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Measurement of Electromagnetic Interference Characteristics of Equipment Intended to Operate in Severe Electromagnetic Environments

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**Measurement of Electromagnetic
Interference Characteristics of
Equipment Intended to Operate in
Severe Electromagnetic Environments**

EIA/IS-648

MAY 1996

**ELECTRONIC INDUSTRIES ASSOCIATION
ENGINEERING DEPARTMENT**



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(From Project Number 3462, formulated under the cognizance of the G-46 Electromagnetic Compatibility Committee.)

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FOREWORD

1. This standard contains the general test methods necessary to demonstrate compliance of subsystems and equipment to the requirements of EIA/IS-647.
2. The annex contains the rationale and background for each paragraph.
3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Electronic Industries Association, 2500 Wilson Boulevard, Arlington, VA 22201-3834

1. SCOPE

1.1 Purpose

This standard establishes general techniques for use in the measurement and determination of the electromagnetic emission and susceptibility characteristics of electronic, electrical, and electromechanical equipment and subsystems.

1.2 Application

The testing techniques of this standard are used to obtain data for determination of compliance with the specified EIA/IS-647 requirements. The test methods contained in this document shall be adapted by the testing activity for each application. The adapted test methods should be documented in the Electromagnetic Interference Test Procedures (EMITP) Application Guide recommended by EIA/IS-647.

1.3 Emission and susceptibility designations

The test methods contained in this standard are designated in accordance with an alpha-numeric coding system. Each method is identified by a two letter combination followed by a three digit number. The number is for reference purposes only. The meaning of the individual letters are as follows:

C = Conducted

R = Radiated

E = Emissions

S = Susceptibility

- a. Conducted emissions tests are designated by "CE---."
- b. Radiated emissions tests are designated by "RE---."
- c. Conducted susceptibility tests are designated by "CS---."
- d. Radiated susceptibility test are designated by "RS---."
- e. "---" = numerical order of test from 101 to 199.

2. APPLICABLE DOCUMENTS

2.1 Electronic Industries Association documents

The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation.

STANDARD

EIA/IS-647	Requirements for the Control of Electromagnetic Interference Emissions and Susceptibility Characteristics of Equipment Intended to Operate in Severe Electromagnetic Environments
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(Application for copies should be addressed to the Electronic Industries Association, 2500 Wilson Boulevard, Arlington, VA 22201-3834, Phone: 703/907-7500, Fax: 703/907-7501)

2.2 Non-Electronic Industries Association publications

The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents are those cited in the solicitation.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/IEEE 268	Metric Practice
ANSI C63.2	Standard for Instrumentation-Electromagnetic Noise and Field Strength, 10 kHz to 40 GHz - Specifications
ANSI C63.4	Standard for Electromagnetic Compatibility - Radio-Noise Emissions from Low Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz - Methods of Measurement
ANSI C63.14	Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD)
ANSI C95.1	Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields (300 kHz - 100 GHz)
ANSI/NCSL Z540-1	General Requirements for Calibration Laboratories and Measuring and Test Equipment
ISO 10012-1	Quality Assurance Requirements for Measuring Equipment

(DoD activities may obtain copies from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia PA 19111-5094. Other Government agencies and the private sector may address application for copies to the American National Standards Institute, 11 West 42nd Street, New York, New York 10036 [Telephone: 212-642-4900 or FAX: 212-398-0023]; or the Institute of Electrical and Electronics Engineers, Incorporated (IEEE) Service Center, 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331 [Telephone: 1-800-701-4333 or FAX: 908-981-9667].)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

ARP 958	Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods
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(Application for copies should be addressed to the Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096 [Telephone: 412-776-4841 or FAX: 412-776-5760].)



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AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380 Standard for Metric Practice. (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187 [Telephone: 215-299-5585 or FAX: 215-977-9679].)

2.3 Order of precedence

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

3. DEFINITIONS

3.1 General

The terms used in this standard are defined in ANSI C63.14. In addition, the following definitions are applicable for the purpose of this standard.

3.2 Acronyms used in this standard

- | | |
|----------|--|
| a. BIT | Built-in Test |
| b. EMI | Electromagnetic Interference |
| c. EMITP | Electromagnetic Interference Test Procedures |
| d. EMITR | Electromagnetic Interference Test Report |
| e. ERP | Effective Radiated Power |
| f. EUT | Equipment Under Test |
| g. LISN | Line Impedance Stabilization Network |
| h. RF | Radio Frequency |
| i. RMS | Root Mean Square |
| j. TEM | Transverse Electromagnetic |
| k. TPD | Terminal Protection Device |

3.3 Metric units

Metric units are a system of basic measures which are defined by the International System of Units based on "Le System International d'Unites (SI)", of the International Bureau of Weights and Measures. These units are described in ASTM E 380 and ANSI/IEEE 268.

3.4 Test setup boundary

The test setup boundary includes all enclosures of the Equipment Under Test (EUT) and the 2 meters of exposed interconnecting leads (except for leads which are shorter in the actual installation) and power leads required by the general section of this standard.

4. REQUIREMENTS

4.1 General

General requirements related to test methods, test facilities, and equipment are as stated below. Any approved exceptions or deviations from these general test requirements shall be documented in the EMITP of EIA/IS-647.

4.1.1 Measurement tolerances

Unless otherwise stated for a particular measurement, the tolerance shall be as follows:

- a. Distance: $\pm 5\%$
- b. Frequency: $\pm 2\%$
- c. Amplitude, measurement receiver: ± 2 dB
- d. Amplitude, measurement system (includes measurement receivers, transducers, cables, and so forth): ± 3 dB
- e. Time (waveforms): $\pm 5\%$

4.2 Shielded enclosures

To prevent interaction between the EUT and the outside environment, shielded enclosures will usually be required for testing. These enclosures prevent external environment signals from contaminating emission measurements and susceptibility test signals from interfering with electrical and electronic items in the vicinity of the test facility. Shielded enclosures must have adequate attenuation such that the ambient requirements of paragraph 4.4 are satisfied. The enclosures must be sufficiently large such that the EUT arrangement requirements of paragraph 4.8 and antenna positioning requirements described in the individual test methods are satisfied.

4.2.1 Radio Frequency (RF) absorber material

RF absorber material (carbon impregnated foam pyramids, ferrite tiles, and so forth) shall be used when performing electric field radiated emissions or radiated susceptibility testing inside a shielded enclosure to reduce reflections of electromagnetic energy and to improve accuracy and repeatability. The RF absorber shall be placed above, behind, and on both sides of the EUT, and behind the radiating or receiving antenna as shown in Figure 1. Minimum performance of the material shall be as specified in Table 1. The manufacturer's certification of their RF absorber material (basic material only, not installed) is acceptable.

Table 1. Absorption at normal incidence

Frequency	Minimum absorption
80 MHz - 250 MHz	6 dB
above 250 MHz	10 dB

4.3 Other test sites

If other test sites are used, the ambient requirements of paragraph 4.4 shall be met.

4.4 Ambient electromagnetic level

During testing, the ambient electromagnetic level measured with the EUT de-energized and all auxiliary equipment turned on shall be at least 6 dB below the allowable specified limits when the tests are performed in a shielded enclosure. Ambient conducted levels on power leads shall be measured with the leads disconnected from the EUT and connected to a resistive load which draws the same rated current as the EUT. When tests are performed in a shielded enclosure and the EUT is in compliance with EIA/IS-647 limits, the ambient profile need not be recorded in the Electromagnetic Interference Test Report (EMITR). When measurements are made outside a shielded enclosure, the tests shall be performed during times and conditions when the ambient is at its lowest level. The ambient shall be recorded in the EMITR required by EIA/IS-647 and shall not compromise the test results.

4.5 Ground plane

The EUT shall be installed on a ground plane that simulates the actual installation. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified below, ground planes shall be 2.25 square meters or larger in area with the smaller side no less than 76 centimeters. When a ground plane is not present in the EUT installation, the EUT shall be placed on a non-conductive surface.

4.5.1 Metallic ground plane

When the EUT is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 milliohms per square. The DC resistance between metallic ground planes and the shielded enclosure shall be 2.5 milliohms or less. The metallic ground planes shown in Figures 2 through 5 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 meter. The metallic bond straps shall be solid and maintain a five-to-one ratio or less in length to width. Metallic ground planes used outside a shielded enclosure shall be at least 2 meters by 2 meters and extend at least 0.5 meter beyond the test setup boundary.

4.5.2 Composite ground plane

When the EUT is installed on a conductive composite ground plane, the surface resistivity of the typical installation shall be used. Composite ground planes shall be electrically bonded to the enclosure with means suitable to the material.

4.6 Power source impedance

The impedance of power sources providing input power to the EUT shall be controlled by Line Impedance Stabilization Networks (LISNs) for all measurement procedures of this document unless otherwise stated in a particular test method. The LISNs shall be located at the power source end of the exposed length of power leads specified in paragraph 4.8.5.2. The LISN circuit shall be in accordance with the schematic shown in Figure 6. The LISN impedance characteristics shall be in accordance with Figure 7. The LISN impedance shall be measured at least annually under the following conditions:

- a. The impedance shall be measured between the power output lead on the load side of the LISN and the metal enclosure of the LISN.
- b. The signal output port of the LISN shall be terminated in fifty ohms.
- c. The power input terminal on the power source side of the LISN shall not be terminated.

The impedance measurement results shall be provided in the EMITR required by EIA/IS-647.

4.7 General test precautions

4.7.1 Accessory equipment

Accessory equipment used in conjunction with measurement receivers shall not degrade measurement integrity.

4.7.2 Excess personnel and equipment

The test area shall be kept free of unnecessary personnel, equipment, cable racks, and desks. Only the equipment essential to the test being performed shall be in the test area or enclosure. Only personnel actively involved in the test shall be permitted in the enclosure.

4.7.3 Overload precautions

Measurement receivers and transducers are subject to overload, especially receivers without preselectors and active transducers. Periodic checks shall be performed to assure that an overload condition does not exist. Instrumentation changes shall be implemented to correct any overload condition.

4.7.4 RF hazards

Some tests in this standard will result in electromagnetic fields which are potentially dangerous to personnel. The permissible exposure levels in ANSI C95.1 shall not be exceeded in areas where personnel are present. Safety procedures and devices shall be used to prevent accidental exposure of personnel to RF hazards.

4.7.5 Shock hazard

Some of the tests require potentially hazardous voltages to be present. Extreme caution must be taken by all personnel to assure that all safety precautions are observed.

4.7.6 Federal Communications Commission (FCC) restrictions

Some of the tests require high level signals to be generated that could interfere with normal FCC approved frequency assignments. All such testing should be conducted in a shielded enclosure. Some open site testing may be feasible if prior FCC coordination is obtained.

4.8 EUT test configurations

The EUT shall be configured as shown in the general test setups of Figures 1 through 5 as applicable. These setups shall be maintained during all testing unless other direction is given for a particular test method.

4.8.1 Bonding of EUT

Only the provisions included in the design of the EUT shall be used to bond units such as equipment case and mounting bases together, or to the ground plane. When bonding straps are required to complete the test setup, they shall be identical to those specified in the installation drawings.

4.8.2 Shock and vibration isolators

EUTs shall be secured to mounting bases having shock or vibration isolators if such mounting bases are used in the installation. The bonding straps furnished with the mounting base shall be connected to the ground plane. When mounting bases do not have bonding straps, bonding straps shall not be used in the test setup.

4.8.3 Wire grounds

When external terminals, connector pins, or equipment grounding conductors in power cables are available for ground connections and are used in the actual installation, they shall be connected to the ground plane after a 2 meter exposed length (see 4.8.5). Shorter lengths shall be used if they are specified in the installation instructions.

4.8.4 Orientation of EUTs

EUTs shall be oriented such that surfaces which produce maximum radiated emissions and respond most readily to radiated signals face the measurement antennas. Bench mounted EUTs shall be located 10 ± 2 centimeters from the front edge of the ground plane subject to allowances for providing adequate room for cable arrangement as specified below.

4.8.5 Construction and arrangement of EUT cables

Electrical cable assemblies shall simulate actual installation and usage. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used only if they have been specified in installation drawings. Cables shall be checked against installation requirements to verify proper construction techniques such as use of twisted pairs, shielding, and shield terminations. Details on the cable construction used for testing shall be included in the EMITP.

4.8.5.1 Interconnecting leads and cables

Individual leads shall be grouped into cables in the same manner as in the actual installation. Total interconnecting cable lengths in the setup shall be the same as in the actual platform installation. If a cable is longer than 10 meters, at least 10 meters shall be included. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified below. At least 2 meters (except for cables which are shorter in the actual installation) of each interconnecting cable shall be run parallel to the front boundary of the setup. Remaining cable lengths shall be routed to the back of the setup and shall be placed in a zigzagged arrangement. When the setup includes more than one cable, individual cables shall be separated by 2 centimeters measured from their outer circumference. For bench top setups using ground planes, the cable closest to the front boundary shall be placed 10 centimeters from the front edge of the ground plane. All cables shall be supported 5 centimeters above the ground plane.

4.8.5.2 Input power leads

Two meters of input power leads (including returns) shall be routed parallel to the front edge of the setup in the same manner as the interconnecting leads. The power leads shall be connected to the LISNs (see 4.6). Power leads that are part of an interconnecting cable shall be separated out at the EUT connector and routed to the LISNs. After the 2 meter exposed length, the power leads shall be terminated at the LISNs in as short a distance as

possible. The total length of power lead from the EUT electrical connector to the LISNs shall not exceed 2.5 meters. All power leads shall be supported 5 centimeters above the ground plane. If the power leads are twisted in the actual installation, they shall be twisted up to the LISNs.

4.8.6 Electrical and mechanical interfaces

All electrical input and output interfaces shall be terminated with either the actual equipment from the platform installation or loads which simulate the electrical properties (impedance, grounding, balance, and so forth) present in the actual installation. Signal inputs shall be applied to all applicable electrical interfaces to exercise EUT circuitry. EUTs with mechanical outputs shall be suitably loaded. When variable electrical or mechanical loading is present in the actual installation, testing shall be performed under expected worst case conditions. When active electrical loading (such as a test set) is used, precautions shall be taken to insure the active load meets the ambient requirements of paragraph 4.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the EUT shall be terminated with shielded, matched loads.

4.9 Operation of EUT

During emission measurements, the EUT shall be placed in an operating mode which produces maximum emissions. During susceptibility testing, the EUT shall be placed in its most susceptible operating mode. For EUTs with several available modes (including software controlled operational modes), a sufficient number of modes shall be tested for emissions and susceptibility such that all circuitry is evaluated.

4.9.1 Operating frequencies for tunable RF equipment

Measurements shall be performed with the EUT tuned to not less than three frequencies within each tuning band, tuning unit, or range of fixed channels, consisting of one mid-band frequency and a frequency within ± 5 percent from each end of each band or range of channels.

4.9.2 Operating frequencies for spread spectrum equipment

Operating frequency requirements for two major types of spread spectrum equipment shall be as follows:

- a. Frequency hopping. Measurements shall be performed with the EUT utilizing a hop set which contains 30% of the total possible frequencies. The hop set shall be divided equally into three segments at the low, mid, and high end of the EUT's operational frequency range.
- b. Direct sequence. Measurements shall be performed with the EUT processing data at the highest possible data transfer rate.

4.9.3 Susceptibility monitoring

The EUT shall be monitored during susceptibility testing for indications of degradation or malfunction. This monitoring is normally accomplished through the use of built-in-test (BIT), visual displays, aural outputs, and other measurements of signal outputs and interfaces. Monitoring of EUT performance through installation of special circuitry in the EUT is permissible; however, these modifications shall not influence test results.

4.10 Use of measurement equipment

Measurement equipment shall be as specified in the individual test methods of this standard. Any frequency selective measurement receiver may be used for performing the testing described in this standard provided that the receiver characteristics (that is, sensitivity, selection of bandwidths, detector functions, dynamic range, and frequency of operation) meet the constraints specified in this standard and are sufficient to demonstrate compliance with the applicable limits of EIA/IS-647. Typical instrumentation characteristics may be found in ANSI C63.2.

4.10.1 Detector

A peak detector shall be used for all frequency domain emission and susceptibility measurements. This device detects the peak value of the modulation envelope in the receiver bandpass. Measurement receivers are calibrated in terms of an equivalent Root Mean Square (RMS) value of a sine wave that produces the same peak value. When other measurement devices such as oscilloscopes, non-selective voltmeters, or broadband field strength sensors are used for susceptibility testing, correction factors shall be applied for test signals to adjust the reading to equivalent RMS values under the peak of the modulation envelope.

4.10.2 Computer-controlled receivers

A description of the operations being directed by software for computer-controlled receivers shall be included in the EMITP described in EIA/IS-647. Verification techniques used to demonstrate proper performance of the software shall also be included.

4.10.3 Emission testing

4.10.3.1 Bandwidths

The measurement receiver bandwidths listed in Table 2 shall be used for emission testing. These bandwidths are specified at the 6 dB down points for the overall selectivity curve of the receivers. Video filtering shall not be used to bandwidth limit the receiver response. If a controlled video bandwidth is available on the measurement receiver, it shall be set to its greatest value. Larger bandwidths may be used; however, they may result in higher measured emission levels. NO BANDWIDTH CORRECTION FACTORS SHALL BE APPLIED TO TEST DATA DUE TO THE USE OF LARGER BANDWIDTHS.

Table 2. Bandwidth and measurement time

Frequency Range	6 dB Bandwidth	Dwell Time	Minimum Measurement Time Analog Measurement Receiver
30 Hz - 1 kHz	10 Hz	0.15 sec	0.015 sec/Hz
1 kHz - 10 kHz	100 Hz	0.015 sec	0.15 sec/kHz
10 kHz - 250 kHz	1 kHz	0.015 sec	0.015 sec/kHz
250 kHz - 30 MHz	10 kHz	0.015 sec	1.5 sec/MHz
30 MHz - 1 GHz	100 kHz	0.015 sec	0.15 sec/MHz
Above 1 GHz	1 MHz	0.015 sec	15 sec/GHz

4.10.3.2 Emission identification

All emissions regardless of characteristics shall be measured with the measurement receiver bandwidths specified in Table 2 and compared against the limits in EIA/IS-647. Identification of emissions with regard to narrowband or broadband categorization is not applicable.

4.10.3.3 Frequency scanning

For emission measurements, the entire frequency range for each applicable test shall be scanned. Minimum measurement time for analog measurement receivers during emission testing shall be as specified in Table 2. Synthesized measurement receivers shall step in one-half bandwidth increments or less, and the measurement dwell time shall be as specified in Table 2.

4.10.3.4 Emission data presentation

Amplitude versus frequency profiles of emission data shall be automatically and continuously plotted. The applicable limit shall be displayed on the plot. Manually gathered data is not acceptable except for plot verification. The plotted data for emissions measurements shall provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and minimum amplitude resolution of 1 dB. The above resolution requirements shall be maintained in the reported results of the EMITR.

4.10.4 Susceptibility testing

4.10.4.1 Frequency scanning

For susceptibility measurements, the entire frequency range for each applicable test shall be scanned. For swept frequency susceptibility testing, frequency scan rates and frequency step sizes of signal sources shall not exceed the values listed in Table 3. The rates and step sizes are specified in terms of a multiplier of the tuned frequency (f_0) of the signal source. Analog scans refer to signal sources which are continuously tuned. Stepped scans refer to signal sources which are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for a minimum of 1 second. Scan rates and step sizes shall be decreased when necessary to permit observation of a response.

Table 3. Susceptibility scanning

Frequency Range	Analog Scans Maximum Scan Rates	Stepped Scans Maximum Step Size
30 Hz - 1 MHz	0.02 f_0 /sec	0.01 f_0
1 MHz - 30 MHz	0.01 f_0 /sec	0.005 f_0
30 MHz - 1 GHz	0.005 f_0 /sec	0.0025 f_0
1 GHz - 8 GHz	0.002 f_0 /sec	0.001 f_0
8 GHz - 40 GHz	0.001 f_0 /sec	0.0005 f_0

4.10.4.2 Modulation of susceptibility signals

Susceptibility test signals above 10 kHz shall be pulse modulated at a 1 kHz rate with a 50% duty cycle unless otherwise specified in an individual test method of this standard.

4.10.4.3 Thresholds of susceptibility

When susceptibility indications are noted in EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Thresholds of susceptibility shall be determined as follows:

- a. When a susceptibility condition is detected, reduce the interference signal until the EUT recovers.
- b. Reduce the interference signal by an additional 6 dB.
- c. Gradually increase the interference signal until the susceptibility condition reoccurs. The resulting level is the threshold of susceptibility.
- d. Record this level, frequency range of occurrence, frequency and level of greatest susceptibility, and other test parameters, as applicable.

4.11 Calibration of measuring equipment and antennas

Test equipment and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ANSI/NCSL Z540-1: "General Requirements for Calibration Laboratories and Measuring and Test Equipment", ISO 10012-1: "Quality Assurance Requirements for Measuring Equipment", or under an approved calibration program traceable to the NIST. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every 2 years unless otherwise specified by the procuring activity, or when damage is apparent. Antenna factors and current probe transfer impedance shall be determined on an individual basis for each device.

4.11.1 Measurement system test

At the start of each emission test, the complete test system (including measurement receivers, cables, attenuators, couplers, and so forth) shall be verified by injecting a known signal, as stated in the individual test method, while monitoring system output for the proper indication.

4.12 Antenna factors

Factors for electric field test antennas shall be determined in accordance with SAE ARP-958: "Electromagnetic Interference Measurement Antennas; Standard Calibration Requirements and Methods".

5. MEASUREMENT PROCEDURES

This section contains the measurement procedures to be used in determining compliance with the emission and susceptibility requirements of EIA/IS-647. The test procedures are applicable for the entire specified frequency range; however, certain equipment or classes of equipment may not require testing throughout the complete measurement frequency range. These modifications are specified in EIA/IS-647. Table 4 is an index of measurement procedures by method number and title.

Table 4. Index of measurement procedures

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS109	Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 400 MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

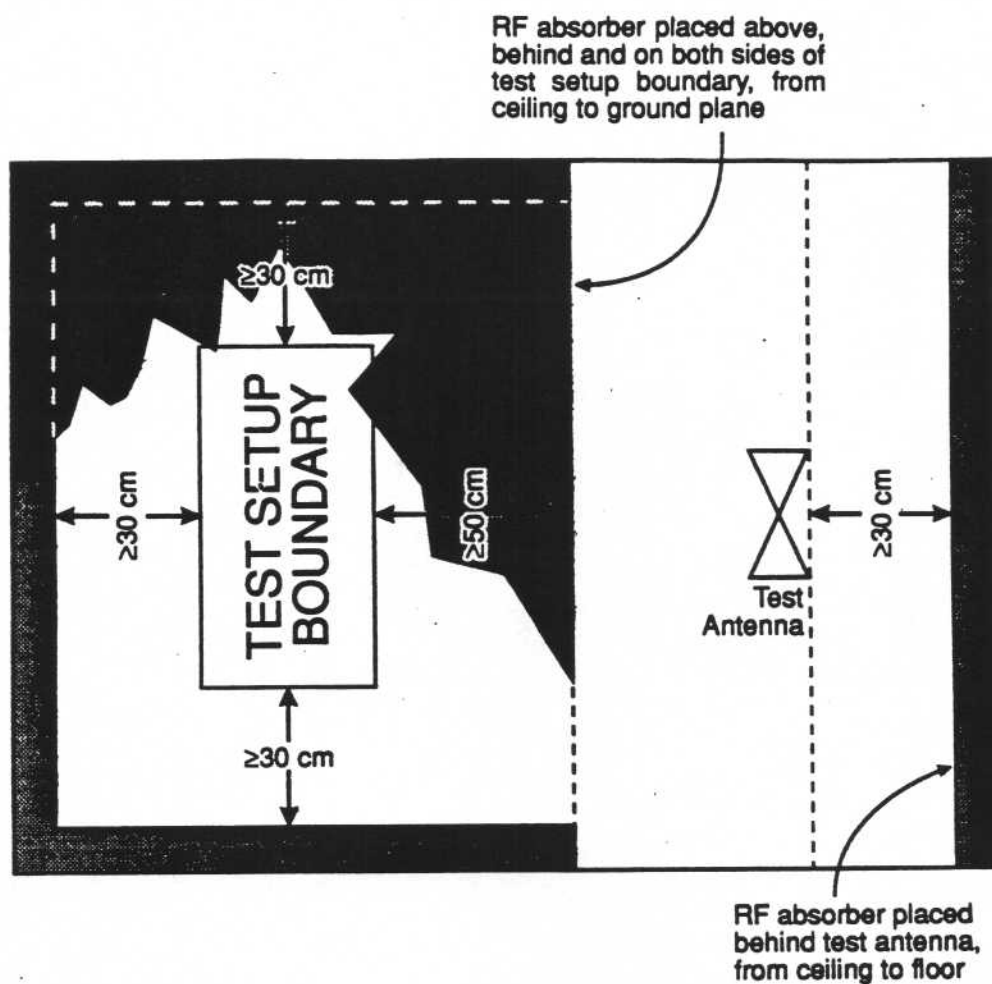


Figure 1. RF absorber loading diagram

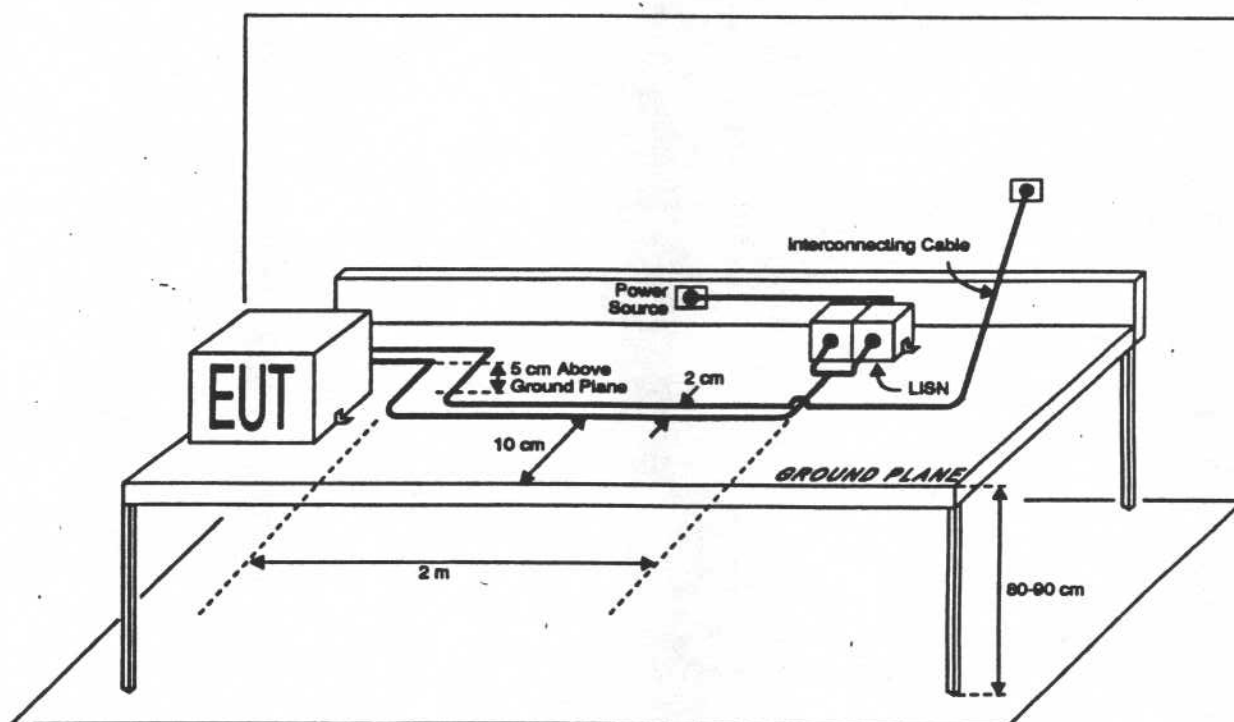


Figure 2. General test setup

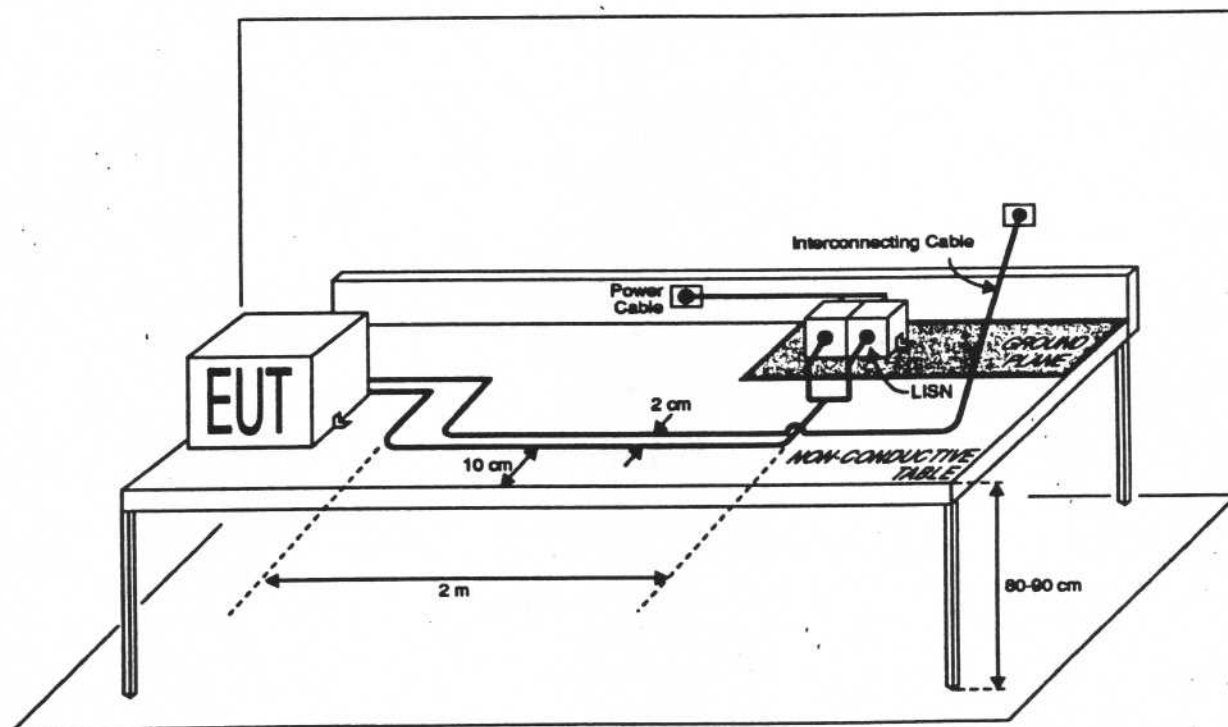


Figure 3. Test setup for non-conductive surface mounted EUT

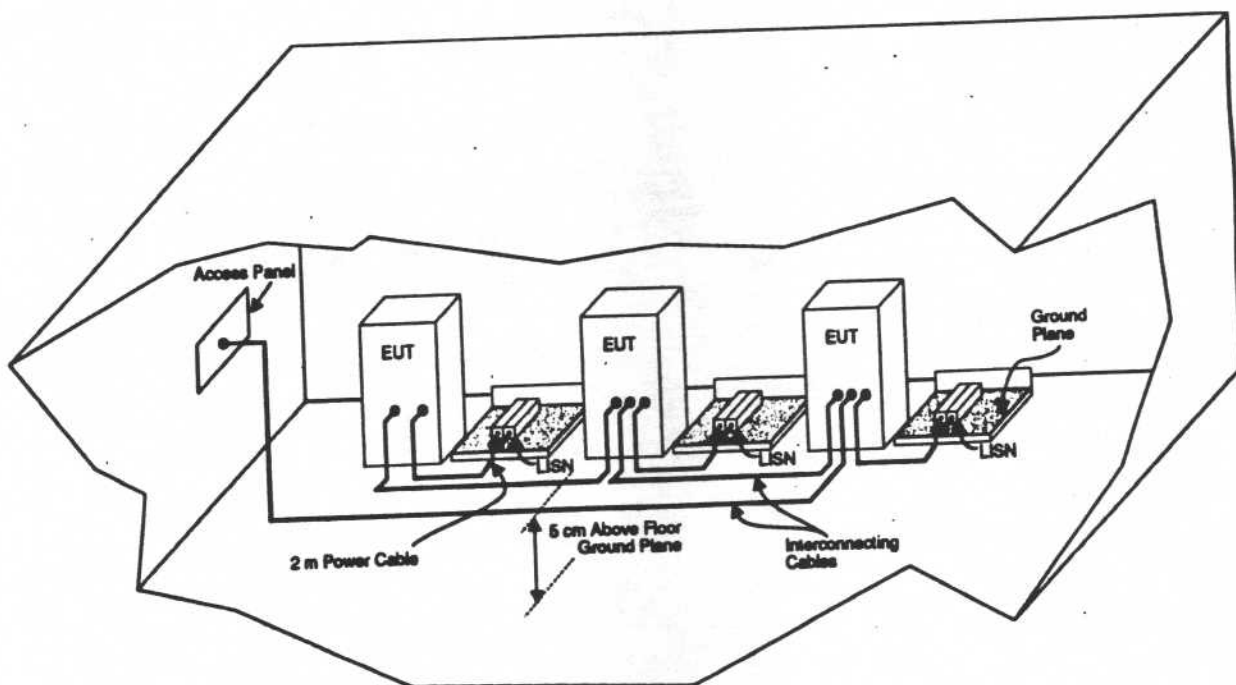


Figure 4. Test setup for free standing EUT, multiple EUT, shielded enclosure

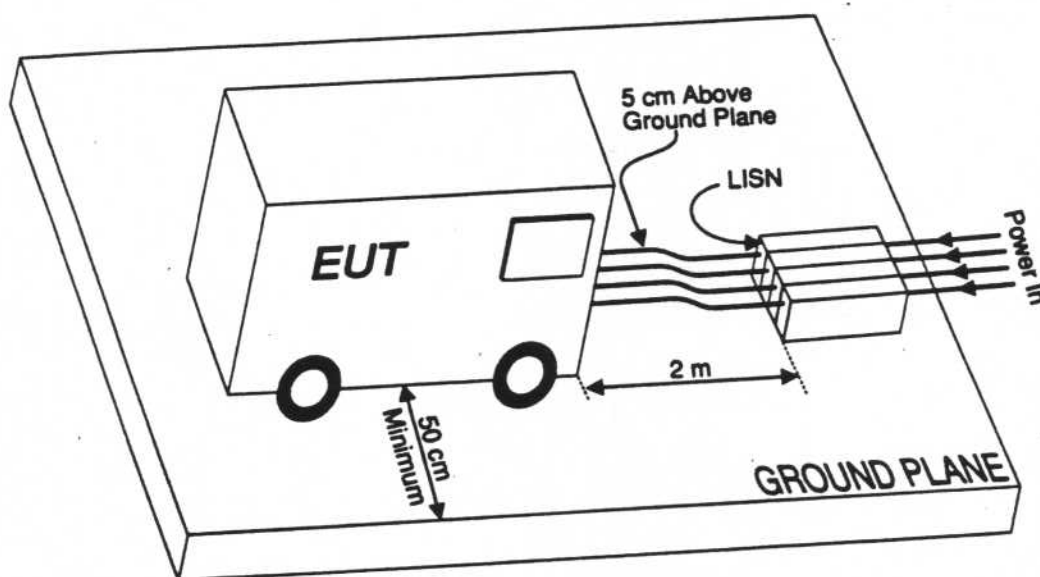


Figure 5. Test setup for free standing EUT

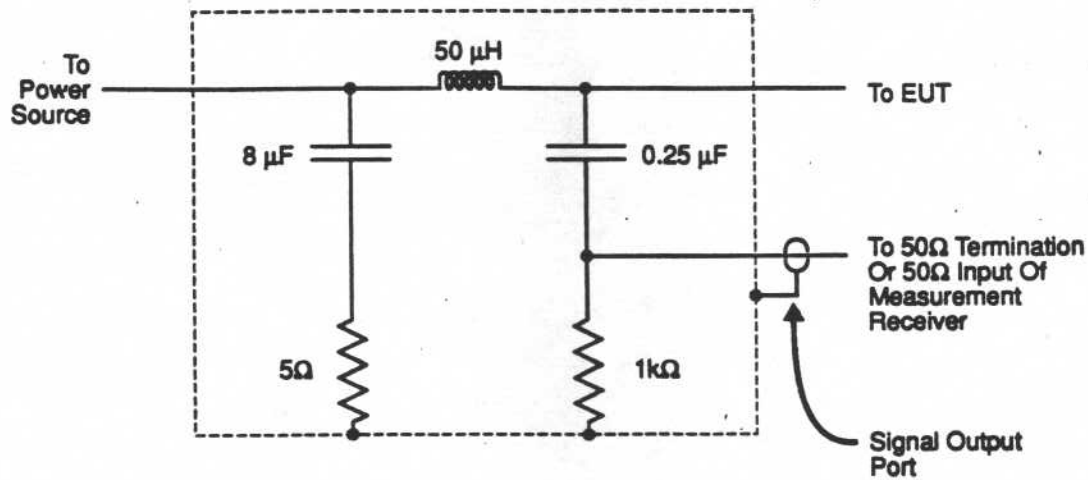


Figure 6. LISN schematic

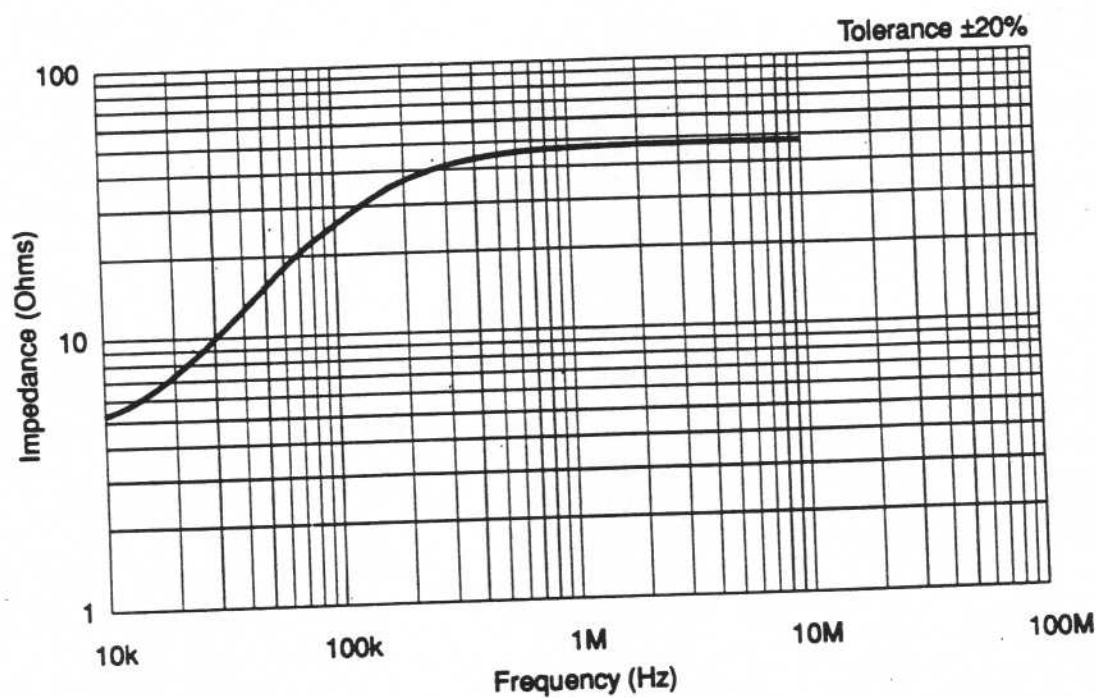


Figure 7. LISN impedance

5.1 METHOD CE101 - CONDUCTED EMISSIONS, POWER LEADS, 30 Hz TO 10 kHz

5.1.1 Purpose

This test method is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

5.1.2 Test Equipment

The test equipment shall be as follows:

- a. Measurement receivers
- b. Current probes
- c. Signal generator
- d. Data recording device
- e. Oscilloscope
- f. Resistor (R)
- g. LISNs

5.1.3 Test Setup

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard. The LISN may be removed or replaced with an alternative stabilization device when approved by the procuring activity.
- b. Calibration. Configure the test setup for the measurement system check as shown in Figure 8.
- c. EUT testing.
 - (1) Configure the test setup for compliance testing of the EUT as shown in Figure 9.
 - (2) Position the current probe 5 cm from the LISN.

5.1.4 Test Procedures

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration. Evaluate the overall measurement system from the current probe to the data output device.
 - (1) Apply a calibrated signal level, which is 6 dB below the EIA/IS-647 limit at 1 kHz, 3 kHz, and 10 kHz, to the current probe.
 - (2) Verify the current level, using the oscilloscope and load resistor; also, verify that the current waveform is sinusoidal.
 - (3) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the data recording device indicates a level within ± 3 dB of the injected level.
 - (4) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.
- c. EUT testing. Determine the conducted emissions from the EUT input power leads, including returns.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Select an appropriate lead for testing and clamp the current probe into position.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times specified in the general section of this standard.
 - (4) Repeat 5.1.4c(3) for each power lead.

METHOD CE101

5.1.5 Data Presentation

Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement and system check portions of the procedure.

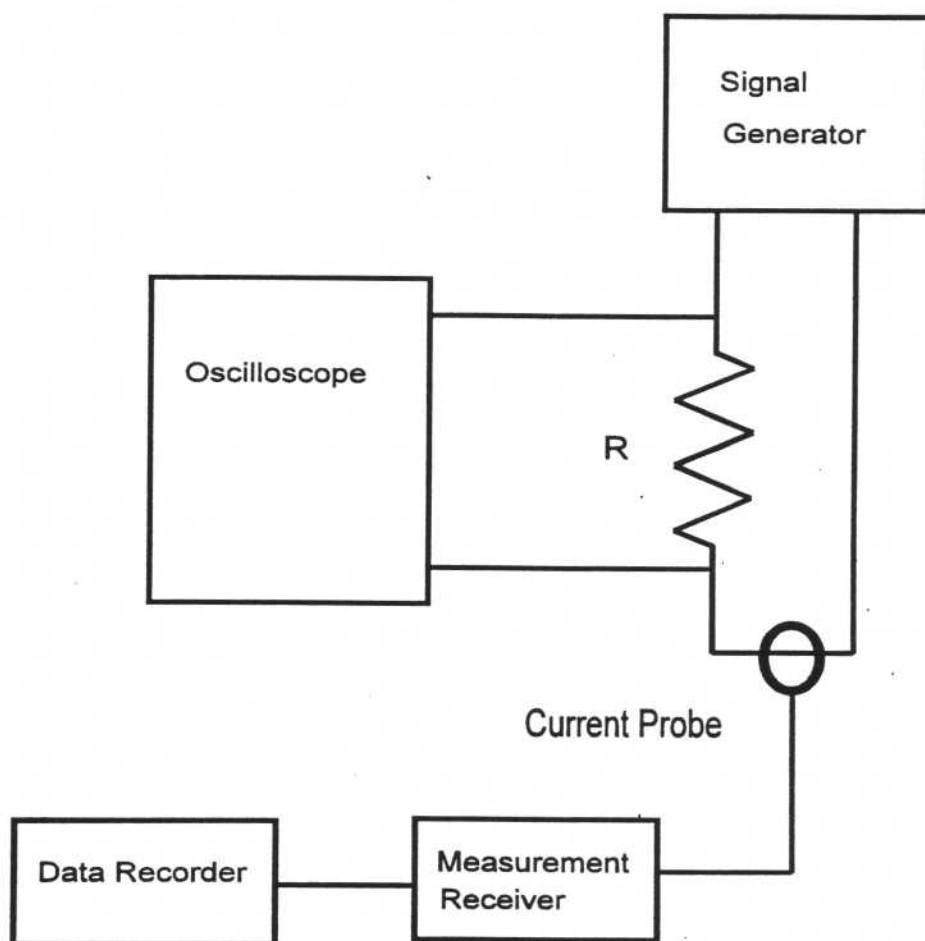


Figure 8. CE101 Measurement system check setup

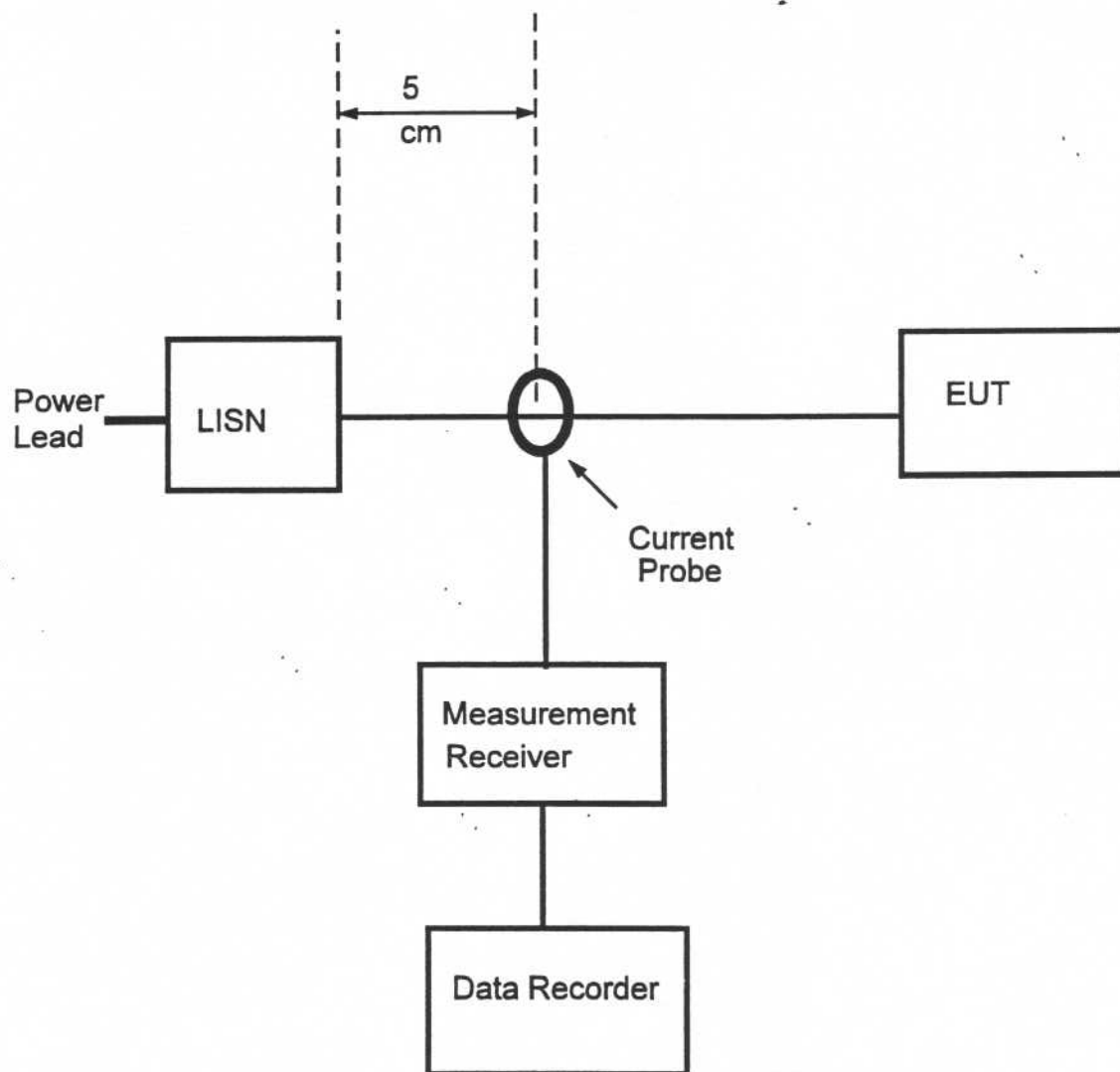


Figure 9. CE101 Measurement setup

5.2 METHOD CE102 - CONDUCTED EMISSIONS, POWER LEADS, 10 kHz TO 10 MHz

5.2.1 Purpose

This test method is used to verify that electromagnetic emissions from the EUT do not exceed the specified requirements for power input leads, including returns.

5.2.2 Test Equipment

The test equipment shall be as follows:

- a. Measurement receiver
- b. Data recording device
- c. Signal generator
- d. Attenuator, 20 dB
- e. Oscilloscope
- f. LISNs

5.2.3 Test Setup

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
- b. Calibration.
 - (1) Configure the test setup for the measurement system check as shown in Figure 10. Ensure that the EUT power source is turned off.
 - (2) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.
- c. EUT testing.
 - (1) Configure the test setup for compliance testing of the EUT as shown in Figure 11.
 - (2) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN.

5.2.4 Test Procedures

The test procedures shall be as follows:

- a. Calibration. Perform the measurement system check using the measurement system check setup of Figure 10.
 - (1) Turn on the measurement equipment and allow a sufficient time for stabilization.
 - (2) Apply a calibrated signal level, which is 6 dB below the EIA/IS-647 limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN. Also, verify that the voltage waveform is sinusoidal.
 - (3) Scan the measurement receiver for each frequency in the same manner as a normal data scan. Verify that the measurement receiver indicates a level within ± 3 dB of the injected level. Correction factors shall be applied for the 20 dB attenuator and the voltage drop due to the LISN 0.25 microfarad coupling capacitor.
 - (4) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the testing.

METHOD CE102

- b. EUT testing. Perform emission data scans using the measurement setup of Figure 11.
 - (1) Turn on the EUT and allow a sufficient time for stabilization.
 - (2) Select an appropriate lead for testing.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the general section of this standard.
 - (4) Repeat 5.2.4b(2) and 5.2.4b(3) for each power lead.

5.2.5 Data Presentation

Data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement system check and measurement portions of the procedure.

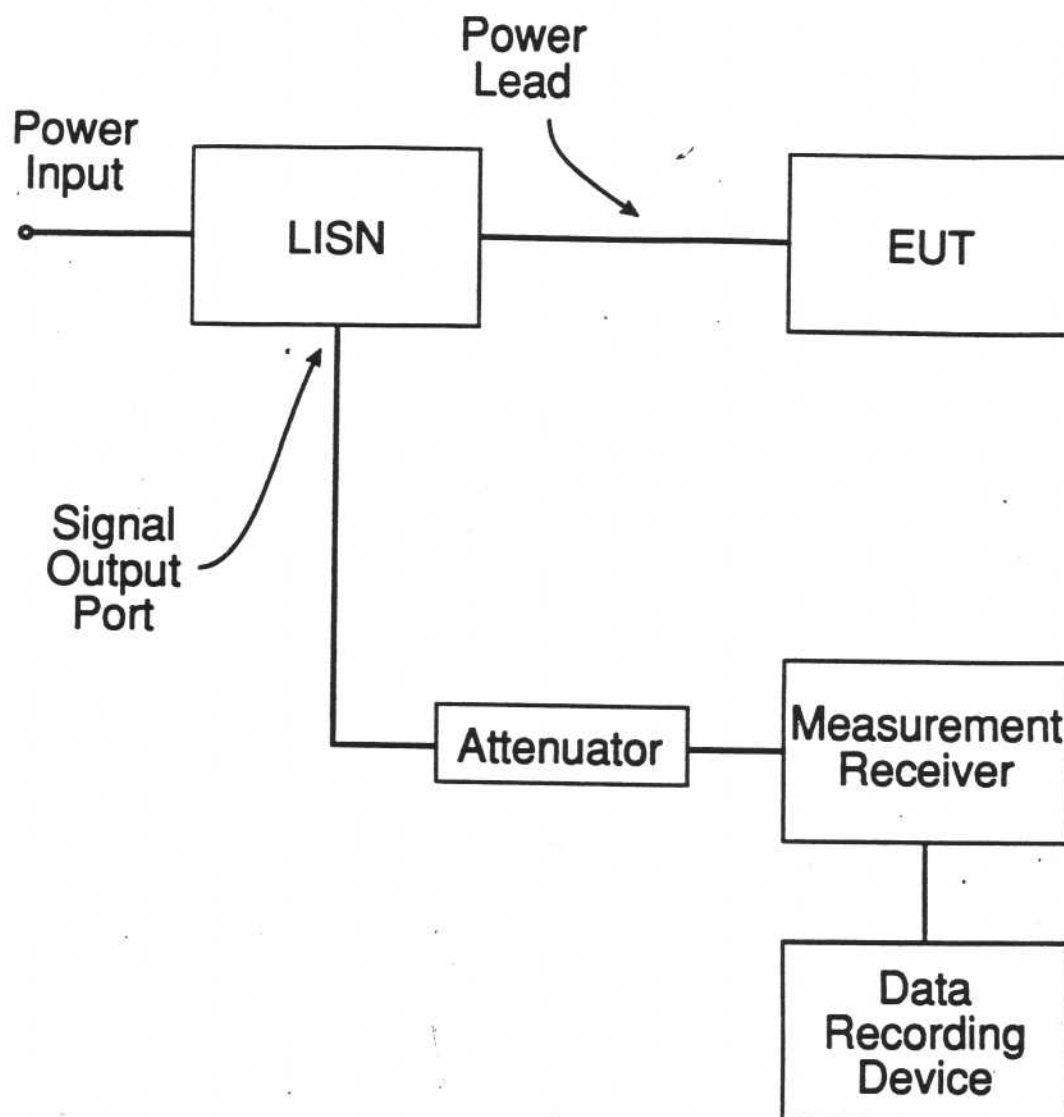


Figure 10. CE102 Measurement System Check Setup

METHOD CE102

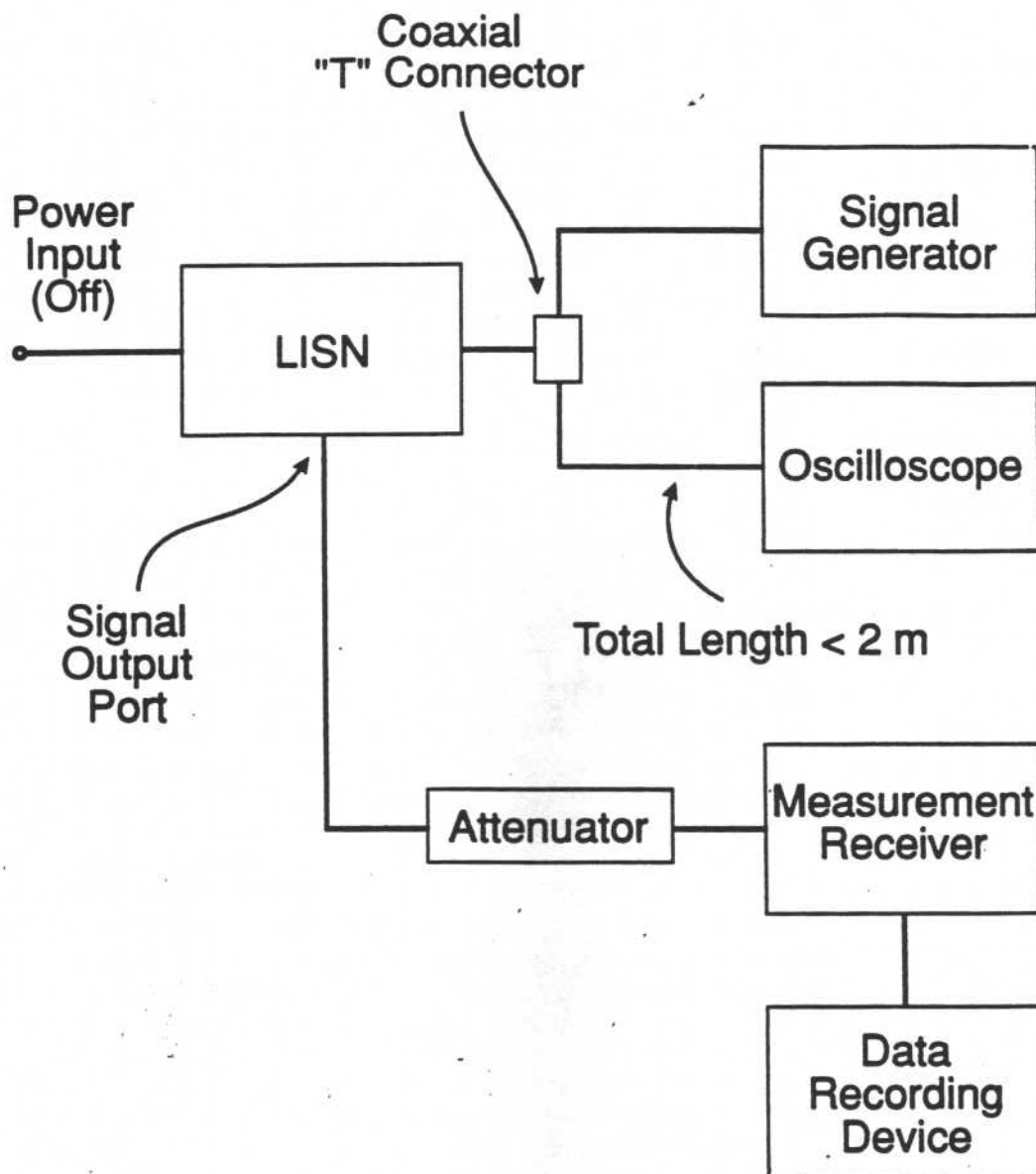


Figure 11. CE102 Measurement Setup

5.3 METHOD CE106 -- CONDUCTED EMISSIONS, ANTENNA TERMINAL, 10 kHz TO 40 GHz

5.3.1 Purpose

This test method is used to verify that conducted emissions appearing at the antenna terminal of the EUT do not exceed specified requirements.

5.3.2 Test Equipment

The test equipment shall be as follows:

- a. Measurement receiver
- b. Attenuators
- c. Rejection networks
- d. Directional couplers
- e. Dummy loads
- f. Signal generators
- g. Data recording device

5.3.3 Test Setup

It is not necessary to maintain the basic test setup for the EUT as shown and described in figures 2 through 5 and paragraph 4.8 of the general section of this standard. The test setup shall be as follows:

- a. Calibration. Configure the test setup for the signal generator path shown in Figures 12 through 14 as applicable. The choice of figure 12 or 13 is dependent upon the power handling capability of the measuring equipment.
- b. EUT Testing. Configure the test setup for the EUT path shown in Figures 12 through 14 as applicable. The choice of figure 12 or 13 is dependent upon the power handling capability of the measuring equipment.

5.3.4 Test Procedures

5.3.4.1 Transmitters (Transmit Mode)

The test procedure shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration.
 - (1) Apply a known calibrated signal level from the signal generator through the system check path at a mid-band fundamental frequency (f_0) in accordance with the general section of this standard.
 - (2) Scan the measurement receiver in the same manner as a normal data scan. Verify the measurement receiver detects a level within ± 3 dB of the expected signal.
 - (3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the test.
 - (4) Repeat 5.3.4.1b(1) through 5.3.4.1b(3) at the end points of the frequency range of test.

- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Tune the EUT to the desired test frequency and use the measurement path to complete the rest of this procedure.
 - (3) Tune the test equipment to the measurement frequency (f_o) of the EUT and adjust for maximum indication.
 - (4) Apply the appropriate modulation for the EUT as indicated in the equipment specification.
 - (5) Record the power level of the fundamental frequency (f_o) and the measurement receiver bandwidth.
 - (6) Insert the fundamental frequency rejection network, when applicable.
 - (7) Scan the frequency range of interest and record the level of all harmonics and spurious emissions. Add all correction factors for cable loss, attenuators and rejection networks. Maintain the same measurement receiver bandwidth used to measure the power level of the fundamental frequency (f_o) in 5.3.4.1c(5).
 - (8) Verify spurious outputs are from the EUT and not spurious responses of the measurement system.
 - (9) Repeat 5.3.4.1c(2) through 5.3.4.1c(8) for other f_o of the EUT.
 - (10) Determine measurement path losses at each spurious frequency as follows:
 - (a) Replace the EUT with a signal generator.
 - (b) Retain all couplers and rejection networks in the measurement path.
 - (c) Determine the losses through the measurement path. The value of attenuators may be reduced to facilitate the end-to-end check with a low level signal generator.

5.3.4.2 Transmitters (Stand-by Mode) and Receivers

The test procedure shall be as follows:

- a. Turn on the measurement equipment and allow a sufficient time for stabilization.
- b. Calibration.
 - (1) Apply a calibrated signal level, which is 6 dB below the EIA/IS-647 limit, from the signal generator through the system check path at a midpoint test frequency in accordance with the general section of this standard.
 - (2) Scan the measurement receiver in the same manner as a normal data scan. Verify the measurement receiver detects a level within ± 3 dB of the injected signal.
 - (3) If readings are obtained which deviate by more than ± 3 dB, locate the source of the error and correct the deficiency prior to proceeding with the test.
 - (4) Repeat 5.3.4.2b(1) through 5.3.4.2b(3) at the end points of the frequency range of test.
- c. EUT Testing.
 - (1) Turn on the EUT and allow sufficient time for stabilization.
 - (2) Tune the EUT to the desired test frequency and use the measurement path to complete the rest of this procedure.
 - (3) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times of the general section of this standard.
 - (4) Repeat 5.3.4.2c(2) and 5.3.4.2c(3) for other frequencies as required by the general section of this standard.

5.3.5 Data Presentation

5.3.5.1 Transmitters (Transmit Mode)

The data presentation shall be as follows:

- a. Provide graphical or tabular data showing f_0 and frequencies of all harmonics and spurious emissions measured, power level of the fundamental and all harmonics and spurious emissions, dB down level, and all correction factors including cable loss, attenuator pads, and insertion loss of rejection networks.
- b. The relative dB down level is determined by subtracting the level in 5.3.4.1c(7) from that obtained in 5.3.4.1c(5).

5.3.5.2 Transmitters (Stand-by Mode) and Receivers

The data presentation shall be as follows:

- a. Continuously and automatically plot amplitude versus frequency profiles for each tuned frequency. Manually gathered data is not acceptable except for plot verification.
- b. Display the applicable limit on each plot.
- c. Provide a minimum frequency resolution of 1% or twice the measurement receiver bandwidth, whichever is less stringent, and a minimum amplitude resolution of 1 dB for each plot.
- d. Provide plots for both the measurement and system check portions of the procedure.

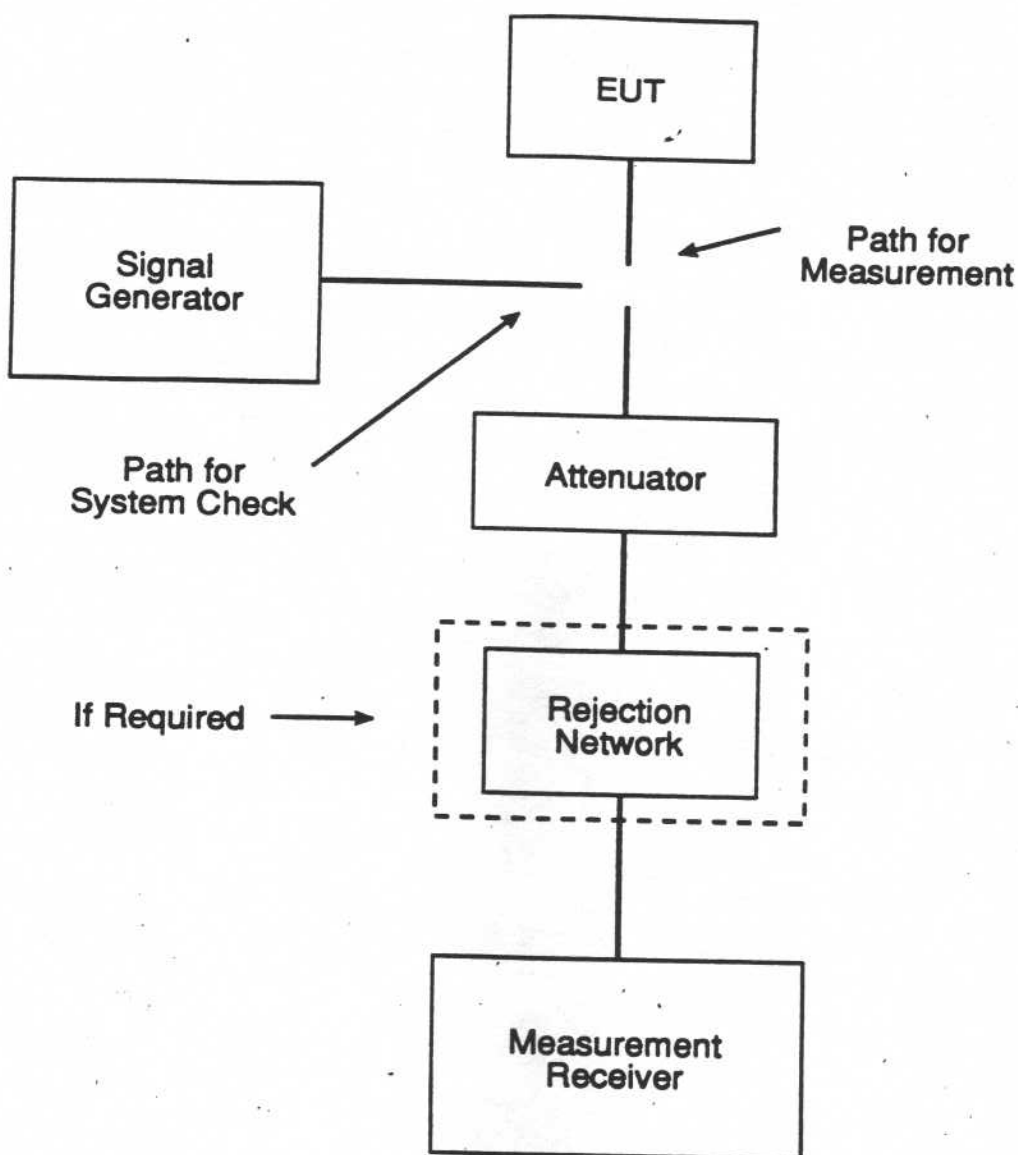


Figure 12. CE106 Setup for low power transmitter

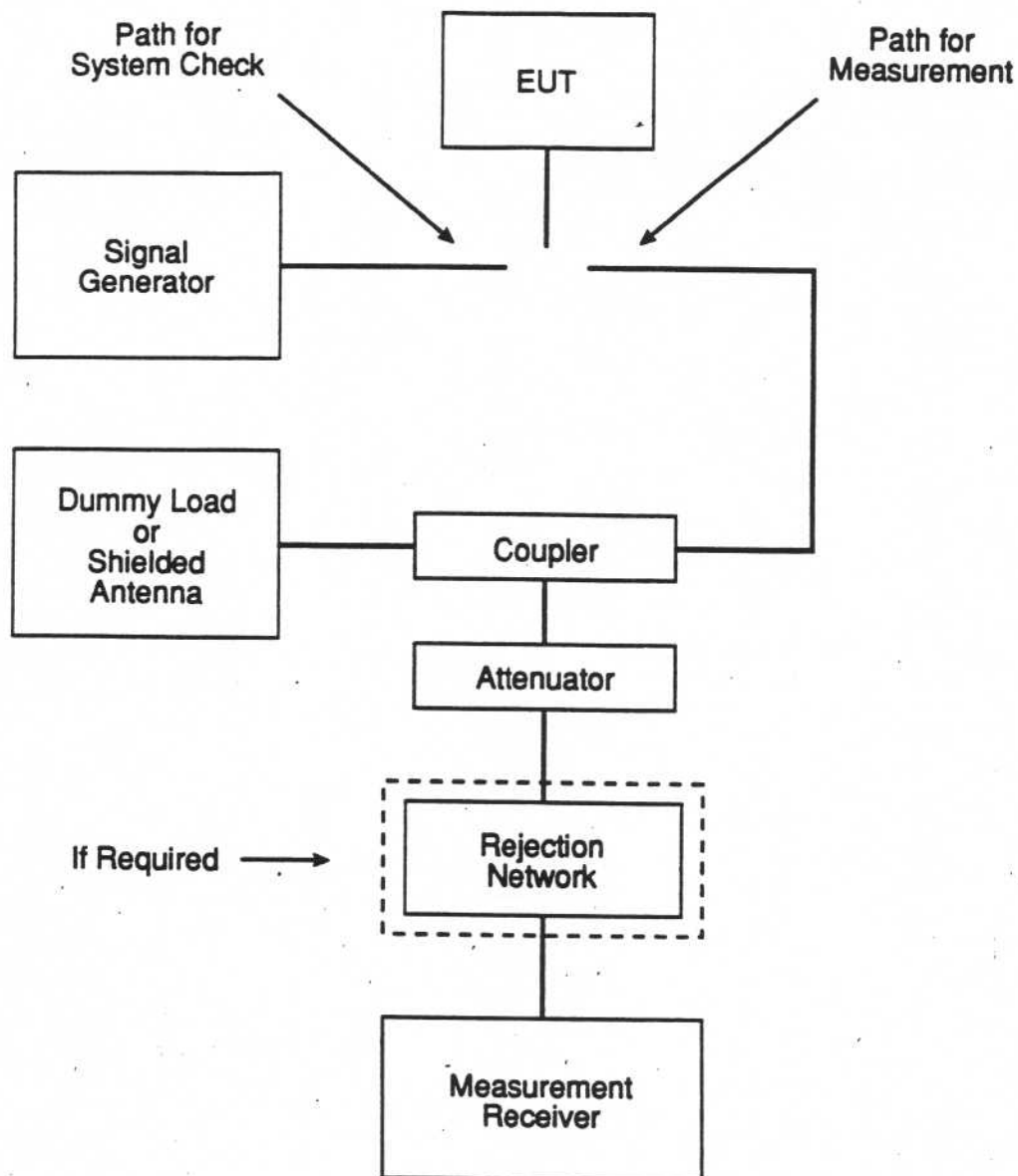


Figure 13. CE106 Setup for high power transmitter

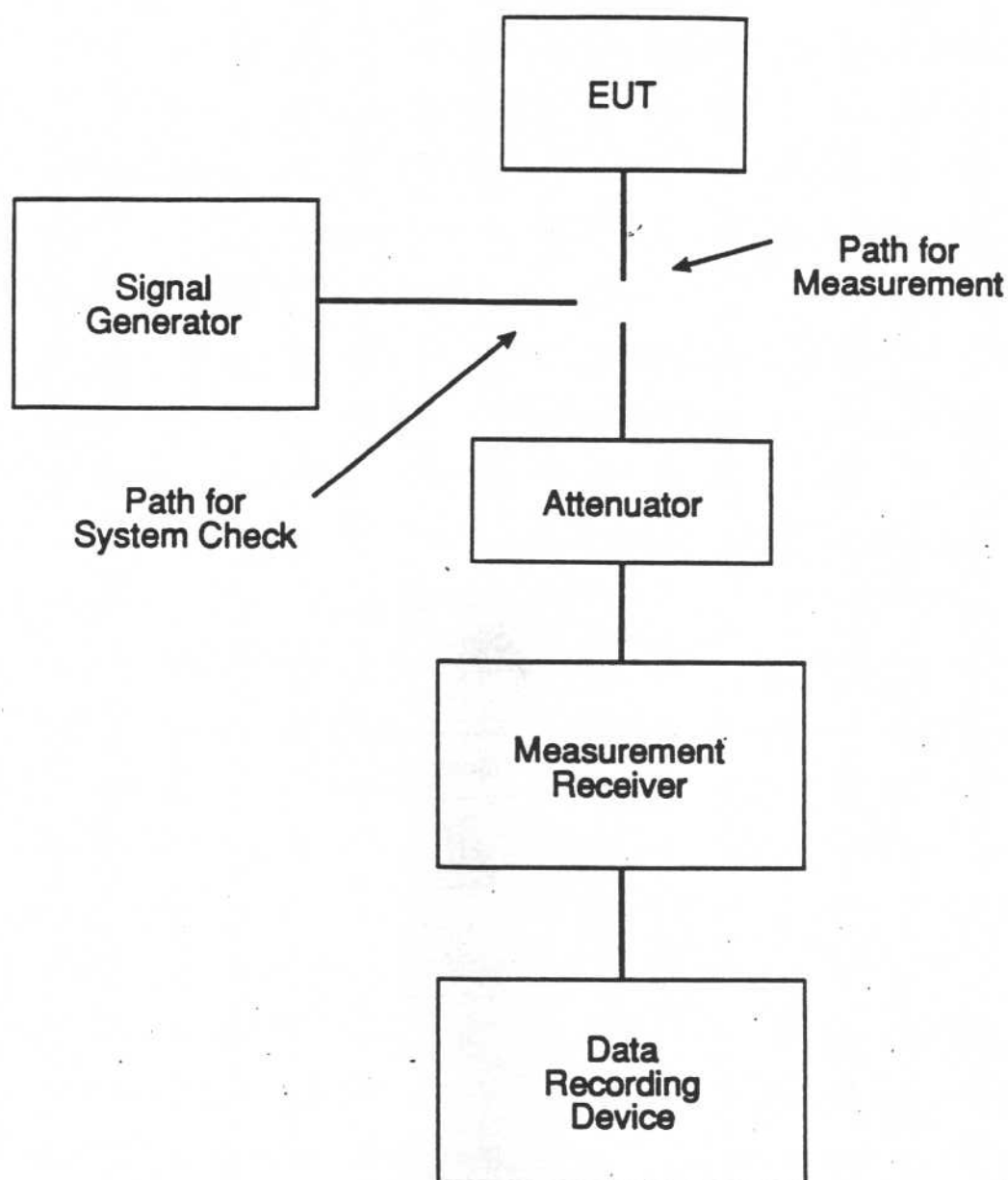


Figure 14. CE106 Setup for transmitters (stand-by mode) and receivers

5.4 METHOD CS101 -- CONDUCTED SUSCEPTIBILITY, POWER LEADS, 30 Hz TO 50 kHz

5.4.1 Purpose

This test method is used to verify the ability of the EUT to withstand signals coupled onto input power leads.

5.4.2 Test Equipment

The test equipment shall be as follows:

- a. Signal generator
- b. Power amplifier
- c. Oscilloscope
- d. Coupling transformer
- e. Capacitor, 10 μ F
- f. Isolation transformer
- g. Resistor, 0.5 ohm
- h. LISNs

5.4.3 Test Setup

The test setup shall be as follows:

- a. Maintain a basic test setup for the EUT as shown and described in Figures 2 through 5 and paragraph 4.8 of the general section of this standard.
- b. Calibration. Configure the test equipment in accordance with Figure 15. Set up the oscilloscope to monitor the voltage across the 0.5 ohm resistor.
- c. EUT testing.
 - (1) For DC or single phase AC power, configure the test equipment as shown in Figure 16.
 - (2) For three phase delta power, configure the test setup as shown in Figure 17.
 - (3) For three phase wye power (four power leads), configure the test setup as shown in Figure 18.

5.4.4 Test Procedures

The test procedures shall be as follows:

- a. Turn on the measurement equipment and allow sufficient time for stabilization.
- b. Calibration.
 - (1) Set the signal generator to the lowest test frequency.
 - (2) Increase the applied signal until the oscilloscope indicates the voltage level corresponding to the maximum required power level specified in EIA/IS-647. Verify the output waveform is sinusoidal.
 - (3) Record the setting of the signal source.
 - (4) Scan the required frequency range for testing and record the signal source setting needed to maintain the required power level.

c. EUT Testing.

- (1) Turn on the EUT and allow sufficient time for stabilization. CAUTION: Exercise care when performing this test since the "safety ground" of the oscilloscope is disconnected and a shock hazard may be present.
- (2) Set the signal generator to the lowest test frequency. Increase the signal level until the required voltage or power level is reached on the power lead. (Note: Voltage is limited to the level calibrated in 5.4.4b(2).)
- (3) While maintaining at least the required signal level, scan through the required frequency range at a rate no greater than specified in Table 3 of the general section of this standard.
- (4) Susceptibility evaluation.
 - (a) Monitor the EUT for degradation of performance.
 - (b) If susceptibility is noted, determine the level at which the undesirable response is no longer present and verify that it is above the EIA/IS-647 requirement.
- (5) Repeat 5.4.4c(2) through 5.4.4c(4) for each power lead, as required. For three phase delta power, the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to B
B	B to C
C	C to A

Three phase wye power (four leads) the measurements shall be made according to the following table:

Coupling Transformer in Line	Voltage Measurement From
A	A to neutral
B	B to neutral
C	C to neutral

5.4.5 Data Presentation

Data presentation shall be as follows:

- a. Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead.
- b. Provide data on any susceptibility thresholds and the associated frequencies which were determined for each power lead.
- c. Provide indications of compliance with the EIA/IS-647 requirements for the susceptibility evaluation specified in 5.4.4c for each lead.

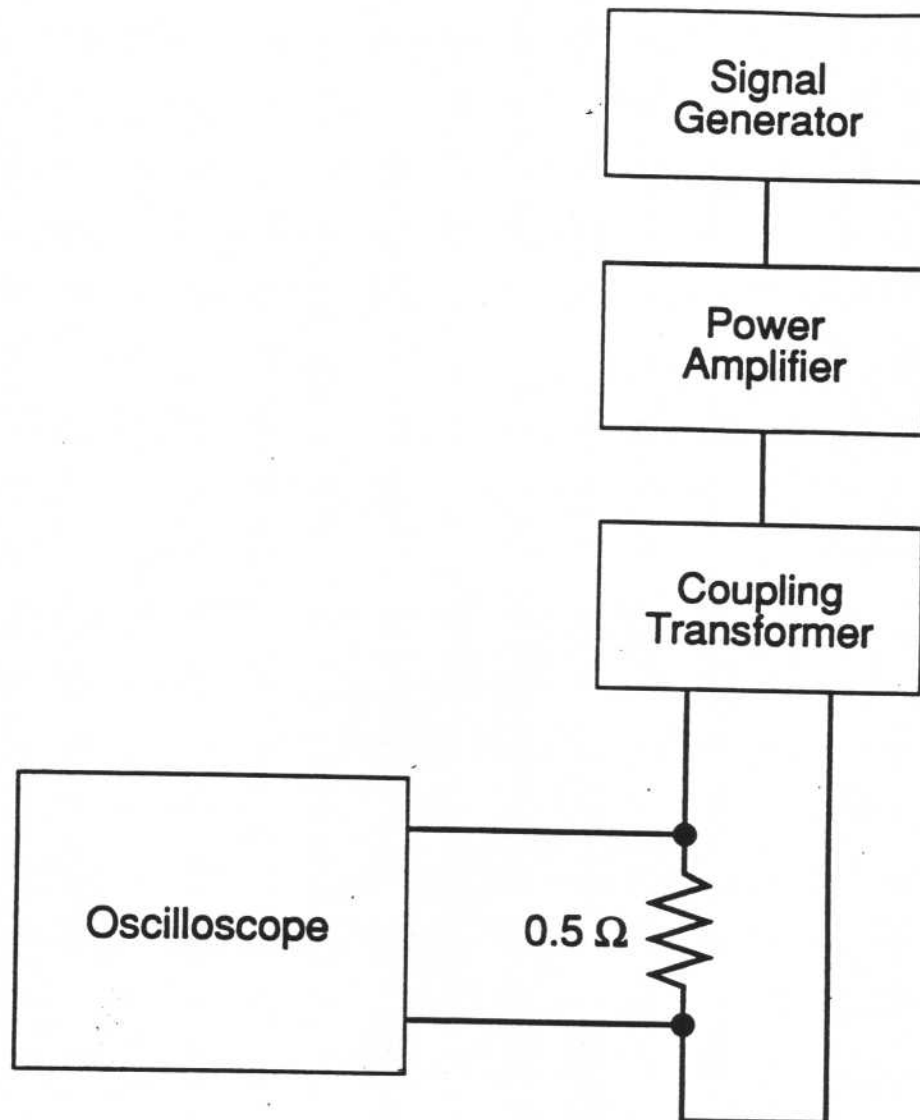


Figure 15. CS101 Calibration