NOT MEASUREMENT SENSITIVE

MIL-STD-188-190
31 JANUARY 1990

MILITARY STANDARD

METHODS FOR COMMUNICATIONS SYSTEMS MEASUREMENTS

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FOREWORD

1. This military standard is approved and mandatory for use by all Departments and Agencies of the Department of Defense (DoD) in accordance with DoD Directive 4640.11, dated 21 December 1987.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Information Systems Engineering Command, ATTN: ASQB-SET-T, Fort Huachuca, Arizona 85613-5300, by using the self-addressed Standardization Document Improvment Proposal (DD Form 1426) appearing at the end of this document, or by letter.

3. Originally, Military Standard 188 (MIL-STD-188) covered technical standards for tactical and long-haul communications, but later evolved through revisions (MIL-STD-188A, MIL-STD-188B) into a document applicable to tactical communications only (MIL-STD-188C).

4. The Defense Communications Agency (DCA) published DCA Circulars (DCACs) promulgating standards and engineering criteria applicable to the long-haul Defense Communications System (DCS) and to the technical support of the National Military Command System (NMCS).

5. As a result of a Joint Chiefs of Staff (JCS) action, standards for all military communications are now being published in a MIL-STD-188 series of documents. The MIL-STD-188 series is now subdivided into a MIL-STD-188-100 series covering common standards for tactical and long-haul communications, a MIL-STD-188-200 series covering standards for tactical communications only, and a MIL-STD-188-300 series covering standards for long-haul communications only. Emphasis is being placed on developing common standards for tactical and long-haul communications published in the MIL-STD-188-100 series.

6. This document contains standardized methods of measurement for selected communications systems performance parameter requirements that are specified in the MIL-STD-188 series of documents for both long-haul and tactical communications systems. These methods are presented in terms of system standards and design objectives (DOs). The terms "system standards" and "design objective (DO)" are defined in FED-STD-1037. In this document, the word "shall" identifies mandatory system standards. The word "should" identifies DOs which are desirable, but not mandatory.

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1. SCOPE

1.1 Scope. This standard establishes methods of measurement for selected electrical parameter requirements that are specified in the military standard (MIL-STD) 188 series of documents.

The methods of measurement in this document shall be the means of ensuring uniform measurement results in all cases where the performance of long-haul and tactical communications systems and subsystems is verified by these methods of measurement.

These methods represent existing techniques selected on the basis of such factors as accuracy and current military and commercial practices and procedures. Emphasis is on the basic principle of measurement to avoid implied restrictions on technological advances and to avoid revisions of the standard as new generations of measuring equipment are developed.

1.2 Applicability. This document shall be applied whenever performance measurements, described by methods in this document, are required on long-haul and tactical communications systems and subsystems. These methods of measurement shall be used to determine compliance with stated parameter values contained in approved and published documents of the MIL-STD-188 series. The methods are intended to be applied, regardless of the type or technology of the measuring equipment used, or the description of the unit under test (UUT).

Each method is presented as a basic principle of measurement, rather than a detailed procedure, for a particular parameter or set of parameters in the existing MIL-STD-188 series documents. Emphasis is on methods that apply to measures of system performance, unless specified otherwise. Operations personnel who use detailed testing procedures and specific test equipment are referred to the appendix for Defense Communications Agency circulars (DCACs), handbooks, or other documents that provide such procedures and test equipment requirements. Detailed procedures and test equipment requirements are also sometimes agency-provided, contractor-provided, or provided in test equipment manuals. The basic measurement methodologies given in this standard generally reflect the currently applied testing procedures found in those circulars, standards, and other documents referenced in the appendix.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Standards and handbooks. The following standard and handbook form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto, cited in the solicitation (see 6.2).

STANDARD

FEDERAL

FED-STD-1037	Glossary of Telecommunication Terms

HANDBOOK

MILITARY

MIL-HDBK-419	Grounding, Bonding, and Shielding for Electronic Equipments and Facilities (Volume 1)

(Unless otherwise indicated, copies of Federal and military standards and handbooks are available from the Standardization Documents Order Desk, Bldg. 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 Other Government documents. The following other Government document forms a part of this document to the extent specified herein. Unless otherwise specified, the issue is that cited in the solicitation.

DEFENSE COMMUNICATIONS AGENCY (DCA)

DCA CIRCULAR (DCAC)

DCAC 310-70-1, Supplement 1	DCS Technical Control, Volume II Procedures, Test Descriptions

(Application for copies should be addressed to Director, DCA, ATTN: Code 316, Washington, DC 20305-2000. Requests for copies may be on DCA Form 117: Publication or Blank Form Request (for Government agencies only), or by letter with appropriate justification.)

2.2 Non-Government publications.

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DoD-adopted shall be those listed in the issue of the DoDISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DoDISS are the issues of the documents cited in the solicitation (see 6.2).

STANDARDS

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

IEEE Std 269-1983	IEEE Standard Method for Measuring Transmission Performance of Telephone Sets
IEEE Std 455-1985	IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band
IEEE Std 743-1984	IEEE Standard Methods and Equipment for Measuring the Transmission Characteristics of Analog Voice Frequency Circuits

(Application for copies should be addressed to the IEEE Service Center, Publication Sales Department, 445 Hoes Lane, Piscataway, NJ 08854, U.S.A.)

THE INTERNATIONAL TELEGRAPH AND TELEPHONE CONSULTATIVE COMMITTEE (CCITT)

CCITT Recommendation G.821 (CCITT Red Book, Volume III, Fascicle III.3)	Error Performance of an International Digital Connection Forming Part of an Integrated Services Digital Network

(Application for copies should be addressed to the U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Terms. Definitions of terms used in this document are as specified in FED-STD-1037. For the purposes of this standard, definitions are provided for the following terms that are not found in FED-STD-1037.

Impairment. Any characteristic or degradation in the transmission path which may reduce the performance or quality of the communications system or subsystem of which the path is a part.

Intrinsic jitter. Digital or time jitter occurring at the output in the absence of input jitter.

Jitter transfer characteristic. The ratio of the magnitude (time, amplitude, frequency, or phase) of output jitter to the magnitude of input jitter for a given jitter frequency and a given bit rate.

Transmission impairment measuring set (TIMS). In a general sense, an item or package of instrumentation used to measure impairments in a transmission path, the measure of which involves detection and display of impairment parameters in appropriate terms.

> NOTE: For the purposes of this standard, "TIMS" is a broad term used to denote the measuring set needed for any given method of measurement. It is not to be construed as vendor-specific or as feature-laden with comprehensive measurement capabilities. A TIMS can be portable or stationary (such as a fixed setup for inservice testing), and only represents the minimum testing unit or units necessary to apply any given method of measurement. For example, the TIMS used in the intermodulation distortion (IMD) measurement setup (see 5.13) represents, as a minimum, an IMD measuring set.

Unit under test (UUT). The specimen subjected to performance analysis which, depending on the measurement task, could be a system, subsystem, or equipment item. Examples of units under test are link, channel, circuit, transmitter, receiver, modulator-demodulator (modem), and multiplexer.

3.2 Abbreviations and acronyms. Abbreviations and acronyms used in this document are defined below. Those that are also found in FED-STD-1037 have been included for the convenience of the reader.

ac	alternating current
ANSI	American National Standards Institute
AT&T	American Telephone and Telegraph
BER	bit error ratio
BLER	block error ratio
CCITT	The International Telegraph and Telephone Consultative Committee
dB	decibel(s)
dBm	dB referred to one milliwatt
dBm0	noise power in dBm referred to or measured at 0TLP
dBrn	decibels above reference noise
dBrnC	noise power in dBrn measured by a set with C-message weighting
dc	direct current
DCA	Defense Communications Agency
DCAC	DCA circular
DoD	Department of Defense
DoDISS	DoD Index of Specifications and Standards
EDD	envelope delay distortion
EFS	error-free second(s)
EIA	Electronic Industries Association
FDM	frequency-division multiplexing
FED-STD	Federal standard
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
IMD	intermodulation distortion
k	kilo
k	Boltzmann's constant (1.380662 x 10^{-23} joules/kelvin)
K	kelvin(s)
log	logarithm
MIL-HDBK	military handbook
MIL-STD	military standard
modem	modulator-demodulator
REA	Rural Electrification Administration
rms	root-mean-square
SES	severely errored second(s)
SNR	signal-to-noise ratio
TIMS	transmission impairment measuring set
UUT	unit under test
VF	voice frequency
vs	versus
vu	volume unit(s)
Z_o	characteristic impedance
0TLP	zero transmission level point(s)

4. GENERAL REQUIREMENTS

4.1 Preliminary requirements. The requirements set forth in this section shall be observed when using the methods described in this standard.

4.1.1 General. Any necessary grounding of measuring equipment and the unit under test (UUT) shall be made to a single grounding point to prevent ground return loops. The accuracy of all connections and switch positions shall be verified before the UUT is connected to measuring equipment. A filtered alternating current (ac) power source should be used for measuring equipment, where possible. Calibration of measuring equipment shall be confirmed for the interval required by the manufacturer's specifications or other applicable documentation to ensure compliance with required tolerances and measurement validation. Balanced or unbalanced interfaces must be taken into account and the UUT, associated circuits, and measuring equipment (including test cables) shall be carefully checked for proper impedance match and internal cable loss each time a test connection is made.

4.1.2 Unit under test (UUT) configuration. To effect a meaningful comparison of measurements, it is necessary to have a standardized method of measurement and consistency in the configuration of the UUT. Therefore, all measurement data should be accompanied by a configuration description of the UUT to include:

a. Cabling diagram.

b. UUT and test hardware configuration with associated documentation, nomenclatures, and model numbers including modifications, waivers, and changes.

c. UUT software configuration and data base entries, where applicable.

d. UUT operating parameters (e.g., bit rate, in-service/out-of-service, and remote loop back/end-to-end).

4.2 Relative test levels. The military standard (MIL-STD) 188 series may specify that a parameter be measured at the "zero reference level," or the "zero transmission-level point (OTLP)." The OTLP is simply an arbitrary point in a communications system chosen as the reference for all relative transmission levels. Other points in the circuit are referenced to the OTLP in the following convention:

XTLP - Level at any point relative to the OTLP where X is in decibels (dB)

dBm - db referred to one milliwatt

dBm0 - A measure of power in dBm referred to or measured at OTLP (i.e., measured power in dBm minus XTLP)

This reference technique, coupled with a knowledge of circuit gains and losses, allows for translation of measurement parameter values throughout a circuit.

4.3 Measuring equipment. Methods have been selected for this document that allow for use of measuring equipment currently in each military service inventory and, moreover, can be implemented with new generations of measuring equipment. The methods are intended to accommodate advances and improvements in measuring equipment and techniques without a need for revision.

Although the equipment technology is not specified by this document, technologically advanced measuring equipment can expedite performance measurements in several ways. A single computer-driven instrument can perform multiple measurements with high precision and efficiency. For example, a single transmission impairment measuring set (TIMS) can measure the following parameters to the accuracy required by a variety of standards: crosstalk, net loss/gain variation, insertion loss vs frequency, envelope delay distortion, intermodulation distortion, peak-to-average ratio, phase hits, gain hits, dropouts, impulse noise, notched noise, signal-to-noise ratio, amplitude jitter, phase jitter, and return loss.

Where possible, these multifunction measuring devices are preferred for reasons of cost, convenience, repertoire of measurement functions, and repeatability. Additionally, measuring apparatus that is computer-controlled (internally or externally) generally provide a means for storing and displaying measurement results and thus provide a time history of the measurement parameter. Microprocessor-based equipment with graphics capability can eliminate errors in manual calculations and can display plots of the data to simplify analysis. Where computer-based instrumentation is not available, devices can be selected that have an output calibrated directly in the parameter units needed for the measurement results. In the event direct-reading instruments are not available, standard mathematical relationships for computing the desired measurement parameter units from empirically derived units are included as a part of the measurement method.

> NOTE: See the appendix for reference to documents containing functional measuring equipment requirements and characteristics pertaining to methods given in this standard for the measurement of analog transmission characteristics of voice frequency (VF) communications systems.

4.4 Accuracy and reproducibility. The accuracy and reproducibility of measurements made in accordance with this standard, though based on preferred methods, will also depend on the accuracy and other characteristics of the measuring equipment used, the consistency with which correct measurements are conducted, and the inherent stability of the unit under test (UUT).

4.5 Documentation of measurement data. Requirements for the formatting and recording of measurement data are not specified by this standard. These requirements will vary, being dictated by the 188 standard values specified and the document (Defense Communications Agency circular (DCAC), military handbook (MIL-HDBK), technical manual, etc.) referred to for detailed procedures.

Depending on the application of the methods of measurement provided by this standard, measurement data requirements can include the following:

- o The actual test sequence used
- o Ambient test conditions recorded periodically during the measurement period
- o A plot of response curves
- o Test point data

Generally, measurement data will always include identification of all measuring equipment, accessories, and UUT configuration (e.g., link number, station, nomenclature, serial number, or model number). The record will also provide for a date and should include a signature block for certification of the data by the test engineer.

The availability of automatic data recording and reduction equipment may preclude the requirement for testing forms included in the procedure for this purpose, provided the end result is the same. Furthermore, some forms are designed for a variety of situations and certain blocks or columns may not apply.

5. DETAILED REQUIREMENTS

5.1 Introduction. This section addresses communications system performance characteristics that must be periodically measured to determine if applicable performance requirements, as set forth in the military standard (MIL-STD) 188 series documents, are being met. These characteristics and associated methods of measurement are given in the subsequent paragraphs. Parameter measurement descriptions are arranged in alphabetical sequence and address analog, digital, and other performance characteristics with an emphasis on system performance parameters (see figure 1).

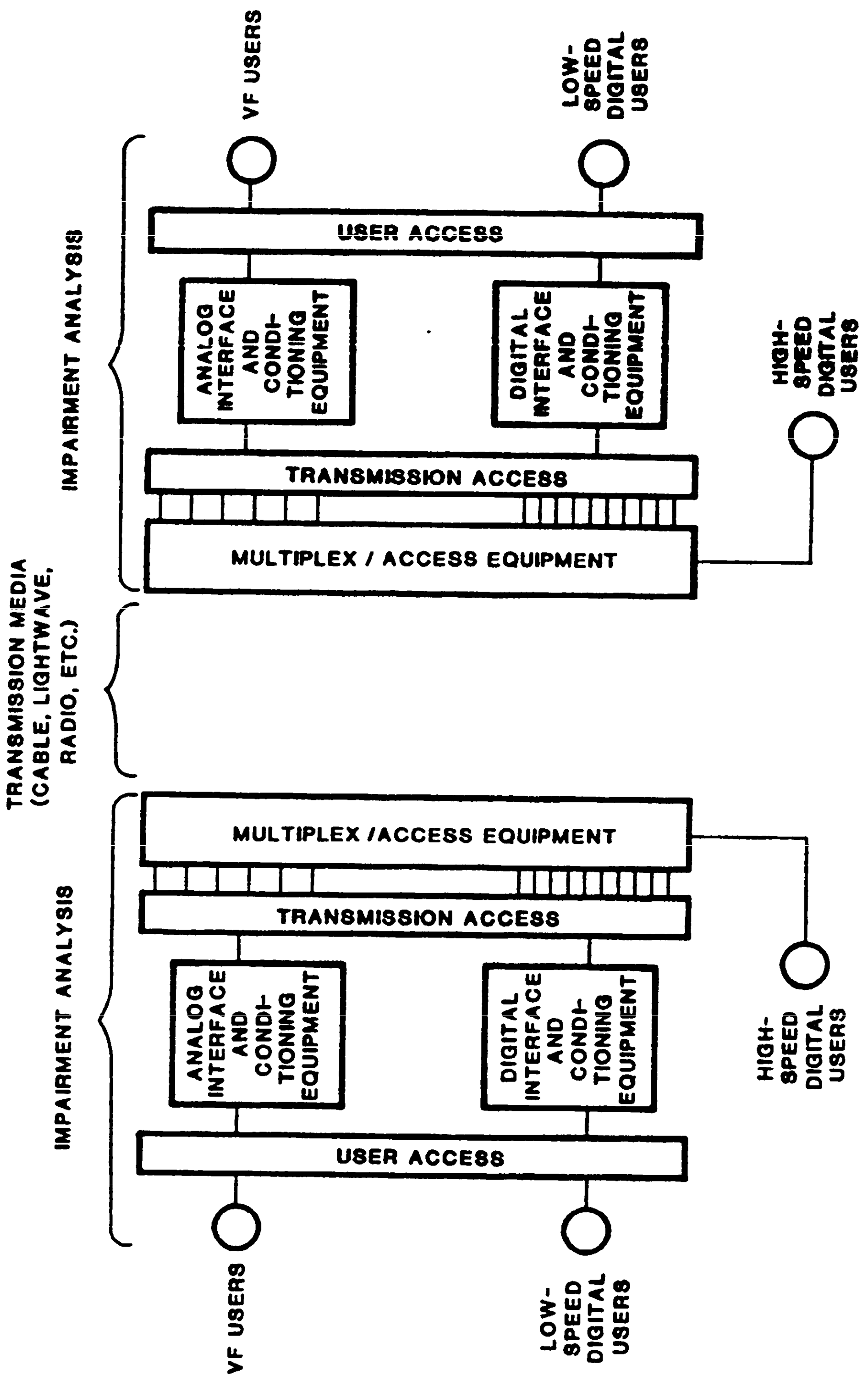


FIGURE 1. Communications system showing end-to-end measurement environments.

5.2 Bond resistance measurements.

5.2.1 Scope. The method described below shall be used to determine the adequacy of the electrical connection between metal-to-metal contact bonds, based on the direct current (dc) resistance of the bond.

5.2.2 Measuring equipment.

Four-terminal low-resistance ohmmeter or dc resistance bridge
Braided or low-resistance wire leads with heavy-duty spring clips

5.2.3 Principles of measurement. Typically, the point-to-point dc resistance of an electrical bond should be less than one milliohm and should be measured with a four-terminal measuring set having a range extending from about one-tenth of a milliohm to a sufficient upper limit. The measuring set detects a fall of potential across the bond that is compared to an internal standard and converted to a direct readout in ohms.

5.2.4 Method. Figure 2 shows the general test arrangement.

NOTE: Although test lead resistance in itself does not affect the accuracy of the reading, the current leads must be of adequate size to carry the maximum test current.

After ensuring that the ohmmeter is properly calibrated, the clip-leads are attached across the bonded junction as illustrated. If a bridge is used, it must be zeroed, including the leads, and the clip-leads connected across the bonded junction as shown. The bridge balance is then adjusted until a null is obtained.

NOTE: By placing the current leads away from the junction while placing the potential leads near the junction, the effects of the probe contact resistance are minimized. However, if the bond to be measured is internal to a metallic grid such that other current paths exist in parallel to the path through the bond under test, the potential and current probes should be near to the same point on each side of the bond to minimize error.

The resistance indicated is recorded and compared to the resistance limit specified for the bond under test.

NOTE: See the appendix for reference to detailed procedures for the method described in this paragraph.

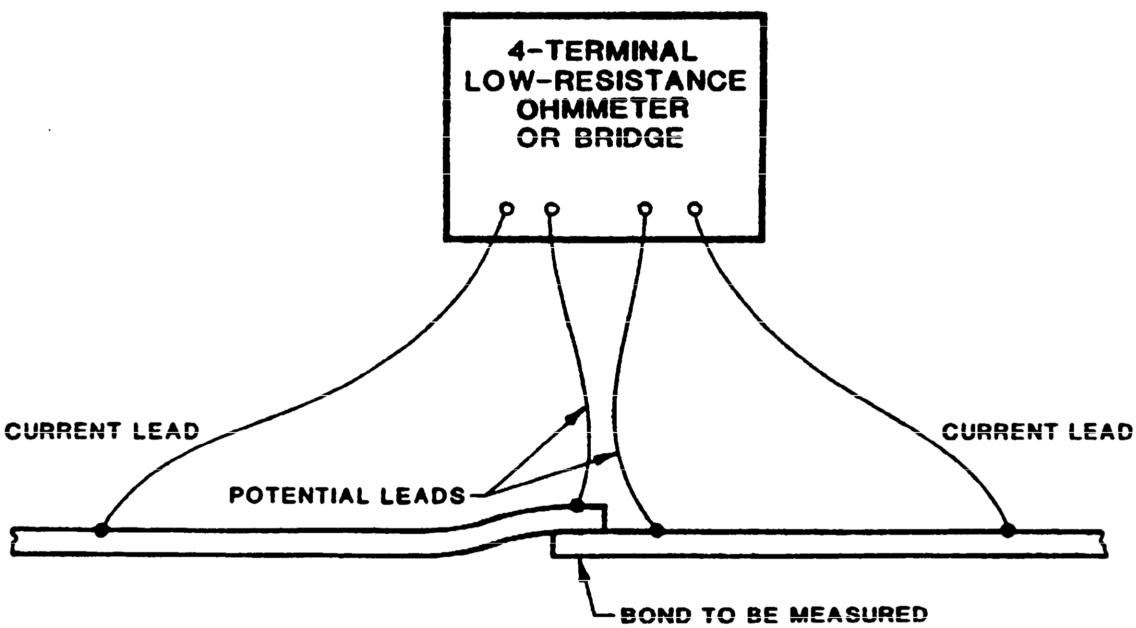


FIGURE 2. Bond resistance measurement setup.

5.3 Crosstalk (intelligible) measurements.

5.3.1 Scope. The method described below shall be used for making near-end and far-end intelligible crosstalk measurements. It is applicable to units which contain two or more parallel channels or circuits for the transmission of analog or quasi-analog signals.

5.3.2 Measuring equipment.

Transmission impairment measuring set (TIMS)
Selective level measuring set

5.3.3 Principles of measurement. Crosstalk is indicated when, in two adjacent signal-carrying channels, signals from one channel may be detected in the other. Near-end crosstalk is measured at the end of the disturbed channel nearest to the source of the disturbing signal. Far-end crosstalk is measured at the end of the disturbed channel remote from the source of the disturbance. If the two channels are for opposite directions of transmission, near-end crosstalk is important. Conversely, when the channels are for the same direction of transmission, the far-end crosstalk must be considered.

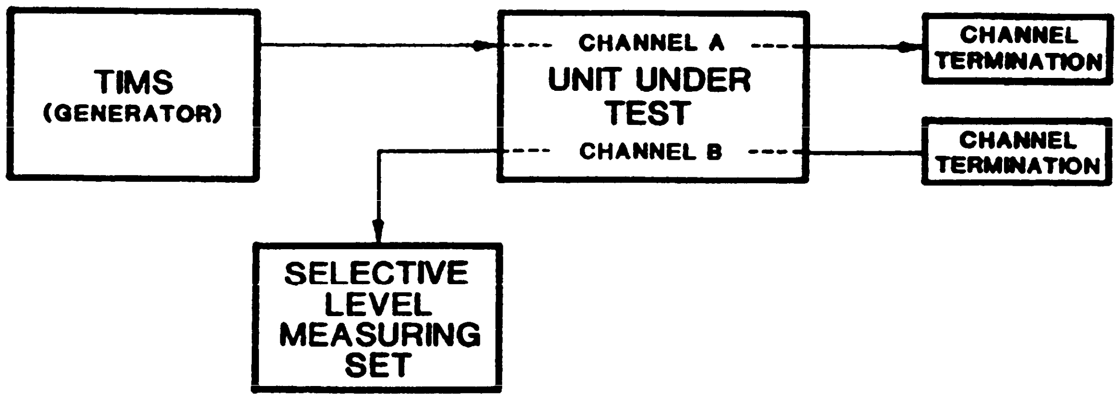
Crosstalk measurement results are normally expressed as the ratio of power delivered by a source to the disturbing channel, to power received at the point of measurement on the disturbed channel. However, in regard to complete transmission systems, it is generally more meaningful to take into account any difference in the nominal relative levels at the measuring points. This is achieved by expressing both of the measured levels in noise power in decibels relative to one milliwatt and referred to or measured at zero transmission level point(s) (OTLP) (that is, dBm0).

5.3.4 Method. Figure 3 shows the general test arrangements for near-end and far-end crosstalk measurements. With the TIMS adjusted to the specified frequency and level and the selective level measuring set switched to its narrowest bandpass position, the difference in dB between this level and the disturbed channel meter reading is recorded (in terms of dBm or dBm0, as required by the standard) and compared to the specification for the unit under test (UUT). The TIMS can be disconnected from the disturbing channel and replaced with a termination to verify that the power level measured on the disturbed channel is primarily crosstalk and not significantly impacted by residual noise.

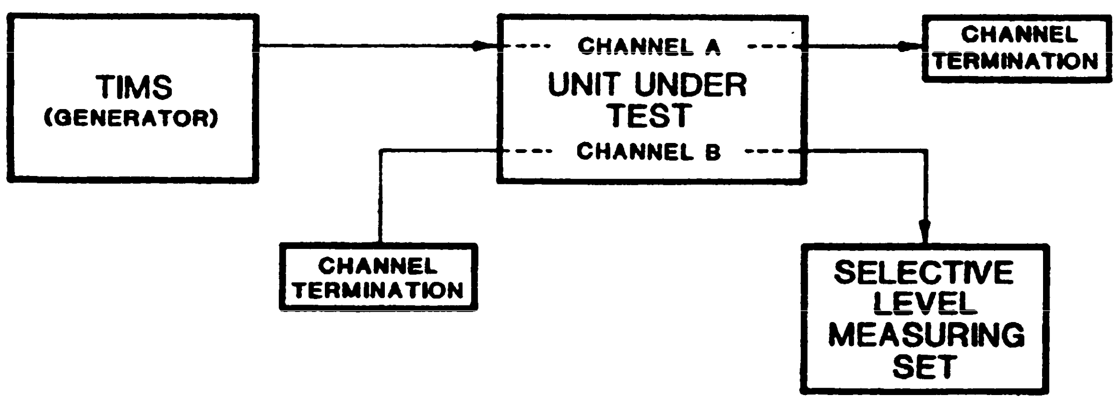
NOTE: The following formula can be used to compensate for any effect that residual noise may have on the crosstalk reading:

$$\text{dB (corrected)} = \text{dB (uncorrected)} - 10 \log_{10} (1 - 10^{-0.1X})$$

where "X" = dB difference between the uncorrected and residual noise readings.



a. Near-end crosstalk.



b. Far-end crosstalk.

FIGURE 3. Crosstalk (intelligible) measurement setup.

This method is repeated for other frequencies as required by the specification applicable to the UUT.

NOTE: See the appendix for reference to corresponding measuring techniques and equipment specifications for the method described above.

5.4 Digital error measurements.

5.4.1 Scope. The method described below shall be used to examine a digital data stream to determine if the transmitted logic state detected at the receiver is the opposite state (i.e., a bit error). This method shall provide data for error analysis to include error count, bit error ratio (BER), block error ratio (BLER), errored seconds, error-free seconds (EFS), percent of availability and unavailability, percent of errored seconds and severely errored seconds (SES), and percent of degraded minutes.

5.4.2 Measuring equipment.

Error measuring set

NOTE: A set is defined as having a pattern generator and an error detector, either integrated into one enclosure, or split. If the set is integrated, two sets are required for the end-to-end setup.

Recording device

5.4.3 Principles of measurement. Digital errors are detected as an error count or an errored interval. BER is derived from the error count as the ratio of bits received in error, to overall number of bits sent. BLER is also derived from the error count as the ratio of blocks received in error, to overall number of blocks sent. To have meaningful results, BER and BLER measurements must be made in a specified averaging period of time.

NOTE: Typically, the required measurement time is inversely proportional to the data rate. The International Telegraph and Telephone Consultative Committee (CCITT) (see CCITT Recommendation G.821) has suggested averaging periods from 1 second to 10 minutes, BER thresholds from 0 to 10^{-3}, and total measurement times as long as 1 month, depending on the type of digital service being evaluated. Common error ratio practice requires the collection of at least 100 errors for a high confidence in the calculated result of the BER analyzer or measuring set.

Errored intervals are usually expressed as errored seconds, with the errored interval beginning at the occurrence of the error and not related to the sampling period. Errored seconds, when measured during a specified period of time, can be used to derive percent of errored seconds, percent of SES, and percent of degraded minutes. EFS measurements are made in a specified sampling period, and BLER can be expressed as EFS with a block size of one second. Percent of availability is another way to characterize digital error performance and is derived from the number of one-second intervals in the measurement period for which the BER exceeds a specified threshold.

NOTE: Percent of availability, percent of unavailability (the converse of the percent of availability), percent of errored seconds, percent of SES, and percent of degraded minutes are measurements derived from "available" time based on CCITT Recommendation G.821. Refer to this document for additional information on requirements for these performance parameters.

Limits for random distributions of errors are specified in BER, whereas BLER and EFS are error criteria used to characterize burst distributions of errors.

An error measuring set is needed that will characterize measurement results in the terms of measurement specified by the standard that applies to the unit under test (UUT).

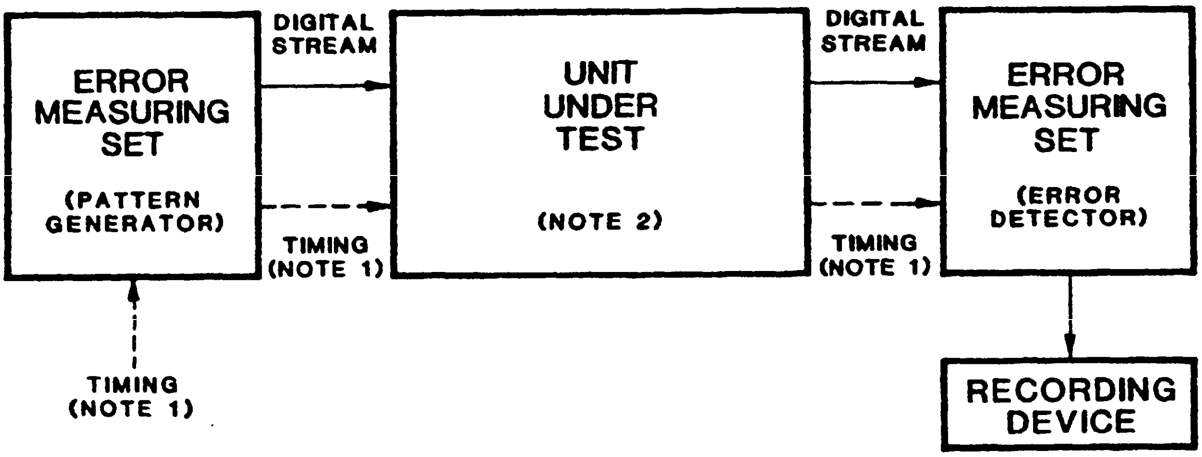
5.4.4 Method. Error analysis with test signals (a known data sequence) is the method given for making digital error measurements.

Figure 4 shows the general test arrangement. As indicated by the broken lines on the figure, timing can be supplied internally by the error measuring set if not available externally from the UUT.

NOTE: Because of the difficulties sometimes associated with synchronizing the measuring set receiver with internally generated timing, external timing is generally preferred.

After selecting the interface and format for the type of modem or other channel terminating equipment used on the UUT, a known pattern of bits (usually a pseudorandom pattern) is transmitted through the UUT. An identical error-free pattern is generated internally by the error measuring set at the receiving end and synchronized and compared with the received signal. Error count or errored intervals are viewed directly on the tester display or monitored on the recording device. At the end of the required test interval, the results are recorded in the appropriate terms of measurement and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures for the method described above.



NOTES:

1. IF A CLOCK SIGNAL FOR SYNCHRONOUS OPERATION IS NOT PROVIDED BY THE UUT, SYNCHRONIZATION IS ACHIEVED BY A CLOCK SIGNAL FROM THE PATTERN GENERATOR, OR BY AN EXTERNAL CLOCK SIGNAL PROVIDED THROUGH THE SENDING END OF THE ERROR MEASURING SET.
2. THE UNIT UNDER TEST MAY BE EITHER ANALOG (TERMINATED BY DATA MODEMS) OR DIGITAL.

FIGURE 4. Digital error measurement setup.

5.5 Digital jitter measurements.

5.5.1 Scope. The method described below shall be used to measure the intrinsic jitter and jitter transfer characteristic of digital transmission systems.

5.5.2 Measuring equipment.

Jitter generator/receiver (jitter measuring set)
Spectrum analyzer (optional)
Voltmeter (optional)
Recording device

5.5.3 Principles of measurement. Digital jitter is a parameter of key importance to digital transmission systems. At higher bit rates, data pulses become narrower with shorter time intervals between pulses. Due to an accumulation of jitter along the digital path, pulse transitions occur earlier or later than anticipated and thus can cause errors in translating pulses at the receiving end. Time jitter measurements are accomplished with a jitter measuring set that includes a time-interval counter for the detection and counting of zero-crossings of a reference timebase, gated or controlled by external start and stop events.

5.5.4 Method. The preferred method for digital jitter measurements employs a jitter generator/receiver (jitter measuring set) which can generate the required input jitter amplitude and frequency and provide a direct readout of jitter measurement parameters. An output port on the receiver portion of the measuring set is normally provided to permit access to the demodulated jitter where its root-mean-square (rms) amplitude can be measured on an external voltmeter, or its spectral content measured on a spectrum analyzer.

Figure 5 shows the general test arrangement. Intrinsic jitter is measured in terms of output jitter in the absence of input jitter. With no input jitter, the intrinsic jitter output of the unit under test (UUT) is displayed in peak-to-peak unit intervals. This value of jitter magnitude is recorded and compared to the limit specified for the UUT.

NOTE: The jitter measuring set specified for this method may not be readily available. An alternate method using an oscilloscope is described in Defense Communications Agency Circular (DCAC) 310-70-1, Volume II, Supplement 1. However, for ease of use and accuracy, the jitter measuring set with generator and receiver is preferred when available and applicable.

Jitter transfer characteristic is measured as the ratio of output jitter to input jitter amplitude versus (vs) jitter frequency for a given bit rate. Input jitter is specified by the applicable standard in terms of both amplitude and frequency. For evaluation of the jitter transfer characteristic, a data stream with jitter is applied by the generator to the input of the UUT and the output jitter frequency and gain across the jitter spectrum of interest is observed at the receiver.

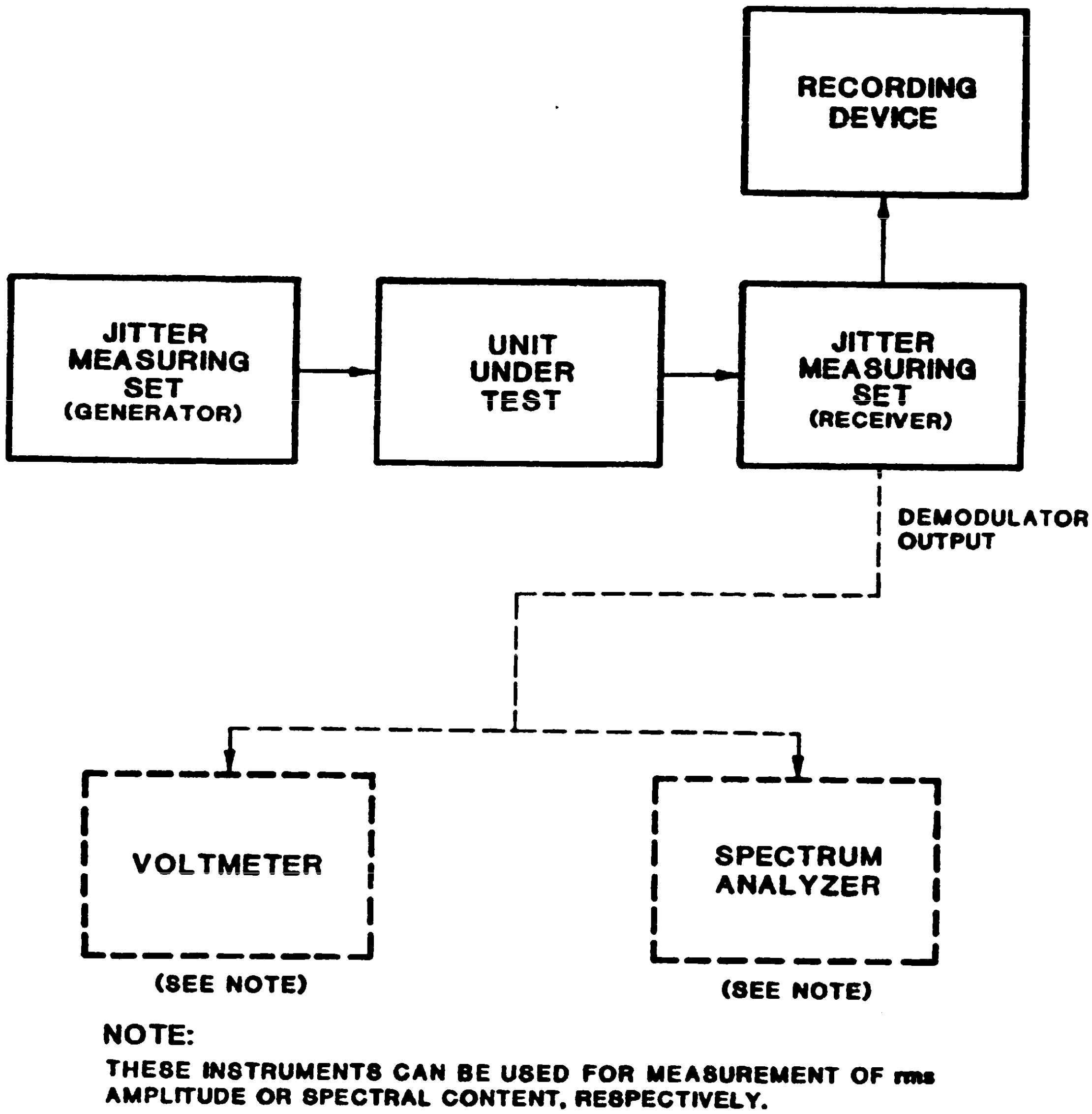


FIGURE 5. Digital jitter measurement setup.

The resulting jitter values are recorded and compared to the specifications for the UUT.

NOTE: A plot of jitter gain vs jitter frequency is normally constructed by a recording device to facilitate comparison of test results with specified values for the UUT.

5.6 Dropout measurements.

5.6.1 Scope. The method described below shall be used for measurements on communications systems subject to large reductions in channel gain or interruptions of continuity such as might result from deep radio fades.

5.6.2 Measuring equipment.

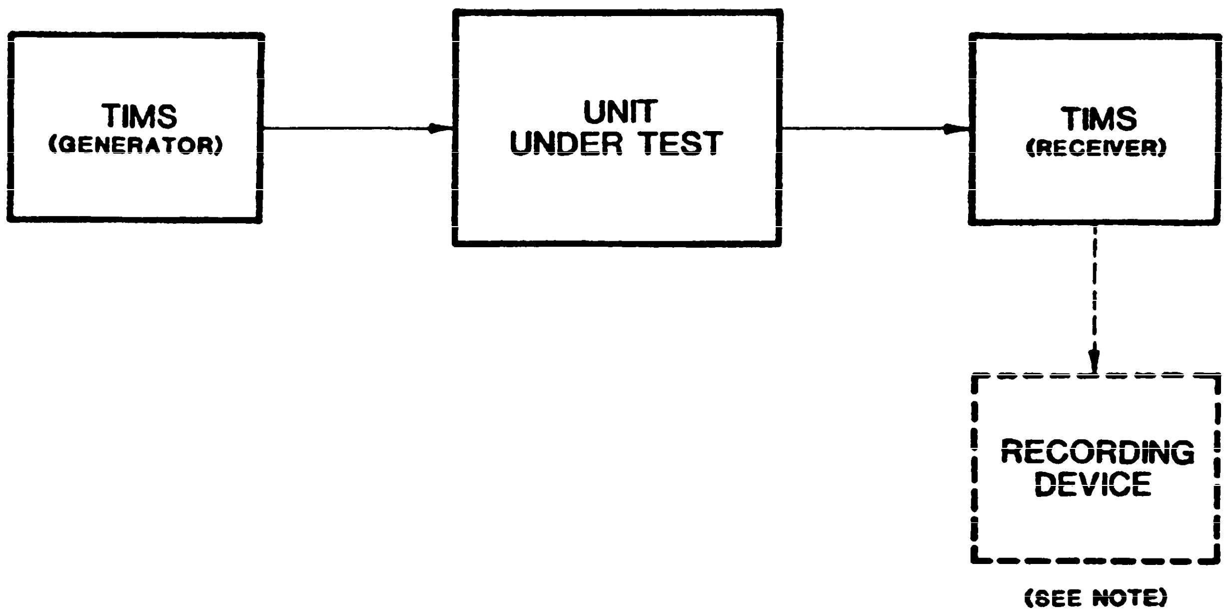
Transmission impairment measuring set (TIMS), 2 ea
Recording device (optional)

5.6.3 Principles of measurement. A dropout is counted when the level of the holding tone decreases by at least 12 dB for a period of time longer than the qualification interval. The dropout measuring set or TIMS measures the received holding tone level at the start of the measuring interval and establishes a dropout threshold 12 dB below this level. This threshold must remain fixed during the remainder of the measuring period.

Parameters for dropout measurements include length of time that gain remains below threshold, number of dropouts in a given time interval, and time distribution of dropouts.

5.6.4 Method. Figure 6 shows the general test arrangement. With the sending TIMS transmitting a holding tone, dropouts are counted by the receiving TIMS after its controls are set for the required threshold and time interval for cumulative dropouts, as specified for the unit under test (UUT). The dropout count is recorded for the required time interval and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



NOTE:
A RECORDING DEVICE CAN BE USED AS SHOWN TO CHARACTERIZE PERFORMANCE RESULTS.

FIGURE 6. Dropout measurement setup.

5.7 Envelope delay distortion measurements.

5.7.1 Scope. The method described below shall be used for making envelope delay distortion (EDD) measurements on a communications system as an assessment of the linearity of the phase vs frequency response of a voice channel.

5.7.2 Measuring equipment.

Transmission impairment measuring set (TIMS), 2 ea
Recording device

5.7.3 Principles of measurement. The absolute delay, or transit time, for signals transmitted through a communications channel may vary with a change in frequency. This variation is equivalent to nonlinear phase shifting, which is defined as phase or delay distortion. Because it is impractical to measure the absolute phase shift or delay of each frequency through the channel, the method must be a relative measurement involving the transmission of a swept carrier that is amplitude modulated with a low-frequency signal (usually 83-1/3 hertz (Hz)). Delay to the carrier and its modulation sidebands also delays the modulation envelope. EDD, then, is the maximum deviation in envelope delay across the specified band of frequencies.

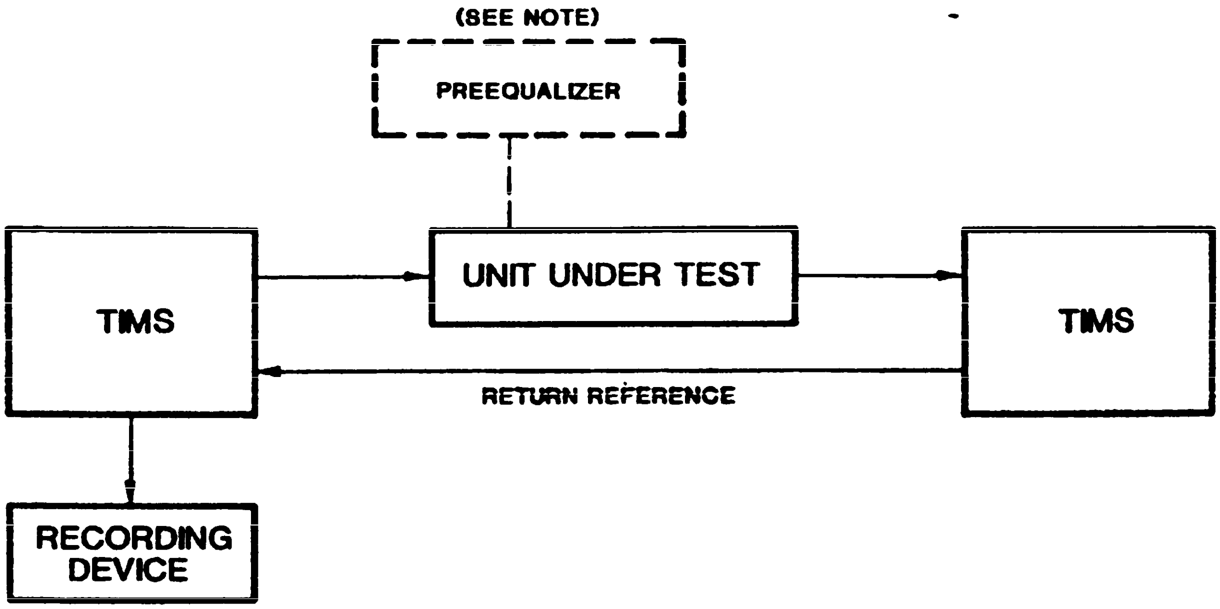
EDD has virtually no adverse effect on voice transmission. However, in data transmission, the distortion gives rise to intersymbol interference which causes errors and increased sensitivity to system noise and bandwidth limitations.

5.7.4 Method. There are two basic methods of measuring EDD: (1) the reference method (forward or return) which requires an additional circuit, and (2) the CCITT method which does not use a forward- or return-reference line. The available measuring sets differ for these two methods and are not compatible. The reference method has been selected for this standard based on the availability of reference-type measuring instruments.

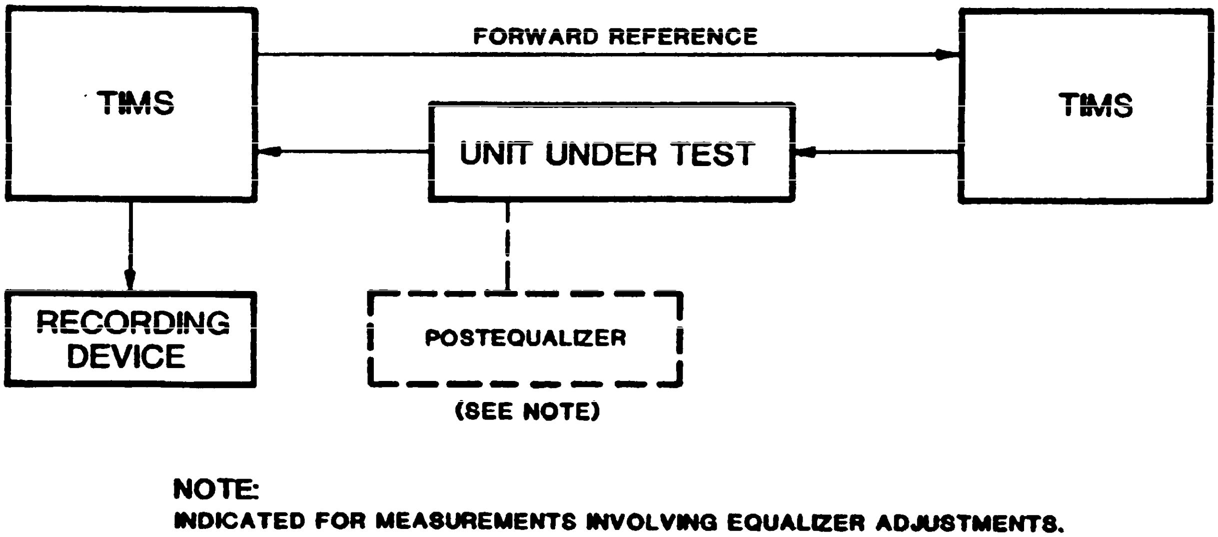
Figure 7 shows the general test arrangements for return- and forward-reference configurations. The figure 7.a. configuration will allow direct observation of results while adjusting a system preequalizer. Conversely, the figure 7.b. configuration will accomplish the same for a postequalizer. If no adjustments are required or if the input and output ports of the unit under test (UUT) are colocated, either configuration can be used.

With the frequency and envelope delay limits established and the recording device calibrated over the appropriate range, the values from the envelope delay measurements are recorded and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



a. Return-reference configuration.



b. Forward-reference configuration.

FIGURE 7. Envelope delay distortion measurement setup.

5.8 Frequency measurements.

5.8.1 Scope. The method described below shall be used to measure the ability of an independent frequency source to maintain a fixed and assigned frequency.

5.8.2 Measuring equipment.

Frequency counter
Frequency and time standard (as required)
Recording device

5.8.3 Principles of measurement. A frequency counter which counts the number of cycles of a signal under test over a precisely known time interval is the basic tool for frequency measurements. In general, the frequency counter must offer an accuracy of at least an order of magnitude greater than that of the unit under test (UUT). To achieve this, a primary or secondary standard must sometimes be employed to serve as the time base for the frequency counter.

Primary standards are cesium atomic beam resonator controlled oscillators, while secondary standards are rubidium gas cell controlled oscillators and quartz crystal oscillators.

5.8.4 Method. Figure 8 shows the general test arrangement.

NOTE: Frequency counters are not generally balanced to ground. The counter used may be sensitive to extraneous noise picked up on the test leads or from longitudinal currents introduced by the UUT.

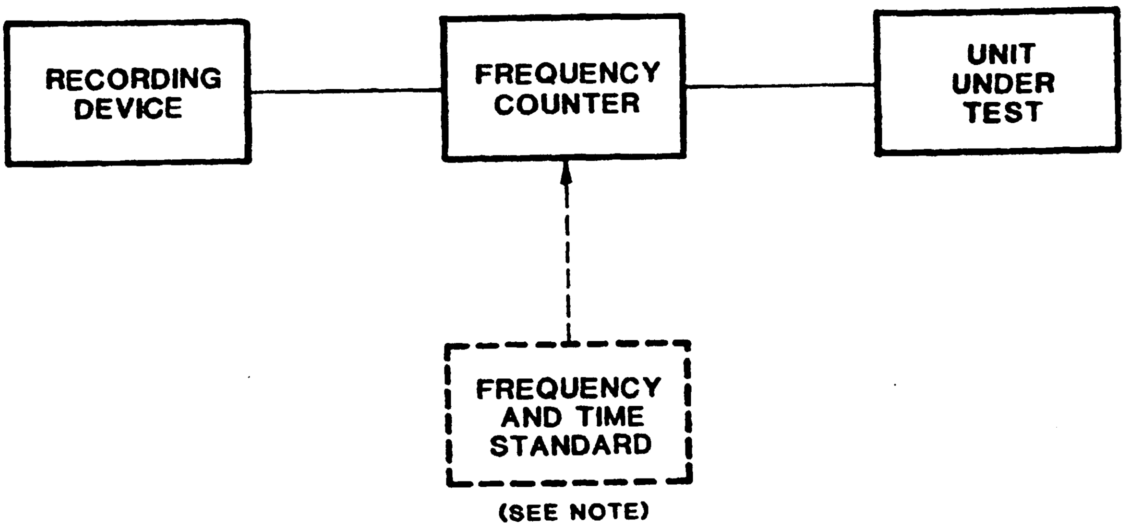
After specified warmup and ambient conditions are met for the UUT, the frequency count is monitored and recorded as a periodic measurement for accuracy, or recorded over a requisite time interval for stability. The maximum recorded excursions from the assigned frequency for the UUT are compared to the specified tolerance for the UUT.

NOTE 1: Stability can be calculated, if not accomplished automatically, by using the following formula:

$$S(\%) = \frac{(F_{max} - F_{min})}{F_c} 100$$

where S = stability;
F_{max} = highest measured excursion of the carrier;
F_{min} = lowest measured excursion of the carrier;
and F_c = assigned carrier frequency.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



NOTE:
THIS INSTRUMENTATION IS ONLY NECESSARY FOR THOSE MEASUREMENTS REQUIRING A HIGH DEGREE OF ACCURACY NOT OBTAINABLE FROM THE OSCILLATOR INTERNAL TO THE FREQUENCY COUNTER.

FIGURE 8. Frequency measurement setup.

5.9 Frequency translation error measurements.

5.9.1 Scope. The method described below shall be used to detect any change in the frequency of an audio signal as it is transmitted through a voice frequency (VF) channel in one direction. Frequency translation error measurements primarily apply to systems using frequency translation techniques such as those incorporated in frequency-division multiplexing (FDM) equipment.

5.9.2 Measuring equipment.

Signal generator
Frequency counter, 2 ea

5.9.3 Principles of measurement. Nonsynchronous FDM systems will cause deviations in the frequencies of audio signals when the transmit and receive carrier frequencies are not identical. These undesired changes are sometimes referred to as frequency displacement or frequency offset errors.

5.9.4 Method. Figure 9 shows the general test arrangement. A test tone is transmitted and any change in its frequency is determined by the difference in the readouts of the two frequency counters. This difference is compared to the specification for the unit under test (UUT).

NOTE: See the appendix for reference to detailed procedures for the method described above.

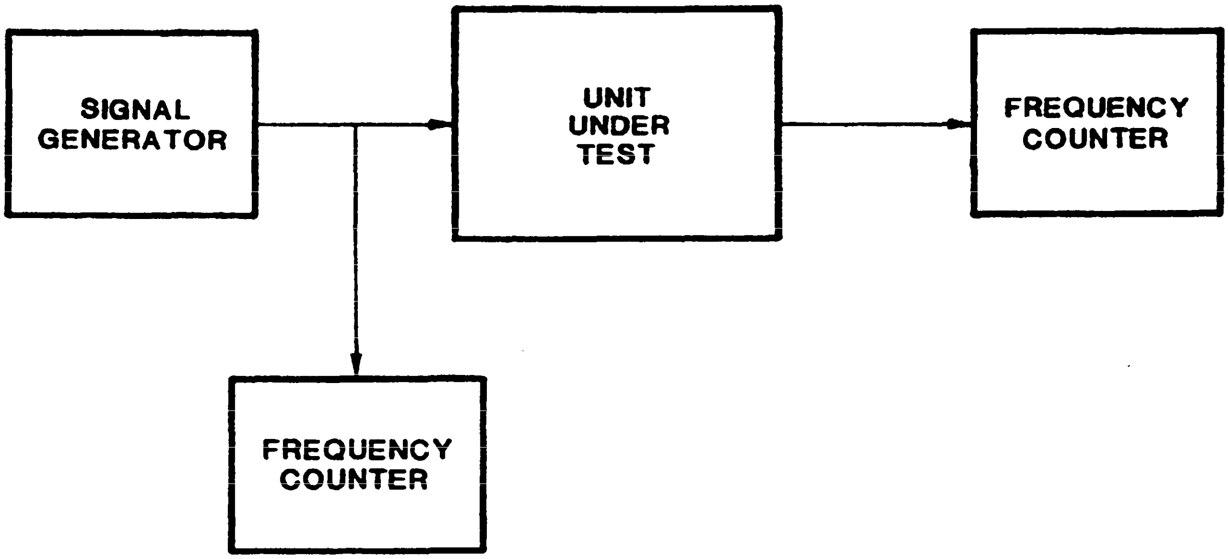


FIGURE 9. Frequency translation error measurement setup.

5.10 Harmonic distortion measurements.

5.10.1 Scope. The method described below shall be used for making single harmonic distortion measurements on analog transmission systems. The method permits the measurement of harmonic distortion of specified signals sent over a transmission system, physical circuit, or any individual part of the analog system (e.g., audio amplifier). Harmonic distortion measurements by this method are necessarily limited to those circuits or units which have harmonics falling within the bandpass of the unit under test (UUT).

5.10.2 Measuring equipment.

Signal generator
Level measuring set
Selective level measuring set or spectrum analyzer

5.10.3 Principles of measurement. Harmonic distortion is caused by nonlinear transfer characteristics of a circuit or device. Therefore, it is a nonlinear distortion resulting from the generation of new signal components not present in the original transmitted signal. This distortion appears as harmonics of a single-frequency input signal and thus is referred to as harmonic distortion. In VF circuits, it is the in-band second and third harmonics that are of primary concern.

5.10.4 Method. Two generic methods for measuring harmonic distortion are commonly used:

a. Single harmonic distortion using a frequency selective level meter or spectrum analyzer.

b. Total harmonic distortion using a nulling-type distortion analyzer.

Since method b. does not differentiate between harmonics and noise and does not provide individual levels of the harmonics, method a. shall serve as the generic standard.

Figure 10 shows the general test arrangement. A single, harmonic-free test tone is required at the input of the UUT and the levels of the harmonic components are measured at the output. Assuming the proper setting of frequencies and levels, in-band harmonic levels are measured relative to the fundamental and recorded as a percentage or number of dB below the fundamental. These values are compared to the specification for the UUT.

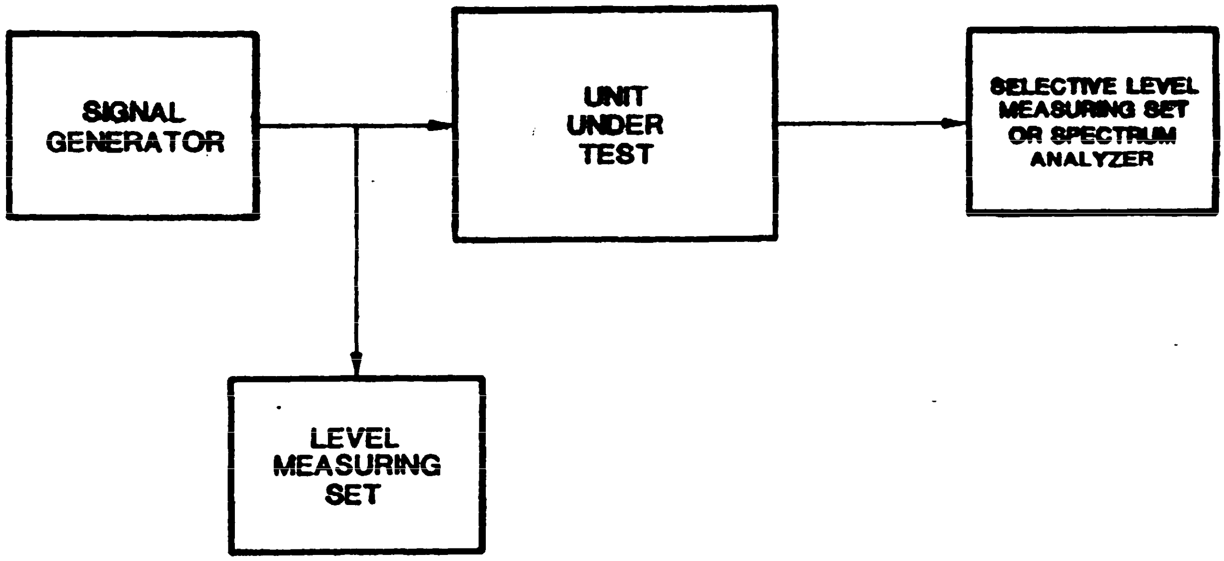


FIGURE 10. Harmonic distortion measurement setup.

NOTE 1: Harmonic distortion (D) can be converted from number of dB below the fundamental to percent distortion by the following formula:

$$D(\%) = \frac{100}{\text{ANTILOG}_{10}\ 0.05D(dB)}$$

Conversely, $D(dB) = -20 \log_{10} 0.01D(\%)$

NOTE 2: Total harmonic distortion (D_t) in percent can be derived from the following formula:

$$D_t(\%\ \text{total}) = (a^2 + b^2 + \ldots)^{0.5}$$

where a, b, ... are the distortion percentages of the individual harmonics.

NOTE 3: See the appendix for reference to detailed procedures for the method described above.

5.11 Impulse noise measurements.

5.11.1 Scope. The method described below shall be used for measurements on communications systems subject to short duration noise spikes and energy bursts.

5.11.2 Measuring equipment.

Transmission impairment measuring set (TIMS) (2 ea for tests requiring a holding tone)
Recording device (optional)

5.11.3 Principles of measurement. Impulse noise consists of deviations of the received noise signal which are much greater in amplitude than the normal rms noise level and occur as short duration spikes or energy bursts. Noise impulse occurrences are generally a function of system activity and measurements should normally be made during periods of peak system activity. To be counted as an impulse, the impulse noise should exceed the rms noise level by a predetermined limit. A counter in the measuring set records the number of noise spikes exceeding this threshold.

Measurement parameters for impulse noise include the number of pulses above threshold in a given time interval, time distribution of noise spikes, and distribution of impulse magnitude in decibels.

NOTE: Low, mid-, or high ranges for magnitude threshold allow for derivation of a profile of the impulse amplitude distribution to facilitate analysis. Such a profile, for example, can aid in determining sources of impulse noise.

5.11.4 Method. Figure 11 shows the general test arrangement. The input of the unit under test (UUT) is terminated in its characteristic impedance (Z_0).

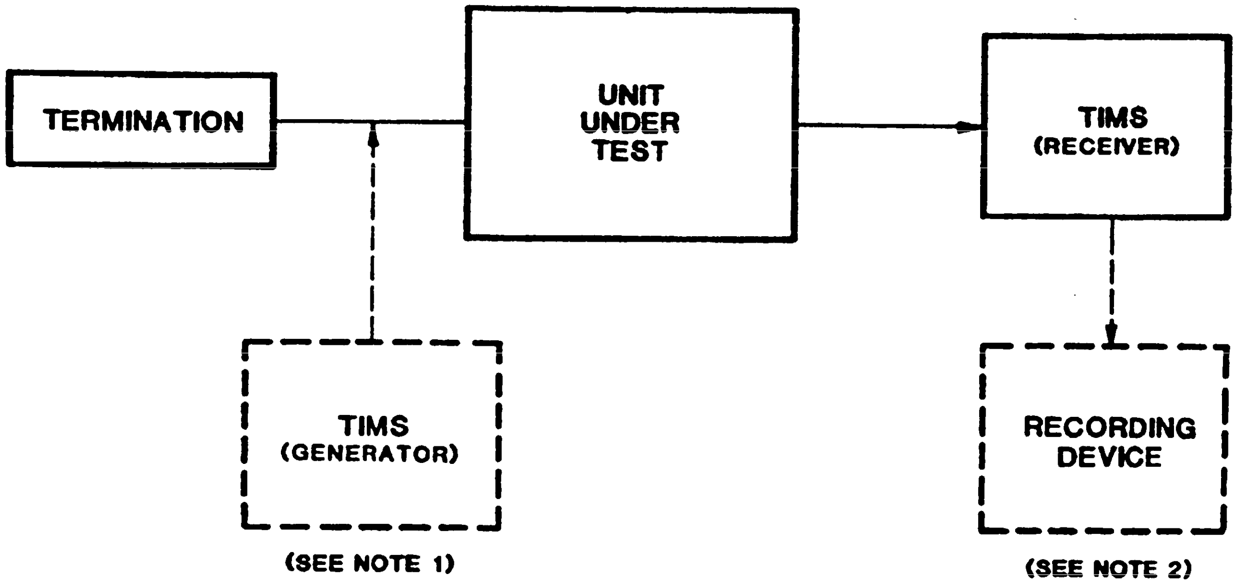
NOTE: Some channel tests require activation of all other channels or adjacent channels.

Impulse noise spikes are counted by the TIMS after its controls are set for the required impedance (terminating mode), weighting, threshold, and time interval for cumulative impulse noise spikes, as specified for the UUT.

NOTE: A notching capability on the TIMS receiver is required for those tests that involve a holding tone.

The impulse noise count is recorded for the required time interval and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



NOTES:

1. THIS INSTRUMENT IS NECESSARY ONLY IF A HOLDING TONE IS REQUIRED.
2. A RECORDING DEVICE CAN BE USED AS SHOWN TO CHARACTERIZE PERFORMANCE RESULTS.

FIGURE 11. Impulse noise measurement setup.

5.12 Insertion loss vs frequency measurements.

5.12.1 Scope. The method described below shall be used for measuring insertion loss as a function of frequency. It is applicable to units which are used for the transmission of analog or quasi-analog signals.

5.12.2 Measuring equipment.

Signal generator
Level measuring set
Recording device (optional)

5.12.3 Principles of measurement. Insertion loss as a function of frequency (also referred to as attenuation distortion, frequency response, or amplitude vs frequency distortion) is the difference in loss at the reference frequency and the loss at the measuring frequency.

5.12.4 Method. Insertion loss is typically measured by applying a constant amplitude, swept-frequency test tone to one end of a circuit and measuring the variations in received level as a function of frequency at the other end.

Figure 12 shows the general test arrangement. While maintaining the appropriate signal generator output level, the frequency is swept over the specified band. The received level is then measured and recorded at enough frequencies to verify that the response is within the limits specified for the unit under test (UUT).

> NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.

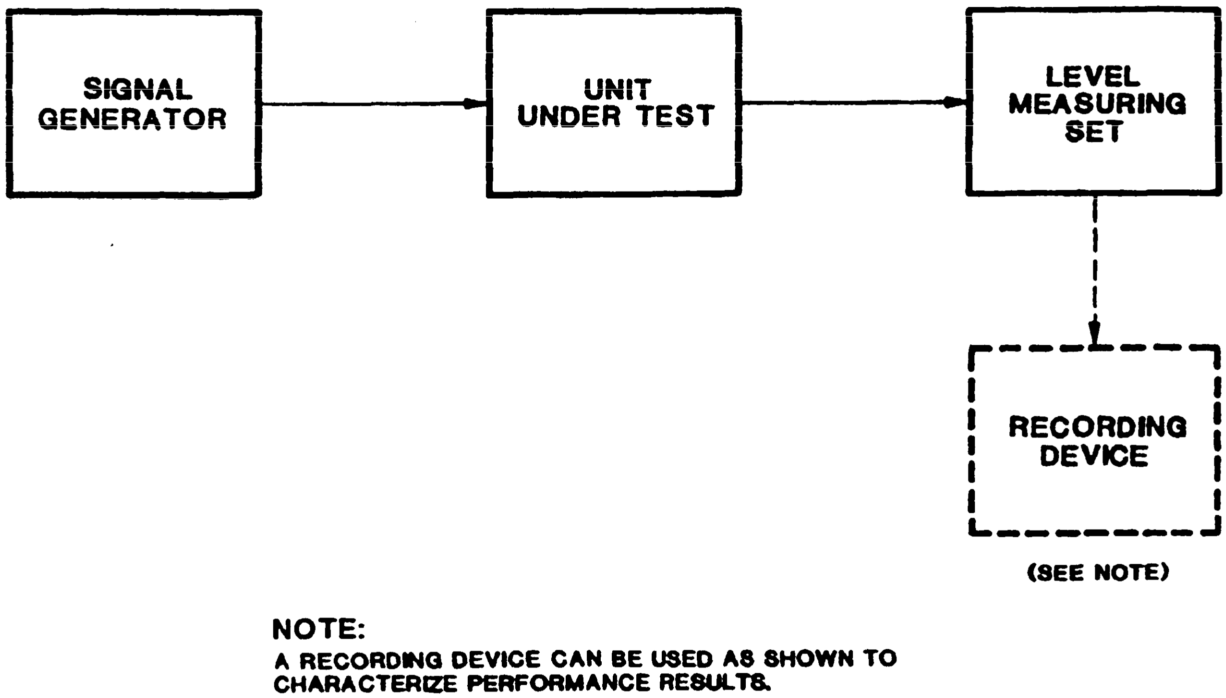


FIGURE 12. Insertion loss vs frequency measurement setup.

5.13 Intermodulation distortion measurements.

5.13.1 Scope. The method described below shall be used for making multitone nonlinear distortion measurements. It is applicable to units which are used for the transmission of a multiple-frequency signal.

5.13.2 Measuring equipment.

Transmission impairment measuring set (TIMS) with four-tone capability, 2 ea

5.13.3 Principles of measurement. Like harmonic distortion (see 5.10.3), intermodulation distortion (IMD) is a nonlinear form of distortion. However, with a multiple-frequency input instead of a single-frequency input, IMD products result from an intermixing of the individual tones and their harmonics. A technique using a multitone input more accurately simulates a working data signal for the testing of data circuits, allowing for a more representative assessment of IMD.

5.13.4 Method. The measurement method (and associated measuring equipment) conforming to Institute of Electrical and Electronic Engineers (IEEE) Standard 743-1984 has been adopted for this standard. Four-tone IMD is measured by applying four equal-level tones at the input of the unit under test (UUT) and measuring second-order and third-order components at the output.

Figure 13 shows the general test arrangement. Following the specified levels for the four tones, the second- and third-order intermodulation components are measured and recorded as required by the applicable standard. Disabling the two lower frequency tones and increasing the other two by 3 dB will reestablish the composite level and provide a measurement of noise components that impact the accuracy of these distortion readings. The IMD values can then be corrected by using the following equation:

$$\text{dB (corrected)} = \text{dB (uncorrected)} - 10 \log_{10} (1-10^{-0.1X})$$

where "X" = dB difference between uncorrected reading and noise reading.

The corrected values are recorded and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.

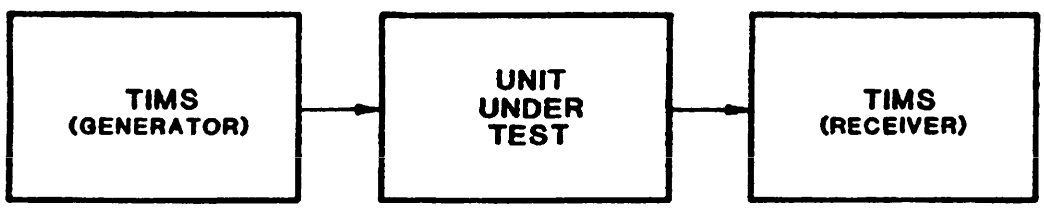


FIGURE 13. Intermodulation distortion measurement setup.

5.14 Longitudinal balance measurements.

5.14.1 Scope. The method described below shall be used for making measurements on communications systems to determine their susceptibility to interference from external sources. These measurements are applicable to one- and two-port units which use balanced-port circuitry.

5.14.2 Measuring equipment.

Longitudinal balance measuring set (2 ea for two-port setup)

5.14.3 Principles of measurement. Most noise on physical circuits is due to longitudinal unbalance. The longitudinal balance test determines if the longitudinal unbalances present are within the specified limit in the physical circuit.

Testing a unit for balance involves the application of a longitudinal voltage (V_l) as a source, and measurement and monitoring of the resulting metallic voltage (V_m) at the terminating end. The degree of longitudinal balance in decibels is derived from the following equation:

$$\text{Balance (in dB)} = 20 \log (V_l/V_m)$$

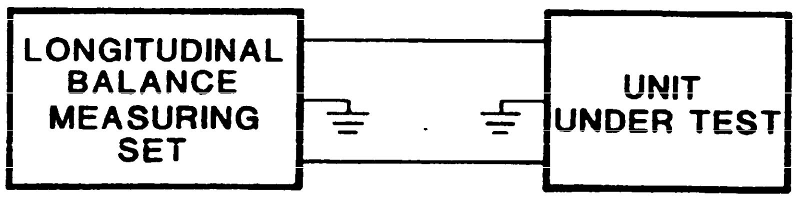
where V_l is the voltage applied to the driving test circuit for longitudinal balance measurements; and V_m is the voltage across the two sides of a circuit resulting from an impedance imbalance in the circuit being tested for electrical symmetry.

5.14.4 Method. Several different test circuits for measuring longitudinal balance were developed by AT&T, CCITT, EIA, REA, and others. The test results differed, depending on which circuit was utilized. To reconcile these differences, IEEE Standard 455-1985 was developed and, subsequently, measuring equipment conforming to this standard has become avaliable.

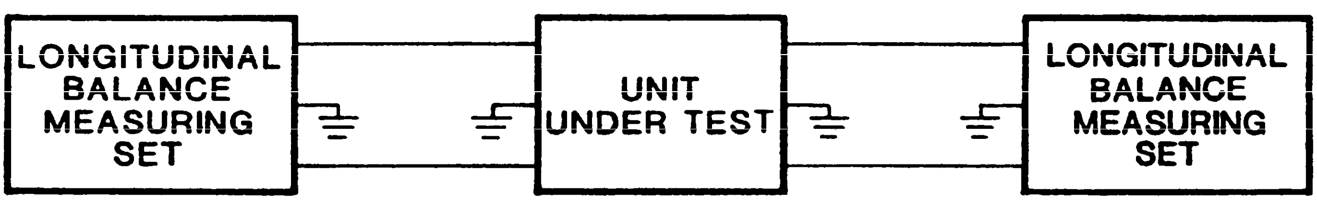
Test methods (and associated measuring equipment) conforming to IEEE Standard 455-1985 have been adopted for this standard and are summarized in the following paragraphs.

Figure 14 shows the general test arrangements with configurations a and b. The figure 14.a. configuration applies to one-port units, and the figure 14.b. configuration to two-port units. With the measuring set calibrated for the specified test frequency or frequencies, the balance of the unit under test (UUT) is measured and recorded.

NOTE: The appropriate value of bias current should be ensured for those UUTs that require a dc bias to operate.



a. One-port test setup.



b. Two-port test setup.

FIGURE 14. Longitudinal balance measurement setup.

For two-port units, the balance readings are measured and recorded for the UUT in one direction (input of UUT connected to the driving test circuit), and then repeated for the reverse direction (output of UUT connected to the driving test circuit). The resulting values are compared with the specification for the UUT.

NOTE 1: For two-port units, series and shunt unbalances are compared by means of a switching feature on the measuring set to determine which is dominant in the UUT.

NOTE 2: Measurement of longitudinal balance using the equipment specified for this method can produce misleading results when testing UUTs, such as telephone loops, which are susceptible to induced discrete signals. In such cases, a longitudinal balance test set with a highly selective tuning capability would have to be used to select only the frequency of the test signal. This type of test set is under development and is not yet available. As an alternate method of measurement (described in ANSI/IEEE Standard 820-1984), C-message weighted metallic noise and noise-to-ground are measured using a noise test set. The longitudinal balance in dB is defined as:

$$\text{Balance} = N_g - N_m$$

where N_g = noise-to-ground (noise power in dB above reference noise measured by a set with C-message weighting (dBrnC));
and N_m = metallic noise (dBrnC).

NOTE 3: See the appendix for reference to detailed procedures and corresponding measuring equipment specifications for the methods described above.

5.15 Net loss/gain variation measurements.

5.15.1 Scope. The method described below shall be used to measure net loss/gain variations with respect to time. It is applicable to units which are used for the transmission of analog or quasi-analog signals through a VF channel.

5.15.2 Measuring equipment.

Transmission impairment measuring set (TIMS)
Level measuring set with recorder output
Recording device

5.15.3 Principles of measurement. The net loss or gain of a communication channel must be determined so that correct operating power levels can be established and maintained. The test signal power level is required to be within the normal operating range of the unit under test (UUT). A net loss is indicated when the input level minus the output level results in a positive value. A gain is indicated when the calculation results in a negative value. The net loss or gain of the channel should remain constant over time with a fixed-level test signal applied at the sending end of the UUT.

5.15.4 Method. Variations of net loss (insertion loss) or gain with respect to time are measured by inserting a fixed-level tone at one end of a circuit or unit and recording the received level at the other end for a prescribed time period.

Figure 15 shows the general test arrangement. The recorder is calibrated and adjusted to accommodate the received test tone level, variation limits, and rate of level variations. Received signal level variations are recorded for the prescribed time period and compared with the variation limits specified for the UUT.

NOTE: See the appendix for reference to detailed procedures for the method described above.

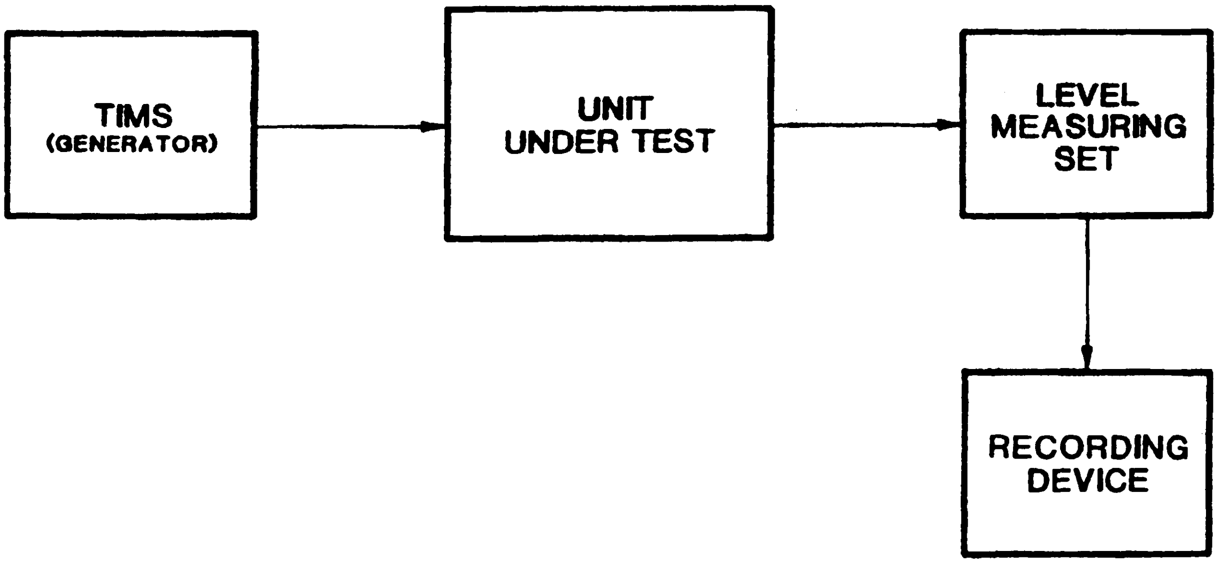


FIGURE 15. Net loss/gain variation measurement setup.

5.16 Noise figure measurements.

5.16.1 Scope. The method described below shall be used to determine how well a unit under test (UUT) can process weak signals. This noise figure measurement method is universal as it applies to components, equipment, or systems.

5.16.2 Measuring equipment.

Broadband noise source
Noise figure meter
Filter (as required)

5.16.3 Principles of measurement. The noise figure is the ratio of the output noise power of a device to the portion attributable to thermal noise in the input termination at standard noise temperature (usually 290 kelvins (290 K)). This ratio then is the actual output noise to that which would remain if the device itself was made noiseless. Mathematically, this definition may be expressed as

$$N_F = \frac{N_O}{kT_OBG} = \frac{S_i/N_i}{S_O/N_O}$$

where N_O = measured noise output power;
k = Boltzmann's constant, 1.380662 x 10-23 joules/K;
T_O = absolute temperature in K;
B = bandwidth in hertz;
G = system gain as a power ratio;
S_i/N_i = input signal-to-noise ratio;
and S_O/N_O = output signal-to-noise ratio.

5.16.4 Method. The numerous approaches to measuring noise figure all rely on some form of measuring the parameters in 5.16.3 and include the following manual techniques:

a. Measurements using a signal generator and a power meter.

b. Measurements using a broadband signal generator as a noise source and a power meter.

c. Measurements using an excess noise source and a power meter and applying either:

(1) The twice-power method;

or (2) The Y-factor method.

While these manual methods yield valid results, they are nevertheless slow, tedious, and complicated. Direct reading, continuously indicating noise figure meters which employ microprocessors that automatically compute and display the noise figure of the UUT are preferred where such instruments are available. The automatic system using an excess noise source is therefore the preferred approach to noise figure measurements and is the method given.

Figure 16 shows the general test arrangement.

NOTE: When measuring noise figure, several possible sources of error must be considered, including errors caused by impedance mismatching, spurious responses in the UUT, and temperature. Matching the measuring equipment to the UUT will ensure that the noise power is effectively coupled into the system. Source noise is limited to the bandwidth of the UUT by a filter that eliminates the effects of image or spurious responses in the UUT. The temperature of the noise source should be known and additional noise caused by ambient temperature compensated for.

With the specified current provided to the noise source and the noise figure meter properly adjusted and calibrated, the noise figure is noted. All corrections required, such as filter or cable loss between the noise source and the UUT, are noted and accounted for in deriving the measured noise figure. The corrected noise figure is recorded and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures for the method described above.

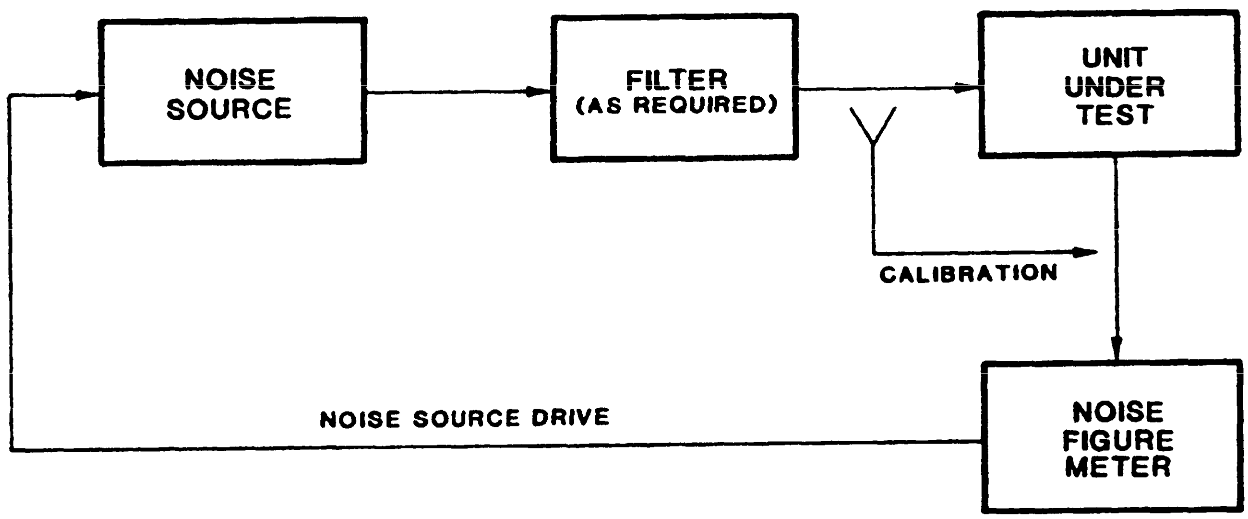


FIGURE 16. Noise figure measurement setup.

5.17 Noise/signal-to-noise ratio measurements.

5.17.1 Scope. The method described below shall be used for making idle-channel or notched-noise measurements. It is applicable to units which are used for the transmission of analog or quasi-analog signals.

5.17.2 Measuring equipment.

Noise measuring set (with C-message, 3-kHz flat, and switchable notch filters)
Test oscillator (holding-tone generator)

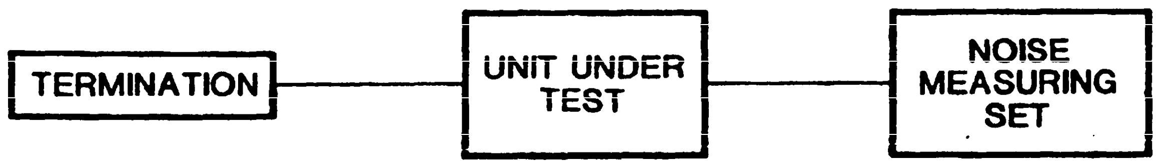
5.17.3 Principles of measurement. Noise measured on a unit that is correctly terminated but not carrying any signals is called idle-channel or background noise. Idle-channel noise measurements on compandored units, or on units which digitize analog signals, do not give a true indication of noise levels. In these cases, a holding tone is inserted at the send terminal and a notching filter is employed at the receive terminal to remove this tone prior to making the noise measurement. The holding tone activates the channel so that harmonic distortion, quantizing noise, phase jitter, and amplitude jitter become part of the noise measurement. This type of measurement is called notched-noise. Signal-to-noise (SNR) ratio is a comparison of the received power of the holding tone to the noise power.

To correlate the interfering effect of idle-channel or notched noise to users, weighting networks are sometimes employed. The most commonly used network is the C-message, which is primarily applicable to voice transmission. It may be used for data applications that are band-limited to about 600 - 3,000 Hz. A 3-kHz flat filter network should be used for data transmissions which require a wider frequency response. Such a network would also allow for detection of low-frequency components (e.g., a 60-Hz signal and its harmonics) that may be impairing transmission performance.

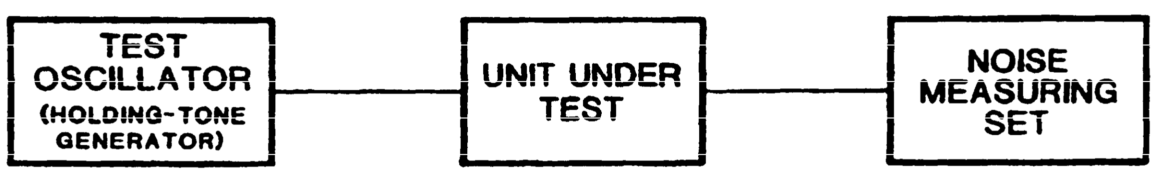
5.17.4 Method. The measurement method (and associated measuring equipment) conforming to IEEE Standard 743-1984 has been adopted for this standard. Figure 17 shows the general test arrangements with configurations a and b. The figure 17.a. configuration is applicable to idle-channel noise measurements, and the figure 17.b. configuration to noise measurements requiring a holding tone.

Measurements are made with the unit under test (UUT) terminated in its nominal impedance. With the noise measuring set switched to the applicable weighting network, the measurement is made and the noise values are recorded and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



a. Idle-channel noise measurement.



b. Notched-noise measurement.

FIGURE 17. Noise/signal-to-noise ratio measurement setup.

5.18 Phase hit measurements.

5.18.1 Scope. The method described below shall be used for measurements on communications systems subject to abrupt changes in the phase of the transmitted signal.

5.18.2 Measuring equipment.

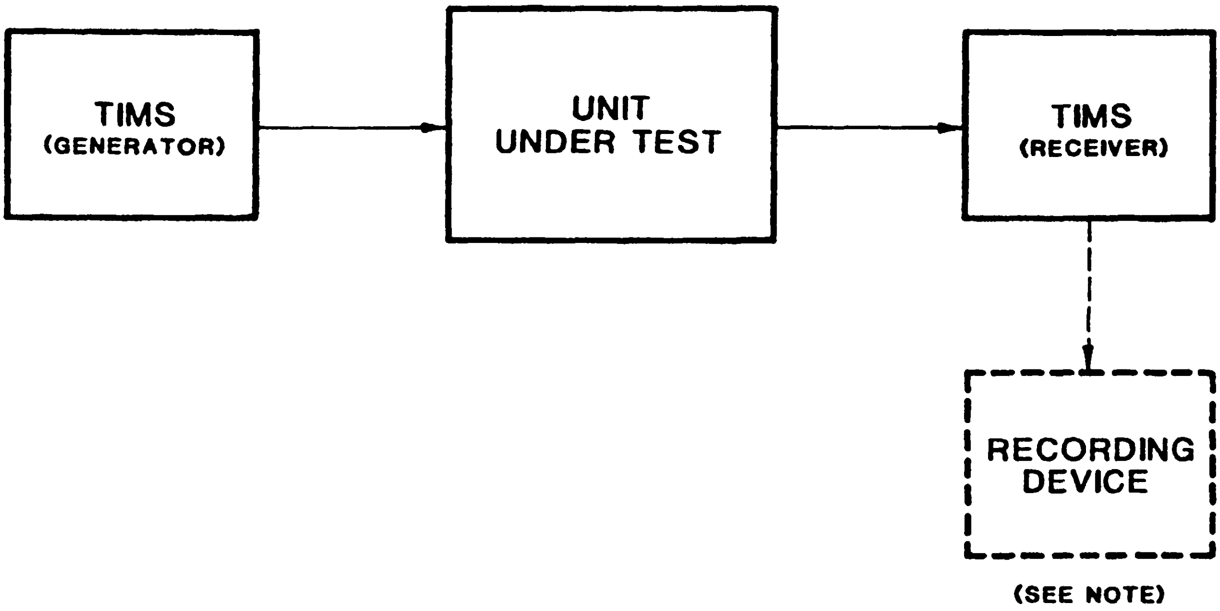
Transmission impairment measuring set (TIMS), 2 ea
Recording device (optional)

5.18.3 Principles of measurement. Phase hits are characterized by random signal jumps to a new phase and a return to the original phase after a brief period (measured in milliseconds). To be classified as a phase hit, the phase change should last from four milliseconds to a duration period of several hundred milliseconds before the original phase is restored. Measurement parameters of phase hits include distribution of hit magnitudes in degrees, the number of hits over a given time period, and the time distribution of hits.

Measurement of phase hits can be somewhat masked by the presence of impulse noise on the transmission system. The significant effects of impulse noise transients, however, have been found to disappear within four milliseconds. Therefore, separate time limits can be imposed on phase hit measurements to guard against noise interference (some test sets have provision to inhibit erroneous counts from impulse noise interference, thereby eliminating the need for such precautionary measures).

5.18.4 Method. Figure 18 shows the general test arrangement. Phase hits are counted by the TIMS after its controls are set for the required threshold (the tolerance for the unit under test (UUT) in degrees) and time interval for cumulative phase hits, as specified for the UUT. The phase hit count is recorded for the required time interval and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.



NOTE:
A RECORDING DEVICE CAN BE USED AS SHOWN TO CHARACTERIZE PERFORMANCE RESULTS.

FIGURE 18. Phase hit measurement setup.

5.19 Phase jitter measurements.

5.19.1 Scope. The method described below shall be used to measure unwanted angular modulation of a transmitted signal.

5.19.2 Measuring equipment.

Transmission impairment measuring set (TIMS), 2 ea
Recording device (optional)

5.19.3 Principles of measurement. Phase jitter results from an incidental phase modulation process that produces unwanted variations in the zero crossings of the received signal as well as discrete sidebands. Both of these effects can be used as a basis for the measurement of phase jitter.

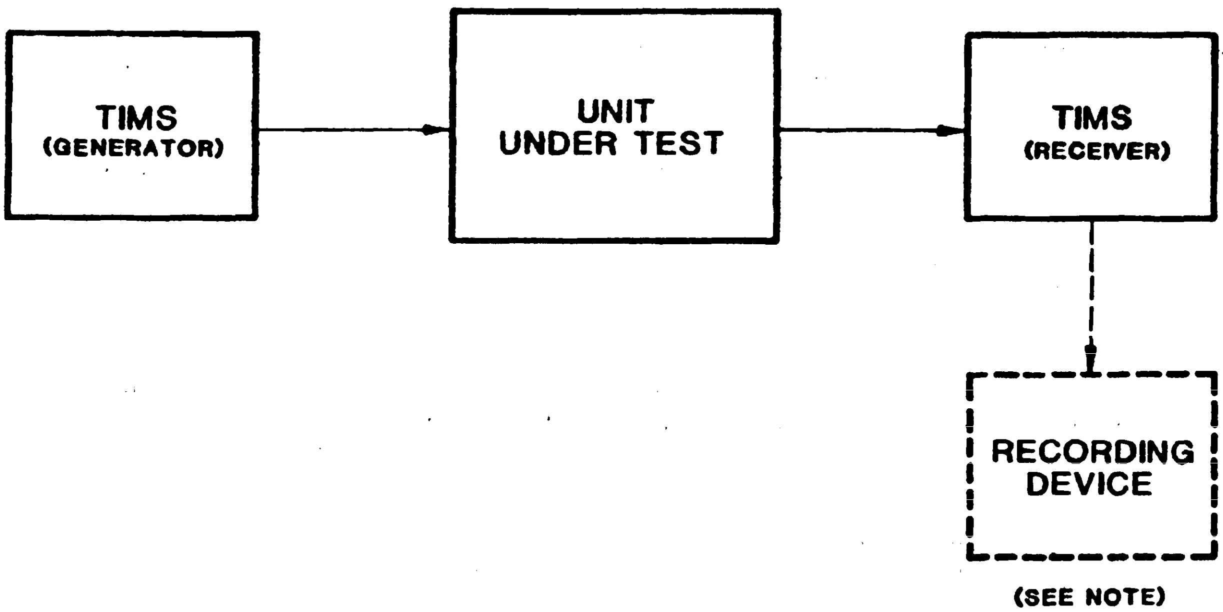
The incidental phase modulation of the transmitted signal is caused by powerline frequencies or multiples thereof, signaling frequencies or their combinations, or low-frequency (5 to 20 Hz) components due to frequency translation factors. Since noise and tone interference also perturb the zero crossings of a signal, phase jitter measurements will indicate the cumulative disturbing effect of incidental (true) phase modulation and additive tones or noise on the zero crossings of a holding-tone signal. Since the frequency band most likely affected by phase jitter is also sensitive to noise and tone interference, a phase jitter measurement should include a technique to limit the contribution of these sources.

5.19.4 Method. Figure 19 shows the general test arrangement. The standard method shall be the zero-crossing method, implemented in the measuring set by band limiting, detection of zero crossings, and display of peak-to-peak deviations in degrees.

NOTE 1: Band limiting the measurements in a range from 4 Hz to 300 Hz (usually 4 Hz to 20 Hz for low-frequency jitter and 20 Hz to 300 Hz for other sources) minimizes the influence of additive noise and tone interference without compromising measurement sensitivity to the incidental phase modulation components.

NOTE 2: A C-notched noise measurement (see 5.17, "Noise/signal-to-noise ratio measurements") can also be made in conjunction with this measurement to determine the extent of the additive noise component.

NOTE 3: Because quantizing noise can also impact the phase jitter reading, a test signal frequency and filtering should be used that will suppress the effect on the measurement.



NOTE:
A RECORDING DEVICE CAN BE USED AS SHOWN TO CHARACTERIZE PERFORMANCE RESULTS.

FIGURE 19. Phase jitter measurement setup.

Following the isolation of the phase jitter from other contributions, the jitter value in degrees is recorded and compared to the specification for the unit under test (UUT).

NOTE: See the appendix for detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.

5.20 Resistance-to-earth measurements.

5.20.1 Scope. The method described below shall be used to measure the resistance to earth of earth electrode subsystems.

5.20.2 Measuring equipment.

Earth resistance measuring set

5.20.3 Principles of measurement. Resistance to current through an earth electrode actually has several components: resistance of the electrode itself and connections to it; contact resistance between the electrode and the soil adjacent to it; and resistance of the surrounding earth. The object or device used for the electrode usually has a cross-sectional area large enough that the electrode contributes a negligible resistance to the path current. Likewise, contact resistance is usually a small part of the total resistance of the subsystem. The greatest resistance is therefore contributed by the resistance of the surrounding earth.

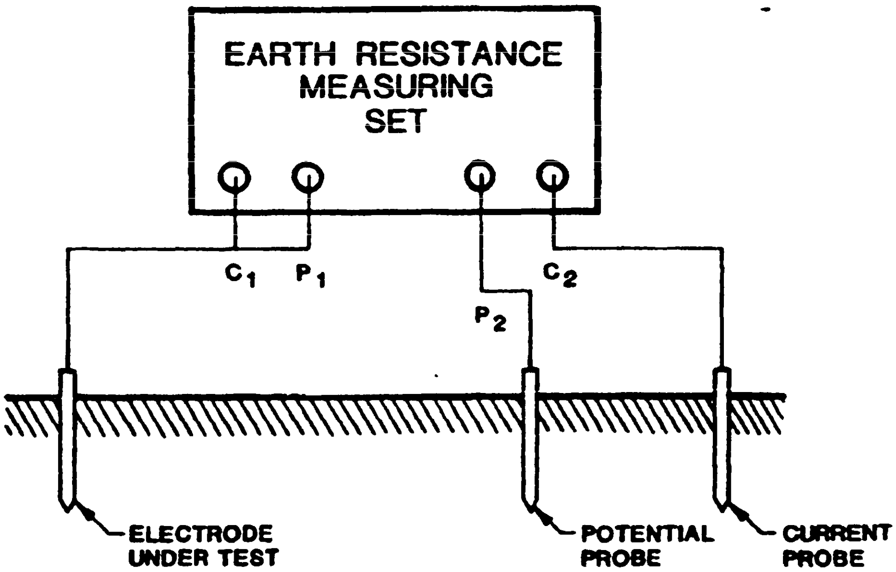
Assuming a uniform resistivity for the surrounding earth, the resistance to earth of an earth electrode subsystem can be theoretically calculated. However, since earth resistivity is neither uniform nor constant and the formulas become complicated, a direct method of measuring resistance to earth of earth electrode subsystems is given in 5.20.4.

5.20.4 Method. Two commonly used methods for measuring the resistance to earth of an earth electrode subsystem are the triangulation method and the fall-of-potential method. The fall-of-potential method is recommended for measurement of single-rod or multirod earth electrode subsystems and is given as the standard method.

Figure 20.a. shows the general test arrangement. The fall-of-potential method involves passing a current between the electrode under test and a current probe. The measuring set detects a drop in voltage between the electrode under test and the potential probe located between the two current probes. The ratio of the voltage drop to the known current gives a measure of the resistance.

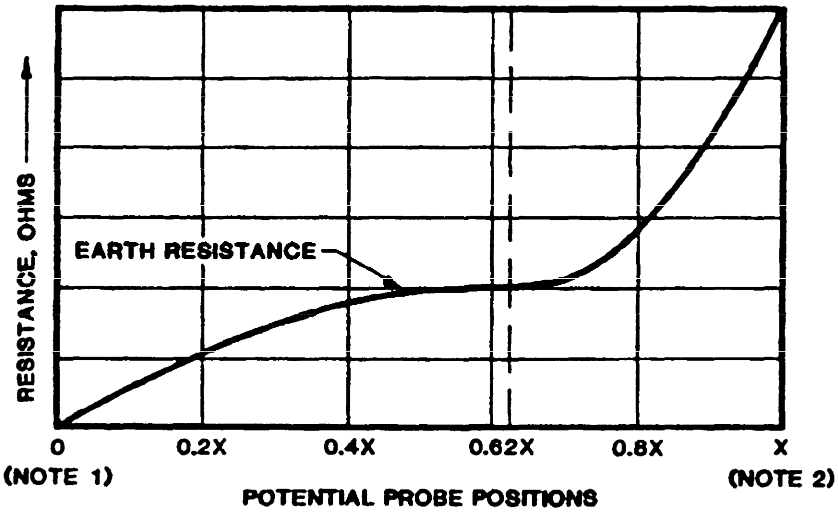
NOTE 1: The voltage potential is in respect to the electrode under test, assumed for convenience to be at zero potential.

NOTE 2: The earth resistance measuring set includes a voltage source, a capability of measuring voltage and current, and, by computing resistance, provides a direct readout in ohms.



NOTE:
C AND P ARE CURRENT AND POTENTIAL SOURCES, RESPECTIVELY.

a. Resistance-to-earth measurement setup.



NOTES:
1. POSITION OF THE ELECTRODE UNDER TEST.
2. X = TOTAL DISTANCE THAT POTENTIAL PROBE IS PLACED FROM ELECTRODE UNDER TEST.

b. Resistance vs distance from earth electrode.

FIGURE 20. Resistance-to-earth measurements.

This measure is repeated while moving the potential probe away from the electrode under test in steps and the resulting resistance values plotted as a function of probe spacing as shown on figure 20.b. The points of measurement must be roughly on a straight line between the electrode under test and the current probe, and the plotted curve extended until resistance values level off to form a flat portion.

NOTE: To obtain a flat portion of the curve, it is necessary that the current probe be effectively outside the range of influence of the electrode under test (i.e., a distance beyond which there is negligible effect on the measured rise of ground voltage caused by ground current). This distance should be a minimum of about five times the longest diagonal of the area of the electrode under test to ensure an accuracy of 90 percent for the measurement. With an extensive earth electrode subsystem, it may not be possible to locate the current probe at this minimum distance. Refer to MIL-HDBK-419 for resistance curves representing a large electrode subsystem and a method of estimating the true value of resistance by extrapolation. This handbook also contains additional information on improving the accuracy of the measurement by extending the current probe location up to 50 times the diagonal for a 99-percent accuracy.

The correct reading of resistance is noted at a distance 62 percent (or 0.62X) of the total distance from the electrode under test as shown by the dotted line on figure 20.b. This value is recorded and compared to the specification for the electrode subsystem under test.

NOTE 1 : The resistance of a large grounding subsystem may have an appreciable reactive component when the resistance is less than 0.5 ohms. Therefore, the measured value is an "impedance" and should be so considered, although the term commonly used is "resistance."

NOTE 2: See the appendix for reference to detailed procedures for the method described above.

5.21 Return loss measurements.

5.21.1 Scope. The method described below shall be used for making return loss measurements. It is applicable to units which require an impedance match to another element of a transmission subsystem.

5.21.2 Measuring equipment.

Directional bridge/directional coupler
Signal generator
Power meter
Reference impedance termination
Short circuit termination

5.21.3 Principles of measurement. A transmission line or interface equipment is normally terminated in its characteristic impedance. A mismatch in impedance gives rise to the reflection of a portion of the incident signal which can result in signal distortion or echo. Return loss is the ratio of the incident to reflected power at the measurement point and is expressed in dB.

Return loss measurements require a directional device to separate the incident and reflected signals. This separation can be accomplished using either a directional bridge or directional coupler. The degree to which the two signals are separated is termed directivity and it is the dominate error factor in measuring small reflected signals (high return loss). For example, to limit worst case measurement errors to less than one dB, the directivity of the bridge or coupler must be a minimum of 20 dB greater than the actual return loss of the unit under test (UUT). Reducing this difference to 10 dB can result in a worst case measurement error of about 3.5 dB.

5.21.4 Method. Figure 21 shows the general test arrangement. With the signal generator set to the specified frequency and level (relatively high to inhibit the impact of residual noise on test results), the reading of the power meter is recorded. The UUT is then replaced with a short circuit and the reading of the meter is recorded again. The difference between the two readings in dB indicates the return loss and this value is recorded and compared to the specification for the UUT. This method is repeated for other frequencies over the frequency range specified for the UUT.

NOTE 1: The following formulas can be used for conversion of terms fundamentally related to return loss measurements:

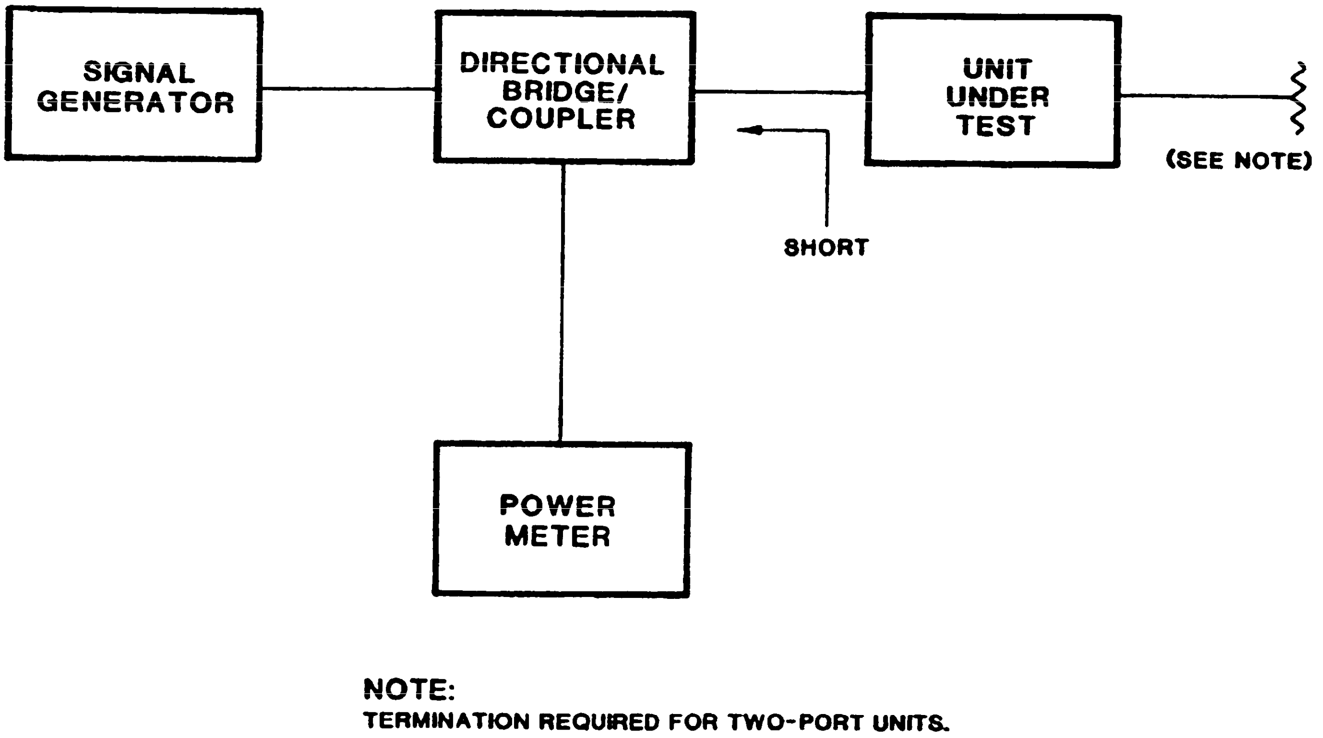


FIGURE 21. Return loss measurement setup.

$$VSWR = \frac{1 + |p|}{1 - |p|} = \frac{1 + 10^{-0.05RL}}{1 - 10^{-0.05RL}};$$

$$p = \frac{Z_1 - Z_0}{Z_1 + Z_0} \text{ or } \frac{Z_1}{Z_0} = \frac{1 + p}{1 - p};$$

$$|p| = \frac{VSWR - 1}{VSWR + 1} = 10^{-0.05RL};$$

and $RL = -20 \log |p|$.

Where p = complex voltage reflection coefficient = $|p|\angle\theta$;
$|p|$ = voltage reflection coefficient magnitude;
RL = return loss in dB;
Z_1 = input impedance of UUT = $R_1 + jX_1$;
and Z_0 = characteristic impedance of UUT = $R_0 + jX_0$.

NOTE 2: See the appendix for reference to detailed procedures, corresponding techniques, and measuring equipment specifications for the method described above.

5.22 Sidetone measurements.

5.22.1 Scope. The method described below shall be used to measure the transmission and reproduction of sounds through a local path from the transmitting transducer to the receiving transducer of the same telephone end instrument.

5.22.2 Measuring equipment.

Signal generator
Ac voltmeter
Artificial mouth
Artificial ear
Standard dc feed circuit with test loop

5.22.3 Principles of measurement. Sidetone is the acoustic output level of a telephone receiver, produced by an acoustic input to the transmitter of the same transmitter set, that may be varied in frequency or level. Speech sidetone serves to assure the speaker that the system is working, and also provides a means of adjusting voice level. A sidetone level of 0 to 6 dB below the normal receiving level is often satisfactory.

5.22.4 Method. The test method (and associated test equipment) conforming to IEEE Standard 269-1983 has been adopted for this standard and is summarized in the following paragraphs. This method of measuring sidetone employs a test fixture which includes an artificial mouth and an artificial ear located relative to each other as shown on figure 22, and the transmitter and receiver are mounted in the same handset.

Figure 22 shows the general test arrangement.

NOTE: The test loop used to connect the unit under test (UUT) to the termination should be variable and capable of representing the range of loop-impedance frequency characteristics that the telephone set is expected to encounter in use.

Following the calibration of the artificial mouth and the conditioning of the transmitter, the sound pressure level developed in the artificial ear is measured while driving the transmitter at the levels specified for the UUT. The measured value is recorded and compared to the specification for the UUT.

NOTE 1: See the appendix for reference to detailed procedures and measuring equipment specifications for this method.

NOTE 2: An alternative method based on the use of two handsets is provided in IEEE Standard 269-1983. Except for modifying the testing arrangement to accommodate two handsets, the procedures are the same as for the preferred method. See the referenced standard for details on this alternative method.

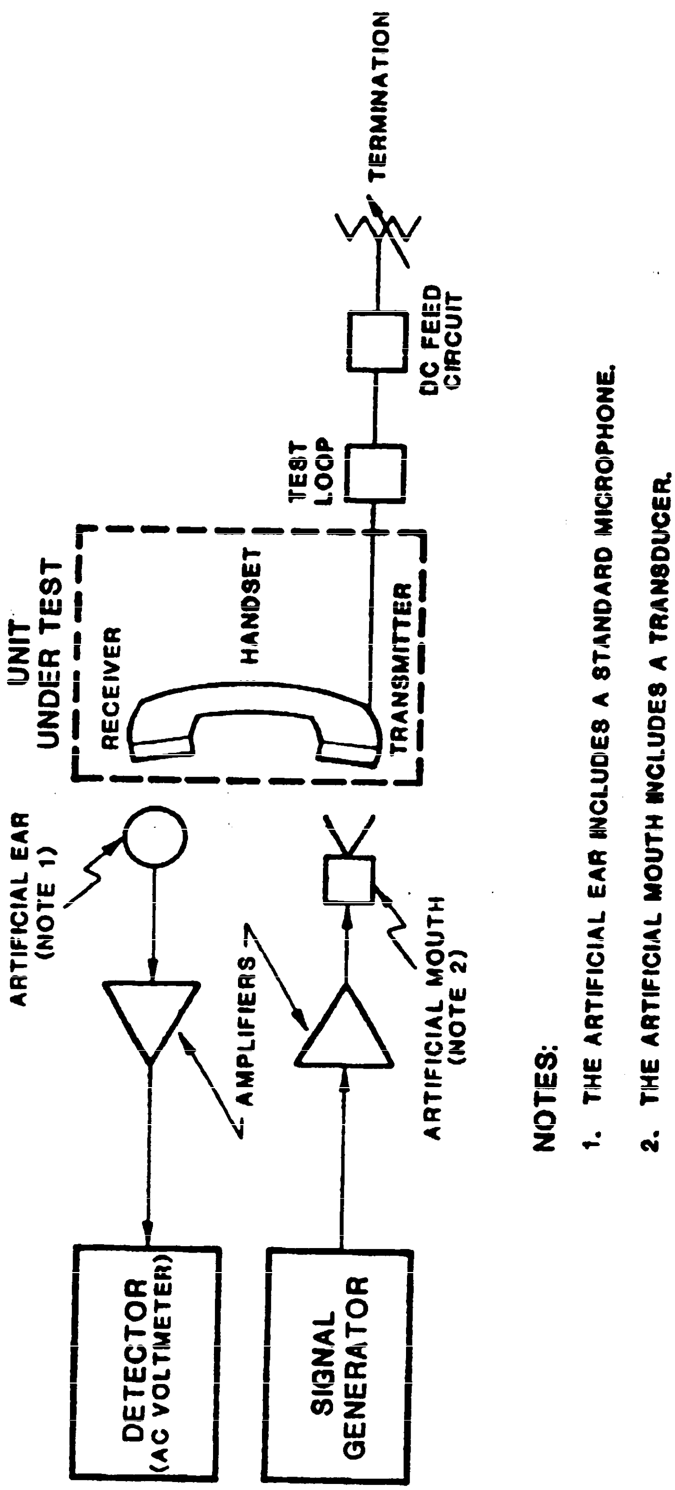


FIGURE 22. Sidetone measurement setup.

5.23 Speech volume measurements.

5.23.1 Scope. The method described below shall be used for measuring the absolute value of speech or music volume. Volume unit (vu) measurements are normally used in cases where a failure to maintain a constant average voice power can result in overmodulation or distortion.

5.23.2 Measuring equipment.

Vu meter

5.23.3 Principles of measurement. Vu meters calibrated in decibel volume units (for recording purposes) or percent modulation (for radio transmitting purposes) are usually kept on-line to measure volume levels of program or speech material being transmitted. The standard vu indicator includes a meter and associated attenuator and is calibrated to read 0 vu under the following conditions: connection is made across a 600-ohm circuit (voice pair) conducting one milliwatt of sine-wave power at any frequency between 35 Hz and 10,000 Hz. The meter frequency response or weighting is intended to approximate that of the human ear.

Given these characteristics, a constant-volume talker will produce a speech signal fluctuating in amplitude at a syllabic rate, but yielding a volume reading on a vu meter that is constant relative to time. Such control of volume is usually found only under specially controlled conditions.

5.23.4 Method. Figure 23 shows the general test arrangement. The talker reads test material (e.g., syllables, words, or sentences) over the unit under test (UUT) in conditions simulating normal use of the equipment. The talker should produce continuous speech including natural pauses such as interword and intersyllable gaps, but not long pauses typically associated with marshalling thoughts or waiting for a reply.

The talker's speech level is monitored on the vu meter over a ten-second interval and the maximum excursions of the instrument needle are noted. After the two or three highest excursions are excluded, the average of the peak deflections over the ten-second interval is estimated, recorded, and compared to the specification for the UUT.

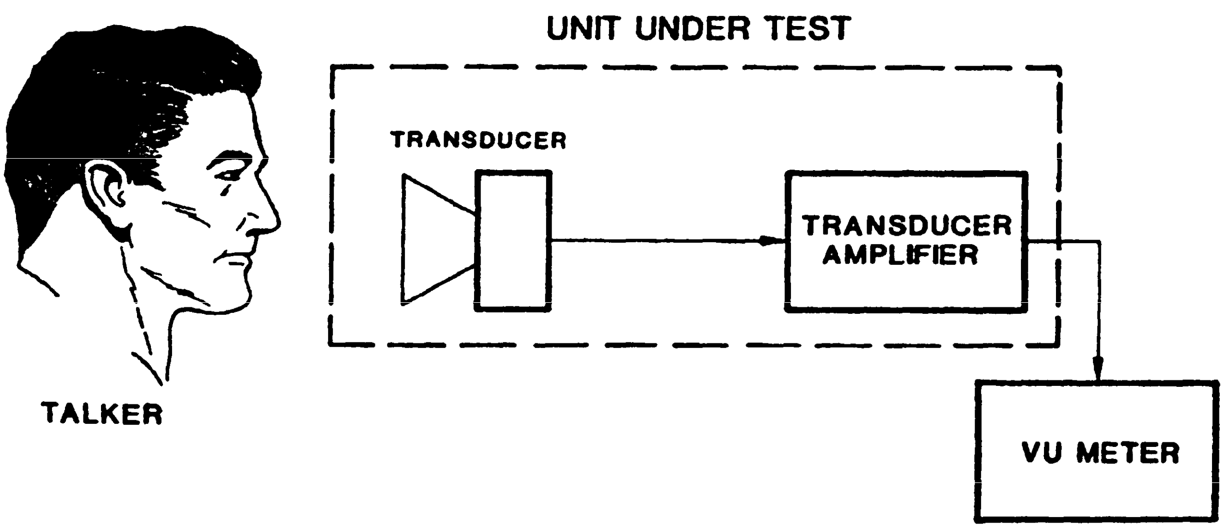


FIGURE 23. Speech volume measurement setup.

5.24 Telephone-set transmitting noise measurements.

5.24.1 Scope. The method described below shall be used to measure the random noise originating in or contributed by telephone sets in a communication system.

5.24.2 Measuring equipment.

Noise measuring set
Feeding bridge
Ammeter

5.24.3 Principles of measurement. The presence of noise (any undesired signal of uniform energy distribution) in a telephone set interferes with the intelligible transmission of voice or supervisory signaling over a communication channel. Measurement of the random noise contribution of a telephone set is fundamental to determining overall system communicability in the presence of noise.

5.24.4 Method. Figure 24 shows the general test arrangement. With the noise measuring set adjusted to the weighting network specified for the unit under test (UUT), the telephone handset is removed from the cradle and the microphone isolated from ambient noise and mechanical vibration. This isolation can be achieved by covering the transmitter with sound-absorbing material and placing the handset on a vibration-free surface. After the feeding bridge potentiometer is adjusted to supply maximum specified current to the UUT (as observed on the ammeter), the weighted noise level is recorded and compared to the specification for the UUT.

NOTE: See the appendix for reference to detailed procedures and corresponding measuring equipment specifications for the method described above.

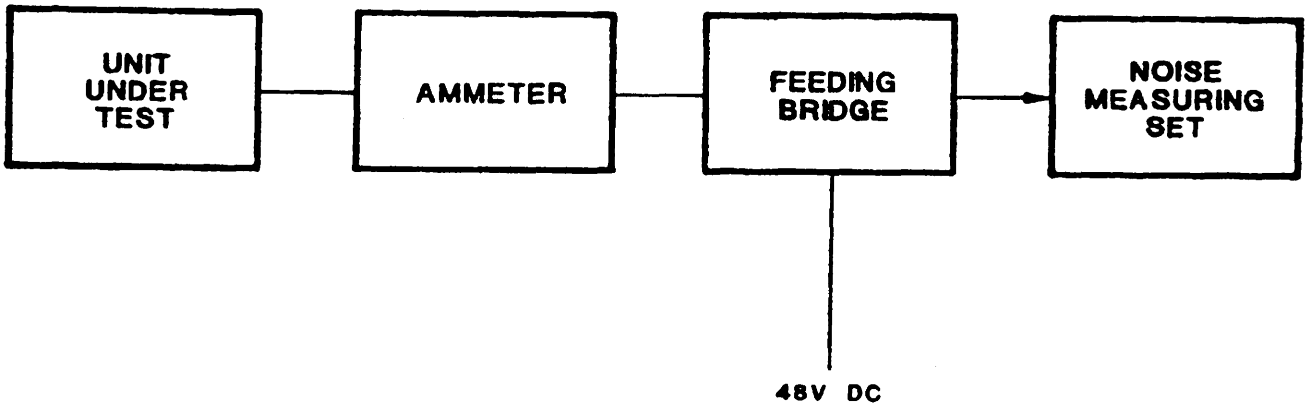


FIGURE 24. Telephone-set transmitting noise measurement setup.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. This standard specifies general measurement techniques for the performance evaluation of long-haul or tactical communications systems and subsystems. These methods are to be applied in the verification of corresponding electrical parameter requirements, given in the 188 series documents as minimum interoperability and performance characteristics.

6.2 Issue of DoDISS. When this standard is used in acquisition, the applicable issue of the DoDISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Subject term (key word) listing.

Bond resistance
Crosstalk
Digital errors
Digital jitter
Dropouts
Envelope delay distortion
Frequency
Frequency translation
Harmonic distortion
Impulse noise
Insertion loss vs frequency
Intermodulation distortion
Longitudinal balance
Net loss/gain variation
Noise figure
Noise and signal-to-noise ratio
Phase hits
Resistance to earth
Return loss
Sidetone
Speech volume
Telephone-set transmitting noise
Testing techniques
Transmission impairments

APPENDIX

REFERENCES SUPPORTING METHODS OF MEASUREMENT IN MIL-STD-188-190

10. SCOPE.

10.1 Purpose. This appendix provides reference information in support of the methods of measurement in MIL-STD-188-190.

10.2 Application. This appendix is for guidance only. It is intended to complement selected methods in this standard with recommended documents containing corresponding detailed measurement procedures and test equipment characteristics. The information contained in this appendix is not a mandatory part of this standard.

20. REFERENCED DOCUMENTS.

20.1 Government documents. The following documents form a part of this appendix to the extent specified:

MILITARY HANDBOOK	MIL-HDBK-419: Grounding, Bonding, and Shielding for Electronic Equipment and Facilities (Volumes 1 and 2)
DEFENSE COMMUNICATIONS AGENCY CIRCULARS (DCACs)	DCAC 310-70-1, DCS Technical Control: Supplement 1, Volume II, Procedures, Test Descriptions (March 1981)
	DCAC 310-70-57, DCS Quality Assurance Program: Supplement 1, Technical Evaluation, Line-of-Sight (LOS) and Tropospheric Scatter Links (April 1981); Supplement 6, Technical Evaluation, Satellite Communications Systems (October 1976)
AIR FORCE COMMUNICATIONS SERVICE PAMPHLET (AFCSP)	AFCSP 100-35, Communications-Electronics, Systems Approach to Wideband Communications (15 December 1978)

20.2 Non-Government publications. The following documents form a part of this appendix to the extent specified:

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE) STANDARDS	IEEE Std 81-1983, IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System

APPENDIX

IEEE Std 269-1983, IEEE Standard Method for Measuring Transmission Performance of Telephone Sets

IEEE Std 455-1985*, IEEE Standard Test Procedure for Measuring Longitudinal Balance of Telephone Equipment Operating in the Voice Band. *ANSI/IEEE 455-1985 (also approved by American National Standards Institute (ANSI))

IEEE Std 743-1984, IEEE Standard Methods and Equipment for Measuring the Transmission Characteristics of Analog Voice Frequency Circuits

30. DEFINITIONS. For purposes of this appendix, the definitions of FED-STD-1037 shall apply.

40. REFERENCES TO DETAILED PROCEDURES, TECHNIQUES, OR FUNCTIONAL REQUIREMENTS. The documents referenced in table I contain detailed procedures, techniques, or functional requirements for test equipment that correspond to methods of measurement in MIL-STD-188-190. The methods are identified by parameter descriptions in alphabetical order followed by the documents referenced and the paragraphs or pages that apply.

APPENDIX

TABLE I. Documents supporting MIL-STD-188-190 methods of measurement.

MIL-STD-188-190 method	Document/Reference
Bond resistance	MIL-HDBK-419, Vol. II, para. 2.2.2.3.1
Crosstalk	IEEE Std 743-1984, para. 4.6.4 to 4.6.4.2
Digital errors	DCAC 310-70-1, Suppl. 1, pages 19-1 to 19-12 AFCSP 100-35, para. 20-6
Dropouts	DCAC 310-70-1, Suppl. 1, pages 15-1 to 15-7 IEEE Std 743-1984, para. 4.4 to 4.4.2.7 and 4.4.6 to 4.4.6.3
Envelope delay distortion	DCAC 310-70-1, Suppl. 1, pages 3-1 to 3-37 DCAC 310-70-57, Suppl. 1, pages 14-1 to 15-8 AFCSP 100-35, para. 19-9 IEEE Std 743-1984, para. 4.3.3 to 4.3.3.3.4
Frequency	IEEE Std 743-1984, para. 4.6.6 to 4.6.6.6
Frequency translation	AFCSP 100-35, para. 19-10 DCAC 310-70-1, Suppl. 1, pages 5-1 to 5-8 DCAC 310-70-57, Suppl. 1, pages 17-1, 17-3, and 17-6 IEEE Std 743-1984, para. 4.6.6 to 4.6.6.6
Harmonic distortion	DCAC 310-70-1, Suppl. 1, pages 12-1 to 12-5 DCAC 310-70-57, Suppl. 1, pages 16-1 to 16-6 AFCSP 100-35, para. 19-12
Impulse noise	DCAC 310-70-1, Suppl. 1, pages 9-1 to 9-11 DCAC 310-70-57, Suppl. 1, pages 11-1 to 11-4 IEEE Std 743-1984, para. 4.4 to 4.4.3.10
Insertion loss vs frequency	DCAC 310-70-1, Suppl. 1, pages 2-1 to 2-14 DCAC 310-70-1, Suppl. 1, pages 12-1 to 13-5 IEEE Std 743-1984, para. 4.3.1 to 4.3.1.5.9
Intermodulation distortion	DCAC 310-70-1, Suppl. 1, pages 14-1 to 14-10 IEEE Std 743-1984, para. 4.6.3 to 4.6.3.2.13
Longitudinal balance	ANSI/IEEE Std 455-1985 (all) IEEE Std 743-1984, para. 5.6.3

APPENDIX

TABLE I. Documents supporting MIL-STD-188-190 methods of measurement--Continued.

MIL-STD-188-190 method	Document/Reference
Net loss/gain variation	DCAC 310-70-1, Suppl. 1, pages 4-1 to 4-10
Noise figure	DCAC 310-70-57, Suppl. 1, pages 19-1, 19-2, and 19-4
Noise and SNR	DCAC 310-70-1, Suppl. 1, pages 7-1 to 7-15 DCAC 310-70-57, Suppl. 1, pages 10-1 to 10-5 AFCSP 100-35, para. 18-3 IEEE Std 743-1984, para. 4.3.2 to 4.3.2.13.3
Phase hits	DCAC 310-70-1, Suppl. 1, pages 15-1 to 15-7 DCAC 310-70-57, Suppl. 1, pages 18-1 to 18-4 IEEE Std 743-1984, para. 4.4 to 4.4.2.7 and 4.4.4 to 4.4.4.8
Phase jitter	DCAC 310-70-1, Suppl. 1, pages 13-1 to 13-4, 13-8, and 13-10 DCAC 310-70-57, Suppl. 1, pages 18-1 to 18-4 IEEE Std 743-1984, para. 4.5 to 4.5.1.14
Resistance to earth	MIL-HDBK-419, Vol. 1, para. 2.7 to 2.7.2.3 DCAC 310-70-57, Suppl. 1, pages 46-1 to 46-5 IEEE Std 81-1983, para. 8.2.1.5, 8.2.1.6, 8.4, and appendix C
Return loss	IEEE Std 743-1984, para. 4.6.1 to 4.6.1.3.2
Sidetone	IEEE Std 269-1983, para. 6.4 to 6.4.2.1
Telephone-set transmitting noise	IEEE Std 269-1983, para. 6.2.4

CONCLUDING MATERIAL

Custodians:
Army--SC
Navy--EC
Air Force--90

Review activities:
Army--CR
Navy--MC, SH
Air Force--01, 02, 17, 21
Defense Communications Agency--DC
Defense Electronics Supply Center--ES
National Security Agency--NS
Joint Tactical C3 Agency--JT

Preparing activity:
Army--SC

(Project TCTS-1900)

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given.
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I RECOMMEND A CHANGE:

1. DOCUMENT NUMBER: MIL-STD-188-190
2. DOCUMENT DATE *(YYMMDD)*: 90/01/31

3. DOCUMENT TITLE: METHODS FOR COMMUNICATIONS SYSTEMS MEASUREMENTS

4. NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible. Attach extra sheets as needed.)*

5. REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*

b. ORGANIZATION

c. ADDRESS *(Include Zip Code)*

d. TELEPHONE *(Include Area Code)*
(1) Commercial
(2) AUTOVON *(If applicable)*

7. DATE SUBMITTED *(YYMMDD)*

8. PREPARING ACTIVITY

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Commander, U.S. Army Information Systems Engineering Command

b. TELEPHONE *(Include Area Code)*
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(2) AUTOVON: 879-7800

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