IEEE STANDARDS ASSOCIATION

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

IEEE
3 Park Avenue
New York, NY 10016-5997
USA

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

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

Accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 13 June 2014

American National Standards Institute

C63®

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

---

The Institute of Electrical and Electronics Engineers, Inc.
3 Park Avenue, New York, NY 10016-5997, USA

PDF: ISBN 978-0-7381-8917-8 STD98540
Print: ISBN 978-0-7381-8918-5 STDPD98540

American National Standard

An American National Standard implies a consensus of those substantially concerned with its scope and provisions. An American National Standard is intended as a guide to aid the manufacturer, the consumer, and the general public. The existence of an American National Standard does not in any respect preclude anyone, whether he has approved the standard or not, from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard. American National Standards are subject to periodic review and users are cautioned to obtain the latest editions.

CAUTION NOTICE: This American National Standard may be revised or withdrawn at any time. The procedures of the American National Standards Institute require that action be taken to reaffirm, revise, or withdraw this standard no later than five years from the date of publication. Purchasers of American National Standards may receive current information on all standards by calling or writing the American National Standards Institute.

Errata

Users are encouraged to check the IEEE Errata URL (http://standards.ieee.org/findstds/errata/index.html), and the one for ASC C63® at (http://www.c63.org/explanations_interpretations_request.htm, for errata periodically.

Interpretations (ASC C63® standards)

Current interpretations are essential to the understanding of all ASC C63® standards. To assist in the meanings of requirements, informative interpretations are available at the following URL: (http://www.c63.org/standards_development.htm). Users are cautioned that, although interpretations do not and can not change the requirements of a standard, they serve to clarify the meanings of requirements. All interpretations are informative rather than normative, until such time as the standard is revised (consistent with ASC C63® ANSI-accredited operating procedures) to incorporate the interpretation as a normative requirement.

Important Notices and Disclaimers Concerning IEEE Standards Documents

IEEE documents are made available for use subject to important notices and legal disclaimers. These notices and disclaimers, or a reference to this page, appear in all standards and may be found under the heading "Important Notice" or "Important Notices and Disclaimers Concerning IEEE Standards Documents."

Notice and Disclaimer of Liability Concerning the Use of IEEE Standards Documents

IEEE Standards documents (standards, recommended practices, and guides), both full-use and trial-use, are developed within IEEE Societies and the Standards Coordinating Committees of the IEEE Standards Association ("IEEE-SA") Standards Board. IEEE ("the Institute") develops its standards through a consensus development process, approved by the American National Standards Institute ("ANSI"), which brings together volunteers representing varied viewpoints and interests to achieve the final product. Volunteers are not necessarily members of the Institute and participate without compensation from IEEE. While IEEE administers the process and establishes rules to promote fairness in the consensus development process, IEEE does not independently evaluate, test, or verify the accuracy of any of the information or the soundness of any judgments contained in its standards.

IEEE does not warrant or represent the accuracy or content of the material contained in its standards, and expressly disclaims all warranties (express, implied and statutory) not included in this or any other document relating to the standard, including, but not limited to, the warranties of: merchantability; fitness for a particular purpose; non-infringement; and quality, accuracy, effectiveness, currency, or completeness of material. In addition, IEEE disclaims any and all conditions relating to: results; and workmanlike effort. IEEE standards documents are supplied "AS IS" and "WITH ALL FAULTS."

Use of an IEEE standard is wholly voluntary. The existence of an IEEE standard does not imply that there are no other ways to produce, test, measure, purchase, market, or provide other goods and services related to the scope of the IEEE standard. Furthermore, the viewpoint expressed at the time a standard is approved and issued is subject to change brought about through developments in the state of the art and comments received from users of the standard.

In publishing and making its standards available, IEEE is not suggesting or rendering professional or other services for, or on behalf of, any person or entity nor is IEEE undertaking to perform any duty owed by any other person or entity to another. Any person utilizing any IEEE Standards document, should rely upon his or her own independent judgment in the exercise of reasonable care in any given circumstances or, as appropriate, seek the advice of a competent professional in determining the appropriateness of a given IEEE standard.

IN NO EVENT SHALL IEEE BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO: PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE PUBLICATION, USE OF, OR RELIANCE UPON ANY STANDARD, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE AND REGARDLESS OF WHETHER SUCH DAMAGE WAS FORESEEABLE.

Translations

The IEEE consensus development process involves the review of documents in English only. In the event that an IEEE standard is translated, only the English version published by IEEE should be considered the approved IEEE standard.

Official statements

A statement, written or oral, that is not processed in accordance with the IEEE-SA Standards Board Operations Manual shall not be considered or inferred to be the official position of IEEE or any of its committees and shall not be considered to be, or be relied upon as, a formal position of IEEE. At lectures, symposia, seminars, or educational courses, an individual presenting information on IEEE standards shall make it clear that his or her views should be considered the personal views of that individual rather than the formal position of IEEE.

Comments on standards

Comments for revision of IEEE Standards documents are welcome from any interested party, regardless of membership affiliation with IEEE. However, IEEE does not provide consulting information or advice pertaining to IEEE Standards documents. Suggestions for changes in documents should be in the form of a proposed change of text, together with appropriate supporting comments. Since IEEE standards represent a consensus of concerned interests, it is important that any responses to comments and questions also receive the concurrence of a balance of interests. For this reason, IEEE and the members of its societies and Standards Coordinating Committees are not able to provide an instant response to comments or questions except in those cases where the matter has previously been addressed. For the same reason, IEEE does not respond to interpretation requests. Any person who would like to participate in revisions to an IEEE standard is welcome to join the relevant IEEE working group.

Comments on standards should be submitted to the following address:

Secretary, IEEE-SA Standards Board
445 Hoes Lane
Piscataway, NJ 08854 USA

Laws and regulations

Users of IEEE Standards documents should consult all applicable laws and regulations. Compliance with the provisions of any IEEE Standards document does not imply compliance to any applicable regulatory requirements. Implementers of the standard are responsible for observing or referring to the applicable regulatory requirements. IEEE does not, by the publication of its standards, intend to urge action that is not in compliance with applicable laws, and these documents may not be construed as doing so.

Copyrights

IEEE draft and approved standards are copyrighted by IEEE under U.S. and international copyright laws. They are made available by IEEE and are adopted for a wide variety of both public and private uses. These include both use, by reference, in laws and regulations, and use in private self-regulation, standardization, and the promotion of engineering practices and methods. By making these documents available for use and adoption by public authorities and private users, IEEE does not waive any rights in copyright to the documents.

Photocopies

Subject to payment of the appropriate fee, IEEE will grant users a limited, non-exclusive license to photocopy portions of any individual standard for company or organizational internal use or individual, non-commercial use only. To arrange for payment of licensing fees, please contact Copyright Clearance Center, Customer Service, 222 Rosewood Drive, Danvers, MA 01923 USA; +1 978 750 8400. Permission to photocopy portions of any individual standard for educational classroom use can also be obtained through the Copyright Clearance Center.

Updating of IEEE Standards documents

Users of IEEE Standards documents should be aware that these documents may be superseded at any time by the issuance of new editions or may be amended from time to time through the issuance of amendments, corrigenda, or errata. An official IEEE document at any point in time consists of the current edition of the document together with any amendments, corrigenda, or errata then in effect.

Every IEEE standard is subjected to review at least every ten years. When a document is more than ten years old and has not undergone a revision process, it is reasonable to conclude that its contents, although still of some value, do not wholly reflect the present state of the art. Users are cautioned to check to determine that they have the latest edition of any IEEE standard.

In order to determine whether a given document is the current edition and whether it has been amended through the issuance of amendments, corrigenda, or errata, visit the IEEE-SA Website at http://ieeexplore.ieee.org/xpl/standards.jsp or contact IEEE at the address listed previously. For more information about the IEEE-SA or IEEE's standards development process, visit the IEEE-SA Website at http://standards.ieee.org.

Errata

Errata, if any, for all IEEE standards can be accessed on the IEEE-SA Website at the following URL: http://standards.ieee.org/findstds/errata/index.html. Users are encouraged to check this URL for errata periodically.

Patents

Attention is called to the possibility that implementation of this standard may require use of subject matter covered by patent rights. By publication of this standard, no position is taken by the IEEE with respect to the existence or validity of any patent rights in connection therewith. If a patent holder or patent applicant has filed a statement of assurance via an Accepted Letter of Assurance, then the statement is listed on the IEEE-SA Website at http://standards.ieee.org/about/sasb/patcom/patents.html. Letters of Assurance may indicate whether the Submitter is willing or unwilling to grant licenses under patent rights without compensation or under reasonable rates, with reasonable terms and conditions that are demonstrably free of any unfair discrimination to applicants desiring to obtain such licenses.

Essential Patent Claims may exist for which a Letter of Assurance has not been received. The IEEE is not responsible for identifying Essential Patent Claims for which a license may be required, for conducting inquiries into the legal validity or scope of Patents Claims, or determining whether any licensing terms or conditions provided in connection with submission of a Letter of Assurance, if any, or in any licensing agreements are reasonable or non-discriminatory. Users of this standard are expressly advised that determination of the validity of any patent rights, and the risk of infringement of such rights, is entirely their own responsibility. Further information may be obtained from the IEEE Standards Association.

Participants

At the time this standard was published, Accredited Standards Committee C63®—Electromagnetic Compatibility had the following membership:

Daniel Hoolihan, *Chair*
Dan Sigouin, *Vice Chair*
Jerry D. Ramie, *Secretary*
Patricia Roder, *Secretariat*

Organization Represented	*Name of Representative*
Alcatel–Lucent	Dheena Moongilan
American Council of Independent Laboratories (ACIL)	Harry H. Hodes
	John Repella *(Alt.)*
American Radio Relay League (ARRL)	Edward F. Hare
	Kermit Carlson *(Alt.)*
Apple, Inc.	Manjit Walia
	Indrandil Sen *(Alt.)*
Blackberry Corporation	Masud Attayi
	Daoud Attayi *(Alt.)*
Bureau Veritas	Jonathan Stewart
	Mairaj Hussain *(Alt.)*
Cisco Systems	Andy Griffin
	Dave Case *(Alt.)*
Dell Inc.	Richard Worley
ETS-Lindgren	Zhong Chen
	Michael Foegelle *(Alt.)*
Federal Communications Commission (FCC)	William Hurst
Food and Drug Administration (FDA)	Jeffrey L. Silberberg
	Donald M. Witters *(Alt.)*
Industry Canada	Dan Sigouin
Information Technology Industry Council (ITIC)	John Hirvela
	Joshua Rosenberg *(Alt.)*
IEEE-Electromagnetic Compatibility Society (EMCS)	Andy Drozd
Liberty Labs	Mike Howard
	Brandt Langer *(Alt.)*
Motorola Mobility	Tom Knipple
Motorola Solutions	William (Mac) Elliot
	Deanna Zakharia *(Alt.)*
National Institute of Standards and Technology (NIST)	Dennis Camell
	William Young *(Alt.)*
Northwest EMC	Dean Ghizzone
	Greg Kiemel *(Alt.)*
PCTEST Engineering Laboratory	Greg Snyder
	Dennis Ward *(Alt.)*
Society of Automotive Engineers (SAE)	Poul Andersen
	Gary Fenical *(Alt.)*
Sony Ericsson Mobile Communications	Mats Hansson
Telecommunication Certification Body (TCB) Council	Art Wall
	William Stumpf *(Alt.)*
Telecommunications Industry Association (TIA)	Stephen Whitesell
TÜV SÜD America, Inc.	Chip Fleury
	David Schaefer *(Alt.)*
Underwriters Laboratories (UL)	Robert DeLisi
	Jeffrey Moser *(Alt.)*
U.S. Department of Defense—Joint Spectrum Center	Marcus Shellman
	Michael Duncanson *(Alt.)*
U.S. Department of the Navy—SPAWAR	Chris Dilay
	David Southworth *(Alt.)*

Individual Members .... H. Stephen Berger
Donald N. Heirman
Daniel Hoolihan
John Lichtig
Werner Schaefer
Dave Zimmerman
Members Emeritus .... Warren Kesselman
Herbert Mertel
H. R. (Bob) Hofmann

At the time this standard was completed, ASC C63® Subcommittee 1 had the following membership:

Zhong Chen, *Chair*
Harry H. Hodes, *Vice Chair*
Janet O'Neil, *Secretary*

Mark Arthurs
Masud Attayi
Dennis Camell
Robert DeLisi
Dean Ghizzone
Andy Griffin
Ed Hare
Tim Harrington
Donald N. Heirman
H. R. (Bob) Hofmann
Daniel Hoolihan
Greg Kiemel
Jeff Klinger
Victor Kuczynski
Randy Long
Doug Parker
Ghery Pettit
Nate Potts
Mits Samoto
Werner Schaefer
Dan Sigouin
Jeffrey L. Silberberg
Art Wall
Dennis Ward
Steve Whitesell
Khairul Zainal

At the time this standard was completed, the ASC C63® Subcommittee 1 working group for C63.4 maintenance had the following membership:

Donald N. Heirman, *Chair*
H. R. (Bob) Hofmann, *Vice Chair*
Tim Harrington, *Technical Editor*
Harry H. Hodes, *Technical Editor*

Mark Arthurs
H. Stephen Berger
Dennis Camell
Robert DeLisi
Andy Griffin
Edward F. Hare
William Hurst
Steve Jones
Horia Popovici
Dan Sigouin

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.

Contents

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

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 17025:2005[3]; 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] IEV 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 $C_{BB} = 20 \log (B_{imp} / B_{meas})$, 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 ± 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.

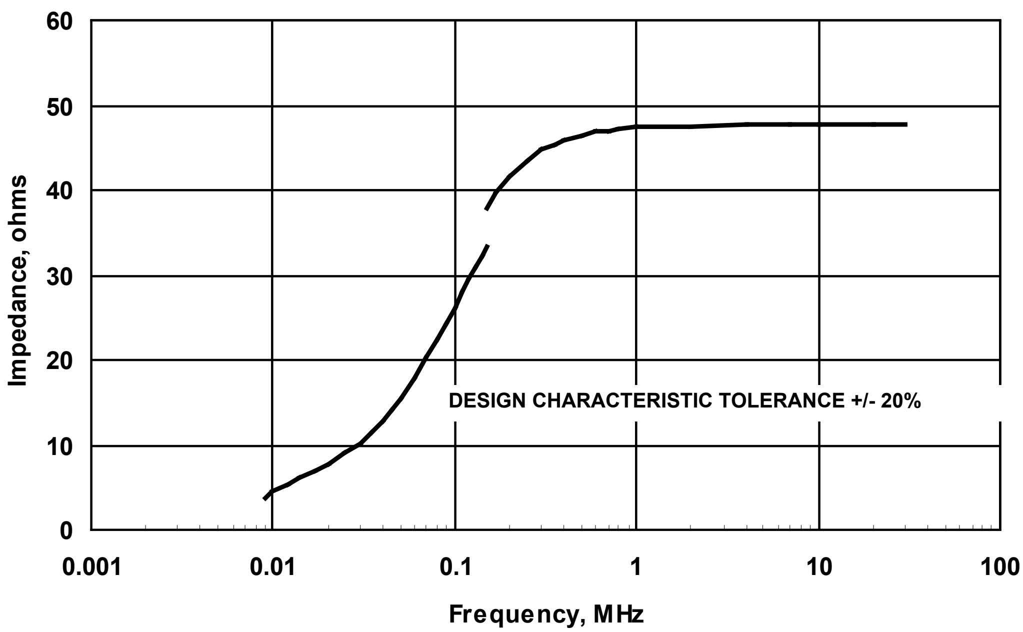
4.7.5 Characterization of absorbing clamp

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 data[21] 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 MHz[22]

[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 ± 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.

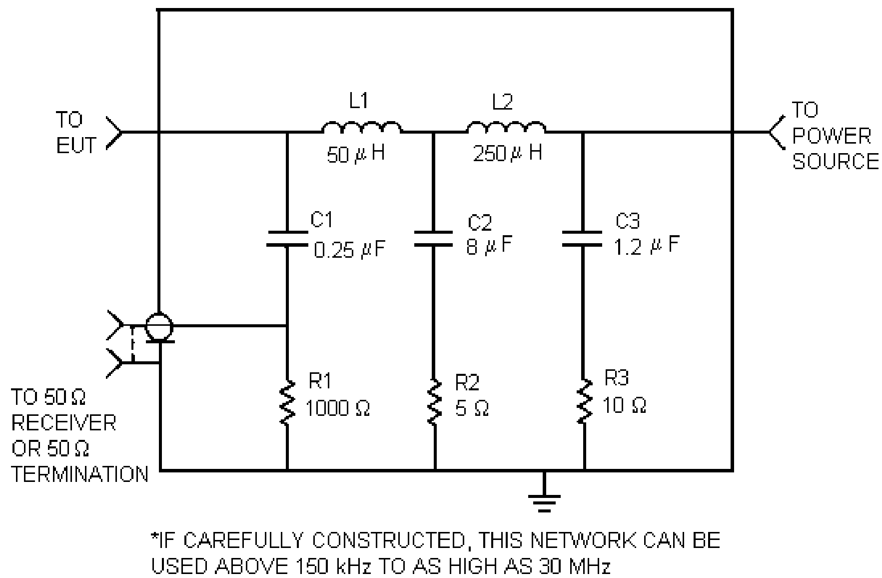


Figure 2—Circuit diagram of LISN to provide impedance of Figure 1 for the 9 kHz to 150 kHz (30 MHz[23]) frequency range

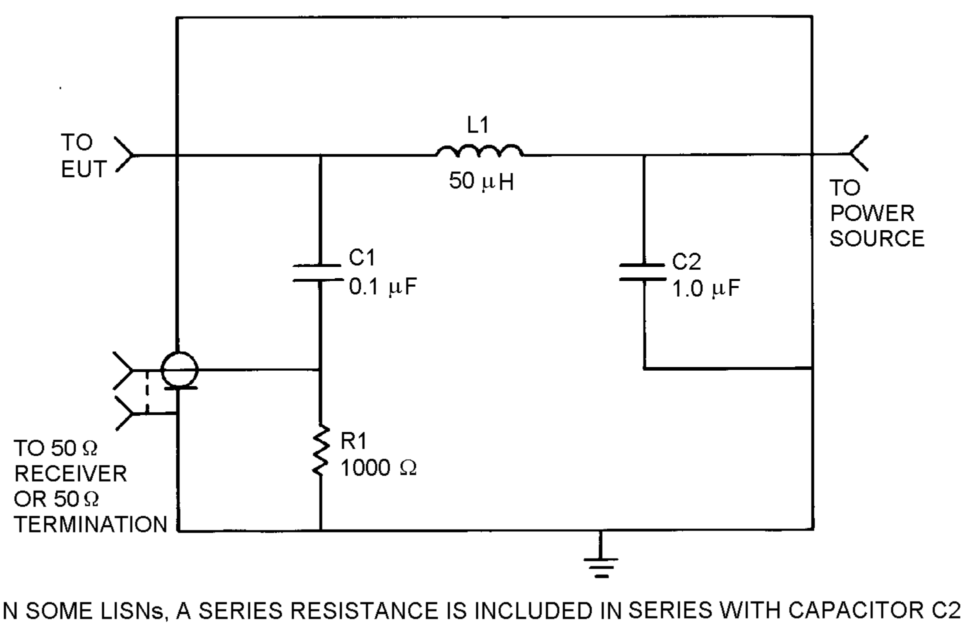


Figure 3—Circuit diagram of LISN to provide impedance of Figure 1 for the 0.15 MHz to 30 MHz frequency range

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

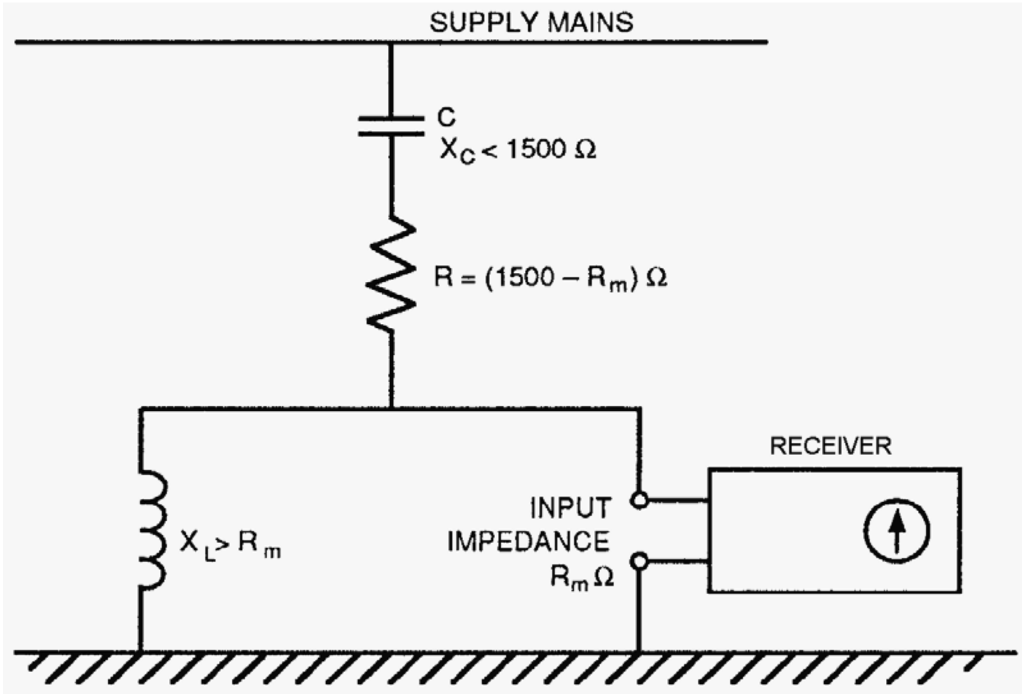


Figure 4—Voltage probe for measurements at a user's installation

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 mΩ. 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 m + 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 m + 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.

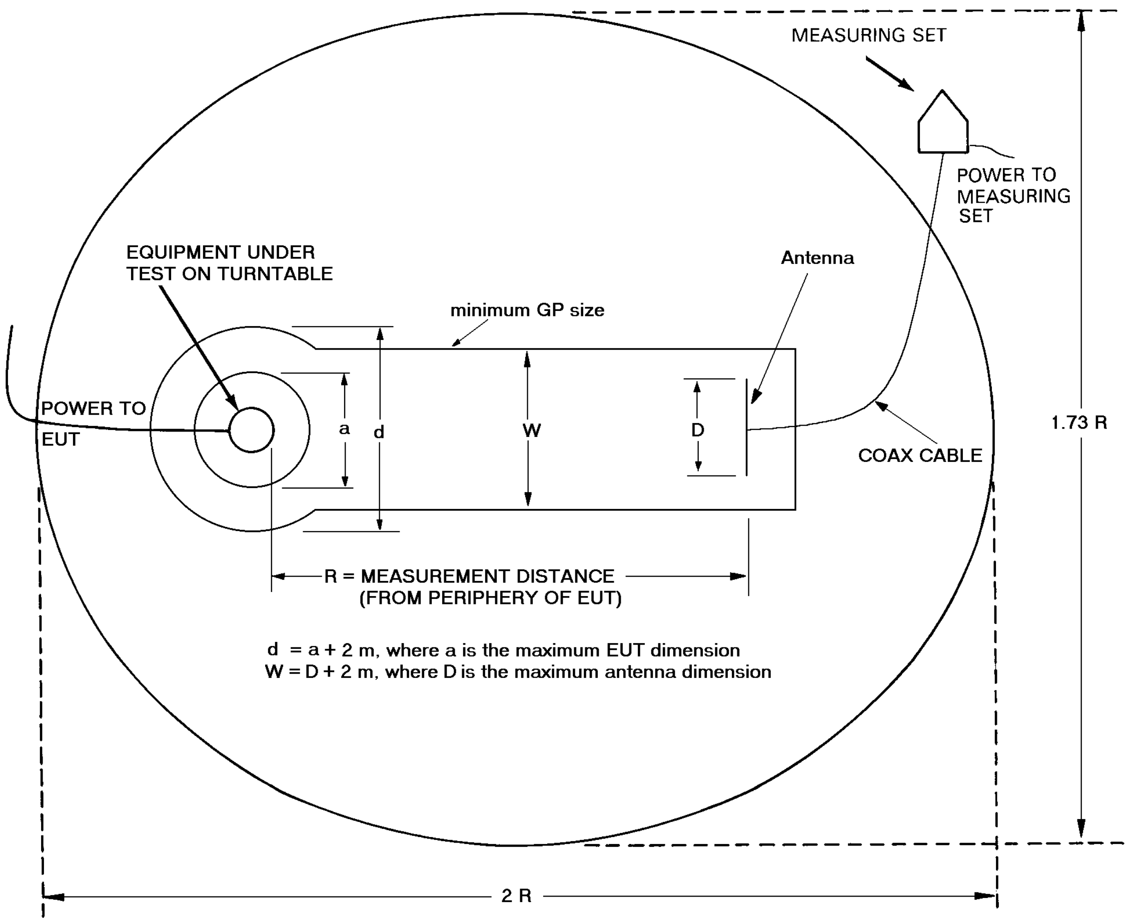
5.5.2 Validation interval

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



AREA DIMENSIONS =

R = 3m	R = 10 m	R = 30 m
6 m x 5.2 m	20 m x 17.3 m	60 m x 52 m

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

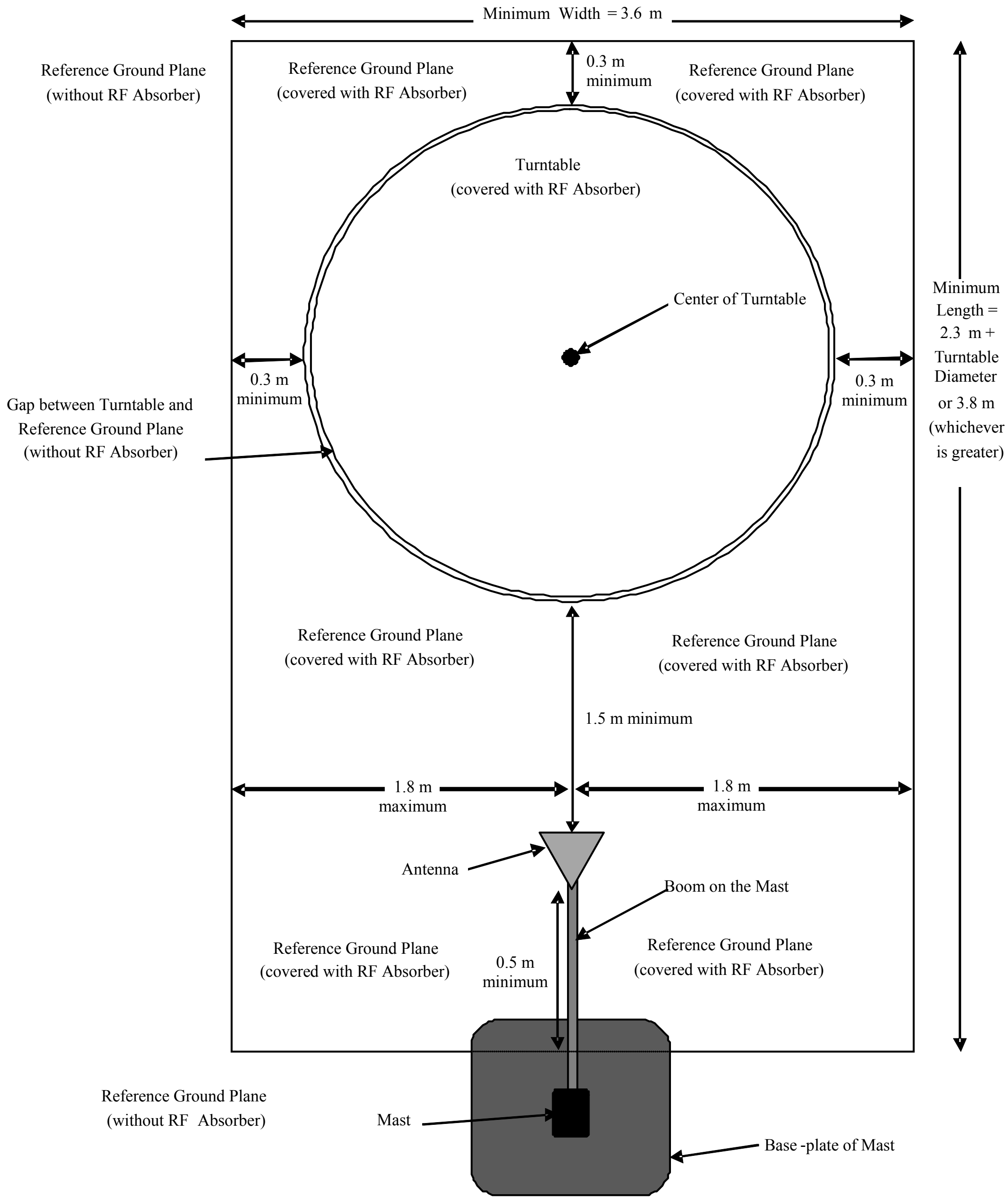


Figure 6—(normative) Absorber placement diagram; see 5.5.1 a) 2) for specific descriptions of the setup and parameters (Note that all distances listed in this figure are minimums, unless indicated otherwise.)

6. General requirements for EUT arrangements, configuration, and operation

6.1 General

This clause specifies general requirements that are applicable to all EUTs covered under the scope of this standard. Additional and more detailed requirements for specific types of EUTs are given in Clause 11 and Clause 12. Both sets of requirements shall be met [i.e., the applicable clause(s) for the specific type of EUT and the requirements of Clause 6 (see also Annex A)].

6.2 Operating conditions

6.2.1 General requirements

The EUT and accessories shall be operated at the rated (nominal) operating voltage, operating temperature, and typical load conditions—mechanical, electrical, or both—for which they are designed. Loads may be actual or simulated as described in the individual equipment requirements. It may be necessary to develop a set of explicit requirements specifying the test conditions, EUT operation, and so on, to be used in testing a specific EUT or class of EUTs for radio-noise emissions. Such requirements shall be documented for the EUT and may be used in determining compliance with the limits. The EUT shall be operated so that all the functions are exercised (e.g., software); for example, see 11.2 on information technology equipment (ITE). If software is used to exercise the EUT, then a description and all identifiers (e.g., model/issue name/number and revision number) of the specific operating software shall be included in the test report to facilitate reproducible test results.

6.2.2 EUT

The EUT and accessories shall be placed in a typical arrangement as defined in 6.3.

6.2.3 Accessory equipment

6.2.3.1 General requirement

Accessory equipment shall be placed in a typical arrangement as defined in 6.3.

6.2.3.2 Remotely located devices

In certain applications, a remotely located device may be connected to the EUT. In these cases, it is permissible for cabling from the remotely located device to the EUT or accessories to be placed directly on the reference ground plane or, if normally installed beneath the reference ground plane, beneath it. The remotely located device shall be located at a distance sufficient so that it does not contribute to the measured radiated emission level. This procedure evaluates the interference potential of the EUT, its accessories, and interconnecting cables or wires standing apart from the remotely located device, which in turn shall be evaluated separately, if required.

6.2.3.3 Distributed networks

Distributed networks (e.g., a wired local area network) may be simulated on the test site using a cable of at least 1 m in length and an actual peripheral or a remote network communications simulator. The network simulator shall be located at a distance sufficient so that it does not contribute to the measured radiated emission level. Signals on the network from the EUT should be typical of normal operation. See 6.2.9 about use of simulators.

6.2.4 EUT ports (or terminals)

a) Interconnect cabling or wiring shall be connected to one of each type of functional port of the EUT, and each cable or wire shall be terminated in a device typical of actual usage. Where there are multiple ports all of the same type, additional connecting cables or wires shall be added to the EUT to determine the effect these cables or wires have on both radiated and conducted emissions from the EUT.

b) The number of additional cables to be added to identical ports may be limited using a process called the *2 dB rule*. The 2 dB rule has two aspects: There must be an indication that the addition of cables changes the EUT emission amplitude closest to the limit by 2 dB or less and that this emission amplitude does not continue to rise as additional cables are attached. If the amplitude of the emission continues to rise as cables are added, then additional cables shall be added even though the change in emission amplitude is less than 2 dB. The maximum signal must asymptotically rise to a level that is below the limit. Emission levels not close to the limit may vary much more than 2 dB, but the lower amplitude emission levels are not of concern because emissions closest to the limit are relevant for demonstrating compliance. The 2 dB rule also applies to the addition of identical modules to a EUT that accepts multiple modules (see 6.2.7).

   NOTE—Typically, the loading of similar connectors, terminals, or ports is limited by the following:
   - Availability of multiple loads (for large systems)
   - Reasonableness of multiple loads representing a typical installation

c) The rationale for the selection of the equipment configuration and loading of ports shall be included in the test report. Additional ports on support or interfacing units or simulators, other than those associated with the EUT or the minimum system required by 11.5 for ITE, need not be cabled or used during testing.

6.2.5 Interconnect and power cabling (or wiring)

a) All interconnecting cable lengths should be typical of normal usage. The interconnect cabling used during testing shall be the specific cabling marketed with the EUT for use in practical applications. Where cables of variable length are used with the EUT, the cables most typical of all applications shall be used throughout the testing. When cable length is unknown, cables of 1 m nominal length shall be used, unless longer length cables are required to physically connect equipment. The same type of cable (e.g., unshielded, braided, foil shielded) specified in the user manual should be used throughout the tests.

b) For equipment tested on a tabletop, excess cable length shall be draped over the back edge of the tabletop. If any draped cable extends closer than 40 cm to the reference ground plane, the excess shall be bundled in the center in a back and forth fashion using 30 cm to 40 cm lengths in the center to maintain the 40 cm height. If the cables cannot be bundled because of bulk, length, or stiffness, they shall be draped over the back edge of the tabletop unbundled, but in such a way that all portions of the interface cable remain at least 40 cm from the horizontal reference ground plane. Interconnecting cables that are connected only between the EUT and the peripheral shall be bundled in the center to maintain the 40 cm height above the reference ground plane. The end of the cable may be terminated, if required, using the correct terminating impedance. The overall length of the bundled cable shall not exceed 1 m. See Figure 8 and Figure 10 (for installations using overhead cables, see 6.2.6).

c) For ac power-line conducted emission measurements of tabletop equipment, power cords of equipment other than the EUT do not require bundling. Drape the power cords of non-EUT equipment over the rear edge of the table and route them down onto the floor of the conducted emission test site to the second LISN. These power cords of non-EUT equipment should not be draped over the top of a LISN. See Figure 8.

d) For radiated emission measurements of tabletop equipment, all power cords drape to the floor and are routed over to the ac power receptacles (on the LISNs if used) (see Figure 10).

e) For floor-standing equipment, excess interconnecting cable lengths shall be folded back and forth in the center to form a bundle between 30 cm and 40 cm in length. If the cables cannot be folded because of bulk, stiffness, or length, they shall be arranged in a serpentine fashion. Interconnecting cables that are not connected to a peripheral may be terminated, if required, using the correct terminating impedance. Cables that are normally grounded shall be grounded to the reference ground plane for all tests. Cables that are normally insulated from the ground shall be insulated from the reference ground plane by up to 12 mm of insulating material. For combined floor-standing and tabletop equipment, the interconnecting cable to the floor-standing unit drapes to the reference ground plane with the excess bundled. Cables not reaching the reference ground plane are draped to the height of the connector or 40 cm, whichever is lower (see paragraph 6 in Figure 14).

6.2.6 Overhead cable trays and suspended ceilings

Where overhead cable trays or suspended ceilings are used to support overhead cables, tests may be performed with overhead cable trays or suspended ceilings as shown in Figure 12 and Figure 13. The trays or ceilings should be representative of a typical installation. The precise cable layout shall be documented.

6.2.7 Modular equipment

Equipment that consists of an enclosure unit populated with multiple plug-in printed circuit boards, modules, enhancement cards, coprocessors, and so on shall be tested with a mixture of plug-ins representative of that used in a typical installation. For installations with a large number of plug-ins (modules), a limited number of representative plug-ins may be used. The number of additional modules to be added may be limited using a process called the *2 dB rule*. The 2 dB rule has two aspects: There must be an indication that the addition of modules changes the EUT emission amplitude closest to the limit by 2 dB or less and that this emission amplitude does not continue to rise as additional modules are attached. If the amplitude of the emission continues to rise as modules are added, additional modules shall be added even though the change in emission amplitude is less than 2 dB. The maximum signal must asymptotically rise to a level that is below the limit. Emission levels not close to the limit may vary much more than 2 dB, but the lower amplitude emission levels are not of concern because emissions closest to the limit are relevant for demonstrating compliance. If applicable, each added plug-in shall have an interconnect cable or wire connected to it. These additional cables need not be terminated unless those boards are used in configuring a minimum system, such as defined in 11.5. The rationale used for selecting the number of plug-ins should be stated in the test report.

NOTE—Modular equipment here generally refers to modules as described in CISPR 22:2008, i.e., part of an ITE that provides a function and may contain RF sources, but does not refer to intentional radiator modules (e.g., as described in 47CFR15.212).

6.2.8 Grounding

The EUT shall be grounded in accordance with the individual equipment requirements and conditions of intended use. When the EUT is furnished with a grounding terminal or internally grounded lead and when this terminal or lead is used in actual installation conditions, the terminal or lead shall be connected to the reference ground plane or under the floor in a raised floor installation, simulating actual installation conditions. Any internally grounded lead included in the plug end of the ac power cord of the EUT shall be connected to the ground through the utility power service (see also 7.3).

6.2.9 Simulators

In case the EUT is required to interact functionally with other units, the actual interfacing units shall be used to provide representative operating conditions unless there is some justified reason for using a simulator. If a simulator is used, it shall represent the common-mode and differential-mode RF impedance of the interface unit, and the reasons for its use shall be documented. For communication networks simulation, see 6.2.3.3.

6.2.10 Shock and vibration isolators

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

6.2.11 Temperature and humidity

a) The ambient air temperature of the test site shall be within the range of 10 °C to 40 °C (50 °F to 104 °F), unless the EUT requirements specify testing over a different temperature range. The EUT and the measuring equipment shall be operated until temperature stabilizes before the testing proceeds. The warm-up time shall be included along with the measurement results if the ambient conditions are outside of the range stated above, and evidence shall be given that the measuring equipment is accurate at the temperatures used.

b) Humidity levels shall be in the range of 10% to 90% relative humidity unless the EUT operating requirements call for a different level. Unless specifically called out in the EUT requirements, there should be no condensation of moisture on the EUT. The ambient temperature and humidity levels shall be recorded and included in the test report if critical to the test results; see 10.2.8.

6.2.12 Special instrumentation connected to EUT

During the time radio-noise measurements are being made, external electrical meters or electrical indicating devices shall not be in the input or output circuits of the EUT, except those normally used with the measuring equipment.

6.2.13 Artificial hand

If the EUT is normally operated while held in the hand, when required by the regulatory and/or purchasing agency, measurements shall be made using an artificial hand (see Clause 8 of CISPR 16-1-2:2006-08) to simulate the effects of the user's hand. If the EUT can be operated either held in the hand or not, it shall be tested in both ways.

6.3 Arrangement of EUT

6.3.1 General requirements

a) EUT arrangement is the manner in which the EUT and its associated equipment are laid out on the test table for tabletop equipment or on the floor for floor-standing equipment. The EUT shall be carefully arranged in a manner that is most representative of the equipment as typically used (i.e., as specified in the EUT instruction manual) or as specified herein. Equipment that typically operates within a system made of multiple interconnected units should be tested as part of such a typical operational system.

b) The system that is tested shall be based on that typically marketed to the end user. If the marketing information is not available or it is not practical to assemble extraordinary amounts of equipment to replicate a complete marketed product installation, the test shall be performed using the best judgment of the test engineer in consultation with the design engineering staff. The results of any such discussion and decision process shall be reported in the test report. A photograph or detailed drawing shall be used to document the equipment arrangement and shall be part of the test report.

c) In order to replicate emission measurements, it is important to document the arrangement of the system components, cables, wires, and ac power cords. Three general equipment test arrangements are tabletop, floor standing, and a combination of tabletop and floor standing defined for testing all classes of devices as described below.

d) An EUT designed for rack mounting only shall be tested mounted in a rack. Where a device can be rack mounted or tabletop, the EUT may be tested in a rack or as a tabletop device. Where the typical location of the EUT within a rack is not defined, the following provisions apply:

    1) For an EUT intended to be mounted in large floor-standing racks, the EUT shall be mounted within the rack so that the height is 0.8 m above the reference ground plane.

    2) For all other EUTs, they shall be mounted as close as possible to the middle of the rack.

    A rack containing equipment may be floor standing or tabletop mounted, depending on its design. The rationale for the placement of the EUT and/or rack shall be indicated in the test report.

6.3.2 Tabletop equipment tests

6.3.2.1 General requirements

Portable, small, lightweight, or modular devices that may be handheld, worn on the body, or placed on a table during operation shall be positioned on a nonconducting platform, the top of which is 80 cm above the reference ground plane. The preferred area occupied by the EUT arrangement is 1 m by 1.5 m, but it may be larger or smaller to accommodate various sized EUTs (see Figure 7, Figure 8, and Figure 10). For testing purposes, ceiling- and wall-mounted devices also shall be positioned on a tabletop (see also 6.3.5 and 6.3.6). In making any tests involving handheld, body-worn, or ceiling-mounted equipment, it is essential to recognize that the measured levels may be dependent on the orientation (attitude) of the three orthogonal axes of the EUT. Thus, exploratory tests as specified in 8.3.1 shall be carried out for various axes orientations to determine the orientation (attitude) having maximum or near-maximum emission level.

6.3.2.2 Placement of tabletop EUTs

For tabletop systems, the EUT shall be centered laterally (left to right facing the tabletop) on the tabletop, and its rear shall be flush with the rear of the table. If the EUT is a stand-alone unit, its center shall be located over the center of the turntable.

6.3.2.3 Placement of tabletop accessories/peripherals

a) Accessories/peripherals that are part of a system tested on a tabletop shall be placed in a test arrangement on one or both sides of the host with a 10 cm separation between the nearest points of the cabinets (see Figure 7). The rear of the host and accessories should be flush with the back of the supporting tabletop unless that would not be typical of normal use. If more than two accessories are present, then an equipment test arrangement should be chosen that maintains a spacing of 10 cm between cabinets unless the equipment is normally located closer together.

b) Multiple peripherals/accessories (more than two) may be distributed around the table as shown in Figure 7. If the EUT peripherals are designed to be stacked in typical use, then they shall be stacked for emission testing, occupying positions of peripheral 1 or peripheral 2. See Figure 7.

c) When there is only one peripheral, place the peripheral as shown in Figure 7 for peripheral 1.

d) Accessories that are typically table mounted because of cable length, such as ac power adapters providing dc power to the EUT, shall be mounted on the tabletop in a typical manner.

e) Accessories that are typically floor mounted shall occupy a floor position directly below the portion of the EUT to which they are typically connected.

   NOTE—The keyboard and mouse cables from the back of a personal computer (PC) should be routed along the side of the central processing unit (CPU) to gain maximum coupling between the CPU and the cables.

f) Power accessories, such as ac power adapters that power other devices, shall be tested in the following manner:

   1) Power accessories that are not the EUT: If the power accessory connects to a tabletop EUT having a power cord to the power accessory less than 80 cm in length, the power accessory is placed on the tabletop. If the EUT power cord to the power accessory is 80 cm or greater in length, then the power accessory is placed on the floor immediately under the EUT.

      If the power accessory plugs directly into the wall outlet, it shall be attached to the source of power on top of the ground plane and directly under the EUT with the EUT connected. If the EUT power cord is less than 80 cm, then a nonconductive support for raising the power accessory is needed along with a short extension cord from the source of power to the raised power accessory.

   2) Power accessories that are the EUT: If the input power cord of the power accessory has length 80 cm or greater, the power accessory shall be placed on the tabletop. If the power accessory has an input power cord that is less than 80 cm, the power accessory shall be placed at a height above the ground plane such that its input power cord is fully extended in the vertical direction.

      If the power accessory plugs directly into the wall outlet, the power accessory shall be tested on the tabletop using an extension cord between the source of power and the accessory. The extension cord shall be connected in a manner such that it takes the most direct path to the power accessory.

6.3.2.4 Placement and manipulation of interconnect cabling (or wiring) of tabletop equipment

The system shall be arranged in one typical equipment arrangement for the test. In making any tests involving several tabletop equipment components interconnected by cables or wires, it is essential to recognize that the measured levels may be critically dependent on the exact placement of the cables or wires. Thus, exploratory tests as specified in 7.3.3 and 8.3.1 shall be carried out while varying cable positions within typical arrangements to determine the maximum or near-maximum emission level. During manipulation, cables shall not be placed under or on top of the system units unless such placement is required by the inherent equipment design or consistent with typical use. Cables that are bundled in accordance with 6.2.5 do not have to be manipulated.

6.3.3 Floor-standing equipment tests

6.3.3.1 General requirements

a) Where a floor-standing EUT is typically installed with its base in direct electrical contact with, or connected to, a grounded metal floor or grid, the EUT shall be connected to, or placed directly on, the test site (or turntable) reference ground plane in a manner representative of this contact or connection.

b) Where floor-standing equipment is not typically installed with its base in direct electrical contact with, or connected to, a metal floor or grid, the EUT shall not be placed in direct electrical contact with the test site (or turntable) reference ground plane. If necessary to prevent direct metallic contact of the EUT and the reference ground plane, insulating material (up to 12 mm thick) shall be placed under the EUT.

c) In order to represent typical raised/false floor installation of EUTs more explicitly, the base of the EUT shall be raised but in no case can exceed 34 cm above the reference ground plane. If an EUT elevation that is not representative of a typical installation is used for testing, the reason for the variation shall be explained in the test report.

d) Floor-standing equipment (i.e., as defined in 3.1) can be interconnected with cabling lying on the floor, under the floor (to simulate a raised floor installation), or overhead, according to normal installation. The material used to raise the test item shall be nonconductive and shall not adversely affect the site validation criteria.

6.3.3.2 Placement of floor-standing EUTs

Test arrangements for floor-standing equipment are shown in Figure 9 and Figure 11 through Figure 13. Normally, tests shall be run with the equipment standing on the reference ground plane, with or without an insulating surface, as appropriate.

6.3.3.3 Placement of floor-standing accessories

Accessories that are part of a floor-standing system shall be placed in one typical arrangement with typical spacing between equipment cabinets or enclosures. If more or less than two accessories are present, a typical arrangement should be chosen that maintains typical spacing between all equipment cabinets or enclosures.

6.3.3.4 Placement and manipulation of interconnect cabling (or wiring) of floor-standing equipment

Interconnecting cables are not normally manipulated for floor-standing equipment in which the typical installation is known. Instead, the cables shall be laid out as shown in Figure 9 and Figure 11. If the configuration of a typical installation is not known or changes with each installation, cables of floor-standing equipment shall be manipulated to the extent possible to produce the maximum level of emissions, within the range of typical installations. Cables that are bundled in accordance with 6.2.5 do not have to be manipulated. For large equipment interfacing with other large equipment normally at a distance, cables may be attached to the EUT, extend away from the EUT in the horizontal direction for at least 1 m, and then return to another port of the EUT (which would normally receive the transmit signal from another equipment), but at an elevation sufficiently different from that of the outgoing direction so as not to cancel the emission potential of either cable in this loop back situation. Loop back for this purpose is then characterized by a single cable leaving a port of the EUT, extending a distance away, and then routed back to the EUT at another port.

6.3.4 Combination equipment tests

6.3.4.1 General requirements

a) Equipment designed for both tabletop and floor operation shall be tested only in the tabletop arrangement. Equipment designed for floor operation shall be tested on the floor.

b) Equipment that is part of a combination of both tabletop and floor-standing equipment, which are typically used together, shall be tested as a combination in accordance with Figure 14.

6.3.4.2 Placement of combination equipment EUTs

Tabletop or floor-standing EUTs shall be positioned following 6.3.2.2 or 6.3.3.2, respectively, unless this produces an atypical arrangement. In such cases, position the EUT in a typical arrangement for testing and document the reason and differences in the test report.

6.3.4.3 Placement of combination equipment accessories

Tabletop or floor-standing accessories shall be positioned following 6.3.2.3 or 6.3.3.3, respectively, unless this produces an atypical arrangement. In such cases, position the accessory or accessories in a typical arrangement for testing and document the justification for the change and description of differences in the test report.

6.3.4.4 Placement and manipulation of interconnect cabling (or wiring) of combination equipment

Follow Figure 8 through Figure 11 and Figure 14, as well as 6.3.2.4, for placement and manipulation of cabling or wiring connecting two tabletop units or a tabletop unit and a floor-standing unit. Follow 6.3.3.4 for placement and manipulation of cabling connecting two floor-standing units.

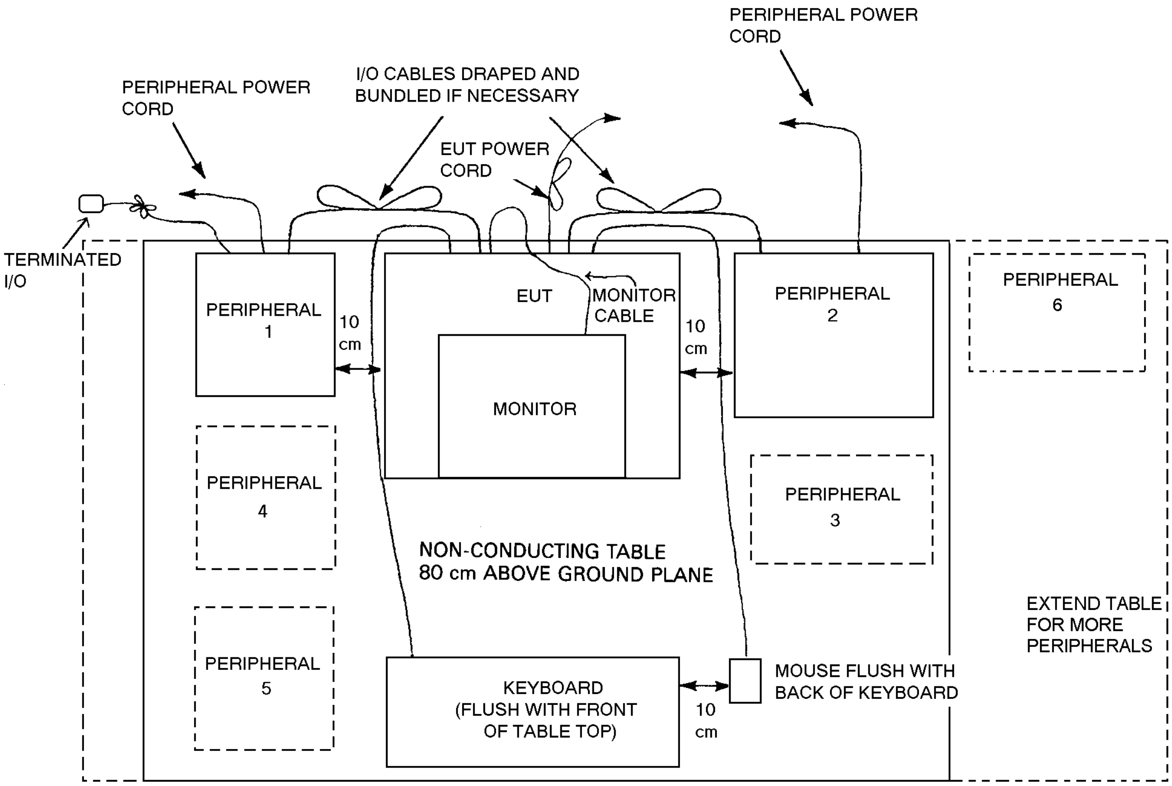
6.3.5 Placement of wall-mounted equipment

Equipment designed for wall-mounted operation shall be tested as tabletop EUT. The orientation of the equipment shall be repeated for all positions that are consistent with that of the normal operation of the EUT. Any special supporting structures shall simulate typical installations and shall put the base of the EUT at a height of 80 cm above the reference ground plane.

6.3.6 Placement of ceiling-mounted equipment

Equipment designed for ceiling-mounted operation shall be tested as tabletop EUT. The orientation of the equipment shall be repeated for all positions that are consistent with that of the normal operation of the EUT. In addition to the downward-facing EUT orientation, the EUT shall be rotated 180° and tested in the upward-facing direction. Any special supporting structures shall simulate typical installations and shall put the base of the EUT at a height of 80 cm above the reference ground plane.

6.4 Figures for Clause 6

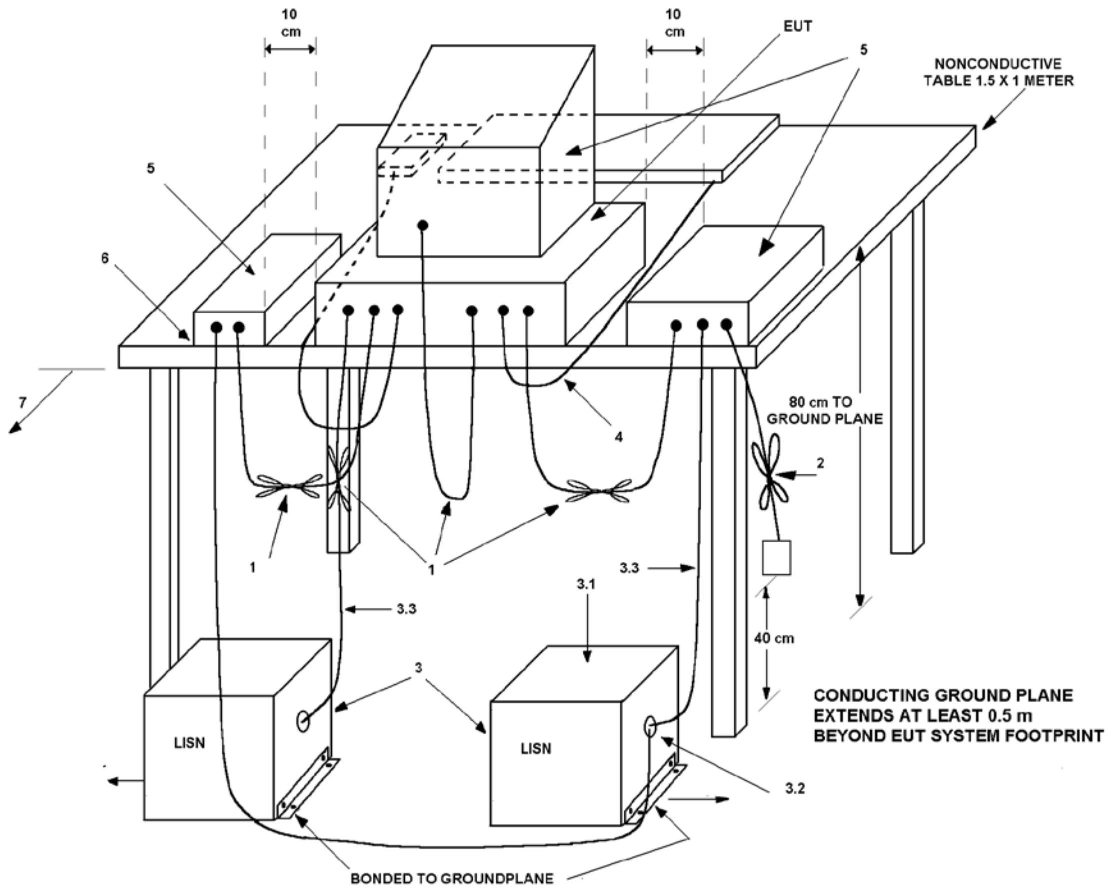


1. LISN(s) (not shown in this EUT configuration top view; see other figures) may have to be positioned to the side of the table to meet the criterion that the LISN receptacle shall be 80 cm away from the EUT. If the LISNs are kept in the test setup for radiated emissions, it is preferred that they be installed under the ground plane with the receptacle flush with the ground plane (see 5.2.4 and 6.2.5). If LISNs are above the ground plane, then they must have been present for the site validation tests.

2. Accessories that are typically table mounted, such as an ac power adapter, shall occupy peripheral positions as is applicable (see 6.3.2.3). Accessories that are typically floor mounted shall occupy a floor position directly below the portion of the EUT to which they are typically connected (see 6.3.3.3).

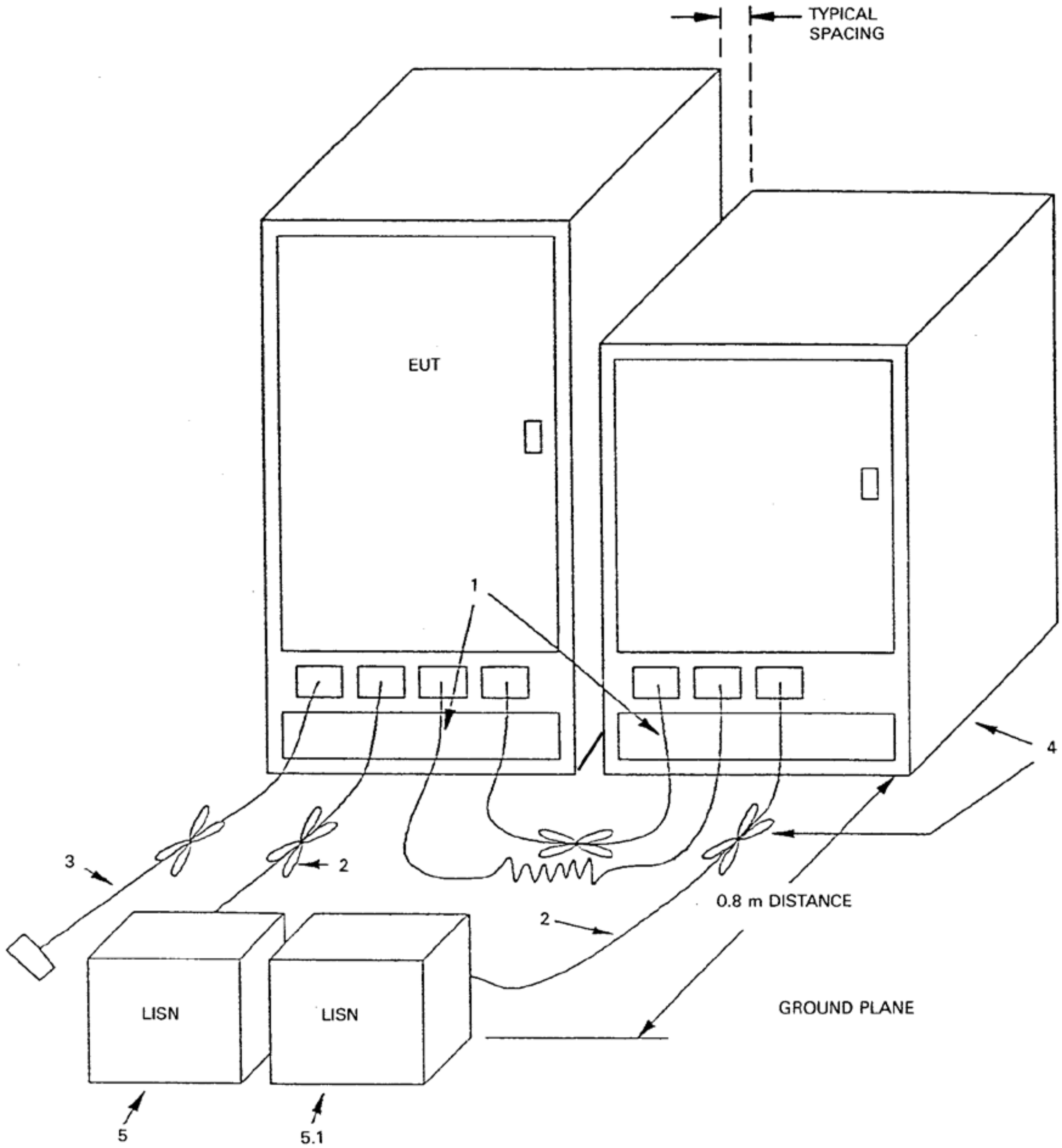
3. Table length may be extended beyond 1.5 m with peripherals aligned with the back edge. Additional peripherals may be placed as shown. The table depth may be extended beyond 1 m.

Figure 7—EUT test configuration/arrangement for tabletop equipment (radiated and conducted emissions)—top view



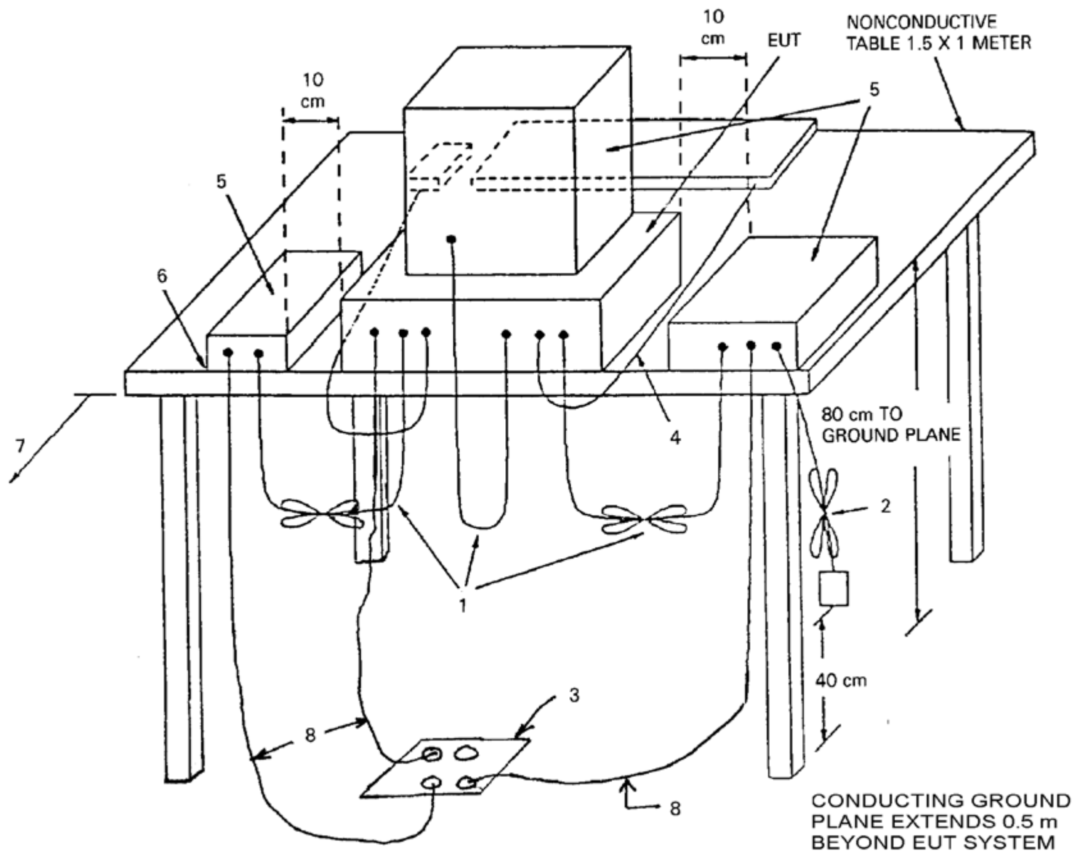
1. Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth in the center forming a bundle 30 cm to 40 cm long (see 6.2.5, also 11.5.5).
2. Input/output (I/O) cables that are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated, if required, using the correct terminating impedance. The overall length shall not exceed 1 m (see 6.2.5).
3. EUT connected to one LISN. Unused LISN measuring port connectors shall be terminated into 50 Ω loads. LISN can be placed on top of, or immediately beneath, reference ground plane (see 5.2.4 and 7.3.1).
   3.1 All other equipment powered from additional LISN(s).
   3.2 Multiple outlet strips can be used for multiple power cords of non-EUT equipment.
   3.3 LISN at least 80 cm from nearest part of EUT chassis.
4. Cables of hand-operated devices, such as keyboards and mice, shall be placed as for normal use (see 6.3.2.4 and 11.5.5).
5. Non-EUT components of EUT system being tested (see also Figure 7).
6. Rear of EUT, including peripherals, shall all be aligned and flush with rear of tabletop (see 6.3.2.2 and 6.3.2.3).
7. Rear of tabletop shall be 40 cm removed from a vertical conducting plane that is bonded to the ground plane (see 5.2.3 for options).

Figure 8—Test arrangement for conducted emissions of tabletop equipment



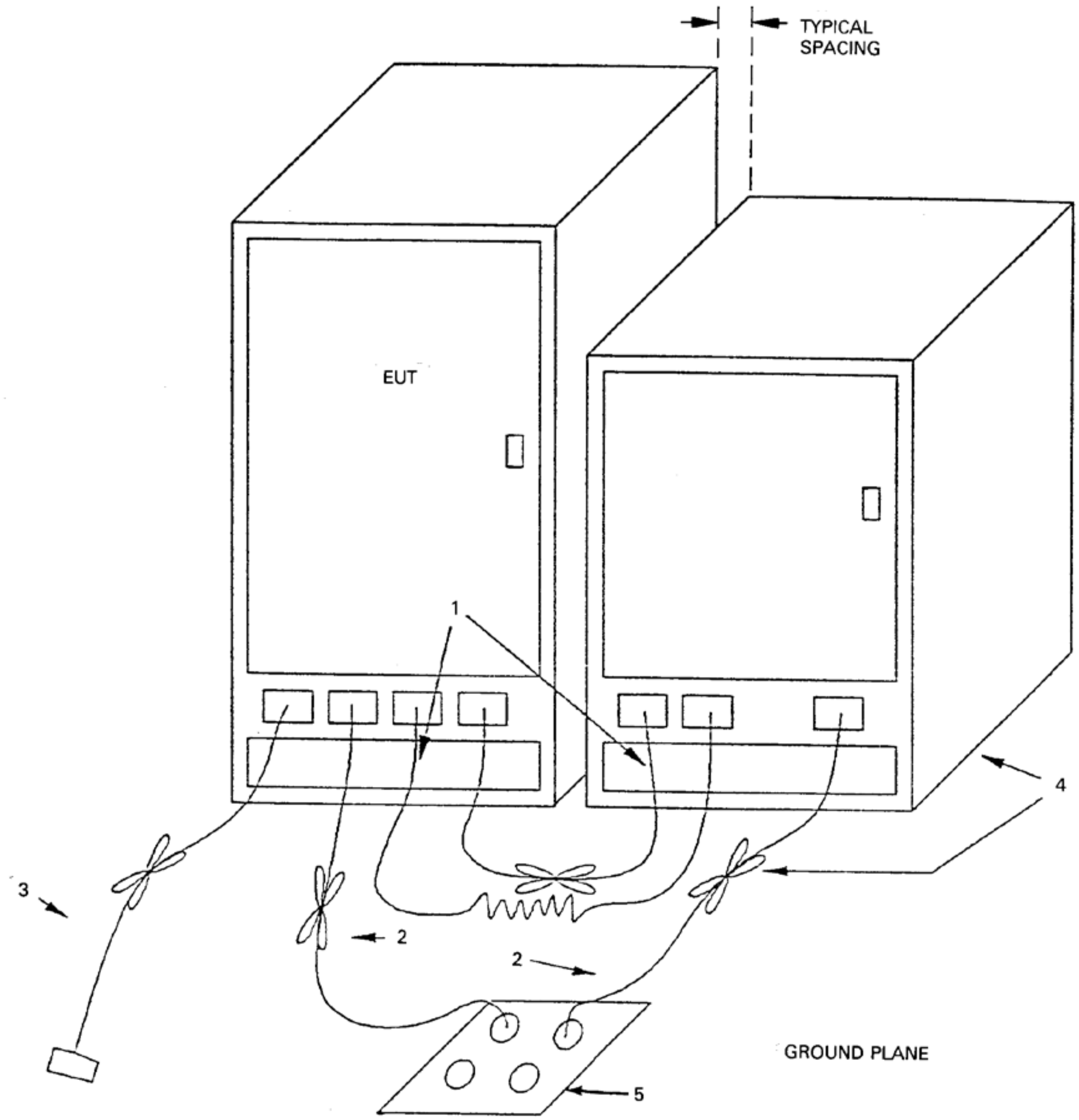
1. Excess I/O cables shall be bundled in the center. If bundling is not possible, the cables shall be arranged in a serpentine fashion. Bundling shall not exceed 40 cm in length (see 6.2.5 and 11.5.5).
2. Excess power cords shall be bundled in the center or shortened to appropriate length (see 7.3.1).
3. I/O cables that are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated, if required, using the correct terminating impedance. If bundling is not possible, the cable shall be arranged in a serpentine fashion (see 6.2.5).
4. EUT and all cables shall be insulated, if required, from the ground plane by up to 12 mm of insulating material (see 6.2.5 and 6.3.3).
5. EUT connected to one LISN. LISN can be placed on top of, or immediately beneath, the ground plane.
   5.1 All other equipment powered from a second LISN or additional LISN(s) (see 5.2.4 and 7.3.1).
   5.2 A multiple outlet strip can be used for multiple power cords of non-EUT equipment.

Figure 9—Test arrangement for conducted emissions of floor-standing equipment



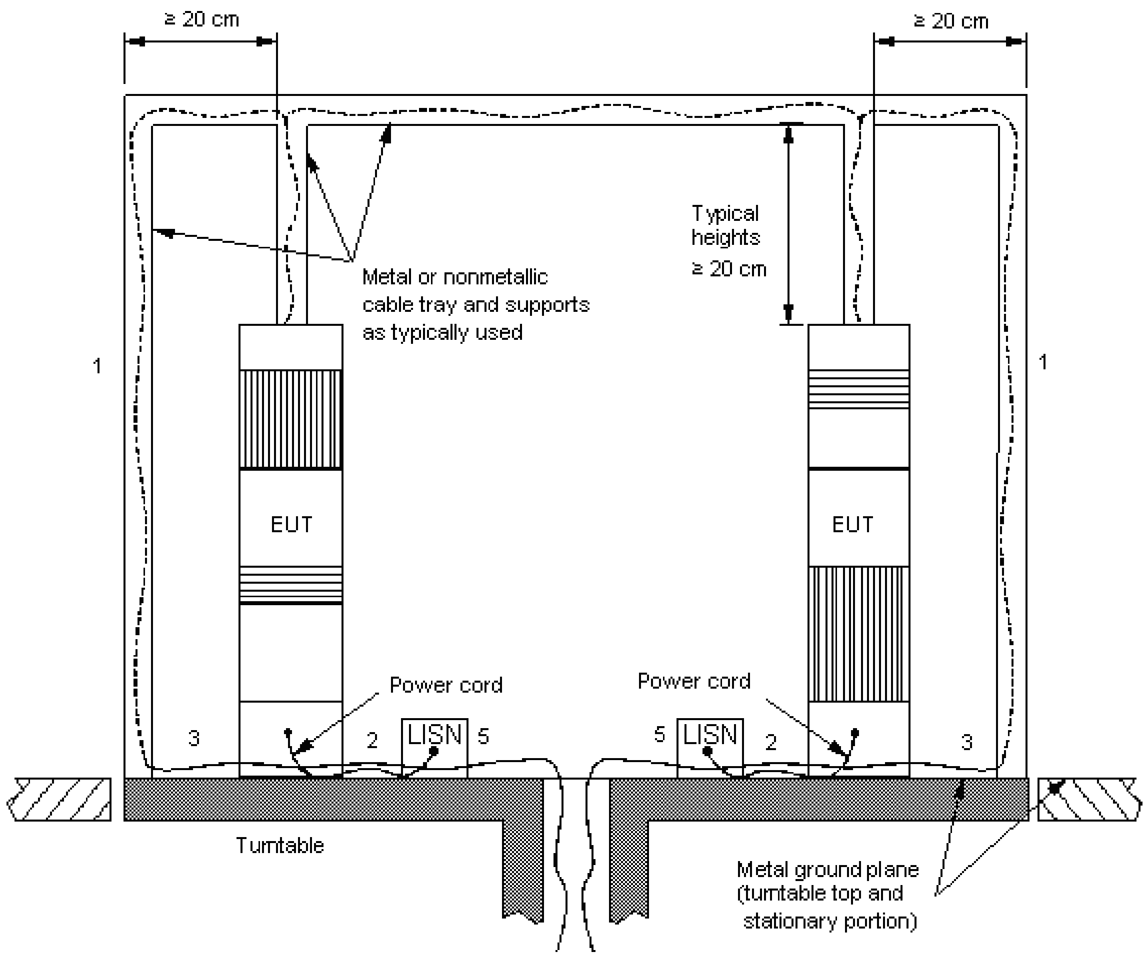
1. Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth in the center, forming a bundle 30 cm to 40 cm long (see 6.2.5 and 11.5.5).
2. I/O cables that are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated if required using the correct terminating impedance. The total length shall not exceed 1 m (see 6.2.5).
3. If LISNs are kept in the test setup for radiated emissions, it is preferred that they be installed under the ground plane with the receptacle flush with the ground plane (see 6.2.5).
4. Cables of hand-operated devices, such as keyboards and mice, shall be placed as for normal use (see 6.3.2.4 and 11.5.5).
5. Non-EUT components of EUT system being tested (see also Figure 7).
6. Rear of EUT, including peripherals, shall all be aligned and flush with rear of tabletop (see 6.3.2.2 and 6.3.2.3).
7. No vertical conducting plane used (see 5.2.3).
8. Power cords drape to the floor and are routed over to receptacle (see 6.2.5).

Figure 10 —Test arrangement for radiated emissions of tabletop equipment



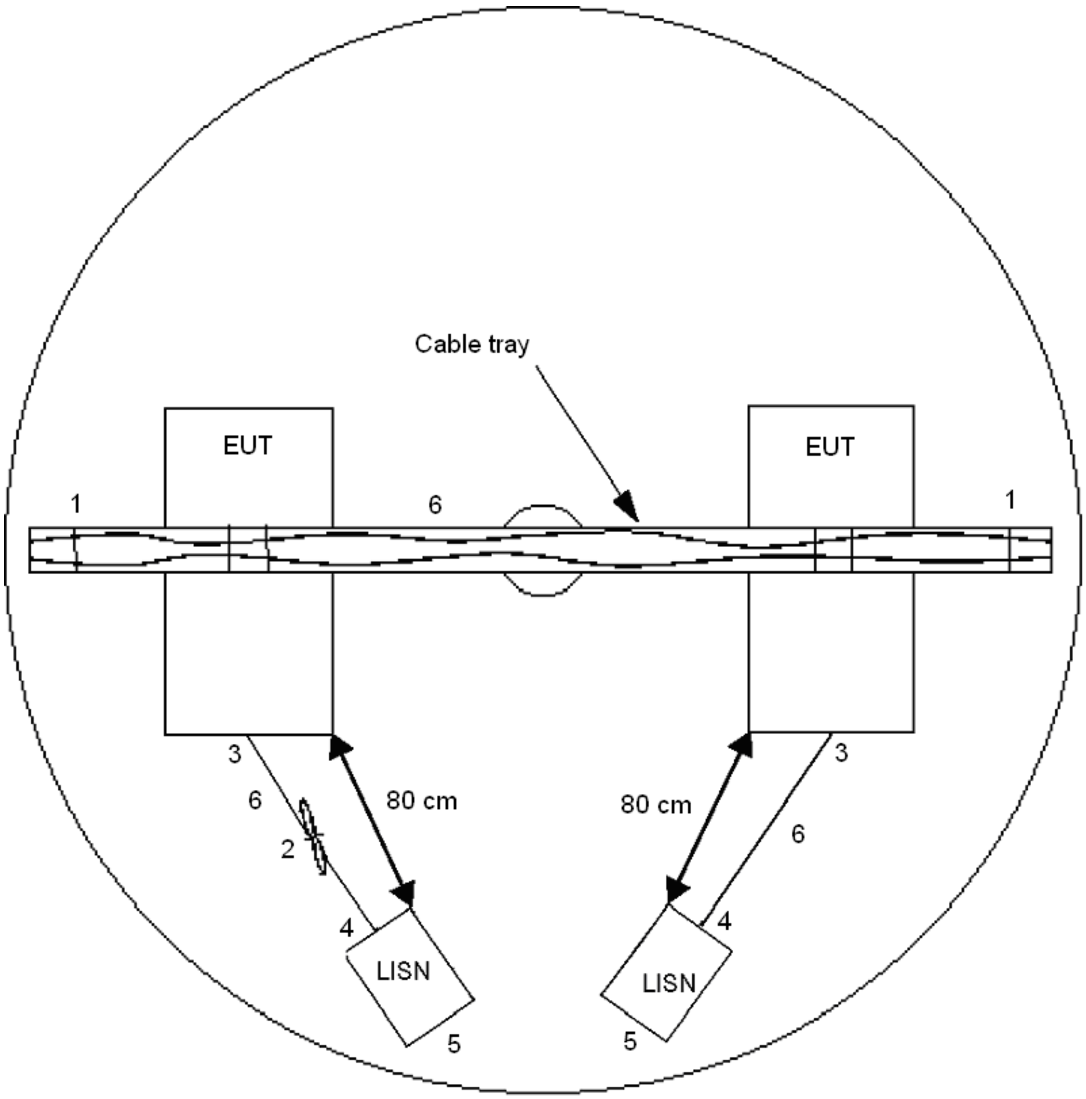
1. Excess I/O cables shall be bundled in center. If bundling is not possible, the cables shall be arranged in a serpentine fashion. Bundling not to exceed 40 cm in length (see 6.2.5).
2. Excess power cords shall be bundled in the center or shortened to appropriate length (see 7.3.1).
3. I/O cables that are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated, if required, using the correct terminating impedance. If bundling is not possible, the cable shall be arranged in a serpentine fashion (see 6.2.5).
4. EUT and all cables shall be insulated, if required, from the ground plane by up to 12 mm of insulating material (see 6.2.5 and 6.3.3).
5. If LISNs are kept in the test setup for radiated emissions, it is preferred that they be installed under the ground plane with the receptacle flush with the ground plane (see 5.2.4 and 8.1).

Figure 11—Test arrangement for radiated emissions of floor-standing equipment



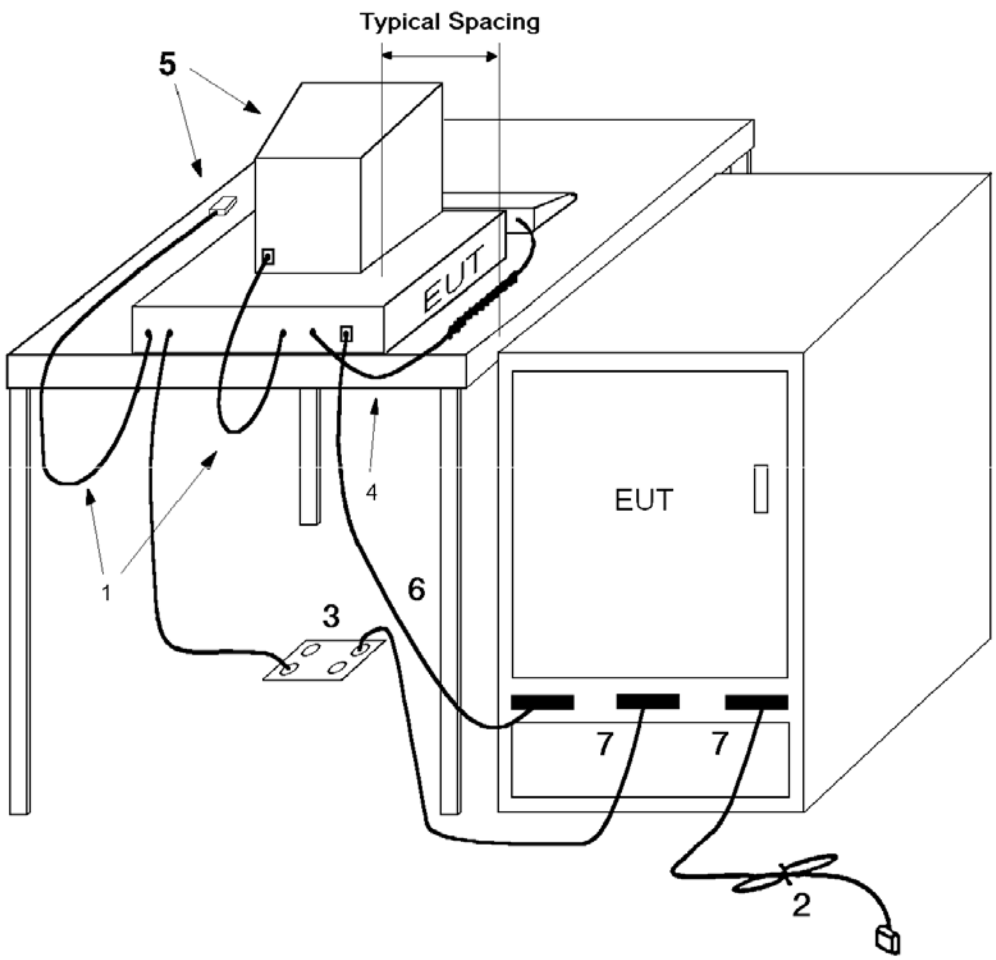
1. Only one vertical riser may be used where typical of system under test.
2. Excess power cord shall be bundled in the center or shortened to appropriate length.
3. EUT and cables shall be insulated from ground plane by up to 12 mm. Where the manual has specified or a code of practice exists for installation of the EUT, the test arrangement shall allow the use of this practice for the tests.
4. Power cords being measured connected to one LISN. All other system power cords powered through other LISN(s). A multiple-outlet power strip may be used for other power cords.
5. For *conducted* tests, the LISNs may be placed on top of or immediately beneath and bonded directly to the ground plane. For *radiated* tests, the LISN(s), if used, should be installed under, with the receptacle flush with the ground plane.

Figure 12—Test arrangement for floor-standing equipment (overhead cables—side view)



1. Only one vertical riser may be used where typical of system under test.
2. Excess power cord shall be bundled in the center or shortened to appropriate length.
3. EUT and cables shall be insulated from ground plane by up to 12 mm. Where the manual has specified or a code of practice exists for installation of the EUT, the test arrangement shall allow the use of this practice for the tests.
4. Power cords being measured connected to one LISN. All other system power cords powered through other LISN(s). A multiple-outlet power strip may be used for other power cords.
5. For *conducted* tests, the LISNs may be placed on top of or immediately beneath and bonded directly to the ground plane. For *radiated* tests, the LISN(s), if used, should be installed under, with the receptacle flush with the ground plane.
6. If power cables are normally installed in metallic conduit, the radiated and conducted emission tests may be performed with these cables in either metallic conduit or nonmetallic conduit or placed on the ground plane.

Figure 13—Test arrangement for floor-standing equipment (overhead cables—top view)



1. Interconnecting cables that hang closer than 40 cm to the ground plane shall be folded back and forth in the center, forming a bundle 30 cm to 40 cm long.
2. I/O cables that are not connected to a peripheral shall be bundled in the center. The end of the cable may be terminated if required using the correct terminating impedance.
3. If LISNs are kept in the test setup for radiated emissions, it is preferred that they be installed under the ground plane with the receptacle flush with the ground plane (see 6.2.5).
4. Cables of hand-operated devices, such as keyboards and mice, shall be placed as for normal use (see 6.3.2.4 and 11.5.5).
5. Non-EUT components of EUT system being tested (see also Figure 7).
6. I/O cable to floor-standing unit drapes to the ground plane and shortened or excess bundled. Cables not reaching the metal ground plane are draped to the height of the connector, or 40 cm, whichever is lower.
7. Power cords and signal cables shall drape to the floor. No extension cords shall be used to the power receptacles.
8. The floor-standing unit can be placed under the table if its height permits.

Figure 14—Test configuration/arrangement for combination floor-standing and tabletop equipment (cables at below floor level)

7. AC power-line conducted emission measurements

7.1 General

AC power-line conducted emission measurements shall be made, unless otherwise specified, over the frequency range from 150 kHz to 30 MHz to determine the line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network. These measurements may also be required between 9 kHz and 150 kHz. When using a spectrum analyzer without preselection for the measurements described in this clause, the considerations for its use called out in 4.2.3 shall be observed, as well as the precautions stated in Annex H.

If the EUT normally receives power from another device that in turn connects to the public-utility ac power lines, measurements shall be made on that device with the EUT in operation so that the device continues to comply with the appropriate limits while providing the EUT with power. If the EUT is operated only from internal or dedicated batteries, with no provisions for connection to the public utility ac power lines (600 VAC or less) to operate the EUT (such as an adapter), then ac power-line conducted measurements are not required. Where required, dc power conducted emissions tests shall be performed the same way as that for ac power conducted tests.

7.2 Measurement requirements

Measured levels of ac power-line conducted emission shall be the radio-noise voltage from the voltage probe, where permitted, or across the 50 Ω LISN port (to which the EUT is connected), as terminated into a 50 Ω EMI receiver or spectrum analyzer. All radio-noise voltage and current measurements shall be made on each current-carrying conductor at the plug end of the EUT power cord or calibrated extension cord by the use of mating plugs and receptacles on the EUT and LISN, if used. The manufacturer shall test equipment with power cords that are normally supplied or recommended by the manufacturer and that have electrical and shielding characteristics that are the same as those cords normally supplied or recommended. For measurements using a LISN, the 50 Ω measuring port is terminated into a 50 Ω EMI receiver or spectrum analyzer. All other ports are terminated into 50 Ω loads. Figure 7 through Figure 9 and Figure 14 show typical test setups for ac power-line conducted emissions testing.

7.3 Measurement procedures

7.3.1 Measurements at a test site

a) Tabletop devices shall be placed on a nonconducting platform, of nominal size 1 m by 1.5 m, raised 80 cm above the reference ground plane. The vertical conducting plane, when used (see 5.2.3), or wall of a screened room shall be located 40 cm to the rear of the EUT. Floor-standing devices shall be placed either directly on the reference ground plane or on insulating material as described in 6.3.3.2. All other surfaces of tabletop or floor-standing EUTs shall be at least 80 cm from any other grounded conducting surface, including the case or cases of one or more LISNs. AC power-line adapters that are used with EUTs, such as notebook computers, should be placed as typically used (i.e., on the tabletop) if the adapter-to-EUT cord is too short to allow the power adapter to reach the floor.

b) Each current-carrying conductor of the EUT power cord(s), except the ground (safety) conductor(s), shall be individually connected through a LISN to the input power source. All 50 Ω ports of the LISN shall be resistively terminated into 50 Ω loads when not connected to the measuring instrument. When the test configuration consists of multiple units (EUT and associated/peripheral equipment, or EUT consisting of multiple equipment) that have their own power cords, ac power-line conducted emissions measurements shall be performed with the ac power-line cord of the particular unit under test connected to one LISN that is connected to the measuring instrument. The power cords for the units in the remainder of the configuration not under measurement shall be connected to a separate LISN or LISNs. This connection may be made using a multiple-receptacle device. Typical ac power-line conducted emissions test setups are shown in Figure 7 through Figure 9. Emissions from each current-carrying conductor of the EUT shall be individually measured. Where multiple portions of the EUT receive ac power from a common power strip, which is furnished by the manufacturer as part of the EUT, measurements need only be made on the current-carrying conductors of the common power strip. Adapters or extension cords connected between the EUT power cord plug and the LISN power receptacle shall be included in the LISN setup, such that the calibration of the combined adapter or extension cord with an adapter and the LISN meets the requirements of 5.2.4.

c) If the EUT consists of a number of devices that have their own separate ac power connections (e.g., a floor-standing frame with independent power cords for each shelf that are able to connect directly to the ac power network), then each current-carrying conductor of one device is measured while the other devices are connected to a second (or more) LISN(s). All devices shall be separately measured. If the manufacturer provides a power strip to supply power to all of the devices making up the EUT, only the conductors in the common power cord to the power strip shall be measured.

d) If the EUT is normally operated with a ground (safety) connection, the EUT shall be connected to the ground at the LISN through a conductor provided in the lead from the ac power to the LISN.

e) The excess length of the power cord between the EUT and the LISN receptacle (or ac power receptacle where a LISN cannot be used), or an adapter or extension cord connected to and measured with the LISN, shall be folded back and forth at the center of the lead to form a bundle not exceeding 40 cm in length. If the EUT does not have a flexible power lead, the EUT shall be placed at a distance of 80 cm from the LISN (or power receptacle where a LISN cannot be used) and connected thereto by a power lead or appropriate connection no more than 1 m long. The measurement shall be made at the LISN end of this power lead or connection.

f) The LISN housing, measuring instrument case, reference ground plane, and vertical conducting plane, if used (see 5.2.3), shall be bonded together.

7.3.2 On-site ac power-line conducted emission measurements

If measurements are performed at a user's installation, then the EUT shall be installed as normally used (see 5.6).

7.3.3 Exploratory ac power-line conducted emission measurements

Exploratory measurements shall be used to identify the frequency of the emission that has the highest amplitude relative to the limit by operating the EUT in a range of typical modes of operation, with typical cable positions, and with a typical system equipment configuration and arrangement. For each mode of operation and for each ac power current-carrying conductor, cable manipulation may be performed within the range of likely configurations. For this measurement or series of measurements, the frequency spectrum of interest shall be monitored looking for the emission that has the highest amplitude relative to the limit. Once that emission is found for each current-carrying conductor of each power cord associated with the EUT (but not the cords associated with non-EUT equipment in the overall system), the one configuration and arrangement and mode of operation that produces the emission closest to the limit across all the measured conductors is recorded.

7.3.4 Final ac power-line conducted emission measurements

Based on the exploratory tests of the EUT, the one EUT cable configuration and arrangement and mode of operation that produced the emission with the highest amplitude relative to the limit is selected for the final measurement. If the EUT is relocated from an exploratory test site to a final test site, the highest emissions shall be remaximized at the final test location before final ac power-line conducted emission measurements are performed. The final test on all current-carrying conductors of all of the power cords to the equipment that comprises the EUT (but not the cords associated with other non-EUT equipment in the system) is then performed for the full frequency range for which the EUT is being tested for compliance without additional variation of the EUT arrangement, cable positions, or EUT mode of operation. If the EUT consists of equipment units that have their own separate ac power connections (e.g., a floor-standing frame with independent power cords for each shelf that are able to connect directly to the ac power network), then each current-carrying conductor of one unit is measured while the other units are connected to a second (or more) LISN(s). All units shall be measured separately. If the manufacturer provides a power strip to supply all the units making up the EUT, only the conductors in the power cord of the power strip shall be measured. Data shall be collected that satisfy the report requirements in Clause 10.

8. Radiated emission measurements

8.1 General measurement and test facilities requirements

a) Radiated emissions measurements shall be made in the 9 kHz to 40 GHz frequency range, as specified by the regulatory and/or purchasing agency or in a specific referenced document.[24] When using a spectrum analyzer without preselection for the measurements described in this clause, the considerations for its use called out in 4.2.3 shall be observed as well as the precautions given in Annex H. Measurements are made at test facilities that meet the requirements of 5.4 for the frequency range of 30 MHz to 1000 MHz and Annex F when using TEM waveguides under certain conditions. For measurements in the frequency range above 1 GHz, the test facilities requirements of 5.5 are applicable.

b) Measurements of the EUT radiated emissions on a standard test site shall be made at the turntable azimuth and antenna height with the antenna positioned to receive emissions in the vertical and horizontal polarizations, such that the maximum radiated emissions level shall be detected. This requires the use of a turntable, as described in 5.1.4, and an antenna positioner, as described in 5.1.6.

c) Continuous azimuth searches shall be made. Where a continuous azimuth search cannot be made, as is the case, for example, where the EUT is so large that a suitable turntable is not readily available, frequency scans of the EUT field strength with both polarizations of the measuring antenna shall be made starting at a minimum of 16 azimuth angles around the EUT, nominally spaced by 22.5°, in characterizing the EUT radio-noise profile. If directional EUT radiation patterns are suspected, especially above 1 GHz, then additional and smaller azimuth angles shall be examined.

d) Figure 7 and Figure 10 through Figure 14 show typical test setups for tabletop, floor-standing, or combinations of tabletop and floor-standing EUTs. The LISNs, installed for the ac power-line conducted emission measurement, may be left in the arrangement for the radiated radio-noise measurements, but unused terminals shall be terminated into 50 Ω loads. If the LISNs are left above the ground plane of the site, the site shall continue to meet the site requirements of 5.3 through 5.5. If LISNs are used as part of the test setup when making radiated emissions measurements, the receptacle for the EUT power connection to the LISN shall be bonded to the OATS or semi-anechoic chamber reference ground plane; it is preferred that the LISNs be located beneath and the receptacles flush with the reference ground plane (exceptions are shown in Figure 8, Figure 9, and Figure 12).

e) Burnout and saturation protection for the measuring instrumentation is required when low-level emissions are to be measured in the presence of a high-level signal. A combination of bandpass, bandstop, low-pass, and high-pass filters may be used. However, the insertion loss of these or any other devices at the frequencies of measurement shall be known and included in any calculations in the report of measurements. NSA performance shall still be met if LISNs are placed above the reference plane on the radiated emissions test site.

[24] Regulatory and/or purchasing agencies may require measurements of radiated emissions at frequencies outside of this range for some types of devices.

8.2 Antenna selection, placement, and measuring distance

8.2.1 Magnetic field radiated emissions below 30 MHz

Magnetic field measurements are made in the frequency range of 9 kHz to 30 MHz using a calibrated loop antenna as specified in 4.5.2, positioned with its plane vertical at the specified distance from the EUT and rotated about its vertical axis for maximum response at each azimuth about the EUT. The center of the loop shall be 1 m above the ground. This method is applicable for radiated radio-noise measurements from all units, cables, power cords, and interconnect cabling or wiring. For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT.

8.2.2 Electric field radiated emissions below 30 MHz

Electric field measurements are made in the frequency range of 9 kHz to 30 MHz using a calibrated monopole antenna as specified in 4.5.3, which shall be positioned at the specified distance from the EUT. The base of the monopole assembly should be placed on the reference ground plane with the antenna monopole element vertical. If the antenna is supplied with a counterpoise, then the counterpoise shall be bonded to the reference ground plane through a low-impedance connection. This method is applicable for radiated radio-noise measurements from all units, cables, power lines, and interconnecting wiring.

NOTE 1—The purpose of a counterpoise is to provide a relatively high capacitance and thus a relatively low impedance path to earth. A counterpoise is sometimes used in medium- and low-frequency applications where it would be more difficult to provide an effective ground connection.

NOTE 2—For example, MIL-STD-461F [B24] specifies a monopole antenna element of length 104 cm (40.95 in), with base/feed-point installed above a square sheet-metal counterpoise with a minimum side length of 60 cm.

NOTE 3—Some regulatory and/or purchasing agencies do not permit the use of monopole antennas for radiated emission measurements below 30 MHz.

NOTE 4—Some regulatory and/or purchasing agency requirements may prohibit electrical bonding of the counterpoise.

8.2.3 Electric field radiated emissions (30 MHz to 1 GHz)

Electric field measurements are made in the frequency range of 30 MHz to 1000 MHz using a calibrated linearly polarized antenna as specified in 4.5.4, which shall be positioned at the specified distance from the periphery of the EUT. The specified distance is the distance between the horizontal projection onto the ground plane of the closest periphery of the EUT and the projection onto the ground plane of the center of the axis of the elements of the receiving antenna. However, if the receiving antenna is an LPDA antenna, the specified distance shall be the distance between the closest periphery of the EUT and the front-to-back center (midpoint along boom/feeder transmission line) of the array of elements.

Measurements shall be made with the antenna positioned in both the horizontal and vertical planes of polarization. The measurement antenna shall be varied in height above the reference ground plane to obtain the maximum signal strength. Unless otherwise specified, the measurement distance shall be 3 m or 10 m. At either measurement distance, the antenna height shall be varied from 1 m to 4 m.

These height scans apply for both horizontal and vertical polarizations, except that for vertical polarization, the minimum height of the center of the antenna shall be increased so that the lowest point of the bottom of the lowest antenna element clears the site reference ground plane by at least 25 cm. For a tuned dipole, the minimum heights as measured from the center of the antenna are shown in Table D.3.

NOTE—The results provided in Heirman [B20] indicate significant differences in the vertically polarized data measured between broadband and tuned dipole antennas. At minimum search heights (maintaining the 25 cm clearance above the conducting ground plane), broadband antennas may yield higher values.

8.2.4 Electric field radiated emissions (1 GHz to 40 GHz)

Radiated emission measurements above 1 GHz are made using calibrated linearly polarized antennas as specified in 4.5.5, which may have a smaller beamwidth (main lobe) than do the antennas used for frequencies below 1 GHz. Because the source of emissions from the EUT is generally limited to relatively small-angle cones of radiation in any elevation above the ground plane including angles above the height of the EUT, the antenna beamwidth shall be known so that when EUT emissions are measured, the area of coverage of the EUT emissions can be determined. Moving the measurement antenna over the surfaces of the four sides of the EUT or another method of scanning of the EUT is required when the EUT is larger than the area covered by the beamwidth of the measuring antenna at the specified distance.

For any EUT, the frequencies of emission should first be detected. Then the amplitudes of the emissions are measured at the specified measurement distance using the required antenna height, polarization, and detector characteristics.

In performing these measurements, the sensitivity of the complete measurement system relative to the limit shall be determined before the test. If the overall measurement sensitivity is inadequate, then low-noise preamplifiers, closer measurement distances, higher gain antennas, and/or narrower bandwidths may be used. Also, measurement system overload levels shall be determined to be adequate when preamplifiers are used. The effects of using bandwidths different from those specified shall also be determined. Any changes from the specific measurement conditions shall be described in the report of the measurements. (See also 10.2.4 and 10.2.9.)

8.3 Radiated emission measurement procedures

8.3.1 Exploratory radiated emissions measurements

8.3.1.1 Exploratory radiated emission measurements (9 kHz to 1 GHz)

a) Exploratory radiated measurements shall be performed at the measurement distance or at a closer distance than that specified for compliance to determine the emission characteristics of the EUT (see also 10.2.8 and Annex E) and recorded in tabular or graphical form. Significant emissions are identified using a remote-controlled turntable and antenna positioner and monitoring the spectrum while changing the EUT (turntable) azimuth, antenna polarity, and height. This spectrum exploratory monitoring can also be performed by manually moving the receiving antenna around the EUT to pick up significant emissions. A shielded room may be used for exploratory testing, but care must be taken to account for shielded room reflections that can lead to significant errors in amplitude measurements.

b) Broadband antennas and a spectrum analyzer or an EMI receiver with a panoramic display are most often used in this type of testing. It is recommended that either a headset or loudspeaker be connected as an aid in detecting ambient signals and finding frequencies of significant emission from the EUT when the exploratory and final testing is performed at an OATS with strong ambient signals. Caution should be taken if either antenna heights between 1 m and 4 m or EUT azimuth is not fully explored. Not fully exploring these parameters during exploratory testing may require complete testing at the OATS or semi-anechoic chamber when the final full spectrum testing is conducted.

c) The EUT should be set up in its typical configuration and arrangement and operated in its various modes. For tabletop systems, cables or wires not bundled in the initial setup shall be manipulated within the range of likely arrangements. For floor-standing equipment, the cables or wires should be located in the same manner as the user would install them and no further manipulation is made. For combination EUTs, the tabletop and floor-standing portions of the EUT shall follow the procedures for their respective setups and cable manipulation. If the manner of cable installation is not known, or if it changes with each installation, cables or wires for floor-standing equipment shall be manipulated to the extent possible to produce the maximum level of emissions.

d) Exploratory radiated emissions testing of handheld and/or body-worn devices shall include rotation of the EUT through three orthogonal axes to determine the orientation (attitude) that maximizes the emissions. Subclause 6.3.6 applies for exploratory radiated emissions testing of ceiling-mounted devices. This equipment arrangement shall be used in the final measurements of radiated emission from the EUT.

e) For each mode of operation required to be tested, the frequency spectrum shall be monitored. Variations in antenna height between 1 m and 4 m, antenna polarization, EUT azimuth, and cable or wire placement (each variable within bounds specified elsewhere) shall be explored to produce the emission that has the highest amplitude relative to the limit. A suggested step-by-step technique for determining maximum radiated emission is given in Annex E.

8.3.1.2 Exploratory radiated emissions measurements (1 GHz to 40 GHz)

When measuring emissions above 1 GHz, the frequencies of maximum emission shall be determined by manually (or with an articulated antenna positioner) positioning the antenna close to the EUT and then moving the measurement antenna over the surfaces of the EUT while observing a spectral display. It will be advantageous to have prior knowledge of the frequencies of emissions above 1 GHz to help in the search for emissions at those frequencies.

8.3.2 Final radiated emission measurements

8.3.2.1 Final radiated emission measurements (9 kHz to 1 GHz)

Based on the exploratory radiated emissions measurement results (i.e., see 8.3.1.1), the single EUT, cable and wire arrangement, and mode of operation that produces the emission that has the highest amplitude relative to the limit are selected for the final measurement. The final measurements are then performed on a site meeting the requirements of 5.3 or 5.4, as appropriate. If the EUT is relocated from an exploratory test site to a final test site, the highest emission relative to the limit shall be remaximized at the final test location before final radiated emissions measurements are performed. However, antenna height and polarization and EUT azimuth are to be varied. In addition, the full frequency range to be checked for meeting compliance shall be investigated.

This investigation is performed with the EUT rotated 360°, the antenna height scanned between 1 m and 4 m, and the antenna rotated by 90° relative to the ground plane to repeat the measurements for both the horizontal and vertical antenna polarizations. During the full frequency range investigation, particular focus should be made on the frequencies found in exploratory testing that were used to find the final test configuration, mode of operation, and arrangement (associated with achieving the least margin with respect to the limit). This full range test constitutes the compliance measurement.

8.3.2.2 Final radiated emission measurements (1 GHz to 40 GHz)

The final measurements are performed on a site meeting the requirements of 5.5. For measurements above 1 GHz, use the cable, EUT arrangement, and mode of operation determined in the exploratory testing to produce the emission that has the highest amplitude relative to the limit. Place the measurement antenna away from each area of the EUT determined to be a source of emissions at the specified measurement distance, while keeping the measurement antenna aimed at the source of emissions at each frequency of significant emissions, with polarization oriented for maximum response. The measurement antenna may have to be higher or lower than the EUT, depending on the radiation pattern of the emission and staying aimed at the emission source for receiving the maximum signal. The final measurement antenna elevation shall be that which maximizes the emissions. The measurement antenna elevation for maximum emissions shall be restricted to a range of heights of from 1 m to 4 m above the ground or reference ground plane. The data collected shall satisfy the report requirements of Clause 10.

NOTE—For physically small EUTs, it may be preferable to vary the height and polarization of the EUT instead of the receiving antenna to maximize the measured emissions.

8.3.3 On-site measurements

When it is required to make radiated emission measurements on site at a user's installation, instructions in the product standards or applicable regulations shall be followed. Unless otherwise specified in the individual equipment requirements, measurements shall be made in accordance with 8.1 to locate the radial of maximum emission at the limit distance from the nearest point of the equipment being tested and the projection of the receive antenna onto the plane of the base of the EUT. Antenna scan heights are normally required to be between 1 m and 4 m above the base of the antenna. Both horizontal and vertical antenna polarizations shall be investigated. Where measurements at the limit distance from the EUT are impractical, measurements may be made at greater or lesser distances as near to the limit distance as practical and extrapolated to the limit distance (see 10.2.8.4). A detailed description of the tests and any rationale for variations in measurement procedures, measurement distances, and so on shall be included in the test report. A LISN shall not be used for testing at the user's installation, unless the LISN is a part of the normal installation, in order that the measured radio noise is representative of the specific site; see also IEEE Std 139-1988.

9. Radio-noise power

9.1 General

Measurements of radio-noise power may be made in lieu of radio-noise radiated emissions measurements for certain restricted frequency ranges and for certain types of EUT. Such measurements use the calibrated absorbing clamp. When using a spectrum analyzer without preselection for the measurements described in this clause, the considerations for its use described in 4.2.3 shall be observed as well as the precautions given in Annex H. Use of the clamp as an alternative to radiated emissions measurement shall be specified in the individual equipment requirements.

9.2 Absorbing clamp calibration

Calibration of the absorbing clamp shall be in accordance with Annex B of CISPR 16-1-3:2004-06.

9.3 Absorbing clamp measurement procedures

The test arrangement for the measurement of radio-noise power is shown in Figure 15. The power cord connects the EUT with the commercial power source.

The EUT is placed on a nonmetallic table or on the floor if it is a floor-standing unit, and it is located at least 40 cm from any other metallic objects. The power cord is positioned to form a straight line so that the absorbing clamp can be moved along the power cord to determine the maximum radio noise. If radio-noise power shall be measured on a floor-standing unit, the power cord shall leave the EUT at an angle of less than 45° with respect to a reference ground plane, until it reaches a height 40 cm above the floor, and then continue horizontally.

The absorbing clamp is then moved along the power cord and shall be positioned to absorb maximum power, that is, power giving the highest indication on the receiver. Normally, the maximum that is nearer to the EUT is used.

The EMI receiver reading in decibels referenced to one microvolt (dBμV) can be directly converted to decibels referenced to one picowatt (dBpW) under conditions of optimum coupling. The coupling varies from the optimum with distance from the EUT (first or second maximum) and frequency. The meter reading shall be corrected in accordance with the calibration data for the particular clamp used (see 4.7.5).

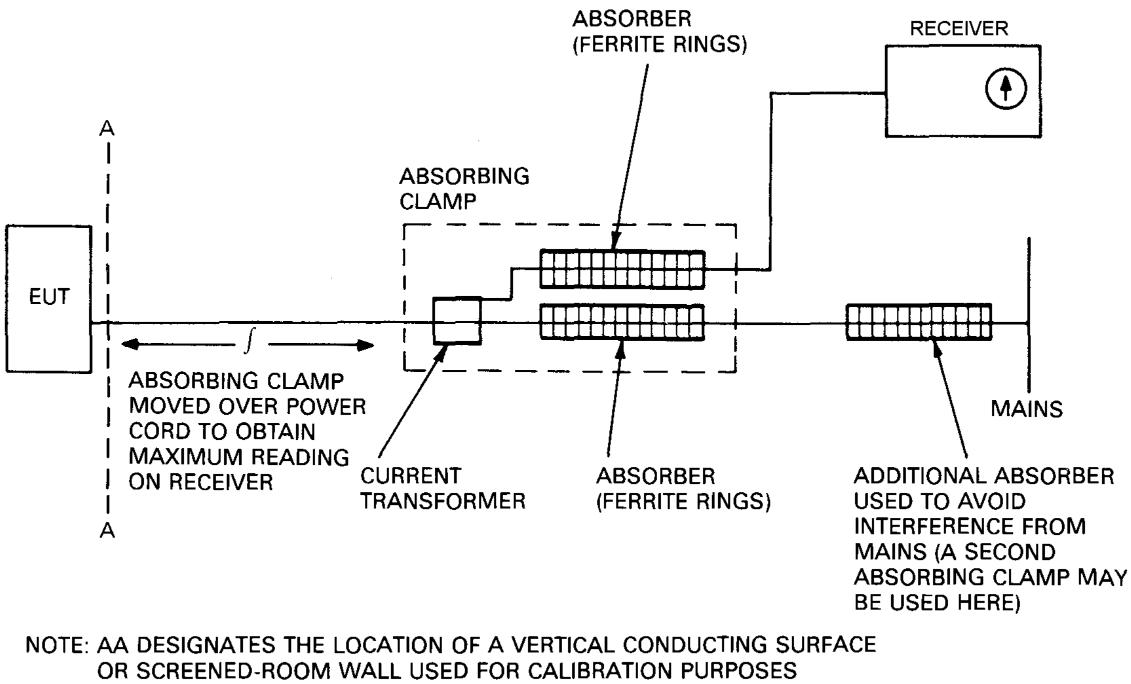


Figure 15—Equipment arrangement for radio-noise power measurement

10. Test reports

10.1 General

Test reports are the means of presenting the test results to the appropriate regulatory and/or purchasing agency or for archiving the data in the permanent files of the testing organization. As such, test reports shall be clearly written in unambiguous language. A practical guide to follow is contained in 5.10 of ISO/IEC 17025:2005. For tests performed using wideband TEM devices, the report requirements in F.6 augment those of this clause; where there are conflicts, the F.6 requirements take precedence.

10.2 Test report content

The conditions, relating to the tests, listed in the following subclauses shall be described in the test report in order for the test results to be properly documented.

10.2.1 Applicable standards

In addition to this standard, any other standards to which the EUT was tested shall be clearly described in the test report. Where referenced standards have more than one measurement procedure, or where the referenced measurement procedure has options, the test report shall state which procedures or options were used (see 1.2). The test report shall also state the issue or year of the referenced standard(s) used.

10.2.2 Equipment units tested

The test report shall list all equipment tested, including product type and marketing designations, where applicable. Serial numbers and any other distinguishing identification features shall also be included in the test report. Identification or a detailed description shall also be made of interconnecting cables.

The rationale for selecting the EUT, comprising the equipment units needed to be functionally complete, and the necessary cabling shall be noted in the test report.

10.2.3 Equipment and cable arrangement

The setup of the equipment and cable or wire placement on the test site that produces the highest radiated and the highest ac power-line conducted emissions shall be clearly shown and described. Drawings or photographs may be used for this purpose (see 10.2.12). A block diagram or photo showing the interconnection of the major functional units is also useful.

10.2.4 List of test equipment

A complete list of all test equipment used shall be included with the test report. The manufacturer's model and serial numbers, date of last calibration, and calibration interval shall be included. Measurement cable loss, measuring instrument bandwidth and detector function, video bandwidth, if appropriate, and antenna factors shall also be included where applicable.

10.2.5 Units of measurement

The measurements of ac power-line conducted emissions, output, and spurious conducted emissions for TV interface devices, and antenna transfer switch isolation for TV interface devices, shall be reported in units of dBμV. The measurements of transfer switch isolation for cable TV switches shall be reported in units of decibels below the input level. The measurements of radiated emissions shall be reported in units of decibels, referenced to one microvolt per meter (dBμV/m) for electric fields, or to one ampere per meter (dBA/m) for magnetic fields, at the distance specified in the appropriate standards or requirements. The measurements of antenna-conducted power for receivers may be reported in units of dBμV, if the impedance of the measuring instrument is also reported. Otherwise, antenna-conducted power must be reported in units of decibels referenced to one milliwatt (dBmW). All formulas for data conversions and conversion factors, if used, shall be included in the measurement report.

10.2.6 Location of test facility

The location of the test site shall be identified in the test report. Facilities that have received recognition or listing from various accreditation bodies shall use the same site address information as was included in their original application for recognition or listing.

10.2.7 Measurement procedures

The sequence of testing followed to determine the emissions included in the test report should be documented. For example, the sequence used during exploratory testing in accordance with 7.3.3 and 8.3.1 should be given in the test report, in sufficient detail to allow replication of the test results by regulatory and/or purchasing agencies, or if required to perform additional tests and ongoing compliance checks. Any measurements that utilize special test software shall be indicated and referenced in the test report.

10.2.8 Reporting measurement data

10.2.8.1 General requirements

The measurement results, along with the appropriate limits for comparison, shall be presented in tabular or graphical form. Alternatively, recorded charts, photographs of a spectrum analyzer display, or printouts of receiver screen contents may be used if the information is clearly presented showing comparison to the limits and all data conversions are explained. In addition, any variation in the measurement environment should be reported (e.g., a significant change of temperature will affect the cable loss and amplifier response).

10.2.8.2 Measurement uncertainty

The results of measurements of emissions shall reference the measurement instrumentation uncertainty considerations contained in ANSI C63.23 or CISPR 16-4-2:2011-06. Determining compliance shall be based on the results of the compliance measurement, not taking into account measurement instrumentation uncertainty. Hence the measurement uncertainty of the measurement instrumentation and its associated connections between the various instruments in the measurement chain shall be calculated, and both the measurement results and the calculated uncertainty shall be given in the test report.

10.2.8.3 AC power-line conducted emissions data

The frequency and amplitude of the six highest ac power-line conducted emissions relative to the limit, measured over all the current-carrying conductors of the EUT power cords, and the operating frequency or frequency to which the EUT is tuned (if appropriate) shall be reported, unless such emissions are more than 20 dB below the limit. AC power-line conducted emissions measurements are to be separately carried out only on each of the phase (“hot”) line(s) and (if used) on the neutral line(s), but not on the ground [protective earth] line(s). If fewer than six emission frequencies are within 20 dB of the limit, the noise level of the measuring instrument at representative frequencies shall be reported. The specific conductor of the power-line cord for each of the reported emissions shall be identified. Measure the six highest emissions with respect to the limit on each current-carrying conductor of each power cord associated with the EUT (but not the power cords of associated or peripheral equipment which are part of the test configuration). Then, report the six highest emissions with respect to the limit from among all the measurements identifying the frequency and specific current-carrying conductor identified with the emission. The six highest emissions shall be reported for each of the current-carrying conductors, or the six highest emissions may be reported over all the current-carrying conductors.

10.2.8.4 Radiated emission data

a) For ITE unintentional radiators, the frequency and amplitude of the six highest radiated emissions relative to the limit and independent of antenna polarization shall be reported, unless such emissions are more than 20 dB below the limit. If fewer than the specified number of emissions (i.e., fewer than six) are within 20 dB of the limit, the system noise level (i.e., the noise level of the entire measurement chain including the measuring instrument, cables, antenna, and, if used, preamplifiers, attenuators, and/or filters) at representative frequencies shall be reported.

b) For unintentional radiators other than ITE, for each of the frequencies to which the device is tuned, the frequency and amplitude of the six highest radiated emissions relative to the limit and the operating frequency, or frequency to which the EUT is tuned (if appropriate), shall be reported unless such emissions are more than 20 dB below the limit. If fewer than the specified number of emissions (i.e., fewer than six) are within 20 dB of the limit, the system noise level (i.e., the noise level of the entire measurement chain including the measuring instrument, cables, antenna, and, if used, preamplifiers, attenuators, and/or filters) at representative frequencies shall be reported.

c) The polarization of the measurement antenna (horizontal or vertical) shall be identified for each of the reported emissions. Radiated emissions measurements taken at alternative distances are to be converted to the limit distance using the inverse distance relationship, unless data can be presented to validate a different conversion. At a reported frequency, the polarization with the highest level shall be reported.

d) For the specific case of measurements made on the receiver portions of transceivers, refer to item b) in 12.2.2.3 for information on the requirements for reporting transmit signals that cannot be sufficiently attenuated.

10.2.8.5 Antenna-conducted power data for receivers

For each of the frequencies to which the receiver is tuned, if antenna-conducted power measurements are performed, the frequency to which the receiver is tuned, the frequency and level of the six highest emissions relative to the limit, and the impedance of the measuring instrument shall be reported, unless such emissions are more than 10 dB below the limit. If fewer than six emissions are within 10 dB of the limit, the noise level of the measuring instrument at representative frequencies shall be reported.

10.2.8.6 Output and spurious conducted data for TV interface devices

For each channel provided in the EUT, the output channel and the peak RF levels shall be reported as follows: the visual carrier, the aural carrier, the three highest spurious emissions relative to the limit observed in the range from 30 MHz to the frequency 4.6 MHz below the visual carrier frequency, and the three highest spurious emissions relative to the limit observed from the frequency 7.4 MHz above the visual carrier frequency to 1 GHz. If the spurious emissions observed are more than 20 dB below the limit, then the noise level of the measuring instrument at representative frequencies shall be reported. The operating mode of the EUT and modulation for each data point shall also be listed.

10.2.8.7 Antenna transfer switch data

For cable TV antenna transfer switches either internal or external to a device, the minimum isolation level above and below 216 MHz for each pair of antenna input ports or terminals shall be reported. For antenna transfer switches associated with TV interface devices, the peak RF level of the visual carrier measured at each antenna input port or terminal for every output channel provided in the EUT shall be reported. For both types of switches, the input port, modulating signal, device powered ON or OFF, and switch position for each data point shall also be listed.

10.2.9 General and special conditions

For EUTs that cannot be arranged in full conformance with the test setups in Figure 7 through Figure 14, a full description of the alternative arrangement used shall be included in the test report. If an alternative test method was used, the test report shall identify and describe that method, provide justification for its use, and describe how the results obtained through its use correlate with, or are equivalent to, the methods specified by the standard to which the EUT was tested. Instrumentation, instrument attenuator and bandwidth settings, detector function, EUT arrangement, and all other pertinent details of the test method shall be provided so that the alternative test method could be replicated. Where automatic scan techniques were used, an explanation of how the highest emission relative to the limit from the EUT was determined and the scan rate used (see 4.2.2) to obtain recorded emissions shall be included in the test report. The actual operating conditions (e.g., voltage and power-line frequency) shall be listed in the report. The actual environmental conditions (e.g., temperature and relative humidity) shall be listed in the report if critical to the test results.

10.2.10 Summary of results

The test report summary section shall indicate whether the EUT passes or fails and, if not stated elsewhere in the test report, shall give margins with respect to the limits to which it was tested. If the equipment only passes with specific modifications or special attributes (such as shielded cables), this information shall be included either in the summary section or in a separate dedicated section of the test report.

10.2.11 Required signatures

The test report shall contain the signature of the representative of the organization performing the tests. In addition, the test report shall contain the identification of the technical staff responsible for the proper execution of the test and the name and address of the party requesting the tests.

10.2.12 Test report appendixes

The test report shall contain photographs or detailed sketches of the EUT configuration and arrangement, showing sufficient information to allow the EUT to be reconfigured and arranged in a manner that would allow the original test to be replicated, with a high likelihood that the test results would be in agreement with the results of the original test within acceptable tolerances.

10.2.13 Required signatures and statements for engineering changes to the EUT

If any modifications are made to the EUT to bring the EUT into compliance with the appropriate specifications, the test report shall give a complete description of, and reasons for, these modifications. A written statement shall be included with the report, signed by the requester of the tests, that the product will have all of the modifications incorporated into the product when manufactured and placed on the market. The report is not complete without these two signed statements.

10.3 Test report disposition

The manufacturer or test facility may be required by an regulatory and/or accreditation agency to maintain a copy of the report for a specific period of time.

11. Measurement of ITE

11.1 General

This clause contains information applying specifically to ITE. In general, testing is performed according to the specifications in Clause 6 through Clause 8, with the additions, specific clarifications, and exceptions described in this clause.

This clause prescribes many procedures designed to enhance repeatability. Deviations from the prescribed procedure are permitted only where justified by typical usage and may require approval of the regulatory and/or purchasing agency. Any deviations from the prescribed procedure shall be described and fully justified as outlined in 1.2 and 10.2.9.

Depending on the internally generated frequency of the ITE (digital device), measurements may be specified on the basis of average, quasi-peak, or peak response, or a combination of these detector functions. Because of the complexity of the individual equipment requirements, careful study of these requirements is recommended before proceeding with testing.

11.2 Operating conditions

11.2.1 General requirements

As pointed out in 6.2, all parts of the system shall be exercised. For example, in a computer system, tape and disk drives shall be put through a read-write-erase sequence, various portions of memories shall be addressed, any mechanical activities shall be performed, and visual display units shall display a variety of characters.

11.2.2 Host acting as the EUT

The host, typically a CPU, should be tested as part of a system. If the host is a PC, it shall be tested with peripherals comprising the system as described in 11.5. Interface cables shall be connected to one of each type of functional interface port on the host, and each cable should be terminated in a peripheral load typical of actual usage.

11.2.3 Host not acting as the EUT

In this case, the host is not fully configured with each of its different types of ports populated. Instead a minimum of two different types of available I/O protocols [e.g., IEEE Std 1394™-2008 [B21], Universal Serial Bus (USB) [B29], serial, parallel] shall have cabling connected to accessory equipment typically attached to these cables.

In the special cases of tablet PCs and/or handheld PC-based devices that are intended to perform only specific application-oriented functions for industrial, medical, commercial, military, or similar purposes, it is permissible to test such host devices with a dedicated peripheral device even when the host device contains only one type of I/O port.

11.3 Peripherals/accessories

11.3.1 General requirements

The appropriate host equipment shall drive any peripheral/accessory being tested separately. The host for a PC peripheral shall be the PC typical of actual usage. If the host is a PC, the host and peripheral/accessory under test shall be tested with any additional equipment needed to satisfy the minimum system requirements of 11.5. In case the peripheral is not the EUT, for instance, a printer, it is not necessary that the printer constantly print scrolling letter-H characters, but rather there shall be some indication that the printer is being communicated with; for instance, a continuous carriage movement is adequate. Where a peripheral is the EUT, the host shall have other peripherals connected to it for a minimum of two different types of available I/O protocols. A minimum of two different types of available I/O protocols [e.g., IEEE Std 1394-2008 [B21], Universal Serial Bus (USB) [B29], serial, parallel] shall have cabling connected to accessory equipment typically attached to these cables.

11.3.2 Peripherals/accessories acting as the EUT

Any peripheral/accessory being tested as the appropriate host equipment shall drive the EUT. If the host is a PC, the host and peripheral/accessory EUT shall be tested with any additional equipment needed to operate the EUT. If the host is a PC, it is not fully configured with each of its different types of ports populated. A minimum of two different types of available I/O protocols [e.g., IEEE Std 1394-2008 [B21], Universal Serial Bus (USB) [B29], serial, parallel] shall have cabling connected to accessory equipment typically attached to these cables.

11.3.3 Peripherals/accessories not acting as the EUT

In this case, for instance, when the peripheral/accessory is a printer, it is not necessary that the printer constantly print scrolling letter-H characters, but rather there shall be some indication that the printer is being communicated with; for instance, a continuous carriage movement is adequate.

11.4 Visual display units

If the EUT system includes a visual display unit or monitor, use of the operational conditions shown in normative Figure 16 is required (including considerations from Nadeau [B25]). The operational conditions are applicable for any ITE with a visual display unit, for example, desktop PCs and PCs for mobile use such as notebook PCs, laptop PCs, tablet PCs, netbook PCs, and all other similar types of devices.

11.5 Tabletop equipment arrangement

11.5.1 General requirements

Follow 6.3.2 for placement of the EUT, placement of the peripheral/accessory, and placement and manipulation of interface cables for testing tabletop ITE systems.

For a PC, or a peripheral/accessory intended to be used with a PC, the minimum system consists of the following devices grouped and tested together:

a) PC.

b) Keyboard.

c) Visual display unit (monitor).

d) When a PC is the EUT and also the host, the minimum functional interface (I/O) ports that shall be populated by attaching cables, which are terminated in a typical load of actual usage. When the PC is the host but a peripheral/accessory is the EUT, at a minimum two different types of available I/O protocols [e.g., IEEE Std 1394-2008 [B21], Universal Serial Bus (USB) [B29], serial, parallel] shall have cabling connected to accessory equipment typically attached to these cables.

e) If the EUT has a dedicated port for a special-purpose device (e.g., a mouse, joystick, or external disk drive), that device shall be part of the minimum system.

NOTE—In some systems, item a) through item c) may be assembled in the same chassis. In no instance shall item a) through item c) or joystick controls satisfy the requirements of item d).

For host PCs on which the monitor cannot be mounted (i.e., notebook or tabletop-mounted tower PCs), the monitor shall occupy an adjacent position to the left or right of the host as appropriate for the specific EUT.

Figure 7, Figure 8, and Figure 10 show the recommended equipment and cable arrangements that are described in 6.3.2 and 11.5 through 11.5.5.

In the special case of a PC (e.g., tablet PC and/or handheld PC-based device) that has a limited number of I/O ports and cannot be configured as described in the preceding paragraphs, it is permissible to test such host devices with a peripheral device and interface cable connected to each I/O port available on the host. The rationale for the selection of the equipment configuration and loading of ports shall be included in the test report.

11.5.2 Placement of host

For tabletop hosts, the host shall be centered laterally on the tabletop and its rear shall be flush with the rear of the table, unless that would not be typical of normal usage (e.g., a mini-tower computer that would normally be placed to the side of the visual display unit).

11.5.3 Placement of monitors and keyboards

The monitor should be placed on top of the host, centered and flush with the front of the host, unless the host is not designed for such usage. In that case, the monitor shall occupy an adjacent position to the left or right of the host, maintaining a 10 cm separation from adjacent equipment. The keyboard shall be positioned in front of the monitor, centered on the monitor, and flush with the front edge of the tabletop surface (see Figure 7, Figure 8, and Figure 10).

11.5.4 Placement of external peripherals/accessories

External peripherals (external to the host) that are part of a tabletop system shall normally be placed in a single arrangement with one peripheral on each side of the host with a 10 cm separation between the closest points of the cabinets if at least two peripherals are present. If more than two external peripherals are present, a typical arrangement should be chosen that maintains a spacing of 10 cm between all equipment cabinets. If fewer than two peripherals are present, position the peripheral as in 6.3.2.3. Peripherals that are designed to be stacked (one on top of another) shall be stacked in a typical manner as long as there is at least one peripheral on each side of the host. A mouse or joystick shall be positioned 10 cm to the right of the keyboard (see Figure 7).

11.5.5 Placement and manipulation of interface cables

a) Excess interface cable length shall be draped over the back edge of the tabletop for tabletop equipment. If any draped cable extends closer than 40 cm to the reference ground plane, the excess shall be bundled in the center in a serpentine fashion using 30 cm to 40 cm lengths to maintain the 40 cm height. If the cables cannot be bundled because of bulk, length, or stiffness, they shall be draped over the back edge of the tabletop unbundled, but in such a way that all portions of the interface cable remain at least 40 cm from the horizontal reference ground plane, as shown in Figure 8 and Figure 10.

b) The system shall be configured and set up in one typical equipment arrangement for the test. In making any tests involving several pieces of tabletop equipment interconnected by interface cables, it is essential to recognize that the measured levels may be critically dependent on the exact placement of the interface cables. Thus, exploratory tests as specified in 7.3.3 and 8.3.1 should be carried out while varying cable positions to determine the maximum or near-maximum emission level. During manipulation, cables shall not be placed under or on top of the system test components unless such placement is required by the inherent equipment design.

c) If the monitor can be powered through a receptacle on the host unit, it shall be tested in two ways (i.e., powered through the host) and powered separately as required during both exploratory ac power-line conducted and exploratory radiated emissions testing.

11.6 Floor-standing equipment arrangement

Follow 6.3.3 for placement of the EUT, placement of peripherals, and placement and manipulation of interface cables for testing a floor-standing ITE system.

11.7 Combination tabletop and floor-standing equipment arrangement

Follow 6.3.4 for placement of the EUT, placement of peripherals, and placement and manipulation of interface cables for testing a combination tabletop and floor-standing ITE system.

11.8 AC power-line conducted emission measurements

11.8.1 Introduction

The following subclauses describe the procedures that should be used for performing the final ac power-line conducted emission measurements of ITE.

11.8.2 Exploratory ac power-line conducted emission measurements

Using the procedure in 7.3.3, determine the mode of operation and cable positions of the EUT system that produce the emission with the highest amplitude relative to the limit. This arrangement shall be used in final ac power-line conducted emission measurement of the EUT.

11.8.3 Final ac power-line conducted emission measurements

Using the mode of operation and arrangement of the EUT determined in 11.8.2, follow the procedure in 7.3.4 to perform final ac power-line conducted emission measurements. Measure significant emissions, and then select and record the six highest emissions relative to the limit on each of the power cords comprising the EUT. The measurements shall be done on all of the current-carrying conductors of each of the EUT power cords over the frequency range specified by the regulatory and/or purchasing agency. See 10.2.8.3 for full reporting requirements and 7.3.4 for arrangement of accessory/peripheral power cords. Photograph or diagram the test setup that was used (see 10.2.12).

The quasi-peak detector function, specified for use between 150 kHz and 30 MHz, may not indicate the same subjective interference level for both narrowband and broadband sources. This has been recognized and ways to account for the unequal interference potential of narrowband and broadband emissions have been adopted.

When the regulatory and/or purchasing agency specifies two limits using different detector functions in the measuring instrument, ac power-line conducted emissions shall be measured with the specified detector functions and emissions shall comply with the appropriate limit.

11.9 Radiated emission measurements

11.9.1 Introduction

The following subclauses describe the procedures that shall be used for performing the final radiated emission measurements of ITE.

11.9.2 Exploratory radiated emission measurements

Using the procedure in 8.3.1, determine the mode of operation and cable positions of the EUT system that produce the emission with the highest amplitude relative to the limit. This equipment arrangement shall be used in final radiated emission measurements of the EUT.

11.9.3 Final radiated emission measurements

Using the mode of operation and equipment arrangement of the EUT determined in 11.9.2, follow the procedure in 8.3.2 to perform final radiated emission measurements. Record the six highest emissions relative to the limit in the frequency range specified by the regulatory and/or purchasing agency. See 10.2.8.4 for full reporting requirements. Provide a photograph or diagram of the test setup that was used (see 10.2.12).

11.10 Figure for Clause 11

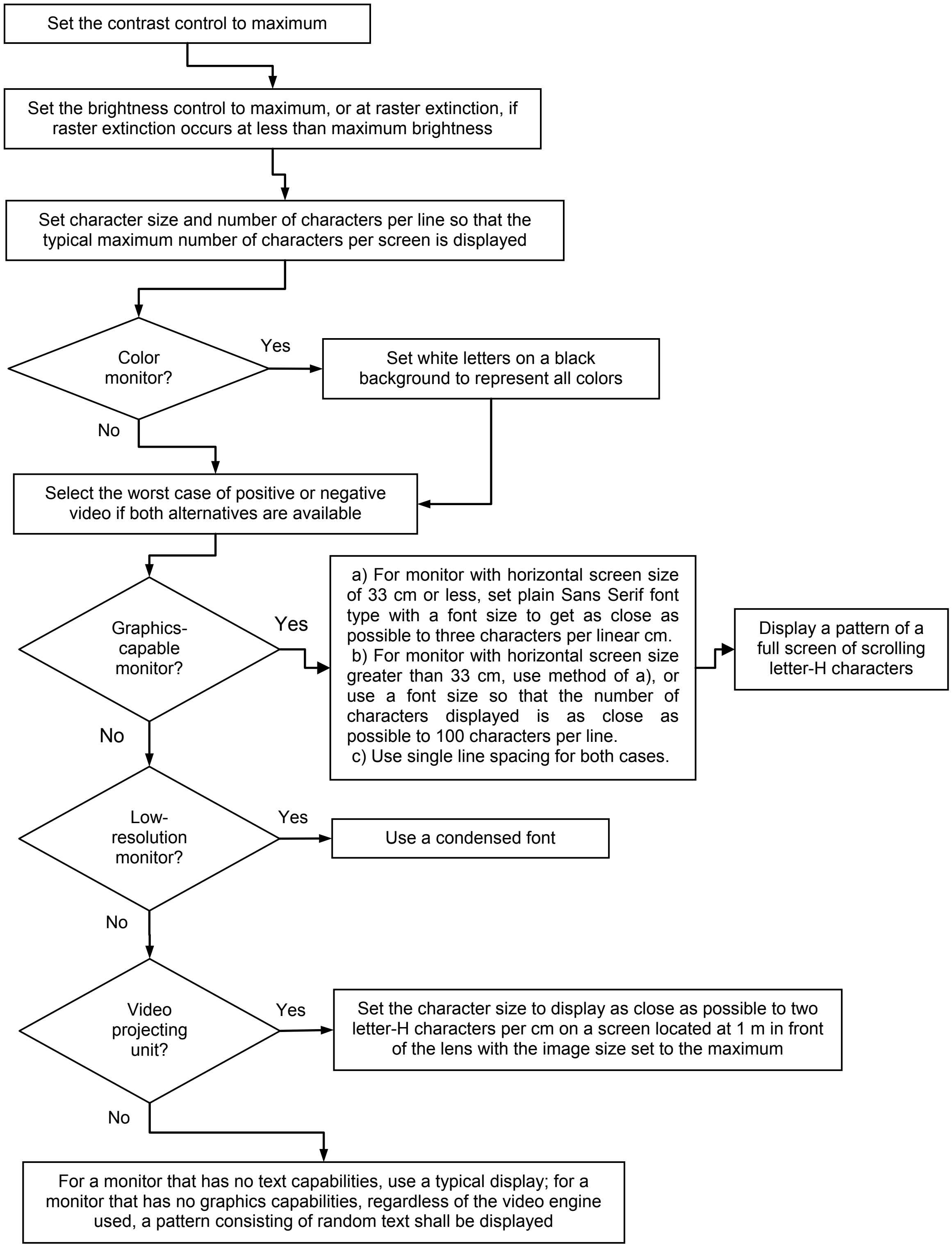


Figure 16—(normative) Monitor settings (see 11.4)

12. Measurement of unintentional radiators other than ITE

12.1 General

This clause contains information applying specifically to unintentional radiators other than ITE, such as receivers, videocassette recorders (VCRs), TV interface devices, and similar devices that are not intended to radiate RF energy. In general, testing is performed according to the specifications in Clause 6 through Clause 8, with the additions, specific clarifications, and exceptions described in this clause.

This clause prescribes many procedures designed to enhance repeatability. Deviations from the prescribed procedure are permitted only where justified by typical usage and may require approval of the regulatory and/or purchasing agency. Any deviations from the prescribed procedure shall be described and fully justified as outlined in 1.2 and 10.2.9.

Depending on the unintentional radiator operating frequency range, measurements may be specified on the average, quasi-peak, or peak detector basis, or a combination of these detector functions. Because of the complexity of the individual equipment requirements and different measurement requirements, careful study of the agency regulations is recommended before proceeding with actual testing.

12.2 Measurement of receivers

12.2.1 General requirements

This subclause contains information that applies only to the measurement of emissions from receivers.

a) FM and TV broadcast receivers shall be measured for radiated emissions and ac power-line conducted emissions in accordance with the procedures set forth in IEEE Std 187-2003.

b) For nonbroadcast receivers, the test procedures in the following subclauses should be followed.

12.2.2 Operating conditions

12.2.2.1 General requirements

a) Equipment that interacts with accessory devices (i.e., sends digital information to or receives digital information from accessory devices via interconnecting wires) shall be tested as part of a typical operational system. The selection and placement of cables, ac power cords, and system components depend on the type of EUT and shall be representative of expected equipment installation.

b) Equipment that does not interact with accessory devices (e.g., only sends audio information to passive accessories, such as external speakers, or provides video information to auxiliary devices, such as VCRs, that are subject to their own regulatory requirements) shall be tested with only the accessories normally marketed with the particular equipment.

c) If the EUT is a nonbroadcast receiver that operates on more than one frequency or over a frequency range or ranges, unless otherwise specified, then all measurements shall be made with the EUT set to the number of frequencies in each band as provided in Table 4.

Table 4—Receiver frequency bands

Frequency range over which device operates	Number of frequencies	Location in the range of operation
Less than 1 MHz	1	1 near middle
1 MHz to 10 MHz	2	1 near top, 1 near bottom
More than 10 MHz	3	1 near top, 1 near middle, and 1 near bottom

d) Unless otherwise specified in the individual tests, a receiver shall be supplied with the signal described below to simulate normal operation.

12.2.2.2 Super-regenerative receiver

a) A signal generator, not the matching transmitter, shall be used to radiate an unmodulated CW signal to a super-regenerative receiver at its operating frequency in order to “cohere” or to resolve the individual components of the characteristic broadband emissions from such a receiver. The level of the signal may need to be increased for this to occur.

b) If a super-regenerative receiver is tested for radiated emissions with a resistive termination instead of an antenna connected to the antenna input terminals, apply the unmodulated signal at a level of approximately –60 dBm to the antenna terminals, using an impedance-matching network if necessary, to “cohere” the emissions. It may be necessary to adjust the signal level to accomplish this.

12.2.2.3 Other types of receivers

a) A typical signal or an unmodulated CW signal at the operating frequency of the EUT shall be supplied to the EUT for all measurements. Such a signal may be either supplied by a signal generator with an antenna in close proximity to the EUT or directly conducted into the antenna terminals of the EUT. The signal level shall be sufficient to stabilize the local oscillator of the EUT.

b) If the product is a transceiver, the receive port measurement shall be performed by notching the transmit signal and/or by reducing the transmit signal to the minimum level necessary to maintain the functionality of the transceiver. After this has been done, if the amplitude of the measured transmit signal has not been attenuated to a level that is 6 dB or more below the applicable unintentional radiator specification limits, the measured transmit frequency and measured radiated emissions level shall be included in the test report, along with a specific notation that identifies the emission as a “transmit signal.”

12.2.3 Equipment arrangement

Follow 6.3 for placement of the EUT, placement of accessories, and placement and manipulation of interconnecting cables and wires for testing an individual receiver or system.

12.2.4 AC power-line conducted emission measurements

12.2.4.1 Introduction

The following subclauses describe the procedures that may be used for making final ac power-line conducted emission measurements on receivers.

12.2.4.2 Exploratory ac power-line conducted emission measurements

On any convenient frequency specified in 12.2.2, use the procedure in 7.3.3, while applying the appropriate signal to the EUT, to determine the operating frequency and cable or wire positions of the EUT system that produce the emission with the highest amplitude relative to the limit. This equipment arrangement shall be used in making final measurements of ac power-line conducted emissions.

12.2.4.3 Final ac power-line conducted emission measurements

a) Using the operating frequency and equipment arrangement of the EUT determined in 12.2.4.2, follow the procedure in 7.3.4, while applying the appropriate signal to the EUT, to perform final ac power-line conducted emission measurements.

b) Record the six highest EUT emissions relative to the limit of each of the current-carrying conductors of the power cords of the equipment that comprises the EUT over the frequency range specified by the regulatory and/or purchasing agency. See 10.2.8.3 for reporting requirements. Diagram or photograph the test setup that was used (see 10.2.12).

12.2.5 Radiated emission measurements

12.2.5.1 General requirements

Radiated emissions from receivers may be measured using a terminating resistor, rather than an antenna, connected to the antenna input ports or terminals, providing the receiver is also tested for antenna-conducted power as specified in 12.2.6.

The following subclauses describe the procedures that may be used for making final measurements of radiated emissions from receivers with either antennas or terminating resistors connected to the antenna input terminals.

12.2.5.2 Exploratory radiated emission measurements

On the number of frequencies specified in 12.2.2, use the procedure in 8.3.1, while applying the appropriate signal to the EUT, to determine the operating frequency and cable or wire positions of the EUT system that produce the emission with the highest amplitude relative to the limit. The EUT antenna shall be manipulated through typical positions during exploratory testing to maximize emission levels. In addition, exploratory radiated emissions testing of handheld or body-worn devices shall include rotation of the EUT through three orthogonal axes to determine the orientation (attitude) that maximizes the emissions. Exploratory radiated emissions testing of ceiling-mounted devices shall include rotation of the EUT through two orthogonal axes to determine the orientation (attitude) that maximizes the emissions (see 6.3.6). This equipment arrangement shall be used in final measurements of radiated emission from the EUT.

12.2.5.3 Final radiated emission measurements

Using the operating frequency, orientation (attitude), and equipment arrangement of the EUT determined in 12.2.5.2, follow the procedure in 8.3.2, while applying the appropriate signal to the EUT, to perform final radiated emission measurements.

Record the six highest EUT emissions relative to the limit over the frequency range specified by the regulatory and/or purchasing agency. See 10.2.8.4 for reporting requirements. Diagram or photograph the test setup that was used (see 10.2.12).

12.2.6 Antenna-conducted power measurements

a) Antenna-conducted power measurements shall be performed when a receiver is measured for radiated emissions with a terminating resistor instead of an antenna connected to the antenna input terminals of the device. Power available from the receive antenna terminals shall be determined by measurement of the voltage present at these terminals. For frequencies below or equal to 1000 MHz, a quasi-peak detector shall be used for these measurements. If the peak detected signals are below the limit, then no further investigation of the quasi-peak readings is required. For frequencies above 1000 MHz, both a peak and an average detector shall be used for these measurements. When emissions limits are specified for both average and peak detection, if the peak measured value meets the average limit, it is unnecessary to perform an average measurement.

b) Antenna-conducted power measurements shall be performed with the EUT antenna terminals connected directly to either a spectrum analyzer or another measuring instrument (see 4.2) if the antenna impedance matches the impedance of the measuring instrument. Otherwise, use a balun or impedance-matching network to connect the measuring instrument to the antenna terminals of the EUT. Losses in decibels in any balun or impedance-matching network used shall be added to the measured value (in dBm).

c) With the receiver tuned to one of the number of frequencies specified in 12.2.2, measure both the frequency and voltage present at the antenna input terminals over the frequency range specified in the individual equipment requirements. Repeat this measurement with the receiver tuned to another frequency until the number of frequencies specified in 12.2.2 has been successively measured. Power available from the receive antenna terminals is the ratio of V^2/R, where V is the loss-corrected voltage measured at the antenna terminals and R is the impedance of the measuring instrument. See 10.2.8.5 for reporting requirements.

12.3 Measurement of TV interface devices

12.3.1 Introduction

A TV interface device may be a TV (video) game, a VCR, or a cable TV converter.

12.3.2 Operating conditions

12.3.2.1 General requirements

a) Unless otherwise specified in the individual tests, all input terminals or connectors on a TV interface device shall be terminated in the proper impedance. However, the output ports or connectors of these devices shall be connected to either the cable provided with the device or a cable of typical length. Unless otherwise specified in the individual tests, the output cable shall be connected to either a terminating resistor of the proper impedance or the antenna transfer switch provided with the device. All other antenna transfer switch ports shall be terminated in the proper impedance.

b) For TV interface devices equipped with multiple inputs, the signals described below shall be individually applied during exploratory tests to determine which input produces the highest emission relative to the limit.

c) Unless specified in an individual test, a VCR shall be operated in the playback and record modes. In addition, the following record signals shall be investigated to determine which produces the highest emission relative to the limit: National Television Systems Committee (NTSC) TV signal supplied through the antenna input port, Advanced Television Systems Committee (ATSC) digital television signal (if applicable) applied through the antenna input port, and a 1 V peak-to-peak vertical interval test signal (VITS) as shown in Figure 17 supplied through the video input port.

12.3.2.2 Internal modulation sources

For devices that contain an internal modulation source (e.g., TV games), that source shall be active during testing.

12.3.2.3 Video modulation sources

For devices that have a baseband video input (e.g., VCRs), a VITS shall be applied with an amplitude of 1 V peak to peak.

12.3.2.4 RF modulation sources

For devices that have antenna terminals for reception of over-the-air analog TV broadcast signals (e.g., VCRs), an NTSC TV signal shall be supplied. For devices that have antenna terminals for reception of over-the-air digital TV broadcast signals, an ATSC TV signal shall be supplied. For devices that have a cable TV input [e.g., cable system terminal device (CSTD)], two cable-TV input signal levels shall be supplied alternately: first 0 dBμV, then 25 dBμV.

12.3.2.5 Other external modulation sources

For devices that use external modulation sources other than those specified above, apply a typical signal.

12.3.3 Equipment arrangement

a) Follow 6.3 for placement of the EUT, placement of accessories, and placement and manipulation of interconnecting cables and wires for testing an individual TV interface device or system.

b) An antenna transfer switch that is connected to the output cable of a TV interface device shall be manipulated with the output cable as if it were an interconnecting cable. The antenna transfer switch is not stationary like an accessory to the EUT.

12.3.4 AC power-line conducted emission measurements

12.3.4.1 Introduction

The following subclauses describe the procedures that may be used for performing ac power-line conducted emission measurements on TV interface devices.

12.3.4.2 Exploratory ac power-line conducted emission measurements

On each output channel of the TV interface device, use the procedure in 7.3.3, while applying the appropriate signals to the EUT, to determine the output channel, operating mode, and cable or wire positions of the EUT system that produce the emission with the highest amplitude relative to the limit. This equipment arrangement shall be used in making final ac power-line conducted emission measurements.

12.3.4.3 Final ac power-line conducted emission measurements

a) Using the output channel, operating mode, and arrangement of the EUT as determined in 12.3.4.2, follow the procedure in 7.3.4, while applying the appropriate signals to the EUT, to perform final ac power-line conducted emission measurements.

b) Record the six highest EUT emissions relative to the limit of each of the current-carrying conductors of the power cords of the equipment that comprises the EUT over the frequency range specified by the regulatory and/or purchasing agency. Diagram or photograph the test setup that was used (see 10.2.3).

12.3.5 Radiated emission measurements

12.3.5.1 Introduction

In 12.3.5.2 and 12.3.5.3, procedures are described that may be used to make radiated emission measurements on TV interface devices.

12.3.5.2 Exploratory radiated emission measurements

On each output channel of the TV interface device, use the procedure in 8.3.1, while applying the appropriate signals to the EUT, to determine the output channel, operating mode, and cable or wire positions of the EUT system that produce the emission with the highest amplitude relative to the limit. This equipment arrangement shall be used in making final radiated emission measurements.

12.3.5.3 Final radiated emission measurements

a) Using the output channel, operating mode, and arrangement of the EUT as determined in 12.2.5.2, follow the procedure in 8.2.3, while applying the appropriate signals to the EUT, to perform final radiated emission measurements.

b) Record the six highest EUT emissions relative to the limit over the frequency range specified by the regulatory and/or purchasing agency. See 10.2.8.4 for reporting requirements. Diagram or photograph the test setup that was used (see 10.2.3).

12.3.6 Output and spurious conducted level measurements

a) The output or spurious signal level is the maximum voltage level present at the output terminal(s) of a TV interface device (i.e., VCR, CSTD, or TV game) on a particular frequency during normal use of the device. The maximum voltage corresponds to the peak envelope power of a modulated signal during maximum amplitude peaks.

b) Measurements shall be made of the levels of the aural carrier, visual carrier, and all spurious emissions for each TV channel on which the device operates by following the procedure below.

c) Use the same arrangement and test setup used for radiated measurements to measure the output signal level of the EUT. Connect the output cable of the EUT to the measuring instrument using the length of interconnecting cable provided with the TV interface device, recommended in the instruction manual, or normally employed by the consumer. When the output cable is coaxial cable, measurements shall be made by direct connection to the measuring instrument with proper impedance matching between the measuring instrument and the EUT. If the output cable is a 300 Ω (twin-lead) transmission line, measurements are to be made through an appropriate balun with connecting cables kept as short as practical. It may be necessary to connect a high-gain, low-noise amplifier between the EUT and the measuring instrument to increase the signal-to-noise ratio of the signals being measured.

d) Support the cable between the EUT and the measuring instrument in a straight horizontal line so it has at least 75 cm clearance from any conducting surface. Terminate all unused inputs and outputs on the EUT antenna transfer switch with the proper impedance.

e) Set the bandwidth of the measuring instrument according to the frequency being measured as listed in Table 5.

Table 5—Bandwidth settings

Measurement frequency	Minimum resolution bandwidth
Below 30 MHz	10 kHz
30 MHz to 1000 MHz	100 kHz
Above 1000 MHz	1 MHz

f) Turn on the EUT and allow a sufficient period of time for the unit to warm up to its normal operating condition. Provide the EUT with a typical signal consistent with normal operation. For each channel on which the device operates and in each mode in which the device operates, measure and record the following:

1) The level of the visual carrier.

2) The level of the aural carrier.

3) The levels of the three highest spurious emissions above the visual carrier.

4) The levels of the three highest spurious emissions below the visual carrier, over the frequency range specified in the individual equipment requirements; for each spurious emission, also record its associated frequency and EUT output channel. See 10.2.8.6 for reporting requirements.

12.4 Antenna transfer switch measurements for unintentional radiators

12.4.1 General requirements

Measurements of antenna transfer switch isolation shall be made with the unintentional radiator configured for typical operation. Isolation shall be measured for all positions of a cable TV antenna transfer switch on the frequencies specified in the individual tests. Isolation shall be measured for all positions of an antenna transfer switch on all output channels of a TV interface device. All unused RF ports or terminals of the unintentional radiator or the antenna transfer switch shall be terminated with the proper impedance during these measurements.

12.4.2 Cable TV antenna transfer switches

The following procedure shall be used to measure the isolation of a cable TV selector switch that either is built into an unintentional radiator or is a stand-alone switch. The isolation of a cable TV antenna transfer switch shall be measured using the procedure below for the following frequencies (in MHz): 54, 100, 150, 200, 250, 300, 350, 400, 450, 500, and 550. If the device or switch is equipped with more than two antenna input ports or terminals, then repeat the following procedure until isolation for each pair of input ports has been measured.

NOTE—Only input ports on the device or switch intended for connection to an antenna are considered antenna input ports.

The cable TV antenna transfer switch isolation, expressed in decibels, is the difference between the level of a signal going into the port that is used for cable TV input to the switch and the level of the same signal coming out of an antenna input port of the transfer switch. Be sure to compare emission levels of the same frequency. The signal levels are expressed in decibel units.

a) Position the device containing the switch in accordance with 6.3.2 or 6.3.3. Place a stand-alone cable TV antenna transfer switch on a nonconductive table 80 cm in height above the ground. Connect a signal generator to the port that is used for cable TV input with a suitable length of coaxial cable. Connect the port of the switch designated for antenna input to the measuring instrument with a suitable length of coaxial cable. Support both of these cables in a straight horizontal line so they have at least 75 cm clearance from any conducting surface. If necessary, impedance-matching devices shall be used and they shall be connected as close as possible to the port(s) on the antenna transfer switch. Terminate all other antenna input ports on the transfer switch in the proper impedance.
b) Turn on the device containing the cable TV switch, if appropriate. Adjust the output of the signal generator to provide a CW signal at a level of 0 dBm on one of the above frequencies. Tune the measuring instrument to the signal generator frequency. Set the detector function to the peak mode and adjust the bandwidth and attenuator settings to any convenient position to obtain the highest level. Do not change the measuring instrument settings during the measurements on this frequency. Change the positions of the switch on the antenna transfer switch, and record the level and frequency of the signal and the position of the switch that gives the highest indication on the measuring instrument. Turn the device off and repeat this measurement.
c) Without changing the settings on the measuring instrument, disconnect the antenna transfer switch from the test setup.
d) Connect the signal generator to the measuring instrument using the matching transformers and coaxial cables that were connected to the switch. Tune the frequency control on the measuring instrument to obtain the highest level, and measure and record the level of this signal. Record the difference between the level going directly into the measuring instrument and the level going through the antenna transfer switch. This is the cable TV antenna transfer switch isolation for that frequency.
e) Repeat this process at each frequency listed above. See 10.2.8.7 for reporting requirements.

12.4.3 Interface-device switches with coaxial connectors

The following shall apply to measurement of transfer switch isolation if the antenna input port or terminal is intended for use with coaxial cable.

TV interface device transfer-switch isolation is the difference between the levels, expressed in decibel units, of a signal going into one antenna input port of the switch and that of the same signal coming out of another antenna input port of the transfer switch. Be sure to compare emission levels of the same frequency.

The isolation of an antenna transfer switch of an unintentional radiator equipped with coaxial connectors shall be performed by measuring the maximum voltage of the visual carrier of the unintentional radiator present at the antenna input ports on the switch using the following procedure. The maximum voltage corresponds to the peak envelope power of a modulated signal during maximum amplitude peaks.

a) Place the unintentional radiator and its switch on a nonconductive table 80 cm in height above the ground. Using an impedance-matching device, if necessary, connect a length of coaxial cable between the antenna input port of the switch and the measuring instrument. Support the cable between the switch and the measuring instrument in a straight horizontal line so it has at least 75 cm clearance from any conducting surface. It may be necessary to connect a high-gain, low-noise amplifier between the impedance-matching device and the measuring instrument to increase the signal-to-noise ratio of the signal being measured.

b) Tune the measuring instrument to the output channel of the unintentional radiator, set the detector function to the peak mode, and adjust the bandwidth and attenuator settings to any convenient position to obtain sufficient signal-to-noise ratio. While applying the appropriate signals specified in 12.2.2, measure and record the voltage level present at the antenna input port of the TV interface device and the output channel of the TV interface device. For switch isolation measurements of a TV interface device, the visual carrier of the device is the only signal that needs to be measured.

c) If the TV interface device operates on other output frequencies, repeat this procedure for all output frequencies.

d) If the device or switch is equipped with more than two antenna input ports, repeat the procedure until isolation for each pair of antenna input ports has been measured. See 10.2.8.7 for reporting requirements.

NOTE—Only input ports on the device or switch intended for connection to an antenna are considered antenna input ports.

12.4.4 TV interface device switches with balanced transmission line connectors

The following shall apply to measurement of the transfer switch isolation if the antenna input port or terminal is intended for use with a balanced transmission line such as twin-lead.

The isolation of an antenna transfer switch of an unintentional radiator equipped with balanced line connectors shall be performed by measuring the maximum voltage of the visual carrier of the unintentional radiator present at the antenna input ports on the switch using the following procedure. The maximum voltage corresponds to the peak envelope power of a modulated signal during maximum amplitude peaks.

a) Place the unintentional radiator and its switch on a nonconductive table 80 cm in height above ground. Connect a section of twin-lead whose length is three-quarter of a wavelength of the TV interface device output channel frequency between the antenna input port of the switch and a balanced RF voltmeter or a balun that is in turn connected to the measuring instrument.

b) Support the twin-lead between the switch and the measuring instrument in a straight horizontal line so it has at least 75 cm clearance from any conducting surface. It may be necessary to connect a high-gain, low-noise amplifier between the balun and the measuring instrument to increase the signal-to-noise ratio of the signal being measured.

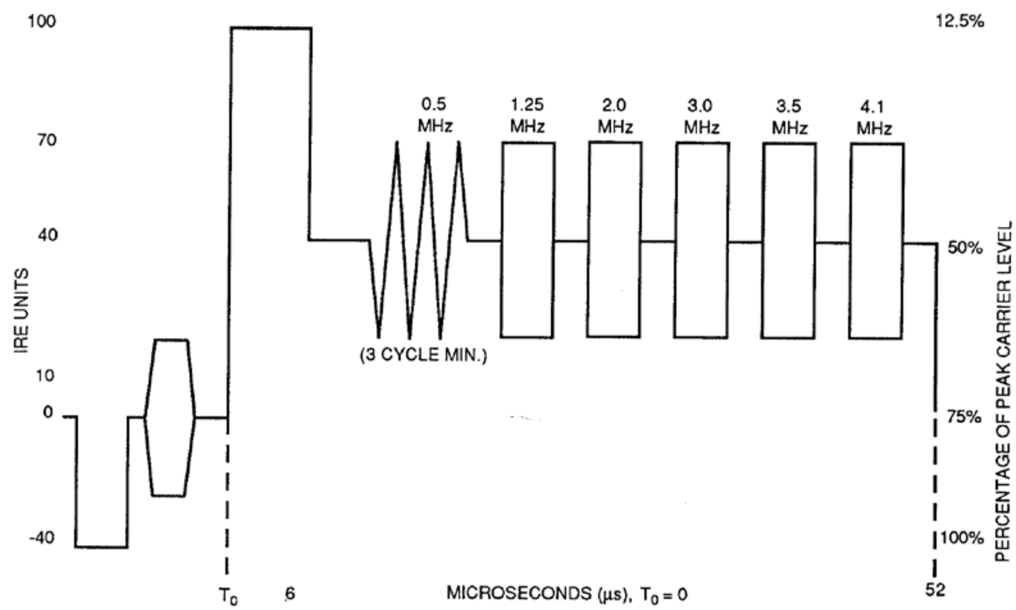
c) Tune the measuring instrument to the output channel of the unintentional radiator, set the detector function to the peak mode, and adjust the bandwidth and attenuator settings to any convenient position to obtain sufficient signal-to-noise ratio. While applying the appropriate signal(s) specified in 12.2.2, measure and record the voltage level of the visual carrier present at the antenna input port with three-quarter wavelength transmission line and with transmission lines of decreasing line length, in at least two equal decrements (total of three measurements, one each at three-quarter, one-half, and one-quarter transmission line length), to a length of one-quarter wavelength. For switch isolation measurements of a TV interface device, the visual carrier of the device is the only signal that needs to be measured.

d) The isolation of a transfer switch that uses a balanced transmission line is taken to be the median of the three values obtained in these measurements. Record the three measured levels, the output channel of the TV interface device, and the length of transmission line that produced each level.

e) If the TV interface device operates on other output frequencies, repeat this procedure for all output frequencies. If the device or switch is equipped with more than two antenna input ports, repeat the procedure until isolation for each pair of antenna input ports has been measured. See 10.2.8.7 for reporting requirements.

NOTE—Only input ports on the device or switch intended for connection to an antenna are considered antenna input ports.

12.5 Figure for Clause 12



1. An off time, as shown between frequency bursts, is recommended. Each burst equals 60 IRE units peak to peak centered at 40 IRE.

2. Rise and fall of white bar shall have a rise time of not less than 0.2 μs.

Figure 17 —Multi-burst test signal (full field)

NOTE—The IRE[25] standard scale in Figure 17 is a linear scale for measuring (in IRE units) the relative amplitudes of the components of a television signal from a zero reference at blanking level, with picture information falling in the positive range and synchronizing information in the negative range.

[25] IRE was the Institute for Radio Engineers, a predecessor organization that was merged with the former American Institute of Electrical Engineers (AIEE) to form IEEE.

13. Limit relaxation for transients

For many devices, transients of short duration repeated infrequently do not cause significant interference. For this reason (when permitted by the regulatory and/or purchasing agency), when transients whose individual durations do not exceed 200 ms (i.e., called "clicks" as used in CISPR 16-1-1:2010-11) occur and exceed the radiated or conducted limit for continuous disturbances (emissions), unless otherwise specified, the limit can be relaxed for the transients according to Table 6, where *N* is the number of clicks per minute above the limit.

Table 6—Transient limit relaxation

Click rate *N*	Relaxation (dB)
≤ 0.2	44
$0.2 < N < 30$	20 log (30/*N*)
≥ 30	0

The EUT is compliant if no more than 25% of the clicks (that exceed the basic limit) exceed the relaxed limit.

Annex A

(informative)

Applicable clauses and subclauses of ANSI C63.4 by equipment type

NOTE—An asterisk symbol (*) following clause or subclause listings designates specific requirements.

A.1 Clauses and subclauses applicable for ITE

A.1.1 Test facility requirements

a) Clause 4: Measurement instrumentation
b) Clause 5: Test facilities
c) Annex B: Specifications and verification of LISN characteristics
d) Annex F: Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)

A.1.2 Equipment conditioning during testing

a) Clause 6: General requirements for EUT arrangements, configuration, and operation
b) Clause 11: Measurement of ITE*

A.1.3 Measurements

a) Clause 7: AC power-line conducted emission measurements
b) Clause 8: Radiated emission measurements
c) Annex E: Method of exploratory radiated emission maximization
d) 11.8: AC power-line conducted emission measurements*
e) 11.9: Radiated emissions measurements*
f) Annex F: Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)*

A.2 Clauses and subclauses applicable for receivers

A.2.1 Test facility requirements

a) Clause 4: Measurement instrumentation
b) Clause 5: Test facilities
c) Annex B: Specifications and verification of LISN characteristics

A.2.2 Equipment conditioning during testing

a) Clause 6: General requirements for EUT arrangements, configuration, and operation
b) Clause 12: Measurement of unintentional radiators other than ITE*
c) 12.2: Measurement of receivers*

A.2.3 Measurements

a) Clause 7: AC power-line conducted emission measurements
b) Clause 8: Radiated emission measurements
c) Annex E: Method of exploratory radiated emission maximization
d) 12.2.4: AC power-line conducted emission measurements*
e) 12.2.5: Radiated emission measurements*

A.2.4 Measurements that may be required

12.2.6: Antenna-conducted power measurements*

A.3 Clauses and subclauses applicable for TV interface devices

A.3.1 Test facility requirements

a) Clause 4: Measurement instrumentation
b) Clause 5: Test facilities
c) Annex B: Specifications and verification of LISN characteristics
d) Annex F: Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)

A.3.2 Equipment conditioning during testing

a) Clause 6: General requirements for EUT arrangements, configuration, and operation
b) Clause 12: Measurement of unintentional radiators other than ITE*
c) 12.3: Measurement of TV interface devices*

A.3.3 Measurements

a) Clause 7: AC power-line conducted emission measurements
b) Clause 8: Radiated emission measurements
c) Annex E: Method of exploratory radiated emission maximization
d) 12.2.4: AC power-line conducted emission measurements*
e) 12.2.5: Radiated emission measurements*
f) Annex F: Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)*

A.3.4 Measurements that may be required

a) 12.3.6: Output and spurious conducted level measurements*

b) 12.4: Antenna transfer switch measurements for unintentional radiators*

Annex B

(normative)

Specifications and verification of LISN characteristics

B.1 General

The impedance and insertion loss of each LISN section shall be measured at least once a year using the following, or an equivalent, procedure. The measurements shall be made at a sufficient number of frequencies to obtain a smooth curve of impedance or insertion loss with frequency. Measurements shall be made at the receptacle into which the EUT power cord is inserted.

B.2 LISN impedance limits

Table B.1 through Table B.4 show the ±20% limit values for the LISN impedance at the LISN terminals[26] and the +30% / –20% limit values for the LISN impedance when extension cords are used with the LISN, respectively. Due to the addition of extension cords to the EUT port of the LISN, an additional tolerance on the high side of the impedance of the nominal LISN impedance is introduced in Table B.3 and Table B.4 because the impedance of the combination LISN and extension cord increases over that of the LISN alone.

For these tables, an extension cord consists of power conductors that attach to the EUT port of the LISN and extends to a location away from the LISN where the EUT power plug is connected to the extension cord. The LISN and extension cord must be maintained within the impedance requirements and tolerances of Table B.3 and Table B.4.

B.3 Measuring the impedance of a LISN

The following requirements shall be applied to the measurement of LISN impedance:

a) This measurement shall be made with the LISN installed in a configuration used for testing an EUT.

b) To avoid the possible introduction of ac power from the ac power supply into the measuring instrument, disconnect the power connections (both neutral and hot conductors) to the LISN at the supply side of the LISN. If an RF filter is used to eliminate high ambient conducted signals, it should remain connected to the LISN for these tests, unless it can be shown that its impedance does not have an effect on the LISN impedance. This determination needs to be made for portable RF filters (removable and/or optional) as well as power-line filters that may be part of the test environment. If an RF filter is used, disconnect the power connections (both the hot and neutral conductors) to the LISN at the supply side of the RF filter.

c) Connect a 50 Ω termination onto each receiver port of the LISN.

[26] The LISN impedance values of subclause 4.3 Table 4 of CISPR 16-1-2:2006-08 are for the ideal case "50 Ω in parallel with 50 μH" circuit as shown in Figure 1b of CISPR 16-1-2:2006-08. However, the idealized impedance values of Figure 1b and Table 4 of CISPR 16-1-2:2006-08 do not correspond to the Table B.2 values calculated for the actual circuit shown in Figure 3 of this standard or equivalently the circuit of Figure 5 of CISPR 16-1-2:2006-08. Specifically, the parallel combination of 1000 Ω and 50 Ω resistors at the receiver port means the actual high-frequency final impedance is approximately 47.2 Ω as shown in Table B.2, not 50 Ω as shown in Table 4 of CISPR 16-1-2:2006-08.

d) The preferred instrument for measuring LISN impedance is a scalar network analyzer that can be tuned continuously over the frequency range of the test. A vector impedance meter or vector network analyzer may also be used. If an instrument that is not continuously tunable is used (such as an RF bridge that is capable only of measuring the impedance at a selected frequency), care should be exercised to make measurements at frequency intervals close enough together, particularly above 20 MHz so that any resonances can be detected.

e) A system calibration is required to improve the accuracy of the measurement. This is usually done by measuring known artifacts (calibration standards) that allow the determination of the systematic errors of the test setup. In case a scalar network analyzer is being used, an “open/short averaging” process should be performed. This includes two measurements (i.e., of an “open” and a “short” standard termination). The results shall be averaged and the impedance measurement data shall be normalized to this calibration data. In case a vector network analyzer is used, an “S_{11} one-port” calibration shall be performed which involves the measurement of “open,” “short,” and “load” (e.g., 50 Ω) standard terminations. The values for directivity, source match, and load match need to be determined, and the LISN impedance results need to be mathematically corrected.

f) Using a suitable impedance adapter, connect the measuring instrument directly to one terminal of the ac receptacle on the load side of the LISN normally used to supply power to the EUT or peripheral. This adapter has a direct impact in the impedance measurement and shall be included in the system calibration. Place a 50 Ω termination at the measurement port of the LISN. Measure the impedance of the LISN in the frequency range of interest to detect any impedance variations that may be caused by resonances or other imperfections.

g) Plot the measured impedance curve for comparison with the tolerances listed in B.2. If any measured value exceeds the permissible error tolerance, the LISN shall be modified to reduce the error to an acceptable level.

h) Repeat step d) with the measuring instrument connected to the other terminal of the ac receptacle of the LISN.

i) If the LISN has more than two sections, then repeat step d), step g), and step h) for all of the additional sections.

j) If the LISN inductors have magnetic materials in their construction, make additional measurements with ac current applied through the LISN so that any variability caused by effects of ac power current can be detected. Shorting together the load terminals of the LISN and feeding current into the supply terminals of the LISN from a low-voltage transformer of suitable current rating can most easily accomplish this. An ac ammeter in series with the circuit can be used to measure the applied current, and a variable transformer can be used to regulate the amount of current by varying the primary voltage of the transformer. The high-current circuit should not have a ground connection. Note that the impedance values measured by this technique shall be approximately one-half of those observed in step g) and step i).

The above procedure shall be repeated for each LISN used for conducted measurements.

B.4 Measuring the insertion loss of a LISN

The following requirements shall be applied to the measurement of LISN insertion loss.

a) The following procedure applies when using a signal generator and an EMI receiver:

   1) Terminate the measurement-port outputs of all unused sections of a multi-section LISN into 50 Ω loads.

   2) Set up the signal generator, LISN, receiver, 10 dB pads, 50 Ω termination, T-connector, and cables as shown in Figure B.1 (a.1).

3) Measure the received signal voltage V_{Direct} (in dBμV) over the frequency range of interest. If the signal source frequency is changed in discrete increments, the frequency step size should be smaller than or equal to 50% of the resolution bandwidth setting on the receiver or spectrum analyzer.

4) Without changing settings on either the signal generator or receiver, set up the signal generator, LISN, receiver, 10 dB pads, 50 Ω termination, T-connector, and cables as shown in Figure B.1 (a.2).

5) Measure the received signal voltage V_{LISN} (in dBμV).

6) Subtract V_{LISN} from V_{Direct} to obtain the insertion loss (in dB) of the LISN.

b) The following procedure applies when using a network analyzer:

1) Terminate the measurement-port outputs of all unused sections of a multi-section LISN into 50 Ω loads.

2) Set up the network analyzer, LISN, 10 dB pads, 50 Ω termination, T-connector, and cables as shown in Figure B.1 (b.1).

3) Follow network analyzer manufacturer's instructions to measure the received signal over the frequency range of interest.

4) Set up the network analyzer, LISN, 10 dB pads, 50 Ω termination, and cables as shown in Figure B.1 (b.2). Do not change any of the settings on the network analyzer.

5) Follow the network analyzer manufacturer's instructions to measure the received signal over the frequency range of interest.

6) Subtract the results from step B.4 b) 5) from the results of step B.4 b) 3) to obtain the LISN insertion loss (in dB).

NOTE 1—If using a network analyzer, the internal calibration routine *cannot* be used; otherwise, a systematic error is introduced that is directly related to the actual impedance of the LISN.

NOTE 2—In this standard, when the term *LISN* is used, it means a LISN set with one, two, or more sections internal to one physical case (enclosure), as necessary.

B.5 Tables and figure for Annex B

Table B.1—Impedance and tolerance specifications in ohms at LISN terminals, 50 μH and 250 μH LISN limit values, without extension cord

Frequency (Hz)	–20%	Nominal	+20%
9000	3.085	3.856	4.628
10 000	3.528	4.410	5.292
12 000	4.346	5.432	6.519
14 000	4.930	6.163	7.395
17 000	5.586	6.982	8.379
20 000	6.174	7.718	9.261
25 000	7.159	8.949	10.739
30 000	8.174	10.217	12.261
35 000	9.206	11.507	13.809
40 000	10.241	12.802	15.362
45 000	11.270	14.087	16.905
50 000	12.284	15.355	18.426
60 000	14.250	17.813	21.376
70 000	16.112	20.140	24.168
80 000	17.854	22.317	26.781
90 000	19.471	24.338	29.206
100 000	20.961	26.201	31.442
110 000	22.328	27.910	33.492
120 000	23.578	29.472	35.367
130 000	24.716	30.896	37.075
140 000	25.752	32.190	38.628
150 000	26.693	33.367	40.040
Usual upper limit frequency for this LISN is 150 kHz			
170 000	28.324	35.405	42.486
200 000	30.251	37.814	45.377
250 000	32.480	40.599	48.719
300 000	33.922	42.402	50.883
350 000	34.892	43.615	52.338
400 000	35.569	44.461	53.354
500 000	36.419	45.523	54.628
600 000	36.907	46.134	55.361
700 000	37.211	46.514	55.817
800 000	37.413	46.766	56.119
1 000 000	37.654	47.068	56.481
2 000 000	37.984	47.479	56.975
4 000 000	38.067	47.584	57.101
7 000 000	38.136	47.671	57.205
10 000 000	38.091	47.613	57.136
20 000 000	38.094	47.618	57.141
30 000 000	38.095	47.618	57.142

Table B.2—Impedance and tolerance specifications in ohms at LISN terminals, 50 μH LISN limit values, without extension cord

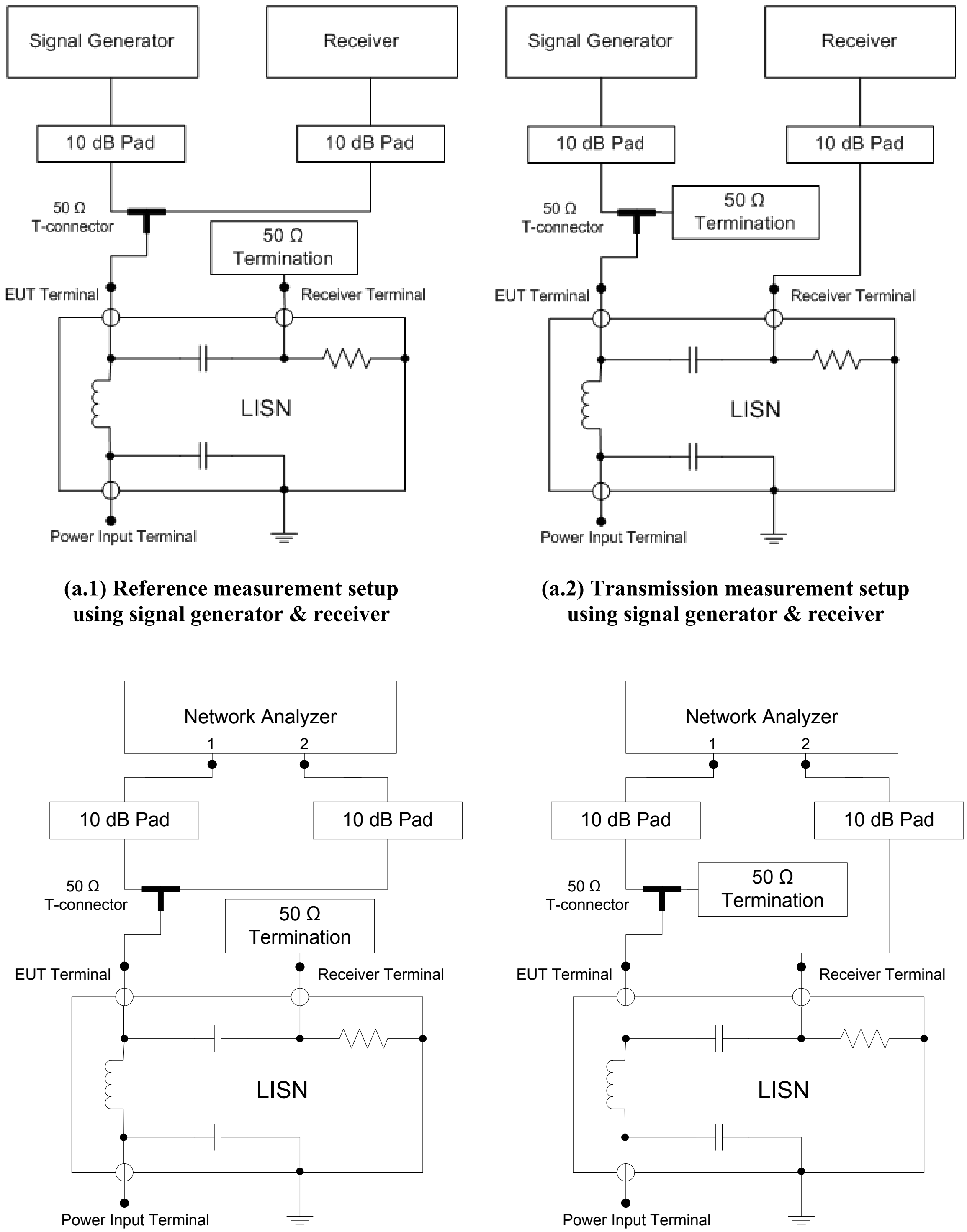
Frequency (Hz)	–20%	Nominal	+20%
150 000	30.283	37.854	45.424
170 000	31.715	39.644	47.572
200 000	33.253	41.566	49.879
250 000	34.841	43.552	52.262
300 000	35.772	44.715	53.658
350 000	36.359	45.449	54.539
400 000	36.751	45.939	55.127
500 000	37.223	46.529	55.835
600 000	37.485	46.857	56.228
700 000	37.645	47.056	56.468
800 000	37.750	47.187	56.624
1 000 000	37.873	47.342	56.810
2 000 000	38.040	47.549	57.059
4 000 000	38.081	47.602	57.122
7 000 000	38.091	47.613	57.136
10 000 000	38.093	47.616	57.140
20 000 000	38.095	47.618	57.142
30 000 000	38.095	47.619	57.142

Table B.3—Impedance and tolerance specifications in ohms at LISN terminals, 50 µH and 250 µH LISN limit values, with extension cord

Frequency (Hz)	–20%	Nominal	+30%
9000	3.085	3.856	5.013
10 000	3.528	4.410	5.733
12 000	4.346	5.432	7.062
14 000	4.930	6.163	8.011
17 000	5.586	6.982	9.077
20 000	6.174	7.718	10.033
25 000	7.159	8.949	11.634
30 000	8.174	10.217	13.282
35 000	9.206	11.507	14.959
40 000	10.241	12.802	16.642
45 000	11.270	14.087	18.313
50 000	12.284	15.355	19.962
60 000	14.250	17.813	23.157
70 000	16.112	20.140	26.182
80 000	17.854	22.317	29.013
90 000	19.471	24.338	31.640
100 000	20.961	26.201	34.062
110 000	22.328	27.910	36.283
120 000	23.578	29.472	38.314
130 000	24.716	30.896	40.164
140 000	25.752	32.190	41.847
150 000	26.693	33.367	43.377
Usual upper limit frequency for this LISN is 150 kHz			
170 000	28.324	35.405	46.026
200 000	30.251	37.814	49.159
250 000	32.480	40.599	52.779
300 000	33.922	42.402	55.123
350 000	34.892	43.615	56.700
400 000	35.569	44.461	57.800
500 000	36.419	45.523	59.180
600 000	36.907	46.134	59.974
700 000	37.211	46.514	60.468
800 000	37.413	46.766	60.796
1 000 000	37.654	47.068	61.188
2 000 000	37.984	47.479	61.723
4 000 000	38.067	47.584	61.859
7 000 000	38.136	47.671	61.972
10 000 000	38.091	47.613	61.897
20 000 000	38.094	47.618	61.903
30 000 000	38.095	47.618	61.904

Table B.4—Impedance and tolerance specifications in ohms at LISN terminals, 50 µH LISN limit values, with extension cord

Frequency (Hz)	–20%	Nominal	+30%
150 000	30.283	37.854	49.210
170 000	31.715	39.644	51.537
200 000	33.253	41.566	54.036
250 000	34.841	43.552	56.617
300 000	35.772	44.715	58.130
350 000	36.359	45.449	59.084
400 000	36.751	45.939	59.720
500 000	37.223	46.529	60.488
600 000	37.485	46.857	60.914
700 000	37.645	47.056	61.173
800 000	37.750	47.187	61.343
1 000 000	37.873	47.342	61.544
2 000 000	38.040	47.549	61.814
4 000 000	38.081	47.602	61.882
7 000 000	38.091	47.613	61.897
10 000 000	38.093	47.616	61.901
20 000 000	38.095	47.618	61.904
30 000 000	38.095	47.619	61.904



(a.1) Reference measurement setup using signal generator & receiver

(a.2) Transmission measurement setup using signal generator & receiver

(b.1) Reference measurement setup using network analyzer

(b.2) Transmission measurement setup using network analyzer

Figure B.1—Measurement of LISN insertion loss

Annex C

(normative)

Absorbing clamp

C.1 General

The absorbing clamp was developed by the International Special Committee on Radio Interference (CISPR) for use in the 30 MHz to 300 MHz frequency range (Clause 4 of CISPR 16-1-3:2004-06). The absorbing clamp measuring procedure is based on the assumption that at frequencies above 30 MHz, radio noise is radiated from the ac power line connected to the EUT and not from the EUT.

C.2 Description

With reference to Figure 15 (see 9.3), the absorbing clamp uses ferrite rings or cores that surround the power cord and the shielded cable leading to the EMI receiver to stabilize the impedance observed by the EUT at approximately 150 Ω in the frequency range from 30 MHz to 300 MHz and to attenuate ambient noise originating on the power system. The current transformer uses similar ferrite cores or rings that are linked by a one-turn loop feeding the coaxial cable to the measuring instrument. The voltage read on the measuring instrument, at any frequency, is proportional to the RF current on the power cord at the location of the current transformer.

Annex D

(normative)

Validation of radiated emissions standard test sites

D.1 Theoretical NSA (30 MHz to 1 GHz)

The theoretical NSA values for an ideal site for the most frequently used measurement separations and antennas are shown in Table D.1 through Table D.3 (see D.7). The theoretical NSA is developed and calculated in Smith et al. [B28]. Table D.1 through Table D.3 are from Berry et al. [B8], Heirman [B19], Pate [B26], and Smith et al. [B28]. The mutual impedance correction factors for tuned dipole antennas were developed in Smith et al. [B28], were subsequently revised in Berry et al. [B8] and Pate [B26], and are shown in Table D.4. The symbols for these tables are defined as follows:

- R is the horizontal separation between the projection of the transmit and receive antennas on the reference ground plane (meters)
- h_1 is the height of the center of the transmitting antenna above the reference ground plane (meters)
- h_2 is the height of the center of the receiving antenna above the reference ground plane (meters)

In the measurement procedure, h_2 is varied, and the maximum received signal in the height scan range is used in the NSA measurements; f_M = frequency (in megahertz) and A_N = NSA. See Equation (D.1).

Table D.1 is used for broadband antennas such as biconical and LPDA antennas. Table D.2 is for tunable dipoles (and broadband antennas for alternative test site qualification) aligned horizontally with respect to the reference ground plane. Finally, Table D.3 is for tunable dipoles, vertically aligned with respect to the reference ground plane. Note that in Table D.3, there are restrictions on the scan height h_2. This takes into account the fact that the lowest tip of the receive dipole is kept 25 cm or more from the reference ground plane.

NSA for frequencies other than for those shown in the tables may be found using linear interpolation between the tabulated values.

The separation distance R between LPDA antennas is measured from the projection onto the reference ground plane of the midpoint of the longitudinal axis of each antenna.

D.2 NSA measurement: Basic procedure

Two antennas are set up on the test site in an appropriate geometry as shown in Figure D.1 and Figure D.2. The NSA procedure requires two different measurements of the voltage received V_R. The first reading of V_R is with the two coaxial cables disconnected from the two antennas and connected to each other via an adapter. The second reading of V_R is taken with the coaxial cables reconnected to their respective antennas and the maximum signal measured with the receive antenna scanned in height (Heirman [B20]). For both of these measurements, the signal source V_I is kept constant. The first reading of V_R is called V_{Direct} and the second is called V_{Site}. These are used in Equation (D.1) for the measured NSA A_N:

$$A_N = \begin{cases} V_{Direct} - V_{Site} - AF_T - AF_R - \Delta AF_{TOT}, & \text{for tuned dipole} \\ V_{Direct} - V_{Site} - AF_T - AF_R - GSCF, & \text{for biconical} \\ V_{Direct} - V_{Site} - AF_T - AF_R, & \text{for all other antennas} \end{cases} \quad \text{(D.1)}$$

where

AF_T is the antenna factor of transmitting antenna (dB/m)
AF_R is the antenna factor of receiving antenna (dB/m)
ΔAF_{TOT} is the mutual impedance correction factor (dB)
$GSCF$ is the geometry-specific correction factor (dB)

The appropriate *GSCF* value as determined from ANSI C63.5 shall be used. The first two terms represent the actual measurement of site attenuations; that is, $V_{Direct} - V_{Site}$ is equal to the classic site attenuation and

$$V_{Direct} = V_I - C_T - C_R \qquad \text{(D.2)}$$

where C_T and C_R are the cable losses that do not need to be measured separately.

The parameters AF_T and AF_R are determined as specified in ANSI C63.5. The mutual impedance correction factor of Table D.4 applies only to the recommended site geometry of 3 m separation, both horizontal and vertical polarization, with the use of resonant tuned dipoles. The correction factor $\Delta AF_{TOT} = 0$ for all other geometries and for broadband antennas in which mutual coupling effects are minimal.

Accurate antenna factors are necessary in determining the measured NSA. In general, antenna factors provided with the antenna are inadequate unless they were specifically or individually measured and the calibration is traceable to a national standard. Linearly polarized antennas are required. ANSI C63.5 contains a design of a reference antenna and methods for calibrating antennas. The reference dipole antenna (see 4.5.4) should be spot checked against a known calibrated antenna. Antenna factors usually account for losses from the balun. If a separate balun or any integrally associated cables are used, their effects shall be accounted for.

Two procedures may be employed to determine the measured NSA: a discrete frequency method (see D.4), or a swept frequency method (see D.5). The swept method may be used only with broadband antennas. Figure D.1 shows the horizontal polarization geometry. In Figure D.2, the recommended vertical polarization geometries for using tunable, resonant half-wave dipoles are shown. This assumes that the dipoles are tuned for all frequencies down to 30 MHz. The limiting factor of maintaining at least a 25 cm clearance between the lower tip of each of the receiving and transmitting antennas is covered by fixing the transmit height at 2.75 m and restricting the downward travel of the receive antenna. These restrictions are stated explicitly by the lower scan-height limit in Table D.3. For vertical NSA measurements with broadband antennas, no such scan height restrictions are usually required because of the much smaller fixed dimensions of a broadband antenna compared with a tuned dipole, especially between 30 MHz and 80 MHz. Using linearly polarized broadband antennas also usually allows a transmit antenna height of 1 m.

NOTE 1—For both methods, an impedance mismatch at the output of the signal source or at the input of the EMI receiver or spectrum analyzer may result in cable reflections that could cause errors exceeding the NSA tolerance. This can be avoided by use of padding attenuators of 10 dB, i.e., one at the output end of each transmitting and receiving cable, for both V_{Direct} and V_{Site} measurements. Attenuator values of 6 dB are often adequate, and values as low as 3 dB can sometimes be used.

NOTE 2—For vertically polarized antennas, it is especially important to maintain cables leaving the antennas in the same horizontal plane as the center of the antenna directly behind the antenna for a minimum distance of 1 m. Use of ferrite beads on both transmit and receive antenna cables close to the antennas can help to eliminate common-mode signals that contribute to measurement errors.

For the discrete frequency method, specific frequencies given in Table D.1 through Table D.3 are measured in turn. At each frequency the receive antenna is moved over the height range given in the appropriate table to maximize the received signal. These measured parameter values are inserted in Equation (D.1) to obtain the measured NSA. Subclause D.4 contains a suggested procedure involving a worksheet approach to record the data, calculate the measured NSA, and then compare it with the theoretical NSA.

For the swept frequency method, measurements using broadband antennas may be made using automatic measuring equipment having a peak hold (maximum hold) storage capability and a tracking generator. In this method, both antenna height and frequency are scanned or swept over the required ranges. The frequency sweep speed shall be much greater than the antenna height scan rate. Otherwise, the procedure is the same as in the previous paragraph. A detailed procedure is given in D.5.

D.3 NSA for alternative test sites

For an alternative test site (test site that has only one conducting surface, i.e., the horizontal floor of the facility; see 5.4.2), a single-position NSA measurement is insufficient to pick up possible reflections from the construction or RF-absorbing materials comprising the walls and ceiling of the test site, or weather-protection coverings for an OATS. For a weather-protected OATS, it shall be confirmed that the weather-protection covering structure does not influence emission measurements. Different from the single-position NSA measurements used for a standard site of 5.4.1, alternative test sites require a multi-position NSA measurement, as follows: For these sites, a "test volume" is defined as that volume traced out by the largest equipment or system to be tested as it is rotated about its center location through 360°, such as by a turntable. In evaluating the site, the transmit antenna shall be placed at various points within the test volume with both horizontal and vertical polarization, such as illustrated in Figure D.3 and Figure D.4 (German [B17]). This may require a maximum of 20 separate site attenuation measurements, that is, five positions in the horizontal plane (center, left, right, front, and rear, measured with respect to the center and a line drawn from the center to the position of the measuring antenna), for two polarizations (horizontal and vertical) and for two heights (1 m and 2 m, horizontal; 1 m and 1.5 m, vertical). The maximum height of the EUTs to be measured, above the reference ground plane, shall not exceed the height at which the volumetric measurements were performed. The maximum volumetric measurement height is to the upper tip of the antenna used in the vertical orientation or horizontal orientation when performing NSA.

These measurements are performed with broadband antennas. Separation distances R are measured with respect to the center of transmit and receive antennas. The separation distance R shall be maintained for all measurements. This requires that the receive antenna be moved along the line in the directions shown in Figure D.3 through Figure D.6 to maintain the separation distance R constant for all transmit antenna positions.

In addition, transmit and receive antennas shall be aligned with the antenna elements parallel to each other and orthogonal to the measurement axis. This requires that for all transmit antenna positions off the centerline, for horizontal polarization, both antennas be rotated about a vertical axis so that the antenna elements remain parallel to each other while maintaining the correct polarization.

For vertical polarization, the off-center positions of the transmit antenna are at the periphery of the test volume. Furthermore, the lower tip of the antenna shall be greater than 25 cm from the floor, which may require the center of the antenna to be slightly higher than 1 m for the lowest height measurement.

For horizontal polarization measurements in the left and right positions, if the distance between the construction or absorbing material on the side walls and the EUT periphery is at least 1 m, the center of the antenna may be moved toward the center position so that the extreme outside tip of the antenna is either at the test volume periphery or at a distance inward from the periphery by not more than 10% of the test volume diameter. The front and rear positions are at the periphery of the test volume.

The number of required measurements can be reduced under the following circumstances:

a) The vertical and horizontal polarization measurements in the rear position may be omitted if the closest point of the construction or absorbing material is at a distance of greater than 1 m from the rear boundary of the test volume (see NOTE).

b) The total number of horizontal polarization measurements along the test volume diameter joining the left and right positions may be reduced to the minimum number necessary for the antenna footprints to cover 90% of that diameter.

c) The vertical polarization measurements at the 1.5 m height may be omitted if the top of the EUT, including any table support fixture, is less than 1.5 m in height.

d) If the test volume is no larger than 1 m in depth, by 1.5 m in width, by 1.5 m in height, including table, if used, horizontal polarization measurements need to be made at only the center, front, and rear positions but at both the 1 m and 2 m heights. If item a) applies, the rear position may be omitted. This will require a minimum of eight measurements: four positions vertical polarization (left, center, right, and front) for one height, and four positions horizontal polarization (center and front) for two heights; see Figure D.5 and Figure D.6.

NSA measurements shall be performed with transmit and receive antenna separation distance held constant according to Table D.1 through Table D.3. The receive antenna shall be moved along a line toward the turntable center to maintain the appropriate separation; see Figure D.3 through Figure D.6. The alternative test site is considered suitable for performing radiated emissions testing if all NSA measurements prescribed above meet the requirements of 5.4.4.2 and the reference ground plane requirements of 5.4.3.

NOTE—Radiated emission sources located near dielectric interfaces, such as absorbing pyramids or ferrite tiles, have been shown to have variations in current distribution that can affect the radiation properties of the source at that location (Pate [B26]). When the EUT can be located near these interfaces, additional site attenuation measurements are required.

D.4 Site attenuation using discrete frequencies

The discrete frequency method is performed using a worksheet approach (Heirman [B19]). The sample worksheet serves the following purposes:

— Sequence the site attenuation measurements

— Direct the application of various corrections

— Provide a method for comparing deviations of the measured NSA data from the NSA for an ideal site

Table D.5 contains the recommended worksheet for making the measured NSA comparisons with the values for the ideal site obtained in Table D.1 through Table D.3. The entries are used for solving Equation (D.1). Descriptions of the entries for each column are as given in Table D.6. Table D.7 gives an example of the use of the worksheet, which considers a 3 m separation horizontal site attenuation measurement using tunable resonant half-wave dipoles at 80 MHz.

See D.6 for several reasons (but not necessarily all) that the NSA criteria are not met. See also ANSI C63.7 for guidance on ways to change the OATS (or alternative site) to meet NSA.

D.5 Site attenuation using swept frequencies

Swept frequency method measurements may be made using broadband antennas and a spectrum analyzer with a peak hold, maximum hold, storage capability, and a tracking generator. This method does not require the use of a worksheet because all comparisons are made with spectrum analyzer traces and separately constructed plots.

a) Adjust the output level of the tracking generator to give a received voltage display above ambient and spectrum analyzer noise but not so high as to overload the spectrum analyzer.

b) Raise the receiving antenna on the mast to the maximum height of the scan range as indicated in the appropriate Table D.1 through Table D.3.

c) Set the spectrum analyzer to sweep the desired frequency range. Confirm that the spectrum analyzer is adjusted so that a similar signal up to 60 dB higher can be displayed on the same amplitude scale. This will accommodate the levels to be recorded in step e).

d) Slowly lower the receiving antenna to the minimum height of the scan range as indicated in the tables for the appropriate site geometry. Store or record the maximum received voltage display (in dBμV). (The time it takes to lower the antenna should be much longer than the spectrum analyzer sweep time.)

e) Disconnect the transmitting and receiving cables from the antennas and connect directly together with a straight-through adapter. Store or record the resulting voltage display.

f) At each frequency, subtract the voltage measured in step d) from the voltage measured in step e). Also subtract the antenna factors for transmit and receive antennas, AF_R and AF_T (dB/m), respectively. Antenna factors as a continuous function of frequency can be obtained using the standard site method for calibrating antennas described in ANSI C63.5 or by using simple linear curve fitting on a set of discrete antenna factor values. The result is the measured NSA over the range of frequencies used, which should be plotted. Also plot the theoretical NSA for an ideal site. If this process is carried out automatically in the analyzer, the accuracy of the analyzer to perform these calculations shall be confirmed.

D.6 Site attenuation deviations

ANSI C63.7 contains descriptions of possible causes for NSA deviations from the theoretical site attenuation of more than the ± 4 dB criterion. Each of these causes should be checked in turn until the excess deviation is reduced to be within the 4 dB criterion. The following items are several causes that should be investigated in sequence:

a) Check the measurement system calibrations. If the signal generator and receiver/spectrum analyzer do not drift during the measurements, the prime suspects are the antenna factors.

b) If these all are within the calibration or operational tolerances, repeat the measurement.[27]

c) If the differences are still greater than 4 dB, the site, the surrounding area, and the antenna and cabling placement are next to be investigated. It is important to eliminate antenna feed cable problems by keeping the antenna cables perpendicular to the antenna for at least 1 m to the rear of the antenna. Ferrite beads may be used on the antenna feed cables, close to the antennas, to reduce any undesired common-mode antenna cable signals.

d) The vertical site attenuation should in general be the most sensitive to site anomalies. If so, use that measurement as the basis for tracking the problem. Antenna balun defects, such as unbalance, are most obvious with vertical polarization. If the results differ by more than 1.0 dB as a function of which end of a vertically polarized antenna is up, the balun should be checked. See ANSI C63.5 for more information. Problems that may be found may also include inadequate reference ground-plane construction and size, reflecting objects too close by (e.g., fences, buildings, light towers), and degraded performance of all-weather enclosures because of inadequate construction techniques, such as long-term problems caused by penetration or coating of residue from airborne conductive contaminants.

[27] Consider adding the 10 dB pads indicated in NOTE 1 of D.2, especially if the antennas are suspected of having a relatively high VSWR.

D.7 Tables and figures for Annex D

Table D.1—Theoretical NSA for an ideal site (recommended geometries for broadband antennas)[a]

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Polarization	**Horizontal**	**Horizontal**	**Horizontal**	**Vertical**	**Vertical**	**Vertical**	**Vertical**	**Vertical**	**Vertical**
***R*, m**	**3**	**10**	**30**	**3**	**3**	**10**	**10**	**30**	**30**
h_1, m	**1**	**1**	**1**	**1**	**1.5**	**1**	**1.5**	**1**	**1.5**
h_2, m	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**	**1 to 4**
f_M (MHz)	**A_N (dB)**								
30	15.8	29.8	47.7	8.2	9.3	16.7	16.9	26.0	26.0
35	13.4	27.1	45.0	6.9	8.0	15.4	15.6	24.7	24.7
40	11.3	24.9	42.7	5.8	7.0	14.2	14.4	23.5	23.5
45	9.4	22.9	40.7	4.9	6.1	13.2	13.4	22.5	22.5
50	7.8	21.1	38.8	4.0	5.4	12.3	12.5	21.6	21.6
60	5.0	18.0	35.7	2.6	4.1	10.7	11.0	20.0	20.0
70	2.8	15.5	33.0	1.5	3.2	9.4	9.7	18.7	18.7
80	0.9	13.3	30.7	0.6	2.6	8.3	8.6	17.5	17.5
90	–0.7	11.4	28.7	–0.1	2.1	7.3	7.6	16.5	16.5
100	–2.0	9.7	26.9	–0.7	1.9	6.4	6.8	15.6	15.6
120	–4.2	7.0	23.8	–1.5	1.3	4.9	5.4	14.0	14.0
140	–6.0	4.8	21.1	–1.8	–1.5	3.7	4.3	12.7	12.7
160	–7.4	3.0	18.9	–1.7	–3.7	2.6	3.4	11.5	11.6
180	–8.5	1.7	16.9	–1.3	–5.3	1.7	2.7	10.5	10.6
200	–9.6	0.6	15.2	–3.6	–6.7	1.0	2.1	9.6	9.7
250	–11.7	–1.6	11.6	–7.7	–9.1	–0.5	0.3	7.7	7.9
300	–12.8	–3.3	8.7	–10.5	–10.9	–1.5	–1.9	6.2	6.5
400	–14.8	–5.9	4.5	–14.0	–12.6	–4.1	–5.0	3.9	4.3
500	–17.3	–7.9	1.8	–16.4	–15.1	–6.7	–7.2	2.1	2.8
600	–19.1	–9.5	0.0	–16.3	–16.9	–8.7	–9.0	0.8	1.8
700	–20.6	–10.8	–1.3	–18.4	–18.4	–10.2	–10.4	–0.3	–0.9
800	–21.3	–12.0	–2.5	–20.0	–19.3	–11.5	–11.6	–1.1	–2.3
900	–22.5	–12.8	–3.5	–21.3	–20.5	–12.6	–12.7	–1.7	–3.4
1000	–23.5	–13.8	–4.5	–22.4	–21.4	–13.6	–13.6	–3.6	–4.3

[a] These data apply for antennas that have at least 25 cm of ground plane clearance when the center of the antenna is 1 m above the ground plane in vertical polarization.

Table D.2—Theoretical NSA for an ideal site (recommended geometries for tunable dipoles and broadband antennas on alternative test sites, horizontal polarization)

(1)	(2)	(3)	(4)
Polarization ***R*, m** **h_1, m** **h_2, m**	**Horizontal** **3 [a]** **2** **1 to 4**	**Horizontal** **10** **2** **1 to 4**	**Horizontal** **30** **2** **1 to 4**
f_M (MHz)		**A_N (dB)**	
30	11.0	24.1	41.7
35	8.8	21.6	39.1
40	7.0	19.4	36.8
45	5.5	17.5	34.7
50	4.2	15.9	32.9
60	2.2	13.1	29.8
70	0.6	10.9	27.2
80	–0.7	9.2	24.9
90	–1.8	7.8	23.0
100	–2.8	6.7	21.2
120	–4.4	5.0	18.2
140	–5.8	3.5	15.8
160	–6.7	2.3	13.8
180	–7.2	1.2	12.0
200	–8.4	0.3	10.6
250	–10.6	–1.7	7.8
300	–12.3	–3.3	6.1
400	–14.9	–5.8	3.5
500	–16.7	–7.6	1.6
600	–18.4	–9.3	0.0
700	–19.7	–10.7	–1.4
800	–20.9	–11.8	–2.5
900	–21.9	–12.9	–3.5
1000	–22.8	–13.8	–4.5

[a] The mutual impedance correction factors in Table D.4 for horizontally polarized tunable dipoles spaced 3 m apart should be inserted in Equation (D.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Table D.3—Theoretical NSA for an ideal site (recommended geometries for tunable dipoles, vertical polarization)

(1)	(2)		(3)		(4)	
f_M (MHz)	R = 3 m [a] h_1 = 2.75 m		R = 10 m h_1 = 2.75 m		R = 30 m h_1 = 2.75 m	
	h_2(m)	A_N (dB)	h_2(m)	A_N (dB)	h_2(m)	A_N (dB)
30	2.75–4	12.4	2.75–4	18.6	2.75–4	26.3
35	2.39–4	11.3	2.39–4	17.4	2.39–4	24.9
40	2.13–4	10.4	2.13–4	16.2	2.13–4	23.8
45	1.92–4	9.5	1.92–4	15.1	1.92–4	22.7
50	1.75–4	8.4	1.75–4	14.2	1.75–4	21.8
60	1.50–4	6.3	1.50–4	12.6	1.50–4	20.2
70	1.32–4	4.4	1.32–4	11.3	1.32–4	18.9
80	1.19–4	2.8	1.19–4	10.2	1.19–4	17.7
90	1.08–4	1.6	1.08–4	9.2	1.08–4	16.7
100	1–4	0.6	1–4	8.4	1–4	15.8
120	1–4	–0.7	1–4	7.5	1–4	14.3
140	1–4	–1.5	1–4	5.5	1–4	13.0
160	1–4	–3.0	1–4	3.9	1–4	12.0
180	1–4	–4.5	1–4	2.7	1–4	11.1
200	1–4	–5.4	1–4	1.6	1–4	10.3
250	1–4	–7.0	1–4	–0.6	1–4	8.7
300	1–4	–8.9	1–4	–2.3	1–4	7.6
400	1–4	–11.4	1–4	–5.0	1–4	3.9
500	1–4	–13.4	1–4	–6.9	1–4	1.8
600	1–4	–14.9	1–4	–8.4	1–4	0.2
700	1–4	–16.3	1–4	–9.8	1–4	–1.2
800	1–4	–17.4	1–4	–11.0	1–4	–2.4
900	1–4	–18.5	1–4	–12.0	1–4	–3.4
1000	1–4	–19.4	1–4	–13.0	1–4	–4.3

[a] The mutual impedance correction factors in Table D.4 for vertically polarized tunable dipoles spaced 3 m apart should be inserted in Equation (D.1) in determining the measured NSA data for comparison with the theoretical NSA values for an ideal site given in this table.

Table D.4— Mutual impedance correction factors (ΔAF_{TOT}) for setups using two resonant tunable Roberts dipoles spaced 3 m apart

(1)	(2)	(3)
f_M MHz	**Horizontal Pol** R = 3 m h_1 = 2 m h_2 = 1 m to 4 m scan	**Vertical Pol** R = 3 m h_1 = 2.75 m h_2 = (see Table D.3)
	ΔAF_{TOT}	
30	3.1	2.9
35	4.0	2.6
40	4.1	2.1
45	3.3	1.6
50	2.8	1.5
60	1.0	2.0
70	–0.4	1.5
80	–1.0	0.9
90	–1.0	0.7
100	–1.2	0.1
120	–0.4	–0.2
140	–0.1	0.2
160	–1.5	0.5
180	–1.0	–0.4

NOTE 1—Calculated for resonant dipoles with reference antenna baluns using method-of-moments numerical computations. Theoretical free-space antenna factors (FSAFs) are for ideal resonant dipoles with an assumed 0.5 dB balun loss (each antenna). If the actual balun loss is known, it should be used to provide an appropriate modification to each antenna factor used in arriving at the correction factors in this table. See reference antenna and FSAF information in ANSI C63.5. These correction factors do not completely describe antenna factors measured above a ground plane (e.g., at heights of 3 m or 4 m), because these antenna factors differ from FSAFs at the lower frequencies. However, within the error bounds used to establish the NSA criteria of 5.4.4.2 (Bronaugh [B9]),[28] and for baluns with substantially different loss than 0.5 dB, the values are adequate to indicate site anomalies.

NOTE 2—User is cautioned when using half-wavelength dipoles or antennas with other than reference antenna baluns; these may exhibit characteristics different from the reference antenna.

NOTE 3—Site adequacy can be assessed by considering these correction factors to be equal to zero for 10 m and 30 m separation geometries and for all measurements using a broadband antenna.

[28] Information of Bronaugh [B9] concerning derivation of the NSA criterion was also contained in ANSI C63.6-1996 [B2], which was withdrawn because the criteria is a requirement in this standard without need for a separate standard to show where the requirement came from.

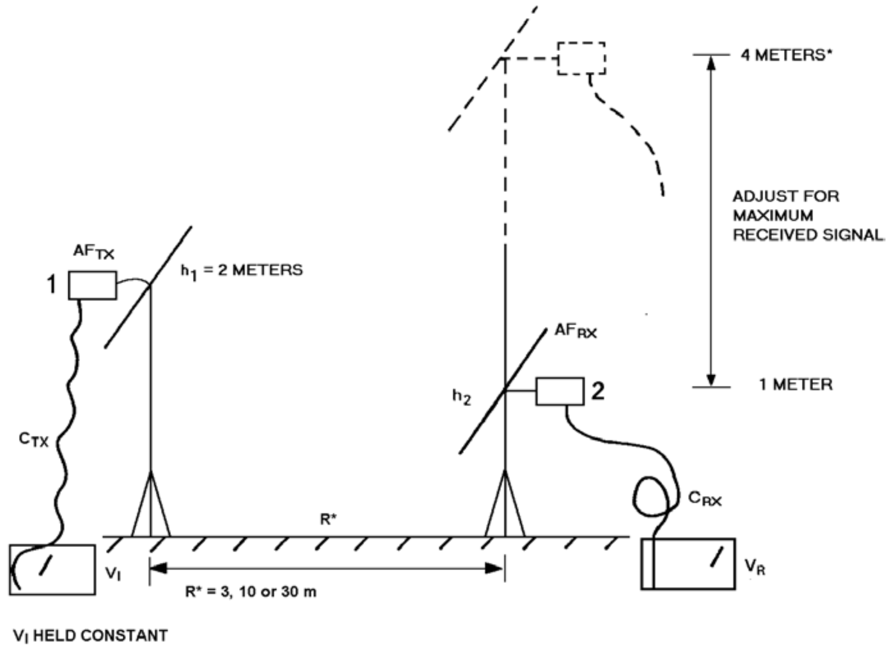


Figure D.1—Site attenuation measurement geometry: horizontal polarization; broadband or tuned dipole antennas

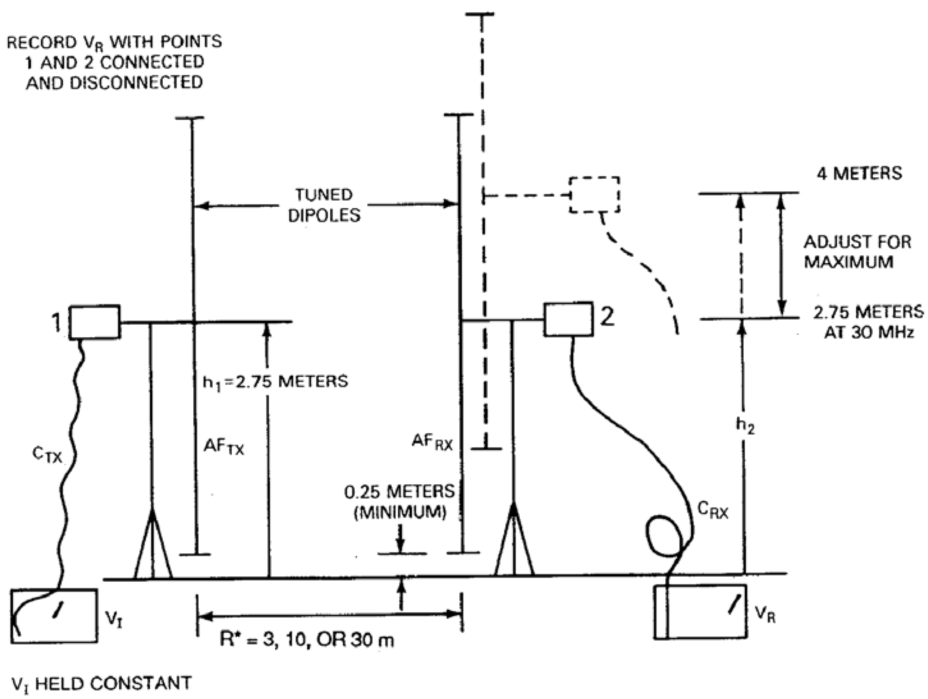


Figure D.2—Site attenuation measurement geometry: vertical polarization using tuned dipole antennas

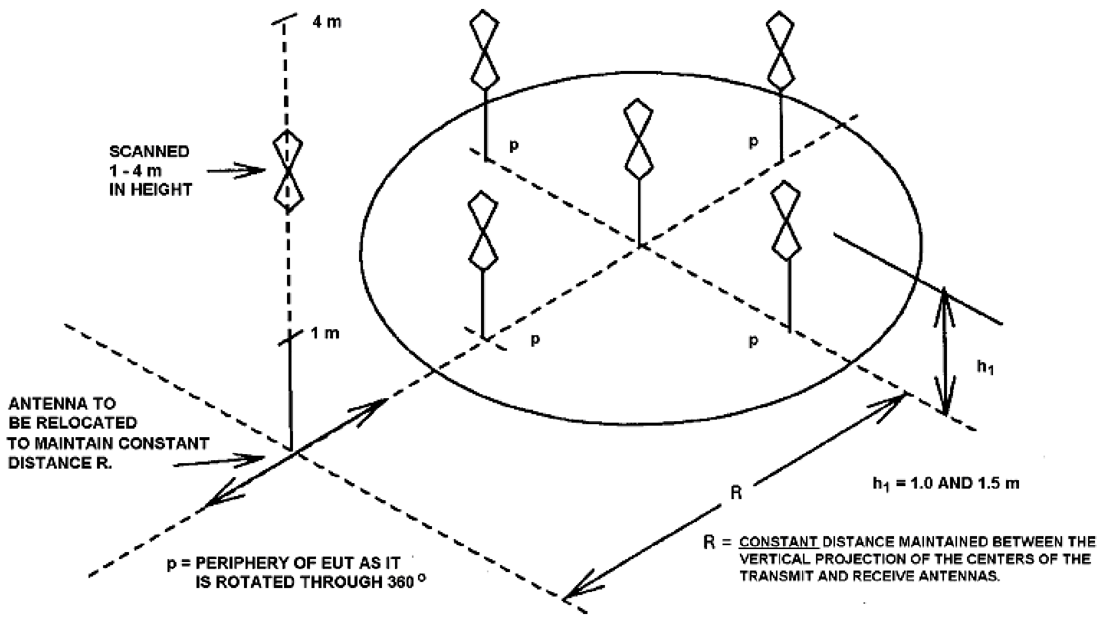


Figure D.3—Typical antenna positions for alternative test sites: vertical polarization NSA measurements (antenna orientation adjusted as described in D.3)

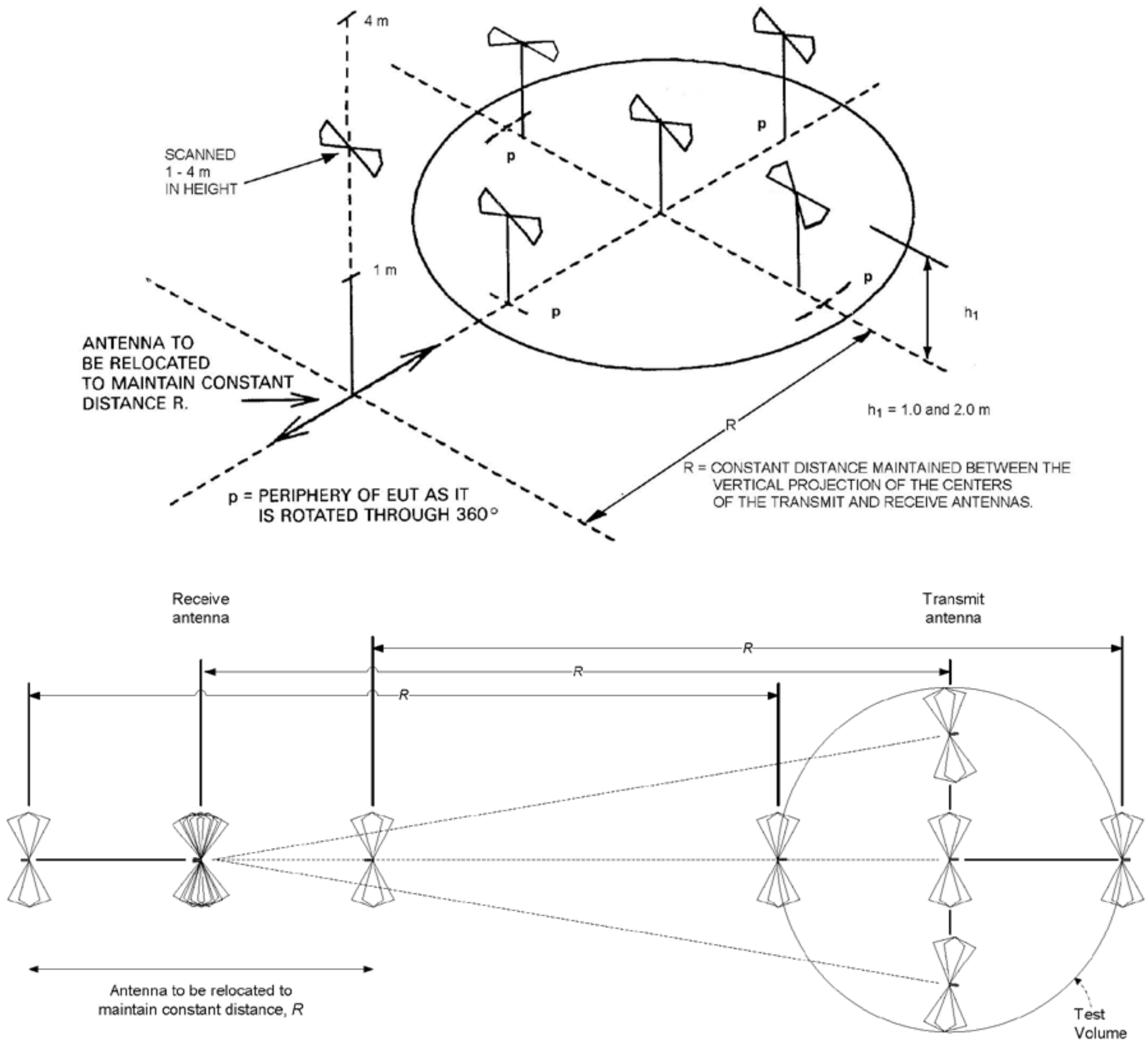


Figure D.4—Typical antenna positions for alternative test sites: horizontal polarization NSA measurements

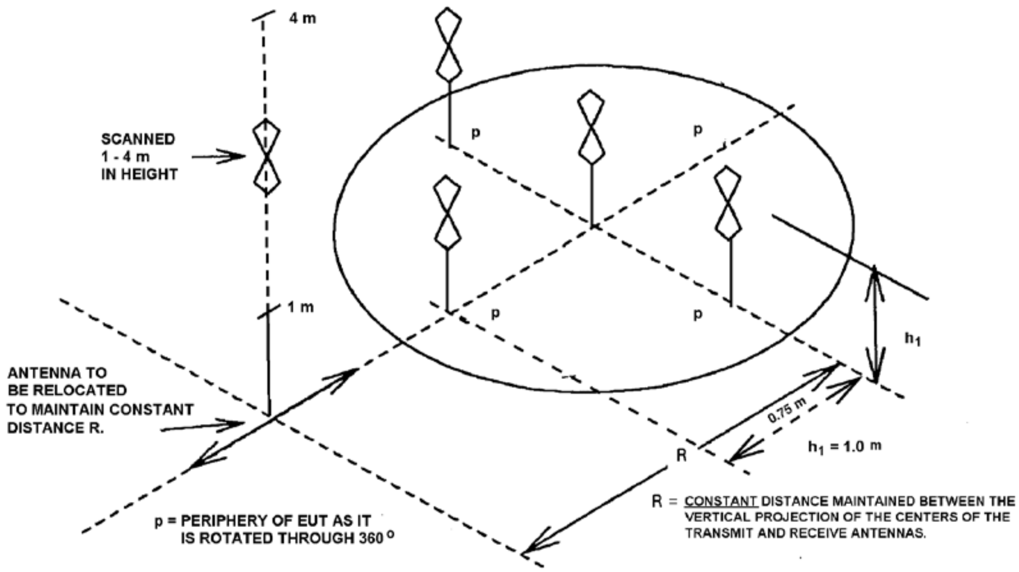


Figure D.5—Typical antenna positions for alternative test sites: vertical polarization NSA measurements for an EUT that does not exceed a volume of 1 m depth, 1.5 m width, and 1.5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections

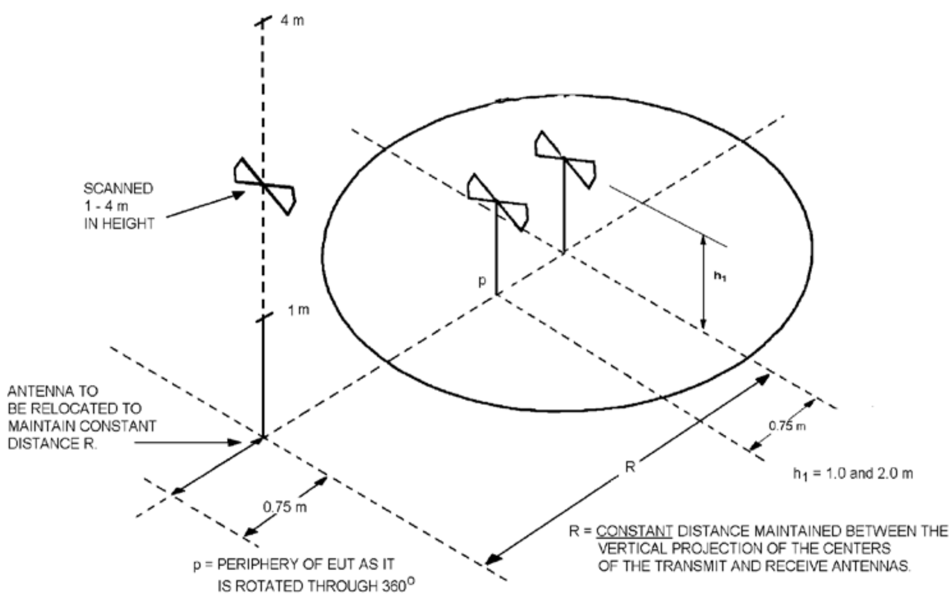


Figure D.6—Typical antenna positions for alternative test sites: horizontal polarization NSA measurements for an EUT that does not exceed a volume of 1 m depth, 1.5 m width, and 1.5 m height, with the periphery greater than 1 m from the closest material that may cause undesirable reflections

Table D.5—Discrete-frequency method site attenuation worksheet

(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
Frequency (MHz)	**Polarization H or V**	**V_{Direct} (dBμV)**	**V_{Site} (dBμV)**	**ΔAF_{TOT} (see Table D.4) (dB)**	**Adjusted site attenuation (dB)**	**AF_T (dB) (1/m)**	**AF_R (dB) (1/m)**	**A_N (NSA) Measured (dB)**	**A_N (NSA) Theoretical (dB)**	**Deviation (dB)**

NOTE—Column operations are as follows: (6) = (3)–(4)–(5) (9) = (6)–(7)–(8) (10) = See Table D.1 through Table D.3 (11) = (10)–(9)	REMARKS:

Table D.6—Descriptions of column headings used in Table D.5

Column #	Description of column heading
(1)	Frequency between 30 MHz and 1000 MHz in steps indicated in Table D.1 through Table D.3.
(2)	The polarizations of both transmit and receive antennas with respect to the reference ground plane.
(3)	V_{Direct} is the level at the receiver or spectrum analyzer when the coaxial feed lines connected to each antenna are directly connected together (points 1 and 2 connected in Figure D.1 and Figure D.2) (dBμV).
(4)	V_{Site} is the level measured at the receiver or spectrum analyzer when the receive antenna is searched in height for the maximum transmitted signal that is required for site attenuation measurements. The level of the signal generator is the same as for the Column (3) measurement (dBμV).
(5)	ΔAF_{TOT} = 0 for all vertical and horizontal site attenuation measurements made at separations of 10 m and 30 m for tunable dipoles and for all other measurements using broadband antennas. ΔAF_{TOT} is not equal to zero for site attenuation measurements at 3 m separation using tunable dipoles (see Table D.4.for these mutual coupling corrections) [dB].
(6)	A = Site attenuation [algebraic sum of Column (3) minus Column (4) minus Column (5)] [dB].
(7)	AF_T = Transmit antenna factor (accurately measured for this antenna) [dB (1/m)].
(8)	AF_R = Receive antenna factor (accurately measured for this antenna) [dB (1/m)].
(9)	A_N = Measured NSA [Column (6) minus Column (7) minus Column (8)]. This is equivalent to A_N given by Equation (D.1) [dB].
(10)	Theoretical NSA (see appropriate values for site attenuation geometry and antennas used in Table D.1 through Table D.3).
(11)	Deviation = Column (10) minus Column (9) [dB].

Table D.7—Example NSA worksheet entries

Column #	Entry
(1)	80 MHz frequency
(2)	Horizontal (polarization)
(3)	81.5 dBμV (assumed value); Receiver/spectrum analyzer reading with coaxial cables connected
(4)	67.5 dBμV (assumed value); Receiver/spectrum analyzer reading with receiver signal maximized by searching the height between 1 m and 4 m
(5)	–1.0 dB (from Table D.4)
(6)	15.0 dB [81.5–67.5 – (–) 1.0]
(7)	6.7 dB (1/m) assumed from calibration curve
(8)	6.5 dB (1/m) assumed from calibration curve
(9)	1.8 dB (15.0 – 6.7 – 6.5)
(10)	–0.7 dB (from Table D.2)
(11)	–2.5 dB [–0.7 – (1.8)] (calculated deviation from theoretical NSA model)

NOTE—The Column (6) value of 15.0 dB is equivalent to the site attenuation for tunable resonant half-wave dipoles. The NSA removes the antenna factor and allows the comparison with the NSA for an ideal site. Column (11), hence, gives deviation amplitude of 2.5 dB with respect to the ideal site attenuation, which shows that at this frequency the example site meets the site validation requirements.

Annex E

(informative)

Method of exploratory radiated emission maximization

The maximum radiated emission for a given mode of operation may be found during exploratory testing by using the following step-by-step procedure:

a) Monitor received signal across the frequency range of interest at a fixed antenna height and EUT azimuth.

b) If appropriate, manipulate the system cables to produce the highest amplitude signal relative to the limit. Note the amplitude and frequency of the suspect signal.

c) Rotate the EUT 360° to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, go back to the corresponding azimuth position and repeat step b). Otherwise, orient the EUT azimuth to repeat the highest amplitude observation and proceed.

d) Move the antenna over its fully allowed range of travel to maximize the suspected highest amplitude signal. If the signal or another at a different frequency is observed to exceed the previously noted highest amplitude signal by 1 dB or more, then return to step b) with the antenna fixed at this height. Otherwise, move the antenna to the height that repeats the highest amplitude observation and proceed.

e) Change the polarization of the antenna and repeat step b) through step d). Compare the resulting suspected highest amplitude signal with that found for the other polarization. Select and note the higher of the two signals. This signal is termed the highest observed signal with respect to the limit for this EUT operational mode.

f) The effects of various modes of operation shall be examined. One way to do this is to vary the equipment modes as step a) through step g) are being performed.

g) After completing step a) through step f), record the final EUT arrangement, mode of operation, and cable arrangement to use for the final radiated emission test in 8.3.2.

Annex F

(normative)

Test procedure for emissions testing in TEM waveguides (30 MHz to 1 GHz)

F.1 General

This annex describes a procedure for the application of TEM waveguides to emission testing. The basic precept is that products can be categorized into EUT types or classes. For each EUT type, a validation procedure consisting of TEM waveguide and OATS comparison testing shall be completed. Once the validation is performed for an EUT type, any permutation within that EUT type may be tested in the validated TEM waveguide.

The generic term *TEM waveguide* is used in this standard, rather than TEM cell, gigahertz transverse electromagnetic (GTEM) cell, or TEM (transmission) line. TEM cell and TEM line refer to specific closed and opened two-conductor systems, respectively, whereas GTEM cell typically refers to a specific single-port system. Descriptions of the various TEM waveguides and correlation algorithms are contained herein.

F.2 Validation and measurement procedures for emissions testing in TEM waveguides

TEM waveguides can provide valid, repeatable measurement results of radiated emissions from equipment. This annex provides basic methods and validation requirements for emission testing in TEM waveguides (e.g., TEM cell, wideband-TEM or GTEM cell, parallel-plate stripline). The basis for this procedure is a specific correlation procedure acceptance between OATS and TEM waveguide measurements using a calculated radiated emissions model. Once this agreement on this procedure is reached between the testing organization and normally the regulatory body receiving the test report results, TEM waveguide measurements are acceptable in lieu of OATS testing for certain classes of products that are defined below.

F.3 Definitions

The following definitions apply for TEM waveguides.

F.3.1 correlation algorithm: A mathematical routine for determining EUT radiated power or equivalent dipole moments from TEM waveguide measured voltages and for converting TEM waveguide measured voltages to an equivalent OATS or free-space field strengths at a selected distance from the EUT.

F.3.2 EUT type: A grouping of products with sufficient similarity in electromagnetic characteristics to allow testing with the same test installation and the same test protocol. In order to be grouped as an EUT type, a group of products shall be similar in the following characteristics:

a) Equipment class (e.g., telephones, pagers, handheld transceivers, desktop computers, notebook computers)

b) Number and type of cables installed for testing (e.g., telephones and telephones with data connection to a computing device may be two different EUT types)

c) Physical size and EUT system configuration (in all cases, the EUT system configuration shall fit within the test volume used in the validation with the OATS); acceptable and validated variations within an EUT type include test configurations with a reduction in the following:

   1) The number of cables

   2) The subsystem components from the EUT configuration as were used for validation with the OATS

F.3.3 exit cable: A cable that connects the EUT to equipment outside of the TEM waveguide or away from the test site. Hence, an exit cable exits the measuring TEM waveguide or measuring site.

F.3.4 manipulator: A device with three independent modes of positioning control, which is used to manually or automatically, to assist with moving an EUT into the positions required by a given test. When installed on the manipulator, all components of an EUT array or system shall maintain a fixed position with respect to a reference point throughout any rotation, and the position of the reference point or approximate geometric center of the EUT shall remain fixed.

F.3.5 ortho-angle: The angle that the diagonal of a cube makes to each side at the trihedral corners of the cube. This angle is widely used in TEM waveguide testing because its coefficients give a vector sum of unity when three orthogonal readings are made and summed (see Figure F.1). When applied to a TEM waveguide, the ortho-angle may alternatively be described as the angle of a ray passing through the center of the test volume of the TEM waveguide, such that its azimuth is 45° to the centerline of the TEM waveguide and its elevation is 45° above the horizontal plane of the TEM waveguide. Thus, the ortho-angle is 54.7° to the edges of each face of a cube centered in the test volume. This assumes that the cube in question is aligned with the Cartesian coordinate system of the TEM waveguide. When associated with the EUT, the ortho-angle is usually referred to as the ortho-axis.

F.3.6 septum: The inner conductor of a one-port or two-port TEM cell—usually a thin metal plate.

F.3.7 TEM cell: A closed measuring device consisting of an inner and an outer conductor in which a voltage difference creates a TEM-mode electromagnetic field between these conductors. Two-port TEM cells typically have symmetrical tapered input and output ports, whereas a one-port TEM cell typically has a tapered input port and a integral, closed nontapered termination in place of the output port.

F.3.8 TEM waveguide: An open or closed transmission line system that uses the TEM mode over the frequency range of interest. The TEM mode is defined as an electromagnetic field in which the electric and magnetic field vectors are orthogonal to each other and orthogonal to the propagation direction. Common examples are the two-port TEM cell (Crawford cell), the one-port or wideband-TEM cell (e.g., GTEM), and the parallel-plate stripline.

F.3.9 test volume: A region in space that has been validated to give acceptable accuracy for a particular radiated emission test. Typically, with TEM waveguides, the test volume is defined as a rectangular parallelepiped, which is centered between the septum and the floor and between the two sidewalls. The test volume is located at a sufficient distance from the I/O tapers or any absorbers to avoid loading effects. The dimensions from the centerline are determined by the accuracy required for the intended test.

F.3.10 wideband-TEM cell: A TEM cell that has been altered to extend the usable frequency range. Typically, this is achieved by replacing one port of a two-port TEM cell with a wideband, nontapered, hybrid discrete resistor/wave-absorber termination.

F.4 TEM waveguide validation requirements

F.4.1 Introduction

TEM waveguides can provide valid, repeatable measurements results of radiated emissions from equipment. For a TEM waveguide to be used in emission compliance testing, various criteria shall be fulfilled, as described in F.4.2 and F.4.3.

F.4.2 TEM waveguide validation requirements

A TEM waveguide shall be validated for every EUT type to be tested. Guidance for classifying products into EUT type categories is given F.4.3. The EUT that is selected for use in the validation of an EUT type shall represent the range of variability found within that EUT type, with respect to the number and type of cables, physical size, and system configuration.

The validation procedure evaluates the test system consisting of the TEM waveguide and the measurement procedure. Use of a different TEM waveguide, or changes in either the physical TEM waveguide, such as absorber replacement, or the correlation algorithm, shall require revalidation of the modified system.

The appropriate regulatory and/or purchasing agency shall be consulted for the acceptance criteria required for the proposed use of the TEM waveguide, if it differs from the guidance given in F.6.2.

F.4.3 EUT type validation requirements

A TEM waveguide shall be validated for use with each EUT type that shall be tested in that TEM waveguide. Care shall be taken to facilitate that each EUT type conforms to the definition in this standard.

The validation test shall be performed at a minimum of one TEM waveguide and one OATS. The OATS shall meet the NSA requirements of 5.4.4. A minimum of three independent scans over the designated frequency range shall be performed at each TEM waveguide and at each OATS. The data from the various frequency scans shall be analyzed statistically and shown to meet the requirements of this clause. As part of the initial validation of a TEM waveguide, it is recommended that comparison be established between two OATS. The purpose of this comparison is to verify the validation procedure with the OATS to be used for subsequent validations with the TEM waveguide (see F.6.2).

A representative sample unit(s) of the EUT type to be validated shall be tested three times at the selected OATS and TEM waveguide. Each test shall be differentiated by a disassembly and reassembly of the test setup as would normally be done for each new product test. At a minimum, a comparison of 10 frequencies with the highest amplitude signal with respect to the radiated emissions limit at each site and within the TEM waveguide shall be recorded. A larger number of emissions may be used in the comparative data set. If the set of frequencies from each site are not identical, then the set shall be expanded to include the frequencies with the highest amplitude with respect to the limit from each set.

The same detector function (peak, quasi-peak, or average) shall be used for each frequency in both the TEM waveguide and OATS measurements. The dwell time at each frequency shall be of sufficient length compared with the duty cycle of the signal being measured. If the measurement bandwidth at the OATS shall be reduced to overcome ambient signal interference, then the bandwidth of the TEM waveguide measurement at that frequency shall be correspondingly reduced. Likewise, the dwell time used at each frequency shall be the same for both the TEM waveguide and the OATS measurements.

The data shall be compared using the guidance found in F.6.1. For each frequency, the field strength measurements made at the TEM waveguide and the OATS shall be averaged over the three independent scans. The difference between the average field strength at the TEM waveguide and the OATS at each frequency compared shall be calculated. Finally, the mean and standard deviation of the differences at each frequency compared shall be calculated using the formulas included in F.6.1.

NOTE—A generalized site validation (e.g., NSA) procedure for TEM waveguides is under consideration.

F.5 General test procedure and equipment configurations

F.5.1 Introduction

Testing in TEM waveguides involves special considerations. In general, the arrangement guidance given for testing at OATS shall be followed, except where specific physical differences in the test facilities require an alternative arrangement. Differences in arrangement are described in this subclause.

F.5.2 TEM waveguide requirements

To be adequate for testing a given EUT, a TEM waveguide (i.e., see F.1) shall meet the following criteria:

a) The validation procedure described in F.4.2 shall be used to demonstrate that a given TEM waveguide can be used for testing of a particular EUT type.

b) If the EUT has power or I/O cables that shall exit the TEM waveguide, an equivalent length of these cables shall be configurable within the TEM waveguide, as would be used in an OATS test for that EUT.

c) The TEM waveguide shall have a characteristic impedance tolerance of ± 10% from the nominal characteristic impedance value (typically 50 Ω) in the frequency range the test measurements are made.

The equivalent cable length at the OATS is the length of cable from the EUT to the point at which it exits the test area, which is normally through a hole in the center of the turntable. The cable routing specified in F.5.4 shall be used when determining the cable length. A TEM waveguide, which cannot accommodate an appropriate length of cable, shall not be used for that EUT.

F.5.3 EUT emissions maximization and stabilization

The EUT shall be arranged following the basic directions given in Clause 6 and Clause 8 and as expanded and modified in this clause. Exploratory testing to determine the emissions characteristics of the EUT as described in 8.3.1 shall be performed. In a TEM waveguide, EUT position and orientation substitute for the antenna height, polarization, and turntable rotation considerations at an OATS. The EUT shall be located within the test volume in the TEM waveguide. The EUT shall be centered in the test volume. For the OATS tests, the maximum electric field measured with horizontal and vertical polarizations shall be used for comparison to the TEM waveguide field strength at the same frequency.

In a TEM waveguide, the EUT system cables shall be handled in a somewhat different fashion than on an OATS. In TEM waveguides equipped with turntables, the EUT system shall be arranged around a circumference with any cables that shall exit the TEM waveguide routed to the center of the turntable. This is similar to an OATS arrangement. In TEM waveguides equipped with manipulators, the EUT system is arranged in a similar fashion to the OATS, but with exit cables routed to a designated edge of the manipulator platform. From the edge of the platform, the cables shall be clamped with a nonconductive fixture perpendicular to the EUT system in all positions. In both cases, interconnecting cables shall be in the same plane as the EUT system and kept as nearly as possible at the same length and separation from the EUT components as they would be on an OATS.

Once the appropriate test configuration is determined, including cable placement, it is imperative that the system be fixed in this position for all positions required by the TEM waveguide correlation algorithm, such as those described in references listed in Berger [B6], Berger [B7], Bronaugh and Osburn [B10], Bronaugh [B9], Ma et al. [B22], Wilson [B30], and Wilson [B31], as well as those given by the manufacturer of TEM waveguides in terms of software codes to compute the OATS equivalent emission. In order to obtain accurate results, such factors as the position of interconnecting cables relative to the EUT, the gap size at the interfaces in shielded EUT enclosures, and the pressure on mechanical grounding points or gaskets caused by changes in gravity effects as the EUT is rotated shall remain constant in all positions to be measured. This typically requires careful restraint of the EUT and fastening of its attached peripherals to a nonreflective, nonconductive structure or manipulator when testing.

Some TEM waveguides can be configured to be repositioned around a horizontal turntable located at the test volume. In these cases the EUT arrangement is very similar to that on a turntable at an OATS (see Figure F.2 through Figure F.4). Figure F.3 shows a typical EUT setup for this case. The primary differences from an OATS are that the interconnecting cables are in the same plane as the EUT and the EUT is arranged around the center of the turntable.

Some TEM devices are used with their long axis essentially parallel to the floor. In those cases, the (ortho-axis) turntable surface, where the TEM device is installed, is not horizontal, so, the EUT will have to be clamped in place when it is rotated in its several axes by nonconducting straps.

F.5.4 Exit cables

EUTs having power or I/O cables that shall exit the TEM waveguide require special consideration. In order to produce results, which correlate well with OATS readings, exit cables shall be routed so that they do not change position relative to the EUT for any of the positions used. Routing the cables along the ortho-angle of the TEM waveguide is the preferred routing. Figure F.3 and Figure F.4 show examples of this cable routing. Such a routing produces a more accurate reading of the emissions radiated from the cables. Routing the cable along the ortho-axis has the added advantage of allowing a greater length of cable to be placed in the TEM waveguide, which results in a greater resemblance to an OATS test. In TEM waveguides, the exit cable is routed from the EUT in the test volume toward the connector on the floor or wall, which in turn is connected to associated equipment outside the TEM waveguide.

An alternative arrangement to the use of the ortho-angle is to keep the exit cables perpendicular to the EUT and rotate them with the EUT through the required positions. Example EUT and cable relative positions are shown in Figure F.4. In this arrangement, the cables are routed away from the EUT and kept fixed in position as far as the TEM waveguide dimensions allow. Then, the cables are routed to the connector or ac outlet in the TEM waveguide wall following a routing that minimizes coupling of the cable section into the TEM mode fields. Coupling from the final section of a cable is minimized by routing the cable, from the point at which it first exits the test volume around the interior perimeter of the TEM waveguide, to the connector or ac receptacle outlet.

Parasitic impedances between the exit cables and the TEM waveguide wall or floor shall be carefully controlled. Exit cables shall not have excess cable length lying on the wall or floor of the TEM waveguide. Any excess cables shall be maintained in the test volume. The cables shall be routed directly from the connection point to the TEM waveguide into the test volume. Exit cables shall be of the same approximate length as would be required for an OATS test. Any excess cable shall be bundled in the center of the half of each cable closest to the EUT. At the connection point where a cable passes through the TEM waveguide wall, an appropriate impedance stabilization network shall be used to terminate the cable and provide for connection to the outside of the TEM waveguide. For the ac power cable, a LISN shall be used if used at the OATS.

F.5.5 TEM waveguide test procedure

The basic TEM waveguide to OATS or free-space correlation procedure involves voltage measurements for three independent positions of the EUT in the TEM waveguide. The three-position algorithm has been shown to give sufficient conformity between an OATS and a TEM waveguide for many EUT types. The TEM cell three-position algorithm can be used with either one- or two-port TEM cells. TEM waveguides with other cross-sectional geometries require modified correlation algorithms. Correlation algorithms with more EUT positions [e.g., nine-position, fifteen-position (Harrington [B18])] can be used if EUT requirements dictate.

In TEM waveguide emission testing, separate three-dimensional Cartesian coordinate systems are assigned to each TEM waveguide and the EUT. A conventional labeling for a TEM waveguide coordinate system *xyz* has the *z*-coordinate along the propagation direction, the *y*-coordinate in the direction of the TEM mode electric field vector, and the *x*-coordinate orthogonal to both of these. A spatial reference point near the geometric center of the EUT array shall be assigned as the origin of the EUT *x'y'z'* Cartesian coordinate system. The three-position correlation algorithm uses three EUT rotations where the axes are successively aligned *xx' yy' zz', xz' yx' zy'*, and *xy' yz' zx'*. Figure F.4 shows an example of the EUT/TEM axes repositioning for the three-position algorithm. The EUT is held in position during the rotations either by a manipulator or by low dielectric constant plastic or foamed-polystyrene support blocks. Voltage readings are recorded at each position and each frequency, and the OATS-equivalent electric field strength is calculated with the correlation algorithm.

F.6 Test report

The requirements for reporting radiated emission measurements using TEM waveguides follow those stated in Clause 10. In addition, the particular EUT type for which the validation is claimed shall be fully described.

F.6.1 TEM waveguide to OATS validation data

The OATS and OATS-equivalent TEM waveguide data for the measurement data sets at each facility shall be recorded in tabular form with parallel columns in units of dBμV/m. Measurement data from the TEM waveguide shall be transformed to OATS-equivalent field strength, computed for the test distance used at the OATS. Wilson [B30] describes the conventional one-port TEM cell three-position correlation algorithm used for computation of OATS-equivalent field strength. If a different correlation algorithm is used, the test report shall include a description of the correlation algorithm and the reasons for its use.

The averages of the OATS and TEM waveguide data at each measured frequency shall be calculated. When calculating these averages, the field strength readings shall be converted from logarithmic values, dBμV/m, to linear values, μV/m. The ratio of the averages of the TEM waveguide and OATS measurements shall be calculated. The same detector function (peak, quasi-peak, or average) shall be used for each frequency in the OATS to TEM waveguide comparison.

The mean and standard deviation of the differences shall be computed using the formulas listed below. The average of the TEM waveguide readings at a single frequency is designated as g_i. The average of the OATS readings at the same frequency is designated as o_i. The number of frequencies compared is n, with n greater than or equal to 10. The difference of the averages x_i is given by the equation

$$x_i = g_i - o_i \qquad \text{(F.1)}$$

The mean $\bar{x}$ is given by the equation

$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{F.2}$$

The standard deviation s is computed with the equation

$$s = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - n(\bar{x})^2}{(n-1)}} \tag{F.3}$$

A sample spreadsheet calculation is shown in Table G.1.

In theory, comparisons shall be made between emissions at exactly the same frequency value. In practice, certain frequency values may differ slightly between the TEM waveguide and the OATS data. This shift in frequency values is caused by EUT instability and measurement system frequency uncertainty. Some judgment is necessary in selecting the correct peaks for comparison. For example, in harmonic-rich spectrum, such as is characteristic of many digital devices, the highest peak may shift from one harmonic to another. For these reasons, it is important to record the frequency as well as the amplitude for each frequency compared. An explanation of the rationale for the selected comparison shall be recorded in the test report.

F.6.2 TEM waveguide to OATS acceptance criteria

This subclause specifies the acceptance criteria that shall be used to determine that a TEM waveguide can be used as a substitute test facility for an OATS. The criteria are based on the maximum difference allowed between the TEM waveguide and the OATS field strength validation results. Once the difference is within allowable values, radiated emission measurements may be made. Reporting requirements follow those stated in Clause 10.

To use the TEM waveguide-calculated results to demonstrate compliance with a radiated emissions limit, the following steps shall be performed:

a) Provide the mean and standard deviation of the frequency correlations in the report.

b) The mean difference over all frequencies compared between the OATS and TEM waveguide correlation results (see column 12 in Table G.1) shall be between 0 dB and less than or equal to 3 dB. The standard deviation over all frequencies between the OATS and TEM waveguide correlation results (see column 12 in Table G.1) shall be less than or equal to 4 dB.

c) No addition of the above mean differences shall be made to the TEM waveguide emission measurement results that are used to compare these results to the radiated emissions limit. If these results are below the disturbance limit, the EUT (for the EUT type being correlated) is considered to be compliant with the appropriate limit.

F.7 Figures for Annex F

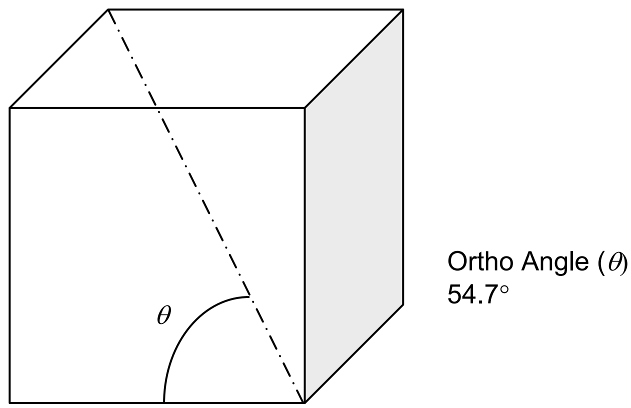


Figure F.1—Ortho-angle

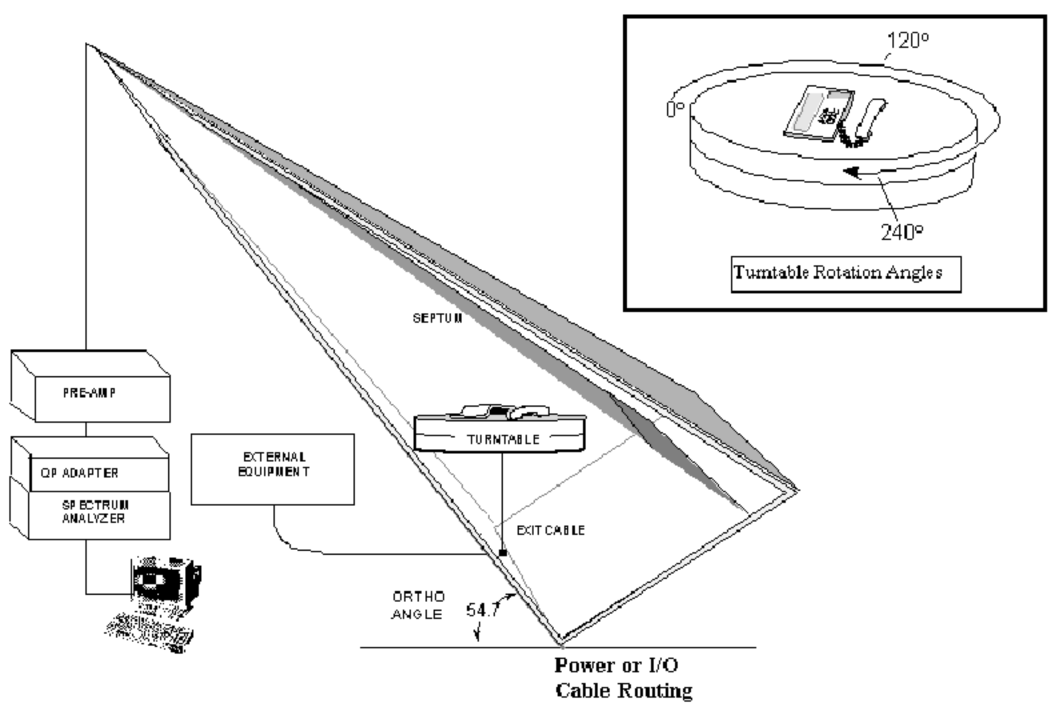


Figure F.2—Exit cable routing in wideband TEM cell with the cell rotated to the ortho-angle

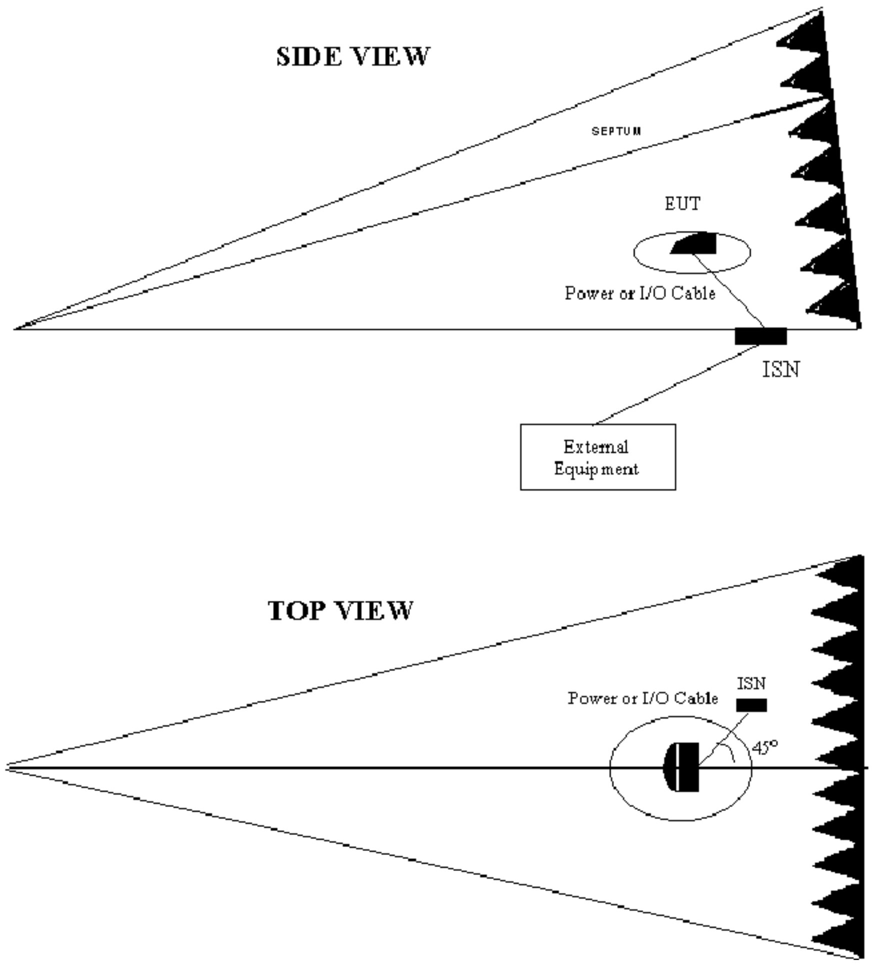


Figure F.3—Exit cable routing in wideband TEM cell with horizontally oriented cell

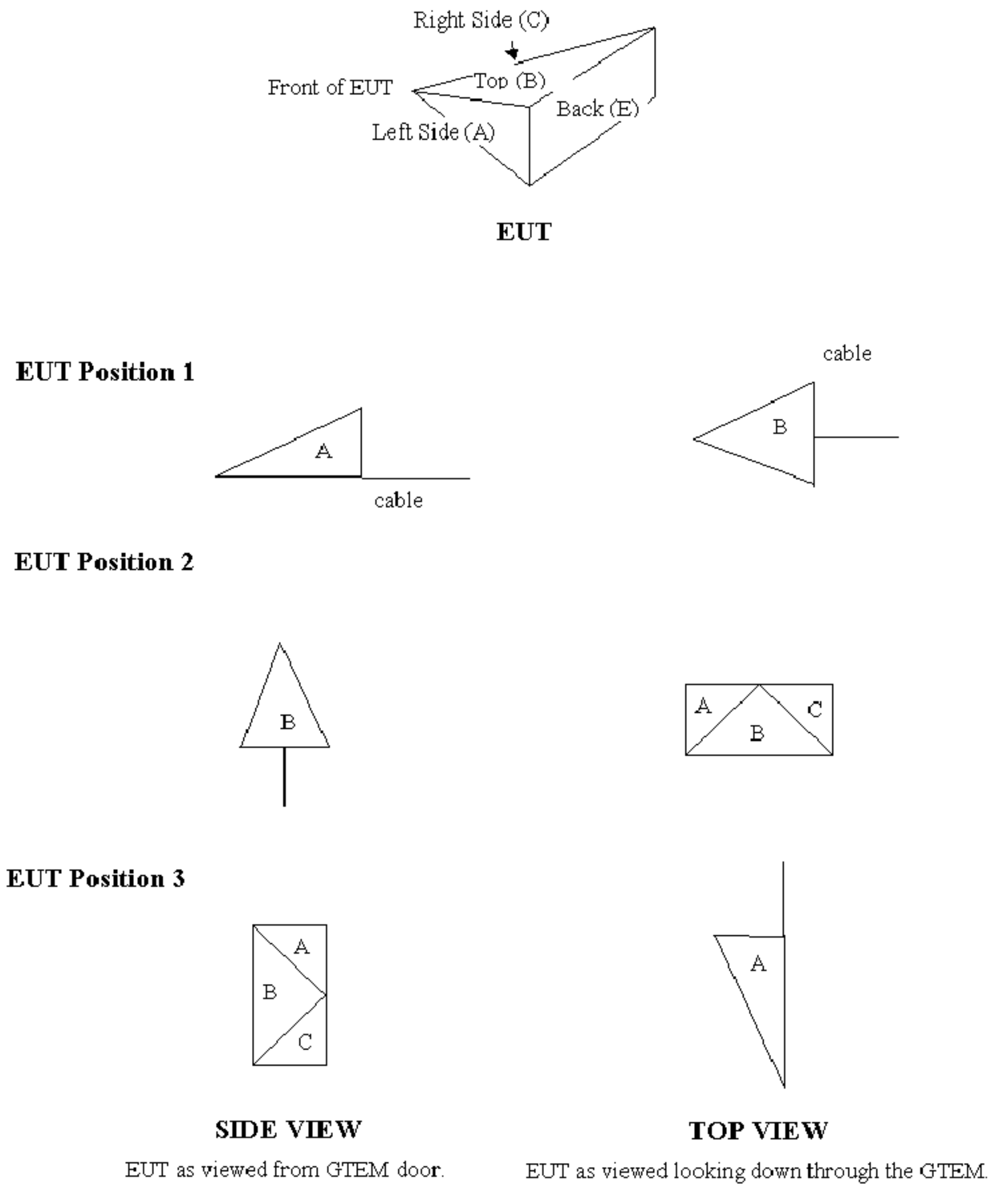


Figure F.4—TEM cell EUT rotation positions using Cartesian framework

Annex G

(informative)

Sample OATS to TEM waveguide validation spreadsheet

The data and calculations for a TEM waveguide to OATS validation can easily be analyzed using a spreadsheet approach. The sample spreadsheet in Table G.1 lists the frequency and amplitude of field strength measurements made at each facility, calculates the average of the readings, calculates the difference between the averages, and calculates the mean and standard deviation of the TEM waveguide to OATS differences.

Column #	Entry
(1)	Frequency of each reading from the TEM waveguide (in MHz).
(2) to (4)	Amplitude of each reading from the TEM waveguide (in dBμV/m) (assumes three independent readings).
(5)	Average of the TEM waveguide amplitude readings (in μV/m). This average is calculated from the linear value, not the logarithmic value. Column (2) to Column (4) first shall be converted from dBμV/ m to μV/m. $\text{Average} = \left[10^{(\text{reading}_1/20)} + 10^{(\text{reading}_2/20)} + 10^{(\text{reading}_3/20)}\right]/3$
(6)	Frequency of each reading taken at the OATS (in MHz).
(7) to (9)	Amplitude of each reading taken at the OATS (in dBμV/m). These readings shall be the maximum of the horizontal and vertical polarization readings at each frequency. Assumes three independent readings.
(10)	Average of the OATS amplitude readings (in μV/m). This average shall be computed from the linear values, not the logarithmic values. Column (7) to Column (9) shall first be converted from dBμV/m to μV/m. $\text{Average} = \left[10^{(\text{reading}_1/20)} + 10^{(\text{reading}_2/20)} + 10^{(\text{reading}_3/20)}\right]/3$
(11)	Difference between TEM waveguide and OATS average amplitudes (in dB). The differences are calculated by 20 log |Column (5) / Column (10)|. $\text{Difference}_{\text{dB}} = 20\log\{[\text{Column}\,(5)\,\text{Average}]/[\text{Column}\,(10)\,\text{Average}]\}$
(12)	Mean and standard deviation of the differences (in dBμV/m). $\text{Mean} = 20\log\left[\sum 10^{(\text{Differences}_{\text{dB}}/20)}/n\right]$ $\text{Standard Deviation} = 20\log\sqrt{\dfrac{n\sum\left(10^{\text{Difference}_{\text{dB}}/20}\right)^2 - \left[\sum\left(10^{\text{Difference}_{\text{dB}}/20}\right)\right]^2}{n(n-1)}}$

Table G.1—Sample spreadsheet

(1)	(2)	(3)	(4)	(5)		(6)	(7)	(8)	(9)	(10)	(11)	(12)
TEM readings						**OATS readings**						**Summation**
Frequency (MHz)	**Field strength (dBµV/m)**			**Average (µV/m)**		**Frequency (MHz)**	**Field strength (dBµV/m)**			**Average (µV/m)**	**Difference (dB)**	**Mean & std. dev.**
	Scan 1	**Scan 2**	**Scan 3**				**Scan 1**	**Scan 2**	**Scan 3**			
frequency[a]	**reading**	**reading**	**reading**	**formula 1**		**frequency**	**reading**	**reading**	**reading**	**formula 2**	**formula 3**	
												Mean
												formula 4
												Std. Dev.
												formula 5
	formula 1 = $\{10^{[(\text{Column 2})/20]} + 10^{[(\text{Column 3})/20]} + 10^{[(\text{Column 4})/20]}\} / 3$											
	formula 2 = $\{(10^{[(\text{Column 7})/20]} + 10^{[(\text{Column 8})/20]} + 10^{[(\text{Column 9})/20]}\} / 3$											
	formula 3 = 20 log [(Column 5) / (Column 10)]											
	formula 4 = $20 \log [\text{SUM } (10^{(\text{column } 11/20)}) / n]$											
	formula 5 = $20 \log \{\text{SQRT } [(n \text{ SUM } [10^{(\text{Column } 11/20)}]^2 - [\text{SUM } 10^{(\text{Column } 11/20)}]^2) / n (n - 1)] \}$											
	n = number of frequencies compared											

[a] A minimum of the 10 frequencies with the highest amplitude readings, relative to the limit, at each facility shall be listed.

Annex H

(informative)

Precautions in using spectrum analyzers

H.1 Importance of preselection

The first mixer of a spectrum analyzer and EMI receiver is a broadband, nonlinear device that can be overloaded by either high-level narrowband signals or broadband signals with a certain spectral intensity. Overload situations may lead to spurious responses, generated in the mixer itself, or amplitude changes in the indication of the input signal. Both cases may lead to erroneous measurement data or misinterpretation of test results.

Distortion caused by narrowband signals is generally related harmonically to these signals. If one input signal is present at the mixer, the internally generated harmonics of this signal change by the amount of their order in logarithmic terms. For example, if the amplitude of an input signal *A* drops 10 dB, its second harmonic is reduced by 20 dB, the third harmonic by 30 dB, and so on, as shown in Figure H.1.

In case of two signals of equal amplitude being present at the mixer, the intermodulation distortion-free dynamic range of a spectrum analyzer or receiver for narrowband signals needs to be considered. It is defined as the amplitude difference between the noise floor of the instrument and two equal amplitude signals whose third order distortion products are just equal to this noise floor. Third-order distortion products change their amplitude by a ratio of 3:1 to the fundamental signal on a logarithmic amplitude scale when the equal amplitude signals change by the same amount. If one signal decreases and the other remains constant, then the distortion products vary by the ratio of 1:1 and 2:1, respectively. If the amplitude of signal *A* and *B* in Figure H.2 drops by 10 dB, the intermodulation products drop by 30 dB. If the amplitude of signal *A* remains constant and amplitude of signal *B* changes by 10 dB, the distortion product with the lower frequency changes by 10 dB and the upper product by 20 dB.

This indicates that an overload situation can be resolved by increasing the input attenuation of the receiver that increases the spurious-free dynamic range. However, this adversely affects the sensitivity of the receiver because the amplitude of low-level input signals that need to be measured in the presence of higher-level emissions may get attenuated to a level below the noise floor of the receiver. Because the resolution bandwidth of the receiver is specified for commercial measurements, the noise floor cannot be lowered by selecting a narrower resolution bandwidth, thus making a measurement impossible in this case.

For broadband signals like impulses, filtering in front of the mixer, also known as preselection, can be used to avoid overload conditions. A broadband signal is defined as a signal whose spectrum exceeds the resolution bandwidth of the measuring receiver. Without preselection, all the spectral components of a broadband signal are present at the mixer at the same time. If the time domain peak amplitude of the broadband signal exceeds the overload level of the mixer, an overload situation will occur.

Figure H.3 shows the effect of preselection on a broadband signal. Because of applied filtering, only a portion of the input signal spectrum is in the passband of the preselector and thus present at the input of the mixer.

It is important to note that the spectral intensity of the input signal is not changed by this filtering process. However, at the preselector output, a signal with reduced amplitude and an extended duration is present. This reduction in signal amplitude, which is achieved by filtering and not by attenuation, improves the dynamic range for measurements of broadband signals while maintaining the ability of the receiver to measure low-level signals. It should be noted that preselection does not improve the dynamic range for measurements of narrowband signals (like CW signals) if they are in the passband of the preselection filter. In this case the signal energy will also be present at the mixer input, only attenuated by the insertion loss of the filter.

On the contrary, if narrowband signals are outside the passband of the preselection filter, as shown in Figure H.4, the spurious-free dynamic range is enhanced by the out-of-band rejection value.

H.2 Sensitivity considerations

When attenuation is added to facilitate the linear operation of an EMI receiver, the required sensitivity to measure low-level signals may be compromised. For example, a local radio station can overload the receiver during a radiated emissions measurement on an OATS. On the other hand, especially in case of radiated emissions measurements, sufficient receiver sensitivity is critical because the loss of antenna cables and the antenna factor reduce the overall measurement sensitivity, thus limiting the overall measurement ability of the system to measure small signal amplitudes. The performance of an EMI receiver for measuring low-level signals is usually specified in terms of noise figure rather than sensitivity. The noise figure can be defined as the degradation of signal-to-noise ratio of a signal passing through a receiver or spectrum analyzer. For a receiver, this general definition can be simplified because the output (measured) signal is equal to the input signal times the gain of the receiver, assuming a sinusoidal input signal. Second, the displayed signal level is equal to the level at the input, assuming linear operation of the receiver; hence, the gain of the instrument is unity. This leads to the following equation in logarithmic terms:

$$NF = 10\log N_{\text{display}} - 10\log N_{\text{in}} \tag{H.1}$$

where

NF is the noise figure
N_{display} is the output noise power (indicated on the display)
N_{in} is the true input noise power

The true noise level at the input of the receiver can be obtained by terminating the receiver input with its characteristic impedance, normally 50 Ω. The input noise level then becomes the following:

$$N_{\text{in}} = kTB \tag{H.2}$$

where

k is the Boltzmann's constant (1.38×10^{-23} J/K)
T is the absolute temperature in Kelvin
B is the receiver bandwidth in Hz

At room temperature and for a 1 Hz receiver bandwidth, the receiver input true noise level $N_{\text{in}} = -174$ dBm/Hz.

Using this value, the noise figure of a receiver can be determined by measuring the noise power in some bandwidth, normalize it to a 1 Hz bandwidth and compare it to N_{in}. For this purpose, the following equation can be used:

$$NF = N_{\text{m}}\big|_{\text{dBm/RBW}} - 10\log\left(\frac{\text{RBW}}{1\,\text{Hz}}\right) - kTB\big|_{B=1} \tag{H.3}$$

where

N_m is the measured noise power
RBW is the measurement resolution bandwidth

The advantage of the noise figure over a sensitivity specification is its independence of the resolution bandwidth being used; therefore, the noise figure allows for direct comparison of performances of different receivers.

A low-noise preamplifier, which is located in the signal path behind the preselector filters and in front of the first mixer, can be used to improve the noise figure of the receiver and, hence, its sensitivity. However, care must be taken that the overall dynamic range is not degraded by the noise output power of the preamplifier that is fed directly into the mixer. In case the best system sensitivity is required and a reduction of the overall dynamic range is not acceptable, a low-noise figure, low-gain preamplifier is needed. If the loss in dynamic range is not critical, then a low-noise, high-gain amplifier can be used. In EMI receivers, it is absolutely crucial to place the preamplifier behind the preselection filters because a preamplifier is a nonlinear device that is prone to overload by high-level narrowband and broadband signals. Overload conditions of the preamplifier, because of broadband signals, are reduced by using the appropriate filtering of the input signal spectrum.

H.3 Input overload detection

A system is linear if its amplitude response obeys the superposition principle within a specified accuracy.

If an input $f_1(t)$ produces an output $g_1(t)$ and an input $f_2(t)$ produces $g_2(t)$, then the input $Af_1(t) + Bf_2(t)$ produces the output $Ag_1(t) + Bg_2(t)$, where A and B are constants. It follows from this definition that a system is linear if it multiplies an input by a factor of C. Then, the output $g_1(t) = Cf_1(t)$ and $g_2(t) = Cf_2(t)$. If the input is $Af_1(t) + Bf_2(t)$, then the output is $C\ [Af_1(t) + Bf_2(t)] = A\ [Cf_1(t)] + B\ [Cf_2(t)] = Ag_1(t) + Bg_2(t)$. The superposition principle is satisfied in this case.

For any spectrum analyzer and EMI receiver, the output indication is related to the input by a constant factor C when the instrument is in linear operating mode. The absolute value of C need not be known, but changes of C with input level indicate nonlinear behavior. In a practical test, the input level to the system is varied by changing the input attenuation by X dB. In many modern receivers the IF gain is automatically adjusted by a corresponding X dB. The output indication therefore remains unchanged if C is constant and the system is in linear mode.

Overload from one signal does not necessarily affect the measurement of all other signals present at the input. Therefore, only the signals in question need to be monitored during the linearity test. The three possible responses of the measured output value when the input attenuation is decreased are as follows:

a) No change: indicating linear system behavior
b) Increase: indicating harmonic and intermodulation distortion
c) Decrease: indicating gain compression

The determination of an overload condition is simplified in modern stepped and scanning receivers by overload detectors, which are located at different points in the signal processing chain. Signal levels are monitored both at the receiver input before the first mixer and at various points in the IF. Special firmware features like auto-ranging assist in eliminating such a condition by either adding more input attenuation to clear an input overload condition or changing the reference level of the receiver to eliminate IF overload situations. If a manual verification of the linear operating mode is desired, the input attenuator test can be used as shown in the previous examples. Decreasing the input attenuation, while examining the amplitude changes before and after the switching of the attenuator, provides a reliable indication of the presence of an overload situation or linear operation.

H.4 Display mode selection

In a scanning EMI receiver or spectrum analyzer, the signals to be measured remain in analog form throughout the processes of frequency translation, filtering, amplification, and detection. In a traditional EMI receiver with an analog meter, the IF signal would then be applied to the meter. Digital displays require some additional signal processing, as well as specialized display modes. Before the measurement data can be displayed, it must be digitized. Therefore, the detected signal is applied to an analog-to-digital converter that provides sufficient speed, resolution, and linearity. Because both the amplitude and frequency axes of the display are digitized, the single data value taken for each point must provide a meaningful indication of the entire signal amplitude history for the cell between two display points. Two display modes are of particular importance for EMI testing: *Positive Peak* and *Sample*. In Figure H.5, the analog signal to be processed is shown at the top. The Positive Peak detector retains the maximum amplitude found in a cell and displays its value at the right digital point defining the cell. Because the worst-case emission amplitudes are displayed, this mode is useful for compliance testing because it allows coverage of wider frequency ranges at once and thus reduces test time. However, larger frequency errors are potentially introduced by selecting a wider cell width that is defined as: (number of horizontal display points minus one) divided by (frequency span). If a single scan is defined to cover the frequency range from 30 MHz to 1 GHz and a receiver with 1001 display points is used for the measurement, then a cell width of 970 kHz is present. This leads to a worst-case frequency error of 970 kHz when the true maximum amplitude of the analog signal happens to be at the beginning of the cell, but the positive peak detector displays it at the end of the cell. The frequency shift is usually of minor importance in an actual compliance test, but it may not be tolerable in other applications. When the ultimate goal of the test is to minimize test time, then positive peak detection should be used to obtain the highest emission amplitudes in a wide-frequency spectrum. In this case, no worst-case amplitude is missed.

The sample detector, as shown at the bottom of Figure H.5, avoids frequency inaccuracies because it displays the cell values present at the display points. Therefore, this mode is useful when signal characteristics are to be determined using a swept EMI receiver: The changes of signal amplitudes between consecutive sweeps, as well as the cell occupancy of signals, contain very valuable information about the nature of the emissions. This information is used effectively in signal comparisons (e.g., automatic ambient discrimination). However, this detection mode should not be employed when the frequency separation between display points exceeds 70% of the receiver IF bandwidth used, because narrow, high-level signals within the cells will not be displayed. For practical purposes, the frequency spacing for the use of the sample detector should be set to 25% or 30% of the resolution bandwidth.

H.5 Use of preamplifiers

Spectrum analyzers may lack the appropriate sensitivity to perform EMI measurements, because of a higher instrument noise figure [see Equation (H.2)]. Adding an external preamplifier to the spectrum analyzer serves as an easy method to improve the measurement system sensitivity. In addition to the sensitivity improvement, the dynamic range of the measurement system will be affected as well as the amplitude accuracy.

Use of a preamplifier with a spectrum analyzer increases sensitivity by amplifying input signals by the amount of gain. The increase in on-screen signal-to-noise ratio is less than the preamplifier gain, because of the noise added to the system noise by the amplifier. The resulting improvement of the system sensitivity depends on the gain and noise figure of the preamplifier and the noise figure of the spectrum analyzer (see Figure H.6).

For systems with a single preamplifier, the achievable system noise is approximately equal to the preamplifier noise figure if the preamplifier gain is greater than or equal to the spectrum analyzer noise figure. If multiple preamplifiers are used, then the overall noise figure of the system asymptotically approaches the noise figure of the first preamplifier.

Preamplifiers also affect the amplitude accuracy of the measurement. Frequency response and mismatch uncertainties predominantly affect the achievable amplitude accuracy of the measurement result. The frequency response of the amplifier contributes to the frequency response of the spectrum analyzer; the resulting overall frequency response is approximately equal to the sum of the individual responses and the effects of the mismatch. Some spectrum analyzers provide an internal data register that can be used to minimize frequency response uncertainties through a mathematical correction of the measured amplitudes. These corrections can also be performed by application software used to automate the measurement. The impact of mismatches is determined by the input and output voltage standing-wave ratio of the preamplifier. Mismatch uncertainties can be improved, if necessary, by using pads at the input and/or output of the preamplifier. It should be noted, however, that the use of such pads will reduce the system sensitivity. Furthermore, the length of the cables connecting the preamplifier to the spectrum analyzer and the other test system components (e.g., antenna) determine the ripple from the mismatch. Short cable lengths are preferable because they lessen these ripples.

Dynamic range is a concept that describes the ability to measure small signals in the presence of large signals. The dynamic range is defined as the ratio of two signals present at the input of the spectrum analyzer or EMI receiver measured to a specified amplitude accuracy. The dynamic range of a spectrum analyzer or EMI receiver is determined by the noise floor of the instrument and the internal distortion level, which is dependent on the input power level of the first mixer. The maximum dynamic range limited only by the noise floor occurs when the signal input level is greatest, up to the gain compression limitation of the mixer, and when the measurement system has the lowest noise figure (i.e., greatest preamplifier gain, least preamplifier noise figure, minimum RF input attenuation at the instrument, and minimum attenuation between the preamplifier and the spectrum analyzer). The maximum dynamic range limited by the internal distortion occurs when the signal input level is smallest. This occurs when the preamplifier gain is zero and the RF input attenuation at the instrument and attenuation between the preamplifier and the spectrum analyzer are at maximums. This directly conflicts with maximizing the dynamic range limited by the noise floor. The maximum dynamic range occurs when the internal distortion products (of the preamplifier and/or the spectrum analyzer) are equal to the noise floor of the system (used with the specified resolution bandwidth). When amplitude accuracy shall be considered, the useful dynamic range will be less. Adding a preamplifier to the input of the spectrum analyzer reduces the maximum input signal level that causes the generation of internal distortions by the amount of preamplifier gain. The preamplifier also adds noise to the system, so the effective system noise floor decreases by less than the preamplifier gain. The spectrum analyzer is generally the primary cause of internal distortions. Preamplifiers may also generate internal distortions that may affect the measurements. The optimum preamplifier gain figure of merit is the ratio of the sensitivity increase and the dynamic range decrease.

H.6 Average detection

Subclause 6.5.4 of CISPR 16-1-1:2010-11 specifies that average measurements shall be based on the peak reading of a meter with a time constant of 160 ms for frequencies from 9 kHz to 30 MHz and 100 ms for frequencies from 30 MHz to 18 GHz. From $\{1 / (2 \pi \times \text{time constant})\}$, the corresponding video bandwidths are established to be 1 Hz for 160 ms (9 kHz to 30 MHz) and 1.6 Hz for 100 ms (30 MHz to 18 GHz).[1] Because the peak reading is specified to be the measurand in 6.5.4 of CISPR 16-1-1:2010-11, the larger amplitude fluctuations that occur with the use of a higher-than-specified video bandwidth produce a conservative measurement result (i.e., higher emission result).

[1] The 100 ms time constant of CISPR 16-1-1:2010-11 is synonymous with the 0.1 s averaging time of 47CFR15.35(c) (see also 5.2.2 of ANSI C63.22-2004).

H.7 Figures for Annex H

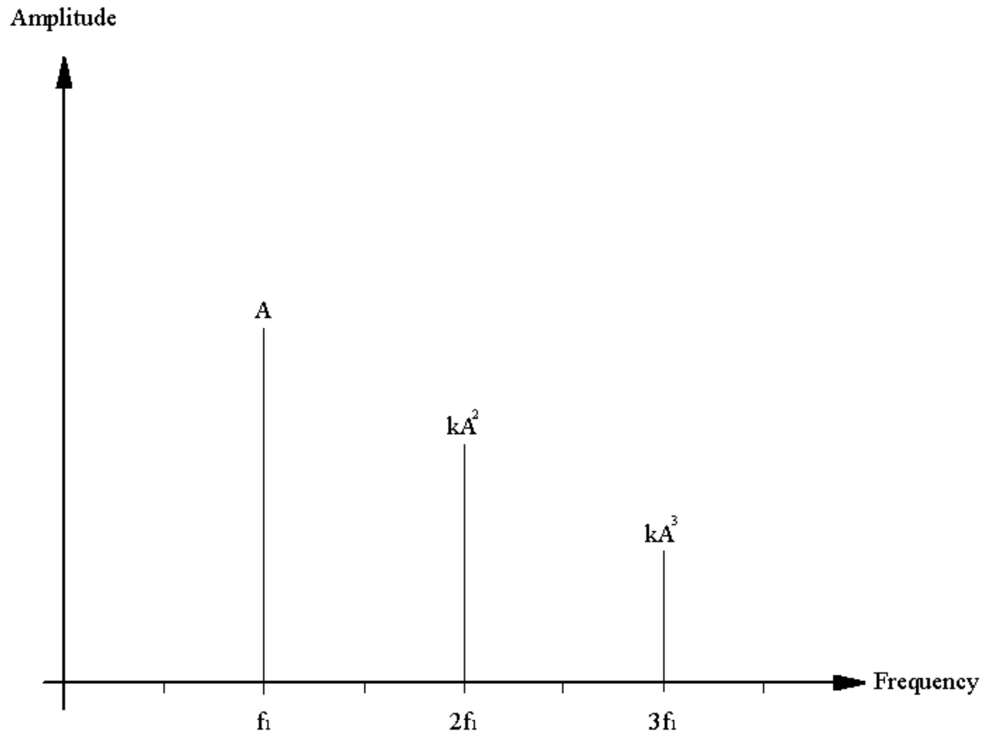


Figure H.1—Distortion caused by narrowband signals

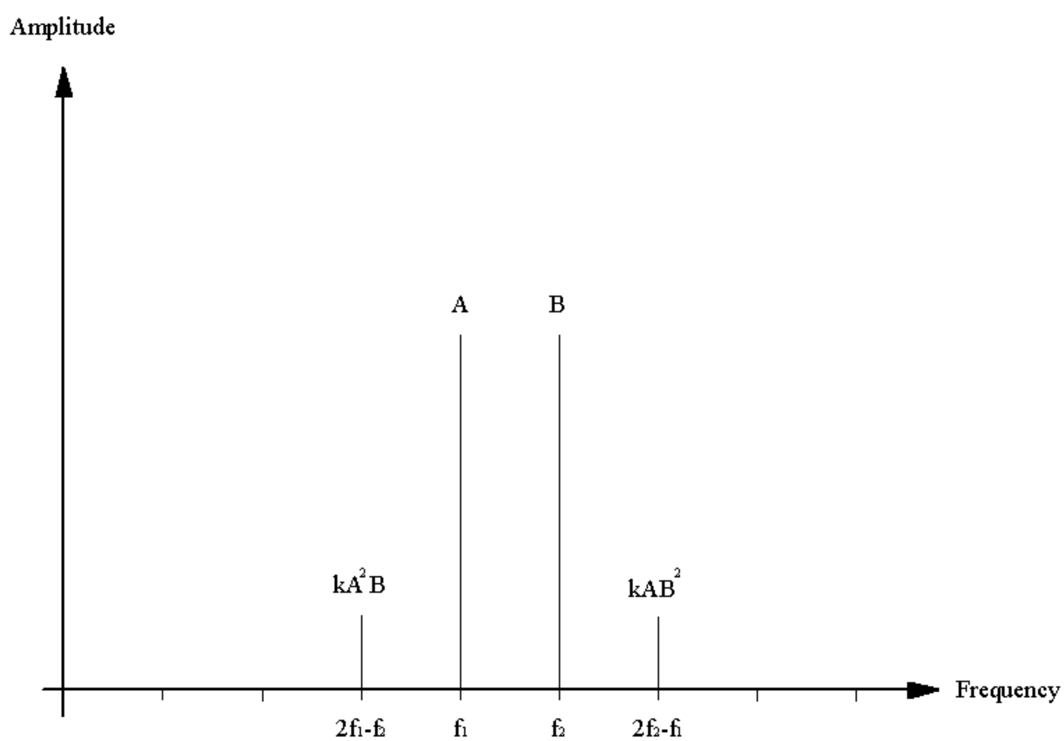


Figure H.2—Distortion caused by multiple signals

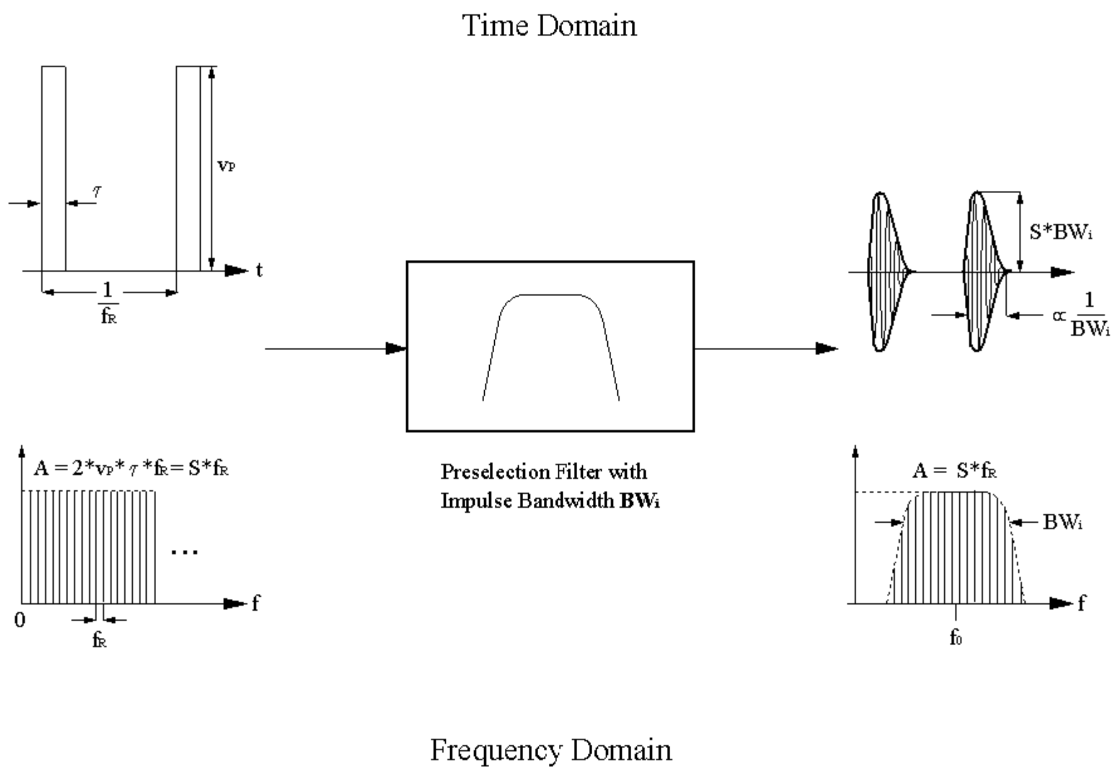


Figure H.3—Importance and function of preselection

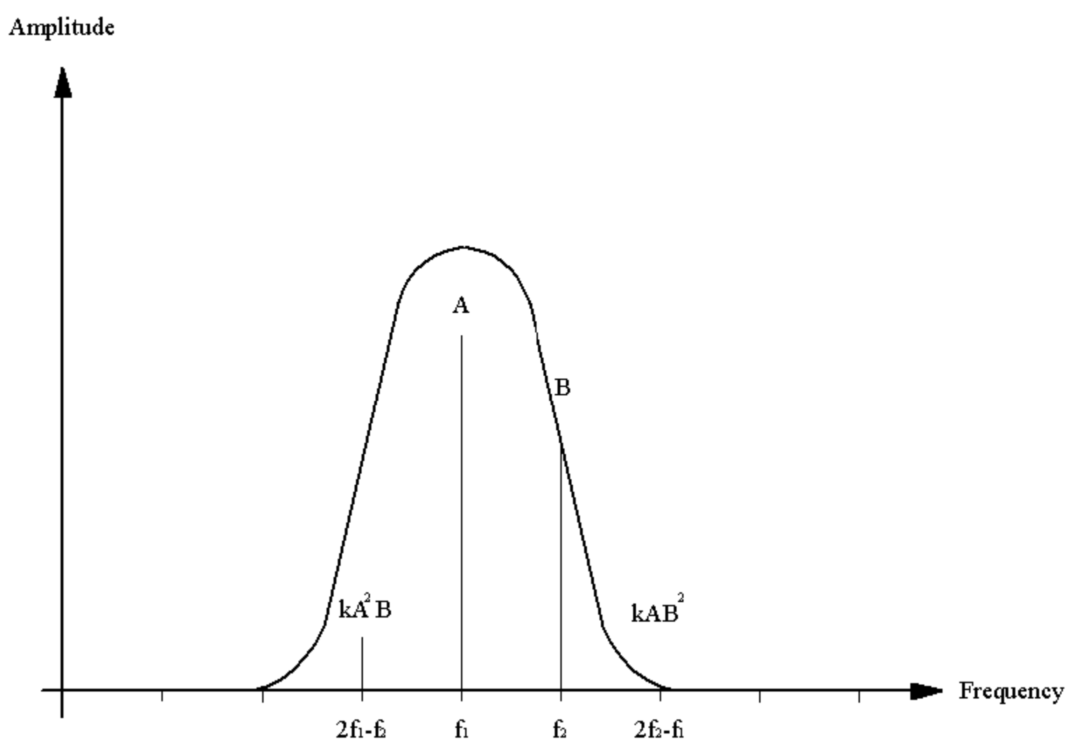


Figure H.4—Spurious-free dynamic range

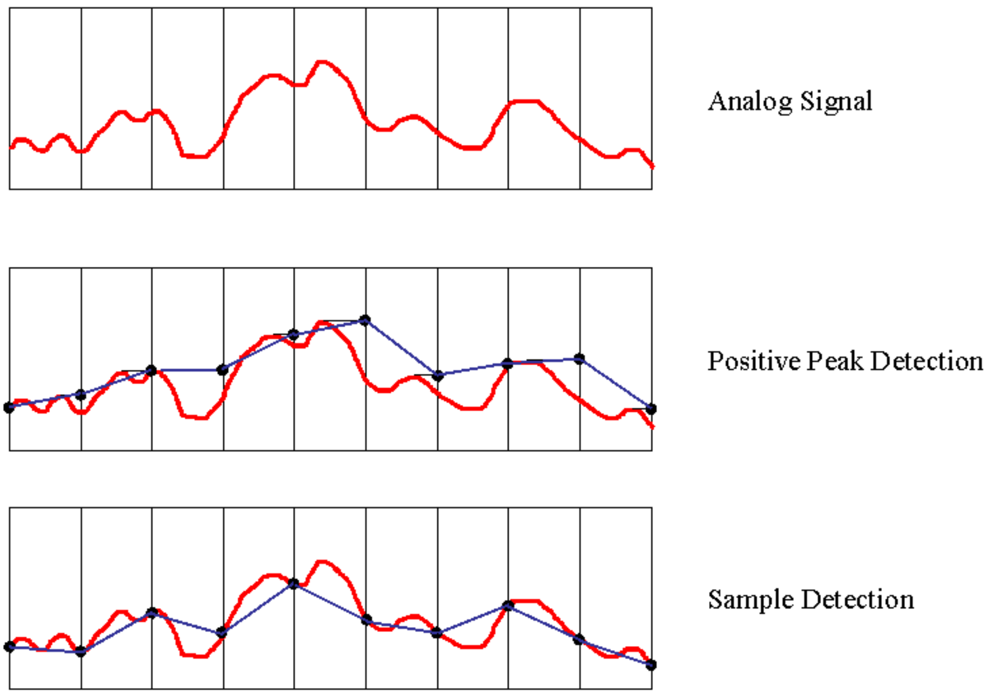
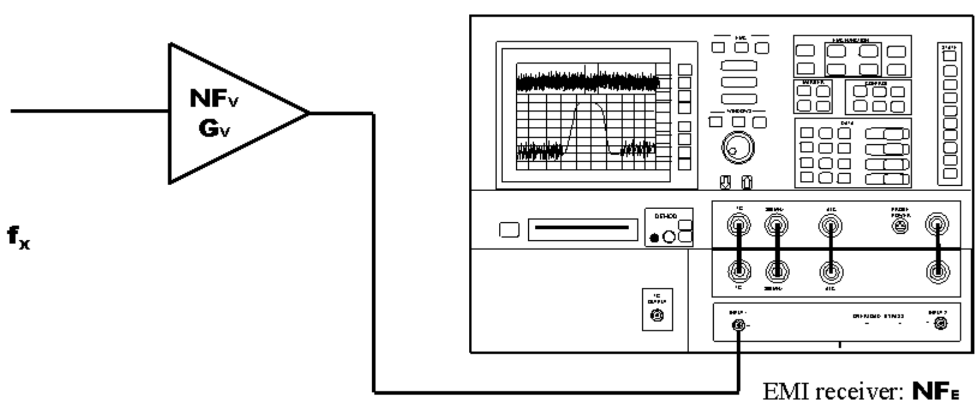


Figure H.5—Display detection modes



$$NF_{sys} = 10\log\left(NF_{v} + \frac{NF_{E} - 1}{G_{v}}\right);\ \text{use linear terms}$$

$$\text{If } G_{v} + NF_{v} > NF_{E} + 10\,\text{dB, then } NF_{sys} \approx NF_{v}$$

Figure H.6—Determination of overall system noise figure

Annex I

(informative)

Application of ANSI C63.4 to United States and Canadian requirements

Users of this standard are advised that, in the United States, all or parts of this standard are, or may become, legally mandatory for making emissions 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 (i.e., see 47CFR15A). Users of this standard are also advised that, in Canada, all or parts of this standard are, or may become, legally mandatory for making digital device emissions measurements on ITE (i.e., see the latest issue of ICES-003). Additionally, users of this standard are advised that all or parts of this standard are, or may become, legally mandatory in other nations. Finally, users of this standard are advised that all or parts of this standard are, or may become, contractually mandatory irrespective of the legal requirements of any nation.

This standard does not contain limit specifications. Users of this standard are advised to consult legally and/or contractually normative regulations and/or specifications and/or standards for information on limits. Users of this standard are further advised that, in the United States, legally normative limits applicable to emissions from unintentional radiators (including digital devices and receivers) and from the digital device portions contained in or used in intentional radiators can be found in 47CFR15B. Users of this standard are also advised that, in Canada, legally normative limits applicable to digital device emissions from ITE can be found in the current version of ICES-003.

Annex J

(informative)

Guidance on the construction of nonconductive EUT support tables

J.1 Introduction

Subclause 5.1.5 of this standard requires that the effects of an EUT support table shall be included in the calculation and reporting of the measurement uncertainty for radiated emissions measurements made on tabletop devices over the frequency range of 200 MHz to 18 GHz. The requirement in 5.1.5 exists because the materials and the assembly techniques used in the construction of an EUT support table have the potential to significantly influence the radiated emissions field strength measurements made of an EUT that has been placed on an EUT support table. The worst-case effects occur with horizontal polarization measurements. Over the frequency range of 200 MHz to 18 GHz, the effects of the EUT support table will be minimized if the table is made from and assembled with materials that have as low a dielectric constant as possible.

J.2 EPS material characteristics

A commercially available material having the lowest dielectric constant is expanded polystyrene foam (EPS), with a dielectric constant of approximately 1.3 (compared to the dielectric constant of dry air which is approximately 1.0).

EPS is produced from solid beads of polystyrene. Expansion is achieved by virtue of small amounts of pentane gas dissolved into the polystyrene base material during production. The gas expands under the action of heat, applied as steam, to form closed cells of EPS. These cells occupy approximately 40 times the volume of the original polystyrene bead. EPS materials are available in various densities. Higher density materials can support greater weight, but are more lossy for electromagnetic waves.

Commercially available sheets of EPS are commonly packaged as rigid panels, which are also known as “bead-board.” Bead-board is commonly used as a building material. EPS is also commercially available in the form of large blocks, which are commonly used in the construction of floating docks and for bulk filler in retaining walls. EPS blocks or boards used in building construction are commonly cut using a “hot wire” knife.

The International Code Council Evaluation Service (ICC-ES) requires EPS boards used in building construction to meet ASTM C578 [B4] requirements. One of these requirements is that the limiting oxygen index (LOI) of EPS, as measured using the ASTM D2863 [B5] method, must be greater than 24% (by volume). Typical untreated EPS has an LOI of around 18% (by volume); thus, a flame retardant such as hexabromocyclododecane (HBCD) is added to the polystyrene during the formation of EPS materials used in the construction industry. It is important to note that untreated EPS material cannot be relied on to self-extinguish once ignited.

The addition of the flame retardant material increases the dielectric constant of the EPS. It is important to note that each manufacturer uses a different flame-retardant formulation and/or concentration; consequently it is not possible to actually know the dielectric constant of a particular brand/model of EPS building materials without an actual measurement of the specific product. However, making of such measurements for every batch can be economically impractical.

EPS materials are sometimes available in colors (pink, blue, and purple are the most common). The coloring materials used all contain metals. The presence of the metal particles in the EPS will drastically increase the dielectric constant of the materials. Consequently, the use of colored EPS should be avoided.

J.3 XPS material characteristics

EPS should not be confused with extruded polystyrene foam (XPS; sometimes referred to as XEPS). XPS is formed from solid polystyrene crystals. The crystals, along with certain additives and a blowing agent, are fed into an extruder. Within the extruder, the mixture is combined and melted under controlled conditions of high temperature and pressure into a viscous plastic liquid. The hot, thick liquid is then forced in a continuous process through a die. As it emerges from the die, it expands into a foam. It is then shaped, cooled, and finally trimmed to dimension. (Dow STYROFOAM™ is a well-known brand of XPS.[2])

XPS is denser material than EPS because there are no air passages between the cells. It is thus considerably stronger than EPS (and thus can bear significantly higher-weight EUTs); additionally, XPS is waterproof (and thus may be more suited for use on a non-weather-protected OATS). XPS is typically made with a fire-retardant additive, but it will burn rapidly when exposed to an open flame and will not self-extinguish once ignited.

XPS has a dielectric constant of approximately 2.55 (at 1 MHz; the typical dielectric constant of XPS at higher frequencies is variously reported as being in the range of 2.4 to 2.7). This fact alone may, in some cases, be sufficient to disqualify XPS from consideration as a construction material for an EUT support table.

XPS is frequently available in colors (again, pink, blue, and purple are the most common). The coloring materials used all contain metals. The presence of the metal particles in the XPS will drastically increase the dielectric constant of the materials. Consequently, the use of colored XPS materials should be avoided.

J.4 Bonding of materials

If it is desired to construct an EUT support table using layers and/or combinations of materials (rather than out of a single block of EPS or XPS), it will be necessary to have some means of bonding these layers and/or combinations of materials together.

For obvious reasons, the use of metal screws, bolts, rod/dowels, etc., should be avoided.

There is anecdotal evidence that suggests that dense construction adhesives (such as those dispensed from a tube that fit into a caulking gun) may be totally unsuitable for bonding EUT support table layers and/or components together. This is likely because, upon curing, they polymerize into long-chain molecules, which are very polar, and because these classes of construction adhesives have high dielectric constants.

Finally, there is anecdotal evidence that suggests that the use of certain low-density spray adhesives of the types used to adhere RF pyramid (carbon-impregnated polyurethane foam) absorber to ferrite tile will produce a suitable result.

[2] This information is given for the convenience of users of this standard and does not constitute an endorsement by the IEEE of this product. Equivalent products and how they are used in constructing a table may be used if they can be shown to lead to the same results.

J.5 Surface treatments

EUT support tables constructed from EPS or XPS should not be painted. Nearly all commercially available paints contain titanium dioxide. Painting the exterior surfaces of an EUT support table constructed from EPS or XPS will have the effect of making the table electromagnetically reflective at frequencies above 1 GHz.

It should be noted that certain blue-colored paints are available that do not contain any titanium dioxide (or other metals). These paints have been used for many decades on the exterior surfaces of RF pyramid absorbers to increase the visible light reflectance of such RF absorbers. At frequencies below about 18 GHz, such titanium dioxide-free paints have little influence on the performance of the RF absorber. However, it is not known if titanium dioxide-free paints will perform in a suitable manner when applied to an EUT support table constructed from EPS or XPS.

Annex K

(informative)

(Reserved for future use)

Annex L

(informative)

(Reserved for future use)

Annex M

(informative)

(Reserved for future use)

Annex N

(normative)

Test site-specific hybrid antenna qualification procedures, limitations and acceptance criteria

NOTE—This Annex N is also reproduced exactly in the 2014 ballot draft for the next edition of ANSI C63.5. Due to publication and balloting schedules differences, this Annex N is temporarily made a part of this edition of ANSI C63.4, so that the users can easily find the test site-specific qualification procedures, limitations, and acceptance criteria for use of hybrid antennas when making final compliance measurements on products. When a more recent version of these hybrid antenna requirements is published, expected to be Annex N in the next publication of ANSI C63.5, then those requirements will take precedence over this ANSI C63.4 Annex N. For example, text references to Annex N (e.g., in Table 2, footnote h) in this standard should then be replaced with references to the more recent requirements. Users of this version of ANSI C63.4 should check the publication status of ANSI C63.5 to verify they are using the most recent version of the hybrid antenna requirements.

N.1 General

A hybrid antenna is herewith defined as any antenna that is constructed such that it includes a combination of both broadband dipole (e.g., biconical, bow-tie, etc.) elements and log-periodic dipole array elements. Hybrid antennas typically have operating frequencies can span a range from below 30 MHz to 6 GHz or more. It is important to note that the definition of a hybrid antenna excludes extended frequency-range LPDA antennas (i.e., LPDAs that have operating frequency ranges from somewhat below 200 MHz to greater than 1 GHz); thus this annex is not applicable to extended frequency-range LPDA antennas.

It has been demonstrated experimentally that in a significant number of cases, the use of hybrid antennas in making emissions measurements on certain test sites at certain measurement distances may result in significant measurement errors at frequencies from 30 MHz to as high as 300 MHz. This annex defines the procedures to be used and the requirements to be met by an EMC test laboratory to demonstrate that the use of a specific hybrid antenna at one or more measurement distances at a specific test site does not result in gross measurement errors in the frequency range 30 MHz to 300 MHz.

A specific hybrid antenna shall be deemed to suitable for use in making final compliance radiated emissions measurements at a specific test site only if either of the following two sets of conditions are fully satisfied:

a) Condition A: the tests and requirements detailed in N.2 through N.6 have been fully satisfied.

b) Condition B: the specific hybrid antenna shall satisfy all of the following requirements:

    1) The hybrid antenna shall have a measured VSWR of 2.5:1 or less at all frequencies from 30 MHz to its highest frequency of operation (i.e., to 1 GHz or possibly higher); it is acceptable to satisfy this requirement by the permanent installation of a suitably chosen attenuator (pad) on the antenna RF output port.

    2) The hybrid antenna shall have measured antenna symmetry of ± 1 dB or less at all frequencies from 30 MHz to its highest frequency of operation (i.e., to 1 GHz or possibly higher). The measurement procedure shall be in accordance with the antenna symmetry subclause of ANSI C63.5, with (the center of phase) antenna height being fixed at 1.00 m (± 0.01 m) above the reference ground plane.

3) The hybrid antenna shall satisfy all of the size limitations stated in N.2.

4) The hybrid antenna shall have been calibrated for antenna factors, VSWR, and antenna symmetry by an ISO/IEC 17025-accredited calibration laboratory that has the following items included within its scope of accreditation:

   i) The Standard Site Method (SSM) [per the associated subclause(s) of ANSI C63.5],

   ii) The measurement of antenna VSWR ,

   iii) The measurement of antenna symmetry [per the associated subclause(s) of ANSI C63.5].

The procedures specified in this annex shall only be employed if the specific test site is in compliance with the applicable site validation requirements [i.e., NSA from 30 MHz to 1000 MHz, and, if the hybrid antenna is to be used above 1 GHz, S_{VSWR} from 1 GHz to 18 GHz].

Test laboratories that wish to employ a hybrid antenna at frequencies above 1 GHz are not permitted to employ the "RF Absorber on the Ground Plane" alternative site qualification procedure detailed in 5.5.1 a) 2) of this edition of ANSI C63.4. Instead, the S_{VSWR} site qualification procedure detailed in 5.5.1 a) 1) of this edition of ANSI C63.4 shall be applied from 1 GHz to 18 GHz (if the hybrid antenna is to be used above 1 GHz).

Notwithstanding the above, the test site-specific hybrid antenna qualification procedures and acceptance criteria specified in this annex apply only over the restricted nominal frequency range from 30 MHz to 200 MHz.

N.2 Hybrid antenna size limitations

If a hybrid antenna is used at a standard test site (i.e., at a non-weather-protected OATS), the size of the hybrid antenna must be small enough that, regardless of polarization, no portion of the antenna elements are closer than 25 cm to the ground plane, when the hybrid antenna is placed at a 1 m height.

If a hybrid antenna is employed at an alternative test site (i.e., at a weather-protected OATS, a semi-anechoic chamber, and/or in a fully anechoic room, the size of the hybrid antenna must be small enough that, regardless of polarization, no portion of the antenna elements are closer than 25 cm to the ground plane when the antenna is set at a 1 m height. Its size must also be small enough that, regardless of polarization, no portion of the antenna elements are closer than 25 cm to any interior surfaces (and including RF absorbers), when the antenna is set to a 4 m height.

The ***overall length*** of a hybrid antenna (as measured from the front of the front-most element to the rear of the rear-most element) should not exceed 1.50 m. (See NOTE 2).

NOTE 1—The requirements listed above have the effect of limiting the maximum allowable width and height dimensions of a hybrid antenna to 1.50 m by 1.50 m.

NOTE 2—To limit the measurement uncertainty associated with the measurement distance, and, to maintain consistency between the qualification procedures and the qualification requirements stated in this Annex, the maximum length of a hybrid antenna (as measured from the center of the front-most element to the center of the rear-most element) should not exceed 1.50 m. However, in some cases, hybrid antennas with overall lengths in excess of 1.50 m can satisfy the acceptance criteria specified in N.5.

N.3 Hybrid antenna VSWR control

It is desirable to minimize the measurement uncertainty associated with a high VSWR that is inherent in the design of many hybrid antennas at low frequencies.

If the test laboratory deems it desirable or necessary (see NOTE), a hybrid antenna impedance matching “pad” (HAIMP) attenuator may be used during the test site-specific hybrid antenna qualification procedure (see N.4).

NOTE—It has been experimentally verified that, in many cases, hybrid antennas having “high” free-space VSWR values below 200 MHz, when tested in accordance with test site-specific hybrid antenna qualification procedure (see N.4) will not satisfy the acceptance criteria specified in N.5. In this context, “high” VSWR values can be considered to be any VSWR values in excess of approximately 10:1 in the frequency range 30 MHz to 200 MHz. In such cases, the use of a HAIMP attenuator may allow a hybrid antenna to satisfy the acceptance criteria specified in N.5. Additionally, it should be noted that any antenna having “high” free-space VSWR values will have higher measurement uncertainties. A suitably chosen HAIMP attenuator can reduce these measurement uncertainties.

If a HAIMP attenuator is used during the test site-specific hybrid antenna qualification procedure (see N.4), then it is essential that 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 on the test site using that hybrid antenna. (See also normative footnote i of Table 2 in 4.5.1.)

A test laboratory can sometimes determine the free-space VSWR values of a particular hybrid antenna from 30 MHz to 200 MHz by referencing the applicable section(s) of the user manual or data sheet of the hybrid antenna(s) under investigation. In the alternative, a test laboratory can determine the free-space VSWR values of a hybrid antenna from 30 MHz to 200 MHz by measurements made either by an accredited antenna calibration laboratory or by the laboratory itself.

N.4 Test site-specific hybrid antenna qualification procedure

N.4.1 General

Given that a hybrid antenna under investigation satisfies the size limitations stated in N.2 as well as the VSWR control requirements stated in N.3, and given that the specific test site where the hybrid antenna is to be used satisfies the applicable site validation requirements stated in N.1, the following procedure shall be used to determine the relative difference between results of field strength measurements made with a set of “reference antennas” and results achieved with the hybrid antenna under investigation at a particular test site at one or more test distances in both horizontal and vertical polarizations. These difference shall be compared to the acceptance criteria stated in N.5 to determine if the use of a given hybrid antenna is permitted at the test site the measurements have been performed at and at one or more measurement distances in both horizontal and vertical polarizations.

N.4.2 Required measurement antennas, attenuators, and (optional) external preamplifier

The tests described in N.4.3 are to be performed on the OATS or in the semi-anechoic chamber or in the fully anechoic room that is used for final compliance measurements of products. In order to perform these tests, the following antennas (and their antenna factors) and impedance matching “pad” attenuators are required:

a) The hybrid antenna under investigation and, if necessary or desirable in accordance with N.3 c), an hybrid antenna impedance matching “pad” (HAIMP) attenuator are required. Near free-space antenna factors (determined in accordance with ANSI C63.5, over the frequency range 30 MHz to 200 MHz) must be available for the hybrid antenna under investigation.

b) Two nominally identical biconical antennas are required; both of which must have baluns of the same nominal impedance. (That is, *either* both biconical antennas must have 200 Ω baluns or both biconical antennas must have 50 Ω baluns). One of the biconical antennas is to be designated as the transmit antenna and the other is to be designated as the receiving antenna. Free-space antenna factors (measured in accordance with ANSI C63.5, in the frequency range 30 MHz to 200 MHz) must be available for the receiving antenna.

NOTE 1—Significantly lower measurement uncertainties will result if the two nominally identical biconical antennas that are used each have a 200 Ω balun.

c) Two 10 dB impedance matching “pad” attenuators are required. One 10 dB attenuator is required to be installed on the input connector of each transmit antenna, and the other 10 dB attenuator is required to be installed on the input connector of the EMI receiver or spectrum analyzer.

d) An external preamplifier is required if and only if the test laboratory wishes to employ that external preamplifier when making measurements on products. If an external preamplifier is to be used over the frequency 30 MHz to 1000 MHz at a given measurement distance at the specific test site under investigation, it must be consistently in-place and operating throughout the qualification tests described in N.4.3.1 or N.4.3.2 (as applicable).

NOTE 2—The use of an external preamplifier at frequencies from 30 MHz to 1 GHz on a 3 m test site is highly inadvisable, due to the likelihood of saturation (overload)—both during this site-specific hybrid antenna qualification procedure and during actual compliance measurements made on products. Regardless of the measurement distance employed, users of external preamplifiers are cautioned to take whatever measures are necessary so that saturation (overload) conditions are detected and mitigated when they occur, so as to avoid making invalid measurements.

N.4.3 Test setup and test procedure

N.4.3.1 Test setup and test procedure for measurements made on 3 m test sites

This subclause is applicable to test sites that have the capability to make measurements only at a 3 m distance. This subclause is also applicable to 5 m and 10 m test sites, but the measurements described herein (and final compliance measurements made on products) shall be performed only at the 3 m distance. Refer to N.4.3.2 for the test setup and test procedures for measurements made on test sites at a 10 m distance.

a) Place the transmit biconical antenna in horizontal polarization at a height of 1 m at the center of the turntable. Install a 10 dB attenuator on the input connector of the transmit biconical antenna.

b) Place the receiving biconical antenna on the antenna mast in horizontal polarization at a height of 1 m at a distance of 3 m, as measured from the reference point of the transmit biconical antenna to the reference point of the receive biconical antenna. Do NOT use an attenuator on the output connector of the receiving biconical antenna. Use a high quality coaxial cable to connect the transmit biconical antenna (with the 10 dB attenuator installed) to a signal source. Use the coaxial cable that is used for regular product testing to connect the receiving antenna to the EMI receiver or spectrum analyzer via a 10 dB attenuator that shall be installed directly onto the input port of the EMI receiver or spectrum analyzer.

c) Scan the receiving biconical antenna from 1 m to 4 m while simultaneously scanning or stepping the EMI receiver or spectrum analyzer over the frequency range 30 MHz to 200 MHz. Use a maximum resolution bandwidth of 120 kHz. Use either linear frequency steps with maximum step-size equal to one-half of the chosen resolution bandwidth, or use a linear scan. Confirm that the received signal is at least 20 dB above the system noise floor. Record the maximum received signal levels. The results recorded are the reference values for the two biconical antennas at 3 m in horizontal polarization and are designated as $S_{21,\mathrm{BB3H}}$.

d) Without moving the transmit biconical antenna, remove the receiving biconical antenna and replace it with the hybrid antenna to be qualified, such that the reference point on the hybrid is at the 3 m distance, as measured from the reference point of the transmit biconical antenna. If required or desired in accordance with N.3 c), install the hybrid antenna impedance matching pad (HAIMP) attenuator at the output connector of the hybrid antenna. Designate the insertion loss of the HAIMP as L_{HAIMP}.

e) Reconnect the receiving coaxial cable, and repeat step c), making certain that the EMI receiver or spectrum analyzer settings are not changed. The results are the "antenna under test" (AUT) values of the transmit biconical antenna and the receiving hybrid antenna at 3 m in horizontal polarization. These results are designated as $S_{21,\text{BH3H}}$.

f) Compute the reference and AUT horizontally polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\text{BB3H}} = S_{21,\text{BB3H}} + FSAF_{\text{biconical}} \quad \text{(N.1)}$$

$$E_{\text{BB3H}} = S_{21,\text{BH3H}} + FSAF_{\text{hybrid}} + L_{\text{HAIMP}} \quad \text{(N.2)}$$

g) Compute the difference between the reference and AUT horizontally polarized field strength results (in dB) as follows:

$$\Delta E_{\text{3mH}} = E_{\text{BB3H}} - E_{\text{BH3H}} \quad \text{(N.3)}$$

h) Compare the ΔE_{3mH} results obtained in step f) with the acceptance criteria given in N.5.1.

i) Repeat steps a) through g) with the biconical antennas and the hybrid antenna under test in vertical polarization at the 3 m measurement distance. Denote the reference and AUT vertically polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\text{BB3V}} = S_{21,\text{BB3V}} + FSAF_{\text{biconical}} \quad \text{(N.4)}$$

$$E_{\text{BB3V}} = S_{21,\text{BH3V}} + FSAF_{\text{hybrid}} + L_{\text{HAIMP}} \quad \text{(N.5)}$$

j) Compute the difference between the reference and AUT vertically polarized field strength results (in dB) as follows:

$$\Delta E_{\text{3mV}} = E_{\text{BB3V}} - E_{\text{BH3V}} \quad \text{(N.6)}$$

k) Compare the ΔE_{3mV} results obtained in step i) with the acceptance criteria given in N.5.1.

N.4.3.2 Test setup and test procedure for measurements made on 10 m test sites

This subclause is applicable to test sites that have the capability to make measurements at a 10 m distance. Refer to N.4.3.1 for the test setup and test procedures for measurements made on 3 m or 5 m sites at a 3 m distance.

a) Place the transmit biconical antenna in horizontal polarization at a height of 1 m at the center of the turntable. Install a 10 dB attenuator on the input connector of the transmit biconical antenna.

b) Place the receiving biconical antenna on the antenna mast in horizontal polarization at a height of 1 m at a distance of 10 m, as measured from the reference point of the transmit biconical antenna to the reference point of the receive biconical antenna. Do NOT use an attenuator on the output connector of the receiving biconical antenna. Use a high quality coaxial cable to connect the transmit biconical antenna (with the 10 dB attenuator installed) to a signal source. Use the coaxial cable that is used for regular product testing to connect the receiving antenna to the EMI receiver or spectrum analyzer via a 10 dB attenuator that shall be installed directly onto the input port of the EMI receiver or spectrum analyzer.

c) Scan the receiving biconical antenna from 1 m to 4 m while simultaneously scanning or stepping the EMI receiver or spectrum analyzer over the frequency range 30 MHz to 200 MHz. Use a maximum resolution bandwidth of 120 kHz. Use either linear frequency steps with maximum step-size equal to one-half of the chosen resolution bandwidth, or use a linear scan. Confirm that the received signal is at least 20 dB above the system noise floor. Record the maximum received signal levels. The results recorded are the reference values for the two biconical antennas at 10 m in horizontal polarization and are designated as $S_{21,\mathrm{BB10H}}$.

d) Without moving the transmit biconical antenna, remove the receiving biconical antenna and replace it with the hybrid antenna to be qualified, such that the reference point on the hybrid is at the 10 m distance, as measured from the reference point of the transmit biconical antenna. If required or desired in accordance with N.3 c), install the hybrid antenna impedance matching pad (HAIMP) attenuator at the output connector of the hybrid antenna. Designate the insertion loss of the HAIMP as L_{HAIMP}.

e) Reconnect the receiving coaxial cable, and repeat step c), making certain that the EMI receiver or spectrum analyzer settings are not changed. The results are the "antenna under test" (AUT) values of the transmit biconical antenna and the receiving hybrid antenna at 10 m in horizontal polarization. These results are designated as $S_{21,\mathrm{BH10H}}$.

f) Compute the reference and AUT horizontally polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB10H}} = S_{21,\mathrm{BB10H}} + FSAF_{\mathrm{biconical}} \quad \text{(N.7)}$$

$$E_{\mathrm{BH10H}} = S_{21,\mathrm{BH10H}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \quad \text{(N.8)}$$

g) Compute the difference between the reference and AUT horizontally polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{10mH}} = E_{\mathrm{BB10H}} - E_{\mathrm{BH10H}} \quad \text{(N.9)}$$

h) Compare the ΔE_{10mH} results obtained in step f) with the acceptance criteria given in N.5.2.

i) Repeat steps a) through g) with the biconical antennas and the hybrid antenna under test in vertical polarization at the 10 m measurement distance. Denote the reference and AUT vertically polarized field strength measurement results (in dBμV/m) as follows:

$$E_{\mathrm{BB10V}} = S_{21,\mathrm{BB10V}} + FSAF_{\mathrm{biconical}} \quad \text{(N.10)}$$

$$E_{\mathrm{BH10V}} = S_{21,\mathrm{BH10V}} + FSAF_{\mathrm{hybrid}} + L_{\mathrm{HAIMP}} \quad \text{(N.11)}$$

j) Compute the difference between the reference and AUT vertically polarized field strength results (in dB) as follows:

$$\Delta E_{\mathrm{10mV}} = E_{\mathrm{BB10V}} - E_{\mathrm{BH310V}} \quad \text{(N.12)}$$

k) Compare the ΔE_{10mV} results obtained in step i) with the acceptance criteria given in N.5.2.

N.5 Acceptance criteria

N.5.1 Criteria for hybrid antennas to be used at the 3 m measurement distance

In the frequency range 30 MHz to 200 MHz, for a given polarization, at the 3 m measurement distance, on a specific test site, a hybrid antenna shall be deemed acceptable for use in making final compliance measurements if the difference in results of measurement performed in accordance with N.4 at each polarization meets the following requirements:

— the results of the ΔE_{3mH} calculations are less then or equal to ±2.5 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive); and,

— the results of the ΔE_{3mV} calculations are less then or equal to ±2.5 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive).

NOTE—The above criteria are based upon the expanded uncertainty values for a $k = 2$ coverage factor that were computed for the exact measurement procedure (at the 3 m measurement distance) detailed in N.4.3.1 steps a) through k) of this annex.

N.5.2 Criteria for hybrid antennas to be used at the 10 m measurement distance

In the frequency range 30 MHz to 200 MHz, for a given polarization, at the 10 m measurement distance, on a specific test site, a hybrid antenna shall be deemed acceptable for use in making final compliance measurements if the difference in results of measurement performed in accordance with N.4 at each polarization meets the following requirements:

— the results of the ΔE_{10mH} calculations are less then or equal to ±2.4 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive); and,

— the results of the ΔE_{10mV} calculations are less then or equal to ±2.4 dB at all measured frequencies in the range 30 MHz to 200 MHz (inclusive).

NOTE—The above criteria are based upon the expanded uncertainty values for a $k = 2$ coverage factor that were computed for the exact measurement procedure (at the 10 m measurement distance) detailed in N.4.3.2 steps a) through k) of this annex.

N.6 Qualification interval

For any given hybrid antenna used at a given measurement distance, on a specific test site, the qualification process detailed in N.4 and N.5.1 and/or N.5.2 (as applicable) shall be performed when the hybrid antenna is first taken into service at the given measurement distance on the specific test site. The subsequent re-qualification intervals may be longer (up to 3 years) or shorter based on review of the hybrid antenna calibration data relative to the recommendations of the antenna manufacturer and the required measurement uncertainty. The qualification process detailed in N.4 and N.5 shall be repeated if any of the following conditions occur:

— Damage to or degradation of the hybrid antenna is known or suspected to have occurred.

— After each periodic recalibration of the hybrid antenna, if any of the hybrid antenna's free-space antenna factor (FSAF) values has been found to have varied by ± 1.0 dB or more from the FSAF values that were previously measured.If FSAF variation greater than or equal to ± 1.0 dB is found, then further investigation shall be undertaken. In particular, it shall be determined if the cause of the variation was due to a change in the calibration procedures and/or equipment used by the antenna calibration laboratory, or was due to a change in the antenna itself.

If the changes in the FSAF values were due to a change in the antenna calibration procedures and/or equipment used by the antenna calibration laboratory, the effects of those changes shall be quantified. Then, using that information, it shall be determined if the ± 1.0 dB criterion is met by the antenna. If the ± 1.0 dB criterion is met by the antenna, it is not necessary to repeat the site-specific hybrid antenna qualification process.

— Whenever physical modifications have been made to the test site or adjacent areas (cf. ANSI C63.7), or whenever significant damage to the test site has been noted and repaired.

Annex O

(informative)

Bibliography

Bibliographical references are resources that provide additional or helpful material but do not need to be understood or used to implement this standard. Reference to these resources is made for informational use only.

O.1 Bibliographic items cited in text

[B1] ANSI C63.2-1996, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications.

[B2] ANSI C63.6-1996, American National Standard Guide for the Computation of Errors in Open-Area Test Site Measurements.

[B3] ANSI C63.10, American National Standard for Testing Unlicensed Wireless Devices.

[B4] ASTM C578-12b, Standard Specification for Rigid, Cellular Polystyrene Thermal Insulation, 2012.[3]

[B5] ASTM D2863-13, Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index), 2013.

[B6] Berger, H. S., "A variable position, gravity down GTEM configuration," *International Zurich Symposium on Electromagnetic Compatibility*, Zurich, Switzerland, pp. 465–470, Mar. 1995.

[B7] Berger, H. S., "Radiated emissions test correlation between G-TEM, SAC (semi-anechoic), and OATS facilities using digital phones," *IEEE International Symposium on Electromagnetic Compatibility*, Dallas, TX, pp. 295–299, Aug. 1993.

[B8] Berry, J. B., J. B. Pate, and A. N. Knight, "Variations in mutual coupling correction factors for resonant dipoles used in site attenuation measurements," *IEEE International Symposium on Electromagnetic Compatibility*, Washington, DC, pp. 444–449, Aug. 1990.

[B9] Bronaugh, E. L., "Derivation of the ± 4 dB criterion for site attenuation on open-area test sites," *IEE International Conference on Electromagnetic Compatibility*, pp. 160–163, Sept. 1992.

[B10] Bronaugh, E. L., "Simplifying EMI immunity (susceptibility) tests in TEM devices," *IEEE International Symposium on Electromagnetic Compatibility*, Washington, DC, pp. 488-491, Aug. 1990.

[B11] Bronaugh, E. L., and J. D. M. Osburn, "The 'hyper-rotated' gigahertz transverse electromagnetic cell (G-TEM)—expanding the performance envelope," *Euro EMC Conference Proceedings*, Sandown, England, pp. 103–105, Oct. 1993.

[3] ASTM publications are available from ASTM International (http://www.astm.org).

[B12] CISPR 16-1-1:2003, Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus—Measuring Apparatus. [4]

[B13] CISPR 16-2-1:2010, Specification for radio disturbance and immunity measuring apparatus and methods—Part 2-1: Methods of measurement of disturbances and immunity—Conducted disturbance measurements.

[B14] CISPR 16-2-3:2010, Specification for radio disturbance and immunity measuring apparatus and methods—Part 2-3: Methods of measurement of disturbances and immunity—Radiated disturbance measurements.

[B15] CISPR 22:2008, Information Technology Equipment—Radio Disturbance Characteristics—Limits and Methods of Measurement.

[B16] FCC/OET MP–5, Methods of Measurements of Radio Noise Emissions from Industrial, Scientific and Medical Equipment, Feb. 1986.[5]

[B17] German, R. F., "Comparison of semi-anechoic chamber and open-field site attenuation measurements," *IEEE International Symposium on Electromagnetic Compatibility*, Santa Clara, CA, pp. 260–265, Sept. 1982.

[B18] Harrington, T. E., "Catalog of TEM waveguide radiated emissions correlation methods," *IEEE International Symposium on Electromagnetic Compatibility*, Minneapolis, MN, pp. 486–491, Aug. 2002.

[B19] Heirman, D. N., "Definitive open area test site qualifications," *IEEE International Symposium on Electromagnetic Compatibility*, Atlanta, GA, pp. 127–134, Aug. 1987.

[B20] Heirman, D. N., "Vertical site attenuation—a necessity," *IEEE International Symposium on Electromagnetic Compatibility*, San Diego, CA, pp. 342–346, Sept. 1986.

[B21] IEEE Std 1394™-2008, IEEE Standard for a High-Performance Serial Bus.[6,7]

[B22] Ma, M. T., I. Sreenivasiah, and D. C. Chang, "A method of determining the emission and susceptibility levels of electrically small objects using a TEM cell," U.S. Department of Commerce, National Bureau of Standards, Technical Note 1040, July 1981.

[B23] MDS-201-0004, Electromagnetic Compatibility Standards for Medical Devices, U.S. Food and Drug Administration (FDA), 1979.[8]

[B24] MIL-STD-461F, Military Standard Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment.[9]

[B25] Nadeau, B., "The need for a new ANSI C63.4 H pattern requirement or how to make a passing product fail," *IEEE International Symposium on Electromagnetic Compatibility*, Santa Clara, CA, pp. 645–648, Aug. 2004.

[B26] Pate, J. B., "Potential measurement errors due to mutual coupling between dipole antennas and radio frequency absorbing material in close proximity," *IEEE National Symposium on Electromagnetic Compatibility*, San Antonio, TX, pp. 13–19, Apr. 1984.

[4] CISPR documents are available from the International Electrotechnical Commission (http://www.iec.ch/). They are also available in the United States from the American National Standards Institute (http://www.ansi.org/).
[5] FCC publications are available from the Federal Communications Commission (http://www.fcc.gov).
[6] The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.
[7] IEEE publications are available from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).
8 FDA publications are available from the U.S. Food and Drug Administration (http://www.fda.gov).
[9] MIL publications are available from the Defense Logistics Agency (DLA) Document Services (http://quicksearch.dla.mil/).

[B27] SAE ARP1972:1993 (Reaff 2003), Recommended Measurement Practices and Procedures for EMC Testing.

[B28] Smith, A. A., Jr., R. F. German, and J. B. Pate, "Calculation of site attenuation from antenna factors," *IEEE Transactions on Electromagnetic Compatibility*, vol. 24, no. 3, pp. 301–316, Aug. 1982.

[B29] Universal Serial Bus (USB) Specification Revision 2.0.[10]

[B30] Wilson, P., "On correlating TEM cell and OATS emission measurements," *IEEE Transactions on Electromagnetic Compatibility*, vol. 37, no. 1, pp. 1–16, Feb. 1995.

[B31] Wilson, P., "On simulating OATS near-field emission measurements via G-TEM cell measurements," *IEEE International Symposium on Electromagnetic Compatibility*, Dallas, TX, pp. 53–57, Aug. 1993.

O.2 Bibliographic items for additional reading

[B32] ANSI C63.4-2003, 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.[11]

[B33] ANSI C63.12-1999, American National Standard Recommended Practice for Electromagnetic Compatibility Limits.

[B34] ANSI/NCSL Z540-1-1994, American National Standard for Calibration—Calibration Laboratories and Measuring and Test Equipment—General Requirements.[12]

[B35] CEA-378-1970, Measurement of Spurious Radiation from FM and TV Broadcast Receivers in the Frequency Range of 100 to 1000 MHz—Using the EIA Laurel Broadband Antenna.[13]

[B36] CENELEC EN 45001-1989, General Criteria for the Operation of Testing Laboratories.[14]

[B37] CENELEC EN 55022-1998, Limits and Methods of Measurement of Radio Interference Characteristics of Information Technology Equipment, ed. 1.

[B38] Code of Federal Regulations Title 47 Part 2 (47CFR2), Telecommunication—Frequency Allocation and Radio Treaty Matters; General Rules and Regulations, republished annually.[15]

[B39] Crawford, M. L., "Measurement of electromagnetic radiation from electronic equipment using TEM transmission cells," U.S. Department of Commerce, National Bureau of Standards, NBSIR 73-306, Feb. 1973.

[B40] Crawford, M. L., and J. L. Workman, "Using a TEM device for EMC measurements of electronic equipment," U.S. Department of Commerce, National Bureau of Standards, Technical Note 1013, July 1981.

[B41] FCC Public Notice 40830, "FCC will accept GTEM measurement data under limited conditions," 2 Dec. 1993.

[10] For more information, visit the following URL: http://www.usb.org/developers/docs/.
[11] 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/).
[12] NCSL publications are available from National Conference of Standards Laboratories (http://www.ncsli.org).
[13] Consumer Electronics Association (CEA) publications are available from Global Engineering (http://global.ihs.com/).
[14] European Committee for Electrotechnical Standardization (CENELEC) publications are available from Global Engineering (http://global.ihs.com/).
[15] CFR publications are available from the U.S. Government Printing Office (http://www.gpoaccess.gov/).

[B42] FCC/OET Bulletin 62, Understanding the FCC Regulations for Computers and other Digital Devices, 1993.

[B43] IEEE Std 291™-1991, IEEE Standard Methods for Measuring Electromagnetic Field Strength of Sinusoidal Continuous Waves, 30 Hz to 30 GHz.[16]

[B44] IEEE Std 376™-1975 (Reaff 1993, 1998), IEEE Standard for the Measurement of Impulse Strength and Impulse Bandwidth.[17]

[B45] IEEE Std 430™-1986 (Reaff 1991), IEEE Standard Procedures for the Measurement of Radio Noise from Overhead Power Lines and Substations.

[B46] Kawana, T., and S. Miyajima, "Theoretical investigations of site attenuation by means of mutual impedance between antennas—in case of 3 meters distance between antennas," *Journal of the Radio Research Laboratories*, vol. 26, no. 120/121, pp. 135–145, July/Nov. 1979.

[B47] Königstein, D., and D. Hansen, "A new family of TEM cells with enlarged bandwidth and optimized working volume," *International Zurich Symposium on Electromagnetic Compatibility*, Zurich, Switzerland, pp. 127–132, Mar. 1987.

[B48] Ma, M. T., and M. Kanda, "Electromagnetic compatibility and interference metrology," U.S. Department of Commerce, National Bureau of Standards, Technical Note 1099, pp. 17–43, July 1986.

[B49] Taggart, H. E., and J. L. Workman, "Calibration principles and procedures for field strength meters (30 Hz to 1 GHz)," U.S. Dept. of Commerce, NBS Tech. Note 370, Mar. 1969.

[B50] Tai, C. T., "Coupled antennas," *Proceedings of the IRE*, vol. 38, pp. 487–500, Apr. 1948.

[16] IEEE Std 291-1991 has been withdrawn; however, copies can be obtained from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).
[17] IEEE Std 376-1975 has been withdrawn; however, copies can be obtained from The Institute of Electrical and Electronics Engineers (http://standards.ieee.org/).

Annex P

(informative)

Keyword index