

IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets

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of the
IEEE Communications Society**

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Abstract: Practical methods for measuring the transmission characteristics of both digital and conventional two-wire analog telephone sets by means of objective measurements on a test connection are described. The test results thus obtained may be used as a means of evaluating or specifying the transmission performance of a telephone set on a standardized basis. The methods are applicable to telephone sets incorporating carbon or linear transmitters. Measurements are over the frequency range most useful for speech: 100–5000 Hz. The test methods are not intended to be applicable to special devices, such as noise-exclusion transmitters, distant-talking transmitters, insert-type receivers, or noise-exclusion receivers equipped with large ear pads.

Keywords: analog telephone sets, digital telephone sets, telephony, voice transmission performance

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Foreword

(This foreword is not a part of IEEE Std 269-1992, IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets.)

This standard has been prepared in response to a widely expressed need by the telecommunications industry for a standard, comprehensive method for testing the transmission performance of telephone sets. The present standard is a revision of IEEE Std 269-1983, prepared by the task force on Telephone Instrument Testing of the Wire Communication Committee of the IEEE Communication Technology Group.

The testing of digital sets using the reference codec approach and the use of a continuous spectrum excitation signal in addition to a sinusoidal signal is being introduced in this edition of the standard. There have been changes in the calibration procedure from past editions, and these must be considered when comparing results. To bring this standard into agreement with the CCITT test position, the use of the loudness rating guard-ring position (LRGP) is being recommended in addition to the AEN position (AEN stands for *Affaiblissement Equivalent pour la Netteté* or equivalent articulation loss).

The IEEE will maintain this standard current with the state of the technology. Comments on this standard and suggestions for the additional material that should be included are invited. Comments should be addressed to: Secretary, IEEE Standards Board, The Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017.

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IEEE Standard Methods for Measuring Transmission Performance of Analog and Digital Telephone Sets

1. Introduction

The methods that are used to measure telephone set transmission performance may be divided into two classes: objective methods and subjective methods. The objective methods, which are those discussed in this standard, utilize a sound source with acoustic characteristics resembling those of the human mouth to drive the transmitter, and a coupler with acoustic characteristics resembling those of the human ear as a termination for the receiver.

The sound source is comprised of a source of electrical energy and a loudspeaker unit having supplementary electrical and acoustical components that produce a sound field simulating that of a typical human voice. This special loudspeaker is referred to as an artificial mouth. The acoustic coupler, referred to as an artificial ear, includes a microphone and a terminating volume of air having supplementary acoustic components that produce a load on the receiver simulating that of a human ear. The artificial mouth and artificial ear are useful in comparing the performance of telephone sets at frequencies in the significant portion of the speech range.

The subjective measurements, which are particularly applicable for rating overall communication connections, include real voice and real ear calibrations. This type of calibration is based on the ratio of the sensations of loudness and clarity, perceived when a real ear is in the sound field produced by a real voice, to those perceived when a telephone connection intervenes between the real voice and real ear. Other subjective methods include articulation tests, repetition counts, and judgment tests. The disadvantages of subjective methods are that they involve human subjects and necessitate a large number of tests for the results to have significance.

When agreements, on the basis of subjective methods, are reached as to the desirability of particular performance characteristics for a given type of telephone connection, the control of the characteristics can be maintained by purely objective methods using the artificial mouth and ear.

The relationships that are established between subjective and objective measurements will vary with the physical constants of the telephone design, such as the size and shape of the handset and the sound leakage between the receiver and the ear of the user. Therefore, the correlation between subjective and objective measurements should be established separately for each telephone handset design before measurements obtained using the techniques covered herein can be interpreted to reflect performance under conditions of actual use.

This standard is written based on a 900 Ω (nominal) system convention for the public switched telephone network. Other impedances can be used for specific applications.

2. Scope

The purpose of this standard is to describe practical methods for measuring the transmission characteristics of a telephone set by means of objective measurements using a test connection. Although the various methods generally produce similar results, some deviations can

be expected depending on telephone characteristics. Measurement conditions should be noted when reporting results. The test results thus obtained may be used as a means of evaluating or specifying the transmission performance of a telephone set on a standardized basis.

This standard is intended for measuring the transmission performance of conventional two-wire analog telephone sets and digital telephone sets. These telephone sets can be equipped with handsets or headsets using carbon or linear transmitters. This standard covers measurements over the frequency range most useful for speech, 100 Hz to 5000 Hz. This standard is not intended to be applicable to special devices such as noise exclusion transmitters, loud-speaking telephones, or noise exclusion receivers equipped with large ear pads. Drawings and test procedures, as well as other pertinent information, are included as an aid in setting up the tests.

The approach taken in this standard to measure digital telephone sets is to convert the digital signal to or from the telephone set via an interface and a reference codec to an analog signal, and then to use standard analog measurement techniques. Although not covered in this standard, direct signal processing in the digital domain could be used.

Where an input signal, electric or acoustic, is required for making the objective measurements, either of two specified signals may be used, i.e., sinusoidal or continuous spectrum. The two types of signal will give essentially identical results for telephone sets measured in the linear region of their operation, when the measurement is sufficiently noise free. For telephone sets incorporating nonlinear devices, however, the continuous spectrum signal is preferable. Nonlinear devices include carbon microphones, compressors, automatic gain control (AGC) circuits, etc.

The basic accuracy and reproducibility of measurements made in accordance with this standard will depend primarily upon the accuracy of the test equipment used, the care with which the calibration and the measurements are conducted, and the inherent stability of the telephone set under test. Where a given set of measurements is repeated in the same laboratory and by the same operator, a relatively high degree of reproducibility should normally be obtained. However, when comparing measurements made by different laboratories, allowances should be made for the influencing factors mentioned above.

3. Definitions

These definitions apply specifically to measurements of the transmission performance of telephone sets, and may not be applicable to other disciplines. For definitions not covered, see IEEE Std 100-1992 [10] and ANSI S1.1-1960 [1].¹

acoustic echo path. In a telephone set, the coupling from the receiver to the microphone (or transmitter).

acoustic input. The free-field sound pressure level developed by an artificial mouth at the mouth reference point. *See* **sound pressure level**.

acoustic output. The sound pressure level developed in an artificial ear. *See* **sound pressure level**.

analog telephone set. A telephone set where the two-way voice communication interface to the network is in an analog format.

artificial test head. A fixture containing an artificial mouth and an artificial ear located in a specified relationship with each other. *See* **loudness rating guard-ring position**.

¹The numbers in brackets correspond to those of the references in Section 4.

digital telephone set. A telephone set where the two-way voice communication interface to the network is in a digital format.

ear reference point. A point on the artificial test head where the intersection of the receiver ear-cap axis with the external ear-cap plane is placed for testing.

feed circuit. An arrangement for supplying dc power to a telephone set and an ac path between the telephone set and a terminating circuit.

frequency response. Electrical, acoustic, or electroacoustic sensitivity as a function of frequency.

ideal codec. A codec that has theoretically optimum characteristics.

interface. A device placed between the line output of a digital telephone set and test equipment. The device performs at least one of the following functions: simulation of a normal network connection, control of the telephone set under test, or access for the reference codec to the digital voice signal.

listener sidetone. The sidetone acoustic output of the telephone caused by a diffuse noise field.

loudness rating guard-ring position (LRGP). The position a handset assumes when it is placed on an artificial test head as described in Annex A to CCITT Recommendation P.76 [8].

mouth reference point (MRP). A point on the axis of the artificial mouth, 25 mm in front of the center of the external plane of the lip ring.

overall. The acoustic output level of a telephone set due to an acoustic input to another telephone set to which it is connected by a test circuit.

receive. The acoustic output of a telephone set due to an electrical input to the telephone set or connecting test circuit.

reference codec. A codec that approaches the performance of an ideal codec and has superior, well-defined characteristics used for testing digital telephone sets.

sidetone. The acoustic output of a telephone set receiver due to an acoustic input to the transmitter of the same telephone set.² There are two types of sidetone to be considered: **listener sidetone** and **talker sidetone**.

sound pressure level. The sound pressure level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to the reference pressure. For this standard, the reference pressure is normally 1 Pa, and sound pressure levels are expressed in decibels per 1 Pa (dBPa). For those cases where a reference pressure of 20 μ Pa is used, the sound pressure will be expressed as dBSPL.

NOTE: 0 dBPa = 94 dBSPL.

²Where the handset is mounted on a test fixture that includes the artificial mouth and artificial ear, the definition includes transmission through the handset proper; there may be also some vibration effect that is expected to be insignificant for handsets of modern design.

spectrum analyzer. An instrument that measures the power of a complex signal in many bands. The frequency bands can be either constant absolute bandwidth or constant percentage bandwidth.

talker sidetone. The sidetone acoustic output of the telephone caused by an input from the artificial mouth.

telephone set. A device that, when connected to a telephone network, allows two-way voice communication.

telephone test circuit. An assembly consisting of a telephone set(s) and interface(s) as may be required to realize simulated partial and overall telephone connections.

transmit. The electrical output of a telephone set or connecting test circuit due to an acoustic input to the telephone set.

two-wire transmission. A transmission scheme where the send and receive signals are carried in one pair of wires.

4. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved standard, the revision shall apply but the impact on results should be determined.

[1] ANSI S1.1-1960 (Reaff. 1976), American National Standard Acoustical Terminology (Including Mechanical Shock and Vibration).³

[2] ANSI S1.4-1983, American National Standard Specification for Sound Level Meters.

[3] ANSI S1.12-1967 (Reaff. 1986), American National Standard Specifications for Laboratory Standard Microphones.

[4] ANSI S3.7-1973 (Reaff. 1986), American National Standard Method for Coupler Calibration of Earphones.

[5] CCITT Blue Book, Vol. III.1 (Recommendations G.101–G.181), General Characteristics of International Telephone Connections and Circuits.⁴

[6] CCITT Blue Book, Vol. III.3 (Recommendations G.601–G.654), Transmission Media Characteristics.

[7] CCITT Blue Book, Vol. IV.4 (Series O Recommendations), Specifications for Measuring Equipment.

[8] CCITT Blue Book, Vol. V (Series P Recommendations), Telephone Transmission Quality.

³ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁴CCITT publications are available from the CCITT General Secretariat, International Telecommunications Union, Sales Section, Place des Nations, CH-1211, Genève 20, Switzerland/Suisse. CCITT publications are also available in the United States from National Technical Information Service, Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

[9] IEC Publication 318 (1970), An IEC artificial ear, of the wideband type, for the calibration of earphones used in audiometry.⁵

[10] IEEE Std 100-1992, The New IEEE Standard Dictionary of Electrical and Electronics Terms.⁶

[11] IEEE Std 661-1979 (Reaff. 1992), IEEE Standard Method for Determining Objective Loudness Ratings of Telephone Connections.

[12] IEEE Std 743-1984, IEEE Standard Methods and Equipment for Measuring the Transmission Characteristics of Analog Voice Frequency Circuits (ANSI).

5. Test Equipment

5.1 General. The equipment needed to evaluate telephone set transmission performance is specified in 5.2 to 5.20. Different equipment will be required depending on whether analog or digital sets are being tested and whether sinusoidal or continuous spectrum methods are used. For analog telephone sets, feed circuits and test loops are required. For digital telephone sets, interfaces and codecs are required. The test equipment required for generating and processing the input and output signals for the sinusoidal method includes a variable frequency generator; a level recording device; and a spectrum analyzer, harmonic analyzer, or distortion analyzer. For the continuous spectrum method, the required equipment includes a continuous spectrum generator, a spectrum analyzer, and a processor (optional).

5.2 AC Voltmeter. A root-mean-square (rms) voltmeter having ranges from 0.01 V to 10 V (full scale reading), with an input impedance greater than 100 k Ω for bridging measurements or equal to 900 Ω for terminated measurements, is suitable. The limit of error of readings on this meter should be within ± 0.5 dB for inputs with a crest factor up to 5:1 over the frequency range of 100 Hz to 5000 Hz.

5.3 Artificial Ear. The artificial ear for this standard is the IEC Publication 318 (1970) [9] coupler for supra-aural earphones. See ANSI S3.7-1973 [4]. See CCITT Recommendation P.51 [8] for possible modification of the coupler for particular ear-cap configurations.⁷

5.4 Artificial Mouth. The artificial mouth shall comply with the specification given in CCITT Recommendation P.51 [8].

5.5 Continuous Spectrum Generator. A continuous spectrum generator is a device producing one of the signals described below. The preferred signal should be used unless the nature of the nonlinearities is understood. If the nonlinearity is sufficiently understood, one of the alternative signals of 5.5.2 may be used. The actual signal used for the measurements shall be reported.

5.5.1 Preferred Signal. The preferred signal should meet the requirements for an artificial voice as defined in CCITT Recommendation P.50 [8]. As CCITT Recommendation P.50 specifies a different signal for male and female voices, the voice used should be reported.

⁵IEC publications are available from IEC Sales Department, Case Postale 131, 3 rue de Varembe, CH 1211, Genève 20, Switzerland/Suisse. IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

⁶IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁷Measurement methods for telephone sets equipped with headsets are currently under study in IEEE Project 1206.

5.5.2 Alternate Signal. Less sophisticated alternative signals for measuring an essentially linear device are noises having the spectral shape of CCITT Recommendation P.50 [8] or band-limited pink noise.

5.6 DC Milliammeter. A dc milliammeter covering the range from 1 mA to 150 mA and having a full scale voltage drop of 0.2 V maximum is suitable. The limit of error of readings on this meter should be within $\pm 1\%$ full scale.

5.7 DC Voltmeter. A dc voltmeter covering the range from 1 V to 75 V and rated at 5000 Ω/V minimum is suitable. The limit of error of readings on this meter should be within $\pm 1\%$ full scale.

5.8 Digital Telephone Interface. The digital telephone under test will be connected to the reference codec through an interface. The interface shall provide all the signalling and supervisory sequences necessary for the telephone set to be working in all tested modes. The interface shall also be capable of converting a digital stream to or from the telephone set under test to a format compatible with the reference codec.

5.9 Distortion Analyzer. A band elimination filter tunable over the frequency range of 100 Hz to 5000 Hz is suitable. This filter should provide at least 60 dB of attenuation at the fundamental frequency, but the attenuation at the frequency of the second harmonic should be less than 2 dB. These requirements can be met using a spectrum analyzer of appropriate selectivity.

5.10 Feed Circuits. Fig 1 shows feed circuits suitable for use in testing.

5.11 Harmonic Analyzer. A bandpass filter tunable over the range of 100 Hz to 15 000 Hz (third harmonic of the highest fundamental frequency 5000 Hz) is suitable. The selectivity of the filter should be such as to provide at least 50 dB attenuation of the fundamental frequency when measured one octave above the fundamental. These requirements can be met using a spectrum analyzer of appropriate selectivity.

5.12 Impedance Bridge. A conventional impedance bridge or an equivalent method may be used. The ac voltage applied should be typical of signal voltage levels expected in use.

5.13 Level Recording Device. An rms recorder is required with a dynamic range of 60 dB over the frequency range from 100 Hz to 5000 Hz. The recorder shall record frequency at $\pm 1\%$ and level ± 0.5 dB for input signals with a crest factor of 3:1.

NOTES: (1) An amplifier or attenuator may be required to adjust the signal level to the sensitivity of the recorder.
(2) Depending on the telephone set noise and distortion, the results will vary depending on measurement bandwidth. The bandwidth of the detector should be reported.
(3) The input impedance of the level recording device should be high enough not to load the circuit under test.

5.14 Microphone Amplifier. An amplifier is required for use with the standard microphone. The frequency response characteristics of this amplifier should be constant within ± 0.3 dB over the frequency range from 100 Hz to 5000 Hz. The input-output characteristics of this amplifier should be linear at ± 0.5 dB for the range of sound pressure levels to be measured.

5.15 Noise Meter

5.15.1 Transmit. A meter with C-message weighting⁸ and time constants per Section 4.3.2 of IEEE Std 743-1984 [12] should be used. Measurements made by this meter are expressed in decibels with respect to reference noise levels with C-message weighting (dBrnC), where 0 dBrnC is 10^{-12} W at 1000 Hz.