



American National Standard for Testing Unlicensed Wireless Devices

C63[®]

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Accredited Standards Committee C63[®] —Electromagnetic Compatibility**

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American National Standard for Testing Unlicensed Wireless Devices

Accredited Standards Committee C63[®]—Electromagnetic Compatibility

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Secretariat

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C63[®]

Abstract: This standard is intended to cover procedures for testing the compliance of a wide variety of unlicensed wireless devices (also called unlicensed intentional radiators) including but not limited to: remote control and security unlicensed wireless devices, frequency hopping and direct sequence spread spectrum devices, anti-pilferage devices, cordless telephones, medical unlicensed wireless devices, Unlicensed National Information Infrastructure 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. The test procedures for new technology wireless devices will be added to future editions of this standard as soon as practical after consensus is achieved for compliance testing methods of the new devices. However, this standard excludes test procedures for unlicensed wireless devices already covered in other published standards, e.g., Unlicensed Personal Communication Services (UPCS) devices.

Keywords: compliance testing, intentional radiators, Spread Spectrum Devices, test procedures, U-NII, unlicensed wireless devices

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Introduction

This introduction is not part of ANSI C63.10-2009, ANSI Standard for Testing Unlicensed Wireless Devices.

This standard provides procedures for testing the compliance of a wide variety of unlicensed wireless devices, including but not limited to: remote control and security unlicensed wireless devices, frequency hopping and direct sequence spread spectrum devices, anti-pilferage devices, cordless telephones, wireless medical unlicensed wireless devices, Unlicensed National Information Infrastructure devices, intrusion detectors, unlicensed wireless devices operating on frequencies below 30 MHz, automatic vehicle identification systems, and other unlicensed wireless devices authorized for operation by a radio regulatory authority. Procedures for testing of some of these devices were previously contained in ANSI C63.4-2003, but 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.

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1. Overview

1.1 Scope

This consensus standard specifies methods, instrumentation, and facilities requirements for measurement of radio-frequency (RF) signals and RF noise emitted from unlicensed wireless devices. It does not include generic nor product-specific emission limits. Measurement methods are provided for radiated and conducted emissions that can be generated by a variety of devices, as described below. This standard does not consider test methods for unlicensed wireless devices already covered in other published standards, such as Unlicensed Personal Communication Services (UPCS) devices, which are covered in ANSI C63.17 [B1].¹ In addition, many types of wireless devices are also subject to regulatory requirements concerning human exposure to RF energy; RF exposure conformity assessment methods are not considered in this standard, but are the subject of other standards, e.g., IEEE Std 1528TM-2003 [B22].

This document provides standard test methods for determining compliance with regulatory requirements for many types of 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
- Anti-pilferage devices
- Cordless telephones
- Radio frequency identification (RFID) tag readers

¹ The numbers in brackets correspond to those of the bibliography in Annex F.

- 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
- Other devices, e.g., with operations authorized under Part 15 of the FCC Rules and Regulations (47 CFR Part 15).²

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 identifies additional tests or requirements for specific unlicensed wireless devices. Clause 8 specifies requirements for reporting test results, with special emphasis on the use of guidance from ISO/IEC 17025:2005.

Annex A is an informative listing of the tests required to show compliance of a specific unlicensed wireless device. 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 informative example of the information to be included in a test report. Annex C is an informative discussion on instrumentation pulse desensitization considerations. Annex D provides information about detector types and functions used in EMC testing. Annex E and Annex F provide an informative glossary and related reading (bibliography), respectively.

Use of the annexes and clauses applicable to a wireless device under test allows users of this standard to determine compliance of a device to national 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.

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

1.2 Purpose

A wide variety of unlicensed wireless devices (also known as intentional radiators) 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 present wireless devices in wide use. It represents a consolidation and elucidation of procedures that were heretofore dispersed throughout a number of documents, which caused confusion regarding where to find the appropriate test method. It is not expected that all of the wireless devices on the market will in fact be covered by this standard. For example, this standard excludes test procedures for unlicensed wireless devices already covered in other published standards; e.g., Unlicensed Personal Communication Services devices. Also, as new measurement methods mature, this standard will be amended or a follow-up standard developed to present the new method. 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.

² Information on references can be found in Clause 2.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, 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 Electromagnetic Noise and Field Strength Instrumentation, 10 Hz 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 C63.5, American National Standard for Electromagnetic Compatibility—Radiated Emission Measurements in Electromagnetic Interference (EMI) Control—Calibration of Antennas (9 kHz to 40 GHz).

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

ANSI C63.14, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD) (Dictionary of EMC/EMP/ESD Terms and Definitions).

CISPR 16-1-1:2006, Specification for radio disturbance and immunity measuring apparatus and methods—Part 1-1: Radio disturbance and immunity measuring apparatus—measuring apparatus.

IEEE Std 139™-1988, IEEE recommended practice for the measurement of radio frequency emission from industrial, scientific, and medical (ISM) equipment installed on user's premises.^{4,5}

ISO 10012-1:2003, Quality Assurance Requirements for Measuring Equipment, Part 1: Metrological Confirmation System for Measuring Equipment.⁶

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

U.S. Code of Federal Regulations Title 47—Telecommunication, Chapter I—Federal Communications Commission, Part 2—Frequency Allocations and Radio Treaty Matters; General Rules and Regulations (47 CFR Part 2).⁷

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

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3. Definitions and acronyms

3.1 Definitions

For the purposes of this document, the following terms and definitions apply. *The IEEE Standards Dictionary: Glossary of Terms & Definitions* and ANSI C63.14, should be referenced for terms not defined in this clause.⁸ Definitions in wireless device product standards or regulations shall take precedence where applicable. See also the Glossary provided in Annex E, which includes various terms relevant for wireless devices compiled from FCC, ITU, and other documents.

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 and including evaluation of measurement uncertainty.

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

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

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

line impedance stabilization network (LISN): A network inserted in the power supply lead of 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 may isolate the apparatus from the power supply in that frequency range, and couples the EUT emissions to the measuring instrument.

NOTE—A LISN unit may contain one or more individual LISN circuits.⁹

peak power: Power measured with the peak detector using a filter with width and shape of which is sufficient to accept the signal bandwidth.

restricted bands: Frequency bands in which intentional radiators are not permitted to operate.¹⁰

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 purposes of performing measurements or scientific investigations. Such equipment includes, but is not limited to field strength meters, spectrum analyzers and modulation monitors.¹¹

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

⁸ *The IEEE Standards Dictionary: Glossary of Terms & Definitions* is available at <http://shop.ieee.org/>.

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

¹⁰ See 47 CFR 15.205.

¹¹ 47 CFR 15.3(dd).

unintentional radiator: A device that intentionally generates radio frequency energy for use within the device, or that sends radio frequency signals by conduction to associated equipment via connecting wiring, but which is not intended to emit RF energy by radiation or induction.¹²

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 5.825 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—High data rate is defined as 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.

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

(B) Device that is permitted to emit radio frequency (RF) energy, but requires no specific device licensing or user authorization.¹³

3.2 Acronyms

ANSI	American National Standards Institute
ASC	Accredited Standards Committee
BB	broadband
CFR	U.S. Code of Federal Regulations
CISPR	International Special Committee on Radio Interference (IEC)
CW	continuous wave
DFS	dynamic frequency selection
DSSS	direct sequence spread spectrum
DTS	digital transmission system
EBW	emission bandwidth
EIRP	equivalent isotropic radiated power
ERP	equivalent radiated power
EUT	equipment under test
FCC	Federal Communications Commission
FHSS	frequency hopping spread spectrum
GPR	ground penetrating radar
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronic Engineers
IF	intermediate frequency
KDB	Knowledge Database (FCC/OET)
LISN	line impedance stabilization network
LO	local oscillator
NB	narrowband
NIST	National Institute of Standards and Technology
NSA	normalized site attenuation
OATS	open area test site
OBW	occupied bandwidth
OET	Office of Engineering and Technology (FCC)

¹² 47 CFR 15.3(z)

¹³ FCC/DA-03-1758 [B11].

PRF	pulse repetition frequency
PDCF	pulse desensitization correction factor
PPSD	peak power spectral density
PSD	power spectral density
PWB	printed wiring board
QP	quasi-peak
RBW	resolution bandwidth
RF	radio frequency
SPL	sound pressure level
TCB	Telecommunication Certification Body (FCC)
TPC	transmitter power control
U-NII	Unlicensed National Information Infrastructure
UPCS	Unlicensed Personal Communications Service
UWB	ultra-wideband
VBW	video bandwidth
VCO	voltage controlled oscillator
WIR	wall imaging radar

4. Measurement instrumentation

4.1 General considerations

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

4.2 Emission measuring instrumentation

This standard recognizes that both spectrum analyzers and EMI receivers may be used for making emission measurements. Measurement instrumentation used for making radiated and ac power-line conducted radio noise measurements include those that conform to the specifications contained in either:

- ANSI C63.2, or
- CISPR 16-1-1:2006

A spectrum analyzer typically will not meet all requirements stated in ANSI C63.2 or CISPR 16-1-1:2006 without additional accessories. Appropriate accessories, such as pre-selection, quasi-peak detection, and specific IF filters may be used with a spectrum analyzer; this combination may be equivalent to a receiver, meeting the requirements in either specification. This standard recognizes that a spectrum analyzer may be used for making measurements.

4.2.1 Receiver

The specifications of a receiver for measurements of radiated and ac power-line conducted radio noise is contained in ANSI C63.2 or CISPR 16-1-1:2006. Other instruments may be used for certain restricted and specialized measurements when data are measured using an instrument conforming to ANSI C63.2 or CISPR 16-1-1:2006. Automatic scanning receivers may be used, but the maximum scan speed shall be limited by the response time of the measuring system and the repetition rate of the radio noise to be measured to ensure that the level of each emission is measured correctly, i.e., in accordance with a measurement with a non-scanning receiver. Bandwidth and scan rates shall be chosen that are appropriate for the frequencies being scanned.

If the output of the quasi-peak or average detector is indicated in decibels (dB) or other logarithmic units, the logarithms shall be taken after the signal is detected and the detector function is fully realized. Otherwise, instruments that use logarithmic detectors, pre-detection logarithmic circuits, or both shall include corrective circuits so that the output indication is the logarithm of the true average or quasi-peak value of the signal or noise. Bandwidths are given in 4.2.3.

NOTE—Users should be aware that the EMI receiver specifications in CISPR 16-1-1:2006 and ANSI C63.2 contain several differences. For example, for measurements above 1 GHz the bandwidth definition for measurements are different. These differences in bandwidth specification may result in different measured values for broadband signals.

4.2.2 Spectrum analyzer

The use of spectrum analyzers for radiated and ac power-line conducted radio noise compliance measurements is permissible, although spectrum analyzers without further accessories will not meet all specifications called out in the standards mentioned in 4.2 and 4.2.1.

To meet the requirements in 4.2, spectrum analyzers shall be equipped with proper quasi-peak detection as the reference detector for measurements up to 1 GHz. However, measurements with the peak detector of the instrument are permissible to demonstrate compliance of a EUT because peak detection will yield amplitudes equal to or greater than amplitudes measured with the quasi-peak detector. Data measured using the peak detector of a spectrum analyzer or EMI receiver will represent the worst-case results.

Minimum values for the resolution bandwidth are specified in 4.2.3. It should be noted that most spectrum analyzers incorporate a 3 dB resolution bandwidth specification, which is acceptable because larger bandwidths are permissible. The resolution bandwidths, cited in the standards listed in 4.2.1 for the frequency range up to 1 GHz do not have a Gaussian shape but are individually specified by their frequency response (“masks”). When using larger bandwidths than those specified or when using filters with different transfer functions, different measurement results for broadband signals must be expected.

In order for a spectrum analyzer to meet the specifications of either of the two standards, it must be equipped with proper filtering at the input, which can provide adequate overload protection and dynamic range of the system to achieve the proper weighting of pulses, using quasi-peak detection and the specified bandwidths in 4.2.3. In this case, the spectrum analyzer performs as a scanning EMI receiver, meeting the specifications for the resolution bandwidth, pulse weighting, and quasi-peak detection.

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

- a) Overload—Most spectrum analyzers have no RF pre-selection in the frequency range up to 2 GHz; that is, the input signal is directly fed to a broadband mixer. To avoid overload, to prevent damage, and to operate a spectrum analyzer linearly, the signal amplitude at the mixer shall be less than 150 mV peak. RF attenuation or additional RF pre-selection may be required to reduce the input signal to this level.
- b) Linearity test—Linearity can be verified by measuring the level of the specific signal under investigation and repeating this measurement after a 6 dB or less external attenuator has been inserted at the input of the measuring set or, if used, the preamplifier. The new reading of the measuring set display should differ by the inserted attenuation by not more than ± 0.5 dB from the first reading when the measuring system is linear. In case of broadband time-variant signals and spread-spectrum signals, the linearity test may be performed by setting the analyzer max hold with peak detector function.
- c) Normal response to pulses—The response of a spectrum analyzer set with quasi-peak detection shall be verified with the calibration test pulses specified in CISPR 16-1-1:2006. The large peak voltage of the calibration test pulses typically requires an insertion of RF attenuation of 40 dB or more to satisfy the linearity requirements. This decreases the sensitivity and makes the measurement of low repetition rate and isolated calibration test pulses impossible for bands B, C, and D.¹⁴ If a pre-selecting filter is used ahead of the measuring set, 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 time varying emissions may be captured with peak-detection and digital display storage if provided. Multiple, fast frequency scans reduce the time to intercept an emission compared to a single, slow frequency scan. The starting time of the scans shall be varied to avoid any synchronism with the emission and thereby hiding it. The total observation time for a given frequency range shall be longer than the time between the emissions. Depending upon the type of disturbance being measured, the peak detection measurements can replace all or part of the measurements needed using quasi-peak detection. Re-tests using a quasi-peak detector shall then be made at frequencies where emission maxima have been found.

¹⁴ CISPR 16-1-1:2006 band B is 0.15 MHz to 30 MHz, and bands C and D are 30 MHz to 1000 MHz.

- e) Average detection—Average detection with a spectrum analyzer is obtained by reducing the video bandwidth until no further smoothing of the displayed signal is observed. The sweep time must be increased with reductions in video bandwidth to maintain amplitude calibration. For measurements in accordance with CISPR 16-1-1:2006 the video bandwidth shall be set to a 10 Hz value to ensure that the proper integration time is realized. For such measurements, the instrument shall be used in the linear mode of the detector. After linear detection is made, the signal may be processed logarithmically for display, in which case the value is corrected even though it is the logarithm of the linearly detected signal. A logarithmic amplitude display mode may be used, for example, to distinguish more easily between narrowband and broadband signals. The displayed value is the average of the logarithmically distorted IF signal envelope. It results in a larger attenuation of broadband signals than in the linear detection mode without affecting the display of narrowband signals. Video filtering in log-mode is, therefore, especially useful for estimating the narrowband component in a spectrum containing both.
- f) Selection of display mode—For EMC measurements the positive peak detector should be selected to ensure that the highest emission amplitudes are displayed. Scanning the frequency range of interest in multiple frequency segments can reduce the introduced frequency error. This will improve frequency accuracy but will increase the overall test time.

4.2.3 Detector functions and selection of bandwidth

4.2.3.1 General considerations

Unless otherwise specified, EMI receivers and spectrum analyzers shall have the reference detector functions and bandwidths specified in ANSI C63.2 or CISPR 16-1-1:2006 for frequencies up to and including 40 GHz. Peak-detector measured data may be substituted for the appropriate detector data to show compliance, if the peak level obtained does not exceed the limit. The bandwidths used shall be equal to or greater than that specified in ANSI C63.2. Use of bandwidths greater than those specified may produce higher readings for certain types of emissions and should be recorded in the test report. More than one instrument may be needed to perform all of these functions.

The measuring instrument shall satisfy the following conditions:

- The measuring instrumentation with the quasi-peak or average detector shall have a linear response.
- When measuring an emission with a low duty cycle, the dynamic range of the measuring instrument shall not be exceeded.

When using a spectrum analyzer or other instrument providing a spectral display the video bandwidth shall be set to a value at least three times greater than the intermediate-frequency (IF) bandwidth of the measuring instrument to avoid the introduction of amplitude smoothing.

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

4.2.3.2 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, unless otherwise specified elsewhere in this standard.

4.2.3.2.1 Frequencies less than or equal to 1000 MHz

On any frequency or frequencies less than or equal to 1000 MHz, measurements shall be made employing a CISPR quasi-peak detector function and related measurement bandwidths, unless otherwise specified for a specific EUT. The specifications for the measuring instrument using the CISPR quasi-peak detector are given in CISPR 16-1-1:2006. As an alternative to CISPR quasi-peak measurements, a test laboratory may demonstrate compliance with the emission limits using measuring equipment employing a peak detector function, as long as the same bandwidths as indicated for CISPR quasi-peak measurements are employed.¹⁵

For pulse-modulated devices with a pulse repetition frequency of 20 Hz or less and for which CISPR quasi-peak measurements are specified, measurements shall be made using measuring equipment employing a peak detector function, using the same measurement bandwidths that are indicated for CISPR quasi-peak measurements.

4.2.3.2.2 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. When an average limit is specified for the EUT, the peak emission must also be measured to ensure that the emission is less than 20 dB above the average limit or below the peak limit specified for the EUT. Unless otherwise specified, measurements above 1000 MHz shall be performed using a minimum resolution bandwidth of 1 MHz. This peak limit applies to the total peak emission level radiated by the device, e.g., the total peak power level. Note that the use of a pulse desensitization correction factor may be needed to determine the total peak emission level. The instruction manual or application note for the measurement instrument should be consulted for determining pulse desensitization factors, as necessary. (See also 4.2.3.2.6.)

4.2.3.2.3 Average measurements using spectrum analyzer reduced video bandwidth

Some regulatory bodies allow the use of spectrum analyzers to make average measurements by reduction of video bandwidth, in which case the following procedure shall be used:

- a) Tune the instrument to the signal of interest by setting the center frequency to the signal frequency.
- b) Reduce spectrum analyzer frequency span to a value of zero. The peak value of the measured signal shall be kept in the center of the display during the reduction of the span.
- c) Select spectrum analyzer linear display mode.
- d) Set spectrum analyzer reference level such that the measured signal is positioned as close as possible to the top line of the display graticule.
- e) Reduce video bandwidth to at least 100 times less than the resolution bandwidth, but no less than 10 Hz.
- f) After items a) through e) are completed, measure the maximum average signal on the display.

Additional details about use of spectrum analyzers for average measurements are given for example in Linkwitz [B29].

4.2.3.2.4 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 measurement field strength shall be determined by

¹⁵ If an average limit is specified for the EUT, the peak emission shall also be measured with instrumentation properly adjusted for factors, such as pulse desensitization, to ensure that the peak emission is less than 20 dB above the average limit per U.S./FCC regulations. [See 47 CFR 15.35(b).]

averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 s. As an alternative (provided the unlicensed wireless device operates for longer than 0.1 s) or in cases where the pulse train exceeds 0.1 s, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval while the field strength is at its maximum value. The exact method of calculating the average field strength shall be included in the test report.

4.2.3.2.5 Measurement of rms-average emissions

For testing ultra-wideband systems and other systems that require average readings based on an rms-average value, a spectrum analyzer with an rms-average display detector function shall be used. The analyzer should provide a means to record, store, and display the rms values across the desired band of operation.

4.2.3.2.6 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 may not display the true peak value of the measured emission. This effect, called “pulse desensitization,” relates to the capabilities of the measuring instrument and the characteristics of the emission. For the measurement and reporting of the true peak of pulsed emissions, it may be necessary to apply a pulse desensitization correction factor (PDCF) to the measured value. In other words, the test report must include the true peak level of the emission when the limit is specified in terms of a peak emission, which may 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.

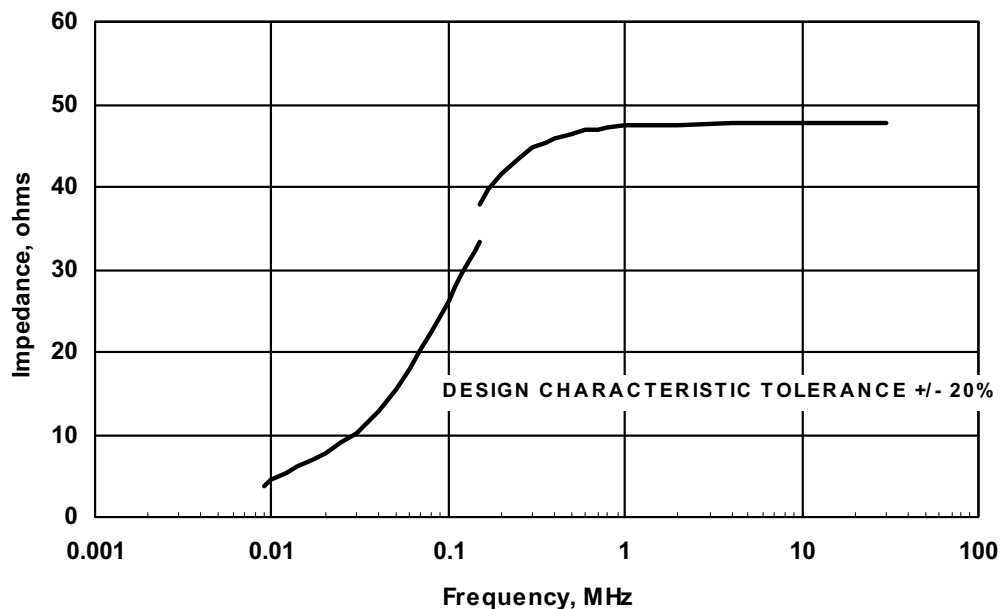
NOTE 2—PDCF typically is not applicable for ultra-wideband (UWB) device measurements; regulatory authorities may specify other measurement procedures for determining compliance with UWB regulations.

4.2.4 Signal monitoring

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

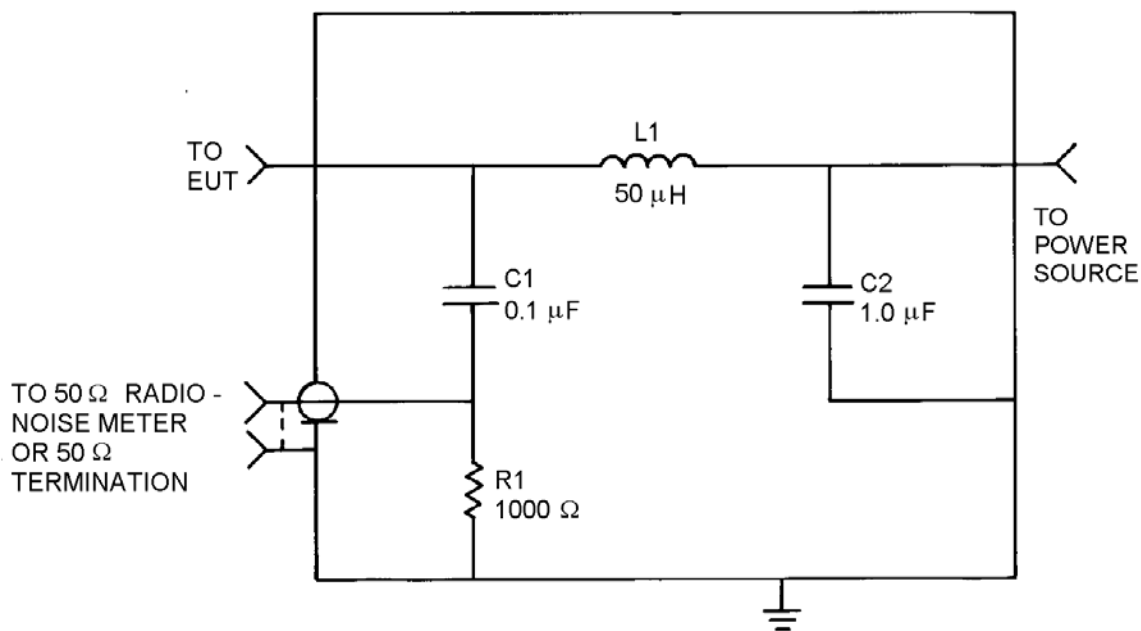
4.3 Line impedance stabilization network (LISN)

A LISN having a nominal impedance characteristic as shown in Figure 1 is required for ac conducted emission measurements. When the “measuring instrument” ports are terminated into 50 Ω loads, the characteristic impedance in Figure 1 shall be present at the EUT ports of the LISN. Figure 2 and Figure 3 show two circuits that, when carefully constructed, can provide separately the impedance characteristics of Figure 1 (for use with connecting cable, see also 6.2.2) within the design characteristic tolerance of $\pm 20\%$. Where specific equipment requirements specify another LISN, the specified LISN shall be used. See Annex B of ANSI C63.4 for the specifications and verification of LISN characteristics.



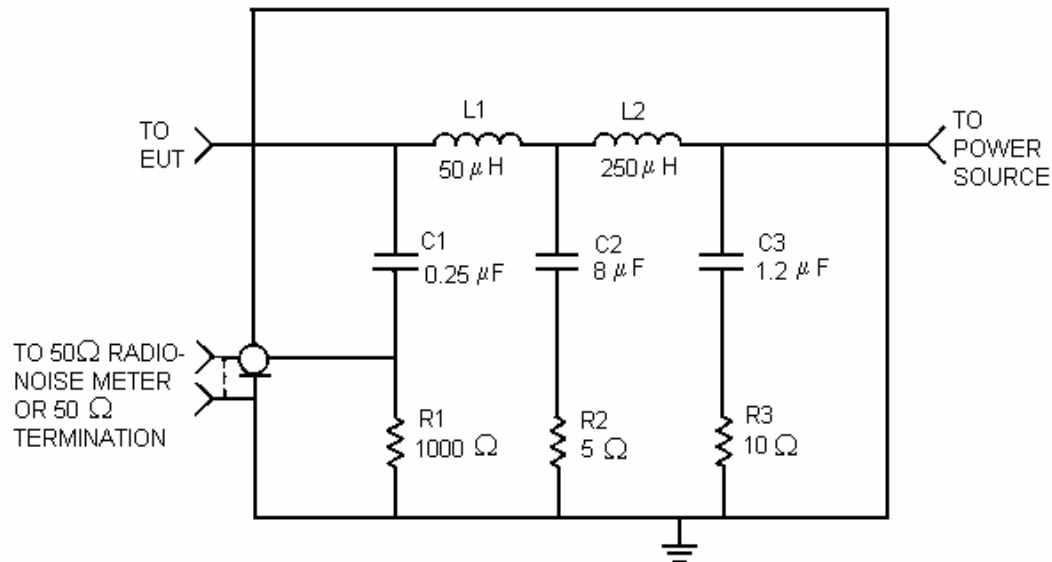
NOTE—The discontinuity in the curve is due to impedance values being derived from the two different circuits for the 9 kHz to 150 kHz and 150 kHz to 30 MHz frequency ranges.

Figure 1—Impedance characteristic of LISN port—9 kHz to 30 MHz



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

Figure 2—Circuit diagram of LISN to provide impedance of Figure 1 for the 0.15 MHz to 30 MHz frequency range



* IF CAREFULLY CONSTRUCTED, THIS NETWORK CAN BE USED ABOVE 150kHz TO AS HIGH AS 30 MHz.

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

4.4 Voltage probe

A voltage probe may be used for radio-noise voltage measurements when measurements are made at a user's installation (see 6.12.3), or when the ac current level exceeds the current-carrying capability of commercially available LISNs.¹⁶ Voltage probes shall be calibrated for use. For such measurements, the method shown in Figure 4 may be used. Special precautions shall be taken to establish a reference ground for the measurements. A LISN shall not be used in conjunction with a voltage probe for measurements at a user installation. The measurements are dependent on the impedance presented by the power supply and may vary with time and location because of variations in the power supply. (It may be necessary to perform repeated measurements over a suitable period of time to determine the variation in measured values. The time period shall be sufficient to cover all significant variations caused by operating conditions at the installation.) Such measurement results shall be regarded as unique to that EUT and installation environment. The measurements shall be made between each current-carrying conductor in the power supply and the ground conductor with a blocking capacitor (C) and a resistor (R), shown in Figure 4, such that the total resistance between line and ground is 1500 Ω . Because the voltage probe attenuates the radio-noise voltage, appropriate calibration factors shall be added to the measured values. Measurements made with LISNs shall take precedence over measurements made with voltage probes.

¹⁶Some measurement method documents refer to a voltage probe as a line probe.

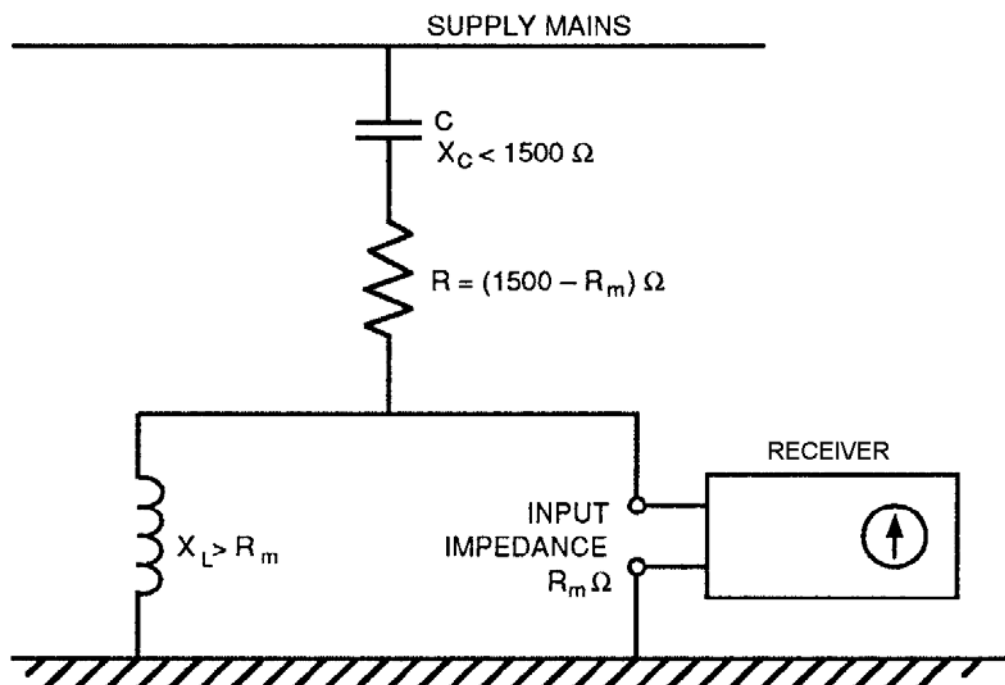


Figure 4—Voltage probe for measurements at a user's installation

4.5 Antennas

The use of specific antennas depends on the frequency range and field type (electric or magnetic) being measured when performing radiated emissions testing, as indicated in 4.5.1, 4.5.2, and 4.5.3. Antennas shall be calibrated in accordance with ANSI C63.5. Table 1 (derived from ANSI C63.2) provides a summary of typical antenna types.

Table 1—Antennas for selected frequency ranges

Antenna	10–20 kHz	10–150 kHz	0.15–30 MHz	30–1000 MHz	Above GHz
Rod (passive)	Yes	Yes	Yes	No	No
Dipole (passive)	No	No	No	Yes	No
Biconical dipole	No	No	No	Yes	No
Log-periodic dipole array	No	No	No	Yes	No
Loop (passive)	Yes	Yes	Yes	No	No
Waveguide horn	No	No	No	No	Yes
Active monopole	Yes	Yes	Yes	No	No
Double-ridged guide horn	No	No	No	Yes	Yes

NOTE 1—This table is adapted from Table 6 of ANSI C63.2.

NOTE 2—Frequency ranges and instrumentation tuning ranges are as suggested in Clause 5 of ANSI C63.2.

NOTE 3—Some designs of dipole, biconical, and log-periodic dipole array antennas operate within portions of the 1 GHz to 40 GHz range.

NOTE 4—Waveguide horn antennas are typically used for emissions testing at frequencies above 40 GHz.

4.5.1 Magnetic field measurements (9 kHz to 30 MHz)

Loop antennas as specified in ANSI C63.2 shall be used to measure magnetic fields in the frequency range of 9 kHz to 30 MHz.¹⁷

4.5.2 Electric field measurements (30 MHz to 1000 MHz)

Linearly polarized antennas as specified in ANSI C63.2 and calibrated to ANSI C63.5 shall be used to measure electric fields in the frequency range of 30 MHz to 1000 MHz. Tunable dipoles should be used. Alternatively, a linearly polarized broadband antenna, or a dipole tuned only above 80 MHz, and set to the 80 MHz tuned length when used between 30 MHz and 80 MHz, may be used in lieu of a tuned dipole, provided that the measurement can be correlated with that made with a tuned dipole with an acceptable degree of accuracy.¹⁸

4.5.3 Electric field measurements (above 1 GHz)

Linearly polarized antennas, such as, those shown in column 6 of Table 1 and calibrated in accordance with ANSI C63.5 shall be used. These include double-ridged waveguide horns, rectangular waveguide horns, pyramidal horns, optimum gain horns, octave-bandwidth horns, and standard gain horns. The main beam or main lobe of the pattern, for any antenna used shall be large enough to encompass the physical size of the EUT, or system arrangement, when located at the measuring distance. See 6.6 for details about techniques for encompassing products during the measurement process.

The aperture dimensions of horn antennas shall be small enough so that the measurement distance in meters is equal to or greater than the Rayleigh distance, i.e., $R_m = 2D^2/\lambda$, where D is the largest dimension of the antenna aperture in meters, R_m is the measurement distance, and λ is the free-space wavelength in meters at the frequency of measurement.¹⁹

4.6 Calibration of measuring equipment

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

4.6.1 Confirmation interval

Calibration of all instruments shall be confirmed in the first year of deployment. Reference antennas that are used only for calibration or normalized site attenuation (NSA) measurement purposes shall be constructed as specified and should be checked using ANSI C63.5 methods at least every three years. For other instruments, subsequent re-calibration intervals may be longer (up to three years) or shorter based on review of calibration data relative to the recommendations of the instrument manufacturer and the required measurement accuracy. All instruments shall be checked as frequently as necessary between calibration intervals to provide evidence that instrument accuracy and system measurement uncertainty is continuously maintained (see ISO 10012-1:2003).

¹⁷ In the U.S., the 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 [$1 \mu\text{V/m} = (1/377\Omega) \times 1 \mu\text{A/m}$].

¹⁸ In case of dispute, some regulatory and purchasing agencies may require the use of a reference antenna (Annex C and Annex E of ANSI C63.5) for measurements of radiated emissions.

¹⁹ In case of dispute, measurements made with a standard-gain horn antenna shall take precedence.

4.6.2 Antenna calibration

All antennas shall be calibrated per ANSI C63.5, including antennas used for performing NSA measurements for alternative test site validation (see 5.4.2 of ANSI C63.4). Antennas shall be calibrated when damage or deterioration is suspected and at regular intervals, as described in 4.6.1.

Standard gain horn antennas have gain characteristics that are established by the physical dimensions and dimensional tolerances. Consequently, standard-gain horn antennas need not be calibrated beyond the dimensional characteristics that are provided by the manufacturer, unless damage or deterioration is suspected, or if used at distances closer than $2D^2/\lambda$.

If the antenna is calibrated at a distance $R \geq 2D^2/\lambda$, (where D is the maximum aperture dimension of the antenna) it may be used to make measurements at any distance greater than $2D^2/\lambda$, with an error of less than 1 dB.

4.6.3 LISN impedance and insertion loss measurements

The impedance and insertion loss of each LISN used in testing emissions shall be measured over the frequency range of use. It is recommended that the insertion loss measurement be carried out after the completion of the impedance measurements. The LISN shall be measured as it is used for testing a product. An acceptable procedure for performing these measurements is given in ANSI C63.4. See 6.2.2 for testing a permanently installed LISN. The LISN should be checked routinely to ensure acceptable performance (see 4.6.1).

4.6.4 Cable insertion loss

The insertion loss of cables used for connection of antennas or transducers to measuring instruments (EMI receivers, spectrum analyzers, etc.) shall be characterized, and checked frequently for deterioration caused by use and environmental exposure (e.g., variation due to change in temperature, damage). Published data²⁰ has shown that temperature variations of 15 °C or more results in 2 % or greater change in cable losses. Consequently, the temperatures present during initial cable loss characterization and product testing shall be recorded. When the temperature change exceeds 15 °C, the cable characterization shall be repeated.

²⁰For 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 may supplant or supersede the standard test methods of Clause 6 and device-specific test methods of Clause 7. Users of this standard shall apply the information of this clause when testing unlicensed wireless devices, particularly those using new technologies.²¹

5.2 Radiated emission test site

Field strength measurements shall be made on a test site meeting the requirements for an acceptable site as defined in ANSI C63.4.^{22, 23}

NOTE—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 may specify that measurements shall 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

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 design and performance criteria of ANSI C63.7 and ANSI C63.4 respectively may, at the discretion of the regulatory authority, 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 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 equipment under test. The EUT, support equipment, and any interconnecting cables shall be included within this boundary.

5.3.1 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. 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. 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 (inverse of linear distance for field-strength measurements, inverse of linear distance-squared for power-density measurements).

NOTE—Measurements in the frequency range above 18 GHz are typically made at a closer distance, because the instrumentation noise floor is typically close to the radiated emission limit.

²¹ In the U.S., many of the general requirements for unlicensed wireless devices in this clause are given in 47 CFR 15.31.

²² In the U.S., an intentional radiator may require special authorization for testing on an open field test site [see 47 CFR 2.803(e)(1)(i)].

²³ In the U.S., see 47 CFR 15.31 for additional guidance regarding test sites.

5.3.2 Test distance for frequencies below 30 MHz

Measurements may be performed at a distance closer than the EUT limit distance; however, an attempt should be made to avoid making measurements in the near field. When performing measurements below 30 MHz at a closer distance than the limit distance, the results shall be extrapolated to the specified distance by either making measurements at a minimum of two or more distances on at least one radial to determine the proper extrapolation factor or by using the square of an inverse linear distance extrapolation factor (40 dB/decade). The test report shall specify the extrapolation method used to determine compliance of the EUT.

NOTE—The extrapolation factor for frequencies below 30 MHz is under review by ASC C63 SC1 for technical accuracy and may be changed in a future edition of this standard.

5.4 Measurements around the EUT

Measurements shall be made at a test site that incorporates a turntable allowing a EUT rotation of 360°. A continuously-rotating, 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. The maximum field strength at the frequency being measured shall be reported in the test report.²⁴ See ANSI C63.4 for details of the test site, turntable, and antenna positioner.

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

NOTE—Some unlicensed wireless devices require specific azimuthal increment examination, as described in the specific subclause in this standard for those unlicensed wireless devices.

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 2.²⁵ However, frequencies below 9 kHz do not need to be investigated.

Table 2—Frequency of measurements of unlicensed wireless devices

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

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, the frequency range shall be investigated up to the range specified in Table 2 or the range applicable to the digital device as shown in Table 3, whichever is the higher frequency range of investigation.

²⁴ See 47 CFR 15.31(f)(5).

²⁵ See 47 CFR 15.33(a).

Table 3—Frequency range of measurement for unlicensed wireless device with digital device

Highest frequency generated or used in the device or on which the device operates or tunes	Upper frequency range of measurement
Below 1.705 MHz	30 MHz
1.705 MHz to 108 MHz	1000 MHz
108 MHz to 500 MHz	2000 MHz
500 MHz to 1000 MHz	5000 MHz
Above 1000 MHz	5th harmonic of the highest frequency or 40 GHz, whichever is lower

Particular attention should 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 should also be checked.

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

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 4.²⁶

Table 4—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

5.7 Swept-frequency device measurements

For unlicensed wireless devices operating on frequencies below 30 MHz and using swept-frequency modulation techniques, 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 may apply. See also 5.10.4. The test report shall document the antenna(s) tested with the EUT to determine compliance.²⁷

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 ensure 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

²⁶ See 47 CFR 15.31(m).

²⁷ See 47 CFR 15.203 and 15.204 and related interpretations in the FCC Knowledge Database (www.fcc.gov/labhelp).

these frequency bands.²⁸ Test reports shall provide measured data to demonstrate compliance with these regulatory requirements.

At frequencies less than or equal to 1000 MHz, compliance with the limits shall be demonstrated using measurement instrumentation employing a CISPR quasi-peak detector. Above 1000 MHz, compliance with the emission limits shall be demonstrated based on both the peak and average values of the measured emissions. The considerations in 4.2.3.2 apply to these measurements.

NOTE—For unlicensed wireless devices, the list of restricted bands and spurious emission limits are specified by a regulatory authority.

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 antennas 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, phones, etc., shall be setup as such. A stand-alone unlicensed wireless device may contain digital device whose functionality is to only 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 non-metallic test fixture or other non-metallic 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.

5.10.2 Modular unlicensed wireless devices

Modular unlicensed wireless devices shall be positioned for testing using a non-metallic test fixture or other non-metallic support(s), in accordance with applicable regulatory guidance.²⁹ 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 should 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 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.

²⁸ See 47 CFR 15.35, 15.205, and 15.209.

²⁹ See FCC/DA-00-1407 [B8] and 47 CFR 15.212.

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 EUT³⁰ (see also 5.8). Antenna(s) shall be supported on a non-metallic 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, this shall be recorded in the test report, and 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 to 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 Software requirements for specific unlicensed wireless devices

Unless otherwise specified for an EUT, software shall be designed to allow the unlicensed wireless device to operate at 100 % duty cycle. The software shall also allow the device to transmit at the worst-case duty cycle to allow measurements in instances where an average correction factor needs to be determined to calculate the average field strength from the measured peak field strength. In addition,

- a) The software should allow configuration and operation on all available unlicensed wireless device channels.
- b) The software should allow configuration and operation at a duty cycle equivalent to the “worst case” during “100 percent and normal mode of operation.”
- c) The software should allow configuration and operation using all available modulations and data rates.
- d) The software should allow configuration and operation on all available power out levels.
- e) For frequency hopping systems, the software should allow the hopping sequence to be turned off.
- f) The test report shall include the date, version number, and storage location of the software used to exercise the wireless devices.

5.10.6 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 may 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.

5.10.7 Composite systems

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

For a composite system, testing for compliance with this standard 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, measurements of

³⁰ Refer to the latest applicable regulatory requirements and interpretations concerning testing of antennas for unlicensed wireless devices.

conducted and radiated emissions shall be performed with all radiating sources that are to be employed emitting.³¹ If the system contained an unlicensed wireless device, 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.

5.10.8 External accessories

If the EUT allows for the connection of external accessories, including external electrical control signals, 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. All possible equipment combinations do not need to be tested. The accessories connected to the EUT shall be unmodified and commercially available equipment. The test report shall identify the operating modes and accessories tested for both exploratory and final emission and the rationale for the modes and accessories used in the final measurement.

5.10.9 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, testing of the control unit and/or the accessory(ies) must 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 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, testing of the central control unit and/or the accessory(ies) must 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. All possible equipment combinations are not required to be tested. The accessories or peripherals connected to the device being tested shall be unmodified, commercially available equipment.

5.11 Operational requirements during testing

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 worst-case duty cycle and this information shall be noted as such in the test report. The unlicensed wireless device shall be tested operating at the highest transmit power allowed for each antenna configuration. See also 5.10.5 about device operating software.

The system shall be tested with each modulation to identify the worst-case modulation. Where a single modulation scheme is used, justification for the single modulation chosen shall be provided in the test report.

The system shall be tested using the data rate that yields the highest emission amplitudes. The data rate and rationale or supporting test data shall be included in the test report.

For frequency hopping systems, the hopping sequence shall be stopped for certain test suites to allow for measurements on a single channel.³²

³¹ See 47 CFR 15.31(h), 15.31(k).

³² See FCC/DA-00-705 [B7].

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.

When modulation is required in an individual test, devices modulated from internal sources shall be tested with typical modulation applied. If a device is equipped with input connectors for external modulation, 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). 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 SPL (sound pressure level) applied 10 cm from the microphone (0 dB SPL is 20 μ Pa).

For systems deploying broadband wireless technologies or spread spectrum technology, the system must 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 shown 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.

When testing systems using frequency hopping technology, the tests must address the additional requirements for operation with modulation as specified in 7.7 of this standard.

All modulations supported by the system shall be recorded in the test report with the justification for selecting 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. For battery-operated equipment, the equipment tests shall be performed using a new battery.³³

5.14 Special accessories

The EUT as marketed to a consumer must be capable of complying with the applicable regulatory requirements in the configuration in which the equipment is marketed. Where special components or accessories, such as shielded cables and/or special connectors, are required to enable the equipment to comply with the applicable emission limits, the equipment shall be tested with those special accessories and components and documented as such in the test report.^{34, 35}

³³ For frequency stability due to variations in temperature and supply voltage, e.g., 47 CFR 15.225, 15.229, and 15.231(e).

³⁴ See 47 CFR 15.27.

³⁵ Regulatory authorities may specify additional labeling, instruction manual, and user requirements for devices and systems that require accessories for the operation or installation of certain unlicensed wireless devices.

6. Standard test methods

6.1 General

This clause covers standard test methods for many unlicensed wireless devices. Additional test methods for specific devices are contained in Clause 7. The standard methods include tests for the following:

- a) Power-line conducted emissions (6.2)
- b) Radiated emissions (6.3 to 6.6)
- c) Antenna port conducted signals (6.7)
- d) Unlicensed wireless device frequency stability (6.8)
- e) Occupied bandwidth and band edge attenuation (6.9)
- f) Unlicensed wireless device output power (6.10)
- g) Power spectral density below 40 GHz (6.11)
- h) In-situ radiated emissions (6.12)

NOTE—For readability and continuity of test procedure descriptions, accompanying figures are all grouped in 6.13 at the end of this clause.

6.2 Standard test method for AC power-line conducted emissions from unlicensed wireless devices

6.2.1 General considerations

AC power-line conducted emission measurements shall be made, unless otherwise specified, over the frequency range from 150 kHz to 30 MHz to determine the line-to-ground radio-noise voltage that is conducted from all of the EUT current-carrying power input terminals that are directly (or indirectly via separate transformers or power supplies) connected to a public power network. These measurements may also be required between 9 kHz and 150 kHz.

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

6.2.2 Measurement requirements

Measured levels of ac power-line conducted emission shall be the emission voltages from the voltage probe or across the 50 Ω LISN port (to which the EUT is connected), where permitted, terminated into a 50 Ω measuring instrument, or where permitted or required, the emission currents on the power line sensed by a current probe. All emission voltage and current measurements shall be made on each current-carrying conductor at the plug end of the EUT power cord by the use of mating plugs and receptacles on the LISN, if used. Equipment shall be tested with power cords that are normally supplied or recommended by the manufacturer, and that have electrical and shielding characteristics that are the same as those cords normally supplied or recommended by the manufacturer. For those measurements, using a LISN, the 50 Ω

measuring port is terminated by a measuring instrument having a 50 Ω input impedance. All other ports are terminated in 50 Ω loads. Figure 5, Figure 6, and Figure 7 show typical test setups for ac power-line conducted emissions testing (see 6.13). For information about the use of a RF-shielded (screen) room, vertical conducting plane and voltage probe, see ANSI C63.4.

Tabletop devices shall be placed on a platform of nominal size, 1 m by 1.5 m, raised 80 cm above the reference ground plane. The vertical conducting plane or wall of an RF-shielded (screen) room shall be located 40 cm to the rear of the EUT. Floor-standing devices shall be placed either directly on the reference ground-plane or on insulating material as described in ANSI C63.4. All other surfaces of tabletop or floor-standing EUTs shall be at least 80 cm from any other grounded conducting surface, including the case or cases of one or more LISNs.

Each current-carrying conductor of the EUT power cord(s), except the ground (safety) conductor(s), shall be individually connected through a LISN to the input power mains. All 50 Ω ports of the LISN shall be resistively terminated in 50 Ω loads when not connected to the measuring instrument. When the test configuration is comprised of multiple units that have their own power cords, ac power-line conducted emissions measurements shall be performed with the ac power-line cord of the particular unit under test connected to one LISN that is connected to the measuring instrument. Those power cords for the units in the remainder of the configuration not under measurement shall be connected to a LISN different from the LISN used for the power cord of the portion of the EUT being measured. This connection may be made using a multiple receptacle device.

Emissions from each current-carrying conductor of the EUT shall be individually measured. Where multiple portions of the EUT receive ac power from a common power strip, which is furnished by the manufacturer as part of the EUT, measurements need only be made on the current-carrying conductors of the common power strip. Adapters or extension cords connected between the EUT power cord plug and the LISN power receptacle shall be included in the LISN setup such that the calibration of the combined adapter or extension cord with an adapter and the LISN meets the requirements of 4.3.

If the EUT is comprised of a number of devices that have their own separate ac power connections, e.g., a floor-standing frame with independent power cords for each shelf, that are able to connect directly to the ac power network, each current-carrying conductor of one device is measured while the other devices are connected to a second (or more) LISN(s). All devices shall be separately measured.

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

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

The LISN housing, measuring instrument case and reference ground plane or vertical conducting plane, if used, shall be bonded together (see ANSI C63.4).

6.2.3 Arrangement of EUT

The EUT shall be carefully installed, arranged, and operated in a manner that is most representative of the equipment as typically used (i.e., as specified in the EUT instruction manual) or as specified herein. Equipment that typically operates within a system made of multiple interconnected units should be tested as part of such a typical operational system. The guidance and consideration in 5.10 shall also be applied in the setup and operating requirements of the unlicensed wireless device.

Generally, the system that is tested shall be based on that typically marketed to the end user. If the marketing information is not available or it is not practical to assemble relatively excessive amounts of equipment to replicate a complete marketed product installation, the test shall be performed using the best judgment of the test engineer in consultation with the design engineering staff. In case of doubt, it may be prudent to contact the regulatory authority for guidance, especially for new technology devices. The results of any such discussion and decision process shall be reported in the test report. A photograph or detailed drawing shall be used to document the equipment arrangement and shall be part of the test report.

In order to replicate emission measurements, it is important to document the arrangement of the system components, cables, wires, and ac power cords. Two general equipment device classes and test arrangements are described below, i.e., tabletop equipment (6.2.3.1) and floor-standing equipment (6.2.3.2).

6.2.3.1 Tabletop equipment testing

Portable, small, lightweight, or modular devices that may be hand-held, worn on the body, or placed on a table during operation shall be positioned at the center of a non-conducting platform, the top of which is 80 cm above the reference ground plane. Ceiling and wall-mounted devices shall also be positioned at the center of a tabletop for testing purposes. The preferred area occupied by the EUT arrangement is 1 m by 1.5 m, but it may be larger or smaller to accommodate various sized EUTs (see Figure 5, Figure 6, and Figure 7).

6.2.3.1.1 Placement of tabletop EUTs

A stand-alone EUT shall be placed in the center of the tabletop. For multi-unit tabletop systems, the EUT shall be centered laterally (left to right facing the tabletop) on the tabletop and its rear shall be flush with the rear of the table.

Accessories that are part of a EUT system tested on a tabletop shall be placed in a test arrangement on one or both sides of the host with a 10 cm separation between the nearest points of the cabinets (see Figure 6). The rear of the host and accessories should be flush with the back of the supporting tabletop unless that would not be typical of normal use. If more than two accessories are present, an equipment test arrangement should be chosen that maintains 10 cm spacing between cabinets unless the equipment is normally located closer together. Multiple accessories (more than two) may be distributed around the table as shown in Figure 6.

Accessories, such as ac power adapters, which are typically table-mounted because of cable length, shall be mounted on the tabletop in a typical manner. Accessories, which are typically floor-mounted, shall occupy a floor position directly below the portion of the EUT to which they are typically connected.

Power accessories such as ac power adapters (battery eliminators), which power other devices, shall be tested per the following provisions.

- a) Power accessories that are not the EUT are configured as follows:
 - 1) If the power accessory connects to a tabletop EUT having a power cord to the power accessory less than 80 cm in length, the power accessory is placed on the table top. If the EUT power cord to the power accessory is 80 cm or greater in length, then the power accessory is placed on the floor immediately under the EUT.
 - 2) If the power accessory plugs directly into the wall outlet, it shall be attached to the source of power on top of the ground plane and directly under the EUT with the EUT connected. If the EUT power cord is less than 80 cm, then a non-conductive support for raising the power accessory is needed along with a short extension cord from the source of power to the raised power accessory.
- b) Power accessories that are part of the EUT are configured as follows:

- 1) If the input power cord of the power accessory is 80 cm or greater, the power accessory shall be placed on the tabletop. If the power accessory has an input power cord that is less than 80 cm, the power accessory shall be placed at a height above the ground plane such that its input power cord is fully extended in the vertical direction.
- 2) If the power accessory plugs directly into the wall outlet, the power accessory shall be tested on the tabletop using an extension cord between the source of power and the accessory. The extension cord shall be connected in a manner such that it takes the most direct path to the power accessory.

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

The system shall be arranged in one typical equipment arrangement for the test. In making any tests, involving several tabletop equipment components interconnected by cables or wires, it is essential to recognize that the measured levels may be critically dependent on the exact placement of the cables or wires. Thus, exploratory tests as specified in 6.2.4 shall be carried out while varying cable positions within typical arrangements to determine the maximum or near-maximum emission level. During manipulation, cables shall not be placed under or on top of the system units unless such placement is required by the inherent equipment design.

6.2.3.2 Floor-standing equipment tests

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

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

To more explicitly represent typical raised/false floor installation of EUTs, the base of the EUT may be raised, but in no case exceed 34 cm above the reference ground plane. If the EUT elevation which is not representative of a typical installation is used for testing, the reason for the variation shall be explained in the test report. However, the preferred method shall be measurements made at elevations that are representative of actual applications.

Floor-standing equipment can be interconnected with cabling lying on the floor, under the floor (to simulate a raised floor installation), or overhead, according to normal installation. The material used to raise the test item shall be nonconductive and shall not adversely affect the measurements. Test arrangements for floor-standing equipment are shown in Figure 7. Normally, tests shall be performed with the equipment standing on the reference ground plane, with or without an insulating surface, as appropriate.

6.2.3.2.1 Placement of floor-standing accessories

Accessories that are part of a floor-standing system shall be placed in one typical arrangement with typical spacing between equipment cabinets or enclosures.

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

Interconnecting cables are not normally manipulated for floor-standing equipment of which the typical installation is known. Instead, the cables shall be laid out as shown in Figure 7. If the configuration of a typical installation is not known or changes with each installation, cables of floor-standing equipment shall

be manipulated to the extent possible to produce the maximum level of emissions, within the range of typical installations. For large equipment interfacing with other large equipment normally placed at some distance away, cables may be attached to the EUT, extend away from the EUT in the horizontal direction for at least 1 m and then return to another port of the EUT (which would normally receive the transmit signal from another equipment), but at an elevation sufficiently different than that of the outgoing direction so as not to cancel the emission potential of either portion (outgoing and incoming) of the cable in this loop back situation. Loop back for this purpose is characterized by a single cable leaving a connector of the EUT, extending a distance away, and then routed back to the EUT at another connector.

6.2.4 Exploratory ac power-line conducted emission measurements

Exploratory tests should be run both with the modulating signal(s) specified in 5.12 applied to the EUT and with no modulating signal applied to the EUT. On any one convenient frequency specified in 5.5 and 5.6, exploratory measurements should be used to identify the frequency of the emission that has the highest amplitude relative to the limit by operating the EUT in a range of typical modes of operation, cable positions, and with a typical system equipment configuration and arrangement. For each mode of operation and for each ac power current-carrying conductor, cable manipulation may be performed within the range of likely configurations. For this measurement or series of measurements, the frequency spectrum of interest should be monitored looking for the emission that has the highest amplitude relative to the limit. Once that emission is found for each current-carrying conductor of each power cord associated with the EUT (but not the cords associated with non-EUT equipment in the overall system), the one configuration and arrangement and mode of operation that produces the emission closest to the limit over all of the measured conductors is recorded.

6.2.5 Final ac power-line conducted emission measurements

Based on the exploratory tests of the EUT performed in 6.2.4, the one EUT cable configuration and arrangement and mode of operation that produced the emission with the highest amplitude relative to the limit is selected for the final measurement, while applying the appropriate modulating signal to the EUT. If the EUT is relocated from an exploratory test site to a final test site, the highest emissions shall be re-maximized at the final test location before final ac power-line conducted emission measurements are performed. The final test on all current-carrying conductors of all of the power cords to the equipment that comprises the EUT (but not the cords associated with other non-EUT equipment in the system) is then performed for the full frequency range for which the EUT is being tested for compliance without further variation of the EUT arrangement, cable positions, or EUT mode of operation. If the EUT is comprised of equipment units that have their own separate ac power connections, e.g., floor-standing equipment with independent power cords for each shelf that are able to connect directly to the ac power network, each current-carrying conductor of one unit is measured while the other units are connected to a second (or more) LISN(s). All units shall be separately measured. If a power strip is provided by the manufacturer, to supply all of the units making up the EUT, only the conductors in the power cord of the power strip shall be measured.

If the EUT uses a detachable antenna, these measurements shall be made with a suitable dummy load connected to the antenna output terminals; otherwise, the tests shall be made with the antenna connected and, if adjustable, fully extended. When measuring the ac conducted emissions from a device that operates between 150 kHz and 30 MHz a non-detachable antenna may be replaced with a dummy load for the measurements within the fundamental emission band of the transmitter, but only for those measurements.³⁶

Record the six highest EUT emissions relative to the limit of each of the current-carrying conductors of the power cords of the equipment that comprises the EUT over the frequency range specified by the procuring or regulatory agency. Diagram or photograph the test setup that was used. See Clause 8 for full reporting requirements.

³⁶ See FCC Knowledge Database publication number: 174176, published 07/02/2008,[B13], [B17].