

American National Standard for Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices

Sponsor

Accredited Standards Committee on Electromagnetic Compatibility, C63

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Abstract: Specific test procedures are established for verifying the compliance of unlicensed personal communications services (UPCS) devices with applicable regulatory requirements regarding radio-frequency (RF) emission levels and spectrum access procedures.

Keywords: etiquette, personal communications, RF emissions, spectrum access, unlicensed devices

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Introduction

[This introduction is not part of ANSI C63.17-1998, American National Standard for Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices.]

In November 1993, the Federal Communications Commission (FCC) invited the Accredited Standards Committee on Electromagnetic Compatibility, C63, “to consider development of standard measurement procedures to support” proposed new provisions to Part 15 of volume 47 of the Code of Federal Regulations (47 CFR 15) for unlicensed personal communications services (UPCS) devices. At its December 1993, meeting, Accredited Standards Committee C63 established a subcommittee (SC 7) to attempt to develop such standards in cooperation with representatives of the WINForum and other interested parties. This document is the result of the efforts of that committee.

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American National Standard for Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices

1. Introduction

1.1 Scope

This standard sets forth uniform methods of measurement of the electromagnetic and operational compatibility of unlicensed personal communications services (UPCS) devices. This standard does not cover licensed personal communications services (PCS) devices. The recommended methods described are applicable to the radio transmitter and monitoring devices contained in the UPCS device. These methods apply to the measurement of individual UPCS devices. Additional methods may be added to this standard to fulfill future requirements.

In addition to the measurements specified herein, UPCS devices may also be required to be tested in accordance with other standards. Examples are listed in Annex A.

1.2 Applications

The procedures given herein may be used to test UPCS devices permitted under 47 CFR 15, Subpart D. The emissions and operational characteristics of UPCS devices are the basic parameters affecting UPCS coexistence with other electronic devices and systems. In particular, compliance with this standard may be used to demonstrate electromagnetic compatibility with other isochronous and asynchronous UPCS systems, the private operational/fixed microwave services systems, and other systems operating in the same and adjacent frequency bands.

This standard describes preferred test methods and facilities and, in some cases, alternative test methods and facilities. If these methods and facilities do not apply to the equipment under test (EUT), the manufacturer shall explain why and shall provide an alternative test procedure that has been approved by the applicable regulatory agency. If alternative test methods or facilities are employed, every effort should be made to establish a correlation with the preferred methods or facilities.

Where the word *shall* is used in this document, it indicates something that is mandatory for compliance with this standard. The word *should* indicates something that is advisory only.

1.3 Road map to the standard

The tests for UPCS devices fall into two categories. The first category includes the traditional radio frequency (RF) measurements of radiated power, emission mask, power spectral density, etc. These tests are given in Clause 6 of this document. The second category includes tests for the channel monitoring and access requirements unique to UPCS devices. These requirements are sometimes collectively referred to as the spectrum etiquette. The associated tests are described in Clauses 7 and 8 of this document, and they relate to Sections 15.321 (asynchronous devices) and 15.323 (isochronous devices) of 47 CFR 15, Subpart D. These sections of 47 CFR 15, Subpart D, require that a UPCS device monitor the received RF power level on the intended transmit channel¹ before transmitting, and provide criteria that the monitored power level shall satisfy to allow the device to transmit on that channel. The tests in Clauses 7 and 8 are designed to verify compliance with these requirements. Annex A provides a table showing the sections in 47 CFR 15, Subpart D, that correspond to the tests in this standard.

To test for compliance with the monitoring and access requirements, it is necessary to subject the EUT to deliberate interference, with controlled spectral and temporal characteristics on a selected channel or channels, and to observe the reaction of the EUT. To restrict operation of the EUT to the selected channel(s), interference can be used to block the other channels. Use of administrative commands to facilitate testing (e.g., to restrict operation of the EUT to the desired channels) is also acceptable; however, test results obtained by using actual interference to block the unused channels take precedence in the event of a difference in results.

Clauses 6, 7, and 8 give the fundamental tests. Clause 4 discusses test methodology for both radiated and conducted RF emission, monitoring, and access tests. Annex D provides the theoretical background. Radiated tests measure field strength to determine the effective isotropic radiated power (EIRP), energy density, and out-of-band emissions (see Clause 6). For the monitoring and access tests of Clauses 7 and 8, a calibrated field strength is applied to the EUT, if radiated measurements are used. If all EUT antennas are detachable, the tests of Clauses 6, 7, and 8 shall be done on a conducted basis (i.e., RF connections can be made between the EUT, its companion device, and the RF measuring equipment and interference generators via shielded coaxial cable). There shall be adequate shielding around the EUT (and possibly the companion device) to prevent unintended RF coupling.

Clause 5 provides guidance on measurement instrumentation and signal generators for performing the tests. Clause 9 summarizes the information that should be provided in the test report.

2. References

The following references shall form a part of this standard to the extent that they are referenced herein. When ANSI and IEEE Standards are superseded by a revision, the version specified in this document shall apply.

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

ANSI C63.4-1992, 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 C63.5-1988, American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electromagnetic Interference (EMI) Control.

¹“Channel” is used here to denote a time/spectrum window.

²ANSI C63 publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA, or from the Sales Department, American National Standards Institute, 11 West 42nd St., New York, NY 10036, USA.

ANSI C63.6-1988, American National Standard Guide for the Computation of Errors in Open-Area Test Site Measurements.

ANSI C63.7-1992, American National Standard for Construction of Open-Area Test Sites for Performing Radiated Emission Measurements.

ANSI C63.14-1992, 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*).

IEEE Std 100-1996, The IEEE Standard Dictionary of Electrical and Electronics Terms.³

IEEE Std 149-1979 (Reaff 1990), IEEE Standard Test Procedures for Antennas.

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

47 CFR 15, Subpart D—Unlicensed Personal Communications Services Devices.⁴

3. Definitions, acronyms and abbreviations, and symbols

3.1 Definitions

The definitions in IEEE Std 100-1996 and ANSI C63.14-1992, unless otherwise noted below, apply throughout this document. Definitions in particular product standards or in applicable regulations take precedence. Sources of definitions (if applicable) are enclosed in brackets following the definition.

3.1.1 absorber-lined open-area test site: An open-area test site with a radio frequency (RF) absorber-covered ground plane, to reduce reflections to an acceptable level.

NOTE—According to the requirements of this standard, an acceptable level is 10 dB below the direct-path signal strength.

3.1.2 anechoic enclosure: An enclosure whose internal walls have low reflection characteristics. [ANSI C63.14-1992]

3.1.3 asynchronous devices: Devices that transmit radio frequency (RF) energy at irregular time intervals, as typified by local area network data systems. [47 CFR 15, Subpart D, 15.303(a)]

3.1.4 asynchronous reaction time: The time interval beginning when a device senses a clear observation window and ending when it begins transmission. [ANSI C63, Subcommittee 7]

3.1.5 asynchronous sub-band: The spectrum allocated for asynchronous transmission. [Extraction from 47 CFR 15, Subpart D, 15.303(i)]

3.1.6 asynchronous transmission burst: A series of transmissions from one or more transmitters acting cooperatively. [47 CFR 15, Subpart D, 15.323(f)]

3.1.7 band: Range of frequency between two defined limits. [IEEE Std 100-1996]

³IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁴CFR publications are available from the Superintendent of Documents, U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20013-7082, USA.

3.1.8 bandwidth (BW): The range of frequencies within which performance, with respect to some characteristic, falls within specific limits. [IEEE Std 100-1996]

3.1.9 Boltzmann's constant (k): The number k that relates the average energy of a molecule to the absolute temperature of the environment. k is approximately 1.38×10^{-23} joules/kelvin. [IEEE Std 100-1996]

3.1.10 center half (of sub-band): A range of frequencies centered in the sub-band and having a span equal to 1/2 of the width of the sub-band. If F_a is the lower-frequency edge of the sub-band and F_b is the upper-frequency edge of the sub-band, then the center half of the sub-band is equal to $(F_a + F_b)/2 \pm (F_a - F_b)/4$. [ANSI C63, Subcommittee 7]

3.1.11 conducted emission and monitoring tests: Tests performed with radio frequency (RF) signal sources (to test monitoring thresholds) and instrumentation (to measure emissions) connected directly to the antenna port on the equipment under test (EUT) transceiver, via shielded coaxial cable and passive combiner/splitter networks. *See also:* **radiated emission and monitoring tests.**

3.1.12 coordinatable PCS device: Personal communications services (PCS) devices whose geographical area of operation is sufficiently controlled either by necessity of operation with a fixed infrastructure or by disabling mechanisms to allow adequate coordination of their locations relative to incumbent fixed microwave facilities. [47 CFR 15, Subpart D, 15.303(b)]

3.1.13 digital modulation: The process by which the characteristics of a carrier wave are varied among a set of predetermined discrete values in accordance with a digital modulating function. [ANSI C63, Subcommittee 7]

3.1.14 emission bandwidth (B): The width, in Hz, of the signal between two points, one below the carrier center frequency and one above the carrier center frequency, that are 26 dB down relative to the maximum level of the modulated carrier. It is based on the use of measurement instrumentation employing a peak detector function with an instrument resolution bandwidth approximately equal to 1% of the emission bandwidth of the device under measurement. [Extraction from 47 CFR 15, Subpart D, 15.303(c)]

3.1.15 equipment under test (EUT): The device, equipment, subsystem, or system that is to be tested or that is under test. [ANSI C63.14-1992]

3.1.16 frame jitter: Time-related, abrupt, spurious variations in the duration of the frame interval. [47 CFR 15, Subpart D, 15.321(e)]

3.1.17 frame period: A set of consecutive time slots in which the position of each time slot can be identified by reference to a synchronizing source. [47 CFR 15, Subpart D, 15.321(e)]

3.1.18 intentional radiator: A device that intentionally generates and emits radio frequency (RF) energy by radiation or induction. [47 CFR 15, Subpart D, 15.3(o)]

3.1.19 isochronous devices: Devices that transmit at a regular interval, typified by time-division voice systems. [47 CFR 15, Subpart D, 15.303(d)]

3.1.20 isochronous reaction time: The duration of radio frequency (RF) power during monitoring that shall be detected by the device that determines that the monitored time and spectrum window is occupied. [ANSI C63, Subcommittee 7]

3.1.21 isochronous sub-band: The spectrum allocated for isochronous transmission. [47 CFR 15, Subpart D, 15.303(i)]

3.1.22 least interfered channel (LIC): An interference avoidance mechanism that extends the listen before transmit (LBT) mechanism to monitor all potential channels, determining the least interfered channel, before

transmitting on that channel. Under 47 CFR 15, Subpart D, 15.323, this mode of operation is limited to those devices with 40 or more channels. *See also:* **listen before transmit**.

3.1.23 listen before transmit (LBT): An interference avoidance mechanism that mandates monitoring of a selected channel to determine availability before transmission.

3.1.24 noncoordinatable PCS device: A personal communications services (PCS) device that is capable of randomly roaming and operating in geographic areas containing incumbent microwave facilities, such that operation of the PCS device will potentially cause harmful interference to the incumbent microwave facilities. [47 CFR 15, Subpart D, 15.303(e)]

3.1.25 open-area test site (OATS): A site for electromagnetic measurements that is open, flat terrain at a distance far enough away from buildings, electric lines, fences, trees, underground cables, pipelines, and other potential reflective objects that the effects due to such are negligible. *See* ANSI C63.7-1992 for guidance on the construction of open-area test sites. [ANSI C63.14-1992]

3.1.26 operational failure: The inability of an equipment under test (EUT) to perform a function that is required as a response to system conditions or to a manually or automatically initiated command. [ANSI C63, Subcommittee 7]

3.1.27 peak transmit power: The peak power output as measured over an interval of time equal to the transmission-burst duration of the device under all conditions of modulation. [47 CFR 15, Subpart D, 15.303(f)]

3.1.28 power spectral density: The average pulse energy in a 3 kHz bandwidth divided by the pulse duration (see Annex C).

3.1.29 radiated emission and monitoring tests: Tests performed with radio frequency (RF) signal sources (to test monitoring thresholds) and instrumentation (to measure emissions) connected to test antennas. *See also:* **conducted emission and monitoring tests**.

3.1.30 semianechoic room/chamber: A test enclosure featuring a reflective ground plane at the floor and RF absorber-lined internal walls and ceiling that produce sufficiently low reflections in the frequency range of interest. As an electromagnetic compatibility (EMC) test facility, the semianechoic room is equivalent to the open-area test site and shall meet the test site attenuation requirements of ANSI C63.4-1992. *See also:* **open-area test site**.

3.1.31 shielded enclosure: A mesh or sheet metallic housing designed expressly for the purpose of separating electromagnetically the internal and the external environment. [ANSI C63.14-1992]

3.1.32 shielded room: *See:* **shielded enclosure**. [ANSI C63, Subcommittee 7]

3.1.33 spectrum window: An amount of spectrum equal to the intended emission bandwidth in which operation is desired. [47 CFR 15, Subpart D, 15.303(h)]

3.1.34 sub-band: The spectrum allocated for isochronous or asynchronous transmission. [47 CFR 15, Subpart D, 15.303(i)]

3.1.35 TEM cell: A measuring device that is designed to utilize the transverse electromagnetic mode (TEM) over the frequency range of interest. Common examples are the two-port TEM cell (also known as the Crawford Cell) and the wideband TEM cell. [ANSI C63.4-1992]

3.1.36 thermal noise power: The noise power (in W) defined by the formula $N = kTB$, where N is the noise power, in W, k is Boltzmann's constant, T is the absolute temperature, in degrees kelvin (e.g., 295 °K), and B is the emission bandwidth of the device, in Hz. [47 CFR 15, Subpart D, 15.303(j)]

3.1.37 time window: An interval of time in which transmission is desired. [47 CFR 15, Subpart D, 15.303(k)]

3.1.38 transmit power: The total energy transmitted over a time interval of no more than $30/B$ (where B is the emission bandwidth of the signal), divided by the interval duration. [ANSI C63, Subcommittee 7]

3.1.39 unlicensed personal communications service (UPCS) device: Intentional radiators operating in the frequency band specified by the applicable regulating agency that provide a wide array of mobile and ancillary fixed communication services to individuals and businesses. [Modification of 47 CFR 15, Subpart D, 15.303(g)]

3.1.40 wavelength (λ): Of a monochromatic wave, the distance between two points of corresponding phase of two consecutive cycles in the direction of the wave normal. [IEEE Std 100-1996]

3.1.41 wideband (WB) TEM cell: A transverse electromagnetic mode (TEM) cell that has been altered to extend the usable frequency range. Often, this is achieved by replacing one port of a two-port TEM cell with a nontapered, wideband load. [ANSI C63.4-1992]

3.2 Acronyms and abbreviations

ANSI	American National Standards Institute
BW	bandwidth
CAT	computed average transient
CW	continuous wave
dB	decibel
dBA	decibels referenced to 1 ampere
dBc	decibels referenced to the carrier
dB _i	decibels referenced to isotropic (antenna gain)
dBm	decibels referenced to 1 milliwatt
dB μ V	decibels referenced to 1 microvolt
dB(μ V/m)	decibels referenced to 1 microvolt per meter
EIRP	effective isotropically radiated power
EMC	electromagnetic compatibility
EMP	electromagnetic pulse
ESD	electrostatic discharge
EUT	equipment under test
FCC	Federal Communications Commission
FDMA	frequency-division multiple access
FFT	Fast Fourier Transform
GHz	gigahertz
Hz	hertz
IEEE	Institute of Electrical and Electronics Engineers
IF	intermediate frequency
kHz	kilohertz
LAN	local area network
LBT	listen before transmit
LIC	least interfered channel
MC	multicarrier
MHz	megahertz
ms	millisecond
μ s	microsecond
mW	milliwatt
OATS	open-area test site
P	transmit power

PCS	personal communications services
ppm	parts per million
PSD	power spectral density
RBW	resolution bandwidth
RF	radio frequency
rms	root mean square
Rx	receiver
TDMA	time-division multiple access
TEM	transverse electromagnetic
Tx	transmitter
UPCS	unlicensed personal communications services
VSWR	voltage standing wave ratio
W	watt
WB-TEM	wideband transverse electromagnetic cell

3.3 Symbols

<i>B</i>	emission bandwidth, in Hz
<i>k</i>	Boltzmann's constant, in joules/kelvin
<i>M</i>	monitoring threshold
<i>T</i>	temperature, in degrees kelvin

4. Radiated and conducted test methodology

To perform the RF emission tests in Clause 6 and the monitoring and access tests in Clauses 7 and 8, it is necessary to have controlled RF paths between the EUT and the measurement instrumentation, and between the EUT and the interference generators. If the EUT requires a companion device to operate, there also shall be a controlled RF path between the EUT and its companion device.

These controlled RF paths may be realized either as “radiated” (through space) or “conducted” (over coaxial cable) paths. In the radiated case, the tests shall be performed in a facility with controlled RF propagation characteristics, so that the path loss can be controlled by varying separation between transceiver and monitoring/source antennas. In the conducted case, the tests can be performed anywhere that there is adequate shielding to prevent external interference from affecting the test results. Signals can be combined and distributed using passive networks (e.g., hybrids, Butler matrices,⁵ and directional couplers). Path loss can be controlled with RF attenuators. Conducted tests are preferred to radiated tests, and should be used if the EUT antenna can be detached for testing purposes.

This clause provides guidance on the implementation of the conducted and radiated measurements of transmit power and monitoring threshold. Supporting derivations are given in Annex D.

4.1 Test facilities and equipment

Tests should be performed at the manufacturer's recommended normal operating temperature and voltage.⁶ Unless stated otherwise, the requirements of ANSI C63.4-1992 apply to the test facilities, including site design, dimensions, and validation. Additional site validation requirements above 1 GHz currently are under development. Portions of this standard place requirements on the test facilities in addition to the general requirements of ANSI C63.4-1992.

When shielded facilities (e.g., shielded rooms, semianechoic chambers, or anechoic chambers) are used for operational compatibility testing, the shielding effectiveness of the room shall be such as to ensure compli-

⁵A Butler matrix is a network of 3 dB hybrids that provides a passive combining/splitting function for coupling multiple RF inputs to multiple RF outputs.

⁶Where this is not specified, conditions of 20 °C and 115 V ac (or fresh battery pack) may be used.

ance with electromagnetic emission limits for the environment outside of the room and to reduce the ambi-ents penetrating into the room to levels at least 10 dB below the weakest measured signal. When the free-space test environment is simulated, the reflections from the facility confines, as well as the reflections from any extraneous objects at the test site, shall be reduced to levels at least 10 dB below the direct (free-space) signal.

The diagram in Figure 1 lists the types of test facilities for measurements specified in this standard.

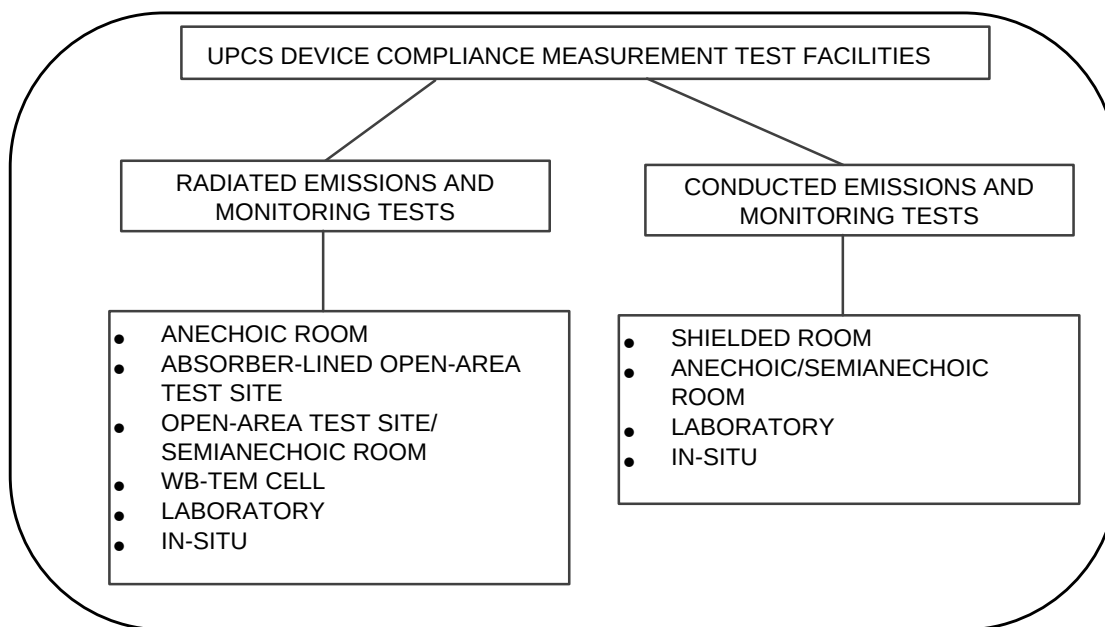


Figure 1—Recommended test facilities

The choice of the test facility is determined by the regulatory agency.

4.2 Test configurations and setup

Clause 6 provides detailed tests of parameters related to RF emissions, such as peak transmit power, emission bandwidth, and power spectral density. These tests are similar to emission tests performed on most non-UPCS devices. Clauses 7 and 8 provide tests that verify compliance with the monitoring and access requirements that are unique to UPCS devices. These tests require observation of the EUT's behavior in the presence of controlled interference of a specific frequency, power level, and modulation format. The monitoring and access tests have implications on the conducted and radiated test setups.

The monitoring antenna refers to the EUT antenna used to monitor the RF signal on the channel prior to transmission. In many cases, the monitoring antenna will be the same as the transmitting antenna. If it is not, then the monitoring and access tests are further complicated by the need to ensure that the monitoring antenna provides "coverage" that is at least equivalent to that which would be provided by the transmit antenna.

This standard identifies six test configurations. Each configuration is discussed in a separate subclause, as shown in the following table.

Transmit/monitoring antenna comparison and placement	Subclause	
	Conducted measurement based test (preferred)	Radiated measurement based test
Single, or identical collocated*	4.4	4.7
Different collocated	4.5	4.8
Arbitrarily placed	4.6	4.9

* Antennas of the same type with a separation distance of 1 m or less, mounted on or within the same physical housing for the purpose of providing diversity against multipath fading, are considered to be "identical collocated."

The measurement type (i.e., conducted or radiated) can be selected independently of type and placement by the product manufacturer and can be specified in the compliance report. Conducted measurements generally are required for systems with detachable antennas.

Compliance measurements utilize standard EMC and antenna techniques for conducted power, radiated field, and EIRP measurements. The conducted test setup is based on power measurements at the EUT transmit, receive, and monitoring antenna terminals. The associated compliance limits for the UPCS products depend on the transmit antenna gain, G_A . The value of G_A is declared by the manufacturer.

Since the transmitter and receiver radiated-power parameters can be expressed in several different but equivalent ways, a number of alternative compliance test procedures can be used for radiated measurements. The general radiated test setup is based on free-space environment measurements, as shown in Figure 2, where D is the largest dimension of the EUT (see Figure 8 for the general conducted test setup). The free-space test site is defined such that the reflections from any ground planes and other reflecting objects are at least 10 dB below the line-of-sight signal. The reference antenna is used to measure the EUT radiating power and to establish the monitoring threshold fields at the transmit and monitoring antennas. The associated compliance limits are based on the EIRP. The antenna gain and the EIRP evaluations should be performed as recommended by IEEE Std 149-1979.

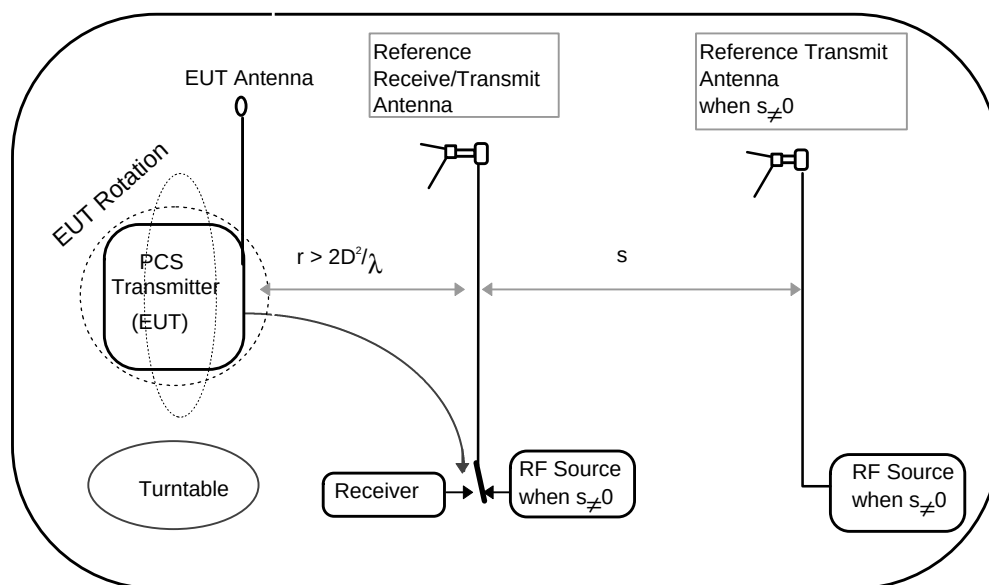


Figure 2—Radiated measurements in free-space environment

Equivalent radiated tests can be performed in facilities that do not provide for a free-space environment and/or measure radiated power (e.g., WB-TEM, etc.). Instead of using the reference antenna, the necessary power levels are generated and/or measured by the test facility itself. If alternative measurements are used, the test results shall be correlated with those obtained using antenna measurements in a free-space environment.

4.3 Transmitted power and monitoring threshold limits

The EUT transmit power limit, at the antenna terminals, is

$$P_{EUT} \leq \begin{cases} P_{\max} - (G_A - g), & \text{when } G_A > g \\ P_{\max}, & \text{when } G_A \leq g \end{cases} \quad (1)$$

where

- $P_{\max}$ equals $5 \log B - 10$ dBm, or $10^{-4} \sqrt{B}$, in W.
- B is the emission bandwidth, in Hz.
- G_A is the EUT transmit antenna maximum gain (declared by the manufacturer), in dBi.
- g is the allowable excess gain over that of an isotropic antenna without a transmit power reduction.⁷

The maximum monitoring threshold power at the monitoring antenna terminals is

$$T_M = T_{Mi} + P_{\max} - P_{EUT} \text{ (dBm)} \quad (2)$$

where

- T_{Mi} equals $-174 + 10 \log B + M$ dBm.
- M is the amount by which the threshold exceeds thermal noise for a device transmitting the maximum allowed power, in dB.

When conducted tests are performed, the limits shown in Equations (1) and (2) apply directly. For radiated tests, those limits shall be translated to the equivalent limits on EIRP and monitoring threshold field strength, respectively. EIRP limits⁸ corresponding to Equation (1) are

$$EIRP_{EUT} \leq \begin{cases} P_{\max} + g, & G_A > g \\ P_{\max} + G_A, & G_A \leq g \end{cases} \quad (3)$$

To test for monitoring threshold compliance using radiated techniques, a reference antenna is used to generate the required field strength at the monitoring antenna. The transmit power that shall be applied to the reference antenna terminals to induce a power level can be expressed in terms of the EIRP as

$$P_{Tref} = T_{Mi} + P_{\max} - EIRP_{EUT} - 20 \log (\lambda/4\pi r) - G_{REF} \quad (4)$$

or, in terms of the maximum measured field strength at a distance, r , from the EUT, as

$$P_{Tref} = T_{Mi} + P_{\max} - E_{EUT\max} + 20 \log_{10} f - G_{REF} - 42.8 \quad (5)$$

⁷47 CFR 15, Subpart D, 15.319(e), specifies that $g = 3$ dBi.

⁸Because the EIRP limit is independent of G_A for $G_A > 3$ dBi, and most practical radiating devices will not have a gain sufficiently below 3 dBi for the difference of 3 dBi $- G_A$ to be accurately measurable, there may be a gain-independent EIRP limit in the future.

where

- G_{REF} is the gain of the reference antenna in the direction of the EUT, in dBi.
- f is the signal frequency, in Hz.
- λ is the wavelength, in meters.
- r is the distance from the reference antenna to the EUT monitoring antenna.

In Equation (5), it is assumed that r is the same for measurement of the radiated field strength and the monitoring threshold.

4.4 Conducted measurements of products with collocated transmitting and monitoring antennas of the same type

The EUT antenna shall be disconnected and the power, P_{EUT} , at its terminals shall be measured during EUT transmission, as specified in Clause 6. The monitoring threshold(s) shall be measured using the procedures in Clause 7. The EUT fails if it does not meet the criteria of Equations (1) and (2).

4.5 Conducted measurements of products with collocated transmitting and monitoring antennas of different types

When the monitoring antenna is different from the transmitting antenna, it shall be verified that the monitoring antenna provides coverage equivalent to that of the transmitting antenna. This means that the monitoring system shall cause deference to any transmission of sufficient strength to induce a power level in the EUT transmit antenna that exceeds the threshold for the EUT, as measured at the transmitting antenna input.

The transmit power compliance test of Clause 6 shall be performed as stated in 4.4. The maximum threshold, T_M , shall be calculated using Equation (2), and it shall be verified that the EUT transmits when power sufficiently less than T_M is applied to the monitoring antenna terminals and defers when power equal to or greater than T_M is applied to the terminals.

The equivalent coverage test for the transmitting and monitoring antennas is performed as follows:

- a) Set up the reference antenna with vertical polarization, and with its major lobe facing the EUT, at a distance, r (meeting the far-field conditions), from the EUT antennas.
- b) Illuminate the EUT with the reference antenna from a number of positions covering the surface of a sphere around the EUT with a radius of r . This can be done by positioning the EUT in three orthogonal planes and rotating it over a range of 0–360° in each plane. The rotation may be discrete or continuous.
- c) While rotating the EUT, apply power to the terminals of the reference antenna and adjust it to the level P_{Tref} so as to maintain a received power of T_M at the EUT transmit antenna terminals for any orientation.
- d) Repeat the test with horizontal polarization for the reference antenna.

The EUT shall defer at each position for one or the other of the two orthogonal polarizations of the reference antenna. Otherwise, the EUT fails the equivalent coverage test.

4.6 Conducted measurements of products with arbitrarily placed transmitting and monitoring antennas

The transmit power compliance test of Clause 6 shall be performed as stated in 4.4. The maximum threshold, T_M , shall be calculated using Equation (2), and it shall be verified that the EUT transmits when power sufficiently less than T_M is applied to the monitoring antenna terminals and defers when power equal to or greater than T_M is applied to the terminals.

The equivalent coverage test for the transmitting and monitoring antennas is performed as follows:

- a) Set up the reference antenna with vertical polarization, and with its major lobe facing the EUT, at a distance, r (meeting the far-field conditions), from the EUT transmit antenna in the direction of the EUT's maximum radiation.
- b) Apply power to the reference antenna terminals and adjust it to the level P_{Tref} so as to obtain power, T_M , at the EUT transmit antenna terminals.
- c) Move the reference antenna (without changing its orientation) in the direction of the EUT's maximum radiation to a distance, $r + s$, from the monitoring antenna (where s is the maximum possible distance between the transmit and monitoring antennas), as specified by the EUT manufacturer.
- d) Align the EUT monitoring antenna such that the direction of its minimum sensitivity faces the reference antenna.
- e) Apply power, P_{Tref} to the reference antenna and illuminate the EUT monitoring antenna.

The EUT shall defer for one or the other of two orthogonal reference antenna polarizations. Otherwise, the EUT fails the equivalent coverage test.

4.7 Radiated measurements of products with collocated transmitting and monitoring antennas of the same type

The EUT and reference antenna shall be set up, with the major lobe of the reference antenna facing the EUT, in the far field with a separation of r . The EUT transmission shall be initiated, and the direction of the EUT's maximum radiation shall be found. The EUT EIRP shall be measured. $EIRP_{EUT}$ (dBm) can be calculated from the measured radiated-field intensity in the direction of maximum radiation, E_{EUTmax} , using

$$EIRP_{EUT} = E_{EUTmax} + 20 \log r - 104.8 \quad (6)$$

where E_{EUTmax} is in dBμV/m.

Using the nominal value of the EUT gain, G_A , declared by the manufacturer, the limit on $EIRP_{EUT}$ shall be calculated using Equation (3). If $EIRP_{EUT}$ exceeds the limit, the EUT fails the test.

Compliance with the monitoring threshold limits is verified as follows:

- a) Using Equations (4) or (5), calculate the power, P_{ref} that shall be applied to the reference antenna terminals to establish the monitoring threshold field level (denoted by E_M in Annex D) at the EUT transmit antenna (this would induce a power level of T_M at the terminals of a lossless antenna with a gain of G_A).
- b) Apply power first smaller than, then equal to, P_{Tref} to the reference antenna terminals. Illuminate the EUT in the direction of maximum radiation, while continuously attempting to initiate the EUT transmission. Verify that there is at least one position of the EUT in which it will transmit when sufficiently low power is applied to the reference antenna terminals.
- c) When the power level applied to the reference antenna is equal to and larger than P_{Tref} the EUT shall defer for one or the other of two orthogonal polarizations of the reference antenna (e.g., vertical and horizontal). Otherwise, the EUT fails the test.
- d) As the EUT is rotated, monitor the power received by the reference antenna when the EUT transmits, and adjust the threshold accordingly.

4.8 Radiated measurements of products with collocated transmitting and monitoring antennas of different types

The EUT and reference antenna shall be set up, with the major lobe of the reference antenna facing the EUT, in the far field with a separation of r . The transmission test shall be performed as described in 4.7, and it shall be verified that $EIRP_{EUT}$ meets the limits.

Compliance with the monitoring threshold limits is verified using the same procedure as described in 4.7.

4.9 Radiated measurements of products with arbitrarily placed transmitting and monitoring antennas

The reference antenna shall be set up, with its major lobe facing the EUT, in the far field with a separation of r . The transmission test shall be performed as described in 4.7, and it shall be verified that $EIRP_{EUT}$ meets the limits.

The equivalent coverage test for the transmitting and monitoring antennas is performed as follows:

- a) Calculate, as described in 4.7, the power, P_{Tref} , that shall be applied to the reference antenna to establish the monitoring threshold field at the EUT transmit antenna.
- b) Move the reference antenna (without changing its orientation) in the direction of the EUT maximum radiation at a distance, $r + s$, from the monitoring antenna (where s is the maximum possible separation distance between the transmit and monitoring antennas), as specified by the EUT manufacturer.
- c) Apply power first smaller than, then equal and larger than, P_{Tref} to the reference antenna terminals and illuminate the EUT monitoring antenna. Investigate a number of the EUT monitoring antenna placements and positions on the surface of a sphere around the EUT monitoring antenna, as described in 4.7, while attempting to initiate transmission. There should exist a sufficiently low reference antenna power level (smaller than P_{Tref}) such that the EUT is able to transmit, at least at one EUT antenna position.
- d) When the power level applied to the reference antenna is equal or larger than P_{Tref} , the EUT shall defer at all positions of the monitoring antenna, for either horizontal or vertical reference antenna polarizations. Otherwise, the EUT fails the test.

5. Measurement instrumentation

This clause provides information on measurement instrumentation.

Alternative test methods using different equipment may be employed. Some items described here are alternative choices.

5.1 Antennas

Calibrated, linearly polarized antennas should be used as specified in ANSI C63.2-1996. These include double-ridged guide horns, rectangular waveguide horns, pyramidal horns, optimum gain horns, and standard gain horns. The beam or major lobe of the pattern of any antenna used shall be large enough to encompass the EUT when located at the measuring distance. The aperture dimensions of these horn antennas shall be small enough 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 dimension of the aperture, in meters, of the antenna, and λ is the free-space wavelength, in meters, at the frequency of measurement). In case of dispute, measurements made with the standard gain horn antenna shall take precedence.

5.2 Digital storage oscilloscope

A digital storage oscilloscope shall provide the following functionality:

- Two channels
- Pre/post trigger delay
- Delayed sweep
- Cursor with readout of amplitude and time values

A digital storage oscilloscope shall meet the following minimum performance requirements:

Bandwidth—repetitive:	dc to 50 MHz
Bandwidth—single shot:	1 MHz
Time accuracy:	$\pm 0.01\%$
Time interval resolution—repetitive:	± 1 ns
Digitizing rate:	20 MSa/s
Sweep speed:	1 s/div to 10 ns/div
Vertical accuracy:	$\pm 3\%$
Vertical resolution:	8 bits
Vertical sensitivity (1:1 probe):	5 mV/div to 5 V/div
Input impedance:	1 M Ω
Input coupling:	ac, dc

5.3 Frequency counter

A frequency counter shall provide the following functionality:

- Frequency and period measurements
- Averaging of measurement with statistics, including standard deviation
- External measurement gating for measurement of noncontinuous (burst) signals

A frequency counter shall meet the following minimum performance requirements:

Frequency range:	Usable over the applicable radio frequency range
Frequency resolution:	9 digits in 1 s of measurement time
Frequency accuracy:	0.2 ppm
Power range and sensitivity:	–25 to +28 dBm

External attenuation may be used to meet the high-power end of the range and can be considered as part of the equipment.

5.4 Low-noise amplifier

A low-noise amplifier shall meet the following minimum performance requirements:

Frequency range:	Usable over the applicable radio frequency range
Gain:	20 dB
Noise figure:	4 dB
Power out 1 dB gain compression:	+10 dBm

5.5 Modulation analyzer or frequency and time-interval analyzer

A modulation analyzer or frequency and time-interval analyzer shall provide the following functionality:

- Continuous measurement for frequency, period, and time intervals
- Presentation of measured values vs. time and presentation of histogram results
- Adjustable sampling rate and sample size
- Calculation of statistics including mean, minimum, maximum, and standard deviation
- RF envelope detection with detected output

A modulation analyzer or frequency and time-interval analyzer shall meet the following minimum performance requirements:

Frequency range:	Tunable over the applicable frequency range
Frequency resolution:	Selectable to 1 ppm
Time interval resolution:	Symbol rate/10
RF burst width:	50 μ s to continuous
Dynamic range:	−10 dBm to + 20 dBm
Input impedance:	50 Ω nominal
Sample rate:	Up to 1 MHz

5.6 Alternative instrumentation

While the tests described in this standard are based on general-purpose instrumentation, tests using alternative, more specialized instrumentation can, in some cases, be performed more quickly with equally valid results. For some EUT (e.g., those operating in conformance with an industry standard air interface), instruments may be available that are specifically designed to test equipment using a particular type of modulation, frequency channelization, frame structure, etc. Those instruments may be capable of automatically performing some of the tests specified in Clause 6 (e.g., emission bandwidth and power spectral density). Such instruments can be used instead of general-purpose instruments (spectrum analyzers, signal analyzers, etc.) to perform the tests of which they are capable, provided that the manufacturer notes that this is permissible on the grant application and provides the necessary data regarding the test instrument.

5.7 Square-notch interference generator

A square-notch interference generator shall provide the following functionality:

- Flat pseudo-random noise output
- Multiple notches in the noise output, adjustable in depth and width
- Multiple continuous wave (CW) tones that can be combined with the noise output

An interference generator shall meet the following minimum performance requirements:

Bandwidth:	Adequate to apply interference over the range of EUT operating frequencies
Frequency resolution:	1 kHz
Output accuracy:	± 2 dB over 1.25 MHz
Power spectral density range:	−150 dBm/Hz to −100 dBm/Hz
External attenuation may be used to meet the low-power end of the range and can be considered part of the equipment.	
Amplitude resolution:	1 dB

5.8 Multicarrier interference generator

A multicarrier interference generator shall be capable of generating CW signals on any selected combination of EUT carrier frequencies. For some EUT, the multicarrier generator is a practical alternative to the square-

notch generator for applying out-of-operating-region interference to the EUT (see 7.2.4). Its exact specifications depend on the EUT, but shall meet or exceed the following:

Independently-switchable (on/off) EUT carriers combined in a single 50 Ω RF output	
Power output per carrier:	≥ -35 dBm
Frequency tolerance:	$\leq 10\%$ of EUT center frequency separation
Adjacent channel interference:	≤ -30 dBc in EUT receiver noise bandwidth

5.9 Power meter

A power meter shall provide the following functionality:

- Average power measurements
- True rms detection for both sinusoidal and nonsinusoidal signals
- Absolute power in linear (W) and logarithmic (dBm) units
- Relative (offset) power in dB and percentage units
- Automatic calibration and zeroing
- Averaging of multiple readings

A power meter shall meet the following minimum performance requirements:

Frequency range:	Covers applicable range of radio frequencies
Power range:	-10 dBm (0.1 mW) to $+30$ dBm (1 W)
Absolute and relative power accuracy:	± 0.2 dB (5%) Excludes sensor and source mismatch (VSWR) errors, zeroing errors (significant at bottom end of sensor range), and power linearity errors (significant at top end of sensor range).
Power measurement resolution:	≤ 0.1 dB
Sensor VSWR:	1.15:1

5.10 Pulse/arbitrary waveform generator

A pulse/arbitrary waveform generator shall meet the following minimum performance requirements:

Arbitrary waveform length:	Up to 16k points
Arbitrary amplitude resolution:	12 bits
Arbitrary sample rate:	40 MSa/s
Arbitrary memory:	Four 16k waveforms
Timing accuracy:	100 ppm
Rise/fall time:	200 ns
Output amplitude:	Up to 10 V peak-to-peak
Output impedance:	50 Ω
Trigger:	Internal and external

5.11 Signal generator

A signal generator shall meet the following minimum performance requirements:

Output frequency range:	Tunable over applicable range of radio frequencies
Frequency accuracy:	± 10 ppm
Frequency resolution:	1 kHz
Output range:	−50 dBm to −10 dBm, and off
Output accuracy:	± 1 dB for above amplitude range and frequencies < 1 GHz
Output resolution:	0.1 dB

5.12 Spectrum analyzer

A spectrum analyzer shall provide the following functionality:

- General purpose frequency domain measurements
- Time domain (zero span) measurements with true average power determination

A spectrum analyzer shall meet the following minimum performance requirements:

Frequency range:	Tunable over the applicable radio frequency range. To test devices under 47 CFR 15, Subpart D, testing up to the tenth harmonic is required.
Frequency setting resolution:	1 kHz
Frequency accuracy:	± 0.2 ppm
Displayed dynamic range:	70 dB
Display log scale fidelity:	± 1 dB over the above displayed dynamic range
Amplitude measurement range for signals from 10 MHz to 2.5 GHz:	
Power measured in 30 kHz RBW:	−50 to +30 dBm

External attenuation may be used to meet the high power end of the range and can be considered as part of the equipment.

Absolute amplitude accuracy in the transmit and receive bands:

For frequency domain measurements with RBW of 300 Hz to 100 kHz:	± 1.5 dB over the range of −40 dBm to +26 dBm
Relative flatness:	± 1.5 dB over frequency range 10 MHz to 2.5 GHz
RBW filter:	Synchronously tuned or Gaussian (at least 3 poles) with 3 dB bandwidth selections of 3 MHz, 1 MHz, 300 kHz, 100 kHz, 30 kHz, 10 kHz, 3 kHz, 1 kHz, and 300 Hz. For asynchronous devices with emission BW > 2.5 MHz, a wider RBW is required for certain measurements.
Post detection video filters:	Selectable in decade steps from 100 Hz to at least 3 MHz
Detection modes:	Selectable to be either peak or sample
RF input impedance:	Nominal 50 Ω
Time domain sweep times:	Selectable from 100 μ s to 100 ms
External delayed sweep trigger:	Selectable from 5 μ s to 40 ms

5.13 Complex waveform analyzer

A complex waveform analyzer shall provide the following functionality:

- FFT-based spectrum measurements, with independent selection of RBW and span.
- Simultaneous measurement of frequency domain and time domain data. The time data will have a 3 dB bandwidth greater than the measurement bandwidth and will be used to compute both the power spectrum (via an FFT) and the power envelope. When time corrections are specified, the analyzer will meet the amplitude accuracy specification for time domain data.
- Frequency domain measurements: peak power and integrated power over a frequency band.
- Time domain measurements: peak power and true average power over a time interval.

A complex waveform analyzer shall meet the following minimum performance requirements:

Frequency range:	Tunable over the applicable radio frequency range
Frequency setting resolution:	1 kHz
Frequency accuracy:	± 0.2 ppm
Frequency span (measurement BW):	$>$ emission BW of EUT, but not < 1.25 MHz
Dynamic range:	70 dBc
Amplitude input range for signals from 10 MHz to 2.5 GHz:	
Peak envelope power:	-30 to $+40$ dBm
Attenuator step size:	≤ 5 dB external attenuation may be used to meet the high-power end of the range and can be considered as part of the equipment.
Input noise density:	-100 dB/Hz (referenced to full-scale input)
Absolute amplitude accuracy:	
Frequency domain:	± 1.5 dB over applicable radio frequency range
Time domain:	± 1.5 dB for a full-scale sine wave placed anywhere within the frequency span
RBW filter (FFT window function):	Uniform (none), Gaussian. For Gaussian window, noise BW ≤ 3 kHz for frequency spans ≤ 2.5 MHz.
Detector mode:	Sample
RF input impedance:	Nominal $50\ \Omega$
Spectral averaging:	RMS
Triggering:	RF envelope with trigger holdoff
Trigger delay:	0–10 ms

5.14 Antenna calibration

All antennas shall be individually calibrated to show traceability to the National Institute of Standards and Technology (NIST) or to an equivalent standards reference organization. Antenna factors shall be rechecked at least once a year, either by recalibration techniques or by checking against reference antennas or known signal sources. Spot-checking during the period between calibrations is recommended. Reference antennas that are used only for calibration or comparison purposes and are not used on a daily basis should be recalibrated at least every three years. Antennas shall be calibrated using an acceptable method, such as one of the methods in IEEE Std 291-1991 or IEEE Std 149-1979. The antenna used shall be calibrated at the measuring distance at which it will be used.

NOTES

- 1—If the antenna is calibrated at a distance of $2D^2/\lambda$, it may be used to make measurements at any greater distance.
- 2—Gain standard horn antennas (sometimes called standard gain horn antennas) need not be calibrated beyond that which is provided by the manufacturer, unless they are damaged, deterioration is suspected, or they are used at a distance closer than $2D^2/\lambda$. Gain standard horn antennas have gains that are fixed by their dimensions and dimensional tolerances.

6. RF measurements

6.1 Emissions test

6.1.1 Test requirements

The equipment that is configured as described in Figure 3 is for the conducted method. If the radiated method is required, refer to the test configuration in Clause 4. The EUT is arranged to communicate via a fixed carrier frequency between its transmitter and a compatible receiver. If the devices provide two-way communications, one should be designated as the transmitter under test. If the EUT is evaluated by a conducted measurement on an external port, the EUT and its associated compatible transceiver should be placed near enough to be able to establish a connection. Tests should be performed at the manufacturer's recommended normal operating temperature and supply voltage.

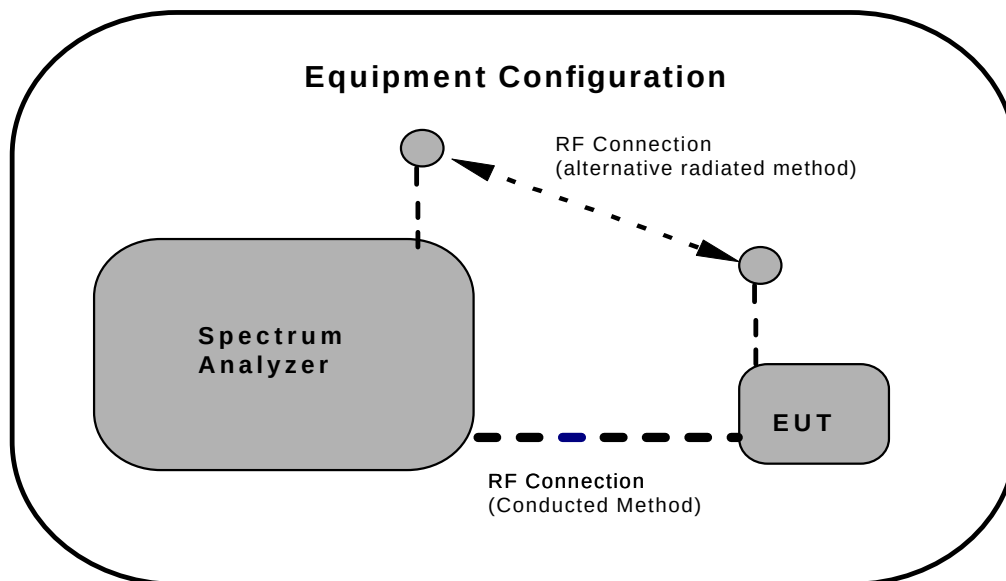


Figure 3—Test configuration

Before testing, the manufacturer shall provide to the testing organization the channel plan and declared values of the following parameters for the device being tested:

- Maximum EUT antenna gain
- Peak power level
- Free channel threshold(s)
- Emission bandwidth
- Mode of operation (isochronous or asynchronous)
- Isochronous frame period and time slot plan
- Minimum and maximum burst length for asynchronous systems

For conducted measurements, cable losses shall be taken into account. For radiated measurement, cable losses and reference antenna factors shall be taken into account.

6.1.2 Peak transmit power

For devices with an emission bandwidth within the capability (that is, less than the maximum RBW) of the spectrum analyzer to be used, the following procedure may be used.

The equipment is configured as shown in Figure 3.

Spectrum analyzer settings for determining the peak power:

RBW:	$\geq$ emission bandwidth
Video bandwidth:	$\geq 2 \times$ emission bandwidth
Span:	0
Center frequency:	Nominal center frequency of channel
Amplitude scale:	log (linear may be used if analyzer has sufficient linear dynamic range and accuracy)
Detection:	Peak detection
Trigger:	Video

The RBW setting for this test shall be adjusted by repeating this test and using increasing values of the RBW until there are negligible changes (within ± 0.5 dB) in the measured values of the maximum power.

Alternative instrument and techniques to the spectrum analyzer may be used in measuring peak power (for example, a complex waveform analyzer or FFT signal analyzer).

6.1.2.1 Digital sequence

The digital sequence(s) used to measure peak power shall be representative of those encountered in the real system operation. If peak power is sequence-dependent, then the worst-case sequence expected to occur during normal operation shall be used.

6.1.2.2 Testing method

6.1.2.2.1 Recommended spectrum analyzer method

This method computes the transmit power over the required measurement interval using digitized samples of the waveform envelope. The spectrum analyzer sampled time-waveform data is converted to linear power.

The average of all consecutive combinations of power samples covering the interval (30/emission bandwidth) over the EUT's maximum continuous transmission interval is computed. In other words, the waveform that is the sliding power average (window filter) of width (30/emission bandwidth) for the continuous transmission interval is computed. The measurement is made over the EUT's maximum continuous transmission interval. If the maximum of the smoothed power waveform does not exceed the power limit, then the unit passes the test for that sequence. The largest of these smoothed power output values over the required sequence types is the peak transmit power.

6.1.2.2.2 Alternative spectrum analyzer method

This method uses a narrow video bandwidth to provide analog smoothing rather than using the calculated digital smoothing. The video bandwidth is set greater than or equal to the emission bandwidth/30. The averaging on a log power scale or on a linear voltage scale will give a result that is less than the true power average by an amount that depends on the variation in the amplitude envelope of the carrier. For relatively constant amplitude modulations (≤ 3 dB variation), the "scale-averaging" error is insignificant. For Gaussian noise, the amplitude envelope will have a Rayleigh distribution, and the scale-averaging error will be -2.5 dB on a log scale and -1.1 dB on a linear voltage scale. Adding a 2.5 dB or 1.1 dB correction to the result will compensate for this error. Other amplitude distributions require different corrections.

6.1.2.2.3 Alternative complex waveform analyzer or signal analyzer method

Signal analyzer settings:

Measurement type:	Vector with time correction
Center frequency:	Nominal center frequency of channel
Span (measurement BW):	$>$ emission bandwidth ($2 \times B$ preferred)
Time record length:	$>$ burst duration
Trigger:	Envelope
Trigger holdoff:	$>$ burst duration
Trigger delay:	Adjust to center burst in time record
Input range:	$>$ peak power (minimum range that will not overload the instrument)

The time data (amplitude vs. time) is obtained.

The signal analyzer time data is used to compute the peak power using the preferred method described in 6.1.2.2.1.

6.1.2.3 Standard test frequencies

If the EUT is only capable of operation on a single frequency, then that is the standard test frequency.

If the EUT is capable of operation on more than one frequency within the sub-band, then the standard test frequencies shall be the lowest frequency within the sub-band for which the device is capable of operation, the highest frequency within the sub-band for which the EUT is capable of operation, and the frequency nearest the center of the sub-band for which the EUT is capable of operation.

6.1.3 Emission bandwidth

The equipment is configured as shown in Figure 3. The EUT shall transmit in a burst mode (i.e., shall not be configured to transmit continuously), so that transient effects associated with initiation of transmission are captured by the emission bandwidth measurement.

RBW:	Approximately 1% of the emission bandwidth (a rough estimate may be obtained from peak power level measurement, or by using the manufacturer's declared value)
Video bandwidth:	≥ 3 times the RBW
Center frequency:	Nominal center frequency of channel
Span:	≥ 2 times the expected emission bandwidth
Sweep time:	Coupled to frequency span and RBW
Amplitude scale:	log
Detection:	Peak detection with maximum hold enabled

The maximum level of the modulated carrier shall be recorded. The two furthest frequencies above and below the frequency of the maximum level of the modulated carrier, where the signal level is 26 dB below the peak level of the carrier, shall be found. The difference in frequency between these two frequencies is the emission bandwidth. If, after measuring the emission bandwidth, it is found that the RBW used was not approximately 1% of the emission bandwidth, then the RBW shall be adjusted and the procedure repeated until the correct RBW is used. If the spectrum analyzer has fixed values of RBW, the one that is the nearest to 1% of the emission bandwidth is acceptable, provided that it is no less than 0.5% of the emission bandwidth and no greater than 2% of the emission bandwidth.

The frequency of the maximum level of the modulated carrier and the furthest frequencies above and below this frequency shall be recorded, where the signal levels are 6 dB, 12 dB, and 24 dB below the peak level of the modulated carrier. These three frequency pairs are to be used later in 7.4 for measuring monitoring bandwidth.

6.1.4 Modulation

Attestation of compliance with the digital modulation requirement will be made in accordance with the disclosure statement that is required by the applicable equipment authorization procedures.

6.1.5 Power spectral density using the computed average transient (CAT) method

The following test methods may be used to verify that the EUT's power spectral density does not exceed 3 mW in any 3 kHz bandwidth.

The test cases shall be representative of those encountered in the real system operation.

The equipment is configured as shown in Figure 3.

Spectrum analyzer settings:

RBW:	3 kHz
Video bandwidth:	$\geq 3 \times \text{RBW}$
Span:	Zero span at frequency with the maximum level [frequency determined per 6.1.3 if the same type of signal (continuous vs. burst) was used in 6.1.3]
Center frequency:	Spectral peak as determined in 6.1.3

Sweep time:	For burst signals, sufficient to include essentially all of the maximum length burst at the output of a 3 kHz filter (e.g., maximum input burst duration plus 600 μ s); for continuous signals, 20 ms
Amplitude scale:	log power
Detection:	Sample detection, averaged for a minimum of 100 sweeps
Trigger:	External or internal

For burst-type signals, arrangements shall be made to measure the wideband burst duration of each burst analyzed and to compute the mean duration.

The level that is 20 dB below the first peak shall be determined. The power-averaged waveform between the 20 dB threshold levels around the first peak shall be recorded with at least 30 000 samples per second, as shown in Figure 4. Multiple wideband bursts may produce the waveform between -20 dB peaks. These shall be included in the determination of the average burst length. If there is no level that is 20 dB below the peak, then the complete sweep shall be analyzed, and all of the wideband waveform that occurs during the sweep time shall be included in the computation of average burst length.

The values of the sample points (in linear units of power) shall be summed and divided by the sample frequency to obtain the total pulse energy in the 3 kHz bandwidth. The results shall then be divided by the average duration of the wideband input pulse to obtain the average pulse power. If the result is less than 3 mW, the EUT passes the power spectral density requirement.

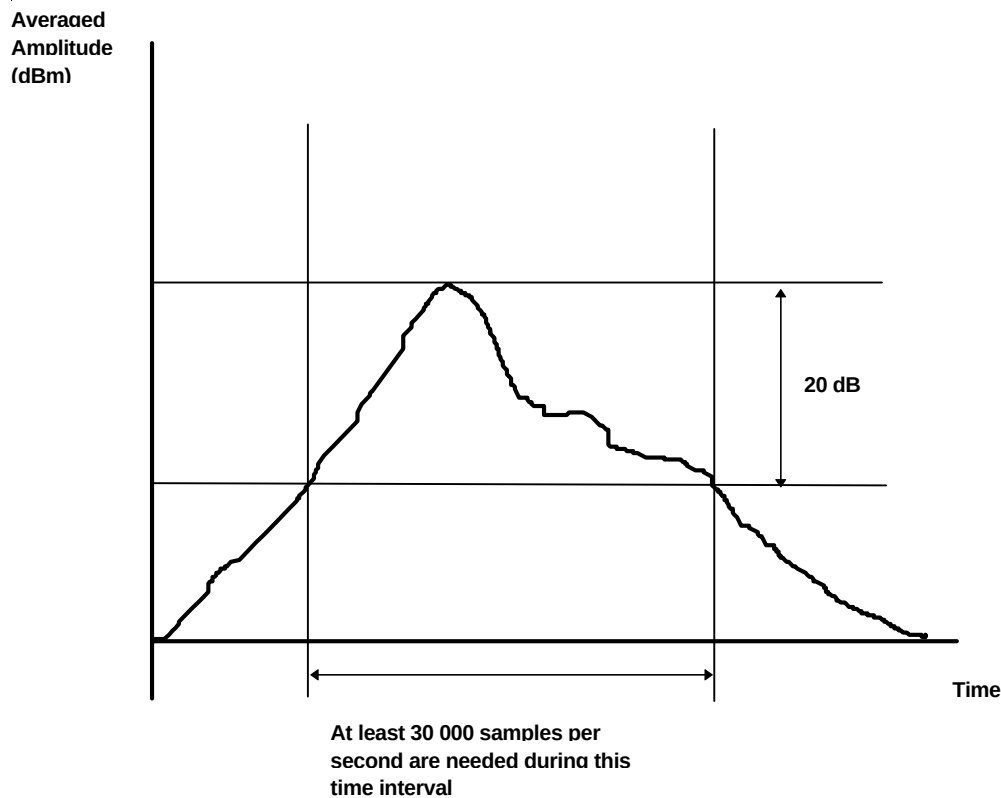


Figure 4—Computed average transient method: sampling of the averaged power waveform measured with 3 kHz resolution bandwidth

6.1.6 Emissions

Unless otherwise specified, the conducted method is the preferred method of measurement. The radiated method should be used if the EUT has a nondetachable antenna. A free-space environment or equivalent should be used in the radiated emission test. The general requirements for conducted and radiated tests are given in Clause 4.

6.1.6.1 Out-of-channel emissions

6.1.6.1.1 Channel edges

The channel edges are defined as the lowest and highest frequencies used in the UPCS device channelization scheme.

- a) *Isochronous devices*—For isochronous devices, for emissions testing purposes, the channel edges are, for example,
 - 1920 MHz
 - 1921.25 MHz
 - 1922.5 MHz
 - 1923.75 MHz
 - 1925 MHz
 - 1926.25 MHz
 - 1927.5 MHz
 - 1928.75 MHz
 - 1930 MHzFor systems that divide the channels into subchannels, the device under test shall use the subchannel that is nearest to the channel edges while the measurement is being carried out.
- b) *Asynchronous devices*—For asynchronous devices, the channel edges are, for example,
 - 1910 MHz
 - 1920 MHz
 - 2390 MHz
 - 2400 MHz

6.1.6.1.2 Measurement procedure

The equipment is configured as shown in Figure 3.

Spectrum analyzer settings:

RBW:	Approximately 1% of emission bandwidth (B) or 10 kHz, whichever is less
Video bandwidth:	$3 \times \text{RBW}$
Sweep time:	$\geq$ pulse repetition interval multiplied by the number of trace elements
Number of sweeps:	Sufficient to stabilize the trace
Amplitude scale:	log
Detection:	Peak detection and maximum hold enabled
Span:	$1.5 \text{ MHz} \leq \text{span} \leq 5 \text{ MHz}$

The out-of-channel emission measurement starts from above or below the channel edge. The out-of-channel emission frequency range of measurement is defined in 47 CFR 15, Subpart D, 15.33. This implies that the out-of-sub-band emissions will be included in these measurements. The limits are described in 6.1.6.3.