

American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

C63[®]

Accredited Standards Committee C63[®]—Electromagnetic Compatibility

Accredited by the
American National Standards Institute

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American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

Accredited Standards Committee C63®—Electromagnetic Compatibility
accredited by the
American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: The procedures for testing the compliance of a wide variety of unlicensed wireless transmitters (also called intentional radiators and license-exempt transmitters) including, but not limited to, remote control and security unlicensed wireless devices, frequency hopping and direct sequence spread spectrum devices, antipilferage devices, cordless telephones, medical unlicensed wireless devices, Unlicensed National Information Infrastructure (U-NII) devices, intrusion detectors, unlicensed wireless devices operating on frequencies below 30 MHz, automatic vehicle identification systems, and other unlicensed wireless devices authorized by a radio regulatory authority are covered in this standard. Excluded by this standard are test procedures for unlicensed wireless devices already covered in other published standards (e.g., Unlicensed Personal Communication Services (UPCS) devices).

Keywords: ANSI C63.10, compliance testing, intentional radiators, license-exempt transmitters, spread spectrum devices, test procedures, Unlicensed National Information Infrastructure (U-NII), unlicensed wireless devices

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Introduction

This introduction is not part of ANSI C63.10-2020, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices.

This standard provides procedures for testing the compliance of a wide variety of unlicensed wireless devices (transmitters). For information concerning those devices that are covered or not covered by this standard, see 1.2. Procedures for testing of some of these devices were previously provided in ANSI C63.4-2014,¹ but they will be removed in a future revision of that standard. The intention is to include all procedures in this standard for testing unlicensed wireless devices, except any devices excluded from the scope; for example, test procedures for Unlicensed Personal Communication Systems devices are addressed by ANSI C63.17-2013 [B5].²

¹ Information on references can be found in Clause 2.

² The numbers in brackets correspond to those of the bibliography in Annex N.

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American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

1. Overview

1.1 Scope

This standard specifies U.S. consensus standard methods and instrumentation and test facilities requirements for measurement of radio frequency (RF) signals and noise emitted from unlicensed wireless devices (also called unlicensed transmitters, intentional radiators, and license-exempt transmitters) operating in the frequency range 9 kHz to 231 GHz. It does not include generic or product specific emission limits. It also does not cover measurement of radio emissions from unintentional radiators, as mentioned in 1.2. Where possible, the specifications herein are harmonized with other national and international standards used for similar purposes.

As described in 1.2 of this standard, measurement methods are provided for radiated and conducted emissions that can be generated by a variety of devices. For terms and phrases contained in the text that do not represent obvious or common usage, definitions are provided. In most cases, measurement instrumentation and calibration requirements, which should be used with this standard, are generally characterized in deference to standards dedicated to these subjects, which should be used in conjunction with this standard. 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.

1.2 Purpose and applications

Various unlicensed wireless devices (also known as unlicensed transmitters, intentional radiators, and license-exempt transmitters) are subject to certain regulatory requirements. The primary way to show compliance in meeting regulatory requirements is by testing such devices in a repeatable and reproducible manner. This standard presents the methods of measurement to show compliance with the technical specifications for the majority of current wireless devices in wide use. It is not expected that all unlicensed wireless devices on the market will in fact be covered by this standard.

This standard does not consider test methods for unlicensed wireless devices already covered in other published standards, such as, but not limited to:

- a) Unlicensed Personal Communications Services devices covered under ANSI C63.17-2013
- b) Dynamic Frequency Selection (DFS) functionality required for U-NII devices in the United States

- c) Industrial, Scientific and Medical equipment
- d) RF exposure conformity assessment methods subject to standards such as IEEE Std 1528-2003

This document provides standard test methods for determining compliance with regulatory requirements for many types of unlicensed wireless devices. These unlicensed wireless devices include, but are not limited to, the following:

- Remote control and security unlicensed wireless devices
- Frequency hopping and direct sequence spread spectrum devices
- Digital transmission system devices
- Antipilferage devices
- Cordless telephones
- Radio frequency identification (RFID) tag readers
- Unlicensed National Information Infrastructure devices
- Intrusion detectors
- Unlicensed wireless devices operating below 30 MHz
- Wireless (garage) door openers
- Ultra-wideband (UWB) devices
- Automatic vehicle identification systems
- Inductive devices

Clause 2 and Clause 3 contain the normative references and definitions used in this standard, respectively. Clause 4 provides the specifications for the necessary test instrumentation needed for performing compliance testing. Clause 5 provides the general requirements for all standard test methods. Clause 6 provides standard test methods required for most unlicensed wireless devices. Clause 7, Clause 8 (FM band devices), Clause 9 (millimeter-wave devices), Clause 10 (ultra-wideband devices), Clause 11 (DTS devices), Clause 12 (U-NII devices), Clause 13 (devices using antenna arrays), Clause 14 (devices with multiple outputs) identify additional tests or requirements for specific types of unlicensed wireless devices, and Clause 15 (Whitespace devices). Clause 17 specifies requirements for reporting test results.

All annexes in this edition are informative however if applied during testing to this standard the information becomes normative for that particular instance where the annex is applied. Annex A is a listing of the tests required to determine compliance of a specific unlicensed wireless device and gives examples of regulatory band-edge requirements for various unlicensed wireless devices. Because Annex A describes regulatory requirements for testing of unlicensed wireless devices, it serves as a key to use of this standard. Annex B is an example of the information to be included in a test report. Annex C is a discussion on instrumentation pulse desensitization considerations. Annex D provides information about detector types and functions used in EMC testing. Annex E provides information about measurements above 1 GHz from an instrumentation perspective. Annex F is a discussion on broadband measurements. Annex G provides guidelines for effective radiated power (ERP) and equivalent isotropic radiated power (EIRP) measurements. Annex H discusses the rationale for making radiated emission measurements using two different methods. Annex I discusses site considerations for measuring inductive-loop devices below 1 MHz. Annex J provides details of an alternative procedure for determining compliance of unlicensed FM transmitters. Annex K provides details and information on Dynamic Frequency Selection (DFS) testing. Annex L is a discussion on FMCW desensitization and sweep time considerations. Finally, Annex M and Annex N provide an informative glossary and a bibliography, respectively.

Use of the annexes and clauses applicable to an unlicensed wireless EUT allows users of this standard to determine compliance of a device with regulatory requirements. However, any test procedure identified for use by the national regulatory authority that differs from the provisions of this standard shall take precedence.

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 can be applied to all devices within its scope and to supplement these methods with particular requirements for some types of devices. Device-specific requirements take precedence over general requirements. See Annex A for guidance in applying this standard to specific types of devices.

This document covers measurement methodologies but is not intended to describe regulatory limits.

As new measurement methods mature, this standard will be amended or a follow-up standard will be developed to present the new methods. It is also expected that the ASC C63® Committee that developed this standard will provide a forum for test laboratories, manufacturers, and government agencies to determine the need for additions and amendments of this standard to accommodate new wireless devices in the future.

1.3 Stating requirements and recommendations

For clarity in what is meant by the use of certain verbs in this standard, the following defines what each verb shown means:

- The word *shall* in this standard indicates a mandatory requirement that must be met to satisfy this standard. The word *shall* used in an informative annex indicates a mandatory requirement for the use of that annex (i.e., while the annex is not normative, if the user chooses to use it, then the mandatory requirements stated therein using the word *shall* must be observed).
- The word *should* is used to indicate recommendations.
- The word *may* is used to indicate that an action is permitted.
- The word *can* is used to express possibility.

NOTE—Use of these verbs follows the requirements in the IEEE Standards Board Operations and Style Manuals.

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 the text takes precedence over the figures, when a figure is identified by inclusion of the word “example” in the figure caption, because the text is complete and the figures are an illustration 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 clauses between a figure and its caption (i.e., the list clauses in Figure 5 through Figure 7).

Numbered cross-references used throughout this standard refer to either a specific clause or subclause of this standard; for example, 6 refers to Clause 6, 6.2 refers to subclause 6.2, and B.2 refers to subclause B.2 of Annex B.

1.4 Measurement uncertainty

The results of measurements of emissions from an unlicensed wireless device shall include measurement instrumentation uncertainty considerations contained in ANSI C63.23. For tests not covered by ANSI C63.23, ETSI TR 100 028-2001 may be used. Determining compliance shall be based on the results of the compliance measurement, not taking into account measurement instrumentation uncertainty. However, 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 measurement uncertainty shall appear in the test report.

1.5 Dimensional tolerances

Normative maximum tolerances on dimensional requirements specified in this standard (e.g., EUT spacing, dimensions, and distances) shall be as stated in Table 1. Any commercial measurement devices (e.g., ruler, tape measure) may be used for the distance measurement. No calibration is required for these devices. Good engineering judgement should be made on any dimensional requirement not covered in Table 1.

Nominal dimensions are those dimensions that are stated without a specified tolerance. Nominal dimensions are, by definition, required to have tolerances that are consistent with good engineering practice. In particular, the tolerances selected by the user should be small in comparison to the dimension itself.

Table 1—EUT spacing, distances, and tolerances

Reference	Element	Spacing/ distances	Tolerance ^a	Measurement
5.10.2, 6.2.3.2.2, 8.3, Figure 6	Spacing between any two elements on the EUT support table.	10 cm	±1.0 cm	Conducted and radiated
6.2.2 Figure 6	Vertical conducting plane to rear of EUT/AE/support table. In case of protruding connectors on the rear face of the EUT/AE, the separation distance requirement applies for the rear face of the EUT/AE, not considering the protruding connector/cable end.	40 cm	±1.0 cm	Conducted
6.2.2, Figure 5	Spacing between LISN and EUT	≥80 cm	*	Conducted
6.2.2, Figure 5	Spacing between LISN and local peripherals.	≥80 cm	*	Conducted and radiated
6.2.2, 6.2.3.1, 6.3.1, 6.6.3.1, 6.6.3.3	Height to the top of EUT support table	80 cm (below 1 GHz) 1.5 m (above 1 GHz)	±1.0 cm	Conducted and radiated
6.2.2, 6.2.3.1, 6.3.1	Table size for tabletop measurements	1.0 m × 1.5 m	Nominal value (may be larger or smaller to accommodate various sized EUTs)	Conducted and radiated
6.3.1 Figure 6	Spacing between: table-top EUT/peripheral cables or bundled EUT/peripheral cables draped over the back of the table; and the RGP	40 cm above the RGP	±4.0 cm	Conducted and radiated
6.3.1	Cable bundles	30 cm to 40 cm	*	Conducted and radiated
5.3, 6.6.5.2	Measurement distance	3 m to 10 m	±0 m, 1 m	Radiated
6.4.6, 6.5.2, 6.6.3.2, 6.11.2	Lowest antenna height above reflecting plane	1 m	−5 cm, +0 cm	Radiated

Table 1—EUT spacing, distances, and tolerances^a (continued)

Reference	Element	Spacing/ distances	Tolerance ^a	Measurement
6.5.2, 6.6.3.2	Highest antenna height above reflecting plane	4 m	−0 m, +5 cm	Radiated
6.2.3.3.1	insulating material thickness for cables that are normally insulated from the ground	>0 mm and ≤12 mm	*	Conducted and radiated
6.8, 9.5	Temperature settings during frequency stability testing	—	±2 °C	Conducted and radiated

^a Where a one-sided range is specified, the tolerance is 0% below the *greater than* value, and 0% above the *less than* value, and no specified tolerance on the other end. Where a two-sided range is specified, there is no tolerance on the upper value and lower value. Both these cases are designated with asterisks in this table.

2. Normative references

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

ANSI C63.2, American National Standard for Specifications of Electromagnetic Interference and Field Strength Measuring Instrumentation in the Frequency Range 9 kHz to 40 GHz—Specifications.³

ANSI C63.4, 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.

ANSI C63.4a, 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—Amendment 1: Test Site Validation.

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

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

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

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

ANSI C63.25.1, American National Standard Validation Methods for Radiated Emission Test Sites, 1 GHz to 18 GHz.

CISPR 16-1-1:2019, Specification for radio disturbance and immunity measuring apparatus and methods—Part 1-1: Radio disturbance and immunity measuring apparatus—Measuring apparatus.⁴

³ C63® publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

⁴ CISPR documents are available from the International Electrotechnical Commission (<http://www.iec.ch/>) and in the United States from the American National Standards Institute (<http://www.ansi.org/>).

CISPR 16-1-4:2019, Specification for radio disturbance and immunity measuring apparatus and methods—Part 1-4: Radio disturbance and immunity measuring apparatus—Antennas and test sites for radiated disturbance measurements.

ETSI TR 100 028 V1.3.1 (2001-03), Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics—Part 1 and Part 2.⁵

IEEE Std 1309-2013, IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz.^{6, 7}

ISO 10012:2003, edition 1, Measurement management systems — Requirements for measurement and measuring equipment.⁸

RSS-210, Licence-Exempt Radio Apparatus: Category I Equipment, Innovation, Science and Economic Development Canada.⁹

RSS-220, Devices Using Ultra-Wideband (UWB) Technology, Innovation, Science and Economic Development Canada.

RSS-247, Digital Transmission Systems (DTSSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices.

RSS-310, Licence-Exempt Radio Apparatus: Category II Equipment, Innovation, Science and Economic Development Canada.

RSS-Gen, General Requirements for Compliance of Radio Apparatus—Limits and Methods of Measurement.

U.S. Code of Federal Regulations Title 47—Telecommunication, Chapter I—Federal Communications Commission, Part 15—Radio Frequency Devices (47 CFR Part 15).¹⁰

3. Definitions, acronyms, and abbreviations

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. ANSI C63.14 and the *IEEE Standards Dictionary Online* should be referenced for terms not defined in this clause.¹¹ Definitions in wireless device product standards or regulations shall take precedence where applicable. See also the Glossary provided in Annex M, which includes various terms relevant for wireless devices compiled from the FCC, ITU, and other documents.

bin size: Frequency span divided by the number of trace points minus one on an instrument display.

calibration: Operation establishing the relation between quantity values provided by measurement standards and the corresponding indications of a measuring system, carried out under specified conditions including measurement uncertainty.

⁵ ETSI publications are available from the European Telecommunications Standards Institute (<http://www.etsi.org/>).

⁶ IEEE publications are available from The Institute of Electrical and Electronics Engineers (<http://standards.ieee.org/>).

⁷ The IEEE standards or products referred to in this clause are trademarks of The Institute of Electrical and Electronics Engineers, Inc.

⁸ ISO publications are available from the ISO Central Secretariat (<http://www.iso.org/>). ISO publications are also available in the United States from the American National Standards Institute (<http://www.ansi.org/>).

⁹ RSS publications are available from Innovation, Science and Economic Development Canada (http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf06129.html).

¹⁰ CFR publications are available from the U.S. Government Printing Office (<http://www.gpo.gov/>).

¹¹ The *IEEE Standards Dictionary Online* is available at <https://dictionary.ieee.org>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

continuous transmit mode: A mode in which the unlicensed wireless device is continuously transmitting at a 100% duty cycle.

NOTE—Where specified by the test requirements, a duty cycle of greater than 98% may be acceptable.

emission bandwidth (EBW): An unlicensed wireless device parameter determined by measuring the width of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, which are 26 dB down relative to the maximum level of the modulated carrier based on the use of measurement instrumentation employing a peak detector function with an instrument resolution bandwidth approximately equal to 1.0% of the emission bandwidth of the device under measurement. [47 CFR §§ 15.303(c), 15.403(i) – MOD]

NOTE—See also the similar but distinct terms and concepts authorized bandwidth, necessary bandwidth, and occupied bandwidth in Annex M.

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).

inductive-loop device: A low frequency unlicensed wireless device used for low frequency radio frequency identification (RFID) devices, access control card readers, electronic article surveillance, and so on, consisting of a simple inductive single-loop coil or co-planar phase aiding loops for generating a magnetic field.

intentional radiator: A device that intentionally generates and emits radio frequency energy by radiation or induction and can be operated with or without an individual license. *Syn:* **license-exempt transmitter; unlicensed wireless device.**

license-exempt transmitter: A device that intentionally generates and emits radio frequency energy by radiation or induction and can be operated with or without an individual license. *Syn:* **intentional radiator; unlicensed wireless device.**

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

NOTE—A LISN unit can contain one or more individual LISN circuits.¹²

occupied bandwidth: the bandwidth containing 99% of the total integrated power of the transmitted spectrum, centered on the assigned frequency.

peak power: Power measured with the peak detector using a filter with adequate bandwidth and shape to accept the signal bandwidth.

restricted-bands: Frequency bands in which fundamental emissions of an intentional radiator are not permitted.¹³ *Syn:* **exclusion bands.**

spectral plot: A graphical representation of the emissions in the frequency-domain showing the full spectrum measured over any given frequency range

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

¹³ See 47 CFR 15.205.

symbol rate: The rate at which the waveform changes per second using a digitally modulated signal. It is measured in baud or symbols per second for a modulated signal. Each symbol can represent or convey one or several bits of data. The reciprocal of the symbol rate is called the symbol period.

system: A configuration of interconnected devices, including accessories and peripherals, and their cables, which 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 (e.g., most personal computers).

test equipment: Equipment that is intended primarily for the purposes of performing measurements or scientific investigations. Such equipment includes, but is not limited to, field strength meters, spectrum analyzers, and modulation monitors.¹⁴

NOTE—Test equipment products that also contain unlicensed wireless device component(s) and/or function(s) are generally subject to applicable radio regulatory requirements.

unintentional radiator: A device that intentionally generates radio frequency (RF) energy for use within the device or that sends radio frequency signals by conduction to associated equipment via connecting wiring but that is not intended to emit radio frequency energy by radiation or induction.¹⁵

Unlicensed National Information Infrastructure (U-NII) device: Intentional radiator operating in the frequency bands 5.15 GHz to 5.25 GHz, 5.25 GHz to 5.35 GHz, 5.470 GHz to 5.725 GHz, and 5.725 GHz to 5.85 GHz that use wideband digital modulation techniques and provide a wide array of high data rate mobile and fixed communications for individuals, businesses, and institutions.

NOTE—A high data rate is defined as a bit rate of 1 Mbps or more.

unlicensed wireless device: (A) A low power communication device that intentionally generates and emits radio frequency energy by radiation or induction. These devices or systems typically can be operated without an individual license in some countries, provided they comply with certain technical and administrative requirements. **(B)** Device that is permitted to emit radio frequency (RF) energy but requires no specific device licensing or user authorization.¹⁶ *Syn:* **intentional radiator; license-exempt transmitter.**

NOTE—This term also is essentially the same as “short range device” used by various regulatory authorities.

3.2 Acronyms and abbreviations

ac	alternating current
AVG	average
dc	direct current
DFS	dynamic frequency selection
DTS	digital transmission system
EBW	emission bandwidth
EIRP	equivalent isotropically radiated power
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ERP	equivalent radiated power
EUT	equipment under test
FHSS	frequency hopping spread spectrum
GNSS	global navigation satellite system
GPR	ground-penetrating radar

¹⁴ 47 CFR 15.3(dd).

¹⁵ 47 CFR 15.3(z).

¹⁶ FCC/DA 03 1758 [B27].

IF	intermediate frequency
LISN	line impedance stabilization network
LPDA	log periodic dipole array
MIMO	multiple-input multiple-output
NSA	normalized site attenuation
OATS	open-area test site
OBW	occupied bandwidth
OET	Office of Engineering and Technology (FCC)
PDA	personal digital assistant
PK	peak
PRF	pulse repetition frequency
PDCF	pulse desensitization correction factor
PPSD	peak power spectral density
PSD	power spectral density
QP	quasi-peak
RBW	resolution bandwidth
RF	radio frequency
RFID	radio frequency identification
SA	Sample
SISO	single input single output
SPL	sound pressure level
TVWS	television whitespace
Tx	transmit
U-NII	Unlicensed National Information Infrastructure
UWB	ultra-wideband
VBW	video bandwidth
WIR	wall-imaging radar
WPT	wireless power transfer

4. Measurement instrumentation

4.1 Emission measuring instrumentation

4.1.1 General considerations

Use of proper measurement instrumentation is critical to obtaining accurate, reproducible results. Various equipment accessories and settings can be needed depending on the particular measurements to be performed, as described in 4.1.2 through 4.1.7.

This standard recognizes that both spectrum analyzers and electromagnetic interference (EMI) receivers can 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:

- ANSI C63.2
- CISPR 16-1-1:2019 (for measurements up to and including 18 GHz)

NOTE—ANSI C63.2 normatively references CISPR 16-1-1 for frequencies up to 18 GHz.

Typically a spectrum analyzer does not meet all the requirements stated in ANSI C63.2 or CISPR 16-1-1:2019 without additional accessories. Appropriate accessories, such as preselection, quasi-peak detection, and specific intermediate frequency (IF) filters, can be used with a spectrum analyzer; this combination can be equivalent to a receiver, meeting the requirements in either specification.

4.1.2 Receiver

The receiver for measurements of radiated and ac power-line conducted radio-noise is an instrument conforming to 4.1.1. Automatic scanning receivers may be used, but the maximum scan speed shall 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). Requirements for selecting the proper bandwidth are given in 4.1.5.

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

4.1.3 Spectrum analyzer

The use of spectrum analyzers for radiated and ac power-line conducted radio-noise compliance measurements are permissible only if they meet all specifications called out in the standards listed in 4.1.1.

To meet the requirements in 4.1.5, spectrum analyzers shall be equipped with proper quasi-peak and linear average detection. However, measurements with the positive peak detector of the instrument are permissible to demonstrate compliance of the EUT, as long as the required resolution bandwidth is used, because positive peak detection yields amplitudes equal to or greater than amplitudes measured with the quasi-peak or linear average detector. Thus, the data measured using the positive peak detector of a spectrum analyzer represents the worst-case results.

Nominal values for the resolution bandwidth shall be as specified in 4.1.5. Most spectrum analyzers implement a resolution bandwidth specification of -3 dB, with a Gaussian shape, which is acceptable because larger bandwidths are permissible. The resolution bandwidths cited in the standards listed in 4.1.1 do not have a Gaussian shape but are instead specified individually by their frequency response (i.e., “masks”). When using larger bandwidths than those specified, or filters with different transfer functions, different measurement results for broadband signals can be expected. In case of dispute, the test results measured with one of the reference receivers defined in 4.1.2 shall take precedence.

For a spectrum analyzer to meet the specifications of one of either of the two standards listed in 4.1.1, it shall 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 16-1-1:2019 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), then the use of a preselector is required to provide adequate dynamic range of the instrument.

When using spectrum analyzers for measurements, the following 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 the broadband input mixer. To avoid overload, to reduce the chance of damage, and to operate the 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.¹⁷ 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 greater external attenuator has been inserted at the input of the measuring instrument, or, if used, of the preamplifier. The new reading of the measuring instrument display, plus the inserted attenuation, shall differ by not more than ± 0.5 dB from the first reading for deeming the measuring system is linear; see ANSI C63.4-2014

¹⁷ 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.

Annex H.3 for details. In case of broadband time-variant signals and spread-spectrum signals, the linearity test may be performed by setting the analyzer in maximum hold with positive peak detector function, separately, for each one of the two measurements.

- c) **Normal response to pulses**—The response of a spectrum analyzer with quasi-peak detection shall be verified with the reference test pulses specified in CISPR 16-1-1:2019. The large peak voltage of the reference test pulses typically requires an insertion of RF attenuation of 40 dB or more to satisfy the linearity requirements. This decreases the instrumentation sensitivity and makes the measurement of low-repetition-rate and isolated test pulses impossible for CISPR bands B, C, and D.¹⁸ If a preselecting filter is used at the input of the spectrum analyzer, then 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 can be captured with positive 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 positive peak detection measurements can replace all or part of the measurements needed using quasi-peak or linear average detection. Retests using a quasi-peak or linear average detector shall then be made at frequencies where emission maxima have been found.
- e) **Linear average detection**—For spectrum analyzers not equipped with a linear average detector as specified in 4.1.5.2, an alternate method of linear average detection with a spectrum analyzer can be obtained by setting the detector mode to positive peak and reducing the video bandwidth until no significant variations in the displayed signal are observed from trace to trace; see 4.1.5.2.3 for a basic measurement procedure. The sweep time shall 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 shall be employed to achieve a maximum reading. After linear detection is made, the signal can be processed logarithmically for display, in which case, the value is corrected even though it is the logarithm of the linearly detected signal.
- f) **Voltage average detection**—For spectrum analyzers not equipped with a linear average detector as specified in 4.1.5.2, an alternative method of linear average detection for measurements with a spectrum analyzer can be obtained by setting the detector mode to peak and reducing the video bandwidth; see 4.1.5.2.3 for a basic measurement procedure.

NOTE 1—A logarithmic amplitude display mode may be used for investigation or exploratory purposes; 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. *This technique is useful for troubleshooting but cannot be used for compliance measurements.*

When performing final compliance measurements, the video bandwidth shall be set to a value lower than the lowest pulse repetition frequency of the measured signal, but not lower than 1 Hz, in accordance with CISPR 16-1-1:2019, so that the proper integration time is realized; H.5 in Annex H of ANSI C63.4-2014 provides other details.

NOTE 2—Notwithstanding the video bandwidth requirements of 6.4 of CISPR 16-1-1:2019, the measurement procedure standards CISPR 16-2-1:2014/AMD1:2017 [B6] (i.e., Annex D therein) and CISPR 16-2-3:2016 [B7] (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 6.4 of CISPR 16-1-1:2019 is specified to be the peak reading, the larger amplitude fluctuations that occur with the use of a higher-than-specified video bandwidth provides a conservative measurement result (i.e., higher emission level).

¹⁸ CISPR 16-1-1:2019 band B is 0.15 MHz to 30 MHz, and bands C and D are 30 MHz to 1000 MHz.

- g) **Selection of display mode**—For measurements with peak detector (e.g., where the limit is specified for peak detection), the positive peak detector shall be selected, so that the highest emission amplitudes are displayed.
- h) **Bin size**—When using a spectrum analyzer, its bin size shall be no larger than half the measurement (resolution) bandwidth when using anything other than peak detection.

NOTE—Bin size is specific to instruments having a digital display and describes the frequency resolution (horizontal resolution) of that instrument's display. The instrument determines the level to be displayed at each "trace point" by applying the selected detector function to all input signal samples within the "bin" corresponding to that "trace point". For example, positive peak detector function will select the input signal sample having the highest amplitude for display and discard all the other samples in that bin. As such, greater frequency accuracy is achieved by decreasing the span because the "bin" will include a larger number of samples. When using peak detection with a bin size $\gg$ RBW caution needs to be taken when determining the actual frequency of the emission and to ensure there are not multiple, high amplitude narrowband signals within a frequency bin by zooming in on the individual frequencies with span $> 2 \times$ bin size to more accurately determine frequency(ies) of signals in the original scan.

- i) When using the auto OBW function of an analyzer, the span setting must be sufficiently wide to include the entire signal being measured plus at least 5%. If this is not done, the OBW data may be incorrect.

4.1.4 FFT-based measurement instrument

Spectrum analyzers or EMI receivers equipped with FFT capabilities shall be compliant with the requirements stated in 4.1.1 in order to be considered acceptable for use.

4.1.5 Detector functions and selection of bandwidth

4.1.5.1 General considerations

Unless otherwise specified, EMI receivers or spectrum analyzers shall have the detector functions and bandwidths specified in either ANSI C63.2 or CISPR 16-1-1:2019 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 9 of CISPR 16-1-1:2019; 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 16-1-1:2019.
- A bandwidth correction factor shall be applied ONLY when broadband signal amplitudes are measured. The broadband correction factor (in dB) shall be calculated using the equation:

$$C_{BB} = 20 \log(B_{imp} / B_{meas})$$

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 item b) or item c).

Positive peak detector measured data may be substituted for the reference 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 bandwidth used shall be equal to or greater than that specified in ANSI C63.2 or CISPR 16-1-1:2019. 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 and/or to cover the complete frequency range of interest.

The measuring instrument shall satisfy the following provisions:

- The quasi-peak detector shall have a linear response.
- The average detector shall have a linear response and shall meet the linear average specifications in ANSI C63.2 or CISPR 16-1-1:2019. This is a voltage average detector. A logarithmic average detector or CISPR rms 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 be adequate to yield correct and calibrated results.

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.

4.1.5.2 Specific detector functions and bandwidths for unlicensed wireless device measurements

Measurement of conducted and radiated emissions from unlicensed wireless devices is based on the following considerations (4.1.5.2.1 to 4.1.5.2.8), unless otherwise specified elsewhere in this standard.

4.1.5.2.1 Frequencies less than or equal to 1000 MHz

At any frequency or frequencies less than or equal to 1000 MHz, measurements shall be made with the CISPR quasi-peak detector and related measurement bandwidths, unless otherwise specified. The specifications for the measuring instrument using the CISPR quasi-peak detector are given in

CISPR 16-1-1:2019. Where average limits are specified, an average detector shall be used. Where peak limits are also specified, proper corrections for factors such as a pulse desensitization shall be applied to the peak emission measurements.¹⁹ As an alternative to CISPR quasi-peak measurements or average measurements, a test laboratory may demonstrate compliance with the emission limits using measuring equipment employing a peak detector function as long as the equivalent or greater bandwidths as indicated for CISPR quasi-peak measurements or average measurements, as applicable, are employed.

Pulse-modulated devices with a pulse repetition frequency of 20 Hz or less have additional requirements.²⁰

4.1.5.2.2 Frequencies above 1000 MHz

Unless otherwise stated, on any frequency or frequencies above 1000 MHz, measurements shall be made with measurement instrumentation employing an average detector function.²¹ Unless otherwise specified,

¹⁹ See 47 CFR 15.35(b).

²⁰ Clause 4 of ANSI C63.4, as referenced by 47 CFR 15.35(a), provides additional guidance for the measurement of signals with a pulse repetition frequency of 20 Hz or less when CISPR quasi-peak measurements are specified.

measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. Peak measurements can apply to the total peak emission level radiated by the device (i.e., the total peak power level) depending on the applicable regulatory requirement. Note that the use of a pulse desensitization correction factor might be needed to determine the total peak emission level. See 4.1.5.2.7 and Annex C for more information and methods for determining pulse desensitization factors.

See 4.1.5.2.8 and Annex L for more information and methods for determining FMCW desensitization factors and suitable instrument sweep times when measuring FMCW emissions.

4.1.5.2.3 Average voltage measurements using spectrum analyzer reduced video bandwidth

When the spectrum analyzer is not equipped with an average detector (4.1.5.1), the following alternative method may be used for average voltage measurements:

- a) Tune the instrument to the signal of interest by setting its center frequency to the signal frequency. The resolution bandwidth shall be set according to the frequency of measurement.
- b) Set the spectrum analyzer frequency span to capture fully the emission that is to be measured while keeping the peak value of the measured signal in the center of the display.
- c) The display mode shall be set to a positive peak detector and the sweep time shall be auto-coupled.
- d) Set the instrument to perform video filtering in a linear (voltage) mode. For many instruments, this will require setting the vertical scale to linear and amplitude units to voltage (μV or $\text{dB}\mu\text{V}$). If the analyzer can set the video filter averaging type independently of the display settings, the average type shall be voltage average.²²
- e) Set the reference level of the instrument, as required, to reduce the chance of the signal exceeding the maximum spectrum analyzer input mixer level for linear operation. In general, the peak of the spectral envelope shall be at least $[10 \log (\text{OBW}/\text{RBW})]$ below the reference level (OBW is occupied bandwidth and RBW is resolution bandwidth). Specific guidance is given in 4.1.6.2.
- f) Reduce the video bandwidth until no significant variations in the displayed signal are observed in subsequent traces, provided the video bandwidth is no less than 1 Hz. For regulatory requirements that specify averaging only over the transmit duration (e.g., digital transmission system [DTS] and Unlicensed National Information Infrastructure [U-NII]), the video bandwidth shall be greater than $[1 / (\text{minimum transmitter on time})]$ and no less than 1 Hz. EUTs shall be operated with a maximum duty cycle which is representative of normal worst-case operating conditions or measured using a peak detector corrected with a duty cycle correction factor.
- g) Set the trace display for maximum hold until it is stabilized, then record the highest level.

This method yields the linear average value of signals at the input of a spectrum analyzer measured with a specified resolution bandwidth.

Additional details about the use of spectrum analyzers for average measurements are given for example in Linkwitz [B64].

²¹ If an average limit is specified for the EUT, then proper corrections for factors such as pulse desensitization and FMCW desensitization shall be applied to peak emission measurements, to demonstrate that the peak emission is less than 20 dB above the average limit per U.S./FCC regulations. [See 47 CFR 15.35(b).]

²² If unsure of the analyzer capabilities, then a check that the correct averaging is being performed using the reduced video filtering method can be made by measuring the peak and average values of a pulse-modulated carrier set for a 50% duty cycle, a period of approximately 2 ms, and an amplitude at least 40 dB above the instrument noise floor. Both peak and average measurements are made using a 1 MHz resolution bandwidth and a peak detector. The average measurement shall be performed using a video bandwidth of 1 Hz. The peak measurement shall be performed using a video bandwidth of at least 3 MHz. The difference between peak and average values of the signal should be ~ 6 dB if a linear voltage average is being performed. The difference will be 20 dB or more between peak and log-average measurement results. The verification should be performed using the same measurement control software used for subsequent EUT measurements.

NOTE—A logarithmic amplitude display mode may be useful, for example, to distinguish more easily between narrowband and broadband signals. A logarithmic amplitude display mode results in a larger attenuation of broadband signals than in the linear display mode without affecting the display of narrowband signals (assuming a 100% duty cycle). Therefore, video filtering in the log display mode is especially useful for determining the narrowband component in a spectrum containing both broadband and narrowband signals.

4.1.5.2.4 Using an external preamplifier with a spectrum analyzer or EMI receiver

Spectrum analyzers or EMI receivers may lack the appropriate sensitivity to perform EMI measurements, because of a higher instrument noise figure. Adding an external preamplifier to the measuring instrument serves as a method to improve the measurement system sensitivity. However, the dynamic range of the measurement system is affected, as well as the amplitude accuracy. In addition, overload requirements for the measuring instrument shall be accounted for, to avoid possible erroneous measurement results. Subclause J.2 in Annex J of CISPR 16-1-1:2019 describes detailed considerations for the best design of an emission test system which includes a measuring instrument and an external preamplifier.

The performance of the system, i.e., system noise level and overload capability, will depend on the characteristics of both the preamplifier and the measuring receiver; therefore, it is necessary to properly understand the linearity specifications of both the measuring instrument and the preamplifier. The guidance given in J.3 of Annex J of CISPR 16-1-1:2019 shall be followed. Proper precautions to avoid overload or saturation conditions during the measurement shall be taken, i.e., in the form of linearity checks of the system, as defined in J.3 of CISPR 16-1-1:2019. If a measuring instrument with fast Fourier transform (FFT) technology is used, specific requirements for overload detection shall be accounted for, as documented in J.4 of Annex J of CISPR 16-1-1:2019.

4.1.5.2.5 Average value of pulsed emissions

Unless otherwise specified, when the radiated emission limits are expressed in terms of the average value of the emission and pulsed operation is employed, the average measurement shall be determined from the peak field strength after correcting for the worst-case duty cycle as described in 7.5. The exact method of calculating the average field strength shall be included in the test report.

As an alternative the average value may be measured directly provided that the device is operating at, or above, the maximum operational duty cycle and the operational duty cycle is fixed through the protocol or device firmware. The averaging time shall be the period of the pulse train or 100 ms, whichever is the smaller.

Where required (e.g., some DTS and U-NII devices) the average value for devices with pulsed emissions must be measured over the on-time of the transmission. For these devices if the average value is measured with the device operating at a duty cycle of less than 100% the measured value must be corrected upwards based on the duty cycle during the measurement (refer to Clause 11 and Clause 12).

The average value may not be determined, except where explicitly allowed otherwise (e.g., for FHSS devices) by measuring the average value and then applying a duty factor correction to further reduce the measured value.

4.1.5.2.6 Measurement of power average (rms) emissions

For testing ultra-wideband systems and other systems that require average readings based on a power average (rms) value, a spectrum analyzer with a power average detector shall be used. The analyzer shall provide a means to record, store, and display the rms values across the desired band of operation. The analyzer bin size shall not exceed 50% of the measurement bandwidth.

4.1.5.2.7 Pulse desensitization

Some unlicensed wireless devices generate wideband emissions using extremely narrow pulses. Compliance measurements are typically performed with a receiver or spectrum analyzer. Depending on various factors (resolution bandwidth, pulse width, etc.), the spectrum analyzer might not display the true peak value of the measured emission. This effect, called “pulse desensitization,” relates to the capabilities

of the measuring instrument and to the characteristics of the emission. For the measurement and reporting of the true peak of pulsed emissions, it can be necessary to apply a pulse desensitization correction factor (PDCF) to the measured value. In other words, the test report shall include the true peak level of the emission when the limit is specified in terms of a peak emission, which can necessitate the use of a PDCF. See also Annex C concerning other pulse desensitization considerations.

NOTE 1—PDCF typically applies only to peak emission measurements. As an example, where a requirement specifies that a minimum 1 MHz resolution bandwidth is employed for emission measurements above 1000 MHz, when pulse widths are narrower than the inverse of the resolution bandwidth employed by a spectrum analyzer, the PDCF is applied to the peak level measured on the spectrum analyzer to compensate for the inability of the analyzer to respond fast enough to reflect the true peak power (i.e., the spectrum analyzer does not have sufficient bandwidth to measure all of the energy in the pulsed signal).

NOTE 2—PDCF typically is not applicable for ultra-wideband (UWB) device measurements; regulatory authorities might specify other measurement procedures for determining compliance with UWB regulations.

4.1.5.2.8 FMCW desensitization and sweep time

Some unlicensed wireless devices utilize FMCW modulation. As with pulse modulation, FMCW modulation can impact instrumentation accuracy due to the response of the RBW filter to the modulation. Additionally, there are sweep time constraints when measuring FMCW signals.

NOTE 1—FMCW modulation is often selected for radiolocation and material characterization applications.

Compliance measurements are typically performed with a receiver or spectrum analyzer. Depending on various factors (resolution bandwidth, instrument sweep time, FMCW Chirp Bandwidth, FMCW Chirp Time, etc.), the instrument might not display the true peak value or the true average value of the emission.

For peak emissions with a valid sweep time, this effect, called “FMCW desensitization,” relates to the capabilities of the measuring instrument and to the characteristics of the emission.

For the measurement of the true peak of FMCW emissions it shall be determined whether to apply an FMCW desensitization factor to the measured value.

For the measurement of the true average of FMCW emissions it shall be determined whether to utilize a very slow instrument sweep time relative to the period of the modulation.

See Annex L for information and methods for determining FMCW desensitization factors and suitable instrument sweep times.

Where harmonics of the FMCW signal are observed the Chirp Time will be the same as for the fundamental, while the Chirp BW will be N times larger than for the fundamental, where N is the harmonic number. For example, the Chirp BW of the 3rd harmonic will be 3 times the Chirp BW of the fundamental.

NOTE 2—A common means of generating an FMCW signal is to apply the FMCW modulation at a relatively low frequency and multiply it up to the fundamental operating frequency.

Where subharmonics of the FMCW signal are observed, the Chirp Time will be the same as for the fundamental while the Chirp BW will be N times smaller than for the fundamental, where N is the subharmonic number. For example, the Chirp BW of the 4th subharmonic will be 0.25 times the Chirp BW of the fundamental.

Thus, the FMCW Desensitization Factor will be different for each subharmonic, the fundamental, and each harmonic.

As the Chirp Time is the same for subharmonics, the fundamental and harmonics, the required instrument sweep time will be the same for all these classes of emissions.

4.1.6 Reference level, attenuation, and headroom

4.1.6.1 General considerations

For measurements where the bandwidth of the emission is greater than the resolution bandwidth of the measuring instrument, care must be taken to ensure that the input mixer of the instrument is operating in its linear region and is not saturating or clipping the signal.

For measurements where the bandwidth of the emission is less than or equal to the resolution bandwidth of the measuring instrument, it is generally sufficient that the peak of the displayed signal be less than the reference level, as long as the instrument attenuation is set to AUTO.

4.1.6.2 Setting the proper reference level and input attenuation

- a) Set attenuation to auto. (If finer control of attenuation is required to achieve a sufficiently low noise floor for out-of-band measurements, then manual setting of attenuation is permitted provided that the power level corresponding to the reference level setting specified below falls within the mixer level range recommended by the instrument manufacturer.)
- b) Set the reference level based on power measurements of the signal or by ensuring that the “head room” between the maximum spectrum level and the reference level is at least $[10 \log (99\% \text{ occupied bandwidth} / \text{RBW})]$. The nominal channel bandwidth or the emission bandwidth may be substituted for 99% occupied bandwidth in this formula, if a measurement of occupied bandwidth is not available.
 - 1) Additional headroom (i.e., higher reference level) equal to $[10 \log (1 / \text{duty cycle})]$ will be needed if the headroom calculation is based on power or spectrum measurements that are averaged across the ON/OFF cycle of the transmission. (For example, the reference level should be set 3 dB higher if the settings are based on power or spectrum measurements that are averaged across the ON/OFF cycles of a 50% duty cycle transmission.)
 - 2) For in-band measurements, the reference level is based on in-band power or maximum in-band spectrum level.
 - 3) The same reference level is also used for out-of-band measurements, unless a preselector attenuates the in-band signal sufficiently to justify a lower reference level.

4.1.7 RF power meter

A peak responding power meter and sensor, where permitted, may be used to measure the fundamental emission of the output power. When used, the video bandwidth of the combination of the power meter and sensor shall be greater than the occupied bandwidth of the unlicensed wireless device.

4.2 Line impedance stabilization network

A LISN having the impedance magnitude and phase angle listed in Table 2 and Table 3, and illustrated in Figure 1 and Figure 2 shall be used for ac power-line conducted emission measurements, except for in situ measurements (see 6.11.4) When the measuring instrument (receiver or spectrum analyzer) ports of the LISN are each terminated into an impedance of 50Ω , the characteristic impedance in Table 2 or Table 3 or both (based on the measurement frequency range of conducted emissions from the EUT) shall be present at the EUT ports of the LISN.

**Table 2—Impedance and tolerance specifications at LISN terminals
(without extension cord), 50 μH and 250 μH LISN**

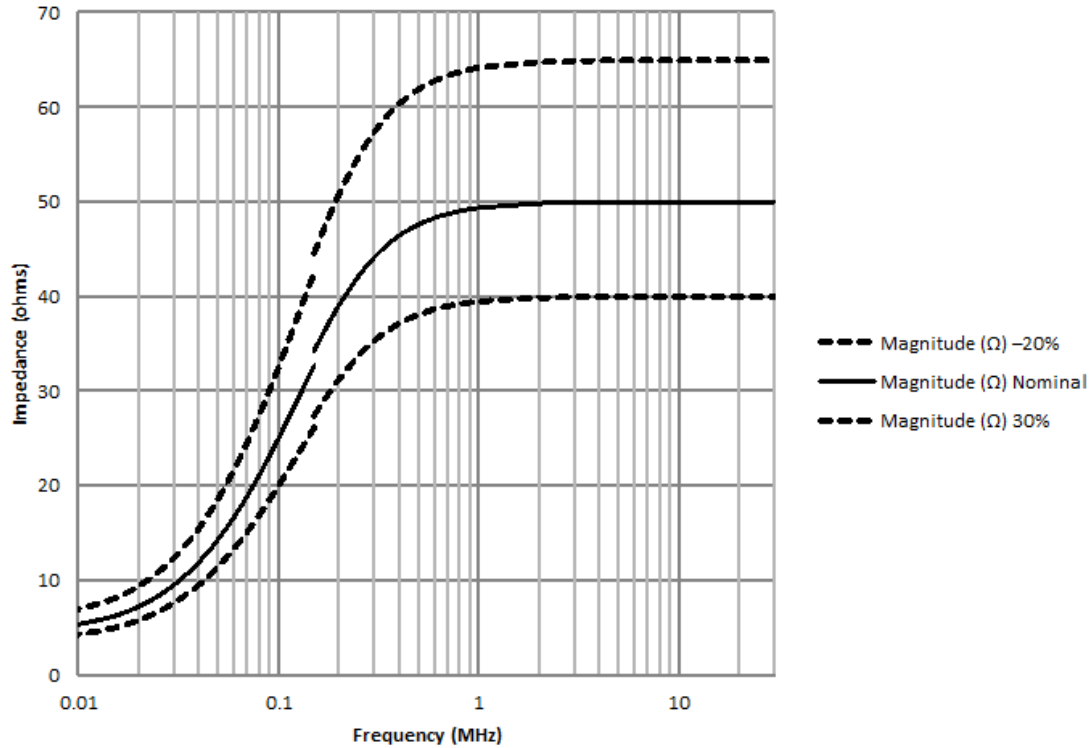
Frequency (kHz)	Magnitude (Ω)			Phase (degrees)		
	–20%	Nominal	+20%	–11.5°	Nominal	+11.5°
9	4.172	5.215	6.258	15.045	26.545	38.045
10	4.288	5.359	6.431	17.373	28.873	40.373
15	4.979	6.223	7.468	26.907	38.407	49.907
20	5.802	7.253	8.703	33.471	44.971	56.471
25	6.703	8.379	10.055	37.891	49.391	60.891
30	7.648	9.560	11.472	40.830	52.330	63.830
35	8.614	10.768	12.921	42.742	54.242	65.742
40	9.589	11.986	14.383	43.933	55.433	66.933
45	10.562	13.203	15.844	44.607	56.107	67.607
50	11.528	14.410	17.292	44.904	56.404	67.904
60	13.417	16.771	20.125	44.726	56.226	67.726
70	15.229	19.037	22.844	43.897	55.397	66.897
80	16.951	21.188	25.426	42.690	54.190	65.690
90	18.572	23.215	27.858	41.265	52.765	64.265
100	20.089	25.112	30.134	39.722	51.222	62.722
110	21.502	26.878	32.253	38.125	49.625	61.125
120	22.813	28.516	34.219	36.517	48.017	59.517
130	24.025	30.031	36.037	34.924	46.424	57.924
140	25.143	31.428	37.714	33.366	44.866	56.366
150	26.172	32.715	39.258	31.853	43.353	54.853

**Table 3—Impedance and tolerance specifications at LISN terminals
(without extension cord), 50 μH LISN**

Frequency (MHz)	Magnitude (Ω)			Phase (degrees)		
	–20%	Nominal	+20%	–11.5°	Nominal	+11.5°
0.15	27.435	34.293	41.152	35.196	46.696	58.196
0.16	28.359	35.449	42.539	33.348	44.848	56.348
0.17	29.200	36.500	43.801	31.613	43.113	54.613
0.18	29.966	37.458	44.949	29.983	41.483	52.983
0.19	30.664	38.329	45.995	28.451	39.951	51.451
0.20	31.299	39.124	46.949	27.012	38.512	50.012
0.25	33.743	42.178	50.614	20.982	32.482	43.982
0.30	35.335	44.169	53.003	16.447	27.947	39.447
0.35	36.412	45.515	54.618	12.953	24.453	35.953
0.40	37.166	46.458	55.749	10.197	21.697	33.197
0.45	37.711	47.139	56.566	7.978	19.478	30.978
0.5	38.116	47.645	57.173	6.157	17.657	29.157
0.6	38.663	48.329	57.994	3.356	14.856	26.356
0.7	39.005	48.756	58.507	1.309	12.809	24.309
0.8	39.231	49.039	58.847	–0.248	11.252	22.752
0.9	39.389	49.236	59.083	–1.472	10.028	21.528
1	39.503	49.379	59.254	–2.457	9.043	20.543
2	39.874	49.842	59.811	–6.950	4.550	16.050

**Table 3—Impedance and tolerance specifications at LISN terminals
(without extension cord), 50 μ H LISN (*continued*)**

Frequency (MHz)	Magnitude (Ω)			Phase (degrees)		
	–20%	Nominal	+20%	–11.5°	Nominal	+11.5°
3	39.944	49.930	59.916	–8.463	3.037	14.537
4	39.968	49.960	59.953	–9.221	2.279	13.779
5	39.980	49.975	59.970	–9.677	1.823	13.323
6	39.986	49.982	59.979	–9.981	1.519	13.019
7	39.990	49.987	59.984	–10.198	1.302	12.802
8	39.992	49.990	59.988	–10.360	1.140	12.640
9	39.994	49.992	59.991	–10.487	1.013	12.513
10	39.995	49.994	59.992	–10.588	0.912	12.412
11	39.996	49.995	59.994	–10.671	0.829	12.329
12	39.996	49.996	59.995	–10.740	0.760	12.260
13	39.997	49.996	59.996	–10.799	0.701	12.201
14	39.997	49.997	59.996	–10.849	0.651	12.151
15	39.998	49.997	59.997	–10.892	0.608	12.108
16	39.998	49.998	59.997	–10.930	0.570	12.070
17	39.998	49.998	59.997	–10.964	0.536	12.036
18	39.998	49.998	59.998	–10.993	0.507	12.007
19	39.999	49.998	59.998	–11.020	0.480	11.980
20	39.999	49.998	59.998	–11.044	0.456	11.956
21	39.999	49.999	59.998	–11.066	0.434	11.934
22	39.999	49.999	59.998	–11.086	0.414	11.914
23	39.999	49.999	59.999	–11.104	0.396	11.896
24	39.999	49.999	59.999	–11.120	0.380	11.880
25	39.999	49.999	59.999	–11.135	0.365	11.865
26	39.999	49.999	59.999	–11.149	0.351	11.851
27	39.999	49.999	59.999	–11.162	0.338	11.838
28	39.999	49.999	59.999	–11.174	0.326	11.826
29	39.999	49.999	59.999	–11.186	0.314	11.814
30	39.999	49.999	59.999	–11.196	0.304	11.804



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

Figure 1—Example impedance characteristics of LISN port 9 kHz to 30 MHz

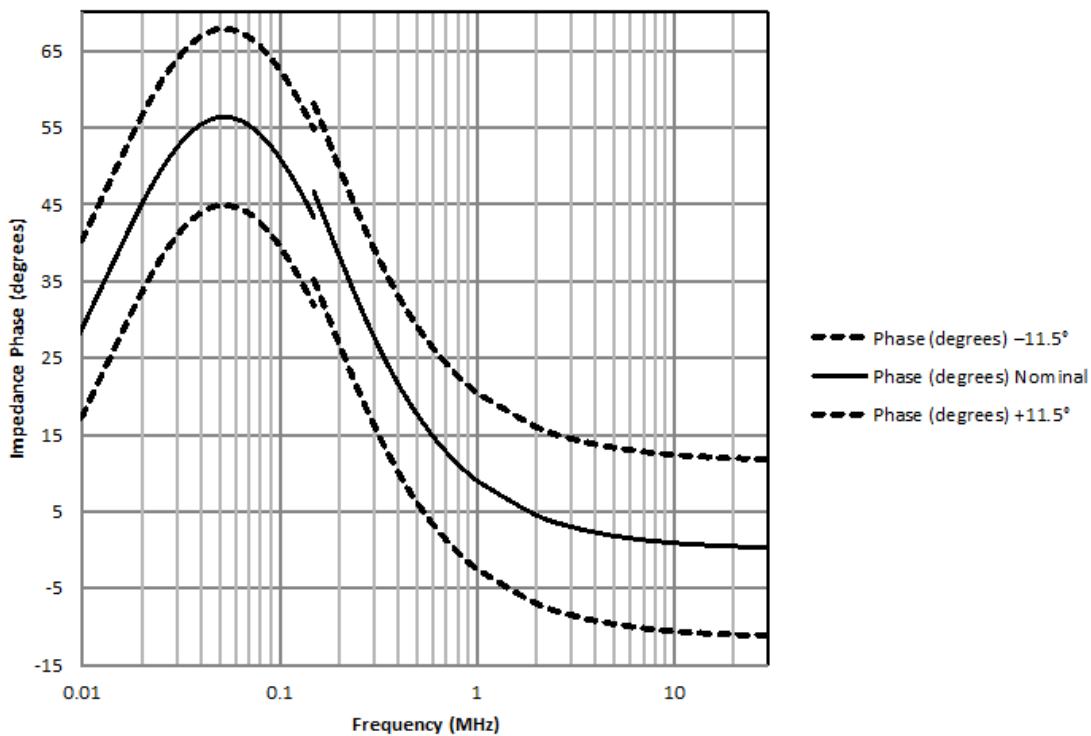


Figure 2—Example phase characteristics of LISN port 9 kHz to 30 MHz

The required nominal impedance values (magnitude and phase) were derived from idealized LISN circuits: $50\ \Omega$ in parallel with a series combination of $5\ \Omega$ and $50\ \mu\text{H}$, for the 9 kHz to 150 kHz frequency range, and $50\ \Omega$ in parallel with $50\ \mu\text{H}$, for the 150 kHz to 30 MHz frequency range. Figure 3 and Figure 4 illustrate two circuits that when carefully constructed can provide the impedance characteristics of Figure 1 and Figure 2.

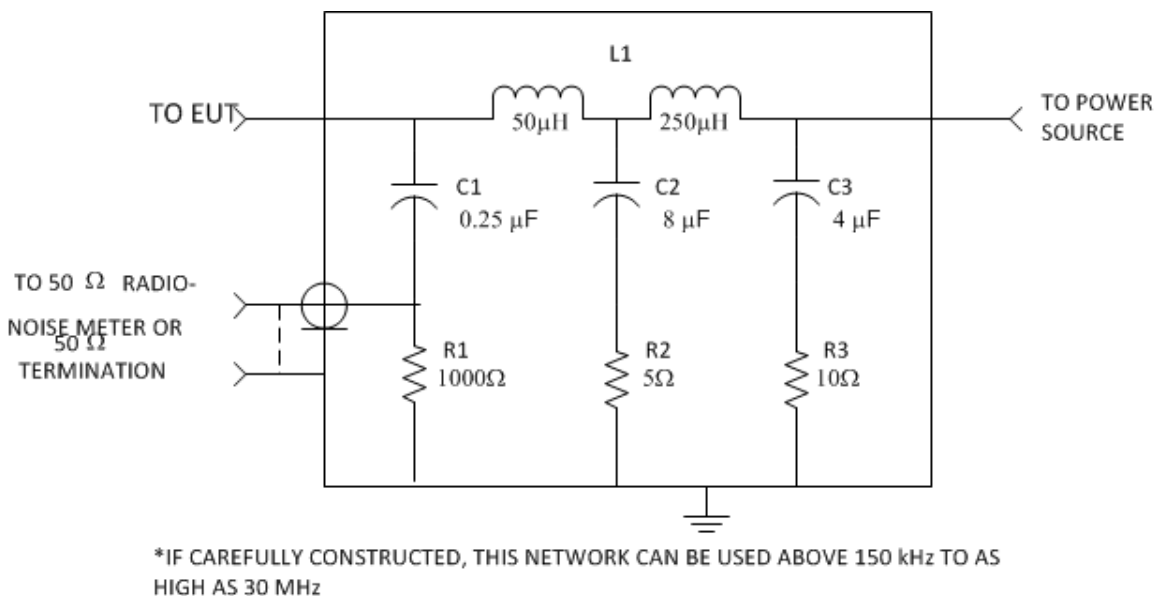
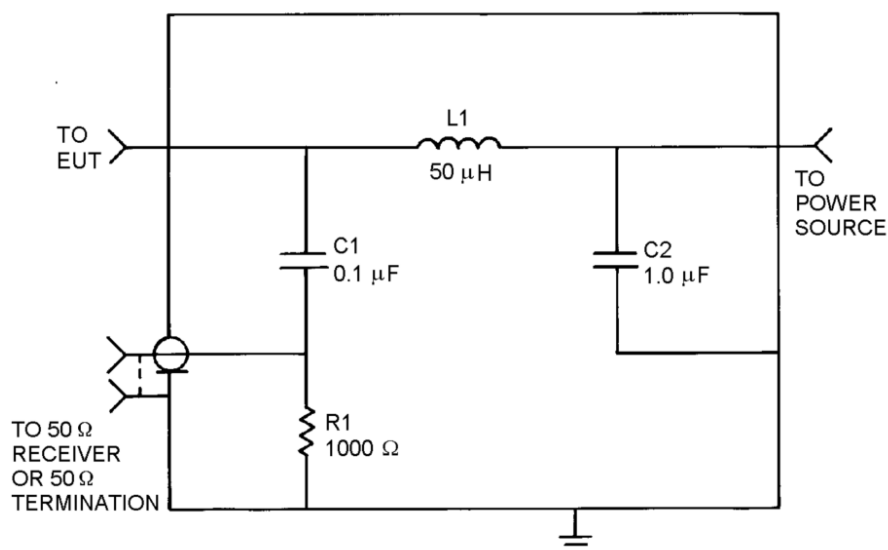


Figure 3—Example circuit diagram of LISN to provide impedance of Figure 1 for the 9 kHz to 150 kHz (30 MHz²³) frequency range



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

Figure 4—Example circuit diagram of LISN to provide impedance of Figure 1 for the 150 kHz to 30 MHz frequency range

²³ Some LISN designs and implementations support use of the Figure 4 circuit up to 30 MHz without impedance resonances or anomalies.

The LISN impedance shall not deviate from the nominal values listed in Table 2 or Table 3 or both (and plotted in Figure 1 and Figure 2), as applicable, by more than $\pm 20\%$ (for the LISN impedance magnitude), and $\pm 11.5^\circ$ (for the LISN impedance phase), at the LISN's EUT terminals.

The insertion loss of the LISN (from its EUT port to the coaxial measurement port), taken from the calibration certificate of the LISN, shall be used for correcting the measurement result before comparing with the applicable limit at each frequency of measurement.

Where specific equipment requirements specify another LISN, the specified LISN shall be used.

4.3 Antennas

4.3.1 General requirements

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 4.3.2 through 4.3.4. Antennas shall be calibrated in accordance with ANSI C63.5.

NOTE—Users of ANSI C63.10 are especially recommended to pay careful attention to the scope and content of Table 4 through Table 9.

4.3.1.1 Antennas for exploratory and relative-comparison evaluation measurements

Table 4, Table 5, and Table 6 provide 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 4, Table 5, and Table 6 identify the typical frequency ranges over which these antennas operate and provide normative footnotes regarding special considerations in their use. *Antenna types other than those specifically listed in Table 4, Table 5, and Table 6 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 4—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (below 30 MHz)

#	Antenna types	Footnotes
3	Passive loop	
4	Active loop	^a

^a When an active antenna is used for exploratory or relative-comparison measurements, users are cautioned to verify whether the ambient and/or measured signals are causing the preamplifier portion of the active 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. It is further recommended that only active antennas equipped with an operating saturation indicator are used, and the saturation indicator is monitored during the course of the testing to help ensure it does not indicate saturation.

Table 5—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (30 MHz to 1000 MHz)

#	Antenna types	Footnotes
1	Resonant tuned dipole (passive)	
2	Biconical dipole (50 Ω or 200 Ω balun)	
3	Log-periodic dipole array (LPDA)	
4	Hybrid (bicon/log)	
5	Double-ridged guide horn (passive)	a, b

^a 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.

^b The largest aperture dimension, D , of these horn antennas (i.e., length or width; in meters) should be small enough so that the measurement distance (in meters) is equal to or greater than the Rayleigh distance (i.e., $R_m = D^2 / 2\lambda$), where λ is the free-space wavelength (in meters) at the frequency of measurement.

Table 6—Radiated emissions antennas for exploratory and/or relative-comparison evaluation purposes (1 GHz to 40 GHz)

#	Antenna types	Footnotes
1	Resonant tuned dipole (passive)	a, b
2	Biconical dipole (50 Ω or 200 Ω balun)	a, b
3	Precision broadband omnidirectional biconical dipole	c
4	Log-periodic dipole array (LPDA)	a, b
5	Hybrid (bicon/log)	
6	Waveguide horn	d
7	Double-ridged guide horn (passive)	a, d
8	Double-ridged guide horn (active)	a, d, e

^a 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.

^b 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.

^c Precision broadband omnidirectional (biconical) antennas should only be used if they comply with the constructional and pattern requirements specified in 7.4.2 of CISPR 16-1-4:2019.

^d The largest aperture dimension, D , of these horn antennas (i.e., length or width; in meters) should be small enough so that the measurement distance (in meters) is equal to or greater than the Rayleigh distance (i.e., $R_m = D^2 / 2\lambda$), where λ is the free-space wavelength (in meters) at the frequency of measurement.

^e When an active antenna is used for exploratory or relative-comparison measurements, users are cautioned to verify whether the ambient and/or measured signals are causing the preamplifier portion of the active 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. It is further recommended that only active antennas equipped with an operating saturation indicator are used, and the saturation indicator is monitored during the course of the testing to help ensure it does not indicate saturation.

4.3.1.2 Antennas for final compliance measurements

Table 7, Table 8, and Table 9 contains the complete list of antennas that are permitted to be used for making *final compliance measurements (including emission maximization measurements)* for this standard and identify the frequency ranges over which those antennas are permitted to operate when making final compliance or emission maximization measurements. *Only the antenna types specifically listed in Table 7, Table 8, and Table 9 and used in the frequency ranges listed for their operation in Table 7, Table 8, and Table 9 (and used in a manner consistent with the normative footnotes in Table 7, Table 8, and Table 9) shall be used for making emission maximization and final compliance measurements.*

Table 7—Radiated emissions antennas for use in making final compliance measurements on devices (9 kHz to 30 MHz)

#	Antenna types	Footnotes
3	Passive loop ^a	
4	Active loop ^a	b

^a When E-field measurements are required to be made, antenna factors shall be converted to E-field values assuming a free-space impedance of 377 Ω .

^b The use of an active antenna for final compliance measurements on devices is permitted ONLY if the active 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.

Table 8—Radiated emissions antennas for use in making final compliance measurements on devices (30 MHz to 1000 MHz)

#	Antenna types	Footnotes
1	Resonant tuned dipole (passive)	
2	Biconical dipole (50 Ω or 200 Ω balun)	
3	Log-periodic dipole array (LPDA)	
4	Hybrid (bicon/log)	a, b

^a See Annex N of ANSI C63.4-2014 for the site-specific hybrid antenna qualifications that shall 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.

^b If a hybrid antenna impedance matching pad (HAIMP) attenuator was used during the site-specific hybrid antenna qualification procedure detailed in Annex N of ANSI C63.4-2014, 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 9—Radiated emissions antennas for use in making final compliance measurements on devices (1 GHz to 40 GHz)

#	Antenna types	Footnotes
1	Precision broadband omnidirectional biconical dipole	a
2	Log-periodic dipole array (LPDA)	b
3	Hybrid (bicon/log)	b, c, d
4	Waveguide horn	e
5	Double-ridged guide horn (passive)	e
6	Double-ridged guide horn (active)	e, f

- ^a The use of precision broadband omnidirectional (biconical) antennas is permitted when making final compliance measurements on devices ONLY if they comply with the constructional and pattern requirements specified in 7.4.2 of CISPR 16-1-4:2019. No other types of biconical antennas shall be used above 1 GHz for making final compliance measurements.
- ^b Users of LPDA and hybrid 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 or hybrid 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.
- ^c See Annex N of ANSI C63.4-2014 for the site-specific hybrid antenna qualifications that shall 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 of ANSI C63.4-2014 is deemed to be suitable for use on that same test site from 1 GHz upwards to its highest frequency of operation.
- ^d If a hybrid antenna impedance matching pad (HAIMP) attenuator was used during the site-specific hybrid antenna qualification procedure detailed in Annex N of ANSI C63.4-2014, 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.
- ^e The largest aperture dimension, D , of these horn antennas (i.e., length or width; in meters) shall be small enough so that the measurement distance (in meters) is equal to or greater than the Rayleigh distance (i.e., $R_m = D^2 / 2\lambda$), where λ is the free-space wavelength (in meters) at the frequency of measurement.
- ^f The use of an active horn antenna is permitted for final compliance measurements on devices; however, users shall verify whether the ambient and/or EUT 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.

4.3.2 Magnetic field measurements (9 kHz to 30 MHz)

Either passive loop antennas or active loop antennas, as specified in Table 4 and Table 7 and/or CISPR 16-1-4:2019 shall be used to measure magnetic fields in the frequency range of 9 kHz to 30 MHz. See Table 7 for applicable conditions of use of loop antennas.²⁴

4.3.3 Electric field measurements (30 MHz to 1000 MHz)

Linearly polarized antennas, as specified in Table 5 and Table 8, shall be used to measure electric field strengths in the frequency range of 30 MHz to 1000 MHz (see also CISPR 16-1-4:2019). Specifically, tunable dipole antennas, biconical dipole antennas, log-periodic dipole array (LPDA) antennas, and hybrid antennas may be used. However, hybrid antennas can be used only if the requirements of either one of the two procedures specified in Annex N of ANSI C63.4-2014 are satisfied. See Table 5 and Table 8 for the applicable conditions of use for tunable dipole antennas, biconical dipole antennas, LPDA antennas, and hybrid antennas.

²⁴ For the United States, the regulatory limits below 30 MHz are in terms of $\mu\text{V/m}$. By convention, magnetic field strength is converted to an electric field strength based on free-space impedance [$\mu\text{V/m} = (1 / 377 \Omega) \times 1 \mu\text{A/m}$].

NOTE—Some regulatory and purchasing agencies may require the use of a reference antenna (i.e., tunable dipole as described in 6.2, Annex C, and Annex D of ANSI C63.5-2017) for measurements of radiated emissions.

4.3.4 Electric field measurements (above 1 GHz)

Linearly polarized antennas, as specified in Table 6 or Table 9, as applicable, and calibrated in accordance with ANSI C63.5, shall be used (see also CISPR 16-1-4:2019). 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, which shall be taken as the half-power (−3 dB) beamwidth of the antenna, shall be large enough to encompass the physical size of the EUT, or system arrangement, in both width and height, when located at the measuring distance, in each antenna polarization used for measurements, or otherwise the measurement procedure detailed in 6.6 shall be employed.

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 distance (i.e., $R_m = D^2 / 2\lambda$), where D is the largest linear dimension (i.e., width or height) of the antenna aperture in m and λ is the free-space wavelength in meters at the frequency of measurement. The same requirement applies for the other types of antennas mentioned above, but in that case D is the largest dimension of the antenna elements active at the frequency of measurement. In case of dispute, measurements made with a standard-gain horn antenna shall take precedence.

4.4 Calibration of measuring equipment

4.4.1 General requirements

All measurement equipment, instruments, and corresponding ancillary equipment (e.g., cables), including all ancillary equipment within the signal path used for measurements made as specified in this standard shall be calibrated. 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.

4.4.2 Confirmation interval

The calibration of all instruments, measurement equipment, and ancillary equipment 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. Other requirements may also apply, such as CISPR 16-1-1:2019 or ANSI C63.2 for the measurement instrument. All instruments, measurement equipment, and ancillary equipment in the measurement path 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 in, and shall be checked using the methods in ANSI C63.5 methods at least every 3 years.

4.4.3 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 5.2) and antennas used for performing S_{VSWR} measurements for test site validation above 1 GHz (see 5.2). Antennas shall be recalibrated at regular intervals (i.e., periodically recalibrated) as described in 4.4.2 and recalibrated after repair or 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 5.2) and complying with the constructional and pattern requirements specified in 7.4.2 of CISPR 16-1-4:2019 need not be periodically recalibrated, unless damage or deterioration is suspected or known to have occurred.

Loop antennas used for radiated emission measurements below 30 MHz shall be calibrated in accordance with Annex N of ANSI C63.5-2017 and their calibration shall be confirmed at regular intervals as described in 4.4.2.

NOTE—Annex N of ANSI C63.5-2017 is informative. However, that annex is made normative for calibrating the loop antenna for use in measurements according to ANSI C63.10, by the use of “shall” in the above paragraph.

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, over the required frequency range, and the calibration certificate (report) shall include the calibration measurement uncertainty.

4.4.4 LISN impedance and insertion loss measurements

The attenuation (insertion loss) between the EUT receptacle and the measuring instrument port on the LISN shall be accounted for when calculating the EUT emission levels, at each frequency of measurement. The impedance and insertion loss of each LISN used in conducted emissions testing shall be measured over the frequency range of use. 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 ANSI C63.4-2014 Annex B, which also includes the requirements the LISN impedance shall comply with (nominal impedance magnitude and phase values and maximum tolerances).—The LISN shall be checked routinely to confirm acceptable performance; see 4.4.2.

NOTE—It is suggested that the insertion loss measurement be carried out after the completion of the impedance measurements.

4.4.5 Insertion loss of passive devices and preamplifier gain

The insertion loss of passive devices included in the measurement path (such as cables, attenuators, directional couplers, and filters), as well as the gain of preamplifiers used for connection of antennas or transducers to measuring instruments (e.g., EMI receivers, spectrum analyzers) shall be characterized over the used frequency range and the calibrated loss or gain factor shall be applied for correcting the measurement result before comparing with the applicable limit, at each frequency of measurement.

Passive components (such as cables, attenuators, filters, couplers, adapters) shall be checked frequently for deterioration caused by use and environmental exposure (e.g., variation due to change in temperature and damage). Published data²⁵ 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 loss characterization of the passive component and product testing shall be recorded. When the temperature change exceeds 15 °C, the passive device characterization(s) shall be repeated.

²⁵ For example, see http://www.gore.com/en_xx/products/cables/microwave/changes_insertion_loss_phase.html.

5. General measurement and setup considerations

5.1 General requirements

The information in this clause shall be used in conjunction with the standard test methods of Clause 6, and the device-specific test methods of Clause 7 through Clause 15, as applicable for a specific EUT. Users of this standard shall apply the information of this clause when testing unlicensed wireless devices, particularly those using new technologies.²⁶

5.2 Radiated emission test site

Radiated emission test sites below 30 MHz shall be free from metal objects, buried pipes, and any objects that can affect radiated measurements. An alternative test site that can demonstrate equivalence to a test site as described in the preceding sentence shall be accepted for the purposes of this standard.

Field strength measurements from 30 MHz up to and including 1 GHz shall be made on a test site meeting the requirements for an acceptable site as defined in ANSI C63.4-2014 as modified by ANSI C63.4a-2017 or any later versions of ANSI C63.4 that incorporate the text of C63.4a-2017.^{27, 28} Guidance for constructing a test site meeting these requirements is provided in ANSI C63.7.

For measurements from 1 GHz to 40 GHz, the test site shall conform to the site validation criteria called out in ANSI C63.25.1 over the frequency range 1 GHz to 18 GHz. Site validation measurements shall be made at heights that encompass the range of EUT heights to be evaluated.

NOTE 1—The requirements of ANSI C63.25.1 permit the use of CISPR 16-1-4:2019 as an acceptable methodology for validating at test site from 1 GHz to 18 GHz.

For measurements above 40 GHz, every attempt shall be made to reduce contributions from reflections to a minimum.

Site validation measurements shall be made at heights that encompass the range of EUT heights to be evaluated when tests are conducted on an alternative test site and volumetric NSA is required.

NOTE 2—In the case of an unlicensed wireless device for which measurements can be performed only at the installation site, such as perimeter protection systems, carrier current systems, and systems employing a “leaky” coaxial cable as an antenna, some regulatory or purchasing agencies might specify that measurements should be performed at a minimum of three installations that can be demonstrated to be representative of typical installation sites.

5.3 Radiated emission test distance

5.3.1 General requirements

To the extent practicable, the EUT shall be measured at the distance at which the limits applicable for the EUT are specified; the following subclauses provide other details. Only unlicensed wireless devices that physically cannot be tested at a test site that meets the criteria of ANSI C63.4, at the discretion of the regulatory authority, may be permitted to be tested in situ. The distance specified corresponds to the horizontal distance between the measurement reference point of the measurement antenna and the closest

²⁶ For the United States, many of the general requirements for unlicensed wireless devices in this clause are contained in 47 CFR 15.31.

²⁷ For the United States, an unlicensed wireless device might require special authorization for testing on an open field test site (see 47 CFR 2.805 [B71] and 47 CFR 5 subpart G [B72]).

²⁸ For the United States, see 47 CFR 15.31 for additional guidance regarding test sites.

point of the EUT, support equipment, or interconnecting cables, as determined by the boundary defined by an imaginary straight line periphery describing a simple geometric configuration enclosing the system containing the EUT. The EUT, support equipment, and any interconnecting cables shall be included within this boundary.

5.3.2 Test distance for frequencies below 30 MHz

Radiated emissions limits are usually defined at a specific distance from the EUT. Where possible, measurements shall be made at the distance specified in the limits. This might not be possible in all cases, however, due to the physical limitations of the test facility, physical access problems at the required distance (especially for measurements that must be made in situ or on-site), or levels of ambient noise or other radiated signals present at the time and location where measurements are made. See 6.4.3 for more information about antenna selection, location, and test distance. If measurements cannot practically be made at the EUT limit distance, then they may be made at a different distance (usually closer) and extrapolated to the limit distance using one of the procedures described in 6.4.4, 6.4.5, or 7.7, depending on the EUT source and size.²⁹ The test report shall specify the extrapolation method used to determine compliance of the EUT.

5.3.3 Test distance for frequencies at or above 30 MHz

Measurements may be performed at a distance other than the limit distance provided they are not performed in the near-field, and the emissions to be measured can be detected by the measurement equipment (see 4.3.4). Measurements shall not be performed at a distance greater than 30 m for frequencies above 30 MHz, unless it can be further demonstrated that measurements at a distance of 30 m or less are impractical. Measurements from 18 GHz to 40 GHz are typically made at distances significantly less than 3 m from the EUT. When performing measurements at a distance other than that specified, the results shall be extrapolated to the specified distance using an extrapolation factor of 20 dB/decade of distance (inverse of linear distance for field strength measurements or inverse of linear distance squared for power density measurements).

NOTE—Instrumentation capabilities can preclude preliminary scans at 3 m from 18 GHz to 40 GHz, but every attempt should be made to make final measurements at a 3 m distance in this frequency range. Measurements in the frequency range above 40 GHz are typically made at a closer distance because the instrumentation noise floor is typically close to the radiated emission limit.

5.4 Measurements around the EUT

Measurements shall be made at a test site that incorporates a turntable allowing EUT rotation of 0° through 360°, except where the EUT is so large that a suitable turntable is not readily available. A remotely controlled turntable shall be installed at the test site to support the EUT and facilitate determination of the direction of maximum radiation for each EUT emission frequency. Continuous azimuth searches shall be made. The maximum field strength at the frequency being measured shall be reported in the test report.³⁰ See ANSI C63.4 for details of the test site, turntable, and antenna positioner.

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 with 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.

NOTE—Some unlicensed wireless devices require specific azimuth increments, as described in the specific subclause in this standard for those unlicensed wireless devices (e.g., see 6.11.1, 7.7.3, and 8.4.3).

²⁹ The use of the procedures in 6.4.4, 6.4.5, and 7.7 are at the discretion of the regulatory authority.

³⁰ See 47 CFR 15.31(f)(5).

5.5 Frequency range of radiated emission measurements

Unless otherwise noted for a specific unlicensed wireless device, the spectrum shall be investigated from the lowest radio frequency signal generated in the device and up to at least the frequency shown in Table 10.³¹ However, frequencies below 9 kHz do not need to be investigated.

If the unlicensed wireless device contains a digital device, regardless of whether this digital device controls the functions of the unlicensed wireless device or the digital device is used for additional control or function purposes other than to enable the operation of the unlicensed wireless device, unless otherwise specified by the regulatory agency, then the frequency range shall be investigated up to the range specified in Table 10 or the range applicable to the digital device as specified by the regulatory authority, whichever is the highest frequency range of investigation.

Particular attention shall be paid to harmonic and subharmonic emissions of the fundamental frequency, as well as to those frequencies removed from the fundamental by multiples of the oscillator frequency. Radiation at the frequencies of all oscillators and harmonics thereof shall also be checked.

Table 10—Frequency range of measurements for unlicensed wireless device

Lowest frequency generated in the device	Upper frequency range of measurement
9 kHz to below 10 GHz	10th harmonic of highest fundamental frequency or to 40 GHz, whichever is lower
At or above 10 GHz to below 30 GHz	5th harmonic of highest fundamental frequency or to 100 GHz, whichever is lower
At or above 30 GHz	5th harmonic of highest fundamental frequency or to 200 GHz, whichever is lower, unless otherwise specified

5.6 Number of fundamental frequencies to be tested in EUT transmit band

5.6.1 General requirement

Measurements of unlicensed wireless devices shall be performed and, if required, reported for each band in which the EUT can be operated with the device operating at the number of frequencies in each band specified in Table 11.³²

Table 11—Number of frequencies to be tested

Frequency range in which device operates	Number of frequencies	Location in frequency range of operation
1 MHz or less	1	Middle
1 MHz to 10 MHz	2	1 near top and 1 near bottom
More than 10 MHz	3	1 near top, 1 near middle, and 1 near bottom

5.6.2 Test channels and test modes (streamline test requirements)

Measurement of all modes and all channels is not always necessary to demonstrate compliance³³. Subclauses 5.6.2.1 and 5.6.2.2 describe cases where testing can be reduced.³⁴ Reductions in the requirement to report test results found in Clause 17 do not constitute a reduction in the actual testing required by this subclause.

³¹ See 47 CFR 15.33(a).

³² See 47 CFR 15.31(m).

³³ Although this clause outlines test reductions for demonstrating compliance, it is the manufacturers' responsibility to ensure that the device under test complies with the regulatory requirements under all modes of operation.

³⁴ For tests on other than U-NII and DTS devices, use of the procedures in 0 is at the discretion of the regulatory authority.

5.6.2.1 Channel bandwidth

The number of channels tested can be reduced by measuring the center channel bandwidth first and then applying the following relaxations as appropriate, which only applies when a regulatory limit on the channel bandwidth is specified:

- a) For each operating mode, if the measured channel bandwidth on the middle channel is at least 150% of the minimum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.
- b) For multiple-input multiple-output (MIMO) systems, if the measured channel bandwidth on the middle channel exceeds the minimum permitted bandwidth by more than 50% on one transmit chain, then it is not necessary to repeat testing on the other chains.
- c) If the measured channel bandwidth on the middle channel is less than 50% of the maximum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.

5.6.2.2 Determining worst-case mode for test parameters being evaluated

For devices with multiple operating modes, measurements on the middle channel can be used to determine the worst-case mode(s). The worst-case modes are as follows:

- a) Band-edge requirements—Measurements on the mode with the widest bandwidth can be used to cover the same channel (center frequency) on modes with narrower bandwidth that have the same or lower output power for each modulation family (e.g., OFDM or direct sequence spread spectrum).
- b) Spurious emissions—Measure the mode with the highest output power and the mode with the highest output power spectral density for each modulation family (e.g., OFDM or direct sequence spread spectrum).
- c) In-band PSD—Measurements on the mode with the narrowest bandwidth can be used to cover all modes within the same modulation family of an equal or lower output power provided the result is less than 50% of the limit.
- d) When testing Multiple Access technologies (e.g., OFDMA), consideration should be given to evaluate both full band mode and with different combinations of resource assignment. When these considerations are used to reduce testing they shall be documented in the test report.

5.6.3 Band-edge channels with reduced output power

In regards to testing the band-edge signals, if the lowest or highest channel frequency is not at the highest fundamental output power setting, the adjacent channel(s) up to the channel that has the highest fundamental output power setting shall, when appropriate, also be tested to demonstrate compliance with the appropriate limits.

5.6.4 AC power-line conducted emissions

AC power-line conducted emissions do not require measurements on the minimum number of channels outlined in 5.6.1. Measurements shall only be performed on the channel and mode with the highest output power.

The exception to this test reduction is for any measurements performed on fundamental emissions that occur within the frequency band covered by an ac power-line emission. For these frequency bands the transmitter shall follow the minimum channels outlined in 5.6.1.

5.7 Swept-frequency device measurements

For unlicensed wireless devices using swept-frequency modulation techniques, other than those employing FMCW modulation, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported.

5.8 EUT antenna requirements

In general, an unlicensed wireless device shall be tested with all antennas provided and recommended for use with the EUT; however, variations and exceptions to this requirement can apply. See also 5.10.4. The test report shall document the antenna(s) tested with the EUT to determine compliance.³⁵

NOTE—Users of this standard are advised to refer to the latest applicable regulatory requirements and interpretations concerning requirements for evaluations of antennas used for unlicensed wireless devices.

5.9 Restricted frequency bands of operation

An unlicensed wireless device shall be tested to demonstrate that any emissions within restricted frequency bands specified by the regulatory authority are spurious emissions only. Unless otherwise specifically authorized, the spurious emission shall meet prescribed limits and the fundamental transmit signal shall not fall within these frequency bands.³⁶ Test reports shall provide measured data to demonstrate compliance with these regulatory requirements.

At frequencies less than or equal to 1000 MHz, compliance testing shall use measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance testing shall address both the peak and average values of the measured emissions. The considerations in 4.1.5.2 apply to these measurements.

5.10 General unlicensed wireless device configurations and test setups

This subclause addresses the general setup and operating requirements for evaluating unlicensed wireless devices, including stand-alone, modular, and embedded unlicensed wireless devices, external antenna considerations, and software requirements.

5.10.1 Stand-alone unlicensed wireless devices

Unlicensed wireless devices that are designed to operate as stand-alone systems (complete finished products), such as network access points, remote control unlicensed wireless devices, cordless phones, smart phones, tablets, and so on, shall be set up as such. A stand-alone unlicensed wireless device can contain a digital device whose functionality is only to control the unlicensed wireless device.

Products such as network access points, network bridges, or the equivalent shall be connected to a server or computer via control/data cable(s) to exercise the product. The controlling server or computer may be placed outside the test area.

A portable or small unlicensed wireless device shall be placed on a nonmetallic test fixture or other nonmetallic support during testing. The supporting fixture shall permit orientation of the EUT in each of three orthogonal axis positions such that emissions from the EUT are maximized.

³⁵ See 47 CFR 15.203 and 15.204 and related interpretations in the FCC Knowledge Database (<http://www.fcc.gov/labhelp>).

³⁶ See 47 CFR 15.35, 15.205, and 15.209.

5.10.2 Modular unlicensed wireless devices

Modular unlicensed wireless devices shall be positioned for testing using a nonmetallic test fixture or other nonmetallic support(s), in accordance with applicable regulatory guidance.³⁷ Peripheral devices are not required to be connected to the host device that is operating the modular unlicensed wireless device within a test fixture. For module unlicensed wireless devices being tested on an extender-card/adaptor-connector from a host computer, the radio module itself shall be extended at least 10 cm from the host computer, if possible, but it shall be located outside the enclosure of the host computer.

5.10.3 Module-like unlicensed wireless device embedded in a host device

For an unlicensed wireless device embedded or integrated in a host device, such as a notebook computer or a personal digital assistant (PDA), the use of peripherals for the host device is not required except for the spurious emission tests. For unintentional spurious emissions from the host, the test setup shall be in accordance with ANSI C63.4 for such testing.

5.10.4 Unlicensed wireless transmission systems with external antennas

The EUT system shall be tested with the highest gain for each antenna type to be marketed with the EUT³⁸ (see also 5.8). Antenna(s) shall be supported on a nonmetallic structure to preclude direct contact with the support table. The antenna shall be connected with the minimum length cable needed to be compliant with the EIRP requirements where applicable. If additional cable longer than the minimum length is used, then this shall be recorded in the test report, and it may need to be recorded as an operating condition for the approval of the equipment if such minimum cable length is required to maintain compliance with the specific regulation.

The EUT and antenna configurations tested shall include at least one configuration that provides the highest conducted output power (e.g., to evaluate worst-case enclosure radiation).

5.10.5 Maximization of EUT controls

The EUT shall be configured, using those controls that are readily accessible to or are intended to be accessible to the end user, in such a manner as to maximize the level of the emissions. For those devices to which wire leads can be attached by the consumer, tests shall be performed with wire leads attached. The wire leads shall be of the length to be used with the equipment, if that length is known. Otherwise, wire leads 1 m in length shall be attached to the equipment. Longer wire leads may be employed if necessary to interconnect to associated equipment.

5.10.6 Composite systems

If the individual devices in a composite system are subject to different regulatory technical requirements, then each part of the system shall comply with its specific technical requirement. In no event shall the measured emissions of the composite system exceed the highest level permitted for an individual component.

For a composite system, testing for compliance shall be performed with all of the parts in the system functioning. If an unlicensed wireless device incorporates more than one antenna or other radiating source and these radiating sources are designed to emit at the same time, then measurements of conducted and radiated emissions shall be performed with all radiating sources emitting simultaneously.³⁹ If the composite system contains an unintentional radiator, then that part of the composite system shall be tested in accordance with the test procedures in the latest version of ANSI C63.4, as accepted by the appropriate regulatory agency.

³⁷ See FCC/DA 00 1407 [B24] and 47 CFR 15.212.

³⁸ Refer to the latest applicable regulatory requirements and interpretations concerning testing of antennas for unlicensed wireless devices.

³⁹ See 47 CFR 15.31(h) and 15.31(k).

5.10.7 External accessories

If the EUT allows for the connection of external accessories, including external electrical control signals, then the EUT shall be tested with the accessories attached. The EUT shall be fully exercised with these external accessories. The emission tests shall be performed with the device and accessories configured in a manner that tends to produce maximum emissions within the range of variations that can be expected under normal operating conditions. In the case of multiple accessory external ports, an external accessory shall be connected to one of each type of port. Only one test using external accessories that are representative of the devices that will be employed with the EUT is required; testing of all possible equipment combinations is not required. The accessories connected to the EUT shall be unmodified and commercially available equipment.

When testing RFID readers that interact with passive tags, they shall be tested with a representative tag and without the tags. Tags that can be used at a distance shall be tested at the minimum separation distance to avoid backscatter emissions to overcome the readers emissions.

The test report shall identify (1) the operating modes and accessories tested for both exploratory and final emission measurements and (2) the rationale for the modes and accessories used in the final measurement.

5.10.8 Central control units

If the EUT consists of a central control unit and external or internal accessory(ies), and the same party manufactures or assembles the central control unit and at least one of the accessory devices that can be used with that control unit, then testing of the control unit and/or the accessory(ies) shall be performed using the devices manufactured or assembled by that same party, in addition to any other needed devices that the same party does not manufacture or assemble. If the same party does not manufacture or assemble the central control unit and at least one of the accessory devices that can be used with that control unit, or if the same party can demonstrate that the central control unit or accessory(ies) normally would be marketed or used with equipment from a different entity, then testing of the central control unit and/or the accessory(ies) shall be performed using the specific combination of equipment that is intended to be marketed or used together. Only one test using peripherals or accessories that are representative of the devices that will be employed with the EUT is required; testing of all possible equipment combinations is not required. The accessories or peripherals connected to the device being tested shall be unmodified, commercially available equipment.

5.11 Operational requirements during testing

The operation of the EUT shall conform to the following provisions:

- a) The unlicensed wireless device shall be configured to operate at 100% duty cycle. For systems incapable of supporting 100% duty cycle, the unlicensed wireless device shall be operated using the maximum possible duty cycle under normal operating conditions, and this information shall be noted as such in the test report.
- b) The unlicensed wireless device shall be tested operating at the highest transmit power allowed for each antenna configuration.
- c) The system shall be tested with each modulation to identify the worst-case modulation that produces the highest level of emissions. Where a single modulation scheme is used to demonstrate full EUT compliance, justification for the single modulation chosen shall be provided in the test report.
- d) The system shall be tested using the data rate that yields the highest fundamental emission levels for each modulation type. The data rate and rationale or supporting test data shall be included in the test report.
- e) For frequency hopping systems, the hopping sequence shall be stopped for certain test suites to allow for measurements on a single channel.

- f) Where applicable, the device shall also be configured to transmit at the worst-case duty cycle under normal operating conditions to determine the average correction factor.
- g) The software shall allow configuration and operation on all available unlicensed wireless device channels.
- h) The software shall allow configuration and operation in the unmodulated carrier model, where applicable.

The test report shall include the date, version number, and storage location of the software used to exercise the unlicensed wireless device.

5.12 Applied modulation

Unless otherwise specified in the individual test requirements or in this subclause, typical modulation shall be applied during testing. The test results shall be documented in the test report for operation with any modulation, devices, or functions used for modifying the spectrum when such devices are optional at the discretion of the user or are adjusted for network conditions during end use operation.

- a) When modulation is required in an individual test, devices modulated from internal sources shall be tested with all types of applied modulation. When a change in applied modulation yields a considerable difference in results, investigative measurements shall be carried out to establish the applied modulation, under foreseeable usage conditions, that will generate the worst-case results.
- b) If a device is equipped with input connectors for external modulation, then typical modulating signals shall be applied at the maximum rated input level for the device (e.g., apply a 1000 Hz tone to an input for an external microphone), unless otherwise specified by the regulatory authority. Voice only modulated devices (200 Hz to 3000 Hz) for which it is not practical to apply an audio signal electrically shall have a 1000 Hz tone at 100 dB sound pressure level (SPL) applied 10 cm from the microphone (0 dB SPL is 20 μ Pa).
- c) For systems deploying broadband wireless technologies or spread spectrum technology, the system shall be tested with the worst-case modulation(s) as determined by the engineering test. Devices employing digital modulation techniques shall be tested with the input modulation set to produce the maximum amplitude and symbol rate. The test results shall be reported for operation with any devices or functions used for modifying the spectrum when such devices are optional at the discretion of the user or are adjusted for network conditions during end use operation.
- d) When testing systems using frequency hopping technology, the tests shall address the additional requirements for operation with modulation as specified in 7.8.
- e) All modulations supported by the system shall be described in the test report with justification provided for selecting specific modulation(s) for compliance testing.

5.13 Variations in supply voltage

When required for unlicensed wireless devices, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage.

- a) Where the device is intended to be powered from an external power adapter, the voltage variations shall be applied to the input of the adapter provided with the device at the time of sale. If the device is not marketed or sold with a specific adapter, then a typical power adapter shall be used.
- b) For devices where operating at a supply voltage deviating $\pm 15\%$ from the nominal rated value may cause damages or loss of intended function, test to minimum and maximum allowable voltage per manufacturer's specification and document in the report.