

IEEE Standard Requirements for the Control of Electromagnetic Interference Characteristics of Replaceable Electronic Modules

IEEE Electromagnetic Compatibility Society

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IEEE Std 1688™-2015

IEEE Standard Requirements for the Control of Electromagnetic Interference Characteristics of Replaceable Electronic Modules

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of the
IEEE Electromagnetic Compatibility Society

Approved 11 June 2015

IEEE-SA Standards Board

Abstract: Electromagnetic performance requirements for replaceable electronic modules (REMs) are specified. This standard is suitable for items that have the following features: removable/replaceable electronic circuit modules that plug into an equipment rack or frame, with electrical interconnections primarily through edge connectors that interface directly with a backplane, and electrical power input derived from the backplane power sources. This standard is based on MIL-STD-461E system/equipment level electromagnetic interference (EMI) controls. The conducted and radiated requirements, limits, and test methods were adapted to provide risk reduction of REM EMI before integration in a system/equipment.

Keywords: electromagnetic compatibility, electromagnetic emission, electromagnetic interference, electromagnetic susceptibility, electrostatic discharge, EMC, EMI, ESD, IEEE 1688™, REM, replaceable electronic module, test limits

The Institute of Electrical and Electronics Engineers, Inc.
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PDF: ISBN 978-0-7381-9762-3 STD20253
Print: ISBN 978-0-7381-9763-0 STDPD20253

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Introduction

This introduction is not part of IEEE Std 1688-2015, IEEE Standard Requirements for the Control of Electromagnetic Interference Characteristics of Replaceable Electronic Modules.

This standard is for use in the specification of electromagnetic performance requirements for replaceable electronic modules (REMs). This standard has been developed in response to changes in the technology used to implement functions and/or subsystems into larger, more complicated integrated systems. The architecture for complex systems and system platforms has evolved in recent years from a collective of stand-alone federated subsystems that each performs a set of functions to a highly integrated rack system that incorporate a backplane and multiple subordinate modules that perform the required functions. Some of the modules are designed for a particular purpose, such as power supply or power distribution, whereas others will provide maximum flexibility by being programmable to perform one or more functions. These modules have become items that are often procured independently from the system rack or frame in which they are designed to reside. For this reason, the module specification requirements have also had to mature to include not only descriptions of the functionality and interfaces required but also operational environment conditions. This standard addresses the module electromagnetic environments, by way of adaptation of the test requirements of MIL-STD-461E.¹ Since MIL-STD-461E is intended for use with electronic systems or subsystems, it is not appropriate to apply that standard directly to REMs. However, many of the environments simulated by MIL-STD-461E tests are relevant for REMs and have been used as the basis for the tests described in this standard.

Beneficial comments (recommendations, additions, and deletions) and any pertinent data that may be of use in improving this document should be addressed to: IEEE, Electromagnetic Compatibility (EMC) Society, Standards Development Committee, PAR-1688 Working Group.

The stated requirements are considered necessary to provide reasonable confidence that a particular REM that complies with these requirements will function within its designated design tolerances when within the electromagnetic operating environment of a designated rack, frame, enclosure, or modular system. The procuring activity should consider tailoring the individual requirements to be more or less severe based on the design features of the intended rack host and its mission in concert with personnel knowledgeable about electromagnetic compatibility issues affecting platform integration.

An annex is included that provides the rationale and background for each requirement and verification section.

A committee consisting of representatives of government and industry prepared this document under the IEEE EMC Society Standards Development Committee.

¹ Information on references can be found in Clause 2.

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1. Overview

1.1 General

This standard is for use in the specification of electromagnetic performance requirements for replaceable electronic modules (REMs). A REM is used in highly integrated rack systems that perform functions that heretofore were performed by a standalone equipment “box.” This standard provides the ability to control the electromagnetic interference (EMI) performance of a REM at the module level, giving the advantage of reducing risk associated with integrating with the host rack system. The requirements have matured to include not only descriptions of the functionality and interfaces required but also operational environment conditions. This standard addresses the module electromagnetic environments, by way of adaptation of the test requirements of MIL-STD-461E.¹ The standard includes general requirements, detailed requirements, verification methods, reporting requirements, and, most important, an informative application guide in the annex. In addition, this document is derived from public domain material and may be duplicated as required to develop test plans and procedures.

¹ Information on references can be found in Clause 2.

1.2 Scope

1.2.1 General applicability

This standard establishes interface and associated verification requirements for the control of the electromagnetic interference (emission and susceptibility) characteristics of replaceable electronic modules. Such equipment is used only as an integral part of other subsystems or systems, and may not be used independently. This standard is best suited for items that have the following features: removable/replaceable electronic circuit card modules that plug into an equipment rack or frame, with electrical interconnections primarily through edge connectors that interface directly with a backplane, and electrical power input derived from the backplane power sources. This standard should not be directly applied to equipment that can be used independently as a stand-alone system or subsystem (separate box intra-connected by a wire harness to other boxes of a subsystem), or to entire system platforms. It is assumed that the rack/frame equipment with its full complement of REMs is tested in some configuration to an equipment EMI standard such as MIL-STD-461E. This standard is best suited for situations where the qualification of the REM is more effective than requalification of the rack/frame equipment with the new REM.

1.2.2 Tailoring of requirements

Application-specific environmental criteria may be derived from operational and engineering analyses on the REM being procured for use in specific systems or platforms. When analyses reveal that the requirements in this standard are not appropriate for that procurement, the requirements may be tailored and incorporated into the request for proposal, specification, contract, order, and so forth before the design is completed. The test procedures contained in this document shall be adapted by the testing activity for each application. The adapted test procedures shall be documented in the electromagnetic interference verification (EMIV), (See A.6.2). The annex of this standard provides guidance for tailoring.

1.3 Purpose

The purpose of the standard is to provide interface and associated verification requirements for the control of the electromagnetic interference (emission and susceptibility) characteristics of REMs.

1.4 Structure

The standard has two primary sections: the normative main body and the informative annex. The main body contains the interface and verification requirements of this standard. The annex is noncontractual and provides rationale for the normative requirements and guidance on their interpretation and use. Occasionally, there are references in the main body to annex material where an obvious need exists for the annex information to be examined.

1.5 Emission and susceptibility designations

The emissions and susceptibility and associated test procedure requirements in this standard are designated in accordance with an alphanumeric coding system. Each requirement is identified by a two-letter combination followed by a three-digit number and the letter “M” for “module.” The number is for reference purposes only. The meaning of the individual letters is as follows:

C = Conducted

R = Radiated

E = Emission

S = Susceptibility

- a) Conducted emissions requirements are designated by “CE---M.”
- b) Radiated emissions requirements are designated by “RE---M.”
- c) Conducted susceptibility requirements are designated by “CS---M.”
- d) Radiated susceptibility requirements are designated by “RS---M.”
- e) “---” in the preceding items is the numerical order of requirement from 101 to 199.
- f) The full designation structure of a REM requirement is “XX---M,” where “XX” is one of the two-letter designations defined in this list.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

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.

ANSI/NCSL Z540.3, Requirements for the Calibration of Measuring and Test Equipment.²

ANS/ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories.³

IEEE Std 1309™, IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz.^{4,5}

IEEE Std C95.1™, IEEE Standard for Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

MIL-STD-461E, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.⁶

SAE ARP958, Electromagnetic Interference Measurement Antennas; Standard Calibration Method.⁷

² ANSI publications are available from the American National Standards Institute (<http://www.ansi.org/>).

³ ISO/IEC publications are available from the ISO Central Secretariat (<http://www.iso.org/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

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3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online* should be consulted for terms not defined in this clause.⁸

replaceable electronic module: A circuit unit that plugs into an equipment rack or frame, with electrical interconnections primarily through edge connectors that interface directly with a backplane and has electrical power input derived from the backplane power sources.

3.2 Acronyms and abbreviations

AC	alternating current
ANSI	American National Standards Institute
AWG	American Wire Gauge
CE	conducted emissions
CS	conducted susceptibility
dBpT	decibels above one picotesla
dc	direct current
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EMICP	electromagnetic interference control procedures
EMIV	electromagnetic interference verification
EMIVR	electromagnetic interference verification report
ESD	electrostatic discharge
EUT	equipment under test
f_o	tuned frequency
Hz	Hertz
GHz	gigahertz
ISO	International Standards Organization

⁸*IEEE Standards Dictionary Online* subscription is available at:
http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

kHz	kilohertz
M	module (in requirement numbering only)
MDN	module decoupling network
MHz	megahertz
NCSL	National Calibration Standards Laboratory
LISN	line impedance stabilization network
Ω	ohm
pF	picofarad
PCB	printed circuit board
RE	radiated emissions
RS	radiated susceptibility
REM	replaceable electronic module
RF	radio frequency
RMS	root mean square
SAE	Society of Automotive Engineers
s	second
V ac	volts alternating current
V dc	volts direct current
V/m	volts per meter
μ F	microfarad

4. General requirements

4.1 General

The REM shall comply with the applicable general interface requirements in 4.2. General requirements for verification shall be in accordance with 4.3. These general requirements are in addition to the applicable detailed emission and susceptibility requirements and associated test procedures defined in Clause 5.

4.2 Interface requirements

4.2.1 Performance requirements

Performance requirements are applied to each individual REM for the purpose of reducing the risks associated with integration of the REM into a subsystem or system. The performance requirements are the attribute or functional operation of the REM that is required for a defined condition. This standard defines the electromagnetic environment conditions to which the REM may be exposed and for which the REM's performance requirements apply.

4.2.2 Susceptibility

The REM shall not be damaged and shall maintain the required functionality during exposure to the applicable susceptibility conditions defined in this standard. The REM's individual procurement specification establishes the REM's functional operations during and/or after exposure to susceptibility conditions, defines the applicable susceptibility environments that are used instead of the default requirements used in this standard, and describes any tailoring of this standard that is deemed appropriate by the system integrator or procuring agency.

4.2.3 Emissions

Radio frequency (RF) emissions produced by the REM shall not exceed the limits defined in this standard during the operations required by its individual procurement specification. The REM's individual procurement specification shall define the applicable emissions constraints and describe any tailoring of this standard that is deemed appropriate by the system integrator or procuring agency.

4.3 Verification requirements

The general requirements related to test procedures, test facilities, and equipment stated in Clause 5, together with the detailed test procedures included in Clause 5, shall be used to determine compliance with the applicable emission and susceptibility requirements of this standard. Any procuring-activity approved exceptions or deviations from these general verification requirements shall be documented in the EMIV document (See A.6.2). Formal verification is not to commence without approval of the EMIV by the procuring agency concerned. Data that are gathered as a result of performing tests in one electromagnetic discipline may be sufficient to satisfy requirements in another. Therefore, to avoid unnecessary duplication, a single test program should be established with tests for similar requirements conducted concurrently whenever possible.

4.3.1 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): $\pm 5\%$

- f) Resistors: $\pm 5\%$
- g) Capacitors: $\pm 20\%$

4.3.2 Shielded enclosures

4.3.2.1 General

To prevent interaction between the REM 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 shall have adequate attenuation such that the ambient requirements of 4.3.4 are satisfied. The enclosures shall be sufficiently large such that the REM arrangement requirements of 4.4 and antenna positioning requirements described in the individual test procedures are satisfied.

4.3.2.2 Radio-frequency 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 REM, 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 its RF absorber material (basic material only, not installed) is acceptable.

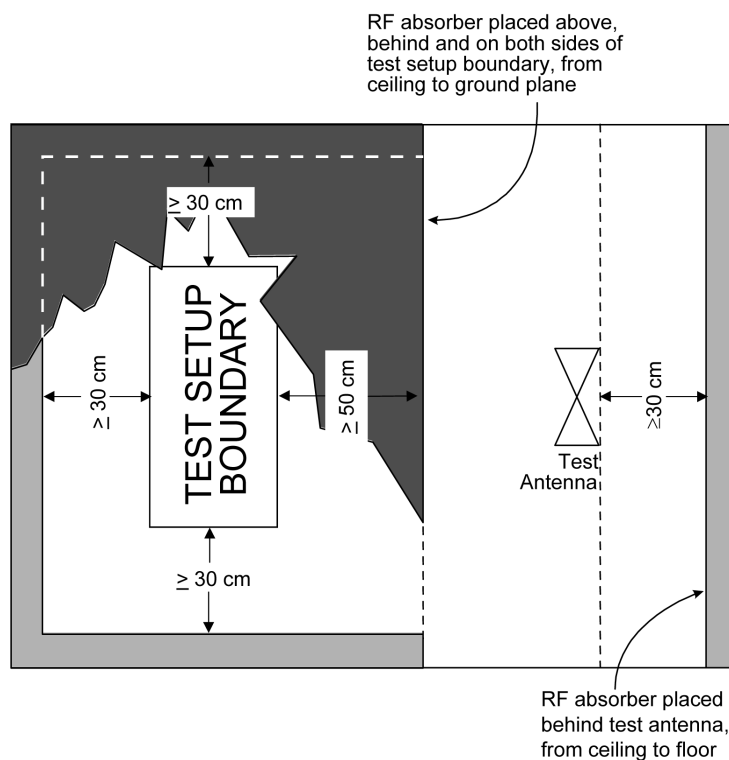


Figure 1 —RF absorber loading diagram

Table 1— Absorption at normal incidence

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

4.3.3 Other test sites

If other test sites [e.g., gigahertz transverse electromagnetic (GTEM), transverse electromagnetic, open area, etc.] that provide different test environments are used, it shall be documented in the test procedure how the test site meets the ambient requirements of 4.3.4 and the equivalences to the verification requirements of this standard.

4.3.4 Ambient electromagnetic level

Prior to and during testing, the ambient electromagnetic level measured with the REM and its test fixture 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 REM test fixture and connected to a resistive load that draws the same rated current as the REM. Repeat the ambient measurements, but with the test fixture only energized, along with required auxiliary equipment. When tests are performed in a shielded enclosure and the REM and its test fixture are in compliance with required limits, the ambient profile need not be recorded in the electromagnetic interference verification report (EMIVR). 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 EMIVR and shall not compromise the test results.

4.3.5 Ground plane

The REM test fixture shall be installed on a ground plane that simulates the actual installation of the REM in the rack/frame. If the actual installation is unknown or multiple installations are expected, then a metallic ground plane shall be used. Unless otherwise specified in 4.3.5.1 and 4.3.5.2, ground planes shall be 2.25 m² or larger in area with the smaller side no less than 76 cm. When a ground plane is not present in the REM rack/frame installation, the REM test fixture shall be placed on a nonconductive table. (See 4.4 for equipment under test (EUT) on the ground plane concept).

4.3.5.1 Metallic ground plane

When the REM test fixture is installed on a metallic ground plane, the ground plane shall have a surface resistance no greater than 0.1 mΩ per square. The dc resistance between metallic ground planes and the shielded enclosure shall be 2.5 mΩ or less. The metallic ground planes (e.g., copper bench) shown in Figure 3 and discussed in 4.4 shall be electrically bonded to the floor or wall of the basic shielded room structure at least once every 1 m. 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 extend at least 1.5 m beyond the test setup boundary in each direction.

4.3.5.2 Composite ground plane

When the REM test fixture 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.

4.3.6 Power source impedance

The impedance of power sources providing input power to the REM shall be controlled by power interface impedance stabilization networks for all measurement procedures of this document unless otherwise stated in a particular test procedure. REM power interfaces to prime power (e.g., 28 volts direct current (V dc), 115 volts alternating current (V ac), 270 V dc) shall use a line impedance stabilization network (LISN). The LISN circuit shall be in accordance with the schematic shown in Figure 2. A REM secondary power interface (e.g., 5 V dc $\pm$ 15 V dc) that derives power from a power supply within the rack/frame shall use a module decoupling network (MDN) or the actual power supply used in the rack/frame. A.4.2.6 provides details concerning suggested MDNs. The secondary power output shall use the MDN and resistive loads or the actual rack/frame loads. The power interface impedance stabilization networks shall be located in the cable tray in between the power source end and the EUT. The power sources, power loads, and/or actual devices may be located in the cable tray or external to the shield enclosure (see 4.4.7). The impedance shall be measured and documented in the EMIVR.

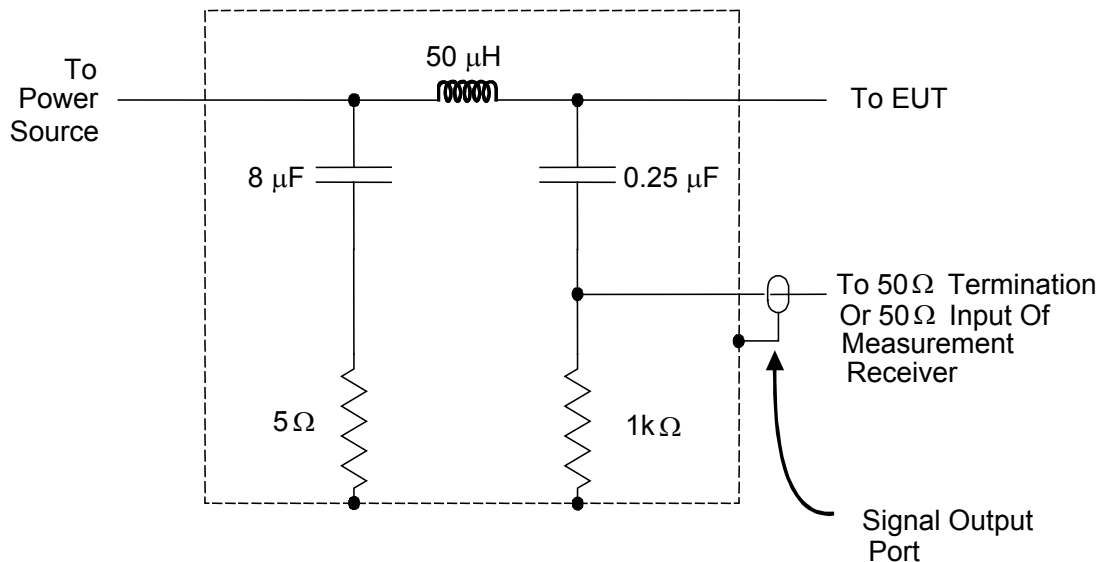


Figure 2 —LISN schematic

4.3.7 General test precautions

4.3.7.1 Accessory equipment

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

4.3.7.2 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.

4.3.7.3 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.

4.3.7.4 RF hazards

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

4.3.7.5 Shock hazard

Some of the tests require potentially hazardous voltages to be present. Extreme caution shall be taken by all personnel, and all safety precautions must be observed.

4.3.7.6 Spectrum restrictions

Some of the tests require high-level signals to be generated that could interfere with normal approved frequency assignments. All such testing should be performed in a shielded enclosure. Limited open-site testing may be feasible if prior spectrum regulatory coordination (such as with the FCC) is accomplished.

4.4 REM test configurations

The REM shall be configured as shown in the general test setups of Figure 1. The setups shall be maintained during all testing unless other direction is given for a particular test procedure.

The REM shall be installed in a test fixture that provides the required interfaces with the backplane or motherboard but at the same time isolates the module from its backplane in terms of electromagnetic environmental conditions. The fixture shall be constructed from electrically conductive materials and shall be electrically bonded to the ground plane of the test platform, such that the power, control, and signal interfaces between the backplane and its own supporting equipment are shielded from the environment conditions to which the REM will be exposed. Figure 3 shows an example of a REM test fixture installed within a shielded enclosure where the REM is bonded to the ground plane. The REM electrical bonding to the copper bench shall be provided to simulate rack/frame installations that have electrical continuity via the card slides and wedge locks. The REM rack/frame installations that are not grounded to the rack frame REM edges (e.g., card slides) shall use Figure 4 where there is no simulation of the grounding or ground plane and the bottom side of the REM is 5 cm above the ground plane.

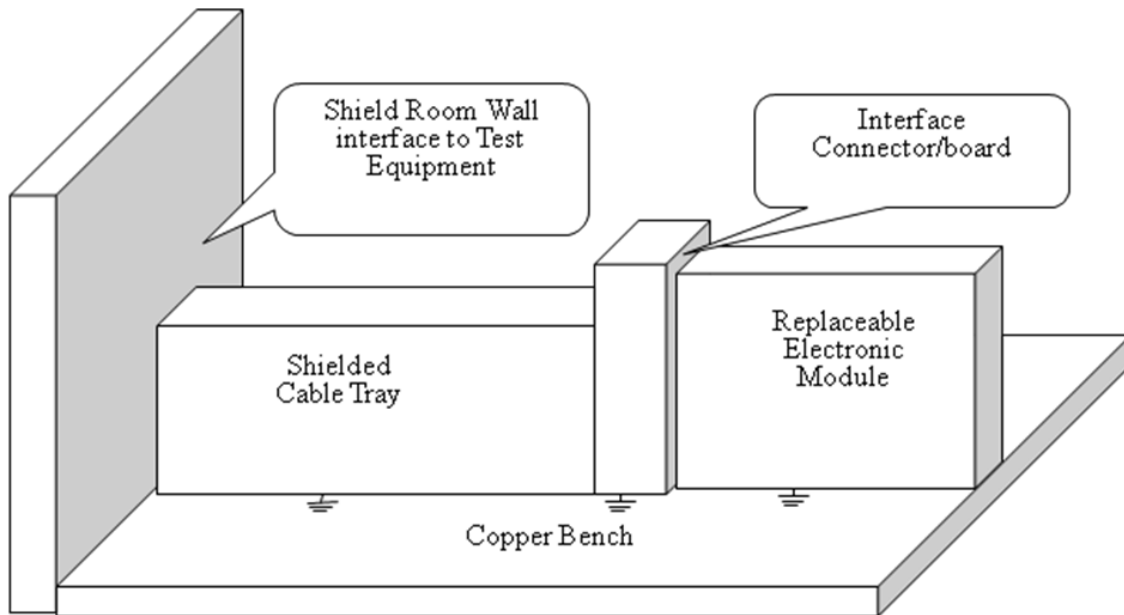


Figure 3 —Grounded connection

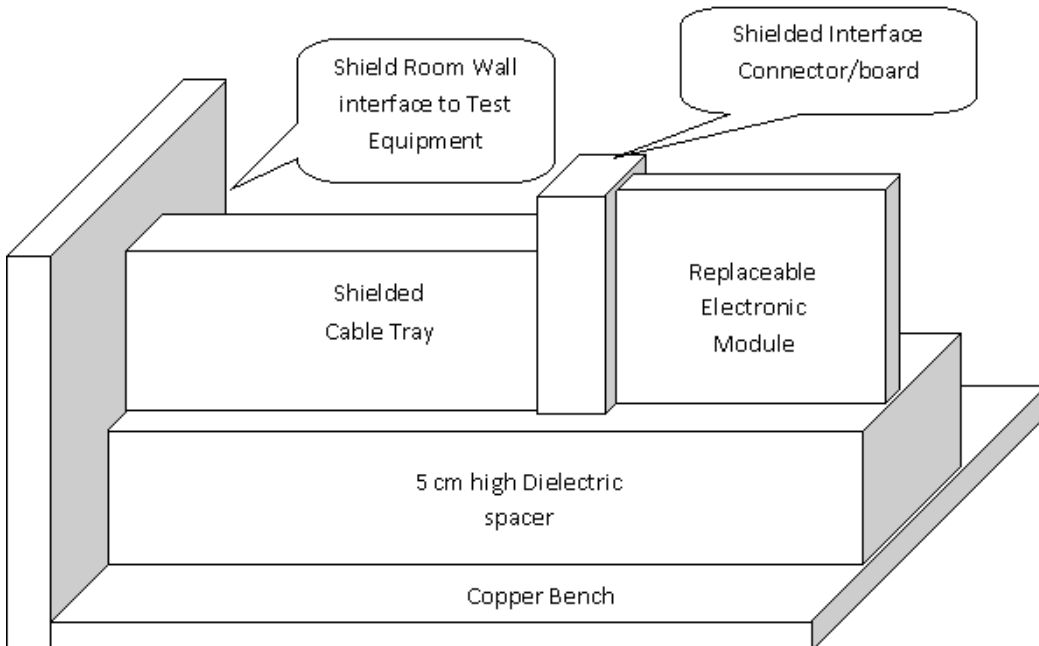


Figure 4 —Nongrounded installation

4.4.1 REM design status

REM hardware and software shall be representative of production. Software may be supplemented with additional code that provides diagnostic capability to assess performance.

4.4.2 Bonding of the REM

Only the provisions included in the design of the REM shall be used to bond units such as module cover and interface wiring connectors together or to the ground plane. When bonding straps are required, they shall be identical to those specified in the installation drawings.

4.4.3 Shock and vibration isolators

REMs shall be secured to mounting bases having shock or vibration isolators only if such mounting bases are used in the installation. The bonding straps furnished with the REM shall be connected to the ground plane or the REM test fixture, whichever most closely replicates the actual installation of REM. When the REM does not have bonding straps, no bonding straps shall be used in the test setup.

4.4.4 Safety grounds

When external terminals, connector pins, or equipment grounding conductors are available for safety ground connections and are used in the actual REM installation, they shall be connected to the ground plane or the REM test fixture, whichever most closely replicates the actual installation of REM. The arrangement and length of safety grounds shall replicate the actual installation.

4.4.5 Orientation of REM

The REM shall be oriented as shown in Figure 1.

4.4.6 Construction and arrangement of REM cables

Electrical interfaces to the REM shall simulate backplane and cabling within the rack/frame installation. Shielded cables or shielded leads (including power leads and wire grounds) within cables shall be used if they have been specified in installation or required to simulate the backplane traces. 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 and backplane simulation used for testing shall be included in the electromagnetic interference control procedures (EMICP).

4.4.7 Interconnecting leads and cables

Individual leads shall be grouped into cables in the same manner as in the actual installation of the REM into its resident rack. For those interfaces connected by the backplane to the REM, the interconnecting cable lengths from the backplane connector via the cable tray to the test equipment and/or decoupling networks should not exceed lengths of 2.5 m. Those cables that are not connected by the backplane to the REM edge connector shall have cable lengths in the setup the same as in the actual installation of the REM into its resident rack/frame. If a cable is longer than 10 m, at least 10 m shall be included. When cable lengths are not specified for the installation, cables shall be sufficiently long to satisfy the conditions specified in the remainder of this subclause. At least the first 2 m (except for cables that are shorter in the actual installation) of each interconnecting cable associated with each enclosure of the EUT 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 cm measured from their outer circumference. For bench-top setups using ground planes, the cable closest to the front boundary shall be placed 10 cm from the front edge of the ground plane. All cables shall be supported 5 cm above the ground plane.

4.4.8 Electrical and mechanical interfaces

All electrical input and output interfaces shall be terminated with either the actual device from the system installation or loads that 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 REM circuitry. 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 so that the active load meets the ambient requirements of 4.3.4 when connected to the setup, and that the active load does not respond to susceptibility signals. Antenna ports on the REM shall be terminated with shielded, matched loads.

4.4.9 Operation of the REM

During emission measurements, the REM shall be placed in an operating mode that produces maximum emissions. During susceptibility testing, the REM shall be placed in its most susceptible operating mode. For REMs 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. The rationale for modes selected shall be included in the EMIVP.

4.4.10 Power-on switching functions

The power-on switching functions and switching transient that result at the moment of initial operation of a REM are not covered by the requirements of this standard. Other repetitive functions, self-test functions, and transient-type conditions, such as automatic sequencing following the power = on initiation switching function, shall meet the requirements of this standard.

4.4.11 Operating frequencies for tunable RF equipment

Measurements shall be performed with the REM 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 $\pm 5\%$ from each end of each band or range of channels.

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

4.4.13 Susceptibility monitoring

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

4.4.14 Use of measurement equipment

Measurement equipment shall be as specified in the individual test procedures 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. Typical instrumentation characteristics may be found in ANSI C63.2.

4.4.14.1 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, nonselective 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.

4.4.14.2 Computer-controlled receivers

A description of the operations being directed by software for computer-controlled receivers shall be included in the EMIVP. Verification techniques used to demonstrate proper performance of the software shall also be included.

4.4.15 Emission testing

4.4.15.1 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 receiver 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 ^a	Minimum measurement time analog measurement receiver
30 Hz to 1 kHz	10 Hz	0.15 s	0.015 s/Hz
1 kHz to 10 kHz	100 Hz	0.015 s	0.15 s/kHz
10 kHz to 150 kHz	1 kHz	0.015 s	0.015 s/kHz
150 kHz to 30 MHz	10 kHz	0.015 s	1.5 s/MHz
30 MHz to 1 GHz	100 kHz	0.015 s	0.15 s/MHz
Above 1 GHz	1 MHz	0.015 s	15 s/GHz

^aAlternative scanning technique. Multiple faster sweeps with the use of maximum hold function may be used if the total scanning time is equal to or greater than the minimum measurement time defined.

4.4.15.2 Emission identification

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

4.4.15.3 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. For equipment that operates such that potential emissions are produced only at infrequent intervals, times for frequency scanning shall be increased as necessary to capture any emissions.

4.4.15.4 Emission data presentation

Amplitude versus frequency profiles of emission data shall be automatically generated and displayed at the time of test and shall be continuous. The displayed information shall account for all applicable correction factors (transducers, attenuators, cable loss, and the like) and shall include the applicable limit. Manually gathered data is not acceptable except for verification of the validity of the output. Plots of the displayed data 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 resolution requirements specified in this subclause shall be maintained in the reported results of the EMIVR.

4.4.16 Susceptibility testing

4.4.16.1 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 that are continuously tuned. Stepped scans refer to signal sources that are sequentially tuned to discrete frequencies. Stepped scans shall dwell at each tuned frequency for the greater of 3 s or the REM response time. 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 to 1 MHz	$0.0333 f_0/s$	$0.05 f_0$
1 MHz to 30 MHz	$0.00667 f_0/s$	$0.01 f_0$
30 MHz to 1 GHz	$0.00333 f_0/s$	$0.005 f_0$
1 GHz to 18 GHz	$0.000167 f_0/s$	$0.0025 f_0$

4.4.16.2 Modulation of susceptibility signals

Susceptibility test signals for CS114M and RS103M shall be pulse modulated (on/off ratio of 40 dB minimum) at a 1 kHz rate with a 50% duty cycle.

4.4.16.3 Thresholds of susceptibility

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

- a) When a susceptibility condition is detected, reduce the interference signal until the REM 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.

4.4.16.4 Calibration of measuring equipment

Test equipment and accessories required for measurement in accordance with this standard shall be calibrated in accordance with ANSI/NCSL Z540.3 or ANSI/ISO/IEC 17025 or under an approved calibration program traceable to the National Institute for Standards and Technology. In particular, measurement antennas, current probes, field sensors, and other devices used in the measurement loop shall be calibrated at least every two years unless otherwise specified by the procuring activity, or when damage is apparent.

4.4.16.5 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 procedure, while monitoring system output for the proper indication. When the emission test involves an uninterrupted set of repeated measurements (such as evaluating different operating modes of the EUT) using the same measurement equipment, the measurement system test needs to be accomplished only one time.

4.4.16.6 Antenna and probe factors

Factors for emissions test antennas should be addressed with SAE ARP-958. Calibration factors for transducers and field probes are addressed in IEEE Std 1309™.

5. Detailed requirements

5.1 General

This clause specifies detailed emissions and susceptibility requirements and the associated test procedures. Table 4 is a list of the specific requirements established by this standard, identified by requirement number and title. General test procedures are included in this clause. Specific test procedures are implemented by the EMIVP approved by the procuring agency. All results of tests performed to demonstrate compliance with the requirements are to be documented in the EMIVR and forwarded to the REM. Design procedures and techniques for the control of EMI shall be described in the EMICP. Approval of design procedures and techniques described in the EMICP does not relieve the supplier of the responsibility for meeting the contractual emission, susceptibility, and design requirements.

Table 4—Emission and susceptibility requirements

Requirement	Description
CE102M	Conducted emissions, power leads, 10 kHz to 10 MHz
CS101M	Conducted susceptibility, power leads, 30 Hz to 150 kHz
CS103M	Conducted susceptibility, antenna port, intermodulation, 15 kHz to 10 GHz
CS104M	Conducted susceptibility, antenna port, rejection of undesired signals, 30 Hz to 18 GHz
CS105M	Conducted susceptibility, antenna port, cross-modulation, 30 Hz to 18 GHz
CS106M	Conducted susceptibility, transients, power lines
CS114M	Conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz
CS115M	Conducted susceptibility, bulk cable injection, impulse excitation
CS116M	Conducted susceptibility, damped sinusoidal transients, cables, and power leads, 10 kHz to 100 MHz
RE101M	Radiated emissions, magnetic field, 30 Hz to 100 kHz
RE102MF	Radiated emissions, electric field, 10 kHz to 18 GHz
RE102MC	Radiated emissions, electric field, 10 kHz to 1 GHz
RS101M	Radiated susceptibility, magnetic field, 30 Hz to 100 kHz
RS103M	Radiated susceptibility, electric field, 2 MHz to 18 GHz
RS107M	Electrostatic discharge from human contact

All frequency domain limits are expressed in terms of equivalent RMS value of a sine wave as would be indicated by the output of a measurement receiver using peak envelope detection (see 4.4.14.1).

5.2 EMI control requirements versus intended installations

Table 5 summarizes the requirements for REMs based on their relevant functionality, power distribution architecture, signal and control interfaces, physical installation characteristics, etc. The total group of attributes for a REM results in the total requirements for a REM.

An “A” entry in Table 5 means the requirement is applicable. An “L” entry means the applicability of the requirement is limited as specified in the appropriate requirement paragraphs of this standard; the limits are contained herein. An “S” entry means the procuring activity must specify the applicability, limit, and verification procedures in the procurement specification. Absence of an entry means the requirement is not applicable.

Table 5—Requirement matrix

REM attribute	Applicability													
	CE102M	CS101M	CS103M	CS104M	CS105M	CS106M	CS114M	CS115M	CS116M	RE100M	RE102M	RS101M	RS103M	RS107M
REM location in rack/frame														
Physical installation less than 7 cm from adjacent REM or other component										A	A	A	A	A
Physical installation more than 7 cm from adjacent REM or other component											A		A	A
REM interfaces														
Provides power supply and/or power distribution function via backplane edge connector to REM	A	A				A	A	A	A					
Wiring interfaces that are internal to rack via the backplane edge connector to REM	A	A				A	A	A	A					
Wiring interfaces that are external to rack via backplane edge connector to REM	A	A				A	A	A	A					
Wiring interfaces that are direct connection to external antenna ports			A	A	A									
Wiring interfaces other than via backplane edge connector to REM	A	A				A	A	A	A	A	A	A	A	A
NOTE 1—Multiple attributes may apply to a REM to total the complete REM requirement (REM Locations in Rack/Frame + REM Interfaces = Total REM Requirement). ⁹														

5.3 Emission and susceptibility requirements, limits, and verification

Individual emission or susceptibility requirements and their associated limits and test procedures are grouped together in the following subclauses. The applicable frequency range and limit of many emission and susceptibility requirements varies depending on the particular platform or installation. The test procedures included in this subclause are valid for the entire frequency range specified in the procedure; however, testing only needs to be performed over the frequency range specified for the particular platform or installation.

5.4 CE102M conducted emissions, power, control, and signal leads, 10 kHz to 10 MHz

5.4.1 CE102M applicability

This requirement is applicable from 10 kHz to 10 MHz for all REM power, control, and signal interfaces. For power interfaces, including returns, that interface power with other devices, both the prime power and secondary interface shall be tested. The types of REM applicability are as follows:

- Power interfaces directly with other components outside the common rack assembly.
- Power interfaces indirectly with other components outside the common rack assembly.

⁹ Notes to text, tables, and figures are for information only and do not contain requirements needed to implement the standard.

- c) Signal and control interface directly or indirectly with other components outside the common rack assembly.
- d) Power interfaces with other components inside the common rack assembly.
- e) Signal and control interface only with other REMs or components within the common rack assembly.

5.4.2 CE102M limits

The CE102 limits are as follows:

- a) Power interfaces directly with other components outside the common rack assembly: The baseline CE102M limit level of Figure 5 CE102M-1 applies for this interface category.
- b) Power interfaces indirectly with other components outside the common rack assembly: The 30 dB above the baseline CE102M limit level of Figure 5 CE102M-1 applies for this interface category.
- c) Steady state signal and control interface (e.g., discrete) directly or indirectly with other components outside the common rack assembly. The limit is the same as the baseline CE102M limit of Figure 5 CE102M-1.
- d) Power interfaces with other components inside the common rack assembly: The limit is 10 dB above the signal spectrum envelope as shown in Figure 6 CE102M-3.
- e) Signal and control interface only with other REMs or components within the common rack assembly: The limit is 10 dB above the signal spectrum envelope as shown in Figure 6 CE102M-3.

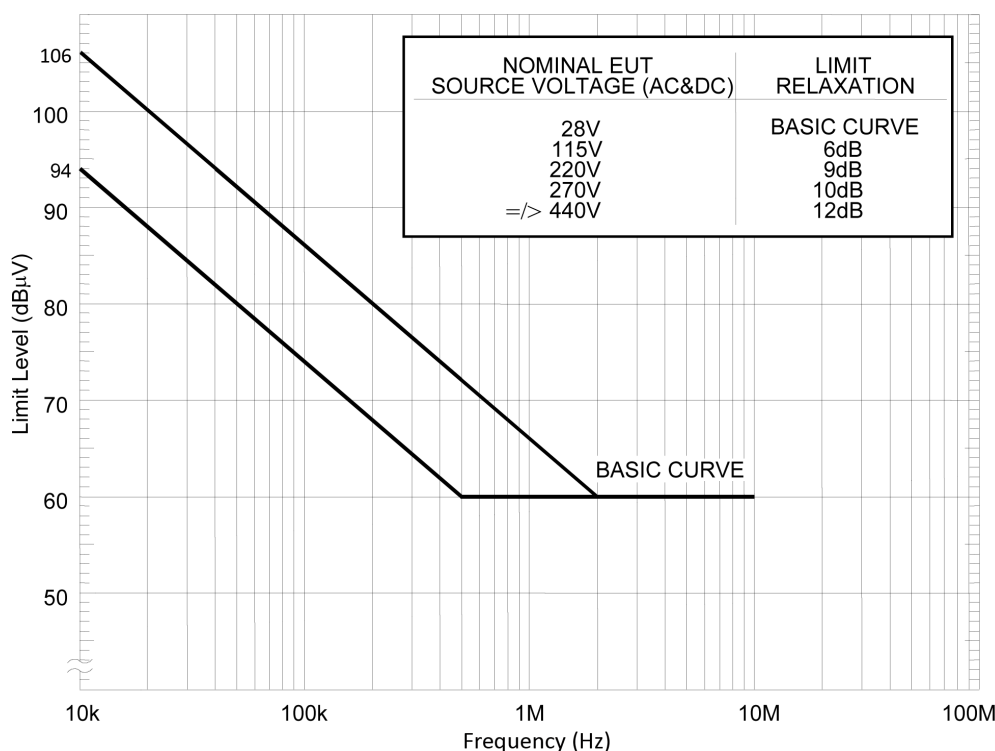


Figure 5 —CE102M-1 limit (REM power, control, and signal leads, ac and dc) for all applications

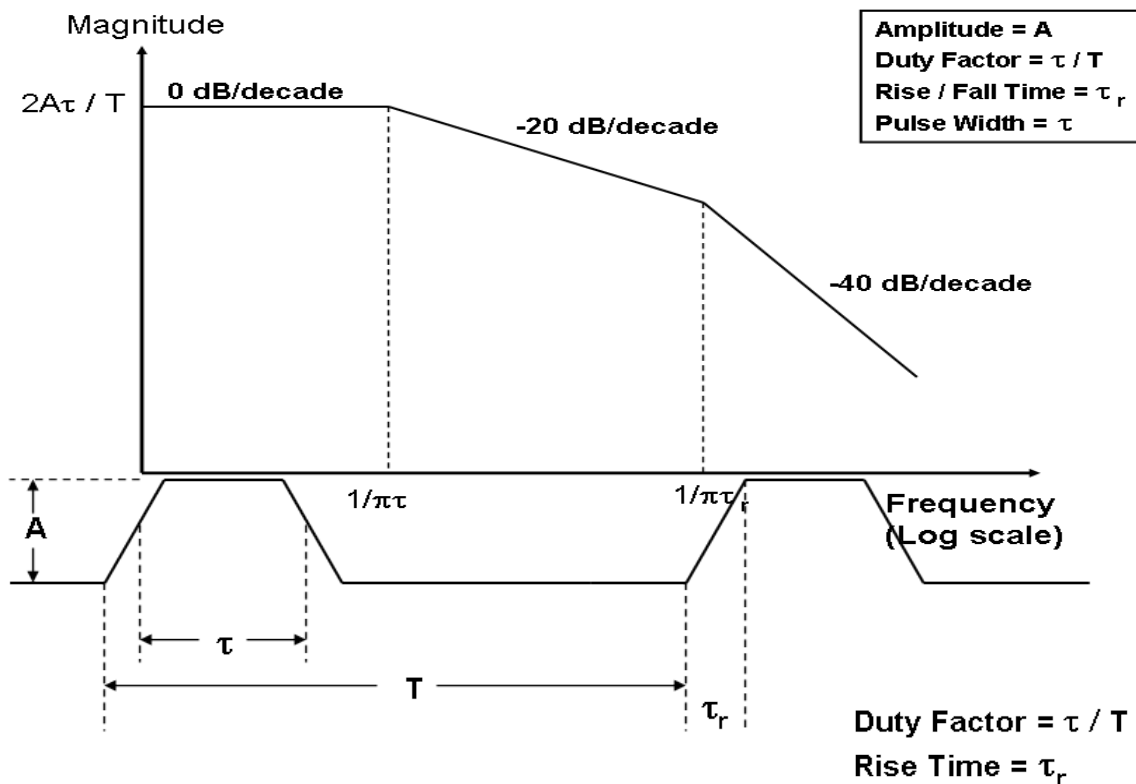


Figure 6 —CE102M-3 pulsed signals

5.4.3 CE102M verification

5.4.3.1 CE102M verification purpose

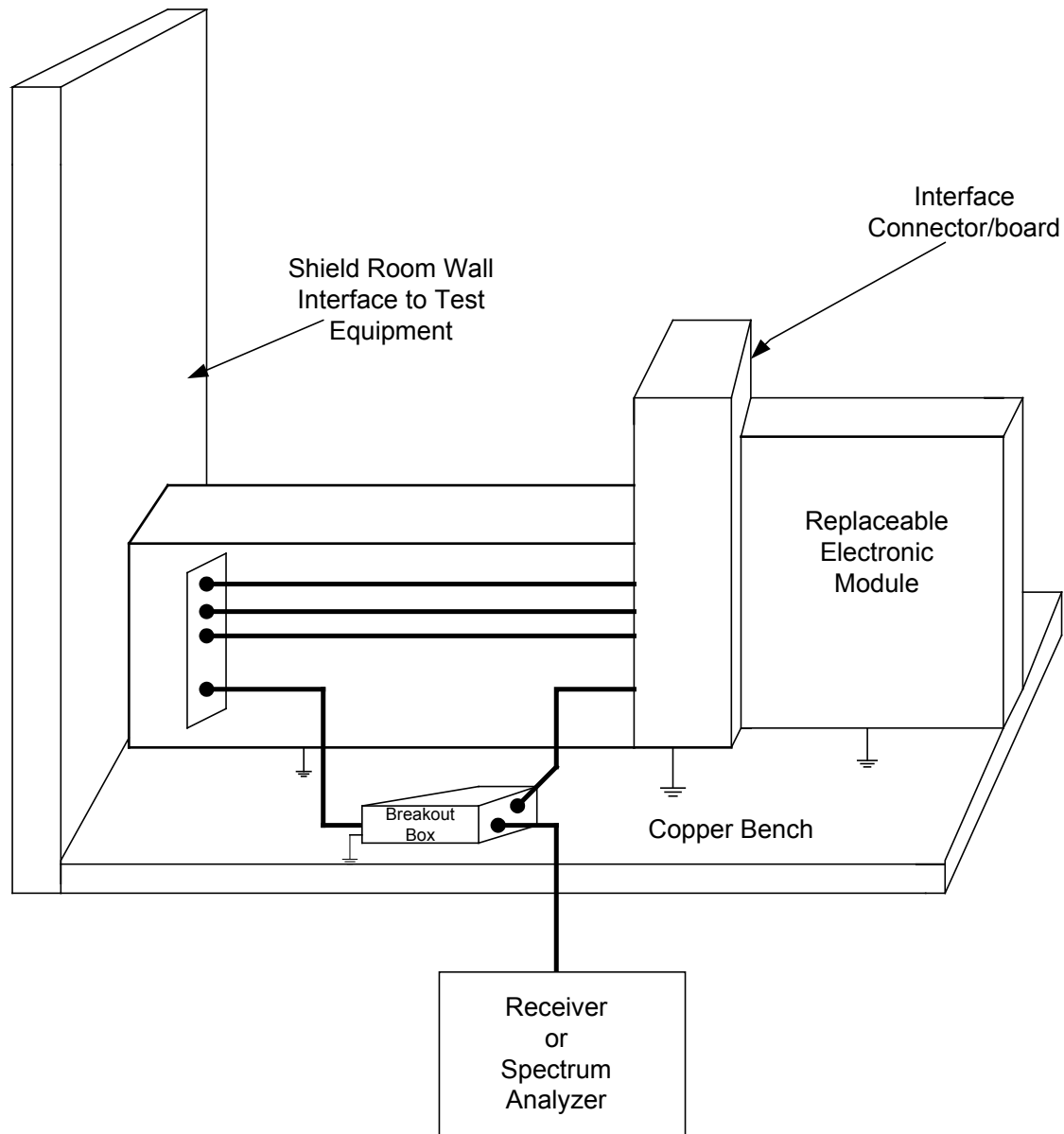
This test procedure is used to verify that electromagnetic emissions from the REM do not exceed the specified requirements for power input leads, control lines, and signal wires including returns.

5.4.3.2 CE102M test equipment

The test equipment shall be as follows:

- Measurement receiver or spectrum analyzer
- Data recording device
- Signal generator
- Attenuator, 20 dB, 50 Ω
- Oscilloscope
- LISN
- MDN
- Shielded interface adapter unit used for other module tests (see Figure 7 (CE102M-3) for signal lines and Figure 8 (CE102M-4) for power lines)

- i) High impedance/wide bandwidth active voltage probe
- j) Signal and control lines breakout box



NOTE—See Annex A for information on the breakout box.

Figure 7 —CE102M-3 measurement setup for signal lines

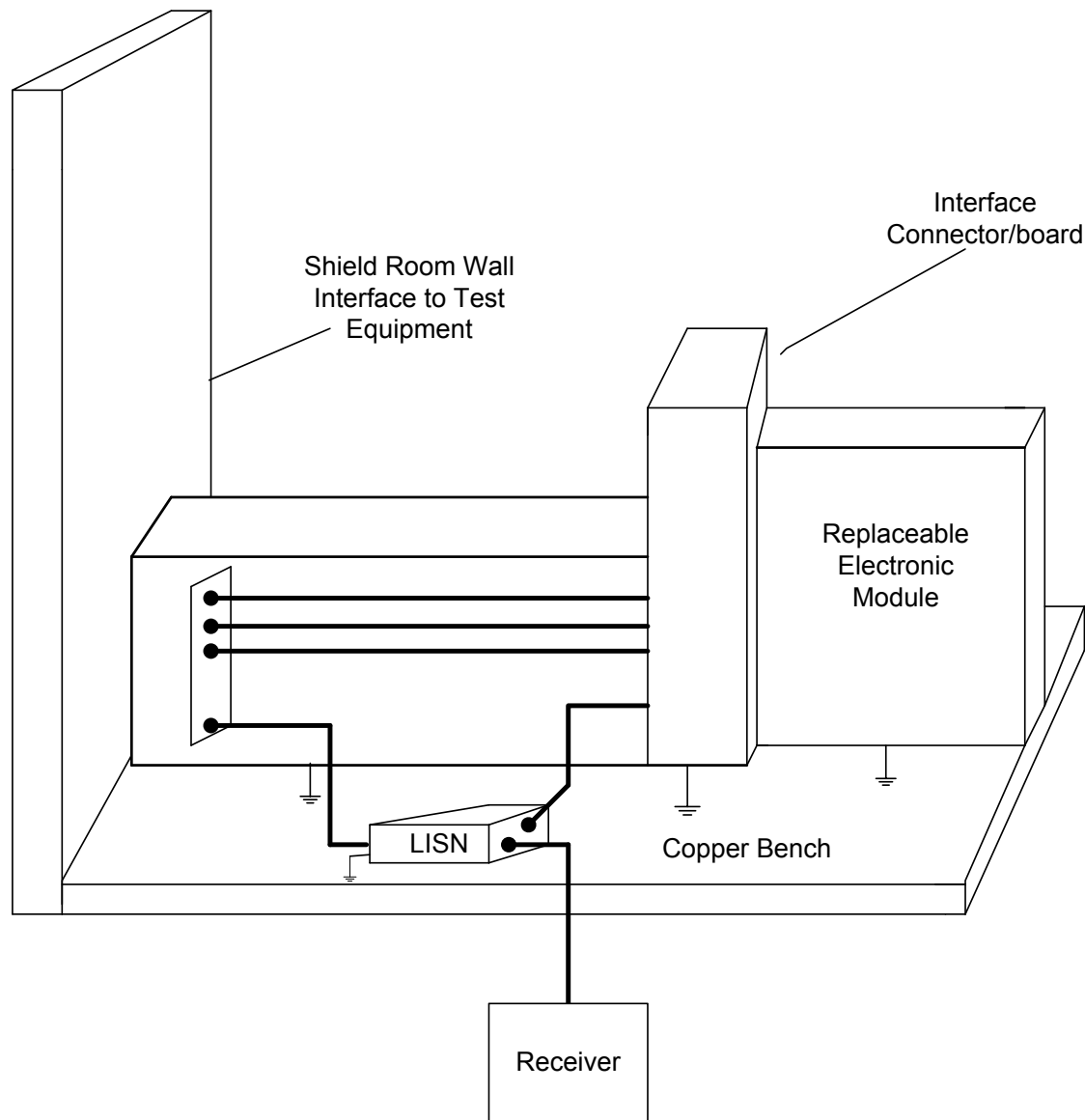


Figure 8 —CE102M-4 measurement setup for power lines

5.4.3.3 CE102M test setup

The test setup shall be as follows:

Maintain a basic test setup for the REM as shown and described in Figure 3, Figure 4, and 4.4.

5.4.3.3.1 CE102M test calibration

- a) Configure the test setup for the measurement system check as shown in Figure 9 (CE102M-2). Ensure that the REM power source is turned off.
- b) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN or MDN.
- c) Conduct CE102M REM testing:
 - 1) Configure the test setup for compliance testing of the REM as shown in Figure 6 (CE102M-3).
 - 2) Connect the measurement receiver to the 20 dB attenuator on the signal output port of the LISN or MDN.

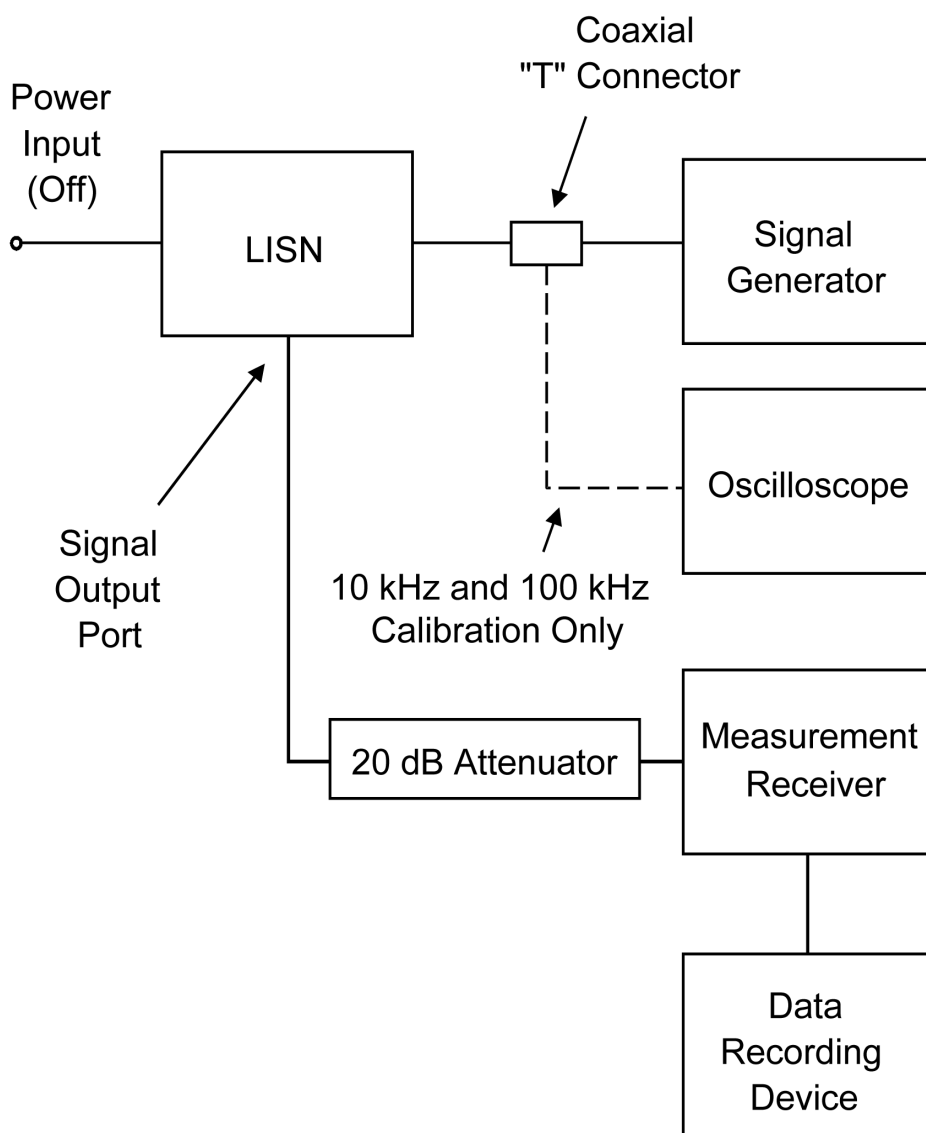


Figure 9 —CE102M-2 measurement system calibration setup, with LISN

5.4.3.3.2 CE102M test procedures

The test procedures shall be as follows:

- a) Turn on the measurement equipment and allow a sufficient time for stabilization.
- b) Calibration:
 - 1) Perform the measurement system check using the measurement system check setup of Figure 9 (CE102M-2).
 - 2) Apply a signal level that is at least 6 dB below the limit at 10 kHz, 100 kHz, 2 MHz and 10 MHz to the power output terminal of the LISN or MDN. At 10 kHz and 100 kHz, use an oscilloscope to calibrate the signal level and verify that it is sinusoidal. At 2 MHz and 10 MHz, use a calibrated output level directly from a 50 Ω signal generator.
 - 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 or MDN 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.
 - 5) Repeat 5.4.3.3.2(b)(2) through 5.4.3.3.2(b)(4) for each LISN or MDN.
- c) REM testing:
 - 1) Perform emission data scans using the measurement setup of Figure 6 (CE102M-3).
 - 2) Turn on the REM and allow a sufficient time for stabilization.
 - 3) Select an appropriate lead for testing.
 - 4) Scan the measurement receiver over the applicable frequency range, using the bandwidths and minimum measurement times in the Table 2.
 - 5) Repeat 5.4.3.3.2(c)(3) through 5.4.3.3.2(c)(4) for each power lead.

5.4.3.4 CE102M test data presentation

Data presentation shall be as follows:

- a) Continuously and automatically plot amplitude versus frequency profiles on X-Y axis outputs.
- b) Manually gathered data is not acceptable except for plot verification.
- c) Display the applicable limit on each plot.
- d) 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.
- e) Provide plots for both the measurement system check and measurement portion procedure.

5.5 CS101M, conducted susceptibility, power supply REM leads, 30 Hz to 150 kHz

5.5.1 CS101M applicability

This requirement is applicable only to REMs that distribute ac or dc power to other REMs or modules within the system rack or chassis from secondary power available through REM internal interfaces. These internal interfaces are power wiring that connect only to other REMs or components within the common rack assembly but are not routed through the power REM edge connector. This requirement applies to the ac and dc input power leads for the power REM, including dedicated returns but not including common (e.g., chassis) returns. If the REM is dc operated, this requirement is applicable over the frequency range of 30 Hz to 150 kHz. If the REM is ac operated, this requirement is applicable starting from the second harmonic of the REM power frequency and extending to 150 kHz. The external interfaces category includes REMs whose signal and control leads interface with other REMs or components outside the common rack assembly.

5.5.2 CS101M limit

The REM shall not be damaged and shall maintain the functionality required in its individual procurement specification during exposure to a test signal with voltage levels as specified in Figure 10 (CS101M-1). The requirement is also met when the power source is adjusted to dissipate the power level shown in Figure 11 (CS101M-2) in a 0.5 Ω load and the REM is not susceptible. For REMs that are power supplies, deriving power from the platform primary power source, the baseline CS101M limit shown in Figure 10 (CS101M-1) shall apply. For the output or secondary side of REMs that are power supplies, and for the input power of REMs deriving their power from secondary power, the test level shall be relaxed by 30 dB from the baseline CS101M limit shown in Figure 10 (CS101M-1).

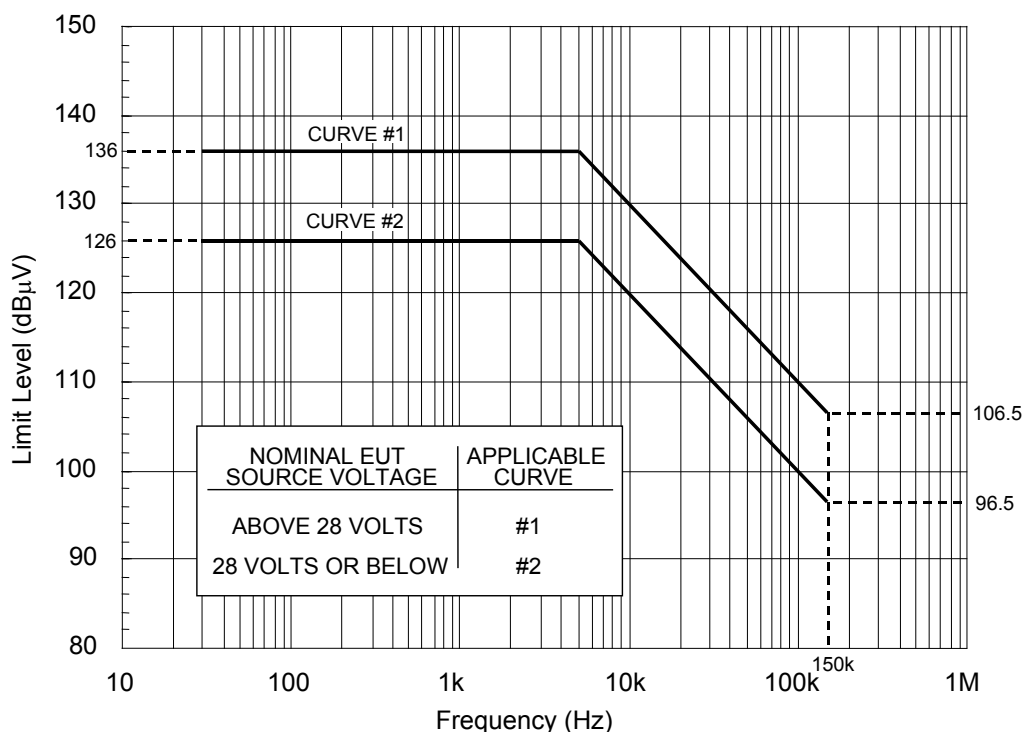


Figure 10 —CS101M-1 voltage limit for all applications

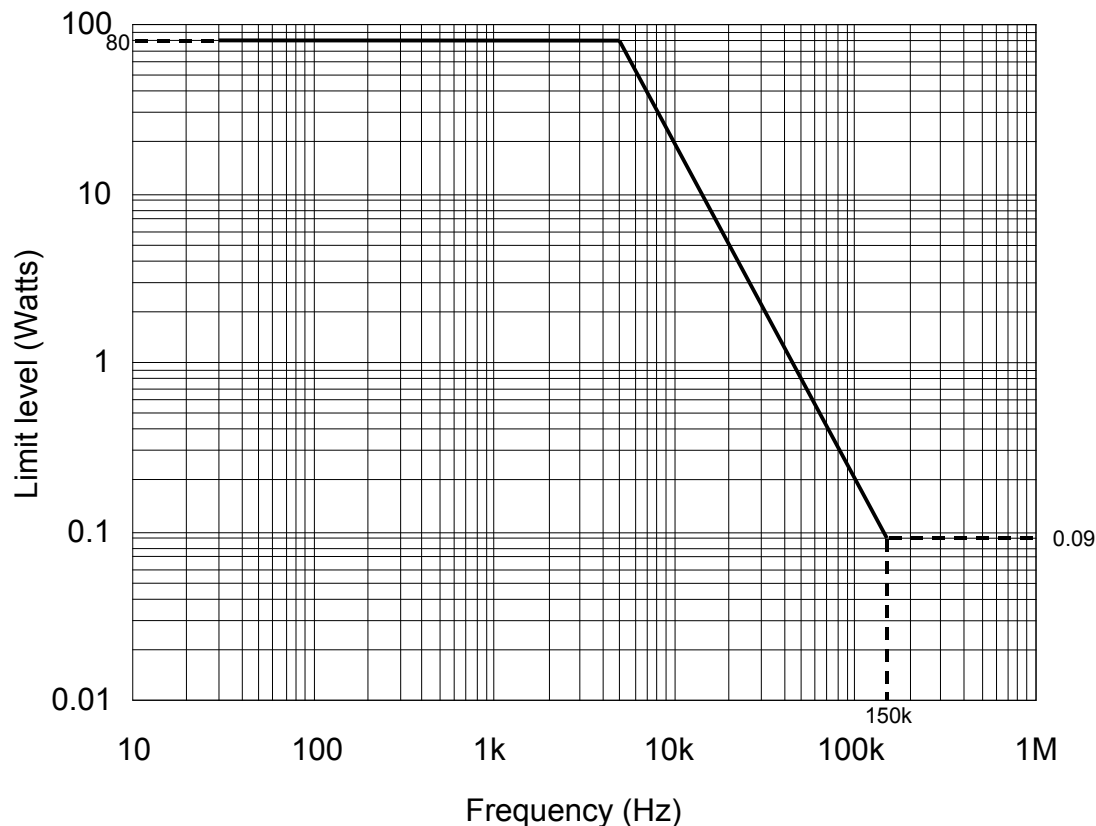


Figure 11 —CS101M-2 power limit for all applications

5.5.3 CS101M verification

5.5.3.1 CS101M verification purpose

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

5.5.3.2 CS101M 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 Ω
- h) LISNs

5.5.3.3 CS101M test setup

The test setup shall be as follows:

- a) Maintain a basic test setup for the REM as shown and described in Figure 3, Figure 4, and 4.4.
- b) Calibration:
 - 1) Configure the test equipment in accordance with Figure 12 CS101M-3.
 - 2) Set up the oscilloscope to monitor the voltage across the 0.5 Ω resistor.
- c) REM testing:
 - 1) For dc or single-phase ac power, configure the test equipment as shown in Figure 13 CS101M-4.
 - 2) For three-phase ungrounded power, configure the test setup as shown in Figure 14 CS101M-5.
 - 3) For three-phase wye power (four power leads), configure the test setup as shown in Figure 15 CS101M-6.
 - 4) For secondary power lines, the simulated loads shall consume 50% of the maximum steady state design power level, or 100% of the nominal steady state operational power level, whichever is greater.

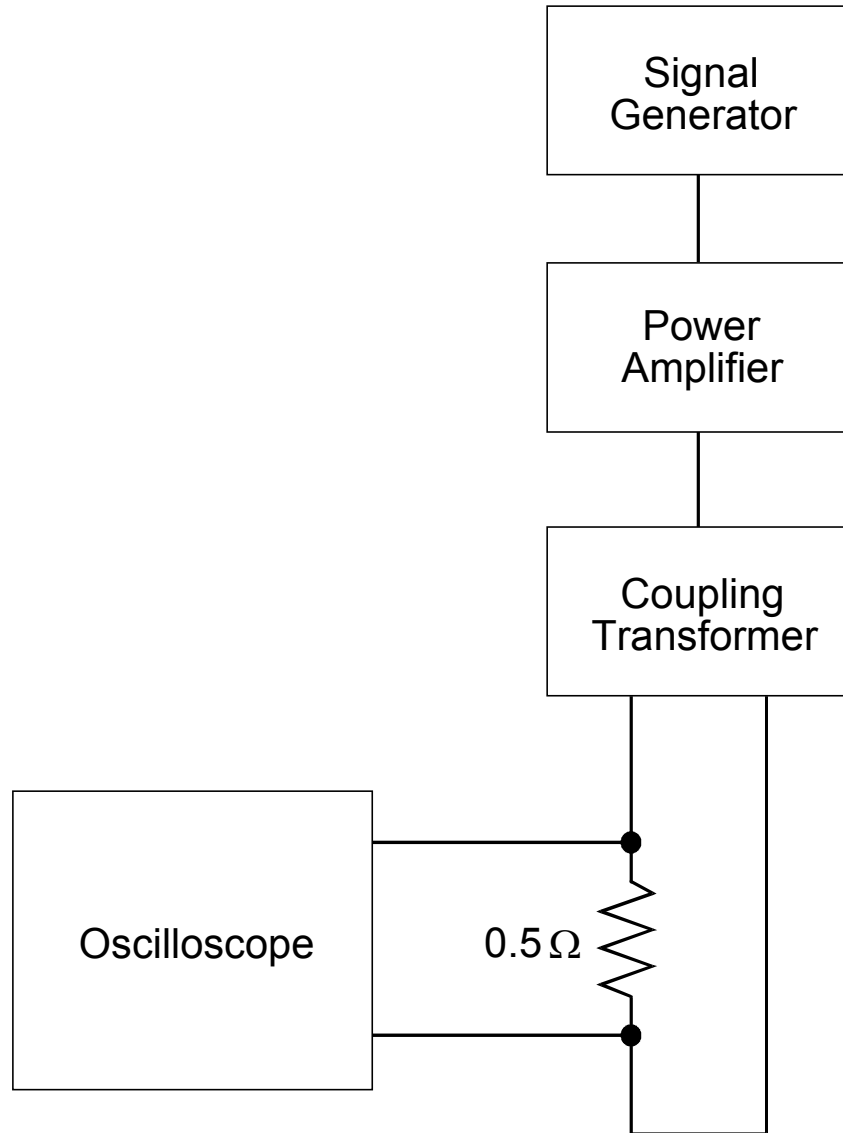
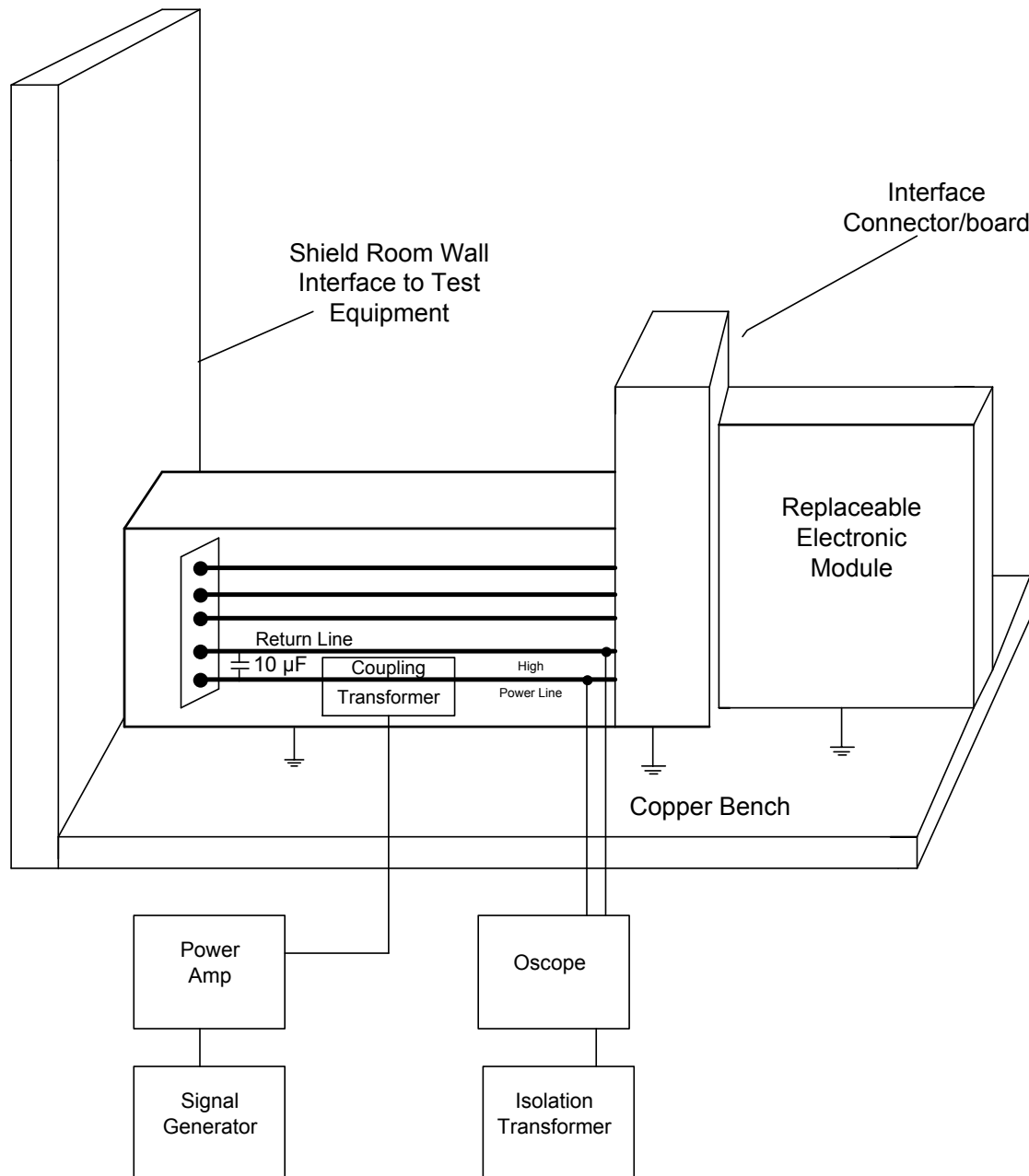


Figure 12 —CS101M-3 calibration



CS101
Signal Injection, dc or Single Phase ac

Figure 13 —CS101M-4 signal injection, dc or single-phase ac

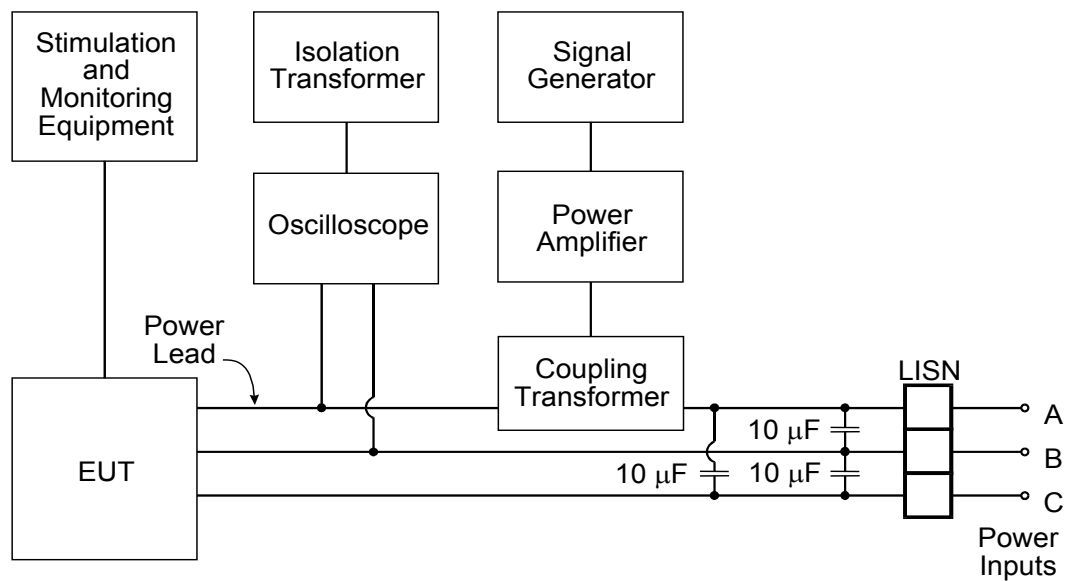


Figure 14 —CS101M-5 signal injection, three-phase ungrounded

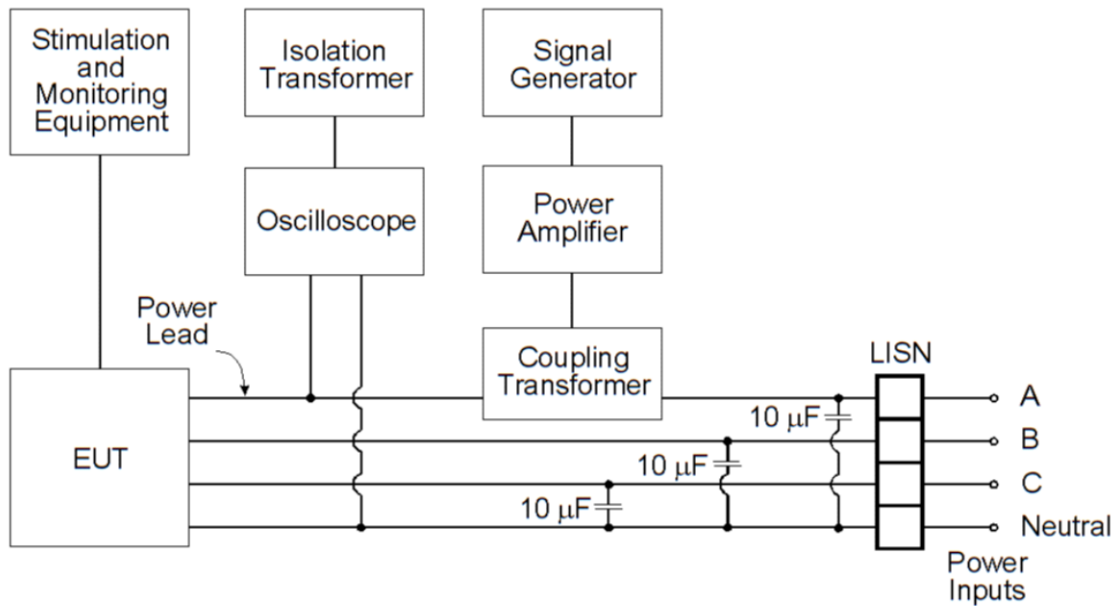


Figure 15 —CS101M-6 signal injection, three-phase wye

5.5.3.4 CS101M 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 for the limit. Verify that 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) REM testing:
 - 1) Turn on the REM and allow sufficient time for stabilization.

CAUTION

Exercise care when performing this test because the “safety ground” of the oscilloscope is disconnected due to the isolation transformer 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—Power is limited to the level calibrated in 5.5.3.4(c)(3).
- 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.
- 4) Conduct a susceptibility evaluation as follows:
 - a) Monitor the REM for degradation of performance.
 - b) If susceptibility is noted, determine the threshold level in accordance with 4.4.16.3 and verify that it is above the limit.
 - c) Repeat 5.5.3.4(c)(2) through 5.5.3.4(c)(3) for each power lead, as required. For three-phase delta power, the measurements shall be made according to Table 6.

Table 6—Three-phase delta

Coupling transformer in line	Voltage measurement from
A	A to B
B	B to C
C	C to A

For three-phase wye power, the measurements shall be made according to Table 7.

Table 7—Three-phase wye

Coupling transformer in line	Voltage measurement from
A	A to neutral
B	B to neutral
C	C to neutral

5.5.3.5 CS101M test data presentation

Data presentation shall be as follows:

- Provide graphical or tabular data showing the frequencies and amplitudes at which the test was conducted for each lead.
- Provide data on any susceptibility thresholds and the associated frequencies that were determined for each power lead.
- Provide indications of compliance with the applicable requirements for the susceptibility evaluation specified in 5.5.3.4 for each lead.

5.6 CS103M conducted susceptibility, antenna port, intermodulation, 15 kHz to 10 GHz

5.6.1 CS103M applicability

This receiver front-end susceptibility requirement is applicable to REMs that have interfaces directly to the antenna ports of other equipment and subsystems, such as communications receivers, RF amplifiers, transceivers, radar receivers, acoustic receivers, and electronic warfare receivers.

5.6.2 CS103M limit

The REM shall not be damaged, shall maintain the functionality required in its individual procurement specification, and shall not exhibit any intermodulation products beyond the tolerances defined in its individual procurement specification when subjected to the limit requirement provided in the individual procurement specification.

5.6.3 CS103M verification

5.6.3.1 CS103M verification purpose

This test procedure is used to determine the presence of intermodulation products that may be caused by undesired signals at the REM antenna input terminals.

5.6.3.2 CS103M test requirements

The required test equipment, setup, procedures, and data presentation shall be determined on a case-by-case basis in accordance with the guidance provided in A.5.4 of the annex of this standard.

5.7 CS104M, conducted susceptibility, antenna port, rejection of undesired signals, 30 Hz to 20 GHz

5.7.1 CS104M applicability

This receiver front-end susceptibility requirement is applicable to equipment and subsystems, such as communications receivers, RF amplifiers, transceivers, radar receivers, acoustic receivers, and electronic warfare receivers, as specified in the individual procurement specification.

5.7.2 CS104M limit

The REM shall not be damaged, shall maintain the functionality required in its individual procurement specification, and shall not exhibit any undesired response beyond the tolerances defined in its individual procurement specification when subjected to the limit requirement provided in the individual procurement specification.

5.7.3 CS104M verification

5.7.3.1 CS104M verification purpose

This test procedure is used to determine the presence of spurious responses that may be caused by undesired signals at the REM antenna input terminals.

5.7.3.2 CS104M test requirements

The required test equipment, setup, procedures, and data presentation shall be determined on a case-by-case basis in accordance with the guidance provided in A.5.5 of the annex of this standard.

5.8 CS105M, conducted susceptibility, antenna port, cross-modulation, 30 Hz to 20 GHz

5.8.1 CS105M applicability

This receiver front-end susceptibility requirement is applicable only to receivers that normally process amplitude-modulated RF signals, as specified in the individual procurement specification.

5.8.2 CS105M limit

The REM shall not be damaged, shall maintain the functionality required in its individual procurement specification, and shall not exhibit any undesired response, due to cross-modulation, beyond the tolerances defined in its individual procurement specification when subjected to the limit requirement provided in the individual procurement specification.

5.8.3 CS105M verification

5.8.3.1 CS105M verification purpose

This test procedure is used to determine the presence of cross-modulation products that may be caused by undesired signals at the REM antenna terminals.

5.8.3.2 Test requirements

The required test equipment, setup, procedures, and data presentation shall be determined in accordance with the guidance provided in A.5.6 of the annex of this standard.

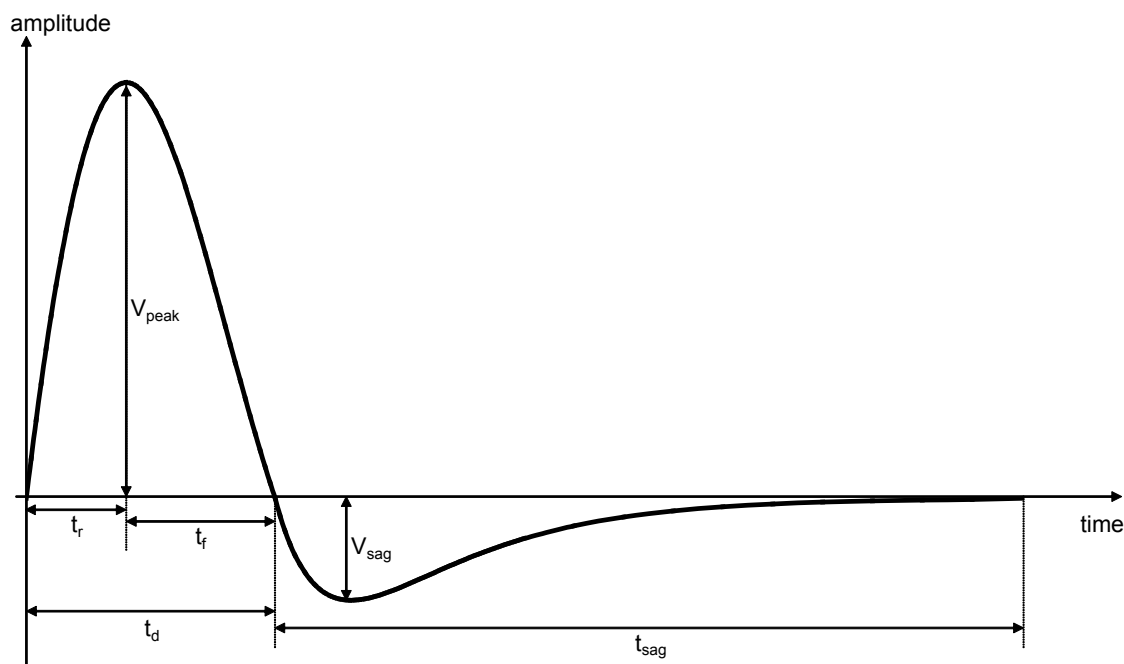
5.9 CS106M, conducted susceptibility, transients, power leads

5.9.1 CS106M applicability

This requirement is applicable to submarine and surface ship equipment and subsystem ac and dc input power leads, not including grounds and neutrals.

5.9.2 CS106M limit

The EUT shall not exhibit any malfunction, degradation of performance, or deviation from specified indications, beyond the tolerances indicated in the individual equipment or subsystem specification, when subjected to a test signal with voltage levels as specified in Figure 16 (CS106M-1).



V_{peak} is 400 V peak
 t_r is 1.5 μs , $\pm 0.5 \mu\text{s}$
 t_f is 3.5 μs , $\pm 0.5 \mu\text{s}$
 t_d is 5.0 μs , $\pm 22\%$
 V_{sag} is less than or equal to 120 V peak (maximum)
 t_{sag} is less than or equal to 20 μs
 Measured across a 5.0 Ω noninductive resistor.

Figure 16 —CS106M-1 voltage limit

5.9.3 CS106M verification

5.9.3.1 CS106M verification purpose

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

5.9.3.2 CS106M test equipment

The test equipment shall be as follows:

- Transient generator, $< 2 \Omega$ source impedance
- Capacitor, 10 μf
- Oscilloscope
- Resistor, 5 Ω (noninductive)
- Isolation transformer

5.9.3.3 CS106M setup

The tests maintain a basic test setup for the EUT as shown and described in Figure 3, Figure 4, and 4.4.

Calibration is as follows:

- a) Configure the test equipment in accordance with Figure 17 CS106M-2. Set up the oscilloscope to monitor the specified voltage across the $5\ \Omega$ noninductive resistor.
- b) EUT testing:
 - 1) For DC or single-phase ac power, configure the test equipment as shown in Figure 18 (CS106M-3).
 - 2) For three-phase ungrounded power, configure the test setup as shown in Figure 19 (CS106M-4).
 - 3) For three-phase wye power (four power leads), configure the test setup as shown in Figure 20 (CS106M-5).

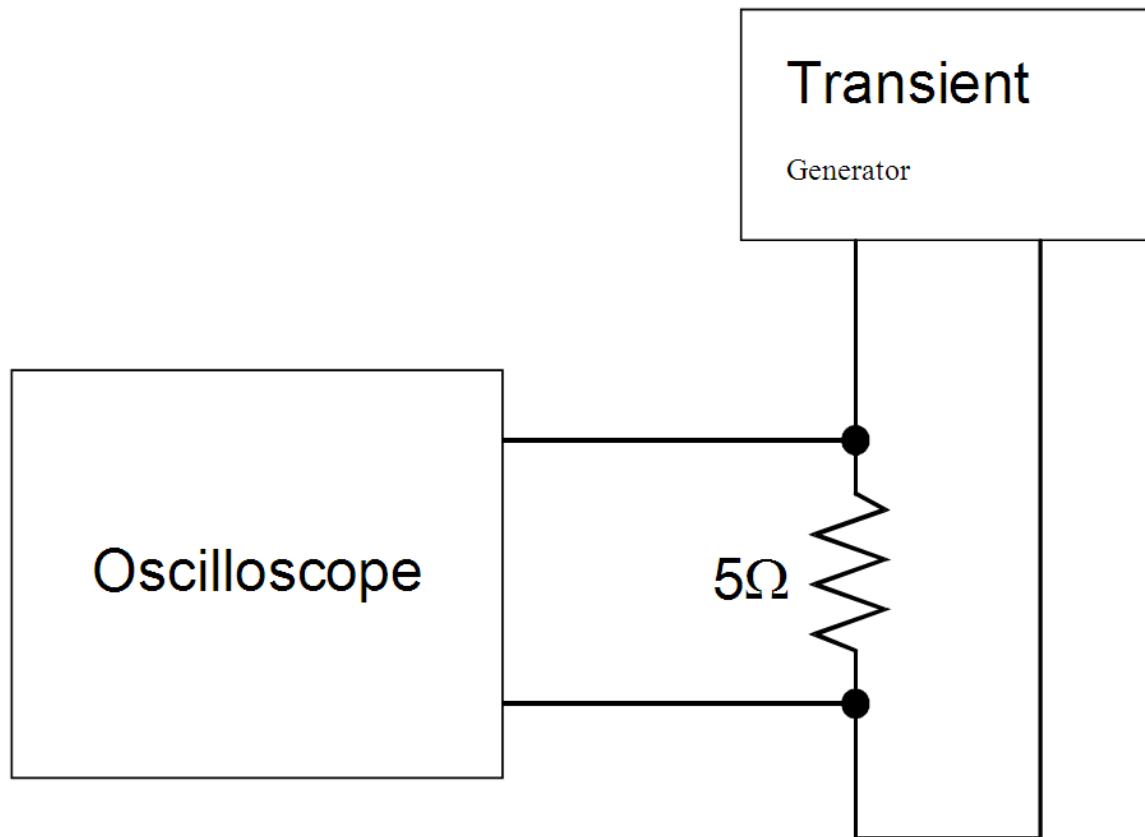


Figure 17 —CS106M-2 Calibration

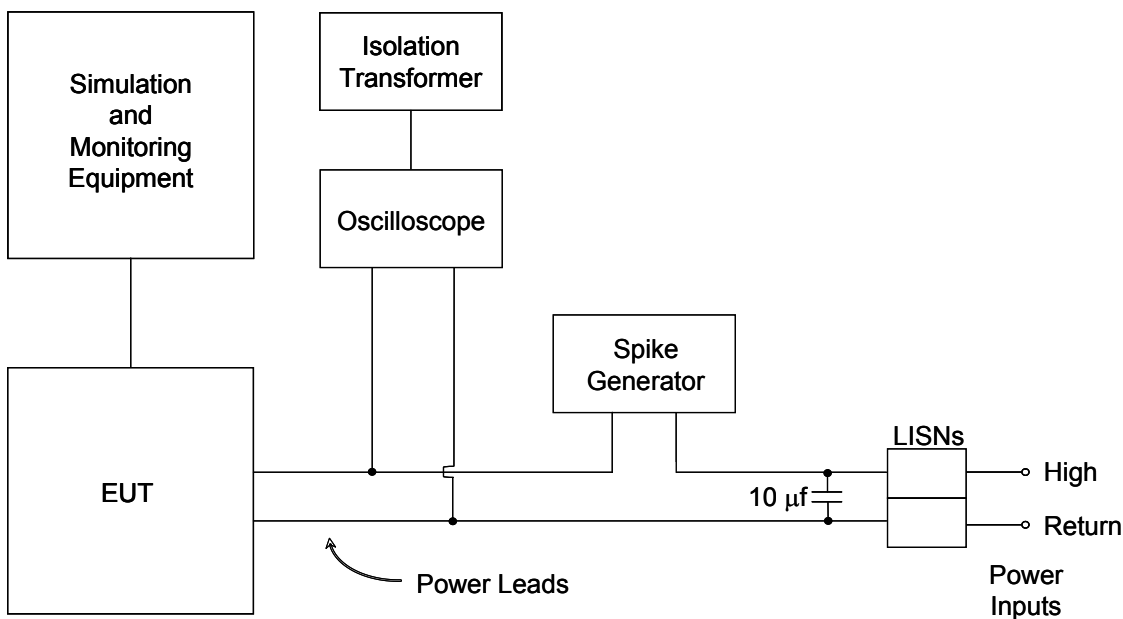


Figure 18 —CS106M-3 signal injection, dc or single-phase ac

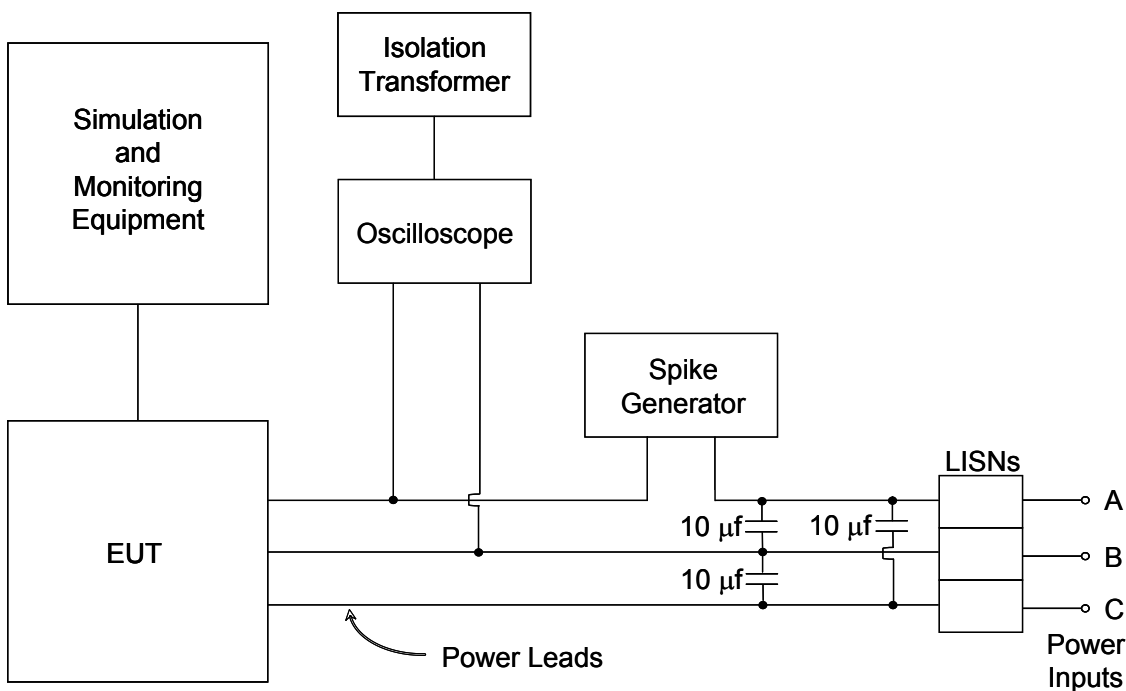


Figure 19 —CS106M-4 signal injection, three-phase ungrounded

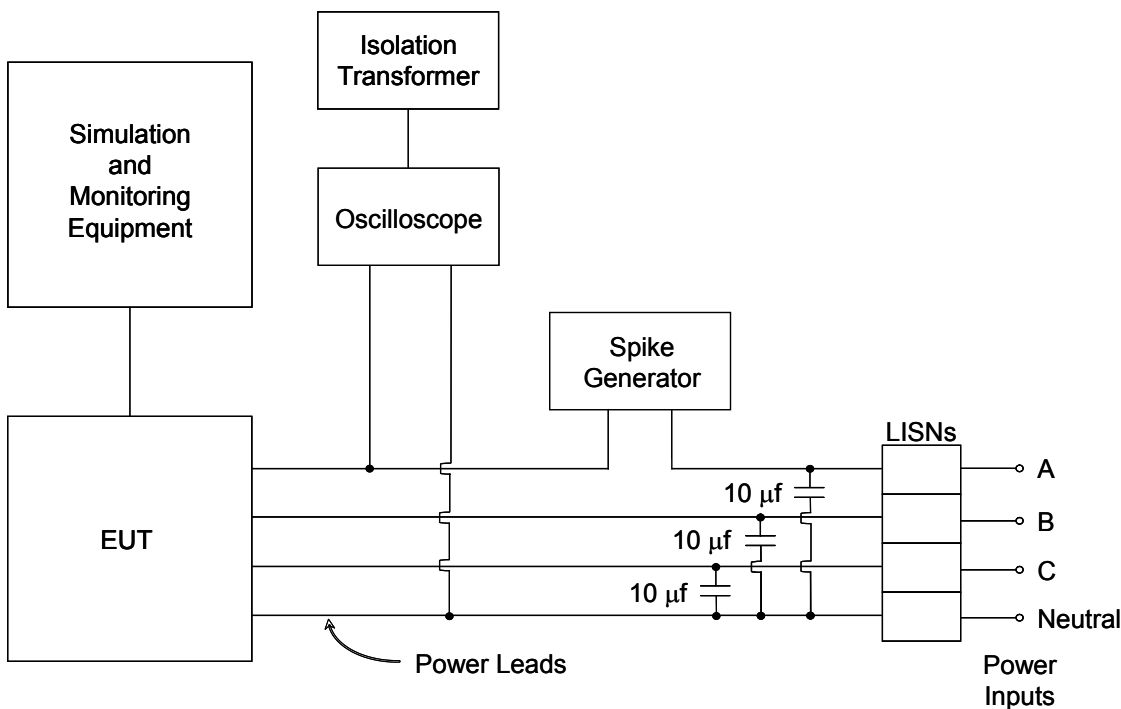


Figure 20 —CS106M-5 signal injection, three-phase wye

5.9.3.4 CS106M test procedures

Test procedures shall be as follows:

- a) Turn on the measurement equipment and allow sufficient time for stabilization.
- b) Calibration:
 - 1) Set the transient generator to minimum output.
 - 2) Increase the applied signal until the oscilloscope indicates the voltage level corresponding to the limit. Verify the output waveform and pulse width.
 - 3) Record the setting of the transient generator.
- 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 due to the isolation transformer and a shock hazard may be present.

- 2) Set the transient generator to minimum output. Increase the signal level until the required voltage is reached on the power lead or the spike generator calibration set point is obtained.
NOTE—The calibration set point is that obtained in 5.9.3.4(b)(3).
- 3) While maintaining at least the required signal level, apply transient pulses to the test sample’s ungrounded input lines at a pulse repetition rate of between 5 and 10 pulses per second for not less than 5 min.
- 4) Repeat 5.9.3.4(c)(2) through 5.9.3.4(c)(3) for each power lead and test condition, as required.

5.9.3.5 Susceptibility evaluation

- a) Monitor the EUT for degradation of performance.
- b) If susceptibility is noted, determine and record its threshold level and phase position on the ac waveform in accordance with 4.4.16.3 and verify that it is above the limit.

5.9.4 Data presentation

Data presentation shall be as follows:

- a) Provide oscilloscope photographs of the calibration waveform obtained in 5.9.3.4(b)(3).
- b) Provide oscilloscope photographs of the injected waveform for each lead.
- c) Provide data on any susceptibility thresholds that were determined for each power lead.
- d) Provide indications of compliance with the applicable requirements for the susceptibility evaluation listed in 5.9.3.5 for each lead.

5.10 CS114M conducted susceptibility, bulk cable injection, 10 kHz to 200 MHz

5.10.1 CS114M applicability

This requirement is applicable to all interconnecting cables, including power cables. It applies both to REMs with interfaces contained within the common rack and to REMs with external interfaces beyond the common rack.

5.10.2 CS114M limit

The REM shall not be damaged, shall maintain the functionality required in its individual procurement specification, and shall exhibit no malfunction, degradation of performance, or deviation from specified indications beyond the tolerances defined in its individual procurement specification when subjected to a injection probe drive level that has been precalibrated to the appropriate current limit shown in Figure 21 and is modulated as specified 5.10.3.4 item c). The appropriate limit curve in Figure 21 shall be selected from Table 8. Requirements are also met if the REM is not susceptible at forward power levels sensed by the coupler that are below those determined during calibration, provided that the actual current induced in the cable under test is 6 dB or greater than the calibration limit.

Any interfaces that are external to the host rack shall be constructed as in the installed configuration and shall be subject to the requirements of Figure 21, unless otherwise specified by the procuring activity. If the REM is hosted in a rack with only internal interfaces, the maximum level for the applicable application can be reduced by 12 dB in Figure 22 for reduced coupling levels for internal power and signal lines. Host rack reductions greater than 12 dB should be supported by the manufacturer of the host rack or characterized by measurement or analysis.

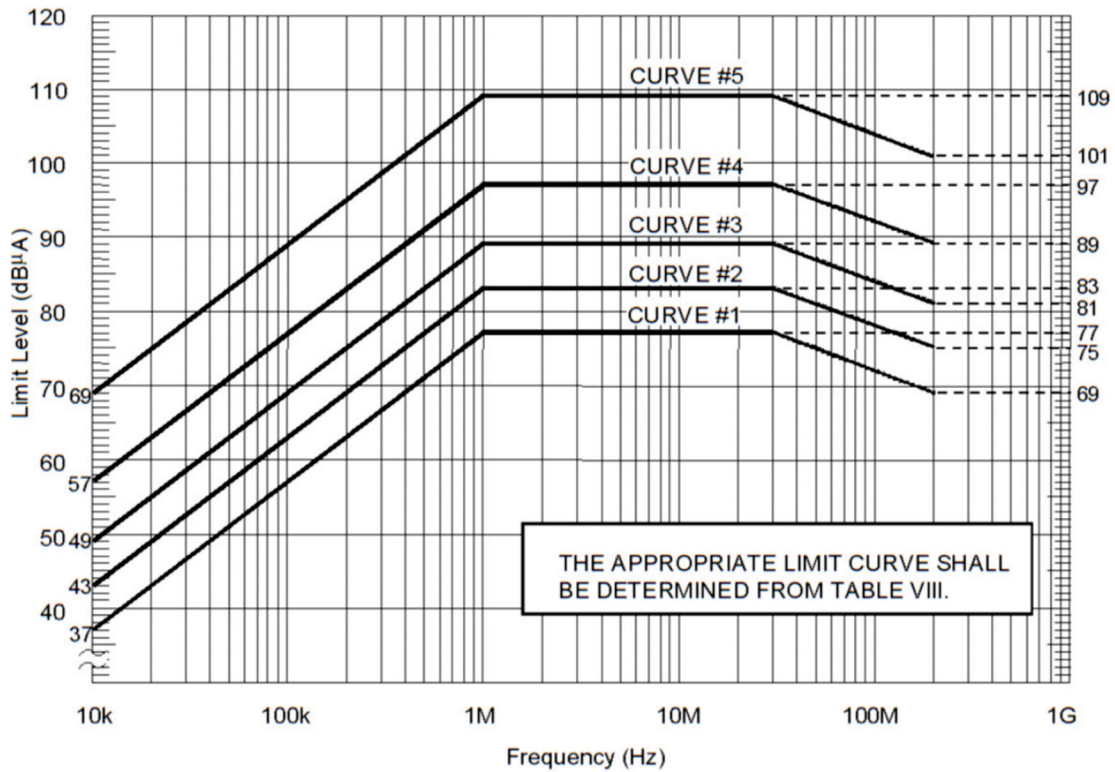


Figure 21 —CS114M-1 calibration limit for all applications, external interfaces

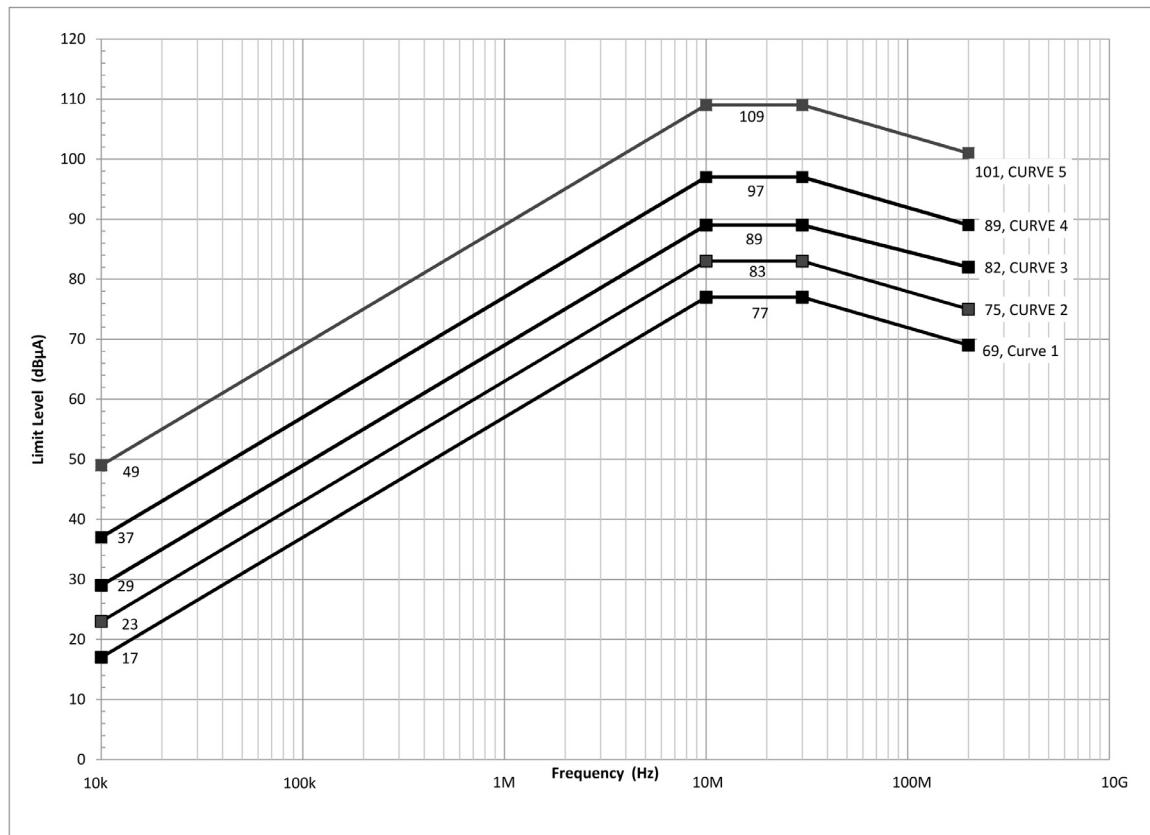


Figure 22 —CS114M-1a calibration limit for all applications; internal power and signal interfaces