table 2/O.41.

For the measurement of AC hum interference on telephone-type circuits an optional low pass filter with a cut-off frequency at approximately 250 Hz and an attenuation of $\geqslant$ 50 dB at 300 Hz may be provided.

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 $\pm$ 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.

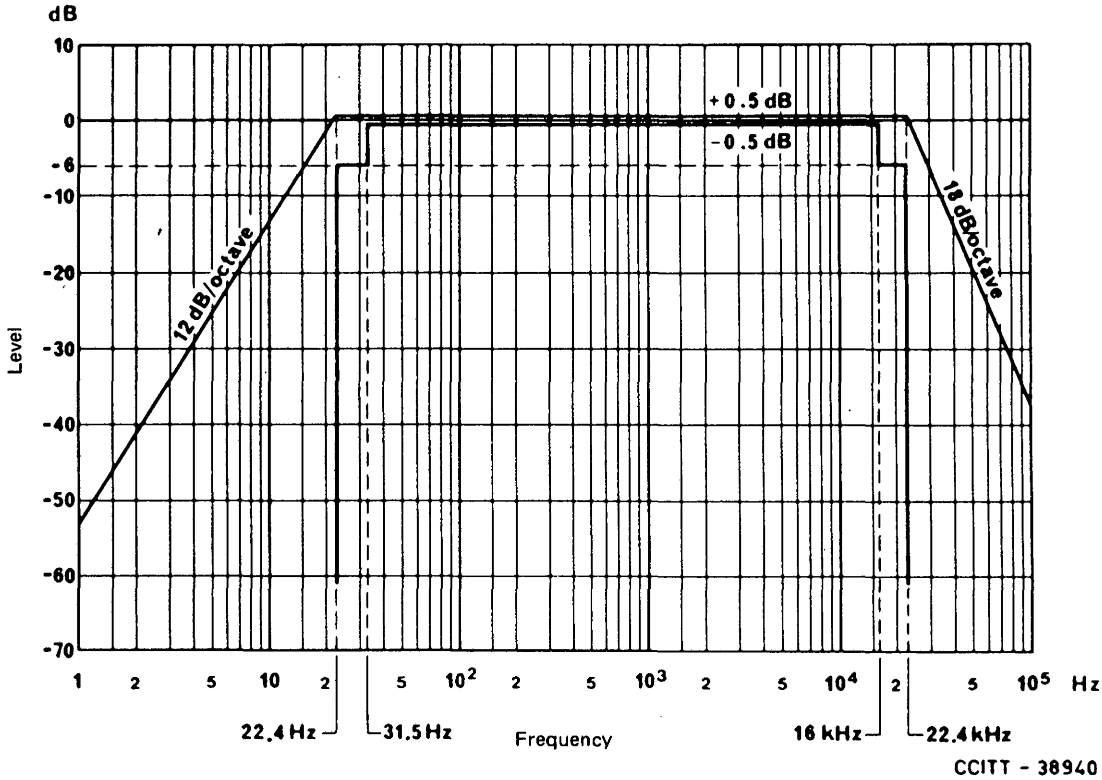

FIGURE 1/O.41

Frequency response characteristics for unweighted measurements

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	–

TABLE 2/O.41

Characteristics of the optional flat fitter with an equivalent noise bandwidth of 3.1 kHz (bandwidth of a telephone channel)

Frequency	Attenuation
< 300 Hz	increasing 24 dB/octave, (Note 1)
300 Hz	approx. 3 dB (Note 2)
400-1020 Hz	⩽ ± 0.25 dB
1020 Hz	0 dB
1020-2600 Hz	⩽ ± 0.25 dB
3400 Hz	approx. 3 dB (Note 2)
> 3400 Hz	increasing 24 dB/octave, (Note 1)

Note 1 – Below 300 Hz and above 3400 Hz the attenuation shall increase at a slope not less than 24 dB/octave up to an attenuation of at least 50 dB.

Note 2 – The exact cutoff frequency shall be chosen to achieve an equivalent noise bandwidth of 3.1 kHz ± 155 Hz.

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 response time for the detector and indicating means shall meet one or both of the following requirements:

3.7.1 *Instrumentation with continuous signal monitoring*

The application of an 800 Hz sinusoidal signal with a duration of 150 to 250 ms 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.

When performing this test the reading error shall be less than ± 0.2 dB.

[1] See Annex A to this Recommendation.

3.7.2 *Instrumentation with non-continuous signal monitoring*

With the application of bursts of 800 Hz tone to the input of the psophometer, gated at a duty cyle of 50%, with half the cycle at full amplitude and the other half down 8.4 dB from full amplitude, the ouput device shall indicate a variation as shown in Table 3/O.41. The levels should be chosen to avoid autoranging points.

TABLE 3/O.41

Variation of the output indication with the application of specified bursts of 800 Hz at the input of the psophometer

Gating frequency	Peak-to-Peak Indicator variation
25 Hz 5 Hz	$\leq$ 1 dB $\geq$ 3 dB

It is permissible to adjust the total input power with a 1 dB vernier control to a point where the display does not change so as to pass the less than 1 dB requirement.

3.7.3 *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 $\pm$ 0.5 dB, for all ranges of the instrument.

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

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.

Another weighting frequently used for measuring telephone circuit noise impairment within the North American domestic telephone networks is referred to as "3 kHz Flat" weighting [1]. This weighting is intended for the investigation of the presence of low-frequency noise (power induction, etc.) on the circuit under test. It is characterized as a 3 kHz low-pass weighting of Butterworth shape attenuating above 3 kHz at 12 dB per octave. The specification for this weighting is given in Table A-2/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.

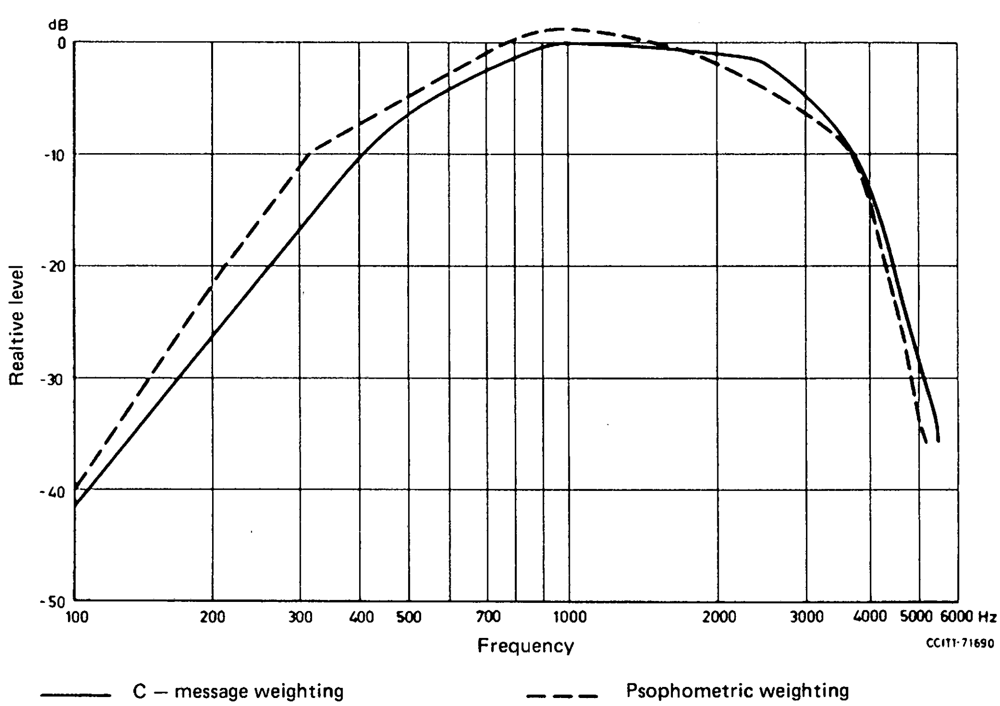

FIGURE A-1/O.41

Comparison between psophometric and C-message weighting

TABLE A-2/O.41

3 kHz flat weighting characteristic

Frequency (Hz)	30	60	400	1000	2000	3000	6000
Relative loss (dB)	0	0	0	0	0.8	3.0	12.3 [a)]
Tolerance (dB)	± 2.5	± 1.7	± 0.5	± 0.2	± 1.0	± 1.8	± 3.0

[a)] The loss shall continue to increase above 6000 Hz at a rate of not less than 12 dB per octave until it reaches a value of 60 dB. The loss at higher frequencies shall be at least 60 dB.

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

EQUIPMENT TO MEASURE NONLINEAR DISTORTION USING THE 4-TONE INTERMODULATION METHOD

(Malaga-Torremolinos, 1984)

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:

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

where:

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

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

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:

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

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

Recommendation O.51

VOLUME METERS

(Geneva, 1972)

(For the text of this Recommendation see Recommendation P.52 [1] of Volume V and for information on other volume indicators, see Table 1/J.15 of Recommendation J.15 [2])

References

[1] CCITT Recommendation *Volume meters*, Vol. V, Rec. P.52.

[2] CCITT Recommendation *Lining-up and monitoring an international sound-programme connection*, Vol. III, Rec. J.15.

Recommendation O.61

SIMPLE EQUIPMENT TO MEASURE INTERRUPTIONS ON TELEPHONE-TYPE CIRCUITS

(Geneva, 1972; amended at Geneva, 1980, and at Melbourne, 1988)

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 § 4).

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

2.4 *Input impedance* (frequency range 300 Hz to 4 kHz)

– balanced, earth free.

– Input longitudinal interference loss . . . . ⩾ 46 dB

2.4.1 *Terminating impedance* (other impedances optional) . . . . 600 ohms

– Return loss . . . . ⩾ 30 dB

2.4.2 *High impedance* . . . . approx. 20 kohms

– Bridging loss across 300 ohms . . . . ⩽ 0.15 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 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.

5 Operating environment

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

Recommendation O.62

SOPHISTICATED EQUIPMENT TO MEASURE INTERRUPTIONS ON TELEPHONE-TYPE CIRCUITS

(Geneva, 1972; amended at Melbourne, 1988)

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. (See also § 4.)

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 4 kHz)

– Balanced, earth free.

– Input longitudinal interference loss . . . . ≥ 46 dB

2.3.4 *Terminating impedance* (other impedances optional) . . . . 600 ohms

– Return loss . . . . ≥ 30 dB

2.3.5 *High impedance* . . . . approx. 20 kohms

– Bridging loss across 300 ohms . . . . ≤ 0.15 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.

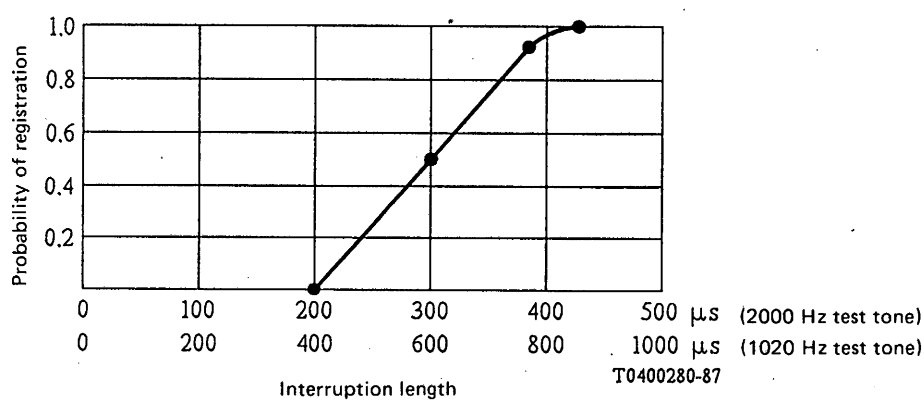

FIGURE 1/O.62

Probability curve for the detection of an interruption

2.6 *Visual indication*

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

3 Display of measurement results

3.1 *Interruption counters*

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

a) 0.3 ms (0.6) ms-3ms (optional, see Note),

b) 3 ms-30 ms,

c) 30 ms-300 ms,

d) 300 ms-1 min,

e) 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.

Note – The value of 0.6 ms applies to the 1020 Hz test tone.

3.2 *Relative duration of interruption events* (optional)

To allow an easier estimation of data transmission errors which may result from interruptions, the instrument shall provide means to calculate and indicate the relative duration of interruption events. This quantity is the ratio of the time where the test tone is below a designated threshold to the total measurement time. Interruptions between 3 ms and 1 minute shall be taken into account. Results shall be indicated in a range 1×10^{-1} to 1×10^{-8}.

3.3 *Seconds containing an interruption* (optional)

As a further option, the instrument shall provide means to calculate and indicate the percentage of seconds containing one or more interruptions of a duration $\geqslant$ 3 ms. Results shall be indicated in a range 0 to 100% with one digit after the decimal point.

3.4 *Power failure*

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

4 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 kHz +2 −7 Hz (see Recommendation O.6), 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.

5 Operating environment

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

Recommendation O.71 [1)]

IMPULSIVE NOISE MEASURING EQUIPMENT FOR TELEPHONE-TYPE CIRCUITS

(Geneva, 1972; amended Geneva, 1976 and Melbourne, 1988)

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.

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

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* (frequency range 300 Hz to 4 kHz)

- Balanced, earth free
- Input longitudinal interference loss . . . . ⩾ 46 dB

3.1.1 *Terminating impedance* (other impedances optional) . . . . 600 ohms

- Return loss . . . . ⩾ 30 dB

3.1.2 *High impedance* . . . . approx. 20 kohms

- Bridging loss across 300 ohms . . . . ⩽ 0.15 dB

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.

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.

For measurements of impulsive noise with a 1020 Hz test signal (see Recommendation O.6) applied to the circuit under test, a notch filter at 1020 Hz shall be provided as an option. This filter shall have the characteristics given in Table 1/O.71.

TABLE 1/O.71

Characteristics of the notch fitter

Frequency (Hz)	Attenuation (dB)
< 400 > 1700	< 0.5
< 700 > 1330	< 1.0
< 860 > 1180	< 3.0
1000 to 1025	> 50.0

Note – It should be noted that measurement results may differ if measurements are performed with and without test tone.

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 *Display of measurement results*

3.8.1 *Impulsive noise 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.

3.8.2 *Relative duration of impulsive noise events* (optional)

To allow an easier estimation of data transmisison errors which may result from impulsive noise, the instrument shall provide means to calculate and indicate the relative duration of the impulsive noise events. This quantity is the ratio of the time that the input signal exceeds a designated threshold to the total measurement time. Results shall be indicated in a range of 1×10^{-1} to 1×10^{-8}.

3.8.3 *Seconds containing impulsive noise events* (optional)

As a further option, the instrument shall provide means to calculate and indicate the percentage of seconds containing one or more occurrences of impulsive noise. Results shall be indicated in a range 0 to 100% with one digit after the decimal point.

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 **Operating environment**

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

Recommendation O.72

CHARACTERISTICS OF AN IMPULSIVE NOISE MEASURING INSTRUMENT FOR WIDEBAND DATA TRANSMISSIONS

(Geneva, 1972)

(For the text of this Recommendation see Recommendation H.16 [1] of Volume III.)

Reference

[1] CCITT Recommendation *Characteristics of an impulsive-noise measuring instrument for wide-band data transmission*, Vol. III, Rec. H.16.

GROUP-DELAY MEASURING EQUIPMENT FOR TELEPHONE-TYPE CIRCUITS

(Geneva, 1972)

The characteristics for a group-delay measuring set for telephone-type 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 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 $\leq$ 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 $\leq \pm$ 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.

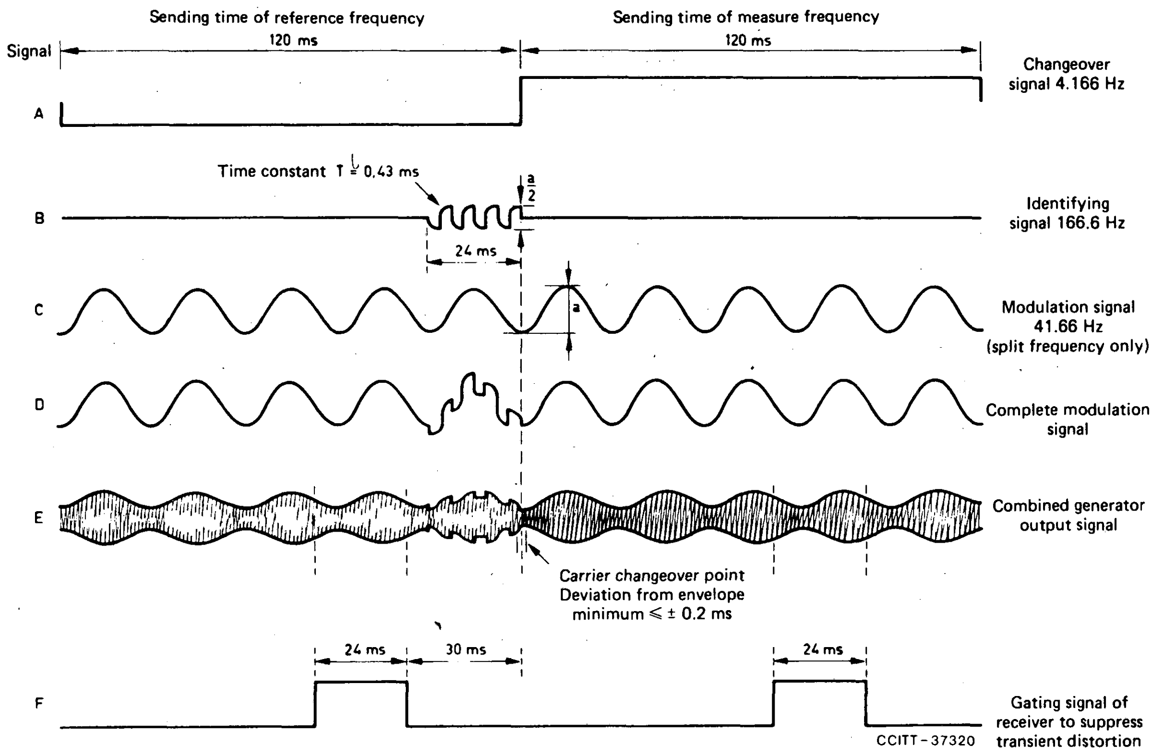


FIGURE 1/O.81

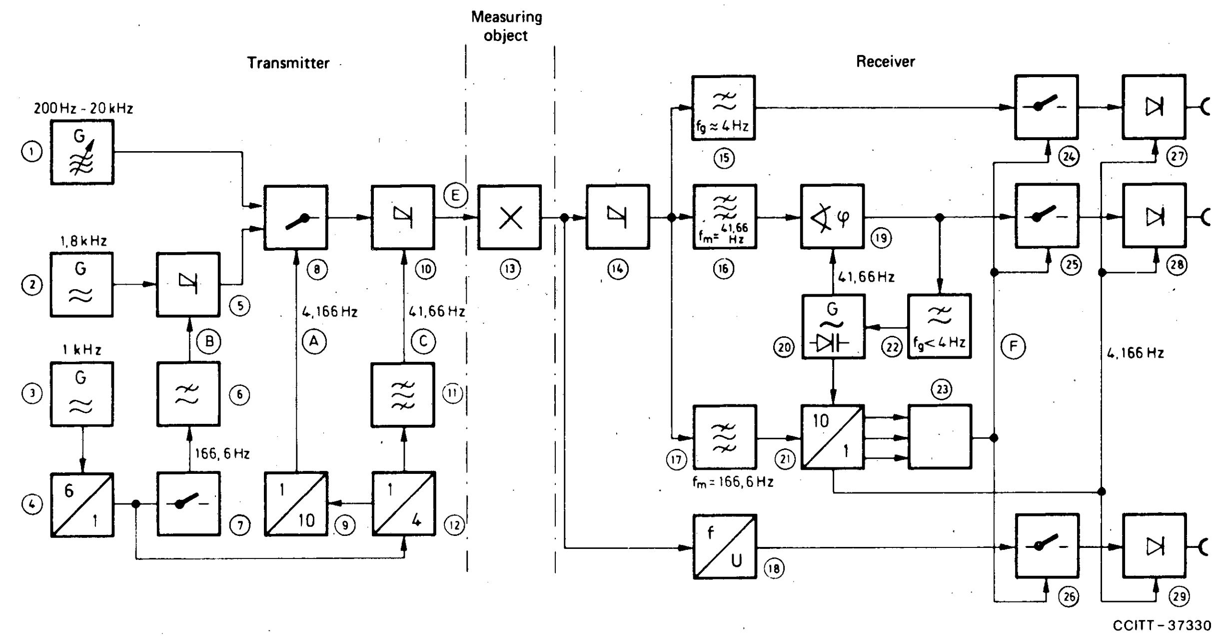
Timing of various signals of group-delay measuring set

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	14	amplitude demodulator
2	oscillator, reference frequency	17	bandpass filter, identifying frequency
3	oscillator, 1 kHz	18	frequency discriminator
4, 9, 12, 21	frequency dividers	19	phase meter
5, 10	amplitude modulators	20	controlled oscillator
6, 15, 22	low pass filter	23	*And* circuit
7	gate, identifying 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.81
13	measuring object		

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	⩽ ± 100 microseconds	± 3% of measuring range [1]
– 400 Hz to 600 Hz	⩽ ± 30 microseconds	
– 600 Hz to 1 kHz	⩽ ± 10 microseconds	
– 1 kHz to 20 kHz	⩽ ± 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 . . . . . . ± 5 microseconds
- variations up to 20 dB . . . . . . ± 10 microseconds
- variations up to 30 dB . . . . . . ± 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 ⩽ ± 1% of actual frequency reading ± 10 Hz
- in temperature range +5 °C to +50 °C ⩽ ± 2% of actual frequency reading ± 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 . . . . . . ⩽ ± 1%
- in temperature range +5 °C to +50 °C . . . . . . ⩽ ± 3%

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

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

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

4.1.4.2 Modulation distortion factor [2, 3] . . . . . . ⩽ 1%

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

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

4.1.5.2 Sending time of identifying signal [2] . . . . . . 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).

---

[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:

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

4.1.6 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.

---

[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).

GROUP-DELAY MEASURING EQUIPMENT FOR THE RANGE 5 TO 600 kHz

(Geneva, 1972)

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 $\leqslant$ 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 $\leqslant \pm 20$ 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.

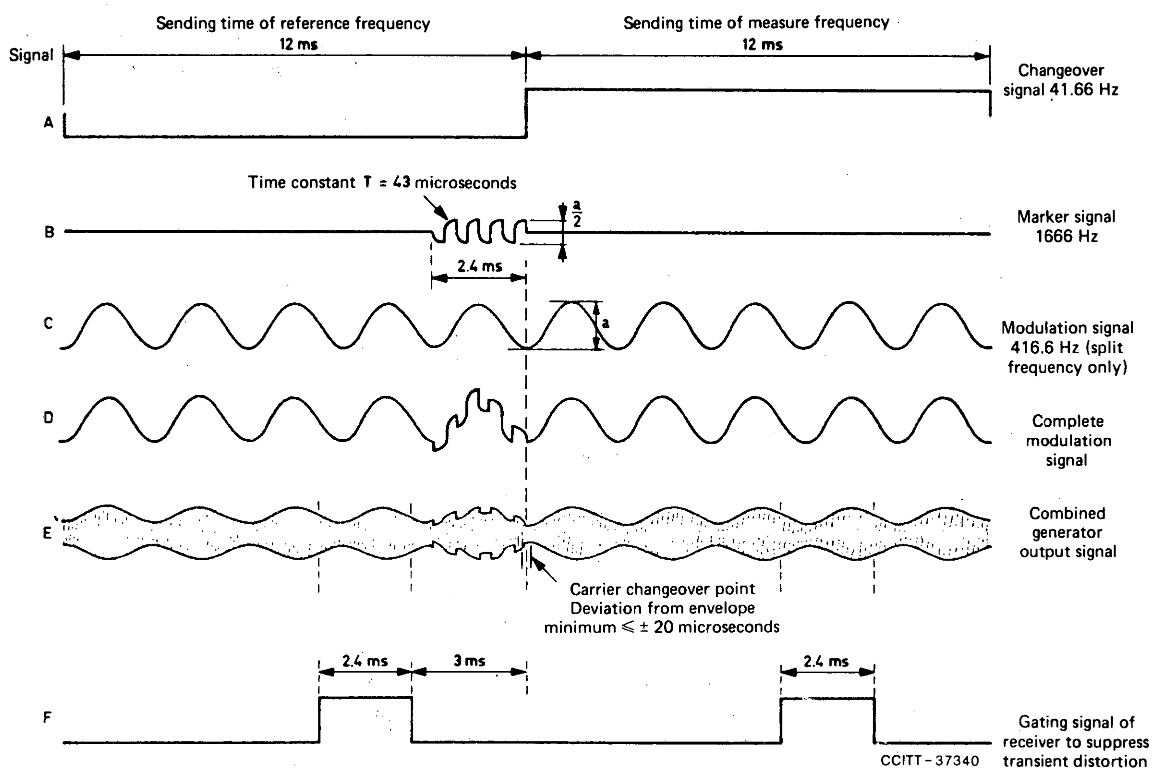


FIGURE 1/O.82

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.

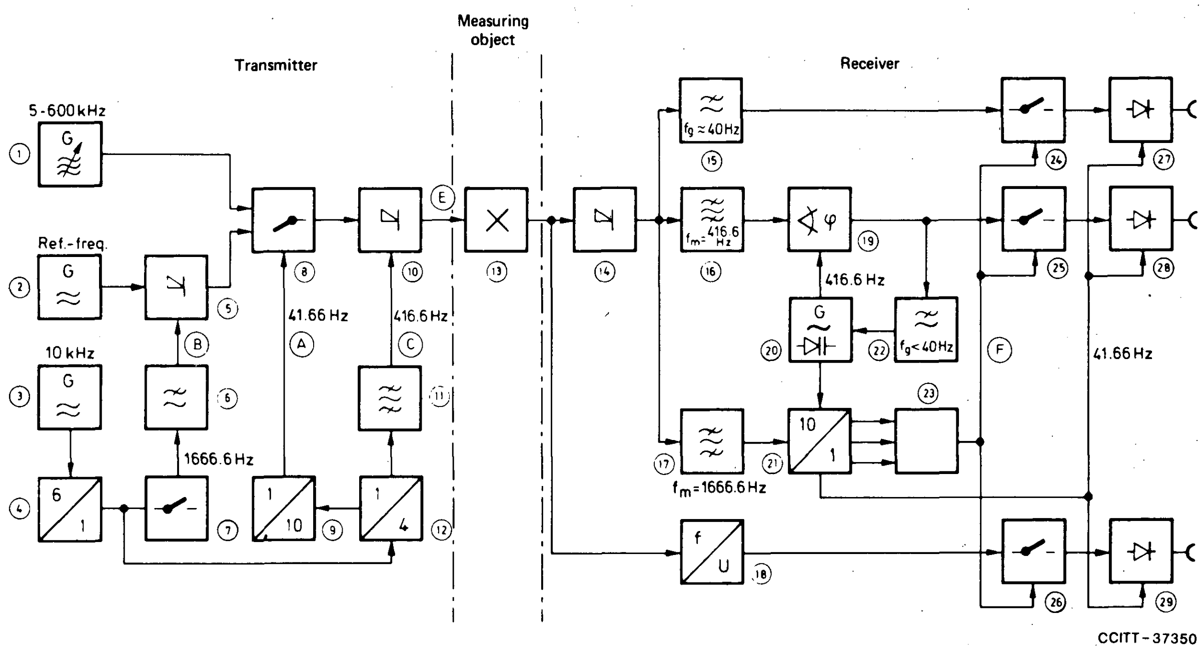
At the output of the phase meter a 41.66-Hz square-wave voltage is obtained, whose amplitude is proportional to the measuring result. In order to enable a correct evaluation of this signal, controlled rectification is required. The control voltage is derived from the modulation (split) frequency which 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.

---

[1] Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.

4.1.6 Changeover frequency[2] (derived from modulation frequency) . . . . 41.66 Hz

4.1.6.1 Carrier changeover time[2] . . . . less than 100 microseconds

4.1.6.2 Deviation between carrier changeover point and envelope minimum[2] . . . . ⩽ ± 0.02 millisecond

4.1.7 *Range of environmental conditions*[3]

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%

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[2]:

- 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.

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

[3] 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 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

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.

[4)] On the ± 50 dB range, the stated accuracy applies over ± 30 dB only (see § 4.3.1.1).

PHASE JITTER MEASURING EQUIPMENT FOR TELEPHONE-TYPE CIRCUITS

(Geneva, 1972; amended at Malaga-Torremolinos, 1984, and at Melbourne, 1988)

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.

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*

2.2.1 Test signal frequency . . . . 1020 ± 10 Hz

2.2.2 Send level . . . . −30 dBm to 0 dBm

2.2.3 *Output impedance* (frequency range 300 Hz to 4 kHz)

– Balanced, earth free (other impedances optional) . . . . 600 ohms
– Return loss . . . . ⩾ 30 dB
– Output signal balance . . . . ⩾ 40 dB

2.2.4 Phase jitter at source . . . . ⩽ 0.1 degree peak-to-peak

2.3 *Receiver*

2.3.1 *Measurement range*

At least as great as . . . . 0.2 to 30 degrees peak-to-peak

2.3.2 *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.

2.3.2 *Input selectivity*

Power line hum protection: highpass filter with a nominal cut-off frequency of 400 Hz with at least 12 dB per octave slope.

Protection for limiter against channel noise: lowpass filter with a nominal cut-off frequency of 1800 Hz with at least 24 dB per octave slope.

2.3.4 *Input impedance* (frequency range 300 Hz to 4 kHz)

- Balanced, earth free
- Input longitudinal interference loss . . . . ⩾ 46 dB

2.3.5 *Terminating impedance* (other impedances optional) . . . . 600 ohms

- Return loss . . . . ⩾ 30 dB

2.3.6 *High impedance* . . . . appox. 20 kohms

- Bridging loss across 300 ohms . . . . ⩽ 0.15 dB

Note — Definitions and measurement to be in accordance with Recommendation O.9.

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.

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.

[1] A single frequency signal with a total nonlinear distortion at least 40 dB below the level of the fundamental signal.

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.

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

Recommendation O.95

PHASE AND AMPLITUDE HIT COUNTERS FOR TELEPHONE-TYPE CIRCUITS

(Geneva, 1980)

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 4 kHz)

- Balanced, earth free (other impedances optional) . . . . 600 ohms
- Return loss . . . . ⩾ 30 dB
- Output signal balance . . . . ⩾ 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 4 kHz)

– Balanced, earth free

– Input longitudinal interference loss . . . . $\geq$ 46 dB

3.3.1 *Terminating impedance* (other impedances optional) . . . . 600 ohms

– Return loss . . . . $\geq$ 30 dB

3.3.2 *High impedance* . . . . approx. 20 kohms

– Bridging loss across 300 ohms . . . . $\leq$ 0.15 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.

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.

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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.

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

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.

Recommendation O.111

FREQUENCY SHIFT MEASURING EQUIPMENT FOR USE ON CARRIER CHANNELS

(Geneva, 1972; amended at Melbourne, 1988)

1 General

The equipment described below is compatible with the measuring method described in Annex A to this Recommendation.

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.

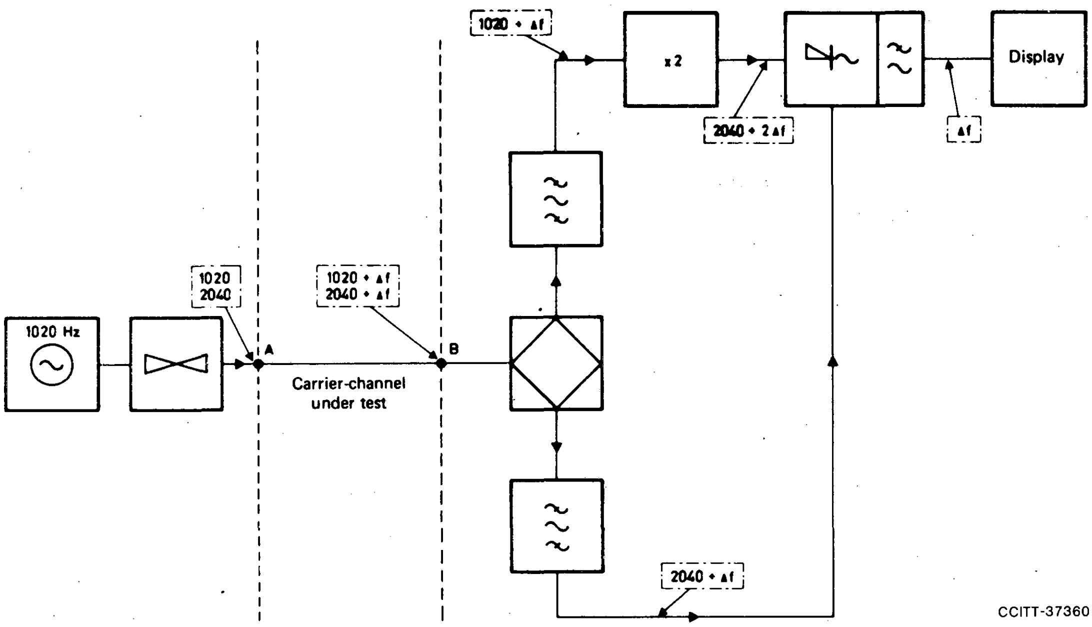


FIGURE 1/O.111

Measurement of frequency shift on a carrier channel A→B, transmitting from A and measuring at B

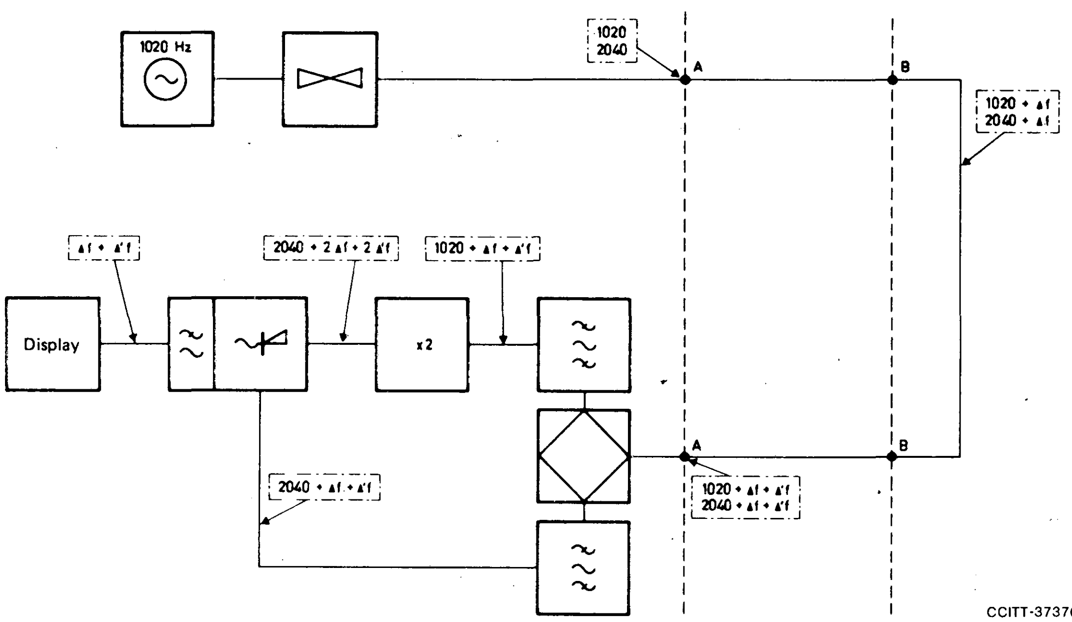


FIGURE 2/O.111

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.

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 *Output impedance* (frequency range 300 Hz to 4 kHz)

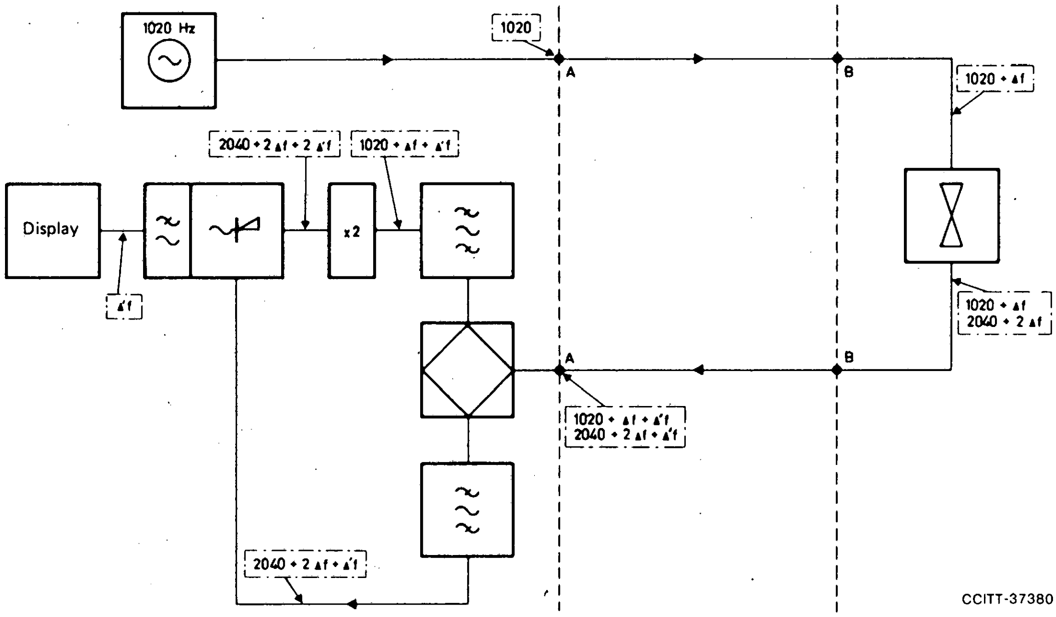
– Balanced, earth free (other impedances optional) . . . . 600 ohms
– Return loss . . . . ⩾ 30 dB
– Output signal balance . . . . ⩾ 40 dB

4 Receiving equipment

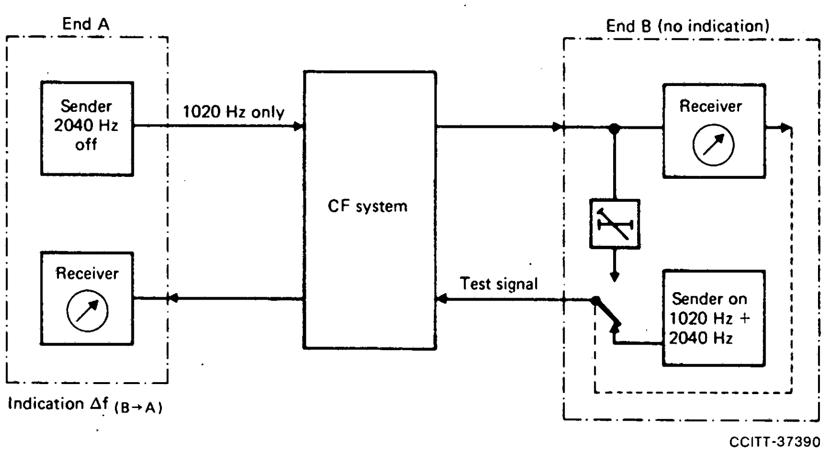
The receiving equipment shall accept the two test tones and shall indicate the frequency shift on a meter or other suitable indicator.

4.1 *Measuring ranges*

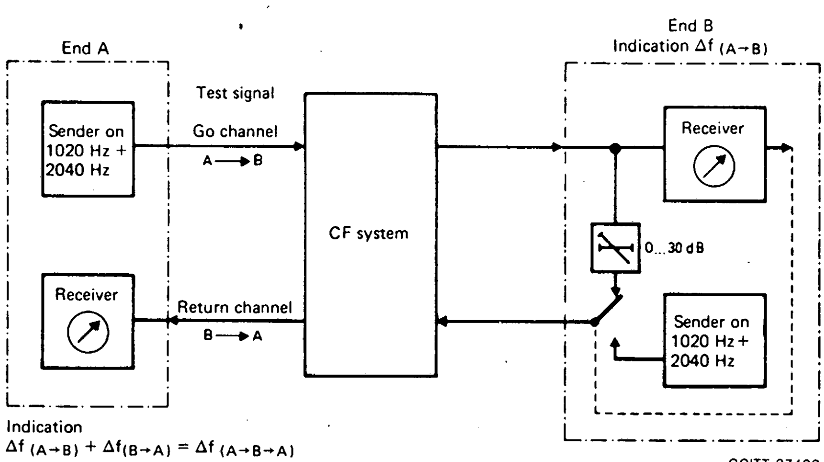
Full-scale measuring ranges of 0-1 Hz and 0-10 Hz shall be provided. The algebraic sign of the shift shall also be indicated.



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

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 *Input impedance* (frequency range 300 Hz to 4 kHz)

- Balanced, earth free (other impedances optional) . . . . 600 ohms
- Return loss . . . . $\geq$ 30 dB
- Input longitudinal interference loss . . . . $\geq$ 46 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 Operating environment

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

ANNEX A

(to Recommendation O.111)

Method for measuring the frequency shift introduced by a carrier channel

The principle of the method is that the harmonic relationship between two sinusoids is destroyed if to both is added the same frequency shift. Figure A-1/O.111 is a block schematic of the arrangement and is largely self-explanatory. From one 1000-Hz oscillator are derived two signals, one at 1000 Hz and the other at 2000 Hz, which are both transmitted. At the receiving end of a channel introducing Δ Hz shift they are no longer harmonically related and the frequency shift can be extracted and counted while at the same time a cathode-ray oscilloscope can be arranged to indicate the sense of the frequency shift. This method is used by the United Kingdom Administration and others.

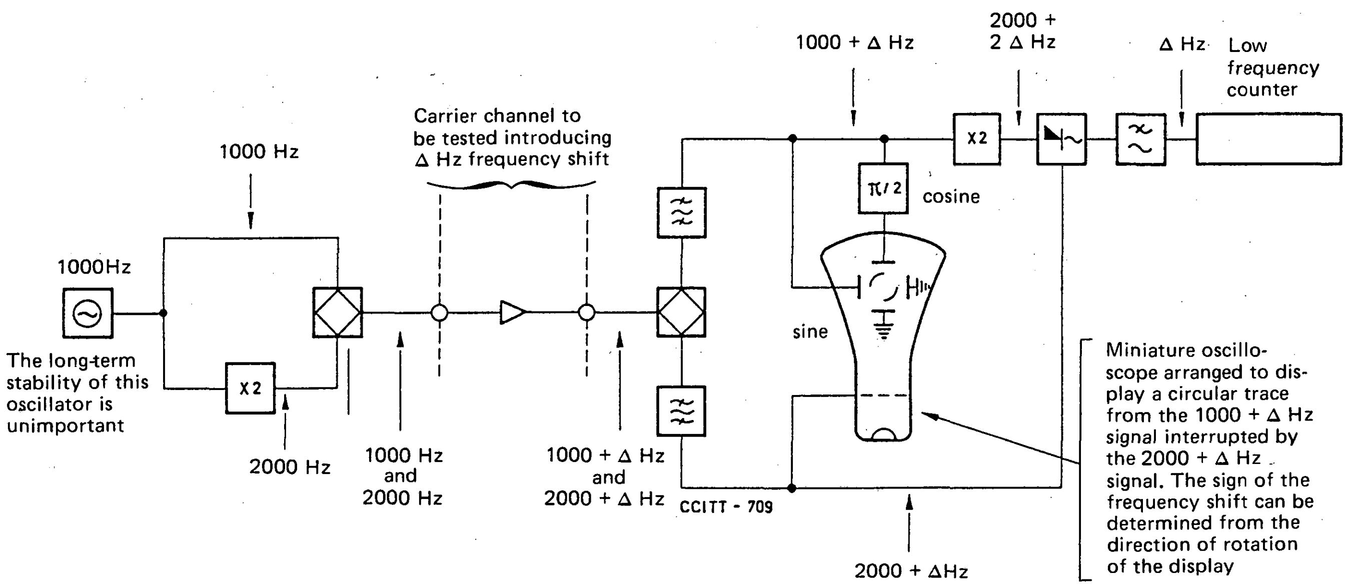


FIGURE A-1/O.111

A method for measuring the frequency shift introduced by a carrier channel

SECTION 5

EQUIPMENT FOR THE MEASUREMENT OF DIGITAL AND ANALOGUE/DIGITAL PARAMETERS

Recommendation O.131

QUANTIZING DISTORSION MEASURING EQUIPMENT USING A PSEUDO-RANDOM NOISE TEST SIGNAL

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

1 Preamble

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

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

2 Testing method proposed

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

[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 Recommendation G.712 [1], the obtained measurement results are related to a bandwidth of 3.1 kHz and that no noise weighting is provided. It should also be noted that results given by the pseudo-random noise and sinusoidal methods may not be the same.

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

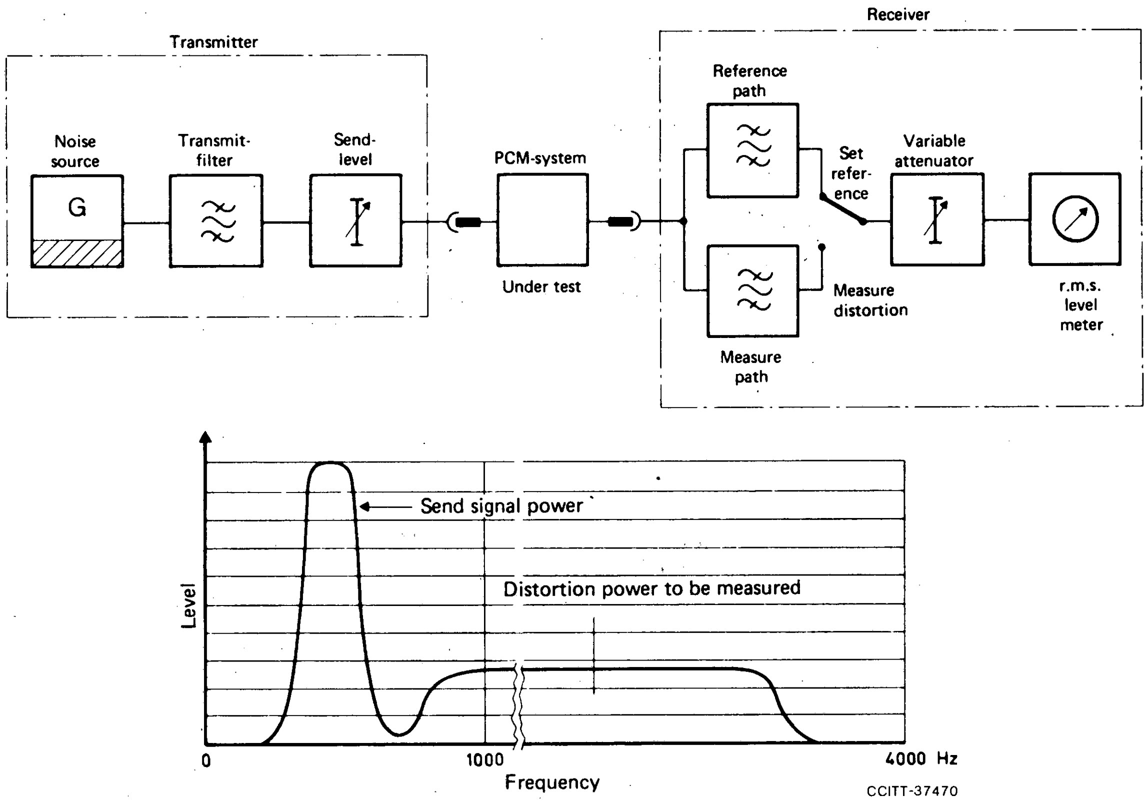


FIGURE 1/O.131

Principle of quantizing distortion measurement

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 [2] with a setting accuracy of ± 0.5 dB.

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

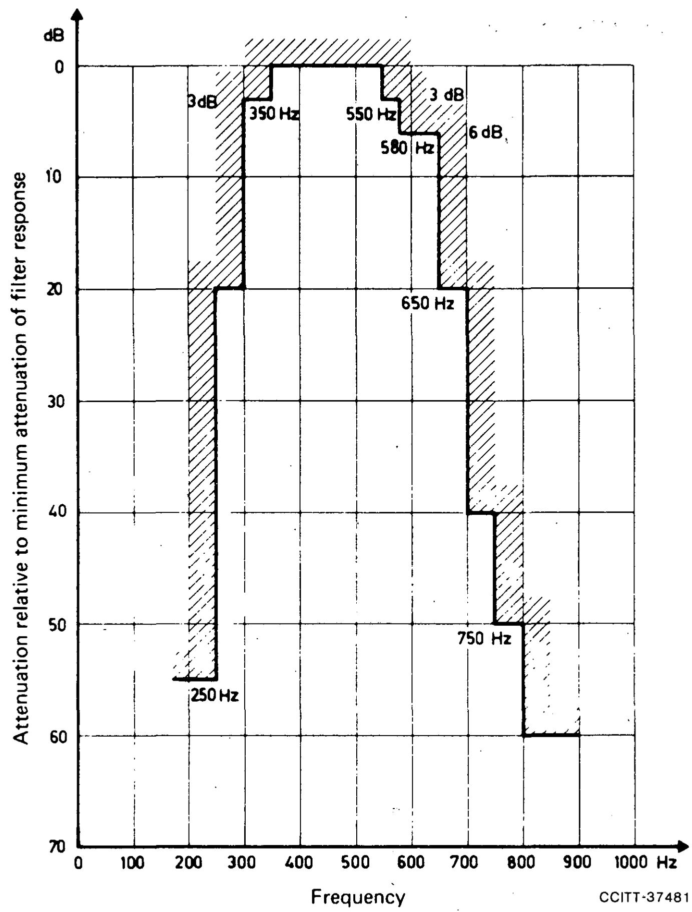
– Balanced, earth free (other impedances optional) . . . . 600 ohms
– Return loss . . . . ≥ 30 dB
– Output signal balance . . . . ≥ 40 dB

3.2 *Receive*

3.2.1 *Receive reference filter*

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

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



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

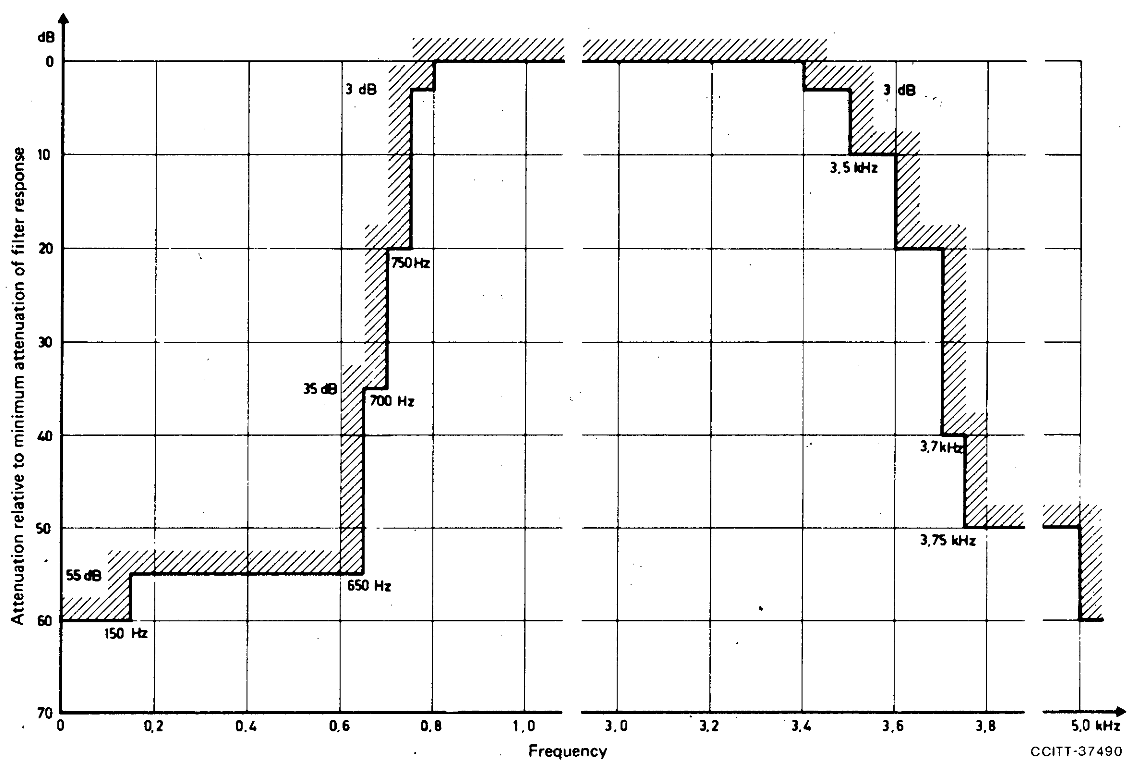
Note – The receive reference filter ideally restricts the bandwidth of the reference path to respond only to the spectrum of the received noise stimulus. However, the bandwidth of 350-550 Hz is chosen to allow for the need to interwork with test apparatus having a noise source bandwidth of up to 200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

– Balanced, earth free (other impedances optional)	600 ohms
– Return loss	⩾ 30 dB
– Input longitudinal interference loss (below 4 kHz)	⩾ 46 dB
– Input longitudinal interference loss (at 40 Hz)	⩾ 60 dB

3.2.5 *Input reference level range*

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

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

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

– Measuring range 10 dB to 40 dB: Accuracy ± 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.

4 Operating environment

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

References

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

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

QUANTIZING DISTORTION MEASURING EQUIPMENT USING A SINUSOIDAL TEST SIGNAL

(Geneva, 1980; amended at Melbourne, 1988)

1 Introduction

This specification gives basic clauses describing the essential features to be provided in test equipment using a sinusoidal test signal for quantizing distortion measurements on PCM channels. 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 § 9 of Recommendation G.712 [1].

2 Testing method

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

3 Specifications

3.1 *Test signal frequencies*

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

3.2 *Characteristics of the signal source*

3.2.1 *Signal level range*

At least −45 to +5 dBm0 for relative levels according to § 11 of Recommendation G.232 [2] with a setting accuracy of ± 0.2 dB.

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

- Balanced, earth free (other impedances optional) . . . . 600 ohms
- Return loss . . . . ⩾ 30 dB
- Output signal balance . . . . ⩾ 40 dB

3.2.3 Distortion and spurious modulation ratio . . . . ⩾ 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 § 11 of Recommendation G.232 [2].

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

- Balanced, earth free (other impedances optional) . . . . 600 ohms
- Return loss . . . . $\geqslant$ 30 dB
- Input longitudinal interference loss (below 4 kHz) . . . . $\geqslant$ 46 dB
- Input longitudinal interference loss (at 40 Hz) . . . . $\geqslant$ 60 dB

3.3.4 *Measuring filter*

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

3.3.5 *Test-signal reject filter*

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

TABLE 1/O.132

Test-signal reject filter characteristics

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

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

References

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

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

Recommendation O.133

EQUIPMENT FOR MEASURING THE PERFORMANCE OF PCM ENCODERS AND DECODERS

(Geneva, 1984; amended at Melbourne, 1988)

1 Introduction

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

- PCM multiplexers (Recommendations G.732 [2] and G.733 [3]);
- transmultiplexers (Recommendations G.793 [4] and G.794 [5]);
- subsystems of digital exchanges (e.g., Recommendation Q.517 [6]).

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

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

2 General

2.1 *Measuring functions and physical configuration*

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

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

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

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

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

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

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

2.2 *Measuring accuracy and compatibility objectives*

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

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

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

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

2.3 *Measurement capabilities*

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

3 Instrument specifications

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

3.1 *Interfaces*

3.1.1 *Analogue interfaces*[1]

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: ⩾ 36 dB.

3.1.1.3 Logitudinal conversion loss (frequency range 200 Hz to 4 kHz): ⩾ 46 dB.

[1] 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)	+	+	+	+ [a]	E
Variation of gain (loss) with time [b]	+	+	+	+	E
Return loss (at voice-frequency ports)	+	+	+	–	O
Longitudinal balance	+	+	+	–	O
Attenuation/frequency distortion	+	+	+	+	E
Weighted noise	+	+	+	+	E
Discrimination against out-of-band input signals	Δ	Δ	Δ	Δ	O
Spurious out-of-band output signals	Δ	Δ	Δ	Δ	O
Single frequency noise	Δ	Δ	Δ	Δ	O
Total distortion (including quantizing distortion)	+	+	+	+	E
Variation of gain with input level	+	+	+	+	E
Crosstalk (measured with sinewave signals) [a]	+	+	+	+	E
Crosstalk (measured with conventional telephone signal)	Δ	Δ	+	Δ	O
Interference from signalling [c]					O
Frequency of repetitive signal	+	+	+	+	0

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

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

[c] Stimulus for signalling channel is not specified.

E Essential Δ Capability not provided

O Optional

+ Yes

– Not applicable

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

3.1.2 *Digital interfaces*

3.1.2.1 *Level conditions and frame format*

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

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

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

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

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

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, 420, 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: $\pm$ 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 $\pm$ 1 ms.

Note – This requirement is also met by a period of 128 $\pm$ 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.

3.3.8 *Frequency of a repetitive signal*

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

3.4 *Digital signal generator*

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

3.4.1 *Digitally encoded sine wave signals*

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

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

3.4.1.3 Deviation of transmitted frequency from indicated frequency: ± 2 Hz ± 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: ± 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 ± 1 ms (2048 samples).

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

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

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

3.4.3 *Additional digital signals*

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

3.4.4 *Time slot assignment*

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

a) any selected speech time slot,

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

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

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

3.4.5 *Test of PCM multiplex alarm unit*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.4.6 *Selectable synchronization*

It shall be possible to either:

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

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

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

3.5 *Digital signal analyzer*

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

3.5.1 *Level*

3.5.1.1 Level measuring range: -60 to $+5$ dBm0.

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

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

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

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

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

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

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

3.5.7 *Alarm detection and display* (optional)

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

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

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

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

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

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

3.5.8 *Frequency of a repetitive signal*

As an option, it shall be possible to measure and display the frequency of any repetitive signal in the frequency range 200 Hz to 4000 Hz applied at a level in the range defined in § 3.5.1. The result shall be displayed to a resolution of 1 Hz. The measurement shall be made to an accuracy of at least $50 \cdot 10^{-6}$.

3.5.9 *External speech time-slot interface*

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

4 Measuring accuracy

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

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

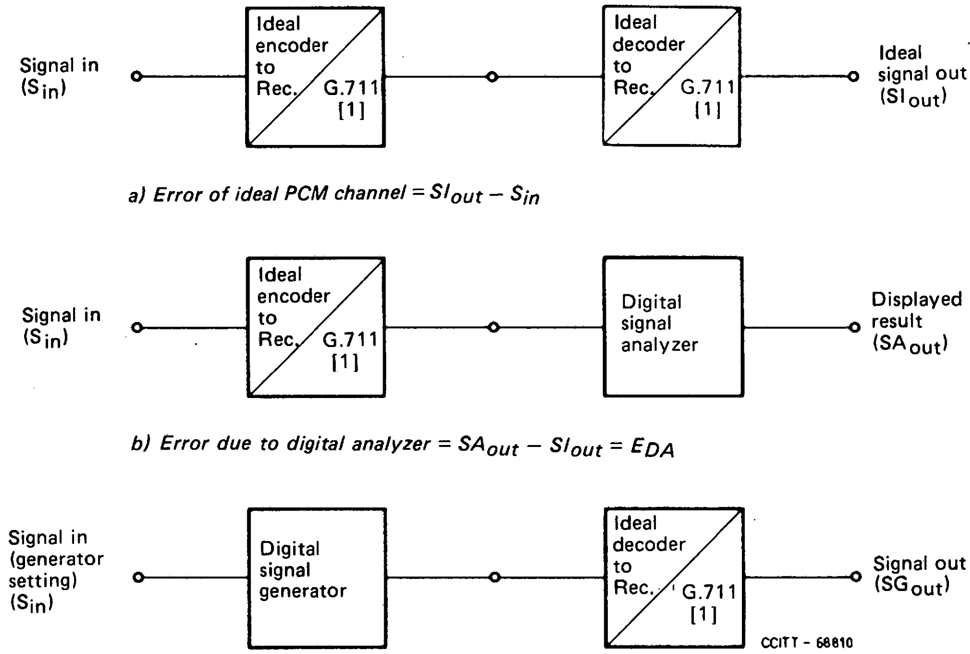
4.1.2 Even ideal encoder/decoder pairs conforming to the requirements of Recommendation G.711 [1] exhibit intrinsic limitations to the PCM process which cannot be avoided[2]. Examples are maximum load capacity, quantizing distortion ratio, variation of gain with input level and limited audio frequency 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[2].

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

[2] See Annex A to this Recommendation concerning the intrinsic errors in the PCM encoding process which may affect the interpretation of measured results.



a) Error of ideal PCM channel = $SI_{out} - S_{in}$

b) Error due to digital analyzer = $SA_{out} - SI_{out} = E_{DA}$

c) Error due to digital generator = $SG_{out} - SI_{out} = E_{DG}$

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 Recommendation O.6.

4.1.5 *Intrinsic distortion of test signals*

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

- Pseudorandom noise, sinusoidal signal, 420 Hz: by the method of Recommendation O.131.
- Sinusoidal signal, 820 Hz or 1020 Hz: by the method of Recommendation O.132.

4.1.6 *Measurement bandwidth for tone measurements*

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

4.2 *Summary of total measuring errors*

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

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

See Table 3/O.133.

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 $\geqslant -10$ 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 $\geqslant -10$ 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 300 to 3000 Hz 3000 to 3600 Hz	± 0.08 ± 0.05 ± 0.08	± 0.08 ± 0.05 ± 0.08	± 0.08 ± 0.05 ± 0.08	± 0.08 ± 0.05 ± 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

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

ANNEX A

(to Recommendation O.133)

Intrinsic errors in the PCM encoding process which may affect the interpretation of measured results

A.1 *Introduction*

Pulse Code Modulation (PCM) has some inherent limitations which affect measurements on PCM encoders. This pertains especially to the measurement of the variation of gain with input level and of the quantizing distortion ratio. Due to the limited number of quantizing steps available for encoding an analogue signal, the output signal of a PCM decoder is not a replica of the input signal to the encoder. Depending on the actual amplitude of the signal samples to be encoded, as compared with the quantizing thresholds, the output values at the decoder are sometimes greater and sometimes smaller than would occur in a linear system. The differences are called quantizing errors, and exist even for an ideal PCM encoder/decoder pair conforming to a practical encoding law. A test signal will experience the average effect of the quantizing errors in all its samples, which depends on the amplitude distribution of the signal. For Gaussian noise, the errors tend to average out, and no measurement problems arise. However, this is not the case for sinusoidal signals, and measurement results for gain linearity and quantizing distortion ratio must be interpreted with care.

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

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

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

Figures A-1/O.133 to A-4/O.133 show the (calculated) variation of gain with input level when measuring a PCM channel with an asynchronous sinusoidal signal. Because the gain variation in the upper segments is always between +0.043 dB and −0.048 dB, only the level range below −30 dBm0 is shown. The gain has a sharp minimum each time the peak of the sinusoid passes through a decision value. As the input amplitude is increased, the gain rises quickly to a maximum before falling again. In the vicinity of the minima, the gain can vary substantially when the input level is varied only by small amounts. With the A-law, for example, the gain changes by approximately 0.8 dB (selective measurements) when the input level is varied between −57.00 dB and −57.066 dB. In this case the ratio of level-to-gain variation is 1:11.8. For greater input levels and for the μ-law, the variation of gain with input level is smaller but still not negligible.

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

When measuring the gain variation of a PCM channel with a sinusoidal stimulus, the theoretical considerations described above must be taken into account. Because the relative level at the encoder input need only be set within a limit of ± 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	-0.022	-42.259	-0.090
-4.585	0.012	-16.626	0.012	-28.667	0.012	-42.834	0.044
-4.684	-0.024	-16.725	-0.024	-28.767	-0.024	-43.087	-0.104
-4.922	0.012	-16.963	0.012	-29.004	0.012	-43.723	0.051
-5.025	-0.025	-17.066	-0.025	-29.107	-0.025	-44.002	-0.122
-5.272	0.013	-17.313	0.013	-29.354	0.013	-44.713	0.061
-5.379	-0.027	-17.421	-0.027	-29.462	-0.027	-45.025	-0.146
-5.637	0.014	-17.678	0.014	-27.719	0.014	-45.831	0.074
-5.749	-0.028	-17.790	-0.028	-29.831	-0.028	-46.185	-0.178
-6.018	0.015	-18.059	0.015	-30.101	0.015	-47.114	0.092
-6.135	-0.030	-18.176	-0.030	-30.218	-0.030	-47.524	-0.226
-6.417	0.017	-18.458	0.017	-30.499	0.017	-48.623	0.119
-6.539	-0.032	-18.580	-0.032	-30.622	-0.032	-49.107	-0.299
-6.835	0.018	-18.876	0.018	-30.917	0.018	-50.451	0.162
-6.963	-0.034	-19.004	-0.034	-31.045	-0.034	-51.045	-0.423
-7.274	0.020	-19.315	0.020	-31.356	0.020	-52.775	0.240
-7.409	-0.036	-19.450	-0.036	-31.491	-0.036	-53.544	-0.668
-7.737	0.023	-19.778	0.023	-31.819	0.022	-55.976	0.408
-7.878	-0.038	-19.919	-0.038	-31.961	-0.039	-57.066	-1.312
-8.227	0.026	-20.268	0.026	-32.309	0.026		
-8.375	-0.040	-20.416	-0.040	-32.457	-0.040		
-8.762	0.035	-20.803	0.035	-32.844	0.035		
-8.901	-0.018	-20.942	-0.018	-32.984	-0.018		

TABLE A-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.

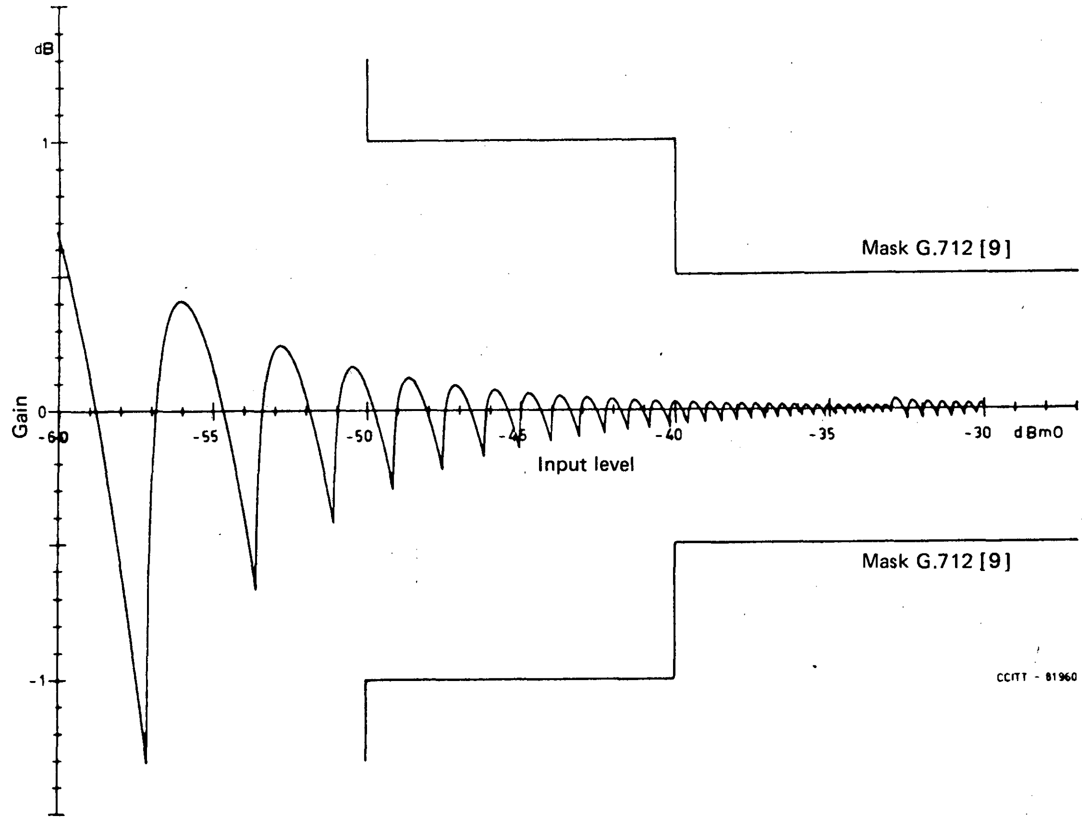


FIGURE A-1/O.133

Variation of gain with input level, A-law, selective measurement

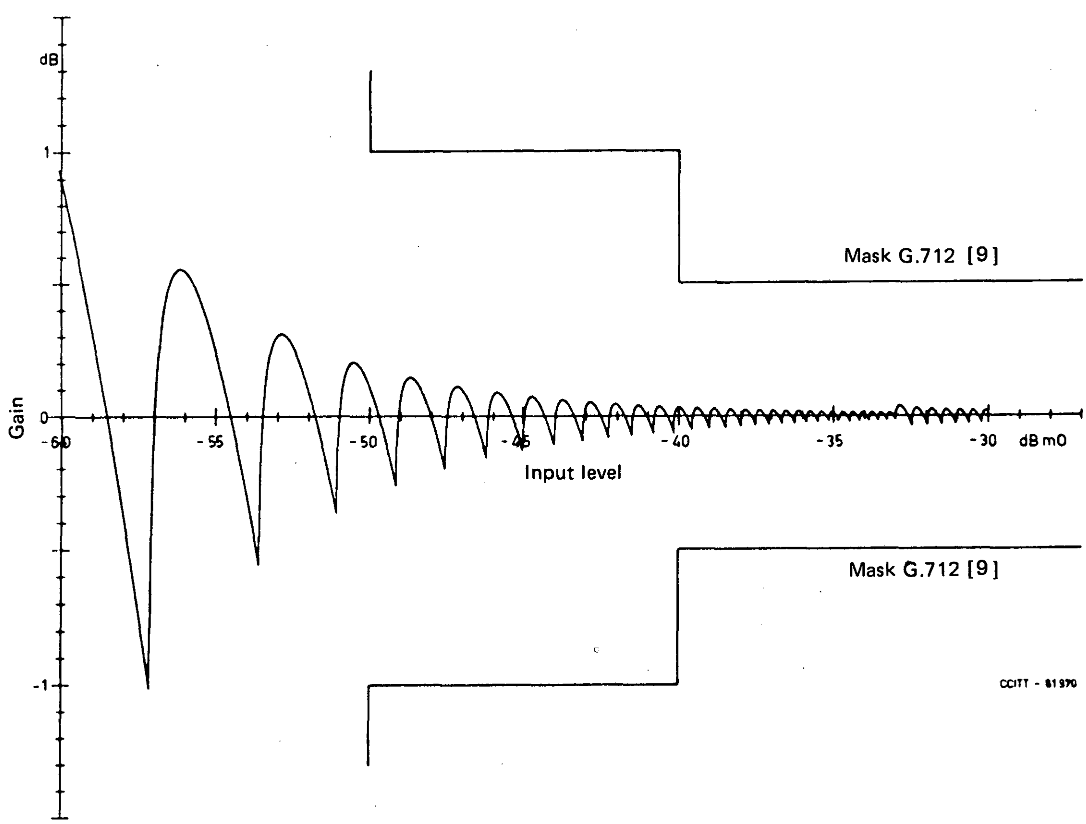


FIGURE A-2/O.133

Variation of gain with input level, A-law, wideband measurement

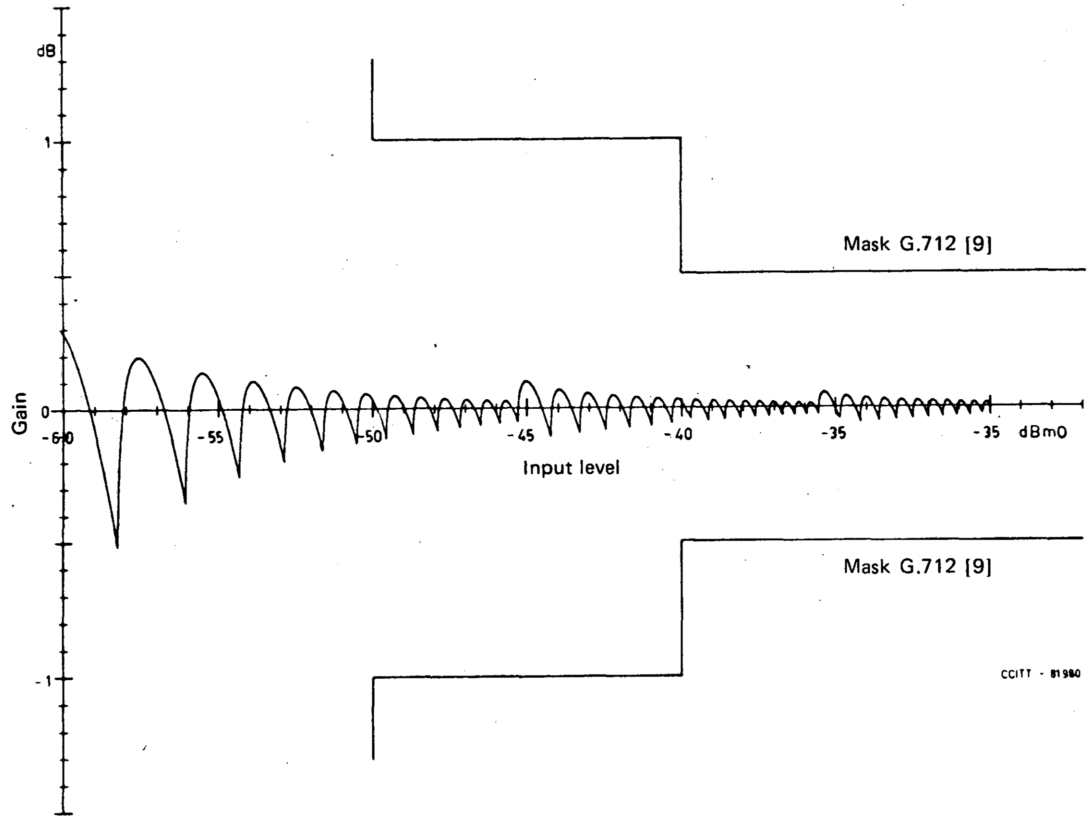


FIGURE A-3/O.133

Variation of gain with input level, μ-law, selective measurement

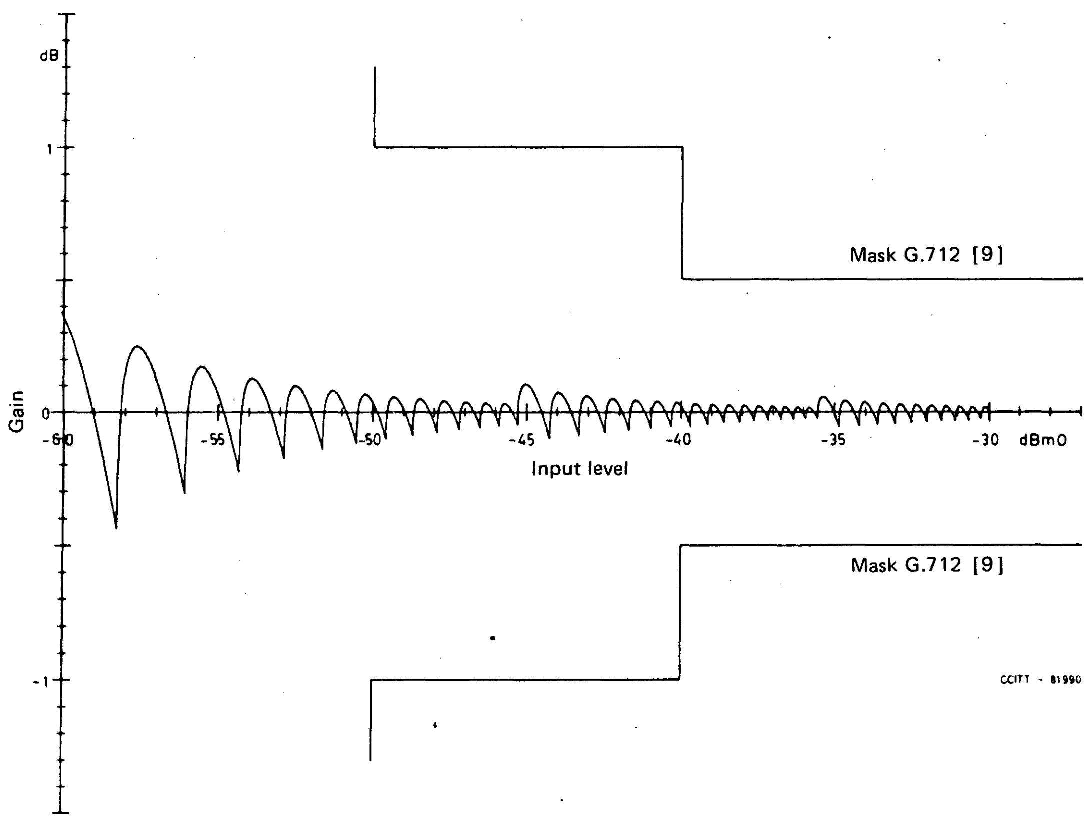
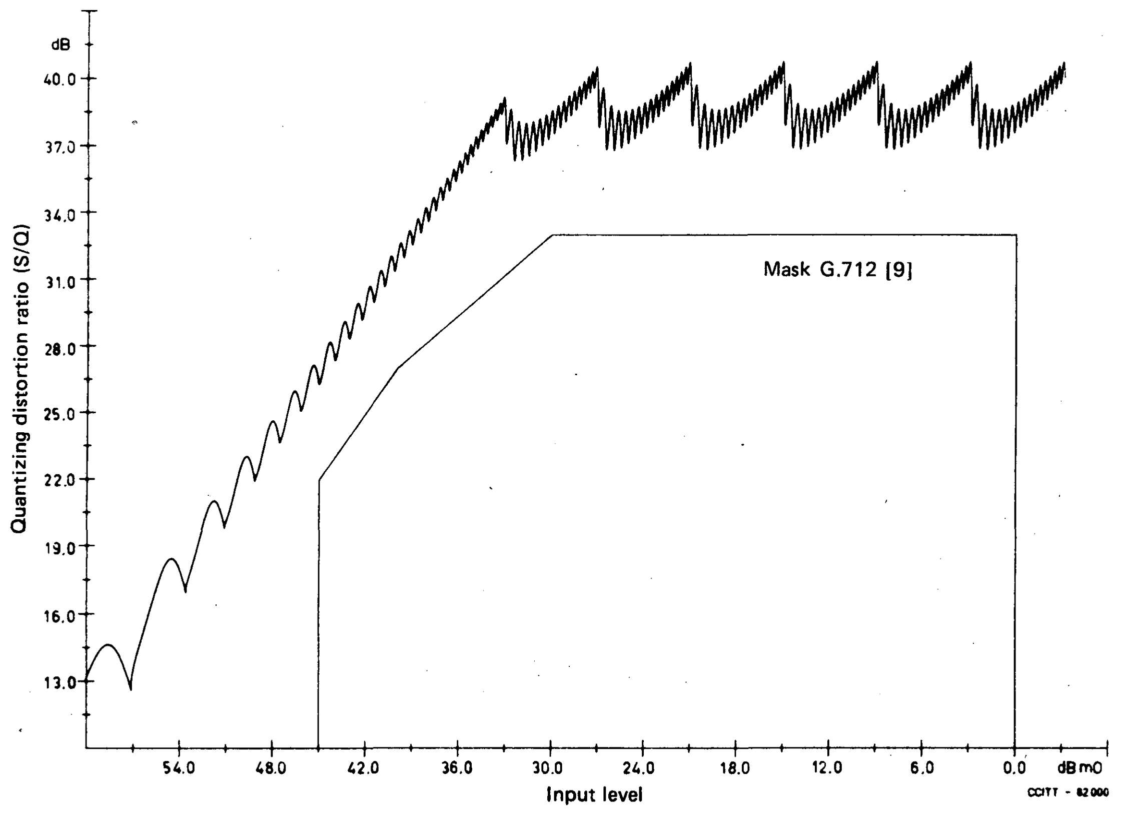


FIGURE A-4/O.133

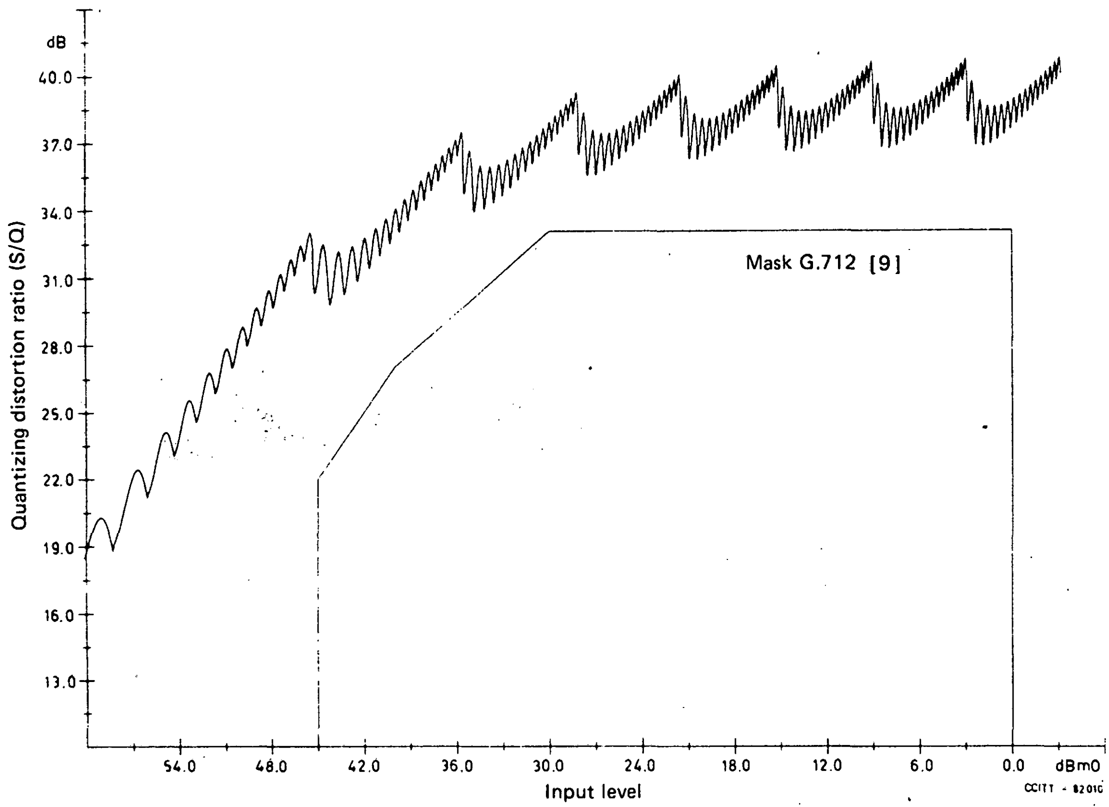
Variation of gain with input level, μ-law, wideband measurement



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*, Red Book, Vol. VI, Rec. Q.517, ITU, Geneva, 1984.

[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.

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

[12] CCITT Recommendation *Separate performance characteristics for the send and receive sides of PCM channels applicable to 4-wire voice-frequency interfaces*, Vol. III, Rec. G.714.

[13] CCITT Recommendation *Characteristics common to all transmultiplexing equipments*, Vol. III, Rec. G.792.

ERROR PERFORMANCE MEASURING EQUIPMENT FOR DIGITAL SYSTEMS AT THE PRIMARY BIT RATE AND ABOVE[1]

(Geneva, 1976; amended Geneva, 1980, Malaga-Torremolinos, 1984 and Melbourne, 1988)

The requirements for the characteristics of bit-error performance measuring equipment 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 equipment is designed to measure the bit-error performance 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	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):

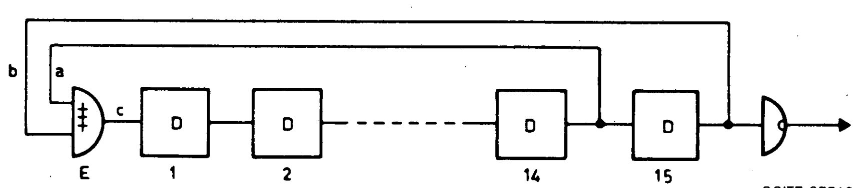
Number of shift register stages	23
Pattern length	$2^{23} - 1 = 8\,388\,607$ bits
Feedback	taken from the 18th and 23rd stages via an exclusive-OR-gate to the first stage
Longest sequence of zeros	23 (inverted signal)

[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.

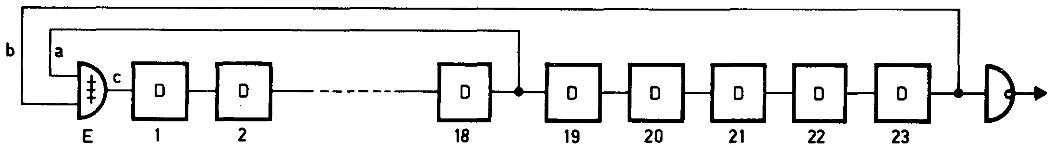
a	b	c
1	0	1
0	1	1
0	0	0
1	1	0

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 *Pseudorandom pattern for systems using $2^{20} - 1$ pattern length*

This pattern may be generated by a twenty stage shift register with feedback taken from the seventeenth and twentieth stages. The output signal is taken from the twentieth stage, and an output bit is forced to be a "one" whenever the next 14 bits are all "zero".

The quasi-random sequence satisfies the following:

$$Q_{n+1}\ (k + 1) = Q_n(k),\ n = 1, 2, \ldots, 19,$$

$$Q_1\ (k + 1) = Q_{17}(k) \oplus Q_{20}(k), \text{ and}$$

$$RD(k) = Q_{20}\ (k) + \overline{Q_6(k) + \ldots + Q_{19}(k)}$$

where

$Q_n(k)$	= Present state for nth stage
$Q_n(k + 1)$	= Next state for nth stage
$RD(k)$	= Present value of output
$+$	= a logic OR operation
$\oplus$	= a logic EXCLUSIVE OR operation
$\overline{(\ )}$	= a logic NEGATION operation.

2.4 *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 random test patterns

Bit rates (kbit/s)	Recommendations corresponding to multiplex system	Recommendations corresponding to digital line section/line system	Bit rate tolerance	Test pattern
1 554	G.733 [1]	G.911 [8], G.951 [9], G.955 [10]	$\pm 50 \cdot 10^{-6}$	$2^{15}-1$, $2^{20}-1$
2 048	G.732 [2]	G.921 [11], G.952 [12], G.956 [13]	$\pm 50 \cdot 10^{-6}$	$2^{15}-1$
6 312	G.743 [3]	G.912 [14], G.951 [9], G.955 [10]	$\pm 30 \cdot 10^{-6}$	$2^{15}-1$, $2^{20}-1$
8 448	G.742 [4], G.745 [5]	G.921 [11], G.952 [12], G.956 [13]	$\pm 30 \cdot 10^{-6}$	$2^{15}-1$
32 064	G.752 [6]	G.913 [15], G.953 [16], G.955 [10]	$\pm 10 \cdot 10^{-6}$	$2^{15}-1$, $2^{20}-1$
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]	$\pm 20 \cdot 10^{-6}$	$2^{15}-1$, $2^{20}-1$
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 in § 1.4 of Recommendation G.821 [20] and of deriving error performance reduced to 64 kbit/s in accordance with Annex D to Recommendation G.821 [20] [2]. 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 Operating environment

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

References

[1] CCITT Recommendation *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.

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[2] Error performance evaluation at bit rates other than 64 kbit/s is under study.

ERROR PERFORMANCE MEASURING EQUIPMENT FOR 64 kbit/s PATHS

(Malaga-Torremolinos, 1984; amended, Melbourne, 1988)

The requirements for the characteristics of a bit-error performance measuring equipment 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 performance 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

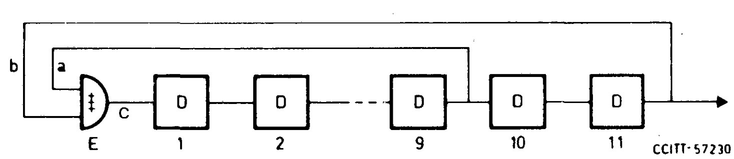
2.1 *Pseudorandom pattern*

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], I.430 [7] (optional) 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 I.430 [7]*

For further study. This study should include means for obtaining access to the individual 64 kbit/s channels at the S and T interface points.

4.4 *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 the climatic conditions as specified in Recommendation O.3, § 2.1.

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 *An Interface system for programmable measuring instruments (byte serial, bit parallel).*

[7] CCITT Recommendation *Basic user-network interface-Layer/Specification*, Vol. III, Recommendation I.430.

Recommendation O.153

BASIC PARAMETERS FOR THE MEASUREMENT OF ERROR PERFORMANCE AT BIT RATES BELOW THE PRIMARY RATE

(Melbourne, 1988)

The requirements for the characteristics of error measuring 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.

While 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. In particular, it is not required that all features listed below shall be provided in one instrument. Administrations may select those functions which correspond best to their applications.

When selecting functions, Administrations may also consider other Recommendations dealing with error measuring equipment, e.g. Recommendations O.151 and O.152.

1 General

The instrumentation is designed to measure the error performance on data circuits operating at bit rates between 0.050 and 168 kbit/s. The measurement is based on the direct comparison of specified test patterns which are transmitted through the circuit under test with identical patterns generated at the receive side. Synchronous and asynchronous operation shall be possible.

2 Test patterns

The following test patterns are standardized (see Note):

Note – The use of certain test patterns may be restricted to synchronous or asynchronous operation only. It shall be possible to transmit the patterns for an unlimited time.

2.1 *511-bit pseudorandom test pattern*

This pattern is primarily intended for error measurements at bit rates up to 14 400 bit/s (see § 3.1 below).

The pattern may be generated in a nine-stage shift-register whose 5th and 9th stage outputs are added in a modulo-two addition stage, and the result is fed back to the input of the first stage. The pattern begins with the first ONE of 9 consecutive ONES.

Number of shift-register stages 9

Length of the pseudorandom sequence . . . . $2^9 - 1 = 511$ bits

Longest sequence of zeros . . . . 8 (non-inverted signal)

2.2 *2047-bit pseudorandom test pattern*

If provided, this pattern is primarily intended for error measurements at bit rates of 64 kbit/s (see § 3.3 below).

The pattern may be generated in an eleven-stage shift-register whose 9th and 11th stage outputs are added in a modulo-two addition stage, and the result is fed back to the input of the first stage. (See also Rec. O.152)

Number of shift-register stages 11

Length of the pseudorandom sequence . . . . $2^{11} - 1 = 2047$ bits

Longest sequence of zeros . . . . 10 (non-inverted signal)

2.3 *1048.575 kbits pseudorandom test pattern*

This pattern is primarily intended for error measurements at bit rates up to 72 kbit/s (see § 3.2 below).

The pattern may be generated in a twenty-stage shift-register whose 3rd and 20th stage outputs are added in a modulo-two addition stage, and the result is fed back to the input of the first stage.

Number of shift-register stages 20

Length of the pseudorandom sequence . . . . $2^{20} - 1 = 1048.575$ kbits

Longest sequence of zeros . . . . 19 (non-inverted signal)

Note – This test pattern is not identical with the pattern of the same length specified in Recommendation O.151.

2.4 *Fixed test patterns* (for continuity tests)

- Permanent space
- Permanent mark
- Alternating space/mark with a ratio of: 1 : 1, 1 : 3, 1 : 7, 3 : 1, 7 : 1
- "Quick brown fox" – text (QBF) [1] (asynchronous mode only).

2.5 *Programmable test patterns*

A freely programmable pattern with a length of at least 1024 bits is recommended.

3 **Bit rates**

The instrumentation shall provide for measurements at bit rate ranges as specified in the categories below.

3.1 *Data transmission via telephone-type circuits using modems*

- Bit rate range 50 bit/s to 19 200 bit/s.

(See Recommendations V.5 [2] and V.6 [3] for details).

Note – Modems operating at bit rates above 14 400 bit/s are not covered by CCITT Recommendations.

3.2 *Data transmission via group-band circuits using wideband modems*

- Bit rate range 48 kbit/s to 168 kbit/s.

(See Recommendations V.36 [4] and V.37 [5] for details).

3.3 *Data transmisison at and above 64 kbit/s*

With regard to error performance measurements at 64 kbit/s, relevant information can be found in Recommendation O.152.

Information on measurements at primary bit rates is contained in Recommendation O.151.

3.4 *Deviation from nominal bit rate*

For bit rates up to 9600 bit/s the maximum deviation from the nominal bit rate shall be $\leqslant$ 0.01% if timing is not derived from the object under test.

For the higher bit rates the maximum deviation shall be $\leqslant$ 0.002% if timing is not derived from the object under test.

3.5 *Clock sources*

Clock signals are provided through the interface, via an external synchronisation input or from an internal clock generator.

4 Interfaces

Depending on the application and the bit rate, one or several of the following interfaces shall be provided:

- Interface according to Recommendation V.10 (X.26) [6]
- Interface according to Recommendation V.11 (X.27) [7]
- Interface according to Recommendations V.24/V.28 [8] [9]
- Interface according to Recommendation V.35 [10]
- Interface according to Recommendation V.36 [4]
- Interface according to Recommendations X.21/X.24 [11] [12].

5 Modes of operation

The instrumentation must fully simulate the characteristics of a DTE and/or a DCE in half duplex and/or full duplex mode. This includes the relevant software or hardware handshaking procedures. In synchronous half duplex mode, the test pattern shall be preceded by two or more leading pads (i.e. characters with alternating mark and space bits) to enable clock recovery. These pads shall be followed by two or more block-synchronization characters.

If the mode of operation requires, it shall be possible to select the parity check conditions even, odd, mark and space.

Note – The insertion of parity check bits is normally not possible when using pseudorandom test patterns.

6 Bit of synchronization

Two modes of synchronization shall be possible:

- Synchronization by means of a timing signal derived from the object under test (e.g. from a modem operating in the synchronous mode).
- Synchronization from the transitions of the received test signal (e.g. when a modem is operating in the nonsynchronous mode).

7 Codes

For encoding the QBF-text or a freely programmable pattern, the following data signal code shall be provided:

- CCITT Alphabet No. 5 with 7 bits/character [13]

For asynchronous operation 1 or 2 stop bits shall be selectable.

8 Error measurements and error evaluation

8.1 *Bit error measurements*

The range for error ratio measurements shall be 10^{-2} to 10^{-7}. The measurement time shall be sufficiently long to achieve accurate results.

Error ratios smaller than 10^{-7} can be observed by providing the capability to count cumulative errors.

8.2 *Block error measurements*

It shall be possible to perform block error measurements. The block length shall be selectable to 1000 or 10 000 bits or shall be equal to the length of the pseudorandom sequence used for the error test. In addition, a block length of 32 768 bits shall be provided for measurements at bit rates above 14.4 kbit/s.

The range for block error ratio measurements shall be 10^{-0} to 10^{-5} with measurement times being sufficiently long to achieve accurate results.

8.3 *Simultaneous measurements*

It shall be possible to perform bit error ratio and block error ratio measurements simultaneously.

8.4 *Error performance evaluation*

The instrumentation shall be capable of detecting errored seconds. The number of errored and error-free time intervals in a selectable time period from 1 minute to 24 hours, or continuous, shall be counted and displayed.

For this measurement the error detection circuits of the instrumentation shall be controlled by an internal timer which sets intervals of equal length and which operates independently of the occurrence of errors.

The measurement of other error performance parameters and the application of Recommendation G.821 [14] are under study.

9 Measurement of distortion

If the instrumentation provides for distortion measurements, the following specifications are applicable:

9.1 *Measurement of individual distortion*

The degrees of early and late individual distortion shall be measured when the instrumentation is operating in the mode in which synchronization is derived from transitions in the received test signal.

When using pseudorandom test signals, the measuring error shall be less than ± 3%.

9.2 *Measurement of bias distortion*

The instrumentation shall measure bias distortion on reversals (alternating space/mark with a ration of 1 : 1).

In this mode, the measuring error shall be less than ± 2%.

10 Remote control, recording of measurement results

As an option, an interface shall be provided which allows remote control of the instrumentation and further processing of the measuring results.

If provided, the interface shall comply with the interface bus according to IEC Publication 625 [15] or with Recommendation V.24 [8].

11 Operating environment

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

References

[1] CCITT Recommendation *Standardization of international texts for the measurement of the margin of start-stop equipment*, Vol. VII, Rec. R.52.

[2] CCITT Recommendation *Standardization of data signalling rates for synchronous data transmission in the general switched telephone network*, Vol. VIII, Rec. V.5.

[3] CCITT Recommendation *Standardization of data signalling rates for synchronous data transmission on leased telephone-type circuits*, Vol. VIII, Rec. V.6.

[4] CCITT Recommendation *Modems for synchronous data transmission using 60-108 kHz group band circuits*, Vol. VIII, Rec. V.36.

[5] CCITT Recommendation *Synchronous data transmission at a data signalling rate higher than 72 kbit/s using 60-108 kHz group band circuits*, Vol. VIII, Rec. V.37.

[6] CCITT Recommendation *Electrical characteristics for unbalanced double-current interchange circuits for general use with integrated circuit equipment in the field of data communications*, Vol. VIII, Rec. V.10.

[7] 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.

[8] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment and data circuit-terminating equipment*, Vol. VIII, Rec. V.24.

[9] CCITT Recommendation *Electrical characteristics for unbalanced double-current interchange circuits*, Vol. VIII, Rec. V.28.

[10] CCITT Recommendation *Data transmission at 48 kbit/s using 60-108 kHz group band circuits*, Vol. VIII, Rec. V.35.

[11] CCITT Recommendation *Interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for synchronous operation on public data networks*, Vol. VIII, Rec. X.21.

[12] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) on public data networks*, Vol. VIII, Rec. X.24.

[13] CCITT Recommendation *International Alphabet No. 5*, Vol. VII, Rec. T.50.

[14] CCITT Recommendation *Error performance of an international digital connection forming part of an integrated digital network*, Vol. III, Rec. G.821.

[15] IEC Publication 624 *An interface system for programmable measuring instruments (byte serial, bit parallel).*

Recommendation O.161

IN-SERVICE CODE VIOLATION MONITORS FOR DIGITAL SYSTEMS

(Geneva, 1980; amended Malaga-Torremolinos, 1984)

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.

[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 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.

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 ohms, nonreactive	20 kHz to 1.6 MHz
2048	75/120/130 ohms, nonreactive	40 kHz to 2.5 MHz
6312	75/110 ohms, nonreactive	100 kHz to 6.5 MHz
8448	75 ohms, 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).

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

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

TABLE 2/O.161

Status	Deflection (mA or volts)	Tolerance (mA or volts)
No signal	0	–
Valid signal	5	± 0.2
Violation rate $\geq 1 \cdot 10^{-3}$	2	± 0.2
Violation rate $\geq 1 \cdot 10^{-4}$	2.5	± 0.2
Violation rate $\geq 1 \cdot 10^{-5}$	3	± 0.2
Violation rate $\geq 1 \cdot 10^{-6}$	3.5	± 0.2
Single code violations	4	± 0.2

Reference

[1] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces*, Vol. III, Rec. G.703.

Recommendation O.162

EQUIPMENT TO PERFORM IN SERVICE MONITORING ON 2048 kbit/s SIGNALS

(Geneva, 1980, amended Melbourne, 1988)

1 General

1.1 This specification describes an instrument for performing in-service error tests on 2 Mbit/s signals having 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 The instrument is required to monitor any cyclic redundancy check (CRC) procedure signals, in accordance with Recommendation G.704 [1], conveyed within the frame alignment signal, and time slot 0 (TSO) of frames not containing the frame alignment signal.

1.5 As an option the instrument may provide access to the information bits conveyed in any selected time slot.

1.6 *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.706 [5], § 4, 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.706 [5], § 4, the indicator shall be extinguished.

Note – The instrument shall be able to synchronize to frames with or without CRC bits.

3.3.4 *Errors in the frame alignment signal*

3.3.4.1 The instrument shall have a means of indicating bit error rates, e.g. $1 \cdot 10^{-3}$, $1 \cdot 10^{-4}$, $1 \cdot 10^{-5}$ and illuminate the appropriate indicator.

The indication of bit 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 bit error rates are present for the whole of the counter measurement period.

TABLE 1/O.162

Bit error rate indication	Average bit error rates in decoded signal	Probability of indication illuminating or extinguishing within the periods stated below	
		Illuminate	Extinguish
$1 \cdot 10^{-3}$	$1 \cdot 10^{-3}$ $5 \cdot 10^{-4}$ $1 \cdot 10^{-4}$	50% within 0.3 s 5% within 0.3 s –	5% within 0.3 s – 95% within 0.3 s
$1 \cdot 10^{-4}$	$1 \cdot 10^{-4}$ $5 \cdot 10^{-5}$ $1 \cdot 10^{-5}$	50% within 3 s 5% within 3 s –	5% within 3 s – 95% within 3 s
$1 \cdot 10^{-5}$	$1 \cdot 10^{-5}$ $5 \cdot 10^{-6}$ $1 \cdot 10^{-6}$	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 *Cyclic redundancy check procedure*

3.4.1 Where a cyclic redundancy check (CRC) procedure in accordance with Recommendation G.704 [1] is implemented within the 2 Mbit/s signal the instrument shall provide the features detailed in §§ 3.4.2, 3.4.3 and 3.4.4.

3.4.2 The instrument shall indicate the presence of CRC framing bits.

3.4.3 The instrument shall have a means of indicating bit error rates of $1 \cdot 10^{-5}$, $1 \cdot 10^{-6}$ and $1 \cdot 10^{-7}$ and shall cause the appropriate indicator to be illustrated under the conditions defined.

The indication of bit error rates occurring in the received decoded signal and detected by means of the CRC procedure information shall comply with the limits given in Table 2/O.162.

TABLE 2/O.162

Bit error rate indication	Average bit error rate in decoded signal	Probability of indication illuminating or extinguishing within the periods stated below	
		Illuminate	Extinguish
$1 \cdot 10^{-5}$	$1 \cdot 10^{-5}$ $5 \cdot 10^{-6}$ $1 \cdot 10^{-6}$	50% within 1 s 5% within 1 s –	5% within 1 s – 95% within 1 s
$1 \cdot 10^{-6}$	$1 \cdot 10^{-6}$ $5 \cdot 10^{-7}$ $1 \cdot 10^{-7}$	50% within 10 s 5% within 10 s –	5% within 10 s – 95% within 10 s
$1 \cdot 10^{-7}$	$1 \cdot 10^{-7}$ $5 \cdot 10^{-8}$ $1 \cdot 10^{-8}$	50% within 100 s 5% within 100 s –	5% within 100 s – 95% within 100 s

3.4.4 It shall also be possible to count the sum of errors indicated. The count capacity shall be 99 999. A separate indication shall be given if the count exceeds this figure.

3.5 *Code violation detection*

3.5.1 *Definition of an HDB3 code violation*

Two consecutive bipolar violations of the same polarity. This may not be the absolute number of errors.

3.5.2 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.

3.5.3 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 § 3.5.1 above, shall be determined by counting the number of code violations that occur during the period of at least 10^6 time slots.

3.5.4 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.

3.5.5 The count capacity shall be 99 999 and a separate indication shall be given if the count exceeds this figure.

3.6 *Performance indications*

As an option the instrument shall be capable of providing performance information in accordance with G.821 [6].

3.7 *Lamp lock – Lamp auto reset*

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.

3.8 *Time slot access*

As an option it shall be possible to access, at an external interface, the contents of any selected time slot, including time slot 16. An external interface meeting the requirements of a co-directional interface, as defined in Recommendation G.703 [2], is preferred.

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 References to counters and displays being illuminated and extinguished does not imply that "light emitting" displays are essential.

4.3 The counter, and its display, shall be capable of being reset.

5 **Alarm function check**

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 **Alarm output signal**

As an option, an interface shall be provided to enable an external device, e.g. printer, to be connected to the instrument to allow recording of the status of the digital signal input to the instrument.

An interface in accordance with Recommendation V.24 [7] or V.28 [8], carrying suitably abbreviated, plain text messages in ASCII/T.50 [9] coded format according to the requirements of Recommendation V.4 [10] is preferred.

7 **Operating environment**

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

References

[1] CCITT Recommendation *Synchronous frame structures used at primary and secondary hierarchical levels*, 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.

[5] CCITT Recommendation *Frame alignment and CRC procedures relating to frames defined in Rec. G.704*, Vol. III, Rec. G.706.

[6] CCITT Recommendation *Error performance of an international digital connection forming part of an integrated digital network*, Vol. III, Rec. G.821.

[7] CCITT Recommendation *List of definitions for interchange circuits between data terminal equipment and data circuit-terminating equipment*, Vol. VIII, Rec. V.24.

[8] CCITT Recommendation *Electrical characteristics or unbalanced double-current interchange circuits*, Vol. VIII, Rec. V.28.

[9] CCITT Recommendation *International Alphabet No. 5*, Vol. VII, Rec. T.50.

[10] CCITT Recommendation *General structure of signals of International Alphabet No. 5 code for character oriented data transmission over public telephone networks*, Vol. VIII, Rec. V.4.

Recommendation O.163

EQUIPMENT TO PERFORM IN-SERVICE MONITORING ON 1544 kbit/s SIGNALS

(Melbourne, 1988)

1 General

1.1 This specification describes frame alignment signal monitoring equipment for 1544 kbit/s frame structures that are in accordance with Recommendation G.704 [1]. This equipment is intended to monitor 12-frame multiframe (superframe format – SF) or 24-frame multiframe (extended superframe format – ESF) structures having either AMI or B8ZS line codes as defined in § 2 of Recommendation G.703 [2].

1.2 This equipment shall provide the following capabilities:

a) monitor and display the error performance of the frame alignment signal;

b) detect and accumulate the counts of occurrences of loss of frame alignment;

c) measure and display the error performance of 24-frame multiframe signals by monitoring the cyclic redundancy check (CRC-6) bits and performing a CRC-6 procedure in accordance with Recommendation G.704 [1] and as described below;

d) detect and display the various alarm or fault conditions including loss of signal, loss of frame alignment, and other alarm conditions indicated by specific bit patterns.

1.3 The equipment may optionally provide the following additional capabilities:

a) detect and display the code violations in the 1544 kbits signal in accordance with Recommendation O.161;

b) provide an external interface for extracting the information bits conveyed in any selected channel time slot;

c) provide an external interface for extracting the 4 kbit/s data link bits defined in the 24-frame multiframe structure;

d) provide an external interface for extracting the signalling bits in the 12-frame and 24-frame structures.

2 Input requirements

2.1 *Interface*

The monitoring equipment shall be capable of operating with a test load impedance at a 1544 kbit/s interface as defined in § 2 of Recommendation G.703 [2]. It shall also be capable of operating when connected to protected monitoring points [1] (see also Recommendation G.772 [3]).

2.2 *Input impedance*

2.2.1 *Input impedance* (resistive) . . . . 100 ohms

2.2.2 *Return loss (20 kHz to 1600 kHz)* . . . . > 20 dB

2.3 *Input sensitivity*

As a minimum, the monitoring equipment shall operate properly in the line terminating mode over the range of bit rates, pulse shapes and signal levels defined in § 2 of Recommendation G.703 [2]. It shall also be equipped with an additional gain to compensate for the isolation loss incurred at protected monitoring points [1] (see also Recommendation G.772 [3]). A signal level indicator, or other means, shall be provided for the proper adjustment of input sensitivity.

2.4 *Input jitter tolerance*

The monitoring equipment shall be able to tolerate input jitter specified in Table 2/G.824 [4] without degradation of measuring accuracy.

2.5 *Input line codes*

The monitoring equipment is intended for use with both AMI and B8ZS line codes. The instrument shall have the capability to select either AMI or B8ZS, through a switch or other appropriate means. The instrument should indicate when it is receiving B8ZS when switched to the AMI mode, and vice versa.

3 Detection, measurement, and indication requirements

3.1 *Detection and indication of fault conditions*

3.1.1 *Loss of line signal*

Under study.

3.1.2 *Loss of frame alignment*

The equipment shall recognize the loss of frame alignment as defined in Recommendation G.706 [5], and an appropriate indication shall be given.

3.1.3 *Recovery of frame alignment*

The procedure for determining recovery of frame alignment shall be in accordance with Recommendation G.706 [5]. When frame recovery is complete, the indication of loss of frame alignment shall cease.

3.1.4 *Alarm indication signal (AIS) from an upstream failure*

The equipment shall recognize the presence of an alarm indication signal (AIS) indicating an upstream failure, and an appropriate indication shall be given. The binary equivalent of the AIS corresponds to an all ones signal. The strategy for the detection of the presence of an AIS shall be such that with a high probability, it is detected even in the presence of a code violation ratio of 1 in 1000.

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[1] The specification of protected monitoring points is under study in SG XV and SG IV.

3.1.5 *Distant alarm indication signal (DAIS)*

The equipment shall recognize the presence of distant alarm indication signal as defined in Recommendation G.733 [6], § 4.2.4 for both 12-frame and 24-frame multiframe signals, and an appropriate indication shall be given. The strategy for the detection of the presence of this distant alarm indication signal shall be such that with a high probability, it is detected even in the presence of a code violation ratio of 1 in 1000.

3.2 *Frame alignment signal (FAS) error performance measurements*

3.2.1 *Count of errored seconds*

The equipment shall be capable of counting the number of one second intervals in which one or more errors occur in the FAS bits associated with the 12-frame or 24-frame structures as defined in Recommendation G.704 [1]. The number of errored seconds in a selectable time period (see § 4.1) shall be counted and displayed. The equipment shall establish one-second intervals independent of the occurrence of errors.

3.2.2 *Count of errors*

The equipment shall be capable of counting the number of FAS bit errors occurring in a selectable time period (see § 4.1).

3.3 *CRC-6 error performance monitoring*

3.3.1 *Count of errored seconds*

The equipment shall be capable of counting the number of one-second intervals in which one or more CRC-6 violations are detected in 24-frame multiframe signals using the CRC-6 procedure defined in Recommendation G.704 [1] and G.706 [5]. The number of errored seconds in a selectable time period shall be counted and displayed. The equipment shall establish one-second intervals independent of the occurrence of errors.

3.3.2 *Performance indications*

As an option the instrument shall be capable of providing performance information in accordance with Recommendation G.821 [7].

3.3.3 *Estimate of bit-error-ratio*

This equipment shall optionally be capable of providing an estimate of the bit-error-ratio performance of 24-frame multiframe signals in the range 10^{-4} to 10^{-7} by detecting CRC-6 violations. In performing this measurement, it shall be assumed that only one bit-error has occurred each time a CRC-6 violation is detected. It is noted that this may not be an accurate estimate since more than one bit-error may occur within a 24-frame multiframe, due to the bursty nature of error occurrences.

The time interval for each bit-error-ratio measurement that is within the required range of the equipment shall be sufficiently long to include at least ten CRC violations.

3.3.4 *Count of errors*

The equipment shall also be capable of counting the number of CRC-6 violations occurring in a selectable time period (see § 4.1).

3.4 *Loss of frame-alignment count*

The equipment shall be capable of counting the occurrences of loss of frame alignment over a selectable time period (see § 4.1). Error counters shall be disabled during intervals of loss of frame alignment.

3.5 *Measurement of code violations*

If the measurement of 1544 kbit/s code violations is included, the equipment shall meet the requirements of Recommendation O.161.

3.6 *Channel time slot access*

As an option, receiving access may be provided to a selected 64 kbit/s channel at an external interface. An interface meeting the requirements of a co-directional interface output port defined in Recommendation G.703 [2], is preferred. In addition a centralized clock interface as defined in Recommendation G.703 [2] may be provided.

3.7 *4 kbit/s data link access*

Under study.

3.8 *Signaling bit access*

Under study.

4 Control and display requirements

4.1 *Measurement timer*

A measurement interval timer shall be provided for the convenience of the user when counting errors. The timer shall be adjustable from 5 minutes to 24 hours in steps of one minute or continuous. Manual "start" and "stop" controls shall also be provided.

4.2 *Count registers*

The count registers shall have a capacity of at least 99999. A separate means for indicating overflow shall be provided. Each of the registers shall be capable of being independently reset. A separate register shall be provided for each parameter or condition listed in §§ 3.1 through 3.4.

4.3 *Selection of multiframe structure*

A control shall be provided to permit a user to select whether the 12-frame or 24-frame multiframe structure is being monitored. As an option the equipment may automatically sense and display whether the signal being monitored is a 12-frame, 24-frame or neither multiframe structure.

4.4 *Lock/reset of displays*

For each of the fault condition indications given in § 3.1 means shall be provided whereby the display will remain visible until a manual reset is operated.

5 Monitoring equipment self diagnostics

5.1 As an option, an internal self diagnostic system to check for correct functioning of the instrument, shall be provided.

6 Interface for remote control and measurement results

6.1 As an option, an interface shall be provided for remote control of the frame signal monitoring equipment, and transmission of measurement results. If provided, the interface bus shall comply with one of the following:

a) ANSI/IEEE Std 488-1978 [8]

b) IEC Publication 625 [9]

c) ANSI/EIA-232-D-1986 [10].

7 Operating environment

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

References

[1] CCITT Recommendation *Synchronous frame structures used at primary and secondary hierarchical levels*, Vol. III, Rec. G.704.

[2] CCITT Recommendation *Physical/electrical characteristics of hierarchical digital interfaces*, Vol. III, Rec. G.703.

[3] CCITT Recommendation *Digital protected monitor points*, Vol. III, Rec. G.772.

[4] CCITT Recommendation *The control of jitter and wander within digital networks which are based on the 1544 kbit/s hierarchy*, Vol. III, Rec. G.824.

[5] CCITT Recommendation *Frame alignment and cyclic redundancy check (RCR) procedures relating to basic frame structures defined in Recommendation G.704*, Vol. III, Rec. G.706.

[6] CCITT Recommendation *Characteristics of primary PCM multiplex equipment operating at 1544 kbit/s*, Vol. III, Rec. G.733.

[7] CCITT Recommendation *Error performance of an international digital connection forming part of an integrated service digital network*, Vol. III, Rec. G.821.

[8] ANSI/IEEE Std 488-1978, *IEEE standard digital interface for programmable instrumentation.*

[9] IEC Publication 625 *An interface system for programmable measuring instruments (byte serial, bit parallel).*

[10] ANSI/EIA-232-D-1986 *Interface between data terminal equipment and data circuit terminating equipment employing serial binary data interexchange.*

Recommendation O.171

TIMING JITTER MEASURING EQUIPMENT FOR DIGITAL SYSTEMS [1]

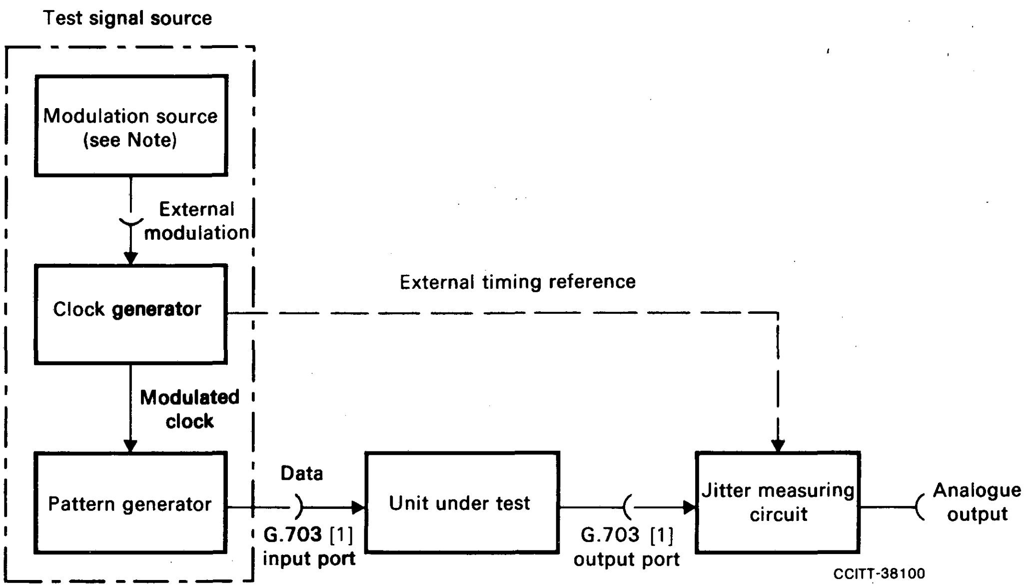
(Geneva, 1980; amended Malaga-Torremolinos, 1984 and Melbourne, 1988)

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.

[1] See the Supplement No. 3.8 at the end of this fascicle.



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,[2)]

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.

2) References to 64 kbit/s relate to the codirectional interface. Limits for other 64 kbit/s interfaces are under study.

1.3 *Interface impedances*

1.3.1 The jitter measuring circuit and signal source shall have a return loss better than 20 dB[3] 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 ohms, nonreactive	3 kHz to 300 KHz
1 544	100 ohms, nonreactive	20 kHz to 1.6 MHz
2 048	75/120/130 ohms, nonreactive	40 kHz to 2.5 MHz
6 312	75/110 ohms, nonreactive	100 kHz to 6.5 MHz
8 448	75 ohms, nonreactive	100 kHz to 10 MHz
32 064	75 ohms, nonreactive	500 kHz to 40 MHz
34 368	75 ohms, nonreactive	500 kHz to 40 MHz
44 736	75 ohms, nonreactive	500 kHz to 50 MHz
139 264	75 ohms, nonreactive	7 kHz to 210 MHz

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. In this Recommendation it is assumed that the modulation source is sinusoidal.

[3] In the case of 1544 kbit/s, the signal source shall have the following return loss: 20 kHz to 500 kHz $\geqslant$ 14 dB and 500 kHz to 1.6 MHz $\geqslant$ 16 dB.

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 bit 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 bit rates of 1544 kbit/s 6312 kbit/s and 44 736 kbit/s, pseudorandom patterns of $2^{15} - 1$, $2^{20} - 1$, $2^{23} - 1$ bit length corresponding to Recommendation O.151, § 2.

Note – Definition of the $2^{20} - 1$ pseudorandom pattern is under study.

2.3.1.3 For use at bit rates of 2048 kbit/s, 8448 kbit/s and 32 064 kbit/s, a pseudorandom pattern of $2^{15} - 1$ length corresponding to Recommendation O.151, § 2.1.

2.3.1.4 For use at bit 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.

2.3.1.5 For use at all bit rates, a 1000 1000 repetitive pattern.

2.3.1.6 As an option and for use at all bit 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.

2.3.2 *Generation errors*

The detailed specification of pattern generator parameters, to be compatible with the jitter measuring circuit specification, is under study.

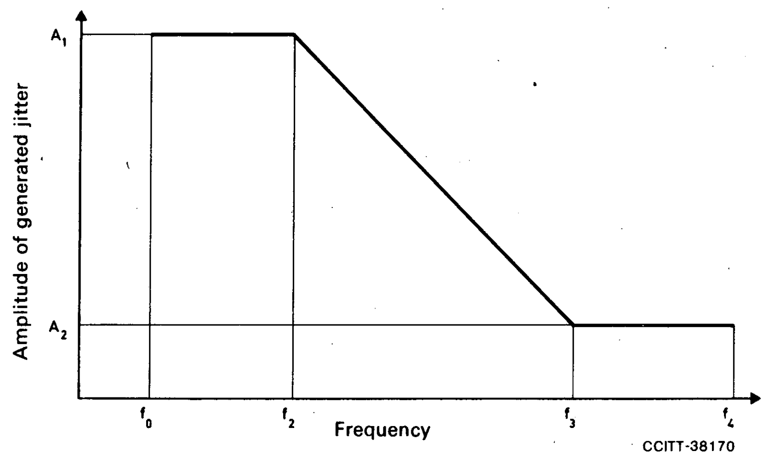


FIGURE 2/O.171

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
1 544	10.0 UI from 2 Hz to 200 Hz	0.5 UI from 4 kHz to 40 kHz
2 048	10.0 UI from 2 Hz to 2400 Hz	0.5 UI from 45 kHz to 100 kHz
6 312	10.0 UI from 2 Hz to 1600 Hz	0.5 UI from 32 kHz to 160 kHz
8 448	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
8 448 (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.

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.

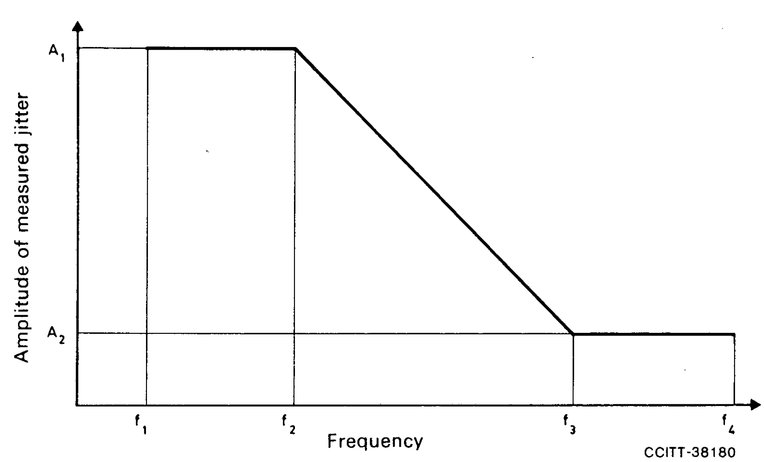


FIGURE 3/O.171

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
1 544	10.0 UI from 10 Hz to 200 Hz	0.3 UI from 7 kHz to 40 kHz
2 048	10.0 UI from 20 Hz to 2400 Hz	0.5 UI from 45 kHz to 100 kHz
6 312	10.0 UI from 10 Hz to 1600 Hz	0.5 UI from 32 kHz to 160 kHz
8 448	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
8 448 (low Q)	10.0 UI from 20 Hz to 10.7 kHz	0.5 UI from 200 kHz to 400 kHz

Note to Figure 3/O.171 and Table 3/O.171 – Amplitude of jitter specified as peak-to-peak value in unit intervals (UI).

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				Point à 3 dB des filtres supplémentaires	
	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
1 544	2	10	40	⩽ 80	10 Hz	8 kHz
2 048	2	20	100	⩽ 200	20 Hz	700 Hz 18 kHz
6 312	2	10	160	⩽ 320	10 Hz 60 Hz	24 kHz 32 kHz
8 448	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 $_{r.m.s.}$) 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
1 544	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
2 048	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
6 312	< 0.005	< 0.002	< 0.025	< 0.004	< 0.004	< 0.001
8 448	< 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

<table>
<tr><th rowspan="2">Bit rate
(kbit/s)</th><th colspan="2">Measurement bandwidth</th><th rowspan="2">Additional error referring to error at 1 kHz</th></tr>
<tr><th>f_1
(Hz)</th><th>f_4
(kHz)</th></tr>
<tr><td>64</td><td>20</td><td>10</td><td>± 2% 20 Hz to 600 Hz
± 3% 600 Hz to 10 kHz</td></tr>
<tr><td>1 544</td><td>10</td><td>40</td><td>± 4% f_1 to 1 kHz; ± 2% to f_4</td></tr>
<tr><td>2 048</td><td>20</td><td>100</td><td>± 2% f_1 to f_4</td></tr>
<tr><td>6 312</td><td>10</td><td>160</td><td>± 4% f_1 to 1 kHz; ± 2% to f_4</td></tr>
<tr><td>8 448</td><td>20</td><td>400</td><td>± 2% f_1 to 300 kHz
± 3% 300 Hz to f_4</td></tr>
<tr><td>32 064</td><td>60</td><td>800</td><td>± 2% 60 Hz to 300 kHz</td></tr>
<tr><td>34 368</td><td>100</td><td>800</td><td>± 3% 300 kHz to f_4</td></tr>
<tr><td>44 736</td><td>10</td><td>4500</td><td rowspan="2">± 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</td></tr>
<tr><td>139 264</td><td>200</td><td>3500</td></tr>
</table>

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 the climatic conditions as specified in Recommendation O.3, § 2.1.

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.

PART II

SUPPLEMENTS TO THE SERIES O RECOMMENDATIONS

(Section 3 of the Supplements to the 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 [1)]

(Geneva, 1972; amended at Melbourne, 1988)

A. *Direct-reading, general-purpose, continuously variable sinusoidal generator (not sweep frequency)*

Table 1 is a list of the essential performance requirements of a range of direct reading, general purpose continuously variable sinusoidal generators.

If discrete frequencies are required, suitable nominal values for international purposes are given in Recommendation M.580 for telephone-type circuits and Recommendation N.21 for sound-programme circuits.

B. *Direct-reading, general-purpose wideband and selective level-measuring instruments (not sweep display or fixed frequency)*

Table 2 is a list of the essential performance requirements of a range of direct-reading, general-purpose wideband and selective level-measuring instruments.

Note – The specifications given in § 8 of Recommendation O.22 are recommended to be used for signal generators and level-measuring instruments to be used on telephone-type circuits.

[1)] For the convenience of the reader of this Book, this Supplement is republished from Volume IV.2 of the CCITT *Green book*, ITU, Geneva, 1973.

TABLE 1

Essential performance requirements for sinusoidal signal generators
(not sweep generators)

	Telephone-type circuits	Sound-programme circuits	Groups, supergroups, and 12-, 60-, 120-, and 300-channel systems	Mastergroups, super-mastergroups and 900- to 2700-channel systems
1	2	3	4	5
Frequency				
a) range	200 Hz to 4 kHz	30 Hz to 20 kHz	4 to 1400 kHz	60 Hz to 17 MHz
b) accuracy of initial setting, without frequency counter, at 20 °C and nominal power supplies	± 1% ± 1 Hz	± 1% ± 1 Hz	below 120 kHz: ± 0.2 % ± 100 Hz 120 kHz land above: ± 0.2% ± 1 kHz	± 0.002% ± 300 Hz
c) stability				
– per hour at 20 °C and with nominal power supplies	± 1%	± 2%	± 0.01% ± 250 Hz	± 0.005% ± 250 Hz
– per 10 °C over a specified range of temperature and with nominal power supplies (Note)	± 0.1%	± 0.1%	± 0.1% ± 250 Hz	± 0.002% ± 10 Hz
– per 10% change in power suppy at 20 °C	± 0.5%	± 0.5%	± 0.05% ± 250 Hz	± 0.001% ± 10 Hz
Ouput level				
a) range	+10 to −40 dBm (+12 to −45 dNm)	+20 to −40 dBm (+23 to −45 dNm)	+10 to −60 dBm (+12 to −70 dNm)	+10 to −60 dBm (+12 to −70 dNm)
b) accuracy at 0 dBm (0 dNm) and at the reference frequency at 20 °C and with nominal power supplies	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.2 dB (± 0.2 dNp)	± 0.2 dB (± 0.2 dNp)
c) accuracy at any level or frequency within the range	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)
d) stability				
– per hour at 20 °C and with nominal power supplies	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
– per 10 °C over a specified range of temperature and with nominal power supplies (Note)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
– per 10% change in power supply at 20 °C	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
Purity of output				
Ratio of total output power to power of unwanted signals (noise, harmonic and non-harmonic frequencies)	at least 40 dB (46 dNp)	at least 50 dB (57 dNp)	at least 46 dB (53 dNp)	at least 46 dB (53 dNp)
Output impedance				
a) nominal value (other values may be specified if required)	600 ohms balanced	600 ohms balanced or not greater than 6 ohms balanced for constant voltage techniques	75 ohms unbalanced or 150 ohms balanced or 600 ohms balanced	50 or 75 ohms unbalanced
b) return loss against the nominal value	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)
c) balance about earth (where applicable)	at least 40 dB (46 dNp)	at least 60 dB (70 dNp)	at least 40 dB (46 dNp)	

Note – The range of temperature on which the apparatus must satisfactorily operate must be specified. This depends very largely on geographical location.

TABLE 2

Essential performance requirements of wideband and selective level-measuring instruments
(not sweep-display of fixed frequency)

	Telephone-type circuits	Sound-programme circuits	Groups, supergroups, and 12-, 60-,120- and 300-channel systems	Mastergroups, super-mastergroups and 900- to 2700-channel systems
1	2	3	4	5
Frequency				
a) range	200 Hz to 4 kHz	30 Hz to 20 kHz	4 kHz to 1400 kHz	60 kHz to 17 MHz
b) nominal bandwith for selective measurements (Note 1)	40 Hz	40 Hz	600 Hz and 4 kHz	600 Hz and 4 kHz
Range of input level				
a) wideband	+20 to −50 dBm (+23 to −58 dNm) down to −70 dBm (−80 dNm) with reduced accuracy	+20 to −50 dBm (+23 to −58 dNm) down to −70 dBm (−80 dNm) with reduced accuracy	+20 to −50 dBm (+23 to −58 dNm)	+20 to −50 dBm (+23 to −58 dNm)
b) selective	+20 to −80 dBm (+23 to −92 dNm)	+20 to −80 dBm (+23 to −92 dNm)	+20 to −90 dBm (+23 to −100 dBm) down to −110 dBm (−127 dNm) with reduced accuracy	+20 to −90 dBm (+23 to −100 dBm) down to −110 dBm (−127 dNm) with reduced accuracy
Measuring accuracy				
a) at 0 dBm (0 dNm) and at the reference frequency at 20 °C and with nominal power supplies if internal calibration is provided	± 0.2 dB (± 0.2 dNp) ± 0.1 dB (± 0.1 dNp)	± 0.2 dB (± 0.2 dNp) ± 0.1 dB (± 0.1 dNp)	± 0.2 dB (± 0.2 dNp) ± 0.1 dB (± 0.1 dNp)	± 0.2 dB (± 0.2 dNp) ± 0.1 dB (± 0.1 dNp)
b) at any level and frequency within the ranges (Note 2)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)
Stability of indicated level (Note 3)				
a) per hour at 20 °C and with nominal power supplies	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
b) per 48 hours at 20 °C and with nominal power supplies	± 0.3 dB (± 0.4 dNp)	± 0.3 dB (± 0.4 dNp)	± 0.3 dB (± 0.4 dNp)	± 0.3 dB (± 0.4 dNp)
c) per 10 °C over a specified range of temperature and with nominal power supplies (Note 3)	± 0.5 dB (± 0.6 dNp)	± 0.5 dB (± 0.6 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
d) per 10% change in power supply at 20 °C	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)	± 0.1 dB (± 0.1 dNp)
Level of unwanted signals				
Generated by the instrument itself and appearing at the input terminals relative to the lowest acceptable input level measured at the input terminals	−20 dB (−23 dNp) or lower	−20 dB (−23 dNp) or lower	−20 dB (−23 dNp) or lower	−20 dB (−23 dNp) or lower

TABLE 2 *(cont.)*

	Telephone-type circuits	Sound-programme circuits	Groups, supergroups, and 12-, 60-, 120- and 300-channels systems	Mastergroups, super-mastergroups and 900- to 2700-channel systems
1	2	3	4	5
Input impedance				
a) nominal value for terminated level measurements. Other nominal values may be specified if required	600 ohms balanced	600 ohms balanced or at least 20 × 10^3 ohms balanced for constant voltage techniques	75 ohms unbalanced or 150 or 600 ohms either balanced or unbalanced	50 or 75 ohms unbalanced
b) value for through-level measurements	at least 25 × 10^3 ohms balanced	at least 20 × 10^3 ohms	through-level measurements not recommended	through-level measurements not recommended
c) return loss against nominal value (for terminated-level measurements)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)	at least 30 dB (35 dNp)
d) balance about earth where applicable through-level or terminated-level	at least 40 dB (46 dNp)	at least 60 dB (70 dNp)	at least 40 dB (46 dNp)	
Image frequency rejection	at least 50 dB (58 dNp)	at least 50 dB (58 dNp)	at least 60 dB (70 dNp)	at least 60 dB (70 dNp)

Note 1 – It is necessary to specify in some detail the response characteristic of the nominal bandwidth for selective measurements.

Note 2 – Although the actual return loss of the input impedance is specified to be not greater than 30 dB (35 dNp) the instrument should be arranged (when connected to a generator of exactly the appropriate nominal value) to indicate the level that would be developed across an impedance, with a return loss of at least 40 dB (46 dNp) against the nominal value.

Note 3 – The stability limits include the effects of frequency variation of any built-in local oscillator in selective measuring sets.

Note 4 – The range of temperature over which the apparatus must satisfactorily operate must be specified. This depends very largely on geographical location.

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*;
additional information on this subject is given in Recommendation O.51)

Supplement No. 3.4

CONSIDERATION OF INTERWORKING BETWEEN DIFFERENT DESIGNS OF APPARATUS FOR MEASURING QUANTIZING DISTORTION

(For this Supplement, see page 85, Volume IV.2 of the *Orange Book*)

Supplement No. 3.5

(Cancelled. Replaced by Recommendation O.6)

Supplement No. 3.6

CROSSTALK TEST DEVICE FOR CARRIER-TRANSMISSION ON COAXIAL SYSTEMS

(Melbourne, 1988)

(Information from the USSR Telecommunication Administration)

1 Introduction

This Supplement contains the description of a method and the basic technical parameters of a device for crosstalk ratio measurement. It is designed for remote localization of repeaters having a low near-end intelligible crosstalk ratio in carrier-transmission coaxial systems.

2 Operation

The device measures propagation delay time of near-end crosstalk signals from different repeaters. Measurement of the test signal delay time in order to determine the distance from a repeater and the amplitude of the received signal make it possible to determine the repeater number and the near-end crosstalk ratio of this repeater.

The test signal is extracted from the noise and signals, coming from other repeaters, by means of time filtering (correlation processing). It is preferred that a special signal having a sufficiently narrow correlation function be used as a test signal. A sinusoidal test signal phase-modulated by a pseudorandom sequence (PRS) of pulses (phase-modulated signal) is used in the device.

A simplified block diagram and a frequency diagram of this device are given in Figure 1 and Figure 2.

Phase modulation of a sinusoidal signal f_1 from an oscillator G1 by a signal from PRS oscillator G2 is carried out in a modulator M1, the formed signal spectrum having no spectral component f_1 (suppressed by more than 54 dB). The modulating and test signals are shown in Figure 3, and the modulating signal spectrum is shown in Figure 4. A phase-modulated test signal in the band from f_{2m} to f_{km} is formed in a modulator M3. A signal from a quartz controlled oscillator at one of the frequencies in the band from f_2 to f_k, which are chosen in the spectrum of transmission systems under test, is used as a carrier. A test signal at $f_{km} \pm f_{1m}$ as well as at f_{1m} contain no central spectral component. The signal f_{km} is applied to the input of an interfering link.

A crosstalk signal from the output of the return path (path subjected to interference) is applied to the input of the device. The signal is reconverted in modulator M4. The signal f_{1m} is then applied to an input of phase detector M2. The PRS signal from G2 shifted by the time interval of Δt with respect to the modulating signal in a time-delay circuit D1 is applied to the other input of the phase detector M2. If the present time interval coincides with the time delay of the crosstalk signal in a line being tested with respect to the test signal at the device output, a single-frequency sinusoidal signal f_1 will be obtained at the output of M2, the signal level then being measured by a selective level meter (SLM). When the present value of Δt does not coincide with the time delay of the crosstalk signal coming from the line, a signal having no frequency f_1 in its spectrum will be present at the output and input of the phase detector M2. By varying the value of the present time delay in D_1, tuning to a crosstalk signal from different repeaters on the section under test, a remote measurement of the crosstalk value of all repeaters is carried out.

It is preferred that the choice of parameters of the test signal be determined by the correlation function $R(t)$ of the chosen signal (see Figure 5). For this purpose, $R(t)$ is estimated at two levels: $R(t) \leqslant 0.1$ corresponding to the zone of low correlation and $R(t) = 0.607$ limiting the high correlation zone.

Resolution between two adjacent signals is practical if the time shifts between them is outside the zone of high correlation. Therefore, the choice of the duration of an elementary PRS pulse is made depending on the minimum crosstalk time shift Δt_{min} of crosstalk from the adjacent repeaters, namely:

$$\tau \leqslant \Delta t_{min} = \frac{2\, l_{RS}}{V}$$

where

l_{RS} is the minimum distance between the adjacent repeaters;

V is the electric wave propagation rate in the cable.

The pulse duration τ in the device depends on the scale oscillator frequency and may be adjusted for various cable types having different propagation rates. Adjustment is carried out by changing the scale oscillator frequency.

The repetition period of a pseudorandom sequence should ensure unambiguity of measurements, i.e. the time between two adjacent autocorrelation function maximums should be greater than the signal propagation time along the section l_{ST} under test in both directions of transmission:

$$T \geqslant \frac{2\, l_{ST}}{V}$$

The minimum step of the time-delay circuit D1 is determined by taking into account the admissible error of tuning to the maximum of the autocorrelation function and may be equal to 0.1 τ (error not more than 5%). The maximum value of the time delay in D1 is determined by the length of the line section l_{ST} under test, i.e. by the time of signal propagation along the line in both directions of transmission:

$$t_{D1} \geqslant \frac{2\ l_{ST}}{V}$$

To measure the crosstalk signal levels corresponding not only to low but also normal crosstalk attenuation of repeaters, the passband of the SLM must be sufficiently narrow (0.1 to 0.3 Hz) so that a test signal may be extracted from the noise. Such a passband may be realized by means of a synchronous phase filter.

3 Basic technical parameters of a device designed for transmission systems at frequencies less than 18 MHz

3.1 *Basic characteristics*

3.1.1 Maximum length of a section under test . . . . 400 km

3.1.2 Minimum distance between repeaters under test . . . . 1.0 km

3.1.3 Minimum step of setting distance to the repeater under test . . . . 0.1 km

3.1.4 Nominal carrier frequencies of a test signal . . . . 0.37; 1.1; 4.4; 7.9; 17.25 MHz

3.1.5 Minimum measurement level . . . . –120 dB

3.1.6 Time for localization of a faulty repeater (with a maximum of 70 repeaters on a section under test) . . . . 20 min

3.2 *Several technical characteristics*

3.2.1 Number of elementary pulses in a pseudorandom sequence (PRS) for the test signal phase modulation . . . . $2^9 - 1 = 511$

3.2.2 PRS repetition rate . . . . 4.2 ms

3.2.3 Test signal level range . . . . –59 dB to 0 dB

3.2.4 Scale oscillator frequency . . . . 2.4 to 2.5 MHz

3.2.5 Level measuring range . . . . –120 to –50 dB

3.2.6 Receiver bandwidth (at a 3 dB level) . . . . 0.3; 3 Hz

3.2.7 Steps of time delay . . . . 83.3 μs (10 km)
8.3 μs (1 km)
0.8 μs (0.1 km)

3.2.8 Reduction in the receiver indicator reading with respect to a value corresponding to the maximum when the PRS is shifted by 24.9 μs (3 km) . . . . more than 40 dB

3.2.9 Measuring error in the "–100 dB" range for the 0 dB reading . . . . less than ± 1 dB

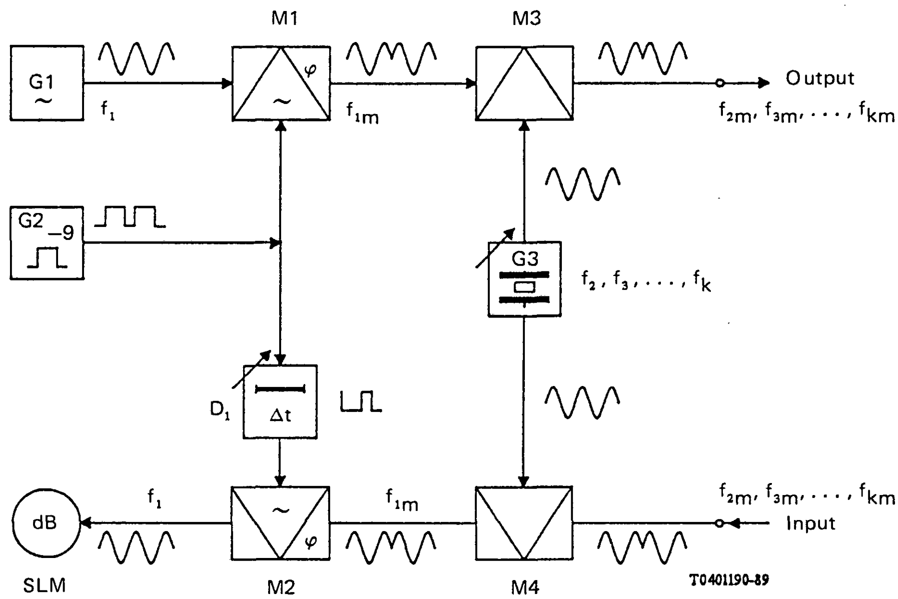

FIGURE 1

Crosstalk test device simplified block diagram

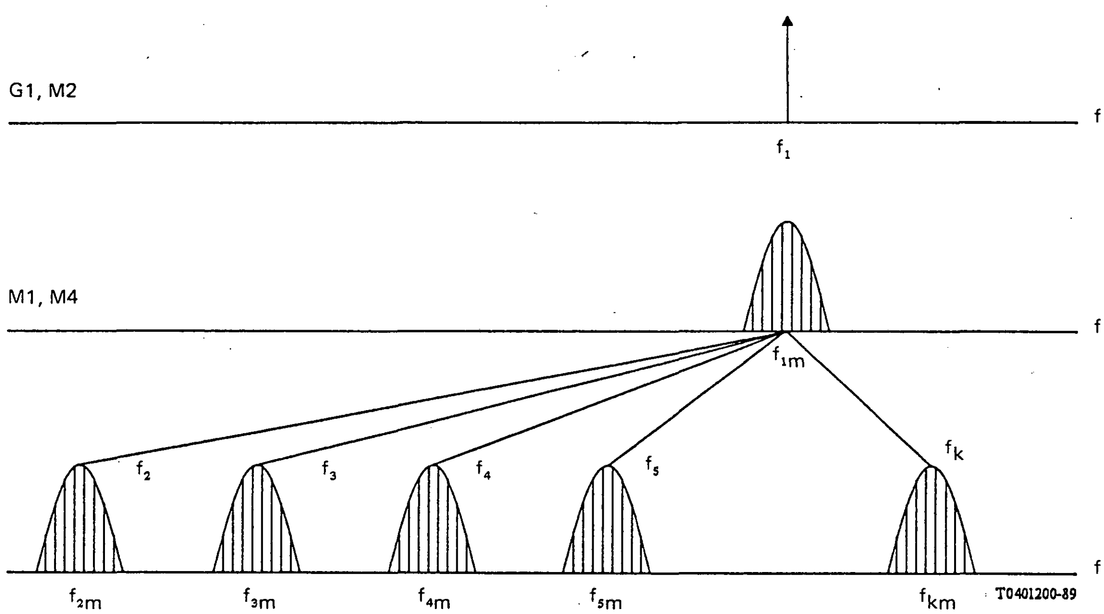

FIGURE 2

Crosstalk test device frequency diagram

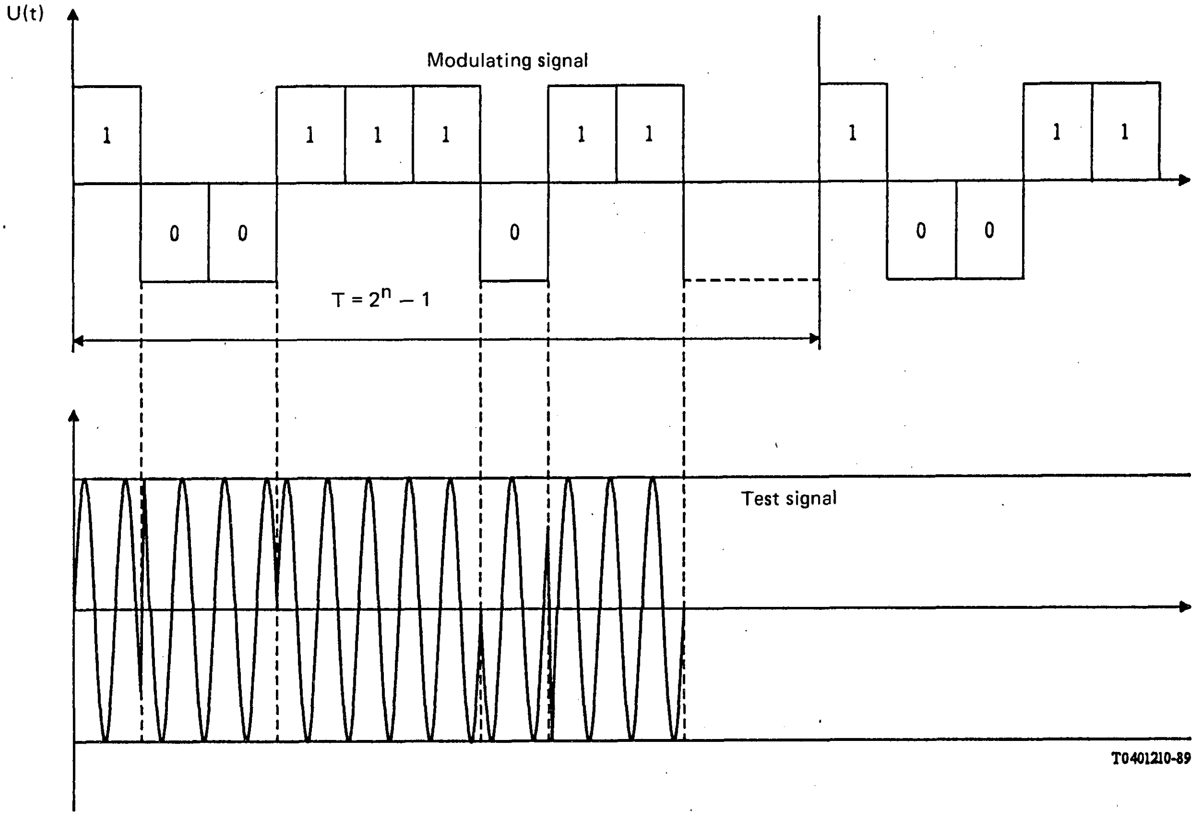

FIGURE 3
Modulating and test signals

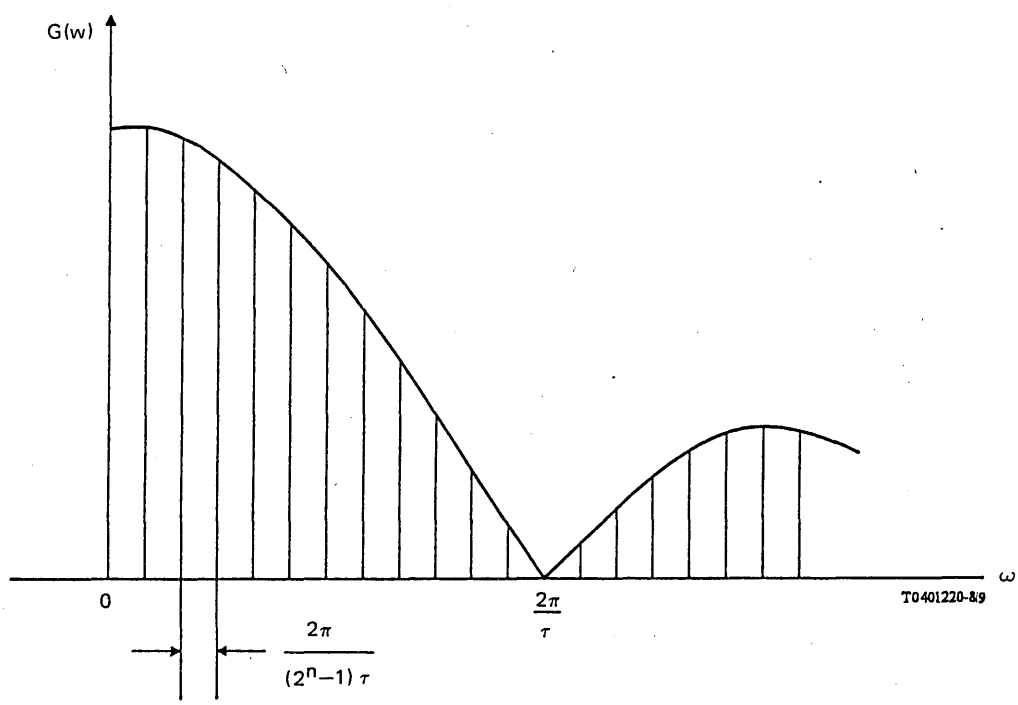

FIGURE 4
Modulating signal spectrum

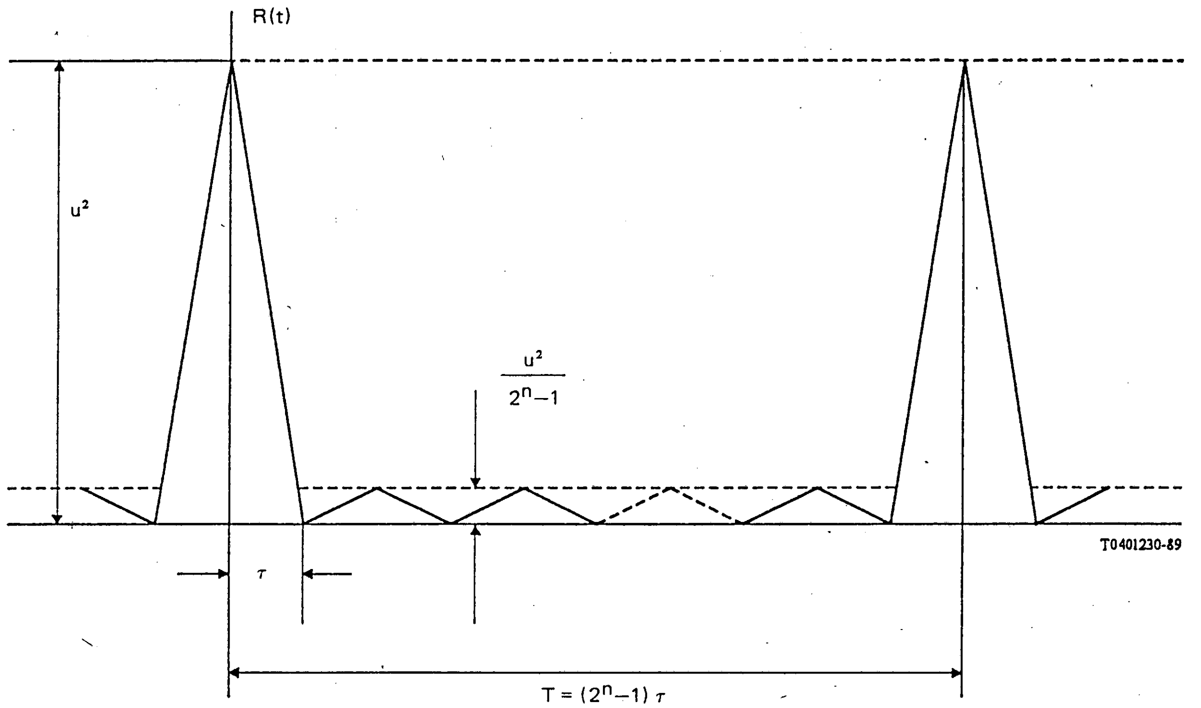

FIGURE 5

Test signal correlation function

Supplement No. 3.7

A MEASURING SIGNAL (MULTITONE TEST SIGNAL) FOR FAST MEASUREMENT OF AMPLITUDE AND PHASE FOR TELEPHONE TYPE CIRCUITS

(Melbourne, 1988)

(Information submitted by the Federal Republic of Germany, France and USSR)

In the following a brief description of a test signal is given, stating its particular advantages for measurement of amplitude and phase simultaneously.

1 The multitone test signal

1.1 *General description*

The multitone test signal (MTTS) consists of a spectrum of N discrete signals separated by frequency spacing of 100 Hz in the low frequency range.

The spectral lines are all of equal amplitude; their phase relationship to each other is chosen on the basis of mathematical considerations so that the energy of the test signal is distributed approximately evenly across the entire period of the test signal.

The transmission characteristics, i.e. the amplitude and phase distortion of a telephone line, produce changes in the test signal. On the receive side, these changes are measured and evaluated, e.g. by means of a Fourier analysis. The results may be displayed on a screen in the form of an amplitude and/or phase graph and also, for example, the group delay may be derived from this.

1.2 *Measuring principle*

The transmit signal consisting of N cosine waveforms is generated in digital circuits: a sufficient number of instantaneous values of the MTTS is read out of a ROM with a clock frequency. After passing through a D/A converter and a filter which suppresses the clock frequency, the composite signal is available:

$$u(t) = \sum^{N} A_n \cdot \cos (2 \pi nft - \varphi_n)$$

where

A amplitude of a single waveform

f is 100 Hz (see Note 2)

φ phase of the single waveforms

n serial number of the single waveforms

t time

N total number of waveforms.

At $f =$ 100 Hz, the duration of one period of the MTTS is 10 ms.

The MTTS is passed to the object to be tested which changes the properties of the MTTS, i.e. the amplitudes and phases of the single waveforms.

In the receiving section, the changed signal is passed to an evaluation circuit, where the signal is sampled with the clock frequency. The sampled analogue values are digitized and stored in a memory. The stored values of the time function are then transferred by means of the Discrete Fourier Transform into the frequency domain. All necessary calculations are performed in a microcomputer.

At measurements where the objects to be tested include carrier frequency systems, frequency shift of the measuring signal can appear. In such cases it is recommended to use window functions in the signal processing section of the receiver.

The characteristics of the object to be tested are derived from the deviation of the received values against the transmitted values.

1.3 *Data of the multitone test signal*

Transmitter

Transmit frequencies

- 35 signals (cosine) simultaneously;
- $n \times 100$ Hz; $n = 2$ to 36 in steps of 100 Hz from 200 to 3600 Hz, or see Notes 1 and 2;
- Accuracy: 1×10^{-4}

Transmit level (multitone test signal) +10 to −40 dBm.

This level corresponds to the level of a single sinusoidal signal which has the same peak value as the test signal.

– Accuracy at 1000 Hz	0.2 dB
– Frequency response	0.1 dB
– Harmonic distortion	40 dB
– Spurious distortion at +10 dBm	50 dB
– Phase constellation	

0	2π/7	4π/7	6π/7	8π/7	10π/7	12π/7
n: 2, 3, 4, 5, 6, 8, 15, 22, 29, 36	9, 12, 20, 24, 35	10, 16, 18, 26, 28, 34 37 (Note 1)	11, 13, 31, 33	21, 23, 27, 32 1 (Note 1)	14, 19, 25, 30	7, 17 38 (Note 1)

Note 1 – Serial numbers of 1, 37 and 38 are optional values.

Note 2 – The French Administration uses frequency steps of 101.56 Hz according to $[26 \times (n-1)] \times f$, where $f = 8000/2048$. This is in accordance with the principle of frequency offset contained in Recommendation O.6 concerning PCM equipment.

Receiver

The receiver takes into account the level and the phase constellation of the transmitted signal.

2 Advantages of the multitone test signal

With the technical means available today the multitone test signal can be generated at low cost with excellent stability of frequency, amplitude and phase. The quantity of 35 discrete signals and thus test points in the frequency range 200 to 3600 Hz is quite adequate for the testing requirements occurring in practice. Optionally, the frequency band can be widened according to Note 1.

When the received signal is evaluated, e.g. with the aid of a Fourier analysis to determine amplitude/frequency response and/or phase or group delay, a test cycle time, allowing for processing time and screen display time, of only less than one second is needed. This short test cycle is of great advantage mainly when equalization work has to be done.

Because the MTTS is normally a continuous signal there are no settling time problems which occur using a sweep mode signal.

The MTTS is an ideal band-limited "noise signal" for determining the rms bandwidth of filters, for example for the filter (psophometric weighting) in Recommendation O.41 or for calibrating PCM instruments measuring quantizing distortion.

Considering the ripple at the frequency response curve one can recognize very clearly that there are frequency components caused by any non-linearity of an item under test.

Using the Fourier analysis to evaluate the received MTTS one can recognize both the amplitude and frequency of unwanted signals; that means, the procedure works like a swept selective receiver.

The period of this MTTS is 10 ms (which corresponds to one period of a 100-Hz fundamental). Since for Fourier analysis it is sufficient to sample just one period of the test signal, i.e. 10 ms, at the receiving side, and 10 ms plus at the sending side, measurements could be performed during correspondingly short gaps in the speech or data transmission signal. These gaps occur in any case in these signals, or they may be created by technical means.

The use of the MTTS in combination with the Fourier analysis makes it possible to provide measurements of parameters which normally require filters; e.g. weighted noise, quantizing distortion, selective crosstalk, etc. In these cases filtering is provided by appropriate calculations in the microcomputer carrier out for the frequency domain of the input signal.

For measurements including PCM sections it is not necessary to shift the frequencies in order to avoid submultiples of 8 kHz, in this case a MTTS without frequency shift leads into a frequency response with a ripple of up to ± 0.1 dB. With the help of an averaging procedure (e.g. 4 or 16 measuring cycles) the ripple can be reduced to a negligible value.

A further possibility to reduce the ripple is to use shifted frequencies of $n \cdot 101 \cdot 56$ Hz, according to Note 2.

In this case the ripple is less than ± 0.05 dB after one measuring cycle; even this relatively small error can be reduced by an averaging procedure.

3 Practical experience

Since 1981, instruments using multitone test signals have been used by various Administrations all over the world.

Measurement results are obtained quickly and unambigously and are compatible with those obtained with conventional methods.

The USSR Telecommunication Administration is investigating theoretically and practically the MTTS in order to determine the best use for further applications.

Supplement No. 3.8

GUIDELINES CONCERNING THE MEASUREMENT OF JITTER

(Melbourne, 1988)

(Information assembled by SG IV and SG XVIII)

1 Definitions and causes of jitter

CCITT Recommendation G.701 [1] defines jitter as "short-term non-cumulative variations of the significant instants of a digital signal from their ideal position in time". This means that jitter is an (unwanted) phase modulation of the digital signal. The frequency of the phase variations is calle jitter-frequency. A second parameter which is closely related to jitter is called wander. It is defined as "long-term non-cumulative variations of the significant instants of a digital signal from their ideal position in time". Up to now there is no clear definition of the boundary between jitter and wander. Components of phase variation having frequencies below the range of 1 to 10 Hz are normally called wander.

Jitter may deteriorate the transmission performance of a digital circuit. As a result of signal displacement from its ideal position in time, errors may be introduced into the digital bit stream at points of signal regeneration. Slips may be introduced into digital signals resulting from either data overflow or depletion in digital equipment incorporating buffer stores and phase comparators. In addition, phase modulation of the reconstructed samples in digital-to-analogue conversion devices may result in degradation of the decoded analogue signals. This is more likely to be a problem when transmitting encoded wide-band signals.

A distinction must be made between the systematic and random jitter. Systematic jitter results from misaligned timing recovery circuits in signal regenerating devices or from inter-symbol interference and amplitude-to-phase conversion caused by imperfect cable equalization. Systematic jitter is pattern-dependent.

Random jitter originates from internal or external interferring signals such as repeater noise, crosstalk or reflections. Random jitter is independent of the transmitted pattern.

Low-frequency jitter produced in pulse justification demultiplexers arises from pulse justification synchronization; the mechanism by which the plesiochronous lower-rate signals are synchronized to a locally generated clock source. This jitter, which appears at the demultiplexer lower-rate output, is denoted "justification jitter" or "waiting time jitter".

As systematic jitter is correlated with the transmitted pulse pattern at different regenerators, it accumulates coherently. Random jitter is uncorrelated at different regenerators and accumulates incoherently. In most existing lower-rate digital systems, systematic jitter is dominant. In some contemporary higher-rate systems the random component may become significant or even predominant.

Unlike some other impairments, disturbing jitter can be reduced by regenerators or by the use of "de-jitterizers" which contain a signal buffer with a narrow-band phase-smoothing circuit. Regenerators can only reduce jitter frequency components above the cut-off frequency of the clock recovery circuits. At lower jitter frequencies, the output signal or a regenerator follows the input jitter. In this case jitter is "transferred" which means that a regenerator behaves like a low-pass filter. This characteristic behaviour leads to the typical jitter tolerance templates as shown in Figure 1.

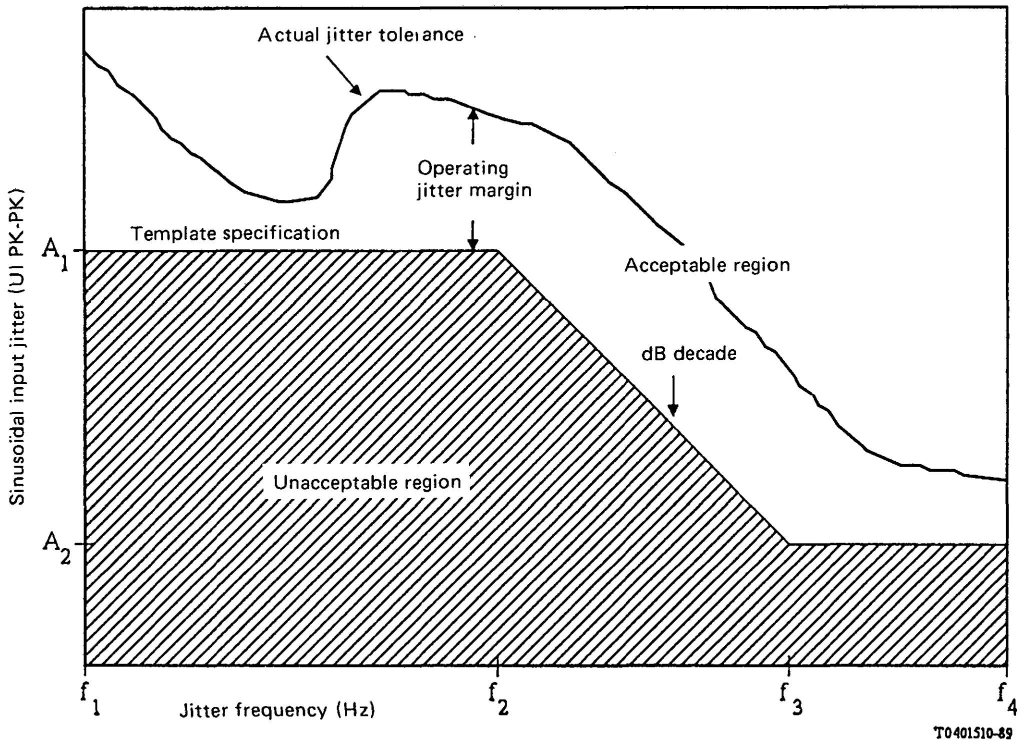

FIGURE 1

Actual tolerance measurement and tolerance template relationship

It can be seen from the considerations above that jitter can severely deteriorate the performance of digital transmission systems. On the other hand, jitter cannot be avoided completely. To evaluate whether jitter is kept within the allowed limits is the task of jitter measurements.

2 Test environment

In order to facilitate repeatable and accurate measurements, and to allow comparisons between measurements made at different times, it is necessary to minimize variations in the test environment. Several test environment parameters which may vary widely within their allowed ranges and may significantly affect jitter measurement results (depending upon the type of equipment involed) include the data pattern, data rate, pulse shape, and cable characteristics. The characteristics of these parameters should be controlled as appropriate. Additionally, there are secondary test environment parameters which may also affect jitter performance, that should be maintained at nominal levels to facilitate repeatable measurements.

In order to verify worst-case equipment performance, it may be necessary to stress the equipment under test with multiple changes in the test environment. However, this type of test does not necessarily provide meaningful jitter performance data due to lack of control of the particular parameter(s) which may be causing errors, as well as their effect on other non-jitter related equipment failure mechanisms. Therefore, multiple changes in test environment should not be used to characterize the jitter performance of the equipment under test.

2.1 *Controlled data patterns*

Some measurement procedures require the application of controlled data patterns. When the controlled data pattern is intended to approximate live traffic encountered in the network, a pseudo-random bit sequence (PRBS) is recommended. Four pseudo-random patterns are specified in Recommendations O.151 and O.152 namely $2^{11} - 1$, $2^{15} - 1$, $2^{20} - 1$ and $2^{23} - 1$ length sequences. To ensure that a particular PRBS will generate adequate jitter spectral line density within the jitter half-power bandwidth of typical clock recovery circuits at the applicable hierarchical level, the PRBS word length should be much greater than the data rate divided by the jitter half-power bandwidth. The CCITT recommends that the PRBS word length be at least 100 times greater than the data rate divided by the jitter half-power bandwidth [2] (see Note). The pseudo-random bit sequence of $2^{15} - 1$ bit length specified in Recommendation O.151 for bit error measurements may generate an inadequate spectral line density for jitter measurements a speeds above the primary rate. Moreover, this pattern has poor binary run properties. Therefore, for bit rates at and above the primary rate, the pattern length should be no less than $2^{20} - 1$, and have a well balanced binary run characteristic [3].

Note – Further study of jitter spectral line density sufficiency is desirable.

2.2 *Bit rate*

The bit rate must be maintained within the specifications for digital interfaces as specified in Recommendation G.703 [4]. For convenience, the bit rates are repeated below:

– basic rate:	64 kbit/s
– primary rate:	1 544 kbit/s ± 50 ppm
	2 048 kbit/s ± 50 ppm
– secondary rate:	6 312 kbit/s ± 30 ppm
	8 448 kbit/s ± 30 ppm
– tertiary rate:	32 064 kbit/s ± 10 ppm
	34 368 kbit/s ± 20 ppm
	44 736 kibt/s ± 20 ppm
– quaternary rate:	139 264 kibt/s ± 15 ppm

2.3 *Pulse shape and cable characteristics*

Pulse shape affects jitter performance by impacting the accuracy of the decision making process in a block recovery circuit. Pulse shape is typically specified by a pulse template at an output interface or at a cross-connect [5] and may vary at the equipment input due to cable effects, resulting from operating within the specified range of cable lengths and specified cable type(s). It is recommended that the pulse shape to be used in jitter tests be centered within the pulse template specified, rather than being at the extreme allowable values (see Note).

Note – A pulse template appropriate for jitter testing needs further study.

2.4 *Secondary test environment parameters*

Other test environment parameters which may affect jitter performance include temperature, cross-talk, and noise. Temperature affects jitter performance by altering the resonant fequency of clock recovery circuits, oscillators, and phase smoothing circuits, as well as changing the filtering properties of analog circuitry. Cross-talk may affect jitter performance when signals in a cable, backplane, or circuit board affect one another to a noticeable degree. Noise affects the decision making process in a clock recovery circuit by decreasing the decision eye margin.

In order to obtain accurate and repeatable jitter measurements and ensure that the effects of jitter applied to the quipment dominate measurement results, it is recommended that these secondary parameters be maintained at their nominal levels.

3 Glossary or test configuration functional block components

This glossary defines the functional block components employed in the test configurations described in the following sections. Note that these functional blocks may be incorporated in various combinations within different test equipment.

- *Attenuator:* A device which reduces the amplitude of a digital signal in order to decrease the signal-to-noise ratio.

- *Digital signal generator:* A signal source which provides a digital network hierarchical signal at the appropriate bit rate with proper output impedance, pulse shape, line coding, and frame format. This functional block component is capable of providing several data patterns, must have a clock and data output, and may accept an external clock input.

- *Digital signal receiver:* An instrument which terminates a digital network hierarchical signal and monitors for bit errors, errored seconds, or bit error ratio (BER).

- *Equipment under test (EUT):* A circuit or system that is being tested with a controlled data pattern.

- *Frequency synthesizer:* An extremely stable frequency source of high accuracy. Some frequency synthesizers are capable of adding phase or frequency modulation (PM or FM) to the primary output while providing an unmodulated secondary output.

- *Jitter generator:* An instrument which produces a hierarchical rate clock modulated by sinusoidal jitter of adjustable frequency and amplitude. A modulation input provides for external jitter control, and an optional clock input provides for external data rate frequency control.

- *Jitter receiver:* An instrument which demodulates and measures the jitter present on a hierarchical clock or data signal. An output provides a voltage proportional to the demodulated jitter.

- *Low-pass filter:* A circuit used to attenuate unwanted spectral components above a given frequency.

- *Jitter measurement filter:* A circuit which attenuates jitter spectral components outside a specified or desired passband.

- *Network under test:* A circuit, system, or network that is being tested using live traffic.

- *Noise source:* An instrument which generates a signal having a near Gaussian amplitude distribution with a flat power spectrum to approximately three times the half-power bandwidth of the retiming circuit.

- *Sine wave generator:* A waveform generator which provides a low distortion frequency and amplitude controlled sine wave.

- *Spectrum analyzer:* An instrument which measures and displays signal power as a function of frequency over a selected frequency range. A tracking oscillator output provides an adjustable amplitude swept frequency sinusoid which tracks the instantaneous measurement frequency of the spectrum analyzer.

- *Voltmeter:* An instrument which measures DC, true rms, or true peak-to-peak voltage as required. Here true peak-to-peak voltage is defined as the difference between the most positive and the most negative instantaneous voltages recorded during the entire measurement interval.

4 Jitter tolerance measurement

Jitter tolerance (also known as jitter accommodation) is defined in terms of the sinusoidal jitter amplitude which, when applied to an equipment input, causes a designated degradation of error performance. Jitter tolerance is a function of the amplitude and frequency of the applied jitter.

Jitter tolerance requirements are specified in terms of jitter templates which cover a specified sinusoidal amplitude/frequency region. Jitter templates represent the minimum amount of jitter an equipment *must accept* without causing the designated degradation of error performance (see Note).

The intended relationship of an equipment's actual tolerance to input jitter and its associated jitter tolerance template is illustrated in Figure 1.

Note – In CCITT terminology, the jitter tolerance template represents the "lower limit of maximum tolerable input jitter".

4.1 *Actual tolerance*

The sinusoidal jitter amplitudes that an equipment actually tolerates at a given frequency are defined as all amplitudes up to, but not including, that which causes the designated degradation of error performance.

The designated degradation of error performance may be expressed in terms of either bit error ratio (BER) penalty or onset of errors criteria. The existence of two criteria arises because the input jitter tolerance of an individual digital equipment is primarily determined by the following two factors:

– The ability of the input clock recovery circuit to accurately recover clock from a jittered data signal, possibly in the presence of other degradations (pulse distortion, cross-talk, noise, etc.).

– The ability of other components to accommodate dynamically varying input data rates (e.g., pulse justification capacity and synchronizer or desynchronizer buffer size in an asynchronous digital multiplex).

The BER penalty criterion allows environment independent determination of the decision circuit alignment jitter allocation, which is critical for evaluating the first factor. A detailed discussion of the BER penalty criterion may be found in References [6], [7]. The onset of errors criterion is recommended for evaluating the second factor.

4.1.1 *Bit error ratio penalty technique*

The bit error ratio (BER) penalty criterion for jitter tolerance measurements is defined as the amplitude of jitter, at a given jitter frequency, that duplicates the BER degradation caused by a specified signal to noise ratio (SNR) reduction.

This technique is separated into two parts. Part one determines two BER versus SNR reference points for the equipment under test. With zero jitter applied, noise is added to the signal, or the signal is attenuated, until a convenient initial BER is obtained. Then the noise, or signal attenuation, is decreased until the SNR at the decision circuit is increased the specified amount of dB (and consequently, the decision circuit is performing with an improved BER). Part two uses the BER versus SNR reference points; at a given frequency, jitter is added to the test signal until the BER returns to its initially selected value. Since a known decision circuit eye width margin was established by the two BER versus SNR points, the added equivalent jitter is a true and repeatable measure of the decision circuit jitter tolerance performance. Part two of the technique is repeated for a sufficient number of frequencies such that the measurement accurately represents the continuous sinusoidal input jitter tolerance of the EUT over the applicable frequency range. The test equipment must be able to produce a controlled jittered signal, a controlled SNR on the data stream, and measure the resulting BER from the EUT.

Figure 2 illustrates the test configuration for the BER penalty technique. The equipment outlined in dashed lines is optional. The optional frequency synthesizer is used to provide a more accurate determination of frequencies utilized in the measurement procedure. This may be particularly important for repeatability of measurements for some types of equipment; i.e., asynchronous digital multiplexes. The optional jitter receiver is used to verify the amplitude of generated jitter.

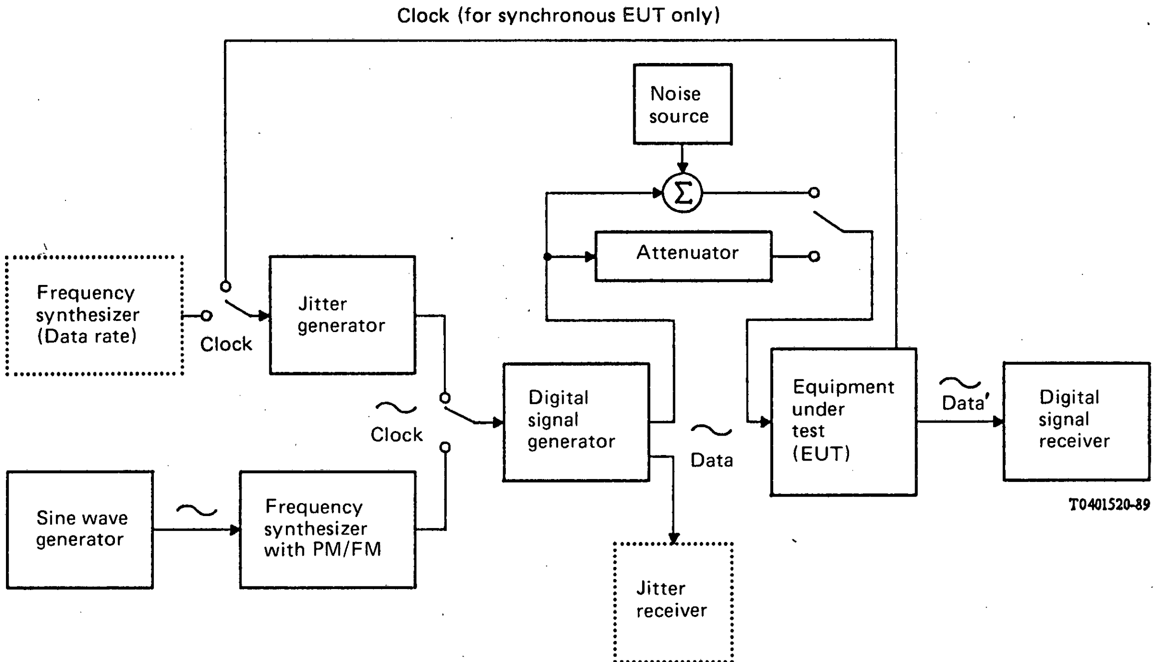

FIGURE 2

Jitter tolerance measurement configuration
Bit error ratio penalty technique

Procedure

i) Connect the equipment as shown in Figure 2. Verify proper continuity and error-free operation.

ii) With no applied jitter, increase the noise (or attenuate the signal) until at least 100 bit errors per second are observed.

iii) Record the corresponding BER and its associated SNR.

iv) Increase the SNR by the specified amount.

v) Set the input jitter frequency as desired.

vi) Adjust the jitter amplitude until the BER returns to the value recorded in step (iii).

vii) Record the amplitude and frequency of the applied input jitter, and repeat steps v) to vii) for a sufficient number of frequencies to characterize the jitter tolerance curve.

4.1.2 *Onset of errors technique*

The onset of errors criterion for jitter tolerance measurements is defined as the largest amplitude of jitter at a specified frequency that causes a cumulative total of more than 2 errored seconds, where these errored seconds have been summed over successive 30 seconds measurement intervals of increasing jitter amplitude.

This technique involves setting a jitter frequency and determining the jitter amplitude of the test signal which causes the onset of errors criterion to be satisfied. Specifically, this technique requires:

1) isolation of the jitter amplitude "transition region" (in which error-free operation ceases),

2) one errored second measurement, 30 seconds in duration, for each incrementally increased jitter amplitude from the beginning of this region, and

3) determination of the largest jitter amplitude for which the cumulative errored second count is no more than 2 errored seconds.

The process is repeated for a sufficient number of frequencies such that the measurement accurately represents the continuous sinusoidal input jitter tolerance of the EUT over the applicable jitter frequency range. The test equipment must be able to produce a controlled jittered signal and measure the resulting errored seconds caused by the jitter on the incoming signal.

Figure 3 illustrates the test configuration for the onset of errors technique. The optional frequency synthesizer is used to provide a more accurate determination of frequencies utilized in the measurement procedure. The optional jitter receiver is used to verify the amplitude of generated jitter.

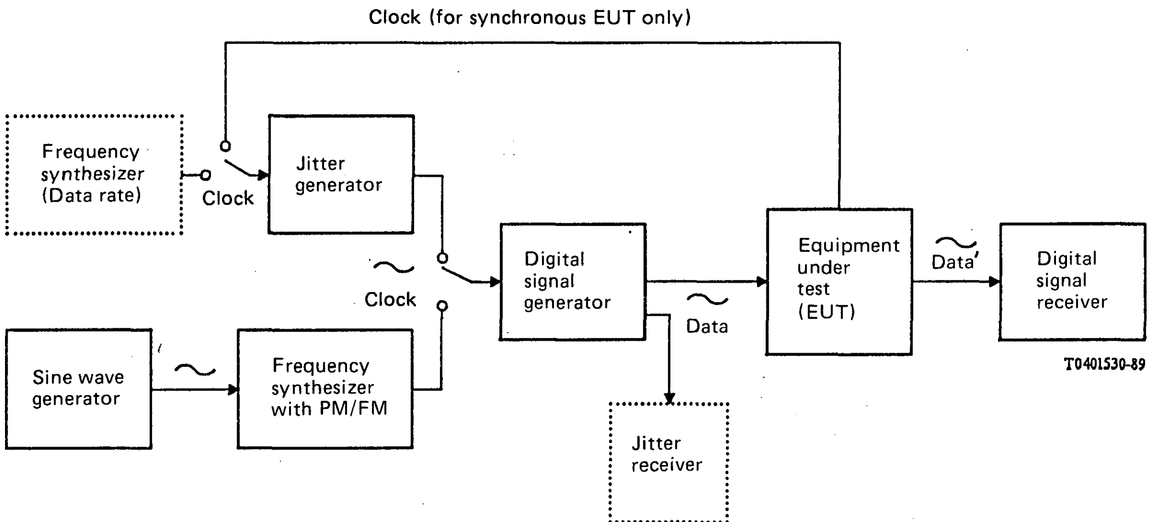

FIGURE 3

Jitter tolerance measurement configuration
Onset of errors technique

Procedure

i) Connect the equipment as shown in Figure 3. Verify proper continuity and error-free operation.

ii) Set the input jitter frequency as desired, and initialize the jitter amplitude to 0 UI peak-peak.

iii) Increase the jitter amplitude in gross increments to determine the amplitude region where error-free operation ceases. Reduce the jitter amplitude to its level at the beginning of this region.

iv) Record the number of errored seconds that occur over a 30 second measurement interval. Note that the initial measurement must be 0 errored seconds.

v) Increase the jitter amplitude in fine increments, repeating step iv) for each increment, until the onset of errors criterion is satisfied.

vi) Record the indicated amplitude and frequency of the applied input jitter, and repeat steps ii) to iv) for a sufficient number of frequencies to characterize the jitter tolerance curve.

4.2 *Jitter tolerance template compliance*

Equipment jitter tolerance is specified with jitter tolerance templates. Each template defines the region over which the equipment must operate without suffering the designated degradation of error performance. The difference between the template and actual equipment tolerance curve represents the operating jitter margin, illustrated in Figure 1.

The template compliance measurement is performed by setting the jitter frequency and amplitude to the template value, and observing that the designated degradation of error performance does not occur.

A sufficient number of template points are measured to assure compliance over the entire frequency range of the template.

Figure 2 or 3, as applicable, illustrates the test configuration for the jitter tolerance template compliance technique.

Procedure

i) Connect the equipment as described in § 4.1.1 or 4.1.2, as applicable. Verify proper continuity and error-free operation.
ii) Set the jitter amplitude and frequency to a template point.
iii) When the onset of errors technique is used, confirm that 0 errored seconds occur. When the BER penalty technique is used, confirm that the designated degradation of error performance is not reached.
iv) Repeat steps ii) and iii) for a sufficient number of template points to verify jitter tolerance template compliance.

5 Jitter transfer characteristic measurement

The jitter transfer characteristic of an individual digital equipment is defined as the ratio of the output jitter to the applied input jitter as a function of frequency.

If the relationship between the jitter appearing at the input and output ports of a digital equipment can be described in terms of a linear process (a process which is both additive and homogeneous), the term "jitter transfer function" is used. The relationship between jitter appearing at the input and output ports of some types of digital equipment cannot be described in terms of a jitter transfer function. In such cases, different measurement techniques may be necessary to obtain meaningful results.

5.1 *Linear processes*

Jitter transfer measurements are commonly required for clock recovery circuits and desynchronizer phase smoothing circuits. Measurement of the jitter transfer function of a linear clock recovery circuit is generally straightforward. However, measurement of the jitter transfer function of a linear desynchronizer phase smoothing circuit requires specialized techniques because it is embedded in a non-linear asynchronous digital multiplex.

5.1.1 *Clock recovery circuit*

Clock recovery circuits are an essential component of individual digital equipment input ports. Of particular interest is the jitter transfer function of clock recovery circuits which dominate the transfer of jitter from the input to output ports. Characterization of linear clock recovery circuits embedded in non-linear equipment (i.e., asynchronous digital multiplexes) are not addressed because they typically do not dominate the overall equipment jitter transfer characteristic.

5.1.1.1 *Basic technique*

This technique involves applying swept sinusoidal jitter at a fixed tolerable amplitude over a selected frequency range to the EUT, and observing the output jitter amplitude over the applied frequency range. The process is repeated for a sufficient number of frequency ranges to characterize the jitter transfer function of the EUT.

Specifically, this technique utilizes a spectrum analyzer to set a jitter frequency range and corresponding tolerable jitter amplitude. Initially, the EUT is bypassed to establish a 0 dB amplitude reference trace for the test equipment. The EUT is then re-connected, and the 0 dB amplitude reference trace subtracted from the overall jitter transfer measurement to obtain the EUT jitter transfer function. Use of a spectrum analyzer with a tracking oscillator output is required to determine the input jitter frequency and amplitude while making a narrow-band measurement of the output jitter. To achieve a high degree of accuracy, the spectrum analyzer bandwidth must be sufficiently narrow to obtain the desired amplitude resolution and dynamic range in each frequency band measured. For example, to verify less than 0.1 dB peaking, and a 20 dB per decade roll-off from 350 Hz to 20 kHz, a spectrum analyzer with 0.1 dB resolution, 3 Hz bandwidth, and 40 dB dynamic range may be required.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. The optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

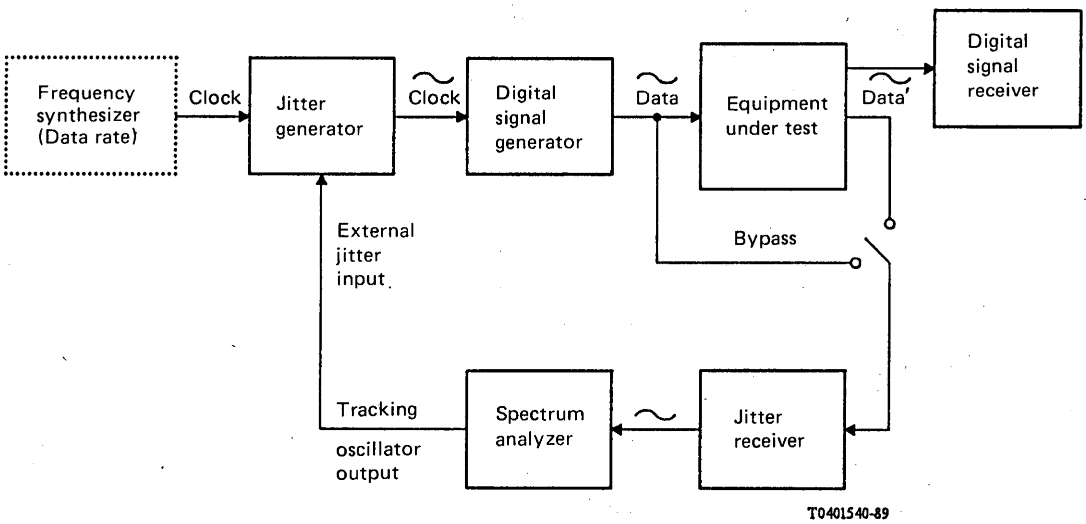

FIGURE 4

Jitter transfer function measurement configuration
Basic technique

Procedure

i) Perform a jitter tolerance measurement of the EUT over the desired frequency range, as described in § 4.

ii) Connect the equipment as shown in Figure 4, bypassing the EUT. Verify proper continuity, linearity, and error-free operation.

iii) Set the frequency range on the spectrum analyzer as desired. Adjust the tracking oscillator output level on the spectrum analyzer to produce a tolerable jitter amplitude over the selected frequency range, which is large enough to ensure adequate measurement accuracy, yet sufficiently small to preserve linear operation.

iv) Setting the spectrum analyzer bandwidth as narrow as feasible, sweep the desired frequency range, and record the 0 dB amplitude reference trace of the test equipment. (Setting a narrow spectrum analyzer bandwidth may allow a reduction in applied jitter amplitude with no loss in measurement accuracy.)

v) Reconnect the EUT as shown in Figure 4. Verify proper continuity, linearity, and error-free operation.

vi) Use the spectrum analyzer to sweep the selected frequency range and record the magnitude of the overall (test equipment and EUT) jitter transfer function.

vii) To obtain the EUT jitter transfer function, substract the 0 dB amplitude reference trace from the overall jitter transfer function recorded in step vi).

viii) Repeat steps i) to vii) for a sufficient number of frequency ranges to characterize the overall frequency range of interest.

5.1.2 *Desynchronizer phase smoothing circuit*

In general, a non-linear process characterizes the relationship between the jitter appearing at the input and output ports of an asynchronous digital multiplex. However, most phase smoothing circuits are intended to operate linearly, and therefore may have a transfer function associated with them. Two techniques have been developed which enable the determination of the jitter transfer function for a linear desynchronizer phase-smoothing circuit using standard multiplex interfaces. The first technique utilizes interfaces at the multiplexer low-speed input and the demultiplexer low-speed output. The second technique utilizes the interfaces at the demultiplexer high-speed input and low-speed output. The second technique utilizes the interfaces at the demultiplexer high-speed input and low-speed output.

5.1.2.1 *Multiplex technique*

This technique attempts to "linearize" the multiplexing process by applying appropriate constraints to the applied input jitter amplitude and frequency. Sinusoidal jitter of a selected amplitude and frequency is applied to the multiplexer low-speed output is observed at the applied frequency. The process is repeated for a sufficient number of frequencies to characterize the desynchronizer jitter transfer function. Specifically, when sinusoidal jitter modulates the phase of the input signal to one of the multiplexer low-speed inputs, the jitter spectrum appearing at the corresponding tributary outputs, in addition to containing other waiting time jitter components at discrete locations throughout the spectrum, contains a discrete component at the frequency of the input jitter. This technique involves making the amplitude of the input jitter sufficiently large to ensure that this discrete component in the output jitter spectrum at the applied frequency dominates the other waiting time jitter components in the measurement bandwidth. However, it should not be so large as to saturate the multiplexer stuffing mechanism (onset of saturation). The smallest magnitude of frequency deviation, $f(t)$, which causes onset of saturation is determined from the smaller magnitude of:

$$f(t) = f_{sc} - f_{nom}$$

$$f(t) = -f_m + f_{sc} - f_{nom}$$

where

f_{sc} represents the multiplexer average synchronous data bit read clock rate,

f_m represents the maximum rate at which pulses can be stuffed into an incoming pulse stream, and

f_{nom} refers to the nominal incoming line rate.

To achieve a high degree of accuracy, the spectrum analyzer bandwidth must be sufficiently narrow to obtain the desired amplitude resolution and dynamic range in each frequency band measured (see § 5.1.1.1). It is also assumed that the transfer function of the multiplexer low-speed input clock recovery circuit does not alter the applied jitter in the frequency range of interest.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. The optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

Procedure

i) Perform a jitter tolerance measurement over the desired frequency range.

ii) Connect the equipment as shown in Figure 4, bypassing the EUT. Verify proper continuity, linearity, and error-free operation.

iii) Manually set the test frequency on the spectrum analyzer.

iv) Adjust the tracking oscillator output level on the spectrum analyzer to produce the largest tolerable jitter amplitude which will not cause onset of saturation (as defined in this paragraph) at the selected frequency.

v) Set the spectrum analyzer bandwidth as narrow as feasible, and record the 0 dB amplitude transfer reference level of the test equipment.

vi) Reconnect the EUT as shown in Figure 4. Verify proper continuity and error-free operation.

vii) Record the magnitude of the overall (test equipment and EUT) jitter transfer function. Averaging is generally required to remove the effects of waiting time jitter on the measurement.

viii) To obtain the magnitude of the EUT jitter transfer function, substract the 0 dB amplitude transfer reference level from the overall magnitude obtained in step vii).

ix) Repeat steps iii) – viii) for a sufficient number of frequencies to characterize the jitter transfer function of the EUT.

5.1.2.2 *Demultiplexer technique*

This technique involves applying sinusoidal jitter of a selected amplitude and frequency to the demultiplexer high-speed input, and observing the jitter amplitude at the demultiplexer low-speed output at the applied frequency. The process is repeated for a sufficient number of frequencies to characterize the desynchronizer jitter transfer function. Specifically, when sinusoidal jitter modulates the phase of the input signal to the demultiplexer, the output jitter spectrum contains a discrete component at the frequency of the input jitter, in addition to the intrinsic waiting time jitter components already present. This technique involves making the amplitude of the applied input jitter sufficiently large to ensure that its contribution to the output jitter spectrum at the applied frequency dominates that of the waiting time jitter, but does not exceed the demultiplexer input jitter tolerance. It is also assumed that the transfer function of the demultiplexer high-speed input clock recovery circuit does not alter the applied jitter in the frequency range of interest.

Figure 4 illustrates the test configuration for the jitter transfer function measurement. It should be emphasized that the following procedure *cannot calibrate out the effects of the low-speed receive circuitry contained in the jitter receiver functional block component*, and therefore requires that this circuitry has flat response.

It should be noted that the digital signal applied to the high-speed input of the demultiplexer must contain framing information to allow proper operation of the equipment under test. "Framed" signals can either be taken from an appropriate digital signal generator or may come from the corresponding digital multiplexer. In the latter case, a transparent jitter modulator has to be inserted between the high-speed multiplexer output and the demultiplexer input. The jitter modulator superimposes jitter on the jitter-free signal coming from the multiplexer.

Procedure

i) Follow the procedure provided in § 5.1.1.1 using Figure 4, scaling the applied jitter in unit intervals (UI) by the ratio of the demultiplexer high-speed input to low-speed output data rates.

5.2 *Non-linear process*

This area requires further study.

6 Ouput jitter measurement

Output jitter measurements fall within two categories:

1) network output jitter at hierarchical interfaces, and
2) intrinsic jitter generated by individual digital equipment.

Measurements of output jitter may be in terms of rms and peak-to-peak amplitudes over designated frequency ranges, and may require statistical characterization.

Output jitter measurements utilize either live traffic or controlled data patterns.

6.1 *Live traffic*

Output jitter measurements at network hierarchical interfaces typically use a live traffic signal. For pre-service testing, in which controlled data patterns are used, see § 6.2. This technique involves demodulating the jitter from the live traffic at the output of a network interface, selectively filtering the jitter, and measuring the true rms or true peak-to-peak amplitude of the jitter over the specified measurement time interval.

Figure 5 illustrates the test configuration for the live traffic technique. The optional spectrum analyzer allows observation of the output jitter frequency spectrum.

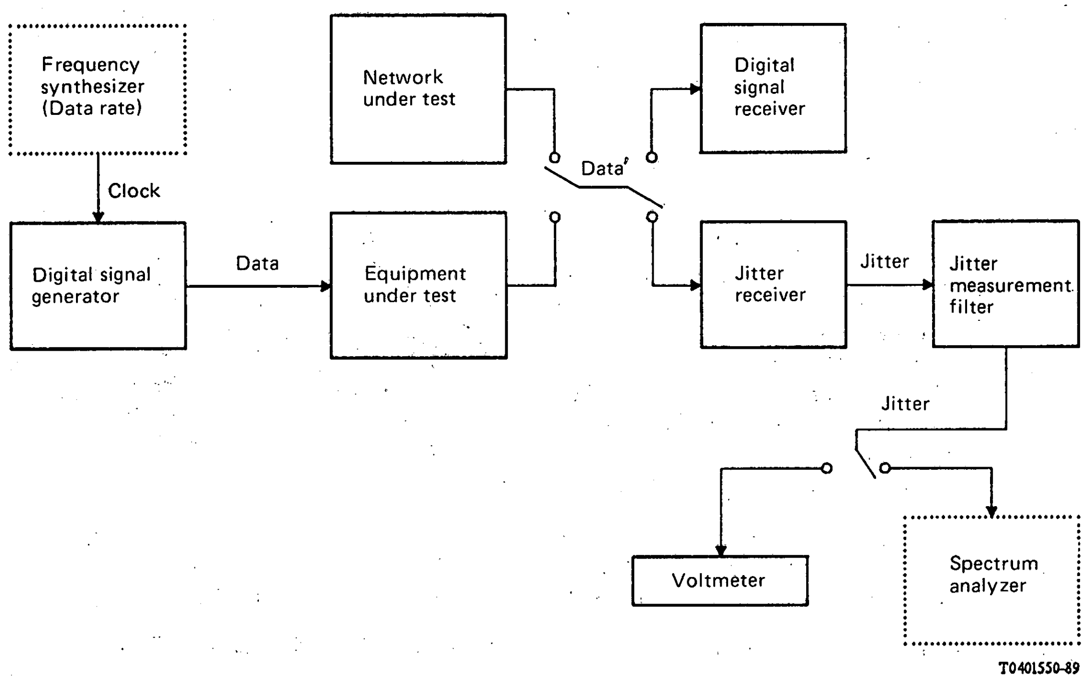

FIGURE 5

Output jitter measurement configuration
Basic technique

Procedure

i) Connect the equipment as shown in Figure 5. Verify proper continuity and error-free operation.

ii) Select the desired jitter measurement filter and measure the filtered output jitter, recording the true peak-to-peak jitter amplitude that occurs during the specified measurement time interval.

iii) Repeat step ii) for all desired jitter measurement filters.

6.2 *Controlled data patterns*

Measurement of intrinsic jitter in individual digital equipment requires the application of controlled data patterns. Controlled data patterns are generally applicable in laboratory, factory, and out-of-service situations. The "basic technique", described below, details how such measurements may be performed.

Where it is desirable to obtain more detailed information regarding output jitter power (specifically, jitter generated in digital regenerators), jitter may be further categorized in terms of random and systematic components. The primary reasons for distinguishing between random and systematic jitter are to enable the comparison of measurement results with theoretical computations, and to refine regenerator design. The "enhanced technique" [6] describes how random and systematic jitter may be measured.

6.2.1 *Basic technique*

This technique is indentical to that described in § 6.1, except for the application of an unjittered controlled data pattern to the EUT. In Figure 5, the optional frequency synthesizer may be used to provide a more accurate determination of frequencies utilized in the measurement procedure.

Procedure

i) Connect the equipment as shown in Figure 5, using the digital signal generator to provide an unjittered controlled data pattern to the EUT. Verify proper continuity and error-free operation.

ii) Select the desired jitter measurement filter and measure the filtered output jitter, recording the true peak-to-peak jitter amplitude that occurs during the specified measurement time interval.

iii) Repeat step ii) for all desired jitter measurement filters.

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