

American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

C63[®]

Accredited Standards Committee C63[®] — Electromagnetic Compatibility

Accredited by the
American National Standards Institute

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ANSI C63.4-2014
(Revision of
ANSI C63.4-2009)

American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

Accredited Standards Committee C63®—Electromagnetic Compatibility

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Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: U.S. consensus standard methods, instrumentation, and facilities for measurement of radio-frequency (RF) signals and noise emitted from electrical and electronic devices in the frequency range of 9 kHz to 40 GHz are specified. This standard does not include generic or product-specific emission limits. Where possible, the specifications herein are harmonized with other national and international standards used for similar purposes.

Keywords: ANSI C63.4, conducted emission testing, conducting ground plane, digital equipment, electric field measurement, line impedance stabilization network, low-voltage electrical equipment, low-voltage electronic equipment, magnetic field measurement, normalized site attenuation, radiated emission testing, radio-noise emissions, radio-noise power, site attenuation, unintentional radiators

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Introduction

This introduction is not part of ANSI C63.4-2014, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

Almost from the beginning of radio broadcasting, the electric utility companies were faced with the problem of radio noise. In 1924, the National Electric Light Association appointed a committee to study the subject. The manufacturers of electric power equipment had encountered similar problems, and in 1930, a subcommittee of the NEMA Codes and Standards Committee was established.^a The following year, the EEI NEMA-RMA Joint Coordination Committee on Radio Reception was organized.

The Joint Coordination Committee issued a number of reports, among which was Methods of Measuring Radio Noise, 1940. This report included specifications for a radio-noise and field-strength meter for the frequency band 0.15 MHz to 18 MHz. The report recommended procedures for measuring radio-noise voltage (conducted noise) from low- and high-voltage apparatus, making noise field-strength measurements near overhead power lines, determining broadcast field strengths, and collecting data on which to base tolerable limits for radio noise.

During World War II, the needs of the armed services for instruments and methods for radio-noise measurement, particularly at frequencies higher than the broadcast band, became pressing, and in 1944, work on developing suitable specifications was begun by a special subcommittee, called the ASA Sectional Committee C63, Radio-Electrical Coordination. This special subcommittee developed a wartime specification that became Army-Navy Specification JAN-I-225 issued in 1945 and later approved as C63.1-1946, American War Standard-Method of Measuring Radio Interference of Electrical Components and Completed Assemblies of Electrical Equipment for the Armed Forces from 150 kHz to 20 MHz.

In 1951, ASA Sectional Committee C63, through its Subcommittee No. 1 on Techniques and Developments, started work on improving and extending measurement methods, taking into account methods mentioned in the 1940 report and those in current military specifications. In the course of this work, Subcommittee No. 1 developed the standard C63.4-1963, Radio-Noise Voltage and Radio-Noise Field Strength, 0.015 to 25 MHz, Low-Voltage Electric Equipment and Non-Electric Equipment. Work continued within the subcommittee on developing methods of measurement above 25 MHz and the subsequent inclusion of these measurement methods in future revisions of C63.4-1963.

C63.4-1963 was reaffirmed in 1969, and work within the subcommittee was accelerated to produce a draft standard that would make use of the experience gained by several years use of the standard, extend its coverage to embrace a broader frequency range, and incorporate newer measurement techniques that had been developed within the United States and by the International Special Committee on Radio Interference (CISPR) as set forth in CISPR 14 and CISPR 16. The revised standard was published in 1981.

Although many improvements had been made in ANSI C63.4 in the several revisions, the reproducibility of measurements of radiated interference from one test site to another had not been completely satisfactory. In 1982, a concerted effort was organized in Subcommittee No. 1 of the American National Standards Committee C63 to determine how the technique could be improved. Evidence showed that the variability was caused, in part, by the following inadequate processes:

- Control of site reference ground plane conductivity, flatness, site enclosures, effects of surrounding objects, and certain other site construction features
- Accounting for antenna factors, associated cabling, and balun and device under test characteristics

^a Acronyms: ASA, American Standards Association; EEI, Edison Electric Institute; JAN, Joint Army-Navy; NEMA, National Electrical Manufacturers Association; RMA, Radio Manufacturers Association.

- Consideration of mutual coupling effects between the device under test and the receiving antenna and their images in the reference ground plane

Accordingly, ANSI C63.4 was further revised in 1988, and the standards ANSI C63.5, ANSI C63.6, and ANSI C63.7 were prepared to provide additional information.

In late 1988 and in 1989, the importance of including additional details on test procedures to provide proper evaluation of complex systems, such as information technology equipment and systems, was recognized. Measurements on such systems can be sensitive to the exact arrangement of equipment units and interconnecting cables. The 1991 edition of ANSI C63.4 was the result of a major effort on the part of the members of the Committee and various other participating individuals.

Work on another revision began during 1991 to provide for the testing of intentional as well as unintentional radiators. The 1992 ANSI C63.4 document included these changes. In 1994, work began on harmonizing the document with emerging international standards, clarifying several issues with respect to ac power-line conducted emission measurements and turntable usage, and standardizing terminology. Also added were provisions for the use of transverse electromagnetic (TEM) wave devices for measuring emissions, extension of the lowest frequency from 10 kHz down to 9 kHz, and revisions to the clause on the artificial hand. Minor changes were made to the normalized site attenuation tables to correct rounding errors. That work culminated in the 2001 issue of ANSI C63.4.

When the 2001 issue of ANSI C63.4 was approved, several subject areas were identified that needed to be considered for the next edition. Those subjects included clarification of what is mandatory and that figures are examples while text takes precedence; allowing emission measurement instrumentation, such as a spectrum analyzer, which does not fully meet either CISPR 16 or ANSI C63.2, to be used, but in case of dispute allowing only instrumentation meeting either of these two standards to take precedence; clarification of instrumentation calibration interval requirements; identifying new test setups when power accessories (power packs) are either the equipment under test (EUT) or not; allowing use of “loop back” cable connections for large floor-standing equipment to accommodate the arrangement of cables connected to output ports to be connected to input ports under certain conditions; warning that test facilities not allowing full antenna height search may not yield sufficient data to predict radiated emissions at a site that meets normalized site attenuation; clarifying EUT setups and minimum ports that need to be populated during personal computer (PC) testing; clarifying test frequencies for intentional radiator measurements; and correcting errors on certain figures, tables, and appendices. The resolution of these subject areas as well as other clarifications appeared in the 2003 edition of ANSI C63.4.

As was the case for the 2003 edition of this standard, several topics continued to be identified for future editions of the standard. There were several areas of interest to be considered for the 2009 edition. Based on the maturity of the work on these areas, significant progress was achieved on the following items:

- a) Adding tables of line impedance stabilization network (LISN) impedances (in addition to the plots in the 2003 edition) with and without the use of extension cords between the EUT power connection of the LISN and the end of the extension cord where the EUT connects its power plug
- b) Clarifying and expanding the information and criteria to be used for selecting what must appear on visual displays during emission testing
- c) Updating of the signal levels used in receiver testing in Clause 12
- d) Clarifying in Annex B the LISN calibration process
- e) Accommodating the concern for the variation in antenna cable loss as a function of significant temperature variation at the test site

These areas were addressed in the 2009 edition as well as further edits in the text resulting from the process of review and entering the above changes. A significant addition was precautions that are needed in using

spectrum analyzers, which appeared in 4.2.2 and Annex H of ANSI C63.4-2009. The informative annexes for step-by-step testing procedures have been omitted, because those were mostly duplicative of the normative procedures in the main text. Basic specifications for current probes have been omitted, because LISN and voltage probe measurements remain preferred. In several clauses, figures were placed at the end of the respective clause to avoid breaking the flow of the text itself.

Additionally, based on comments received during the initial ballot of the 2009 edition, other areas deserved due attention, which led to the following changes:

- Ensured that the standards not under the control of Accredited Standards Committee (ASC) C63[®] were dated to facilitate the acceptance of the versions that are referenced, whereas the ASC C63[®] standards were undated because ASC C63[®] would be voting their acceptance.
- Added information on the effects of materials used to construct EUT support tables and antenna masts.
- Condensed the information about absorbing clamp calibration and use, as well as the artificial hand, as these continue to be in limited use.
- Retained the Clause 13 requirements for emission measurements of intentional radiators.
- Introduced site validation specifications above 1 GHz from CISPR 16-1-4:2007, while still allowing use of absorber material on the ground plane for an open-area test site (OATS) and semi-anechoic chambers without any further site validation measurements.
- For measurement methods above 1 GHz, there remained international standards activity as to the final outcome about how such measurements are to be made; meanwhile, the 2009 edition of ANSI C63.4 retained the associated provisions of ANSI C63.4-2003 with no change.

In this edition, significant changes have been made based primarily on several requests made for interpretations on the 2009 edition. The major changes are as follows:

- Addition of what should be on visual displays based on the size of the screen.
- Addition of information on test setup for tablet PCs.
- Clarification on the proper use of the average detector and the frequency range over which it is to be used (Clause 4 and Annex H).
- Replacement of Table 1 of the 2009 edition with three tables: Table 1 now shows antennas that may be used for exploratory and/or relative-comparison evaluation purposes; Table 2 shows antennas for use in making final compliance measurements on unintentional radiators; and Table 3 shows antennas for use in performing test site validation measurements.
- Addition of test site validation interval for sites used above 1 GHz.
- Modification of the requirements for the “RF absorber material on the ground plane” alternative to the use of the above 1 GHz S_{VSWR} site qualification procedure (5.5).
- Clarification of antenna factors to be used for site validation, including the information in Annex D with that in ANSI C63.5-2006.
- Addition of a new test site-specific hybrid antenna qualification procedure (Annex N).
- Reinforcement that bundled cables are not to be further manipulated to achieve maximum emissions.
- Further clarification and simplification of text on radiated emission testing above 1 GHz to continue the need, as indicated in the 2003 and 2009 editions, for the antenna to be aimed at the source of emissions and the requirement for full height scan for emission maximization.

- Addition of measurement instrumentation uncertainty using CISPR 16-4-2 and/or ANSI C63.23. However, the determination of compliance is based on the results of the compliance measurement, not taking into account measurement instrumentation uncertainty.
- Removal of Clause 13 on the testing of transmitters as that information is now contained in ANSI C63.10. Information contained in A.4 on transmitter testing is also removed.
- Addition of text in 1.2 to clarify the scope of the standard.
- Addition of a new informative annex to provide information about the application of this standard in the United States and Canada (Annex I).
- Addition of a new informative annex with guidance on selecting material for tables used in testing tabletop products (Annex J).
- Clarification and description of testing provisions for rack-mounted equipment.
- Addition of a definition of hybrid antenna as described in Annex N.
- Addition of laboratory accreditation requirement for calibrating antennas used in compliance measurements (4.5.1 and 4.7.3).

Other topics remain under consideration for the next edition of the standard to be prepared after this version. For more information, visit the ASC C63[®] Website (<http://www.c63.org>).

Dedication

This revision of ANSI C63.4 is dedicated to the memory of Ralph M. Showers, 1918–2013, Ph.D., emeritus professor of electrical engineering, University of Pennsylvania. Dr. Showers had an esteemed career dedicated to improving electronic communications by controlling electromagnetic interference. He was both a national and international leader whose contributions have had tremendous impact on standardization in the field of interference to radios, televisions, and other electronic devices.

By his long-serving presence in ASC C63[®], Dr. Showers showed his outstanding commitment to the voluntary standards process. He became chairman of ASC C63[®] in 1968 and for decades led the committee to its preeminence in electromagnetic compatibility (EMC) standardization. He also contributed his technical expertise to many of the working groups developing ASC C63[®] standards, including ANSI C63.4. Dr. Showers was a founder of the Professional Group on Radio Frequency Interference of the Institute for Radio Engineers in 1957, and he served as chair of that group's administrative committee in 1960-61. The group evolved into the EMC Society of the IEEE.

Internationally, Dr. Showers served as vice president of the U.S. National Committee (USNC) of the International Electrotechnical Commission (IEC) and as a member of its executive committee. He chaired the International Special Committee on Radio Interference (CISPR) from 1979 to 1985. He served as technical advisor for many years for several USNC technical advisory groups, including IEC Technical Committee (TC) 1, TC 77, Subcommittee 77A, and Subcommittee 77B.

Dr. Showers was a true friend and expert EMC standards colleague. His loss to ASC C63[®] cannot be measured, but it is enormous.

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American National Standard for Methods of Measurement of Radio- Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz

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1. Overview

1.1 Scope

This standard specifies consensus standard methods, instrumentation, and facilities for measurement of radio-frequency (RF) signals and noise emitted from electrical and electronic devices in the frequency range of 9 kHz to 40 GHz, as usable, for example, for compliance testing to U.S. (47CFR15) and Canada (ICES-003) regulatory requirements.¹ It does not include generic or product-specific emission limits. Where possible, the specifications herein are harmonized with other national and international standards used for similar purposes.

¹ The Federal Communications Commission (FCC) rules for unintentional radiators require the use of ANSI C63.4 test methods {i.e., Code of Federal Regulations, Title 47, Section 15.31(a)(3) [47CFR15.31(a)(3)]}. The use of ANSI C63.4 test methods is explicitly allowed in Industry Canada ICES-003 Issue 5. See also related discussion in Annex I.

Uses of the word *shall* in this standard indicate a mandatory requirement that must be met to satisfy this standard. The word *should* is used to indicate that a requirement is recommended but not mandatory. Tolerances on dimensions and distances are based on good engineering practice where not specified. The word *may* is used to indicate a recommendation that is at the discretion of the user. In addition, notes in this document are informative and are not part of the requirements. Notes are used in the text for emphasis or to offer informative suggestions about the technical content of the standard, and these notes provide additional information to assist the reader with a particular passage but do not include mandatory requirements. Footnotes in text are included only for information, clarification, and/or as an aid applicable to the use of the standard, but mandatory requirements are not included in text footnotes. In this standard, unless otherwise identified by inclusion of the word “normative” in the caption, the text takes precedence over the figures because the text is complete and the figures are illustrative of a typical application of the text. Notes to tables and figures are informative; however, footnotes (i.e., superscript notation) to tables and figures are normative, as are numbered paragraphs between a figure and its caption (i.e., the list paragraphs in Figure 7 through Figure 14).

Measurement methods are included for radiated and line-conducted emissions that can be generated by a variety of devices, as described in 1.2. Definitions are provided for terms and phrases contained in the text, in which the words do not represent obvious or common usage. Measurement instrumentation, facilities, and test sites are specified and characterized, including open-area test sites (OATS) and RF absorber-lined, metal chambers used for radiated emission measurement. Transverse electromagnetic (TEM) wave devices used for radiated emission measurement are treated in normative Annex F. The requirements of Annex F, when such tests are performed, shall take precedence in this standard. In most cases, measurement instrumentation and calibration requirements are only generally characterized in deference to standards dedicated to these subjects, which should be used in conjunction with this standard. The requirements for operation of test samples during measurements are presented for devices in general, as well as for specific types of devices that are frequently measured. Specific requirements for emission test data recording and reporting are presented with reference to general requirements contained in documents dedicated to standard laboratory practices, which should be used in conjunction with this standard. The main text is augmented by a series of annexes that provide details for certain measurement methods and facilities. Annex A provides an index of main text clauses to be used when testing particular equipment under test (EUT) types.

1.2 Purpose and applications

This document is intended to standardize methods, instrumentation, and facilities used to characterize device emissions with respect to voluntary or regulatory compliance requirements designed to protect authorized communication services. The specified procedures are intended to be applied primarily in controlled laboratory environments, but they may be used for emission measurement of in situ devices where indicated.

This standard may be applied to emission measurement of a variety of electrical and electronic devices, regardless of size and characteristics. The devices may be single, stand-alone units, or multiple, interconnected units.

Notwithstanding other possible uses, this standard is intended to be used for making emission measurements of unintentional radiators (including digital devices and receivers) and for making emission measurements of the digital device portions contained in or used in intentional radiators. See Annex I for guidance on the application of this standard for U.S. and Canadian requirements.

The methods described in this standard may not be adequate or applicable for measurement of emissions from incidental radiators, avionics, or industrial, scientific, and medical (ISM) equipment.¹ The companion document ANSI C63.10 [B3]² specifies methods of measurement for certain devices (other than ISM) that purposefully radiate RF energy, such as intentional radiators, but the methods of ANSI C63.10 might not be applicable for licensed transmitters in the United States and other countries.

All limit specifications, relevant to a given emitting device, should be applied in their entirety to the characterization of the device over the specified frequency range in all propagation modes. Piecewise application is discouraged and runs the risk of incomplete characterization, which could fail to protect the authorized radio communications services in the manner intended. Emission limit requirements shall be obtained from other voluntary and regulatory sources, and certain other procedural documents shall be applied concurrently where specified herein. Still other procedural documents may be used as alternatives to this standard where equivalent results can be demonstrated. For regulatory applications invoking the methods in this standard, results obtained as prescribed herein shall take precedence over results obtained with alternative methods.

Not all clauses in this standard are applicable to all devices that can be measured with these methods. The nature of this standard is to specify general methods that may be applied to all devices within its scope and to supplement these methods with particular requirements for some types of devices. Device-particular requirements take precedence over general requirements. See Annex A for guidance in applying this standard to specific types of devices.

A complete voluntary or regulatory requirement should specify the following information in conjunction with the application of this standard:

- a) Limits and frequency ranges for both ac power-line conducted and radiated emission measurements
- b) Measurement antenna distances for radiated emission measurements
- c) Identification of any uncommon requirements such as the following:
 - 1) Radiated magnetic field strength measurements below 30 MHz (see 8.2.1)
 - 2) Radiated electric field strength measurements below 30 MHz (see 8.2.2)
 - 3) Use of the absorbing clamp for radiated emission measurements (see Clause 9)
 - 4) Relaxation of the limits for clicks (transients) (see Clause 13)
 - 5) Use of the artificial hand for measurement of portable, hand-held devices (see 6.2.13)
 - 6) Any requirements that differ from the requirements contained herein
 - 7) Any requirement concerning statements of uncertainty of the measurement results (see ISO/IEC 17025:2005³; see also 10.2.8.2)

¹ Various standards used in the United States require emission measurements below 9 kHz (e.g., MIL-STD-461F [B24], MDS-201-0004 [B23], SAE ARP1972:1993 [B27]). These have their own measurement procedures and thus require no reference to ANSI C63.4 emission measurement procedures. However, they may require reference to ANSI C63.2 and ANSI C63.4 for instrumentation specifications. Individual regulatory and/or purchasing agency requirements normally take precedence.

² Numbers in brackets correspond to the numbers in the bibliography in Annex O.

³ Information on references can be found in Clause 2.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used; therefore, 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.

ANSI C63.2, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz Specifications.⁴

ANSI C63.5, American National Standard for Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas (9 kHz to 40 GHz).

ANSI C63.7, American National Standard for Construction of Open-Area Test Sites for Performing Radiated Emission Measurements.

ANSI C63.14, American National Standard Dictionary of Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3).

ANSI C63.22, American National Standard Guide for Automated Electromagnetic Interference Measurements.

ANSI C63.23, American National Standard Guide for Electromagnetic Compatibility—Computations and Treatment of Measurement Uncertainty.

CISPR 14-1:2005-11, Electromagnetic Compatibility—Requirements for Household Appliances, Electric Tools and Similar Apparatus—Part 1: Emission, Ed. 5.0.⁵

CISPR 16-1-1:2010-11, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus—Measuring Apparatus, Ed. 3.1.

CISPR 16-1-2:2006-08, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-3: Radio Disturbance and Immunity Measuring Apparatus—Ancillary Equipment—Conducted Disturbances, Ed. 1.2.

CISPR 16-1-3:2004-06, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-3: Radio Disturbance and Immunity Measuring Apparatus—Disturbance Power, Ed. 2.

CISPR 16-1-4:2010-04, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-4: Radio Disturbance and Immunity Measuring Apparatus—Ancillary Equipment—Radiated Disturbances, Ed. 3.

CISPR 16-4-2:2011-06, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 4-2: Uncertainties, statistics and limit modelling—Measurement instrumentation uncertainty, Ed. 2.

Code of Federal Regulations Title 47 Part 15 (47CFR15), Telecommunication—Radio Frequency Devices.⁶

⁴ ANSI C63® publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>) or from the American National Standards Institute (<http://www.ansi.org/>).

⁵ CISPR documents are available from the International Electrotechnical Commission (<http://www.iec.ch/>). CISPR documents are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

ICES-003, Spectrum Management and Telecommunications, Interference-Causing Equipment Standard, Information Technology Equipment (ITE) – Limits and methods of measurement, Industry Canada, Issue 5, August 2012.⁷

IEEE Std 139™-1988, IEEE Recommended Practice for the Measurement of Radio Frequency Emission from Industrial, Scientific, and Medical (ISM) Equipment Installed on User's Premises.^{8,9}

IEEE Std 187™-2003, IEEE Standard for Measurement Methods of Emissions from FM and Television Broadcast Receivers in the Frequency Range of 9 kHz to 40 GHz.

IEEE Std 1309™-2005, IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes, Excluding Antennas, from 9 kHz to 40 GHz.

ISO 10012:2003, Measurement management systems—Requirements for measurement processes and measuring equipment.¹⁰

ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories.

⁶ CFR publications are available from the U.S. Government Printing Office (<http://www.gpoaccess.gov/>).

⁷ ICES standards, including various related Industry Canada Spectrum Management and Telecommunications publications, are available from <http://www.ic.gc.ca/spectrum>.

⁸ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

⁹ The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

¹⁰ ISO publications are available from the ISO Central Secretariat (<http://www.iso.ch/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary Online*¹¹ and ANSI C63.14 should be consulted for terms not defined in this clause. See F.3 for definitions specific to testing in TEM waveguides.

3.1 Definitions

active antenna: An antenna system with integral amplifiers, preamplifiers, and/or other nonlinear active devices that amplify the signal and/or shape the frequency response. [CISPR 16-1-4:2010-04, A.4.2.4, modified] *Contrast:* **passive antenna.**

NOTE—Examples of active antennas used for electromagnetic compatibility (EMC) measurements include active monopole antennas, active loop antennas, and active double-ridged guide horn antennas.¹²

ambient level: The values of radiated and conducted signal and noise existing at a specified test location and time when the test sample is not activated.

antenna factor: Ratio of the electric field strength E in the polarization direction of the antenna to the voltage induced across the load connected to the antenna terminals V_o and expressed in decibel form $[20 \log (E/V_o)]$. [ANSI C63.5-2006, 3.2]

click: A disturbance that exceeds the limit of continuous disturbance not longer than 200 ms and that is separated from a subsequent disturbance by at least 200 ms.

NOTE—For the specified values and conditions, guidance may be found in CISPR 14-1:2005-11 and CISPR 16-1-1:2010-11.

counterpoise: A system of conductors designed to simulate actual ground that may be elevated above and insulated from the ground, forming a lower system of conductors of an antenna.

digital device: An unintentional radiator (device or system) that uses digital techniques and generates and uses timing signals or pulses at a rate in excess of 9000 pulses (cycles) per second, inclusive of telephone equipment that uses digital techniques or any device or system that generates and uses radio-frequency (RF) energy for the purpose of performing data processing functions, such as electronic computations, operations, transformations, recording, filing, sorting, storage, retrieval, or transfer.

NOTE—Computer terminals and peripherals that are intended to be connected to a computer are digital devices.

(electromagnetic) disturbance: Any electromagnetic phenomenon that may degrade the performance of a device, piece of equipment, or system, or adversely affect living or inert matter.

NOTE—An electromagnetic disturbance may be a noise, an unwanted signal, or a change in the propagation medium.

(electromagnetic) emission: **(A)** The phenomenon by which electromagnetic energy emanates from a source. **(B)** Electromagnetic energy propagated from a source by radiation or conduction.

equipment arrangement: An equipment configuration spatially arranged with cables at the test site to form an equipment under test (EUT). *Syn:* **test setup.**

¹¹ *IEEE Standards Dictionary Online* subscription is available at http://www.ieee.org/portal/innovate/products/standard/standards_dictionary.html.

¹² Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement the standard.

equipment configuration: A combination of equipment units constituting the equipment under test (EUT).

equipment under test (EUT): A device or system being evaluated for compliance that is representative of a product to be marketed.

floor-standing equipment: Equipment designed to be used directly in contact with the floor or supported above the floor on a surface designed to support both the equipment and the operator (e.g., a raised computer floor).

host: A device to which other devices (peripherals) are connected and that generally controls those devices.

hybrid antenna: Any antenna that is constructed such that it includes a combination of both broadband dipole (e.g., biconical, bow-tie) elements and log-periodic dipole array (LPDA) elements.

incidental radiator: A device that does not intentionally generate any radio-frequency (RF) energy, but that may create such energy as an incidental part of its intended operation.

NOTE—Common examples include brush-type electric motors, fluorescent light ballasts operating at 60 Hz ac line frequency, faulty doorbell transformers, doorbell control circuits, and aquarium heaters.

industrial, scientific, and medical (ISM) equipment: Equipment or appliances designed to generate and use radio-frequency (RF) energy locally for industrial, scientific, medical, domestic, or similar purposes, excluding applications in the field of telecommunication.

information technology equipment (ITE): Any equipment that

- Has a primary function of one or more of the following: entry, storage, display, retrieval, transmission, processing, switching, or control of data or telecommunication messages;
- May be equipped with one or more terminal ports typically operated for information transfer; and
- Has a rated supply voltage not exceeding 600 V.

NOTE—Examples of ITE include data-processing equipment, office machines, electronic business equipment, predominantly digital audio and video equipment, and telecommunications equipment that contain digital circuits.

intentional radiator: A device that intentionally generates and emits radio-frequency (RF) energy by radiation or induction.

line impedance stabilization network (LISN): A network inserted in the power supply conductor of an apparatus to be tested that provides, in a given frequency range, a specified load impedance for each current-carrying conductor for the measurement of conducted emission voltages. A LISN is used to isolate the apparatus from the supply mains in that frequency range and couples the equipment under test (EUT) emissions to the measuring instrument.

NOTE—A LISN unit may contain one or more individual LISN circuits.

low-voltage electrical and electronic equipment: Electrical and electronic equipment with operating input voltages of up to 600 V dc or 600 V rms ac.

module: Any assembly of interconnected components that constitutes an identifiable device, instrument, or piece of equipment.

normalized site attenuation (NSA): Site attenuation divided by the antenna factors of the radiating and receiving antennas (all in linear units).¹³ *See also:* **site attenuation.**

¹³ See ANSI C63.5 for details about applicable antenna factors and other parameters.

passive antenna: An antenna that functions without any source of energy other than input signals. [IEV 702-09-07, modified]¹⁴ *Contrast:* **active antenna.**

NOTE—Examples of passive antennas used for electromagnetic compatibility (EMC) measurements include tuned dipoles, biconical dipoles, log-periodic dipole array (LPDA) antennas, hybrid antennas, and many types of horn antennas.

peripheral device: A digital accessory that feeds data into or receives data from another device (host) that, in turn, controls its operation.

personal computer (PC): An electronic computer that is marketed for use in the home, notwithstanding business applications.

NOTE—Other definitions given in product standards or applicable regulations may take precedence.

reference ground plane: A conducting flat surface or plate that is used as a common reference point for circuit returns and electric or signal potentials and that reflects electromagnetic waves.

site attenuation: The ratio of the power input of a matched, balanced, lossless, tuned dipole radiator to that at the output of a similarly matched, balanced, lossless, tuned dipole receiving antenna for specified polarization, separation, and heights above a flat electromagnetically reflecting surface. It is a measure of the transmission path loss between two antennas. *See also:* **normalized site attenuation (NSA).**

NOTE—The above is the classic definition of site attenuation. In this standard, it is extended to cover broadband antennas as well as tuned dipole antennas.

system: A configuration of interconnected devices, including accessories and peripherals, and their cables that is designed to perform a particular function or functions.

tabletop device: A device designed to be placed and normally operated on the raised surface of a table or other surfaces of similar height, e.g., most personal computers (PCs).

transfer switch: A device used to alternate between the reception of over-the-air radio-frequency (RF) signals via connection to an antenna and the reception of RF signals received by any other method, such as from a television (TV) interface device.

television (TV) interface device: An unintentional radiator that produces or translates in frequency a radio carrier modulated by a video signal derived from an external or internal signal source and that feeds the modulated radio-frequency (RF) energy by conduction to the antenna terminals or other nonbaseband input connections of a TV broadcast receiver.

unintentional radiator: A device that generates radio-frequency (RF) energy for use within the device or that sends RF signals by conduction to associated equipment via connecting wiring, but that is not intended to emit RF energy by radiation or induction.

¹⁴ IEC Online, IEC 60050, International Electrotechnical Vocabulary, International Electrotechnical Commission, Geneva, CH, (<http://www.electropedia.org/>).

3.2 Acronyms and abbreviations

AC, ac	alternating current
ASC	Accredited Standards Committee
ATSC	Advanced Television Systems Committee
AUT	antenna under test
CPU	central processing unit
CSTD	cable system terminal device
CW	continuous wave
DC, dc	direct current
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EUT	equipment under test
FCC	Federal Communications Commission
FSAF	free-space antenna factor
GSCF	geometry-specific correction factor
GTEM	gigahertz transverse electromagnetic
HAIMP	hybrid antenna impedance matching pad
IF	intermediate frequency
I/O	input/output
ISM	industrial, scientific, and medical
ITE	information technology equipment
LISN	line impedance stabilization network
LPDA	log-periodic dipole array
NSA	normalized site attenuation
NTSC	National Television Systems Committee
OATS	open-area test site
PC	personal computer
RF	radio frequency
S_{VSWR}	site-voltage standing wave ratio
TEM	transverse electromagnetic
VCR	videocassette recorder
VITS	vertical interval test signal
VSWR	voltage standing wave ratio

4. Measurement instrumentation

4.1 General

The use of proper measurement instrumentation is critical to obtaining accurate, reproducible results. Various measuring accessories that may be needed depend on the particular measurements to be performed, as described in the following subclauses.

4.2 Emission measuring instruments

4.2.1 General requirements

This standard recognizes that both spectrum analyzers (see 4.2.3) and electromagnetic interference (EMI) receivers (see 4.2.2) may be used for making emission measurements. Measurement instrumentation used for making radiated and alternating current (ac) power-line conducted radio-noise measurements include those that conform to the specifications contained in either or both of the following documents as appropriate to the frequency range of measurement:

- a) ANSI C63.2 (for measurements up to and including 40 GHz)
- b) CISPR 16-1-1:2010-11 (for measurements up to and including 18 GHz)

A spectrum analyzer typically will not meet all requirements stated in ANSI C63.2 or CISPR 16-1-1:2010-11 without additional accessories. Appropriate accessories, which provide, for example, preselection, quasi-peak detection, and specific intermediate frequency (IF) filters, may be used with a spectrum analyzer; this combination can be equivalent to a receiver, meeting the specifications in either item a) or item b) of this subclause.

4.2.2 Reference receiver

The receiver for measurements of radiated and ac power-line conducted radio noise is an instrument conforming to ANSI C63.2 or CISPR 16-1-1:2010-11. Other measuring instruments may be used for certain restricted and specialized measurements when these instruments conform to ANSI C63.2 or CISPR 16-1-1:2010-11. Automatic scanning receivers may be used, but the scan speed is to be selected such that calibrated measurements can be performed (based on the IF bandwidth selection) and the signals are properly intercepted (e.g., based on the pulse repetition frequencies). Guidance for selecting the proper bandwidth is given in 4.2.4.

If the output of the quasi-peak or linear average detector is presented in logarithmic units, the logarithms shall be taken in the measuring instrument after the signal is detected. It shall be confirmed that the output indication represents the logarithm of the true quasi-peak or linear average value of the signal measured.

NOTE 1—Instruments that use logarithmic detectors, predetection logarithmic circuits, or both should include corrective circuits so that the output indication is the logarithm of the true linear average or quasi-peak value of the signal or noise.

NOTE 2—Users should be aware that the EMI receiver specifications in CISPR 16-1-1:2010-11 and ANSI C63.2 contain several differences.¹⁵ For example, for measurements above 1 GHz, the bandwidth definitions for measurements are different. These differences in bandwidth specification may result in different measured values for broadband signals.

4.2.3 Spectrum analyzer

The use of spectrum analyzers for radiated and ac power-line conducted radio-noise compliance measurements is permissible, although spectrum analyzers without additional accessories will not meet all specifications called out in the standards listed in 4.2.1 and 4.2.2.

To meet the requirements in 4.2.4, spectrum analyzers shall be equipped with proper quasi-peak and linear average detection. However, measurements with the peak detector of an instrument are permissible to demonstrate compliance of an EUT, as long as the required resolution bandwidth is used, because peak detection will yield amplitudes equal to or greater than amplitudes measured with the quasi-peak or linear average detector. The measurement data from a spectrum analyzer peak detector will represent the worst-case results.

Nominal values for the resolution bandwidth shall be as specified in either CISPR 16-1-1:2010-11 or ANSI C63.2. It should be noted that most spectrum analyzers implement a resolution bandwidth specification of 3 dB, which is acceptable because larger bandwidths are permissible. The resolution bandwidths cited in the standards listed in 4.2.2 do not have a Gaussian shape but are individually specified by their frequency response (i.e., “masks”). When using larger bandwidths than the ones specified, or filters with different transfer functions, different measurement results for broadband signals must be expected. In case of dispute, the test results measured with one of the reference receivers defined in 4.2.2 will take precedence.

For a spectrum analyzer to meet the specifications of one of the two reference receivers, it must provide adequate overload protection and system dynamic range, achieve proper weighting of pulses when using quasi-peak detection, and have the resolution bandwidths specified in either CISPR 16-1-1:2010-11 or ANSI C63.2. If a spectrum analyzer is to be used to make quasi-peak measurements of low repetition rate signals (i.e., pulse repetition rate of 20 Hz or less), the use of a preselector is required to provide adequate dynamic range of the instrument.

When using spectrum analyzers, the following instrumentation characteristics shall be addressed:

- a) Overload—Most spectrum analyzers have no RF preselection in the frequency range up to 2 GHz; that is, the input signal is directly fed to a broadband mixer. To avoid overload, to prevent damage, and to operate a spectrum analyzer linearly, the signal amplitude at the mixer shall be less than the manufacturer’s stated specification for the maximum input level for linear operation.¹⁶ RF attenuation and/or additional RF preselection may be required to reduce the input signal to this level.
- b) Linearity test—Linearity can be verified by measuring the level of the specific signal under investigation and repeating this measurement after a 6 dB or less attenuator has been inserted at the input of the measuring instrument, or the preamplifier if used. The new reading of the measuring instrument display should differ by the inserted attenuation by not more than ± 0.5 dB from the first reading when the measuring system is linear; see H.3 for details. In case of broadband time-variant

¹⁵ The 2009 edition of ANSI C63.2 is a compilation and comparison summary of specifications from ANSI C63.2-1996 [B1] and CISPR 16-1-1:2003 [B12]. Using the other provisions in ANSI C63.2 that are not contained in CISPR 16-1-1:2010-11 may entail additional or different specifications relative to Clause 3 of ANSI C63.2-2009. The testing organization should determine whether the additional or different specifications need to be taken into account with any specific measurement condition. When any additional provisions in ANSI C63.2 are not needed, CISPR 16-1-1:2010-11 can be used without any further justification.

¹⁶ The typical maximum input level for the linear operation of a spectrum analyzer is 150 mV peak; regardless, users should be aware of the actual maximum input level for the linear operation of their particular spectrum analyzer.

signals and spread-spectrum signals, the linearity test may be performed by setting the analyzer in maximum hold with peak detector function.

- c) Normal response to pulses—The response of a spectrum analyzer with quasi-peak detection shall be verified with the calibration test pulses specified in CISPR 16-1-1:2010-11. The large peak voltage of the calibration test pulses typically requires an insertion of RF attenuation of 40 dB or more to satisfy the linearity requirements. This decreases the sensitivity and makes the measurement of low repetition rate and isolated calibration test pulses impossible for bands C and D.¹⁷ If a preselecting filter is used ahead of the measuring instrument, the RF attenuation can be decreased. The filter limits the spectrum width of the calibration test pulse as seen by the mixer.
- d) Signal interception—The spectrum of intermittent and/or time varying emissions may be captured with peak detection and digital display storage (i.e., “max hold” function). Multiple, fast frequency scans reduce the time to intercept an emission compared with a single, slow frequency scan. The starting time of the scans shall be varied to avoid any synchronism with the emission and thereby masking it. The total observation time for a given frequency range shall be longer than the time between the emissions. Depending on the type of emission being measured, the peak detection measurements can replace all or part of the measurements needed using quasi-peak detection. Retests using a quasi-peak detector shall then be made at frequencies where emission maxima have been found.
- e) Average detection—For spectrum analyzers not equipped with a linear average detector as specified in 4.2.4.1, an alternate method of linear average detection with a spectrum analyzer can be obtained by setting the detector mode to peak and reducing the video bandwidth until no significant variations in the displayed signal are observed from trace to trace; see 4.2.4.2 for a basic measurement procedure. The sweep time must be increased with reductions in video bandwidth to maintain amplitude calibration. For such measurements, the instrument shall be used in the linear mode of the detector, and maximum-hold processing of traces should be employed to achieve a maximum reading. After linear detection is made, the signal may be processed logarithmically for display, in which case, the value is corrected even though it is the logarithm of the linearly detected signal. A logarithmic amplitude display mode may be used, for example, to distinguish more easily between narrowband and broadband signals. The displayed value is the average of the logarithmically distorted IF signal envelope. A logarithmic amplitude display mode results in a larger attenuation of broadband signals than in the linear detection mode without affecting the display of narrowband signals. Therefore, video filtering in the log display mode is especially useful for estimating the narrowband component in a spectrum containing both broadband and narrowband signals.

When performing final compliance measurements in accordance with CISPR 16-1-1:2010-11, the video bandwidth shall be set to a value of 1 Hz so that the proper integration time is realized; H.6 provides other details.

NOTE— Notwithstanding the video bandwidth requirements of 6.5.4 of CISPR 16-1-1:2010-11, the measurement procedure standards CISPR 16-2-1:2010 [B13] (i.e., Annex D therein) and CISPR 16-2-3:2010 [B14] (i.e., Annex C therein) allow the use of higher video bandwidths, at least for pre-scan measurements, when measuring slowly intermittent, unsteady, or drifting narrowband disturbance signals that have pulse repetition frequencies or modulation frequencies greater than 5 Hz. Also, because the measurand in 6.5.4 of CISPR 16-1-1:2010-11 is specified to be the peak reading, the larger amplitude fluctuations that occur with the use of a higher-than-specified video bandwidth will provide a conservative measurement result (i.e., higher emission level).

- f) Selection of display mode—For electromagnetic compatibility (EMC) measurements, the positive peak detector should be selected so that the highest emission amplitudes are displayed. Scanning the frequency range of interest in multiple frequency segments can reduce the introduced frequency error. This will improve frequency accuracy but will increase the overall test time.

¹⁷ CISPR 16-1-1:2010-11 bands C and D are 30 MHz to 1000 MHz.

See also Annex H and ANSI C63.22 for more details on and precautions concerning the use of spectrum analyzers.

4.2.4 Detector functions and selection of bandwidth

4.2.4.1 General requirements

Unless otherwise specified, EMI receivers or spectrum analyzers shall have the detector functions and bandwidths specified in either ANSI C63.2 or CISPR 16-1-1:2010-11 for frequencies up to and including 18 GHz; above 18 GHz, the detector functions and bandwidths specified in ANSI C63.2 shall be used.

In the frequency range from 1 GHz to 18 GHz, the IF filter used in an EMI receiver or in a spectrum analyzer shall satisfy any one of the following requirements.

- a) The IF filter shall comply with the selectivity criterion called out in Figure 4 of CISPR 16-1-1:2010-11; or
- b) The IF filter shall have a 1 MHz impulse bandwidth; or
- c) If the 1 MHz measurement bandwidth of the IF filter is not calibrated as the impulse bandwidth, a correction factor for broadband signal amplitudes shall be applied.

For EMI receivers or spectrum analyzers subject to the preceding condition c), the necessary correction factor shall be determined as follows:

- The impulse bandwidth, B_{imp} , of the 1 MHz IF filter shall be determined by measurements made in accordance with the method stated in E.7 of CISPR 16-1-1:2010-11.
- A bandwidth correction shall be applied ONLY when broadband signal amplitudes are measured. The broadband correction factor (in dB) shall be calculated using $C_{\text{BB}} = 20 \log (B_{\text{imp}} / B_{\text{meas}})$, where B_{meas} equals the measurement bandwidth (i.e., 1 MHz). This correction factor is to be added algebraically to the broadband signal level measured using the available 1 MHz IF bandwidth.

In the frequency range from 18 GHz to 40 GHz, the IF filter used in an EMI receiver or in a spectrum analyzer shall satisfy the requirements stated under either the preceding b) or c).

Peak detector measured data can be substituted for the appropriate detector data to show compliance, as long as the required resolution bandwidth is maintained or exceeded, if the peak level obtained does not exceed the limit. The bandwidths used shall be equal to or greater than that specified in ANSI C63.2. Use of bandwidths greater than those specified may produce higher readings for certain types of emissions. If bandwidths greater than those specified are used, the actual bandwidths used shall be recorded in the test report. In case of dispute, the reference receiver shall take precedence. More than one instrument may be needed to perform all of these functions.

The measuring instrument shall satisfy the following provisions:

- The quasi-peak detector and average detector shall have a linear response.
- The average detector shall meet the linear average specifications in ANSI C63.2 or CISPR 16-1-1:2010-11. A logarithmic average detector shall not be used for making measurements in accordance with ANSI C63.4.
- When measuring an emission with a low duty cycle, the dynamic range of the measuring instrument shall not be exceeded.

When using a spectrum analyzer or other instrument that allows access to the video bandwidth setting, for peak measurements, this bandwidth shall be set to a value at least three times greater than the IF bandwidth of the measuring instrument to avoid the introduction of unwanted amplitude smoothing.

NOTE—For the purposes of this document, the terms *IF bandwidth* and *resolution bandwidth* are synonymous.

4.2.4.2 Average measurements using spectrum analyzer with reduced video bandwidth

For a spectrum analyzer not having a dedicated average detector function, the following procedure shall be used to make average measurements by reduction of video bandwidth. This method yields the average value of signals at the input of a spectrum analyzer measured with a specified resolution bandwidth.

- a) Tune the instrument to the signal of interest by setting the center frequency to the signal frequency, and set the resolution bandwidth to the required resolution bandwidth.
- b) Select the spectrum analyzer linear display mode.
- c) Set the spectrum analyzer reference level such that the measured signal is positioned as close as possible to the top line of the display graticule.
- d) Reduce the video bandwidth to a value that does not result in any further reduction in the displayed signal amplitude, but no less than 1 Hz [see also the NOTE in 4.2.3 e)].
- e) After items a) through d) are completed, measure the maximum average signal on the display.

Additional discussion about the use of spectrum analyzers for average measurements is given in H.6.

4.2.5 Signal monitoring

All radio-noise measurements should be monitored (audio and/or visual) by the test operator using a headset, a loudspeaker, a spectrum display, or any combination thereof as an aid to detecting ambient signals and selecting the emissions that have the highest amplitude relative to the limit. Precautions shall be taken to ascertain that the use of a headset or speaker does not affect the measuring instrument indication during measurements.

4.3 Line impedance stabilization network (LISN)

A LISN having the nominal impedance characteristic shown in Figure 1 (see figures in 4.8) is required for ac conducted emission measurements.¹⁸ When the measuring instrument (receiver or spectrum analyzer) ports are terminated into an impedance of 50 Ω , the characteristic impedance in Figure 1 shall be present at the EUT ports of the LISN. Figure 2 and Figure 3 (see 4.8) show two circuits that when carefully constructed can provide the impedance characteristics of Figure 1 (for use with connecting cable, see also 5.2.4). Table B.1 through Table B.4 show the $\pm 20\%$ limit values for the LISN impedance at the LISN terminals and the $+30\%$ / -20% limit values for the LISN impedance when extension cords are used with the LISN, respectively. Where specific equipment requirements specify another LISN, the specified LISN shall be used.

NOTE 1—Care shall be taken to check for and confirm that no unusual resonances exist in situations where LISNs are used for making measurements below 9 kHz (see 1.2).

¹⁸ In this document, associated figures are placed at the end of each clause.

NOTE 2—This standard does NOT require the use of LISNs that meet the phase angle tolerances specified in 4.2 and 4.3 (and Tables 3 and 4, respectively) of CISPR 16-1-2:2006-08; however, such LISNs may be used if the nominal impedance characteristics and tolerances shown in Figure 1 (and Table B.1 through Table B.4, as applicable) of this standard are met. Regardless of whether a LISN satisfies the phase angle tolerances of 4.2 and 4.3 of CISPR 16-1-2:2006-08, the applicable uncertainty characteristics associated with the LISN calibration should be used when the measurement uncertainty of an ac power-line conducted emissions measurement is calculated and included in a test report (see 10.2.8.2).

4.4 Voltage probe

A voltage probe may be used for radio-noise voltage measurements when measurements are made at a user's installation (see 5.6) or when the ac current level exceeds the current-carrying capability of commercially available LISNs.¹⁹ Voltage probes shall be calibrated for use. For such measurements, the method shown in Figure 4 (see 4.8) may be used. Special precautions shall be taken to establish a reference ground for the measurements. A LISN shall not be used in conjunction with a voltage probe for measurements at a user installation. The measurements are dependent on the impedance presented by the power supply and may vary with time and location because of variations in the power supply. (It may be necessary to perform repeated measurements over a suitable period of time to determine the variation in measured values. The time period shall be sufficient to cover all significant variations caused by operating conditions at the installation.) Such measurement results shall be regarded as unique to that EUT and installation environment. The measurements shall be made between each current-carrying conductor in the power supply and the ground conductor with a blocking capacitor (C) and a resistor (R), shown in Figure 4, such that the total resistance between line and ground is 1500 Ω . Because the voltage probe attenuates the radio-noise voltage, appropriate calibration factors shall be added to the measured values. Measurements made with LISNs shall take precedence over measurements made with voltage probes.

4.5 Antennas

4.5.1 General considerations

The use of specific antennas depends on the frequency range and field type (electric or magnetic) being measured in performing radiated emissions measurements, as indicated in 4.5.2 through 4.5.5. Antennas shall be calibrated in accordance with ANSI C63.5.

NOTE—Users of ANSI C63.4 are especially recommended to pay careful attention to the scope and content of Table 1, Table 2, and Table 3.

Table 1 provides a summary listing of types of antennas that may be used in making *exploratory* radiated emissions measurements and/or for making *relative-comparison evaluation* measurements (e.g., A/B comparisons). Table 1 identifies the typical frequency ranges over which these antennas operate and provides normative footnotes regarding special considerations in their use. *Antenna types other than those specifically listed in Table 1 may also be employed for making exploratory radiated emissions measurements and/or relative-comparison evaluation measurements, but users are cautioned to carefully consider the performance characteristics of those antennas as well as the applicable calibration procedures for those antennas prior to their use.*

Table 2 contains the complete list of antennas that are permitted to be used for making *final compliance measurements* for this standard and identifies the frequency ranges over which those antennas are permitted to operate when making final compliance measurements. *Only the antenna types specifically listed in Table 2 and used in the frequency ranges listed for their operation in Table 2 (and used in a manner consistent with the normative footnotes in Table 2) shall be used for making final compliance measurements.*

¹⁹ Some measurement method documents refer to a voltage probe as a line probe [e.g., FCC/OET MP-5 [B15] (47CFR18.311)].

Table 3 contains the complete list of antennas that are permitted to be used for making *test site validation measurements* and identifies the frequency ranges over which those antennas are permitted to operate when making test site validation measurements. *Only antenna types specifically listed in Table 3, when used over the frequency ranges listed for their operation in Table 3 (and used in a manner consistent with the normative footnotes in Table 3) shall be used for making test site validation measurements.* (Note that NSA stands for *normalized site attenuation*, and S_{VSWR} stands for *site-voltage standing wave ratio*.)²⁰

Table 1—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (and their frequency ranges of operation)^a

#	Antenna types	10 Hz to 0.15 MHz	0.15 MHz to 30 MHz	30 MHz to 1000 MHz	1 GHz to 40 GHz
1	Passive monopole ^b	Yes	Yes	No	No
2	Active monopole ^b	Yes	Yes	No	No
3	Passive loop ^c	Yes	Yes	No	No
4	Active loop ^c	Yes	Yes	No	No
5	Resonant tuned dipole (passive)	No	No	Yes	Yes ^{d, e}
6	Biconical dipole (50 Ω or 200 Ω balun)	No	No	Yes	Yes ^{d, e}
7	Precision broadband omnidirectional biconical dipole	No	No	No	Yes ^f
8	Log-periodic dipole array (LPDA)	No	No	Yes	Yes ^{d, e}
9	Hybrid (bicon/log)	No	No	Yes	Yes
10	Waveguide horn	No	No	No	Yes
11	Double-ridged guide horn (passive)	No	No	Yes	Yes ^g
12	Double-ridged guide horn (active)	No	No	No	Yes ^{g, h}

^a This table was originally adapted from Table 6 of ANSI C63.2-1996 [B1].

^b When monopole antennas are used for making exploratory or relative-comparison measurements, the use of an active monopole is permitted when these measurements are made in a shielded enclosure (e.g., an RF anechoic chamber). The use of an active monopole antenna is permitted when making exploratory or relative-comparison measurements in a non-shielded environment (e.g., an OATS) if the active monopole antenna is equipped with an operating saturation indicator and ONLY if the saturation indicator is monitored during the course of the testing and that the monitor does not indicate saturation.

^c When loop antennas are used for making exploratory or relative-comparison measurements, the use of an active loop antenna is permitted when these measurements are made in a shielded enclosure (e.g., an RF anechoic chamber). The use of an active loop antenna is permitted when making exploratory or relative-comparison measurements in a non-shielded environment (e.g., an OATS) if the active loop antenna is equipped with an operating saturation indicator and ONLY if the saturation indicator is monitored during the course of the testing and that the monitor does not indicate saturation.

^d In general, tuned dipole, biconical dipole, and LPDA antennas operate within the 30 MHz to 1000 MHz frequency range, and waveguide/DRG horn antennas operate over portions of the 1 GHz to 40 GHz band. However, some designs of tuned dipole, biconical dipole, and LPDA antennas also operate within portions of the 1 GHz to 40 GHz range, and some designs of DRG horns operate at frequencies as low as 170 MHz.

^e Users of biconical antennas, with 50 Ω or 200 Ω baluns, and LPDA antennas are cautioned that the required calibration methods for these antennas at frequencies up to and including 1 GHz are completely different from those required to be used at frequencies above 1 GHz. For further details, see the ANSI C63.5.

^f The use of precision broadband omnidirectional (biconical) antennas complying with the constructional and pattern requirements specified in 8.3.3.1 of CISPR 16-1-4:2010-04 are permitted.

^g The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh (far-field) distance (i.e., $R_m = 2D^2 / \lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

^h The use of an active horn antenna is permitted when measurements are made in shielded enclosures (e.g., shielded enclosures, RF anechoic chambers). The use of an active horn antenna is permitted when final compliance measurements are made in a non-shielded environment (e.g., an OATS); however, users are cautioned to verify whether the ambient signals are causing the preamplifier portion of the active horn antenna to saturate (thus yielding unacceptable, erroneous measurements) and, if they are, to take corrective action (e.g., use of a notch filter, reorientation of the measurement axis) to eliminate the saturation condition.

²⁰ The shading on table footnotes is used only to enhance readability; all footnotes have equal importance.

Table 2—Antennas (and their frequency ranges of operation) for use in making final compliance measurements on devices

#	Antenna types ^a	9 kHz to 30 MHz	30 MHz to 1000 MHz	1 GHz to 40 GHz
1	Passive monopole ^b	Yes	No	No
2	Active monopole ^b	Yes	No	No
3	Passive loop	Yes	No	No
4	Active loop ^c	Yes	No	No
5	Resonant tuned dipole (passive)	No	Yes	No
6	Biconical dipole (50 Ω or 200 Ω Balun)	No	Yes	No
7	Precision broadband omnidirectional biconical dipole	No	No	Yes ^d
8	Log-periodic dipole array (LPDA)	No	Yes	Yes ^e
9	Hybrid (bicon/log)	No	Yes ^{h, i}	Yes ^{h, i}
10	Waveguide horn	No	No	Yes
11	Double-ridged guide horn (passive)	No	No	Yes ^f
12	Double-ridged guide horn (active)	No	No	Yes ^{f, g}

^a To be acceptable for use in making final compliance measurements on devices, each antenna used shall have a current, valid calibration that was performed in accordance with ANSI C63.5 and is evidenced by a calibration certificate/report that, among other things, states the specific antenna calibration method or methods used, the antenna factors determined for that specific antenna, and the associated calibration measurement uncertainty. To be acceptable, an antenna calibration certificate/report shall have been issued by an antenna calibration laboratory whose scope of accreditation includes the applicable antenna calibration method or methods and the capability to cover the required frequency range. For further details, see 4.7.3.

^b Users are advised that certain regulatory and/or purchasing agencies (e.g., the FCC) prohibit the use of active monopole antennas for making E-field final compliance measurements on devices below 30 MHz. In such cases, if E-field measurements are required to be made, the use of an active or passive loop antenna is required (with its antenna factors converted to E-field values assuming a free-space impedance of 377 Ω). Also, when monopole antennas are permitted to be used for making E-field final compliance measurements, the use of an active monopole is permitted when final compliance measurements are made in a shielded enclosure (e.g., an RF anechoic chamber). The use of an active monopole antenna is permitted when final compliance measurements are made in a non-shielded environment (e.g., an OATS) if the active monopole antenna is equipped with an operating saturation indicator and ONLY if the saturation indicator is monitored during the course of the testing and that the monitor does not indicate saturation.

^c The use of an active loop antenna is permitted when final compliance measurements on devices are made in a shielded enclosure (e.g., an RF anechoic chamber) in accordance with the provisions of 5.3. The use of an active loop antenna is permitted when final compliance measurements are made in a non-shielded environment (e.g., an OATS) if the active loop antenna is equipped with an operating saturation indicator and ONLY if the saturation indicator is monitored during the course of the testing and that the monitor does not indicate saturation.

^d The use of precision broadband omnidirectional (biconical) antennas complying with the constructional and pattern requirements specified in 8.3.3.1 of CISPR 16-1-4:2010-04 are permitted when making final compliance measurements on devices. No other types of biconical antennas shall be used above 1 GHz for making final compliance measurements.

^e Users of LPDA antennas are cautioned that the required calibration methods for these antennas at frequencies up to and including 1 GHz are completely different from those required to be used at frequencies above 1 GHz. Users are further cautioned that an LPDA antenna whose operating frequency range extends above 1 GHz shall be acceptable for use in making final compliance measurements on devices ONLY if the calibration certificate/report for that antenna explicitly states the differences between the calibration methods used below 1 GHz and the calibration method used above 1 GHz and separately lists the antenna factors below and above 1 GHz.

^f The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh (far-field) distance (i.e., $R_m = 2D^2 / \lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

^g The use of an active horn antenna is permitted when final compliance measurements on devices are made in a shielded enclosure (e.g., RF anechoic chamber). The use of an active horn antenna is permitted when final compliance measurements are made in a non-shielded environment (e.g., an OATS); however, users are cautioned to verify whether the ambient signals are causing the preamplifier portion of the active horn antenna to saturate (thus yielding unacceptable, erroneous measurements) and, if they are, to take corrective action (e.g., use of a notch filter, reorientation of the measurement axis) to eliminate the saturation condition.

^h See Annex N for the site-specific hybrid antenna qualifications that are required to be met for a specific hybrid antenna to be used at a specific test site over the frequency range of 30 MHz to 1 GHz. A specific hybrid antenna that has been determined to be suitable for use on a specific test site from 30 MHz to 1 GHz by means of the procedures detailed in Annex N is deemed to be suitable for use on that same test site from 1 GHz upwards to its highest frequency of operation.

ⁱ If a hybrid antenna impedance matching pad (HAIMP) attenuator was used during the site-specific hybrid antenna qualification procedure detailed in Annex N, then an attenuator of the same insertion loss value and the same or greater frequency range of operation shall be used during all final compliance measurements made with that specific hybrid antenna on that specific test site.

**Table 3—Antennas (and their frequency ranges of operation)
for use in performing test site validation measurements**

#	Antenna types ^a	Test site validation method & frequency range		
		NSA 30 MHz to 200 MHz	NSA 200 MHz to 1000 MHz	S_{VSWR} 1 GHz to 18 GHz
1	Resonant tuned dipole (passive)	Yes	Yes	No
2	Biconical dipole ^b	Yes	No	No
3	Precision biconical dipole ^{c, e}	No	No	Yes
4	Log-periodic dipole array (LPDA)	No	Yes	Yes ^{d, f}
5	Hybrid (bicon/log)	Yes	Yes	Yes ^{e, i}
6	Waveguide horn	No	No	Yes ^{e, f, g}
7	Double-ridged guide horn (passive)	No	No	Yes ^{e, f, g}
8	Double-ridged guide horn (active)	No	No	Yes ^{e, f, g, h}

^a To be acceptable for use in making test site validation measurements, each antenna used shall have a current, valid calibration that was performed in accordance with ANSI C63.5 and is evidenced by a calibration certificate/report that, among other things, states the specific antenna calibration method or methods used and the antenna factors determined for that specific antenna. To be acceptable, an antenna calibration certificate/report shall have been issued by an antenna calibration laboratory whose scope of accreditation includes the applicable antenna calibration method or methods and the capability to cover the required frequency range. For further details, see 4.7.3.

^b When performing NSA measurements, users are cautioned that the geometry-specific correction factors (GSCFs) required for biconical dipole antennas with 50 Ω baluns are significantly different from those applicable to biconical dipole antennas with 200 Ω baluns. Additionally, users are cautioned that the GSCFs for all biconical dipole antennas vary with measurement distance and frequency. ANSI C63.5 provides specific instructions and appropriate tables for the use of these antennas with the different balun designs and at different measurement distances as a function of frequency when performing NSA measurements. For further details, see Annex D and ANSI C63.5. Notwithstanding the requirement to use biconical dipole antennas for *NSA Method* test site validation measurements from 30 MHz to 200 MHz, it is permissible (but not recommended) to *also* use biconical dipole antennas for *NSA Method* test site validation measurements from 200 MHz to 300 MHz. If biconical dipole antennas are used for *NSA Method* test site validation measurements at frequencies from 200 MHz to 300 MHz, the GSCFs will need to be measured from 200 MHz to 300 MHz, because Annex G of ANSI C63.5 does not contain computed GSCFs for biconical dipoles in the frequency range from 200 MHz to 300 MHz.

^c The use of precision broadband omnidirectional (biconical) antennas complying with the constructional and pattern requirements specified in 8.3.3.1 of CISPR 16-1-4:2010-04 is required for test site validation measurements using the S_{VSWR} *Method*. No other types of biconical antennas shall be used for test site validation above 1 GHz.

^d Users of LPDA antennas are cautioned that the required calibration methods for these antennas at frequencies up to and including 1 GHz are completely different from those required to be used at frequencies above 1 GHz. Users are further cautioned that an LPDA antenna whose operating frequency range extends above 1 GHz shall be acceptable for use in making test site validation measurements ONLY if the calibration certificate/report for that antenna explicitly states the differences between the calibration methods used below 1 GHz and the calibration method used above 1 GHz and separately lists the antenna factors below and above 1 GHz. Notwithstanding the requirement to use LPDA antennas for *NSA Method* test site validation measurements from 200 MHz to 1000 MHz, it is permissible (but not recommended) to use LPDA antennas for *NSA Method* test site validation measurements only from 300 MHz to 1000 MHz if biconical dipole antennas are used for *NSA Method* test site validation measurements at frequencies from 30 MHz to 300 MHz (see footnote b of this table).

^e When performing test site validation by means of the S_{VSWR} *Method*, it is required that the same type of receive antenna(s) used for making test site validation measurements above 1 GHz also be used for performing final EUT radiated emissions measurements above 1 GHz.

^f A test site validation option above 1 GHz is described in 5.5.1 a) 2) wherein a specific sized area of the ground plane is covered with RF absorber having specific performance characteristics, without the need for test site validation measurements at frequencies above 1 GHz.

^g The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in m) is equal to or greater than the Rayleigh (far-field) distance (i.e., $R_m = 2D^2 / \lambda$), where D is the largest dimension of the antenna aperture (in m) and λ is the free-space wavelength (in m) at the frequency of measurement.

^h The use of an active horn antenna is permitted when S_{VSWR} *Method* test site validation measurements are made in a shielded enclosure (e.g., RF anechoic chamber). The use of an active horn antenna is permitted when S_{VSWR} *Method* test site validation measurements are made in a non-shielded environment (e.g., an OATS); however, users are cautioned to verify whether the ambient signals are causing the preamplifier portion of the active horn antenna to saturate (thus yielding unacceptable, erroneous measurements) and, if they are, to take corrective action (e.g., use of a notch filter, reorientation of the measurement axis) to eliminate the saturation condition.

ⁱ If it is intended to use a specific hybrid antenna to make final compliance measurements on products at a specific test site, then the use of that same hybrid antenna is mandatory when making S_{VSWR} *Method* test site validation measurements at that specific test site over the frequency range from 1 GHz up to the highest frequency at which the hybrid antenna will be used to make final compliance measurements on products.

4.5.2 Magnetic field measurements (9 kHz to 30 MHz)

Either passive loop antennas or active loop antennas, as specified in ANSI C63.2 and/or CISPR 16-1-4:2010-04, shall be used to measure magnetic fields in the frequency range of 9 kHz to 30 MHz. See also Table 1 and Table 2 for the applicable conditions of use of loop antennas.

4.5.3 Electric field measurements (9 kHz to 30 MHz)

Either passive monopole antennas or active monopole antennas, as specified in ANSI C63.2 and ANSI C63.5, shall be used to measure electric fields in the frequency range of 9 kHz to 30 MHz (see also CISPR 16-1-4:2010-04). Generally, a 1.04 m (approximately 41 in) vertical monopole antenna is used with or without a counterpoise, as specified by the manufacturer or the regulatory and/or purchasing agency requirements, as applicable. The height of the base of the monopole antenna element shall be placed to be within 0 cm to 20 cm above the height of the base of the EUT. See also Table 1 and Table 2 for the applicable conditions of use of monopole antennas.

NOTE—Some regulatory and/or purchasing agencies (e.g., FCC) do not allow the use of a monopole antenna for measurements of radiated emissions.

4.5.4 Electric field measurements (30 MHz to 1000 MHz)

Linearly polarized antennas, as specified in ANSI C63.2 and/or ANSI C63.5, shall be used to measure electric fields in the frequency range of 30 MHz to 1000 MHz (see also CISPR 16-1-4:2010-04). Specifically, tunable dipole antennas, biconical dipole antennas, LPDA antennas, and hybrid antennas may be used. However, hybrid antennas can be used only if the requirements of the site-dependent qualification procedure specified in Annex N are satisfied. See Table 1, Table 2, and Table 3 for the applicable conditions of use for tunable dipole antennas, biconical dipole antennas, LPDA antennas, and hybrid antennas.

NOTE—Some regulatory and/or purchasing agencies may require the use of a reference antenna (i.e., tunable dipole as described in 6.2, Annex C, and Annex E of ANSI C63.5-2006) for measurements of radiated emissions.

4.5.5 Electric field measurements (1 GHz to 40 GHz)

Linearly polarized antennas, as specified in Table 1, Table 2, or Table 3, as applicable, and calibrated in accordance with ANSI C63.5, shall be used (see also CISPR 16-1-4:2010-04). These antennas include hybrid antennas, LPDAs, double-ridged waveguide horns, quadruple-ridged waveguide horns, rectangular waveguide horns, pyramidal horns, optimum-gain horns, octave-band horns, and standard-gain horns. The main “beam” or main lobe of the pattern for any antenna used shall be large enough to encompass the physical size of the EUT, or system arrangement, when located at the measuring distance. See 8.2.4 for details on techniques for encompassing products in the measurement process.

The aperture dimensions of these horn antennas shall be small enough so that the measurement distance (in meters) is equal to or greater than the Rayleigh (far-field) distance [i.e., $R_m = (2D^2)/\lambda$], where D is the largest dimension of the antenna aperture (in meters) and λ is the free-space wavelength (in meters) at the frequency of measurement. In case of dispute, measurements made with a standard-gain horn antenna shall take precedence.

4.6 Absorbing clamp

Measurements of radio-noise power, if required, are made with an absorbing clamp; see Clause 9.

4.7 Calibration of measuring equipment

4.7.1 General requirements

All instruments that can have a significant effect on the accuracy or validity of measurements made as specified in this standard shall be calibrated in accordance with the manufacturer's recommendations and the instrument requirements of ANSI C63.2. A calibration records system shall be maintained, as part of a laboratory quality system, which monitors the calibration status of the test equipment and facilitates the traceability to national standards.

4.7.2 Confirmation interval

The calibration of all instruments shall be confirmed in the first year of deployment. The subsequent recalibration intervals may be longer (up to 3 years) or shorter based on review of calibration data relative to the recommendations of the instrument manufacturer and the required measurement accuracy. All instruments shall be checked as frequently as necessary between calibration intervals to provide evidence that instrument accuracy and system measurement uncertainty is continuously maintained; see ISO 10012:2003.

Reference antennas that are used only for calibration or test site validation measurement purposes shall be constructed as specified and should be checked using ANSI C63.5 methods at least every 3 years.

4.7.3 Antenna calibration

All antennas shall be calibrated in accordance with ANSI C63.5, including antennas used for performing NSA measurements for standard test site validation and alternative test site validation (see 5.4.2) and antennas used for performing S_{VSWR} measurements for test site validation above 1 GHz. Antennas shall be recalibrated at regular intervals (i.e., periodically recalibrated) as described in 4.7.2 and recalibrated after repair when damage or deterioration is suspected or known to have occurred. Notwithstanding the provisions of the preceding sentence:

- Standard gain horns need not be periodically recalibrated, unless damage or deterioration is suspected or known to have occurred. If a standard gain horn is not periodically recalibrated, its critical dimensions (see IEEE Std 1309-2005) shall be verified and documented on an annual basis.
- Precision broadband omnidirectional (biconical) antennas used for S_{VSWR} site validation testing [see also 5.5.1 a) 1)] and complying with the constructional and pattern requirements specified in 8.3.3.1 of CISPR 16-1-4:2010-04 need not be periodically recalibrated, unless damage or deterioration is suspected or known to have occurred.

To be acceptable, an antenna calibration certificate/report shall have been issued by an antenna calibration laboratory whose scope of accreditation includes the applicable antenna calibration method or methods including the calibration measurement uncertainty.

4.7.4 LISN impedance and insertion loss measurements

The impedance and insertion loss of each LISN used in testing emissions shall be measured over the frequency range of use. It is suggested that the insertion loss measurement be carried out after the completion of the impedance measurements. The LISN shall be measured in the configuration for which it is used for testing a product. Acceptable procedures for performing these measurements are given in Annex B. See 5.2.4.2 for verifying a permanently installed LISN. The LISN should be checked routinely to confirm acceptable performance; see 4.7.2.

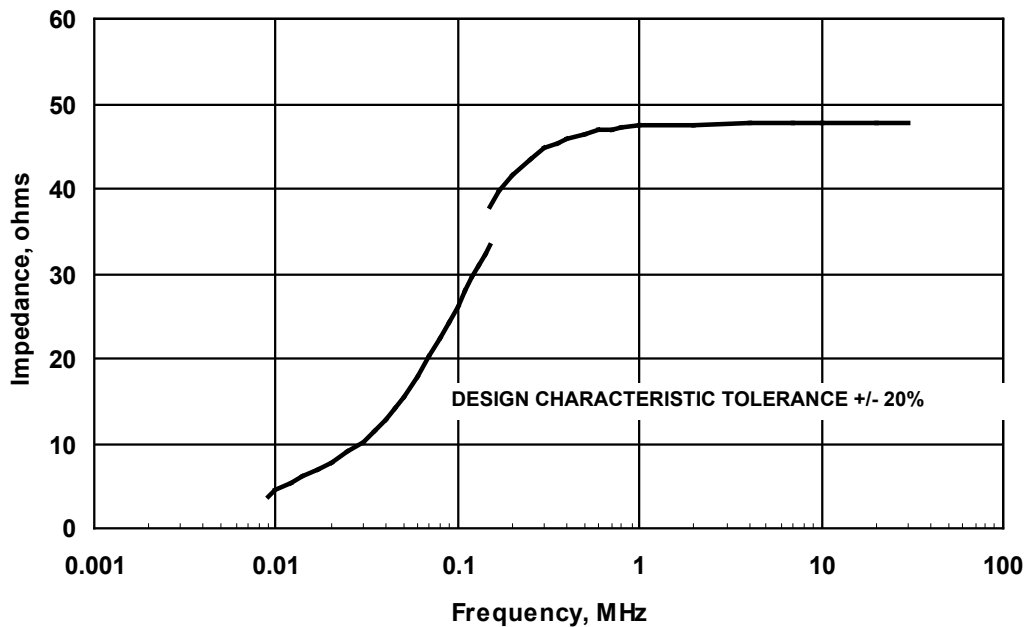
4.7.5 Characterization of absorbing clamp

Absorbing clamps used to measure disturbance power on cables should be characterized in accordance with Annex B of CISPR 16-1-3:2004-06; see also Annex C herein.

4.7.6 Cable insertion loss

The insertion loss of cables used for connection of antennas or transducers to measuring instruments (e.g., EMI receivers, spectrum analyzers) shall be characterized or checked frequently for deterioration caused by use and environmental exposure (e.g., variation due to change in temperature and damage). Published data²¹ have shown that temperature variations of 15 °C or more result in 2% or greater change in cable losses. Consequently, the temperatures present during initial cable loss characterization and product testing shall be recorded. When the temperature change exceeds 15 °C, the cable characterization shall be repeated.

4.8 Figures for Clause 4



NOTE—The discontinuity in the curve is due to the impedance values being derived from the two different circuits for the 9 kHz to 150 kHz (Figure 2) and 150 kHz to 30 MHz (Figure 3) frequency ranges.

Figure 1—Nominal impedance characteristic of LISN port, 9 kHz to 30 MHz²²

²¹ For example, see http://www.gore.com/en_xx/products/cables/microwave/changes_insertion_loss_phase.html.

²² Past editions of ANSI C63.4 contained an idealized continuous version of the LISN nominal impedance curve. Although the previous idealized curve was within the $\pm 20\%$ impedance tolerances corresponding to the piecewise curve of Figure 1, it did not reflect the actual calculated responses of the circuits of Figure 2 and Figure 3 at frequencies above and below the 150 kHz break point.

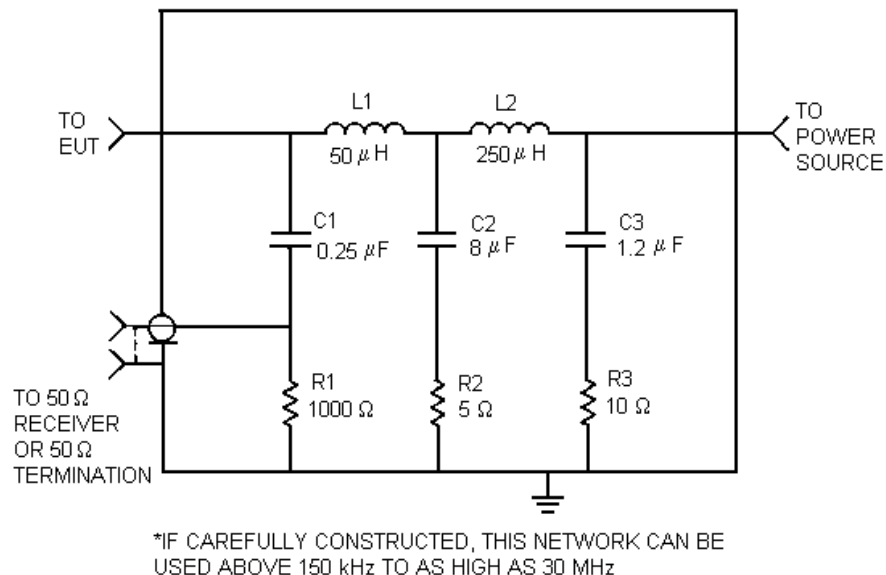
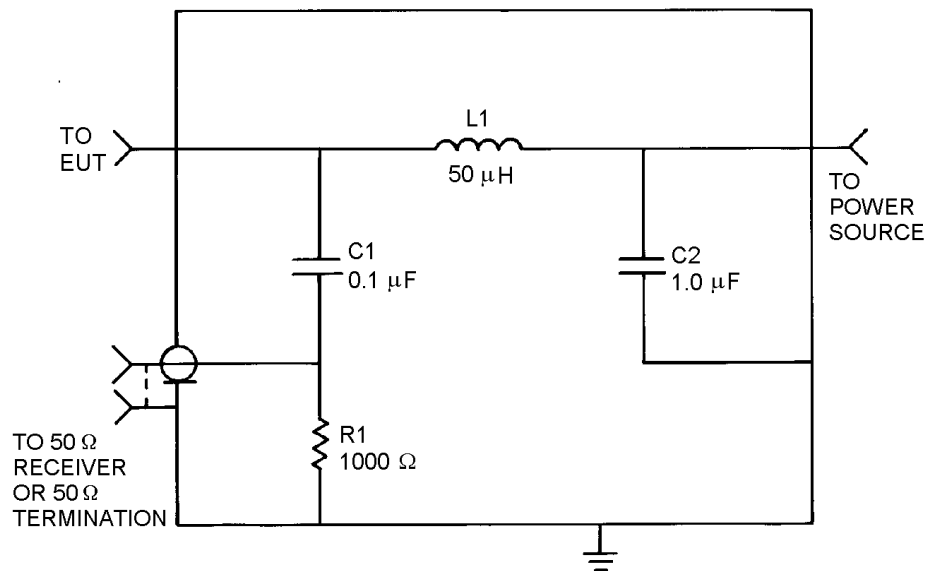


Figure 2—Circuit diagram of LISN to provide impedance of Figure 1 for the 9 kHz to 150 kHz (30 MHz²³) frequency range



*IN SOME LISNs, A SERIES RESISTANCE IS INCLUDED IN SERIES WITH CAPACITOR C2

Figure 3—Circuit diagram of LISN to provide impedance of Figure 1 for the 0.15 MHz to 30 MHz frequency range

²³ Some designs and implementations support use of the Figure 2 circuit up to 30 MHz without impedance resonances or anomalies.

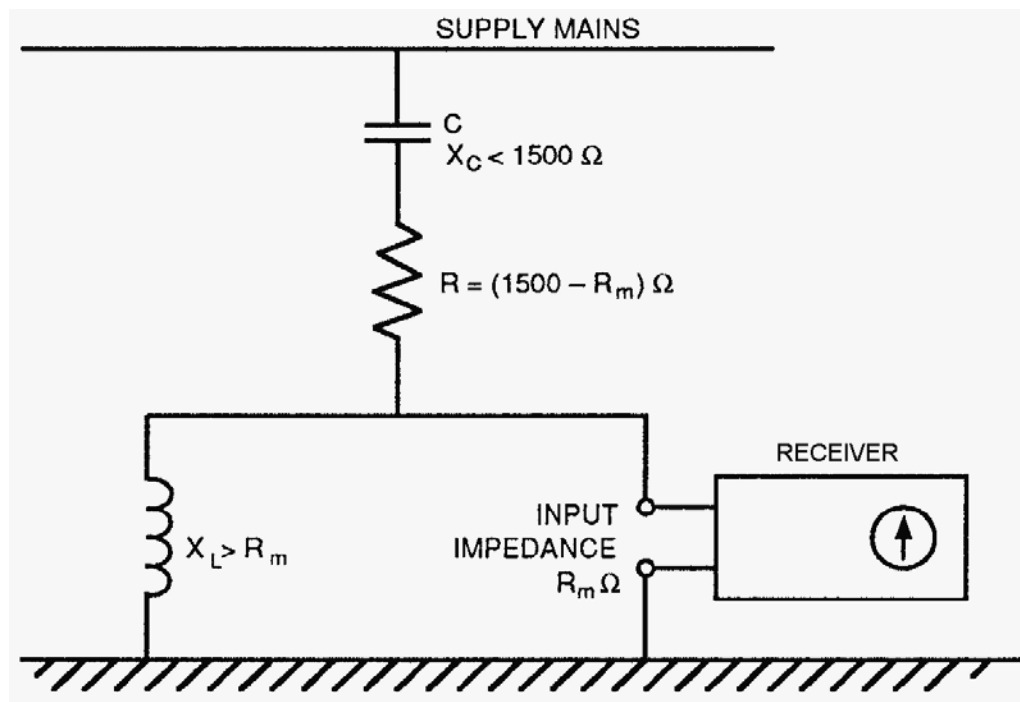


Figure 4—Voltage probe for measurements at a user's installation

5. Test facilities

5.1 General requirements

5.1.1 General considerations

Radiated and ac power-line conducted emission measurements shall be made in an environment that provides valid, repeatable measurement results (i.e., as described in 5.2 for ac power-line conducted emission test sites or 5.3 through 5.5 for radiated emission test sites). Where appropriate, tests may be made at the manufacturer's location or the user's installation (see 5.6). In any case, the requirements of this subclause shall be observed.

5.1.2 Power source

Sufficient ac power shall be available to operate the EUT at its rated voltage, current, power, and frequency.

5.1.3 Ambient radio noise and signals

AC power-line conducted and radiated ambient signal levels, measured at the test site in peak detection mode (preliminary scans) with the EUT deenergized, shall be at least 6 dB below the allowable limit of the applicable specification or standard. In the event that the measured levels of ambient plus EUT radio noise are not above the applicable limit, the EUT shall be considered to be in accordance with the limit.

If the ambient field exceeds the applicable limit(s), the following alternatives may be used:

- a) In the case of radiated emission measurements, perform measurements at the closest distance permitted by 5.4.1 and extrapolate results to the specified limit distance. The method of extrapolation shall be justified and described in the test report.
- b) Perform radiated emission measurements of critical frequency bands during hours when broadcast stations are off the air and at times when ambient signals from industrial equipment are reduced to less than the 6 dB level.
- c) Perform measurements in an absorber-lined shielded room (see 5.4.2 for conditions of use).
- d) Orient the radiated emission test site to discriminate against such ambient signals insofar as possible.
- e) If the signal being measured is a continuous wave (CW) signal or if only one single spectral component of the signal to be measured is within the pass-band of the IF filter at any time, and if the ambient electric field is broadband, then reduce the resolution bandwidth if using a spectrum analyzer or reduce the bandwidth if using an EMI receiver.
- f) Rotate the EUT on a turntable while observing possible correlation between radiated emission amplitude and EUT azimuth.
- g) Monitor the audio output of the EMI receiver with a loudspeaker or headphones and its video output with a time-based oscilloscope display to discriminate between ambient noise and signals and EUT emissions.

If the power-line ambient level exceeds the applicable limit(s), the following alternatives may be used for ac power-line conducted emission testing:

- Perform measurements in a shielded enclosure. However, this method is recommended only at frequencies below the resonant frequencies of the enclosure, usually under 30 MHz.
- Insert suitable power-line filters between the power source and the LISN.

5.1.4 EUT turntable

A continuously rotating, remotely controlled turntable shall be used for installation at the test site to support the EUT and facilitate determination of the direction of maximum radiation for 360° azimuth rotation at each EUT emission frequency. For floor-standing EUTs, the turntable shall be metal covered and flush with the ground plane. For tabletop EUTs, the turntable may be nonmetallic and located on top of the reference ground plane. Turntable design and operation should be based on the radiated emission measurement requirements specified in 8.1 and adhere to the reflecting structure and ground plane limitations that facilitate compliance with the NSA requirements. See ANSI C63.7 for additional specific guidance on turntable installations.

5.1.5 EUT support table

Tabletop devices shall be placed on a nonconducting platform (i.e., an “EUT support table”), of nominal size 1 m by 1.5 m, whose top surface is nominally 80 cm above the reference ground plane. Guidance on the construction of EUT support tables is given in Annex J.

The effects of the EUT support table shall be included in the calculation and reporting of the measurement uncertainty for radiated emissions measurements made on tabletop devices (i.e., see 10.2.8.2).

The method for evaluating the effects and the uncertainty contribution of the table on EUT radiated emissions given in 5.5 of CISPR 16-1-4:2010-04 shall be used for frequencies from 200 MHz up to 1 GHz. For 1 GHz to 18 GHz, the same method as for 200 MHz up to 1 GHz shall be used, except that the receive antenna shall be kept at a fixed height of 1 m (without height scanning).

Because there is no generally accepted method for evaluating the effects of the table on EUT radiated emissions above 18 GHz, there is no requirement for evaluating the effects of the table on EUT radiated emissions from 18 GHz to 40 GHz.

5.1.6 Antenna positioner

A remote-controlled antenna positioner with continuously variable height is recommended for installation at the site to support the measuring antenna and facilitate determination of the height of maximum radiation at each EUT emission frequency, over a range of 1 m to 4 m above the reflecting plane. Antenna positioner design and operation should be based on the radiated emission measurement requirements specified in 8.1, and one shall facilitate compliance with the NSA requirements.

5.2 AC power-line conducted emission test requirements

5.2.1 General considerations

AC power-line conducted emission measurements may be made at a facility that meets the requirements of 5.2. This may include a shielded (screened) room or a radiated emission test site.

5.2.2 Reference ground plane

The reference ground plane for measuring ac power-line conducted emissions is to consist of a floor earth-grounded conducting surface, which may be the metal floor of a shielded test chamber. There shall be a direct connection between the conducting surface and earth. It is NOT permissible to use the metallic structure of a building as an intermediate path to ground.

The connection from the conducting surface should be accomplished by connecting (bonding) a tinned-copper ground strap or a heavy ground lead to the conducting surface using a brass or bronze ground stud fitted with brass or bronze washers and a nut or by brazing or sweat-soldering. The connection of the ground strap or ground lead to a copper-plated steel earth (ground) rod should be made (bonded) by means of a ground-cable clamp and/or by brazing or sweat-soldering. The bonds used shall each individually have a direct current (dc) resistance of less than or equal to 2.5 mΩ.

If a shielded enclosure is used to provide the reference ground plane, it is permissible to install the ground stud on a metal wall of the shielded enclosure, provided that the metal wall of the shielded enclosure is continuously bonded (by mechanical compression or by brazing, sweat-soldering, or welding) to the metal floor of the shielded enclosure.

The reference ground plane shall be at least 2 m by 2 m in size, and it shall extend at least 0.5 m beyond the vertical projection of the horizontal perimeter (i.e., footprint) of the EUT or EUT arrangement. For a floor-standing EUT, if the EUT normally does not make electrical contact with a ground plane, then insulating materials with thickness of up to 12 mm shall be used to cover the reference ground plane.

5.2.3 Vertical conducting plane

Optionally, for measurements of ac power-line conducted emissions for a tabletop device, a vertical conducting plane or screen, with a size of at least 2 m by 2 m, may be located 40 cm to the rear of the EUT. The vertical conducting plane or screen shall be electrically connected to the reference ground plane at intervals not greater than 1 m along its entire length through low impedance connections (e.g., 3 cm wide metal straps). The metal wall of a screen room will normally satisfy this requirement. A tabletop device may be measured for ac power-line conducted emissions without a vertical conducting plane while maintaining the 80 cm EUT elevation specified in 6.3.2. In case of a dispute, ac power-line conducted emission measurements performed on a tabletop device with a vertical conducting plane in place shall take precedence.

A vertical conducting plane is not required for ac power-line conducted emissions measurements on a floor-standing device. A vertical conducting plane shall not be used for any radiated emission measurements.

5.2.4 LISN installation

5.2.4.1 General considerations

LISNs may be required for ac power-line conducted emission measurements and may be utilized for radiated emission measurements. For exceptions, see 5.6.

5.2.4.2 LISN connected to the reference ground plane

Where use of a LISN is required (see Clause 7), it shall be placed on and electrically bonded to the top surface of, or immediately beneath, the reference ground plane and shall be bonded to the ground plane.

The site reference ground plane is the ground reference for the LISN. The bond used shall have a dc resistance of less than or equal to 2.5 m Ω . If LISNs are kept on the test site for radiated emission measurements, it is preferred that they be installed under the reference ground plane with the ac power receptacle flush with the reference ground plane. Otherwise, the LISN(s) must be present during NSA measurements.

The impedance at the receptacle end of any cable connected to the EUT end of the LISN (as contrasted to the impedance at the LISN terminals given in Figure 1), with the measuring instrument port of the LISN terminated into a 50 Ω load, shall be within +30% and –20% of the nominal LISN impedance shown in Figure 1 over the frequency range of the network to be used; see 4.3. If the attenuation (insertion loss) between the EUT receptacle and the measuring instrument port on the LISN is more than 0.5 dB (see Annex B for an example of a method of measurement), it shall be accounted for when calculating the EUT emission levels.

5.2.4.3 Use of filters or isolation transformers

Ambient noise may be present on the ac power lines at some locations and at some frequencies within the frequency range of interest. If the levels are sufficient to cause interference with readings made using a LISN, filtering of the ac power may be required. The filter should be inserted between the ac power supply and the ac input connection to the LISN, preferably as close as possible to the LISN to reduce interference pickup by the leads between the filter and the LISN.

Where an isolation transformer is used between the ac power supply and the LISN, care shall be taken to confirm that the rating of this transformer is large enough to not affect the peak current drawn by the EUT. This may require up to 10 times the kilovolt-ampere rating of the EUT. If other than air-core inductors are used in the LISN, they shall be in a linear permeability range at the peak currents drawn by the EUT.

5.2.5 Voltage probe

If use of a LISN is impossible because of the high current requirements of the EUT or if a reference ground plane is not available, ac power-line conducted emission measurements shall be performed using a voltage probe, as discussed in 4.4; see also 5.6.

5.3 Radiated emission test facilities (9 kHz to 30 MHz)

For magnetic field strength measurements (see 8.2.1), a site similar to that shown in Figure 5, should be used, except that a reference ground plane is not required. The site does not have to meet an NSA requirement at these frequencies because NSA is based on electric fields. If a reference ground plane is present, the measured level of emissions may be higher than if measurements were made without a ground plane. The magnetic field strength measurements made at a site with no reference ground plane shall take precedence. If permitted by the regulatory and/or purchasing agency, measurements may also be made in a shielded enclosure at frequencies below its resonant frequency, or in a TEM device (see Annex F).

5.4 Radiated emission test facilities (30 MHz to 1 GHz)

5.4.1 Standard test sites

The standard test site shall be an open, flat, level area that is clear of overhead wires and reflecting structures and is sufficiently large to permit measuring antenna placement at the specified distance. This is

commonly called an OATS when the ground is covered with conductive material. Adequate spacing shall also be provided between the site, including the EUT and the measuring antenna, and any adjacent, large reflecting structures. Reflecting structures are defined as objects or housings that are conductive or become conductive over time (e.g., structures may absorb conductive airborne contaminants when in use). Test personnel shall not be permitted within the perimeter of the area during testing. A conductive metal ground plane shall cover the floor of the site, as described in 5.4.3. ANSI C63.7 provides additional important guidance on the desired characteristics, construction, and deterioration possibilities of standard sites. A suggested layout for the standard site is diagrammed in Figure 5, where the recommended EUT-to-antenna distances R are 3 m, 10 m, and 30 m (measured along the main EUT-to-measurement-antenna axis). A standard test site shall comply with the NSA requirements of 5.4.4. In case of disagreement, measurements made at a standard test site take precedence.

5.4.2 Alternative test sites

Radiated emissions measurements may be made at certain types of alternative test sites. Alternative test sites include RF absorber-lined metal test chambers with only the floor composed of a conductive material, office or factory buildings large enough for reflections to not disrupt the field at the point of measurements, and weather-protected OATS because the potential effects of the cover material cannot be shown without volumetric NSA measurements. All such alternative sites shall comply with the volumetric NSA requirements of D.3 over the volume occupied by the EUT or the EUT arrangement in order to be acceptable as an alternative test site. Metal-shielded enclosures and other sites that do not comply with the volumetric NSA requirements may be used only for exploratory radiated emission measurements, unless it can be demonstrated that the results achieved are equivalent to those obtained at a standard or alternative site that complies with the appropriate NSA requirement. In addition, measurements may be made in a TEM device under certain conditions; see Annex F.

5.4.3 Reflecting ground plane

A reflecting ground plane shall be installed on the floor of the radiated electric field emission test site to provide a uniform, predictable reflection of radiated emissions measured at the site. The ground plane shall be constructed of metallic material with limited discontinuities and sufficiently high conductivity and surface smoothness to facilitate compliance with the NSA requirements. The surface smoothness of the ground plane shall comply with the maximum values for terrain roughness defined by the Rayleigh criterion, as shown in ANSI C63.7. Ground planes with discontinuities (including connection point separation between adjacent metallic materials) larger than 3.0 cm, or with overall size less than the minimum configuration shown in Figure 5, are not recommended; see ANSI C63.7 for guidance about test sites in the frequency range of 30 MHz to 1 GHz.

5.4.4 Site validation

5.4.4.1 General requirements

Radiated emission test sites shall be validated by measurement of the attenuation of signals propagated over the site and compared with theoretical attenuation of signals propagated over an ideal site. Horizontally and vertically polarized attenuation measurements shall be made over the frequency range of 30 MHz to 1 GHz. These measurements shall be made in accordance with the procedures of D.2 and/or D.3, as applicable, and the results normalized for comparison with the theoretical attenuation values.

During site attenuation measurements, the receiving antenna positioner normally used, the raised turntable if used, and ground-plane-mounted LISNs (see 5.2.4.2) shall be in place at the site. If special antenna

connecting cabling is required to meet the site validation requirements, the same or similarly treated cabling with the same RF characteristics shall also be used for radiated emissions testing.

5.4.4.2 Site acceptability criterion

The measured NSA for a radiated emissions test site shall be within ± 4 dB of the theoretical NSA for an ideal test site (see D.1).

5.4.4.3 Site validation interval

Validation of the acceptability criterion shall be confirmed in the first year for a new site or one that has undergone physical and electrical upgrades or changes. Subsequent validation intervals may be longer (up to 3 years) or shorter, based on a review of NSA data relative to the extent and severity of use of the site, weather effects on the site, drifting of reflective characteristics of covering structures of weather-protected OATS, and physical modifications made to the site or adjacent areas (see ANSI C63.7). It is recommended that periodic site-attenuation measurements be made in order to detect anomalies due to degradation of all-weather protection caused by weather conditions (moisture absorption, for example) or contamination of enclosure materials. A 12-month interval is generally adequate unless physical signs indicate material degradation sooner; that is, the weather-proofing material changes color due to airborne contaminants. In those cases, a 6-month interval is recommended. The objective is to optimize the balance of risks and costs consistent with the required accuracy; see also Annex A of ISO 10012:2003 for more guidance.

5.5 Radiated emission test facilities for frequencies above 1 GHz (1 GHz to 40 GHz)

5.5.1 General

A test facility (i.e., test site) may be deemed acceptable for making final compliance radiated emissions measurements in the frequency range of 1 GHz to 40 GHz, regardless of whether it complies with the site validation requirements for the 30 MHz to 1 GHz frequency range described in 5.4.1 for standard test sites or 5.4.2 for alternative test sites.

It is explicitly permitted to convert a test site from use over the frequency range of 30 MHz to 1 GHz to use over the frequency range of 1 GHz to 40 GHz by placing loose-laid RF absorber material on the ground plane. It is also explicitly permitted to convert a test site from use over the frequency range of 1 GHz to 40 GHz to use over the frequency range of 30 MHz to 1 GHz by removing loose-laid RF absorber material on the ground plane.

- a) For a measurement distance of 3 m, test facilities (i.e., test sites) used for making final compliance radiated emissions measurements in the frequency range of 1 GHz to 40 GHz are deemed to be acceptable when *either* of the following conditions [i.e., item 1) or item 2)] is met.
 - 1) **Site validation by means of S_{VSWR} measurements:** The test site has been shown to comply with the S_{VSWR} requirements specified in 8.3.2 of CISPR 16-1-4:2010-04 over the frequency range of 1 GHz to 18 GHz, when tested in accordance with the site validation procedures requirements specified in 8.3.3 of CISPR 16-1-4:2010-04. Additionally, the RF absorbing material used on the reference ground plane (i.e., the ground plane of an OATS or the conductive metal floor of an RF anechoic chamber, as applicable) and on the turntable shall have a maximum height (thickness) of 30 cm (12 in) and shall have a minimum-rated attenuation of 20 dB (at normal incidence) at all frequencies from 1 GHz to 18 GHz.

NOTE—When performing the site validation procedures specified in 8.3.3 of CISPR 16-1-4:2010-04, an automated multiple-axis translational positioner (i.e., mechanical translation stage), typically an xy -axes positioner, may be used to move the precision broadband omnidirectional dipole antenna, if desired.

- 2) **Alternative site validation without S_{VSWR} measurements:** RF absorbing material is placed on the test site ground plane and turntable, covering a minimum area with length of $(2.3 \text{ m} + \text{turntable diameter, in m})$ or 3.8 m, whichever is greater, and width of 3.6 m, for a 3 m test distance between the antenna and the center of the turntable; normative Figure 6 shows the geometry. The layout diagram of Figure 6 applies to the measurement axis selected for compliance measurements, and other considerations may be needed related to the extent of the overall ground plane or the placement of the center axis of the test site.

Other descriptions for the setup and parameters of normative Figure 6 are as follows:

- i) The RF absorbing material used on the reference ground plane (i.e., the ground plane of an OATS or the conductive metal floor of an RF anechoic chamber, as applicable) and on the turntable shall have a maximum height (thickness) of 30 cm (12 in) and shall have a minimum-rated attenuation of 20 dB (at normal incidence) at all frequencies from 1 GHz to 18 GHz.
- ii) The footprint of the RF absorber material must extend a minimum of 30 cm (12 in) beyond the edges of the gap between the turntable and the reference ground plane of the test site. The gap between the turntable and the reference ground plane of the test site does not need to be covered with RF absorber. Additionally, if necessary to avoid mechanical clearance problems, a zone that extends up to ± 1 cm (nominal) from the edges of the gap between the turntable and the reference ground plane of the test site does not need to be covered with RF absorber material.
- iii) The footprint of the RF absorber material must extend from a minimum of 50 cm behind the phase center of the antenna forward to a minimum distance of $(2.3 \text{ m} + \text{turntable diameter, in m})$ or 3.8 m, whichever is greater. If necessary, the RF absorber material may be placed on the base-plate of the antenna mast, regardless of the resulting height of the tips of the RF absorbing materials, as long as the movement of the antenna at its lowest height (i.e., 1 m from the floor to the phase center of the antenna) is not impeded.
- iv) The footprint of the RF absorber material must extend a minimum of 1.8 m leftward and rightward of a horizontally projected line from the phase center of the antenna to the center of the turntable. In other words, the total minimum width of the footprint of the RF absorber material must be 3.6 m.
- v) Except as indicated in item 2) ii) of this list, the turntable must be entirely covered with RF absorber material; however:
 - During radiated emission testing of table-top-mounted EUTs, the RF absorbing material placed on the turntable may be removed in the immediate area of the footprint of the table and for up to 10 cm surrounding the footprint of the table.
 - During radiated emission testing of floor-standing EUTs, the RF absorbing material placed on the turntable may be removed in the immediate area of the EUT footprint and for up to 10 cm surrounding the EUT footprint.
- b) For measurement distances of 10 m, test facilities (i.e., test sites) used for making final compliance radiated emissions measurements in the frequency range of 1 GHz to 40 GHz are deemed to be acceptable only if the test site has been shown to comply with the S_{VSWR} requirements specified in 8.3.2 of CISPR 16-1-4:2010-04 over the frequency range of 1 GHz to 18 GHz, at the desired separation distance(s), when tested in accordance with the site validation procedures requirements specified in 8.3.3 of CISPR 16-1-4:2010-04. Additionally, the RF absorbing material used on the reference ground plane (i.e., the ground plane of an OATS or the conductive metal floor of an RF anechoic chamber, as applicable) and on the turntable shall have a maximum height (thickness) of

30 cm (12 in) and shall have a minimum-rated attenuation of 20 dB (at normal incidence) at all frequencies from 1 GHz to 18 GHz.

- c) Regardless of the measurement distance:
- 1) During radiated emission testing of table-top-mounted EUTs, the RF absorbing material placed on the turntable may be removed in the immediate area of the footprint of the table and for up to 10 cm surrounding the footprint of the table.
 - 2) During radiated emission testing of floor-standing EUTs, the RF absorbing material placed on the turntable may be removed in the immediate area of the EUT footprint and for up to 10 cm surrounding the EUT footprint.

There are no test site validation requirements applicable to the frequency range of 18 GHz to 40 GHz. A test site that satisfies the requirements stated in this subclause from 1 GHz to 18 GHz is deemed to be suitable for use over the frequency range of 18 GHz to 40 GHz.

5.5.2 Validation interval

When the S_{VSWR} acceptance criterion (as specified in CISPR 16-1-4:2010-04) option is selected, the site validation shall be confirmed in the first year for a new site or one that has undergone physical and electrical upgrades or changes. Subsequent validation intervals may be longer (up to 3 years) or shorter, based on the extent and frequency of use of the site and any modifications made to it. A 12-month interval is generally adequate for the validation of a site to facilitate continual compliance with the S_{VSWR} requirements. See also Annex A of ISO 10012-1:2003 for further guidance in establishing a suitable validation interval based on the results of periodic checks.

5.6 Testing at manufacturer's location or user's installation (on-site/in situ testing)

Testing is permitted at the end user or manufacturer's premises, if the equipment cannot be set up on an OATS or alternative test site (see 8.3.3). In this case, both the equipment and its location are considered the EUT. The radiated emission test results are unique to the installation site because site containment properties affect the measurements. The ac power-line conducted emission test results also may be unique to the installation. However, where testing of a given system has been accomplished at three or more representative locations, the results may be considered representative of all sites with similar EUTs for the purposes of determining compliance with emission requirements (if allowed in the regulatory and/or purchasing agency requirements). A voltage probe (see 4.4) shall be used for ac power-line conducted emission measurements (see IEEE Std 139-1988 for additional information). Neither a reference ground plane nor a LISN shall be installed for user's installation testing, unless one or both are to be a permanent part of the installation.

5.7 Figures for Clause 5

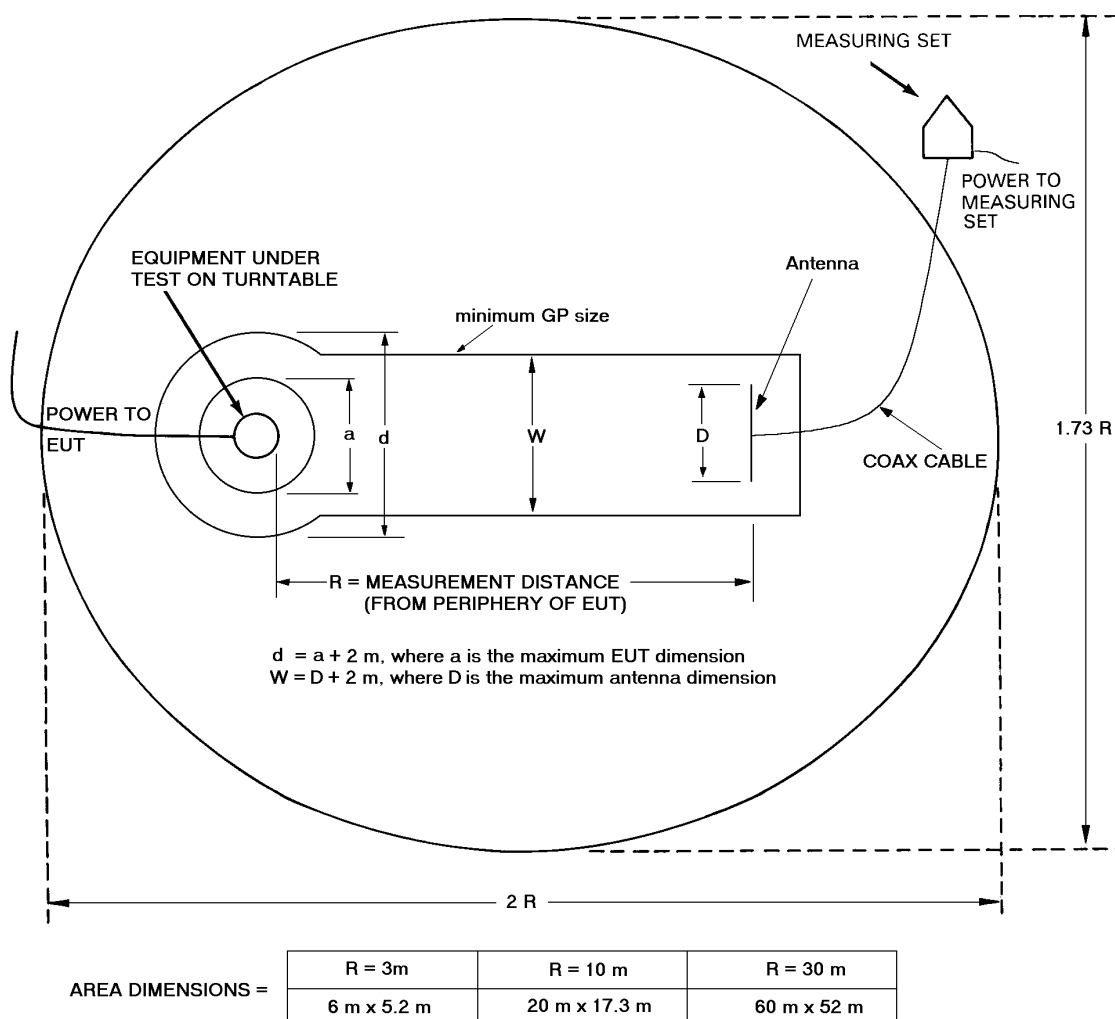


Figure 5—Radiated emissions measurement obstruction-free area and minimum size of ground plane for test site with a turntable