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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 ± | .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 0.15 dB from 300 to 4000 Hz.

3.2 *Longitudinal losses*

Input longitudinal interference loss and longitudinal conversion loss shall 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.)

3.3 *Measuring range*

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

3.4 *Calibration accuracy at 800 Hz*

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

Range	*Error limit*
0 to —60 dBm	±	.5 dB
—60 to —90 dBm	±	.0 dB

3.5 *Relative gain versus frequency (frequency weighting)*

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

Also, the unit may be provided with the 1004 to 1020 Hz test-signal reject filter , described in Table 1/O.132 of Recommendation O.132, for use with the characteristics described in Table 1/O.41. In this case, the calibration of the measuring instrument shall include a correction factor of appropriate value to account for the loss in effective noise bandwidth due to the test-signal reject filter. The correction factor assumes a uniform distribution of distortion power over the frequency range involved and is of the following form:

Correction (dB) = 10 log

10

$$\frac{ffective\ bandwidth\ of\ standard\ noise\ weighting}{ffective\ bandwidth\ of\ the\ measuring\ instrument}$$

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 ≥" 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 ± | .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, p. 1

H.T. [T1.41]

TABLE 1/O.41

Telephone circuit psophometer weighting coefficients and limits

Frequency (Hz)	Relative weight (dB)	Limit (± | B)
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	—

Tableau 1/O.41 [T1.41], p. 2

H.T. [T2.41]

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
< | 00 Hz increasing 24 dB/octave, (Note 1) }	{
1020-2 300 Hz approx. **| (+- | fR** **3 dB (Note 2)** **}**	{
400-1020 Hz **approx.** | (+- | .25 dB }	**{**
1020- 1020 Hz **approx. | (+- | fR** **0 dB** **}**	{
1020-2600 Hz **approx.** | (+- | .25 dB }	**{**
1020- 3400 Hz approx. **| (+- | fR** **3 dB (Note 2)** **}**	{
> | 400 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.

Tableau 2/O.41 [T2.41], p. 3

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 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*

See Annex A to this Recommendation.

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 ± | .2 dB.

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.

H.T. [T3.41]

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	1 dB ≥" 3 dB

Table 3/O.41 [T3.41], p.

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 ± | .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^{D}lF261^{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.

Blanc

H.T. [T4.41]

TABLE A-1/O.41

{

C-message weighting coefficients and accuracy limits

}

Frequency (Hz)	Relative weight (dB)	Limit (± | B)
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.

Tableau A-1/O.41 [T4.41], p. 5

Figure A-1/O.41, p. 6

H.T. [T5.41]
TABLE A-2/O.41
3 kHz flat weighting characteristic

Frequency (Hz)	| 0	| 0	| 00	1000	2000	3000	6000
Relative loss (dB)	| 0	| 0	| 0	| 0	| 0.8	| 3.0	| 12.3 | ua)
Tolerance (dB)	± | .5	± | .7	± | .5	± | .2	± | .0	± | .8	± | .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.

Tableau A-2/O.41 [T5.41], p. 7

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 non-linearity 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:

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

where:

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

V

2nd

[Unable to Convert Formula]

where:

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

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

Third order intermodulation distortion is defined as follows:

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

where:

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

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

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

3 Specific requirements

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

3.1 *Transmitter*

3.1.1 *Level accuracy*

The r.m.s. signal output level error shall be less than ± | 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 ± | .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 ± | 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 ± | 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 ± | 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 ± | 00 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 Θ 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 | fR 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 ± | 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 | fR 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: ± | dB |

3, 6 and
20 dB: ± | 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 ≥" | 6 dB

2.3.4 *Terminating impedance* | other impedances optional) 600 ohms

— Return loss ≥" | 0 dB

2.3.5 *High impedance* approx. 20 kohms

— Bridging loss across 300 ohms
| .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, p.

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^{D}lF261^{1} to 1×10^{D}lF261^{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 ≥" | 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

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.

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 ≥" | 6 dB

3.1.1 *Terminating impedance* | other impedances optional) 600 ohms

— Return loss ≥" | 0 dB

3.1.2 *High impedance* approx. 20 kohms

— Bridging loss across 300 ohms
| .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 (± | .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 ± | dB from 275 to 3250 Hz:

— 3 dB point ± | 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 ± | 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.

H.T. [T1.71]
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
| 000 | o | 1025	> 50.0

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

Table 1/O.71 [T1.71], p.

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 $1 \times 10^{\mathrm{D}}$lF261^{1} to $1 \times 10^{\mathrm{D}}$lF261^{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.

Recommendation O.81

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 | 00 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 | (+- | .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, p.

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.

Figure 2/O.81 p.

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
| (+- | 00 microseconds⎫

— 400 Hz to 600 Hz

| (+- | 30 microseconds |
± | % of

— 600 Hz to 1 kHz

| (+- | 10 microseconds ⎬ |
measuring range

— 1 kHz to 20 kHz

| (+- | 5 microseconds⎭

Outside a temperature range of +15 | (deC to +35 | (deC 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 ± | 0 microseconds
— variations up to 30 dB ± | 0 microseconds

4.1.2 Measuring frequency 200 Hz to 20 kHz

4.1.2.1 Measuring frequency accuracy:

— in temperature range +15 | (deC to +35 | (deC
| (+- | % of actual frequency reading ± | 0 Hz

— in temperature range +5 | (deC to +50 | (deC
| (+- | % of actual frequency reading ± | 0 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 | (deC to +35 | (deC | (+- | %
— in temperature range +5 | (deC to +50 | (deC | (+- | %

Requirements that have to be met on grounds of compatibility between equipments made by different manufacturers.
4.1.4 Modulation frequency (1 kHz | | 4) :

— in temperature range +15 | (deC to +35 | (deC 41.66 Hz ± 0.5%
— in temperature range +5 | (deC to +50 | (deC 41.66 Hz ± 1% |

4.1.4.1 Modulation depth m = 0.4 ± 0.05

4.1.4.2
Modulation distortion factor
,

| %

The measurement range is taken to be the indicated value at full-scale deflection on the range in use.
The modulation distortion factor is taken to be: r.m.s. value of unwanted sidebands × 100%.

r.m.s. value of wanted sidebands

4.1.5 Identifying frequency (1 kHz | |) derived from modulation frequency 166.6 Hz

4.1.5.1 Modulation depth $m = 0.2 \pm 0.05$

4.1.5.2 Sending time of identifying signal 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).

$\times$ 100%.

4.1.6 Changeover frequency (1 kHz | | 40) derived from modulation frequency 4.166 Hz

4.1.6.1 Carrier changeover time Less than 100 microseconds

4.1.6.2 Deviation between carrier changeover point and envelope minimum | (+- | .2 milliseconds

4.1.7 *Range of environmental conditions*

4.1.7.1 Power supply voltage variation +10 to —15%

4.1.7.2 Temperature range +5 | (deC to +50 | (deC

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 : — 200 Hz to 400 Hz ± | 0 microseconds
— 400 Hz to 600 Hz ± | 3 microseconds
— 600 Hz to 20 kHz ± | 1 microsecond s

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 | (+- | .5 dB

at the reference frequency | (+- | .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 ≥" | 0 dB

4.2.3.2 Signal balance ratio ≥" | 6 dB

4.2.4 Harmonic distortion of send signal | % (40 dB)

4.2.5 Spurious distortion of send signal | .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.

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 ≥" | 0 dB

4.3.2.2 Signal balance ratio ≥" | 6 dB

4.3.3 Range for measuring group-delay

0 to ± | 00, ± | 00, ± | 00 microseconds

frequency distortion

0 to ± | , ± | , ± | , ± | 0 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 | (+- | , ± | , ± | 0, ± | 0, ± | 0 dB

4.3.4.1 Accuracy (+5 | (deC to +50 | (deC) ± | .1 dB ± | % 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 | (deC to +35 | (deC) ± | .25 dB

Accuracy (+5 | (deC to +50 | (deC) | (+- | dB

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

200 Hz to 4 kHz

4.3.7 Measuring ranges for frequency measurements 200 Hz to 20 kHz

4.3.7.1 Accuracy of frequency indications ± | % ± | 0 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.

On the ± | 0 dB range stated accuracy applies over the ± | 0 dB range only (see § 4.3.1.1).

4.3.9.3 The error in indication due to discrete tones ± | 50 Hz around either test or reference signals shall not exceed ± | 0 microseconds and for ± | 00 Hz shall not exceed ± | microseconds when the level of such interfering frequency is 26 dB below the mean carrier level of the received test signal.

Bibliography

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Recommendation O.82

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 (= | 0 | 00 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 | 00 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 | (+- | 0 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, p.

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.

Figure 2/O.82, p.

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
| (+- | | icroseconds⎫
± | % of measuring range
— 10 kHz to 50 kHz
| (+- | | icroseconds |
(see Note 1 at the end of
— 50 kHz to 300 kHz
| (+- | | icrosecond s ⎬ |
this Recommendation)
— 300 kHz to 600 kHz
| (+- | .5 microsecond s ⎭

Outside a temperature range of +5 | (deC to +40 | (deC 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 microsecond s
— variations up to 20 dB ± | .0 microsecond s
— variations up to 30 dB ± | .0 microseconds

4.1.2 Measuring frequency 5 kHz to 600 kHz

4.1.2.1 Measuring frequency accuracy:

— in temperature range +5 | (deC to +40 | (deC | (+- | % ± | 00 Hz of actual reading
— in temperature range +5 | (deC to +50 | (deC | (+- | % ± | 00 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 | (deC to +40 | (deC | (+- | %
— in temperature range +5 | (deC to +50 | (deC | (+- | %

4.1.4 Modulation frequency accuracy :

— in temperature range +5 | (deC to +40 | (deC 416.66 Hz ± 0.5%
— in temperature range +5 | (deC to +50 | (deC 416.66 Hz ± 1% |

4.1.4.1 Modulation depth 0.4 ± 0.05

4.1.4.2 Modulation distortion factor | %

(See Note 3 at the end of this Recommendation) 4.1.5 Identifying frequency (derived from modulation frequency) 1.666 kHz

4.1.5.1 Modulation depth 0.2 ± 0.05

4.1.5.2 Sending time of identifying signal 2.4 milliseconds terminating with the end of the sending time of the reference frequency

4.1.5.3 The identifying signal shall commence with an increase in the amplitude of the carrier as shown in Figure 1/O.82.

4.1.6 Changeover frequency (derived from modulation frequency) 41.66 Hz

4.1.6.1 Carrier changeover time less than 100 microseconds
4.1.6.2 Deviation between carrier changeover point and envelope minimum
| (+- | .02 millisecond

4.1.7 *Range of environmental conditions*

4.1.7.1 Power supply voltage variation ± | 0%
4.1.7.2 Temperature range +5 | (deC to +40 | (deC
Temperature range for storage and transport —40 | (deC to +70 | (deC
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 : — 5 kHz to 10 kHz ± | .5 microsecond
— 10 kHz to 50 kHz ± | .2 microsecond
— 50 kHz to 300 kHz ± | .1 microsecond
— 300 kHz to 600 kHz ± | .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 | (+- | .5 dB
At the reference frequency | (+- | .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 ≥" | 0 dB
Signal balance ratio ≥" | 0 dB
4.2.3.2 Unbalanced 75 ohms
Return loss ≥" | 0 dB
4.2.4 Harmonic distortion of send signal
| % (40 dB)

4.2.5 Spurious distortion of send signal
| .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.

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 ≥" | 0 dB
Signal balance ratio ≥" | 0 dB
4.3.2.2 Unbalanced 75 ohms
Return loss ≥" | 0 dB

4.3.3 Range for measuring group-delay/frequency distortion: 0 to ± | 0, ± | 0, ± | 0, ± | 00, ± | 00, ± | 00, ± | 000 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 ± | , ± | , ± | 0, ± | 0, ± | 0 dB

4.3.4.1 Accuracy (+5 | (deC to +50 | (deC) ± | .1 dB ± | % 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 | (deC to +40 | (deC) ± | .25 dB
Accuracy (+5 | (deC to +50 | (deC) | (+- | 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 ± | % ± 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:

r.m.s. value of unwanted sidebands
× 100%.

r.m.s. value of wanted sidebands
× 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

On the ± 50 dB range, the stated accuracy applies over ± | 0 dB only (see § 4.3.1.1).

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

Recommendation O.91

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 ± | 00 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 ± | per cent of the measured value plus ± | .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 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*

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

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.

H.T. [T1.91]
TABLE 1/O.91

{	Phase jitter (degrees) Frequency band (Hz)	4 to 300	4 to 20
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.

Table 1/O.91 [T1.91], p.

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 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 |) to 2.2 |) and §§ 2.3 |) to 2.3 |) 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 ≥" 46 dB

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

— Return loss ≥" 30 dB

3.3.2 *High impedance* approx. 20 kohms

— Bridging loss across 300 ohms 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 ± | .5°, ± | 0% referred to the selected threshold 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.

This specification should not preclude the use of existing instruments which have tolerances of ± | ° ± | % on the accuracy of the threshold setting.

4.4 *Amplitude of phase conversion*

An 8 dB amplitude hit of either polarity shall not cause a phase hit to be counted at thresholds of 10° or more.

5 Amplitude hit detection characteristics

5.1 *Threshold settings*

Settings of 2, 3 and 6 dB shall be provided with an accuracy of ± | .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 ± | 0%. 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 ± | % 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 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 | | 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 ($\Delta + \Delta'$ 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 ($\Delta + \Delta'$ Hz) is detected.

Figure 1/O.111, p.

Figure 2/O.111, p.

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 | (+- | %. 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 ± | % 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.

Figure 3/O.111, p.

4.2 *Measuring accuracy*

— ± | .05 Hz on 0-1 Hz range,

— ± | .5 Hz on 0-10 Hz range.

4.3 The meter or indicator shall be such that frequency shifts down to ± | .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 ≥" 30 dB

— Input longitudinal interference loss ≥" 46 dB

4.7 *Input frequency*

The receiving equipment shall operate correctly with test signals up to ± | % from nominal frequency as applied at the transmitting end and having experienced a frequency shift of up to ± | 0 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 ± | .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, p.