

IEEE
No. 269
MAY 1966

IEEE STANDARDS
ARCHIVES
DO NOT REMOVE

Proposed

Method for Measuring

**TRANSMISSION PERFORMANCE OF
TELEPHONE SETS**

(Published for Trial Use)



PUBLISHED BY

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, Inc.

345 EAST 47 STREET, NEW YORK, N. Y. 10017



Documents

Document Sharing Hub

Authorized licensed use limited to: Tsinghua University. Downloaded on March 06, 2026 at 21:26:26 UTC from IEEE Xplore. Restrictions apply.

Full document details: IEEE 269-1966

ACKNOWLEDGMENT

The Institute wishes to acknowledge its indebtedness to those who have so freely given of their time and knowledge, and have conducted experimental work on which many of the IEEE publications are based.

This publication was prepared by a Task Force of the IEEE Wire Communication Committee of the Communication Technology Group, whose membership was:

F. T. Andrews, *Chairman*

M. D. Fagen, *Secretary*

D. M. Atkinson

F. L. Crutchfield (*Consultant*)

J. W. Emling (*Chairman to 1962*)

J. B. Eppes

W. D. Goodale (*to 1963*)

A. S. Howell

T. G. Ladshaw

M. J. Leach

A. Mamkivsky

C. H. McGuire

L. R. Montfort (*Secretary to 1964*)

H. C. Pye (*to 1964*)

R. H. Tanner

S. H. Whitaker

© Copyright 1966 by The Institute of Electrical and Electronics Engineers, Inc.

This publication may be reproduced, without change, in part or in its entirety, provided that notice of its copyright by the IEEE is included.

CONTENTS

1. INTRODUCTION	5
2. SCOPE AND PURPOSE	5
3. DEFINITIONS	5
3.1 Acoustical Output	5
3.2 Artificial Ear	5
3.3 Artificial Mouth	5
3.4 Constant Available Power	6
3.5 Direct-Current Feed Circuit	6
3.6 Electrical Impedance	6
3.7 Equalization	6
3.8 Frequency Characteristics	6
3.9 Handset	6
3.10 Loop	6
3.11 Modal Distance	6
3.12 Modal Position	6
3.13 Output-Input Characteristic	6
3.14 Receive	7
3.15 Sidetone	7
3.16 Sound Pressure	7
3.17 Sound-Pressure Level	7
3.18 Standard Test Circuits	7
3.19 Speech Network	8
3.20 Sweep Oscillator	8
3.21 Telephone Set	8
3.22 Test Connection	8
3.23 Transmit	8
3.24 Two-Wire Circuit	8
3.25 Volume Indicator	8
4. TEST EQUIPMENT	8
4.1 General	8
4.2 Artificial Mouth	8
4.3 Standard Circuits	9
4.4 Artificial Ear	9
4.5 Standard Pressure Microphone	9
4.6 Microphone Amplifier	10
4.7 Variable Frequency Oscillator	10
4.8 Volume Indicator	10
4.9 Harmonic Analysis	10
4.10 Distortion Analysis	10
4.11 Impedance Bridge	10

4.12	Direct-Current Milliammeter	10
4.13	Direct-Current Voltmeter	11
4.14	Noise Meter	11
4.15	Sound-Attenuating Cover for the Handset Transmitter.....	11
4.16	Sound-Attenuating Cover for the Handset Receiver	11
5.	TEST PROCEDURE	11
5.1	General	11
5.2	Transmit	11
5.2.1	General	11
5.2.2	Procedural Steps	12
5.2.3	Noise Generated by the Transmitter.....	12
5.2.4	Input-Output Characteristics	12
5.2.5	Nonlinear Distortion	12
5.2.6	Transmitter Resistance	13
5.3	Receive	13
5.3.1	General	13
5.3.2	Procedural Steps	14
5.3.3	Nonlinearity	14
5.4	Sidetone	14
5.4.1	General	14
5.4.2	Procedural Steps	14
5.5	Air-to-Air Transmission	14
5.5.1	General	14
5.6	Telephone Set Impedance.....	15
5.7	Telephone Set Resistance.....	15
Fig. 1—	Modal Position Recommended by the CCITT Laboratories.....	16
Fig. 2—	Telephone Transmission Test Circuits.....	17
Fig. 3—	Use of Gauge for Positioning Pressure Microphone in Sound Field of Artificial Mouth	18
Fig. 4—	Direct-Current Supply Circuit for Testing Transmit Equalization.....	19
Fig. 5—	Direct-Current and Alternating-Current Signal Voltage Supply for Testing Receive Equalization.....	19
Fig. 6—	Artificial Mouth	20
Fig. 7—	Intensity Level Versus Frequency.....	21
Fig. 8—	Artificial Ear	21
Fig. 9—	Circuit for Telephone Impedance Measurements.....	22
Fig. 10—	Circuit for Transmitter Noise Measurements.....	22
Fig. 11—	Circuit for Transmitter Resistance Measurements.....	23
Fig. 12—	Circuit for Measuring Sidetone.....	23
Fig. 13—	Circuit for Telephone Resistance Measurements.....	24

Proposed Method for Measuring

TRANSMISSION PERFORMANCE OF 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 to be discussed in this Standard, utilize a sound source resembling the human voice and mouth to drive the transmitter, and a simple air volume resembling that of the human ear as a termination for the receiver. The sound source comprises a source of electric energy corresponding to speech and a moving-coil loudspeaker unit having supplementary electric and acoustical components that provide a sound field similar to that produced by a typical human voice. This special loudspeaker is referred to as an Artificial Mouth. The terminating air volume, in which the sound pressure generated by the receiver is measured, is provided by a device referred to as an Artificial Ear. The Artificial Mouth and 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 over-all 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 disadvantage of subjective methods is that they involve human subjects and necessitate a large number of tests for the results to have significance.

When agreements are reached, on the basis of subjective methods, as to the desirability of particular performance characteristics for a given type of telephone connection, the maintenance of these characteristics can be achieved by purely objective methods such as the Artificial Mouth and Ear measurements. It must be emphasized that the relationships which are established between subjective and physical measurements will vary with the physical constants of the telephone design such as size and shape of the handset.

It would be expected, therefore, that correlation between subjective performance and objective measurements should be established separately for each telephone set design before measurements obtained using the techniques covered herein could be interpreted to reflect performance under conditions of actual use.

2. SCOPE AND PURPOSE

2.1 The purpose of this Standard is to describe a practical and reproducible method for measuring the transmission characteristics of a telephone set, and the components thereof, by means of objective measurements in a test connection. Performance characteristics obtained using this method will approximate but will not duplicate performance under actual use conditions.

2.2 The method requires a suitable Artificial Mouth. It also specifies a standard Artificial Ear, standard circuits comprising direct-current power feed and connecting loops, and a standard pressure microphone.

2.3 This Standard is intended for use in measuring the transmission characteristic over the frequency range most useful for speech, e.g. 150 to 5000 hertz. It is to be used for single-frequency measurements and for measurements with continuously varying frequencies such as slow sweeps and warble bands.

2.4 It is suitable also for measuring the transmission performance of conventional telephone sets equipped with handsets using carbon transmitters and used with 2-wire circuits. It is 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.

2.5 This Standard is based on a standard pressure microphone to measure the sound field produced by the Artificial Mouth and to measure the pressure developed in the Artificial Ear.

2.6 Drawings and test procedures as well as other pertinent information have been included as an aid to designers in setting up the tests.

3. DEFINITIONS

3.1 *Acoustical Output*—In this Standard, the sound pressure developed in an Artificial Ear, measured in newtons per square meter, N/m^2 .

3.2 *Artificial Ear*—A device for the measurement of telephone receivers that presents an acoustic impedance to the receiver equivalent to the impedance presented by the average human ear. It is equipped with a microphone for measurement of the sound pressure developed by the receiver.

3.3 *Artificial Mouth*—An electroacoustic transducer having predetermined controls that

enable it to produce a sound field simulating that produced by a typical human talker.

3.4 Constant Available Power Source—Has a purely resistive internal impedance and has a constant open-circuit terminal voltage, independent of frequency. Telephone set Receive is tested under conditions of constant available power if it is connected to such a source.

A generator having a power capacity corresponding to an open-circuit voltage, E , and an internal resistance, R_o , both constant with frequency, provides available power of $E^2/4R_o$.

When the load impedance is a resistance equal to R_o , an impedance match exists and the maximum available power of $E^2/4R_o$ is dissipated in the load.

When a generator with a constant voltage and a constant internal resistance of the required value is not available, suitable test conditions for this type of measurement can be provided by a generator whose voltage is maintained at a constant value, E_o , across its terminals in series with a resistance, R_o . The generator and the resistance R_o in series are then equivalent to a source of constant available power.

3.5 Direct-Current Feed Circuit—An arrangement for supplying direct-current power to the telephone set under test and for supplying an alternating-current path from the telephone set to the specified termination.

3.6 Electrical Impedance—Of a telephone set, at any given single frequency, the ratio of the voltage to the current at the line terminals. The expression of the electrical impedance is a complex number.

3.7 Equalization—In this Standard, a property of the telephone circuit design that causes both Transmit and Receive responses to be inverse functions of the loop current which thus tends to equalize variations in loop loss.

3.8 Frequency Characteristics—Electrical and acoustical properties as functions of frequency. Examples include an amplitude-frequency characteristic and an impedance-frequency characteristic.

3.9 Handset—In this Standard, a telephone transmitter and a telephone receiver assembled in the handle with which they are normally used, and equipped with electric conductors for connecting the transmitter and receiver to the speech network. It is further taken that the arrangement and dimensions of the assembly are such that, when the receiver is properly placed on the ear of a typical user, the transmitter is placed in a predetermined optimum or near-optimum position in the sound field produced by the user's mouth.

Note: The speech network may be located in the handset.

3.10 Test Loop—The pair of wires connecting the telephone set to the direct-current feed circuit and to the termination. It is characterized by series and shunt impedance and attenuation. The direct-current resistance of the loop is of major importance because it is a control of the direct current in the transmitter.

3.11 Modal Distance—The distance between the center of the grid of a handset transmitter and the center of the lip ring of the Artificial Mouth when the handset is in the modal position.

3.12 Modal Position—For this Standard, the required position of the handset transmitter with respect to the lip ring of the Artificial Mouth during transmitter measurements. It is illustrated in Figure 1 where the lip ring of the Artificial Mouth and some typical handsets are shown in place. The data in Figure 1 were determined from applicable dimensions of the modal head adopted by the CCITT* Laboratory for the measurement of AEN.†

For a more descriptive purpose the modal position is the position a handset assumes when the receiver of the handset is held close to the ear of a person with head dimensions that are modal for a population. The point of reference for the handset and the head is the center of the circular plane of contact of the handset earcap and the ear. If the handset earcap is not circular or has no external plane of contact, an effective center and an effective plane of contact must be determined. The modal point is the position of the center of the lips with respect to the center and plane of the earcap point of reference. The modal direction is along a line passing through the modal point and through the midpoint of a line between the centers of the earcap planes of reference. Accurate determination of this point requires an earcap on each ear.

3.13 Output-Input Characteristic—Of a telephone system, or component thereof, the output characteristic as a function of the input level. There are three cases:

- (a) Transmit—as in Figure 2B where the output is electric, E_t , measured across a resistive load, and the input is sound pressure, P_t , in the free field of the Artificial Mouth at the test position shown in Figure 3. Transmit is expressed as the ratio

$$T = -20 \log_{10} \frac{E_t/E_{t0}}{P_t/P_{t0}}$$

* CCITT Red Book (International Telecommunication Union, 1962), Vol. 5, p. 155.

† Affaiblissement équivalent pour la Netteté (equivalent articulation loss).

where E_t is the observed voltage.

E_{t0} is a reference voltage measured across the same or equal resistive load and in the same units.

P_t is the observed pressure.

P_{t0} is a reference pressure measured in the same units.

- (b) **Receive**—as in Figure 2C where the output P_r is the sound pressure developed in the Artificial Ear, and the input is the electrical quantity $E_r/2$ where E_r represents the open-circuit voltage across a resistive source. Receive is expressed as the ratio

$$R = -20 \log_{10} \frac{P_r/P_{r0}}{\frac{E_r}{2} / \frac{E_{r0}}{2}}$$

where P_r is the observed pressure.

P_{r0} is a reference pressure measured in the same units.

E_r is the observed voltage; $E_r/2$, applied voltage.

E_{r0} is a reference voltage measured across the same resistive source and in the same units.

- (c) **Air-to-Air**—as in Figure 2A where the input is sound pressure P_t in the free field of the Artificial Mouth at the test position shown in Figure 3, and the output is sound pressure P_r developed in the Artificial Ear, measured in the same units. Air-to-air is expressed as the ratio

$$A = -20 \log_{10} \frac{P_r}{P_t}$$

Note: The ratios in these equations involve either pressures across dissimilar acoustic impedances or electric voltages and acoustic pressures, and therefore should not be expressed as decibels. However the equations yield decibel-like quantities which may be measured on meters calibrated in decibel scales which will give numerically accurate results if properly correlated. The use of logarithmic units permits the addition of component measurements.* Correlated units in frequent use are:

if $E_0 = 1$ volt or $E_0 = 1$ millivolt,

then $P_0 = 1$ mbar (100 N/m^2) or $P_0 = 1 \mu\text{bar}$ (0.1 N/m^2).

3.14 Receive—In this Standard, the ratio of sound output pressure to the electric input from a standard source. See 3.13 (b).

3.15 Sidetone—In this Standard, the ratio of sound output pressure of the receiver of a given handset to the sound input pressure of the transmitter of the same handset both measured in newtons per square meter. Sidetone is due to transmission through the speech network of the telephone set when it has operating power and is terminated. It has been found that acoustic loss through existing handset handles exceeds 25 decibels for the 300- to 3000-hertz range.

3.16 Effective Sound Pressure—The sound pressure at a point is the total instantaneous pressure at that point minus the static pressure at that point. The meter in the sound pressure measuring system is a volume indicator.

3.17 Sound Pressure Level (SPL)—In decibels (dB SPL), of a sound, 20 times the logarithm to the base 10 of the ratio of the sound pressure to a reference pressure. In this Standard the reference pressure is taken to be 20×10^{-5} newtons per square meter, which may also be expressed as 10^{-12} watt per square meter normal to the direction of propagation.

3.18 Standard Test Circuits—In this Standard, comprise the following cases:

- (a) **Transmit**—a telephone set, a test loop, a direct-current feed circuit, and a resistive terminating load as in Figure 2B.
- (b) **Receive**—a resistive source, a direct-current feed circuit, a test loop, and a telephone set as in Figure 2C.
- (c) **Air-to-Air**—two telephone sets, two test loops, and a direct-current feed circuit as in Figure 2A.
- (d) **Transmit Equalization**—a telephone set, a direct-current feed circuit, and a termination. Figure 4 shows three suitable circuit arrangements.
- (e) **Receive Equalization**—a resistive source, a direct-current feed, and a telephone set. Figure 5 shows three suitable circuit arrangements.
- (f) **Telephone Set Impedance**—a telephone

* P. W. Blye, O. H. Coolidge, and H. R. Huntley, "A Revised Telephone Transmission Rating Plan," *Bell System Technical Journal*, Vol. XXXIV, No. 3 (May, 1955).

set and a direct-current feed as illustrated in Figure 9.

- (g) **Handset Transmitter Noise Measurements**—a telephone set, a direct-current feed, and a resistive termination as shown in Figure 10.
- (h) **Handset Transmitter Resistance**—a telephone handset and a direct-current source as in Figure 11.
- (i) **Sidetone**—a telephone set, a direct-current feed and termination, and a loop. Figure 12 shows a suitable arrangement.
- (j) **Telephone Set Direct-Current Resistance**—a telephone set and a direct-current feed as in Figure 13.

3.19 Speech Network—In this Standard taken to be an electric circuit that connects the transmitter and the receiver to the test loop (or customer line) and to each other.

3.20 Sweep Oscillator—One in which the output frequency varies continuously. When the frequency interval is traversed linearly, by means of sawtooth or triangular modulation, at a syllabic rate (approximately 6 traversals per second), the output is referred to as a warble band. When 5 seconds, or more, are required for the traversal, the output is referred to as a slow sweep.

For the purpose of this Standard, the output of the slow-sweep oscillator should be of constant available power with frequency, but the output of the warble-band oscillator should conform to the energy-frequency characteristic of average speech* as shown in Figure 7 for the frequency range of 300 to 3300 hertz.

3.21 Telephone Set—Because this Standard is concerned only with transmission performance, an assembly comprising a handset connected to a speech network.

3.22 Test Connection—In this Standard, two telephone sets connected together by means of test loops and a direct-current feed circuit which supplies direct-current power to both telephone sets.

3.23 Transmit—In this Standard, the ratio of the electric output to the free-field acoustical input. See 3.13 (a).

3.24 Two-Wire Circuit—A metallic circuit formed by two conductors insulated from each other. In this Standard it is taken that electric waves are transmitted in both directions over the path provided by the 2-wire circuit.

3.25 Volume Indicator—A standardized in-

strument having specified electrical and dynamic characteristics and read in a prescribed manner, for indicating the volume of a complex electric wave such as that corresponding to speech or music.

Note: The reading in vu is equal to the number of decibels above a reference level. The sensitivity is adjusted so that the reference level or zero vu is indicated when the instrument is connected across a 600-ohm resistor in which there is dissipated a power of 1 milliwatt at 1000 hertz.

4. TEST EQUIPMENT

4.1 General—The test equipment needed to evaluate telephone transmission performance includes the following items:

- (a) An Artificial Mouth
- (b) A standard direct-current feed circuit with two test loops
- (c) An Artificial Ear
- (d) A standard pressure microphone
- (e) A variable frequency oscillator
- (f) Electric devices suitable for measuring electrical levels, impedances, and non-linear distortion
- (g) Sound-attenuating covers for the transmitter and receiver of the handset.

4.2 Artificial Mouth

Note: The question of a suitable Artificial Mouth is under study in various areas of the industry. Published material* states that an Artificial Mouth should be capable, when driven by appropriate electric inputs, of producing a sound field similar to that produced by a human voice. Inputs may include recorded human speech or warble bands as well as single-frequency tones. Stated objectives include the following items:

- (a) It should introduce no amplitude distortion within the specified frequency range.
- (b) It should introduce no nonlinear distortion within the specified intensity range.
- (c) The distribution of the sound field about the Artificial Mouth should simulate that of a typical human mouth for all frequencies within the specified range.

* N. R. French and J. C. Steinberg, "Factors Governing the Intelligibility of Speech," *Journal of the Acoustical Society of America* (January, 1947), Vol. 19, pp. 90-120.

* A. H. Inglis, C. H. G. Gray, and R. T. Jenkins, "A Voice and Ear for Telephone Measurement," *Bell System Technical Journal* (April, 1932), Vol. XI.