American National Standard for Evaluation of Wireless Coexistence

C63®

Accredited Standards Committee C63®—Electromagnetic Compatibility

Accredited by the
American National Standards Institute

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ANSI C63.27-2017

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Secretariat

Institute of Electrical and Electronics Engineers, Inc.

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Abstract: An evaluation process and supporting test methods are provided in this standard to quantify the ability of a wireless device to coexist with other wireless services in its intended radio frequency (RF) environments.

Keywords: ANSI C63.27, coexistence, electromagnetic environments, EMI, immunity, interference, reliability, RF, RFI, susceptibility

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Introduction

This introduction is not part of ANSI C63.27-2017, American National Standard for Evaluation of Wireless Coexistence.

The proliferation of radio-frequency (RF) wireless devices has been both explosive and pervasive in virtually every field in our society. The everyday use of wireless devices goes well beyond the early hand-held walkie-talkies, introduced in the 1950s. It is estimated that cellular telephones outnumber individuals in the US population and other countries have even higher penetration rates for cell (mobile) phone usage. Wireless technologies have resulted in the birth of new applications like radio-frequency identification (RFID) systems and distributed sensor systems. Thousands of types of equipment used in consumer and industrial environments now contain one or more wireless technologies. Almost every building now contains a wireless network to support multiple uses of wireless devices.

While the benefits of wireless technology are obvious and explain the explosive growth in both number and applications of wireless technology, there are also risks and disadvantages. These risks must be carefully evaluated and managed. As wireless technology is integrated into systems that require high degrees of reliability, such as medical devices, aircraft, and nuclear power plants, it is imperative that risks be quantified, mitigated, and managed to be at or below acceptable levels. Verification of the risk control measures associated with the following two areas are of interest to this group: 1) traditional EMC and 2) coexistence. Traditional EMC testing is designed to exclude frequency bands where the device under test communicates wirelessly. Coexistence testing focuses on devices and systems that intentionally use wireless and it extends beyond traditional EMC to examine the device's performance in frequency bands where it uses wireless communication. This standard provides methods for evaluating the ability of a device to coexist in its intended RF wireless communications environment.

History

On May 3, 2011, ASC C63® Subcommittee 7 commissioned a task group to study the need for wireless coexistence evaluation methods. In response to a request from the U.S. Food and Drug Administration (FDA) the committee considered developing such evaluation methods. The FDA has observed an increasing use of wireless communication links in medical devices and, simultaneously, a growing application of home telehealth, with wireless devices going with patients into a wider variety of environments. Their concern is that these devices and their wireless interface be designed to be suitable for a range of electromagnetic environments in which they will be used, particularly in the presence of in-band and adjacent band congestion.

The assignment of the task group, quoting from its PINS-C, was:

> *This committee project will study the need and approach to a set of tests and evaluation methods for wireless interference and coexistence. Regulators, IT system planners and others need tests that accurately evaluate the ability of wireless devices to operate in their intended environments, particularly in the vicinity of nearby in-band and adjacent-band transmitters.*

The task group presented its report to Subcommittee 7, recommending development of this standard. That recommendation was acted on by Subcommittee 7. As a result, ASC C63® approved this project on April 19, 2012.

This project builds upon the guidance of IEEE Std 1900.2™, *IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence between Radio Systems*. IEEE Std 1900.2 provides a structure for, and guidance to be used in, performing a coexistence analysis.

Contents

American National Standard for Evaluation of Wireless Coexistence

1. Overview

1.1 Scope

This standard specifies methods for assessing the radio frequency (RF) wireless coexistence of equipment that incorporates RF communications. This standard specifies key performance indicators (KPIs) that can be used to assess the ability of the equipment under test (EUT) to coexist with other equipment in its intended operational environment.

1.2 Purpose

The purpose of this standard is to provide evaluation procedures, test methods, and other guidance for assessing the ability of the EUT to successfully maintain its functional wireless performance (FWP) (see 5.3) in the presence of unintended signals that are likely to be found in the same operating environment. This standard includes assessment of the effects of the EUT on the unintended signals. The results of this test may optionally be used to compute the likelihood of coexistence (LoC), or as an input to a risk assessment.

1.3 Interference and coexistence

Interference is the unintentional effect of energy emitted by a source. Coexistence is the ability of one wireless system to perform a task in a given shared environment where other systems (in that environment) have an ability to perform their tasks and might or might not be using the same set of rules.

2. Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

3GPP TS 36.101 V13.2.1 (2016-01), Technical Specification 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 13).

3GPP TS 36.104 V13.2.0 (2016-01), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Base Station (BS) radio transmission and reception (Release 13).

AAMI TIR 69 (Draft), Risk Assessment of Radio-Frequency Wireless Coexistence for Medical Devices and Systems.[1]

ANSI C63.14-2014, American National Standard Dictionary for Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3).[2]

ANSI C63.17-2013, American National Standard Methods of Measurement of the Electromagnetic and Operational Compatibility of Unlicensed Personal Communications Services (UPCS) Devices.

ANSI C63.19-2011, American National Standard Methods of Measurement of Compatibility between Wireless Communications Devices and Hearing Aids.

ATSC A/54A, 04 DEC 2003, Recommended Practice: Guide to the Use of the ATSC Digital Television Standard, including Corrigendum No. 1, Cor No 1 20 DEC 2006.

ETSI EN 300 328 v1.9.1 (2015-02), Electromagnetic compatibility and Radio Spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2.4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering the essential requirements of article 3.2 of the R&TTE Directive.[3]

IEC TR 80001-2-2:2012, Application of risk management for IT-networks incorporating medical devices – Part 2-2: Guidance for the disclosure and communication of medical device security needs, risks and controls.[4]

IEEE Std 1900.2™, IEEE Recommended Practice for the Analysis of In-Band and Adjacent Band Interference and Coexistence between Radio Systems.[5, 6]

ISO 14971:2007, Medical devices – Application of risk management to medical devices.[7]

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

ISO/IEC Guide 98-1:2009, Uncertainty of measurement – Part 1: Introduction to the expression of uncertainty in measurement.

ISO/IEC Guide 98-3:2008, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995).

ISO/IEC Guide 98-3:2008/Suppl 1:2008, Propagation of distributions using a Monte Carlo method.

ISO/IEC Guide 98-3:2008/Suppl 2:2011, Extension to any number of output quantities.

[1] AAMI publications are available from the Association for the Advancement of Medical Instrumentation (http://www.aami.org/).
[2] ANSI publications are available from the American National Standards Institute (http://www.ansi.org/).
[3] ETSI publications are available from the European Telecommunications Standards Institute (http://www.etsi.org/).
[4] IEC publications are available from the International Electrotechnical Commission (http://www.iec.ch) and the American National Standards Institute (http://www.ansi.org/).
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[7] ISO publications are available from the International Organization for Standardization (http://www.iso.org/) and the American National Standards Institute (http://www.ansi.org/).

ISO/TR 24971:2013, Medical devices – Guidance on the application of ISO 14971.

JCGM 100:2008, Evaluation of measurement data – Guide to the expression of uncertainty in measurement.[8]

JCGM 101:2008, Evaluation of measurement data – Supplement 1 to the "Guide to the expression of uncertainty in measurement" – Propagation of distributions using a Monte Carlo method.

JCGM 102:2011, Evaluation of measurement data – Supplement 2 to the "Guide to the expression of uncertainty in measurement" – Extension to any number of output quantities.

JCGM 104:2009, Evaluation of measurement data – An introduction to the "Guide to the expression of uncertainty in measurement" and related documents.

3. Definitions, acronyms, and abbreviations

For the purposes of this document, the following terms and definitions apply. The *IEEE Standards Dictionary Online*[9] and ANSI C63.14-2014[10] should be consulted for terms not defined in this clause. Unless otherwise noted, the definitions of this clause apply throughout this document.

3.1 Definitions

co-channel: Operation in the same channel.

coexistence: (A) The ability of two or more spectrum-dependent devices or networks to operate without harmful interference. (IEEE Std 1900.1-2008 [B28]) *See also*: **interference. (B)** The ability of one system to perform a task in a given shared environment where other systems have an ability to perform their tasks and may or may not be using the same set of rules. (IEEE Std 802.15.3-2016 [B29]) **(C)** A state of acceptable co-channel and/or adjacent channel operation of two or more radio systems (possibly using different wireless access technologies) within the same geographical area. (IEEE Std 802.16-2012 [B30]) **(D)** A situation in which one radio system operates in an environment where another radio system having potentially different characteristics [e.g., radio access technology (RAT)] may be using the same or different channels, and both radio systems are able to operate with some tolerable impact to each other. (ETSI EN 303 145 V1.2.1 [B17]) *Syn:* **RF coexistence; wireless coexistence.**

EUT companion device: The corresponding wireless node that is wirelessly communicating with the EUT [e.g., of a wireless fidelity (Wi-Fi) access point].

frequency band: A frequency allocation that has been made available for use by a wireless device by a regulatory authority.

functional wireless performance (FWP): The subset of the total functionality that both uses the wireless capabilities of the EUT and would result in unacceptable consequences if degraded or disrupted.

likelihood of coexistence (LoC): An estimation of the EUT's ability to provide its FWP in the intended use environment.

operational frequency range: The range of frequencies that may be occupied by an intended transmission.

[8] Available at: http://www.bipm.org/en/publications/guides/gum.html.
[9] *IEEE Standards Dictionary Online* is available at http://dictionary.ieee.org/.
[10] Information on references can be found in Clause 2.

uncertainty (of evaluation): An estimate of the range of values that can reasonably be expected in the projected field experience, predicted from laboratory test results.

uncertainty (of measurement): A parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand. (JCGM 100:2008)

unintended signal: the signals used to determine if the EUT can maintain its functional wireless performance during a coexistence test.

3.2 Acronyms and abbreviations

3GPP	3rd Generation Partnership Project
AAMI	Association for the Advancement of Medical Instrumentation
AFH	adaptive frequency hopping
ASC	Accredited Standards Committee
ANSI	American National Standards Institute
CCA	clear channel assessment
CFR	Code of Federal Regulations
CGD	cumulative gain distribution
CTIA	Cellular Telecommunications & Internet Association
dB	decibel
dBm	decibels referenced to 1 mW
DECT	Digital Enhanced Cordless Telecommunications
EARFCN	EUTRA absolute radio-frequency channel number
EIRP	effective or equivalent isotropic radiated power
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
ETSI	European Telecommunications Standards Institute
EUT	equipment under test
EUTRA	Evolved Universal Terrestrial Radio Access
EVM	error vector magnitude
f	frequency
FCC	Federal Communications Commission
FDA	Food and Drug Administration
FHSS	frequency hopping spread spectrum
FRC	fixed reference channel
FWP	functional wireless performance
g_{eff}	effective gain in dB: $g_{eff}(f)$ [dB] = EIRP(f) [dBm] – TRP(f) [dBm]
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IM	intermodulation
IRIL	input-referenced interference level
ISM	industrial, scientific, medical

I/U	intended-to-unintended signal ratio
KPI	key performance indicator
LBT	listen-before-talk
LIC	least interfered channel
LTE	long term evolution[11]
LoC	likelihood of coexistence
LOS	line-of-sight
MIMO	multiple-input, multiple-output
MU	measurement uncertainty
NLOS	non-line-of-sight
OOBE	out-of-band emissions
OTA	over-the-air
PER	packet error rate
QAM	quadrature amplitude modulation
RAC	radiated anechoic chamber
RAT	radio access technology
RF	radio frequency
RFID	radio frequency identification
ROE	radiated open environment
RSS	received signal strength
RX	receive or receiver
SNR	signal-to-noise ratio
ToI	threshold of interference
ToPP	threshold of peak performance
ToV	threshold of visibility
TX	transmit or transmitter
UE	user equipment
UNII	Unlicensed National Information Infrastructure
VSWR	voltage standing wave ratio
Wi-Fi	wireless fidelity
WLAN	wireless local area network
Z_0	free space impedance (Z_0= 377Ω)

4. Process overview

This clause gives an overview of the coexistence evaluation process, depicted in Figure 1.

[11] LTE is a trademark of European Telecommunications Standards Institute (ETSI).

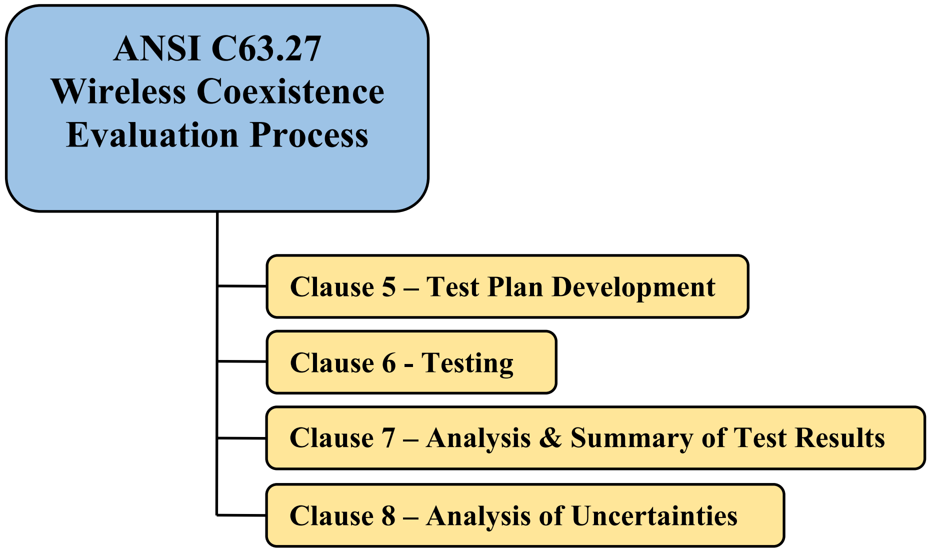

Figure 1—Evaluation process overview

The evaluation process begins with a statement of the purpose and deliverables desired from coexistence testing. Testing can be performed for a variety of reasons. Depending on the final purpose for doing the coexistence testing, the test plan and deliverables can be different. Examples of different purposes for coexistence testing and deliverables are as follows:

— *To develop user guidance necessary to achieve a desired level of reliable operation.* In this case the deliverables can be guidance to the user on the maximum recommended operational distance between communicating devices and the minimum recommended separation distances to equipment that has the potential to cause loss of FWP due to interference.

— *To determine the potential for successful operation of the FWP with regard to coexistence.* The deliverables for this purpose can be a risk assessment, written with the intention that it be a part of a larger and more extensive total risk assessment for the product.

— *To estimate the user experience.* When the purpose is to predict the user experience, the test results are applied to the understanding of the intended operating environment to estimate the user experience in the intended operating environments. In estimating user experience, additional factors, beyond those included in testing, are involved. The resulting estimation has an evaluation uncertainty, which includes the measurement uncertainty (MU) of the test results, the estimation of the variability in the operating environment, and the certainty of the operating environment data used in preparing the estimate.

— *To diagnose complaints and failure reports, reproduce those field environments, and qualify modifications that remediate the product performance.* With this objective, the deliverables will include evidence that the problematic field environment has been reproduced and that test modifications can be expected to achieve desired levels of performance.

— *To identify the intended environment parameters at which the EUT fails to coexist.* Coexistence among wireless devices is dependent on three main parameters: 1) frequency, 2) range, and 3) time. An investigation can be done by varying each parameter accordingly. Differing deliverables affect the test plan; for example, determining the parameters of the unintended signal(s). The test results are reported to fulfill the test plan deliverable.[12]

[12] For example, a report to management that needs to decide if a product will meet their customer's expectations will differ significantly from a report intended to be used in a larger risk assessment.

The next step is to identify and document the following items in the test plan for the EUT (Clause 5) as follows:

- The intended electromagnetic (EM) environment
- The FWP of the EUT
- The KPI(s) to be monitored for each FWP during testing
- The method to monitor the KPI(s)
- The KPI(s) thresholds
- The RF bands and protocols used for each FWP
- The operational frequency range
- The evaluation tier selected
- The test method selected
- The intended signal and received signal parameters
- The unintended signal parameters (frequency, transmission power, channel utilization)
- The method to monitor the unintended signal during testing

The wireless interfaces used for each wireless function shall be identified. The intended EM environment of the EUT shall be identified and the EM characteristics should be quantified. Finally, the level of testing is determined based on the test deliverables and the consequences of the FWP failure.

Coexistence testing can be similar for devices that use the same RAT. Specific test guidance is provided in Annex A for common RATs.

Test methods supported by this standard are given in Annex B through Annex E. Each test method has different factors that influence the MU. MU shall be determined and documented for the coexistence test setup. Guidance to determine the MU of the coexistence testing is given in Clause 8. Uncertainty components shall be identified and quantified when they have the potential to affect the test results. Clause 9 identifies information to be included in coexistence test reports. Rationale for the approach and processes used in this standard is discussed in Annex F.

Coexistence testing shall be performed on the final deployable device. Evaluation of a radio module or subsystem that might later be integrated into a larger device can result in substantial inaccuracies for the coexistence estimation of the final product due to changes that can occur when a module or subsystem is integrated into a product.

An optional extension of the coexistence test results can be used in a risk assessment of the EUT. Clause 7 provides information regarding application of coexistence test results to risk management. Below is a (non-exhaustive) list of risk management/assessment documents that can be used for coexistence:

- ISO 14971:2007 and ISO/TR 24971:2013
- IEC TR 80001-2-2:2012

Another optional extension of the coexistence test results can be used to predict the LoC to gain an understanding of the field performance of the EUT. Determining the LoC requires quantified information on 1) the probability distribution of the intended signal and its received signal quality, 2) the intended EM environment of the EUT, and 3) coexistence test results of the FWP of the EUT in the presence of unintended signals.[13]

[13] When testing with representative devices as the unintended signal source, the modulation and coding used can sometimes change automatically. It is important that these changes not influence the outcome of the test. To accomplish this, either the test should be

5. Test plan

5.1 Overview

A coexistence evaluation assesses the ability of the EUT to perform its intended operation in the EM environments in which it will be used. The evaluation focuses on the functions that use the wireless capability of the EUT. The following steps are outlined in this clause to create a test plan for the EUT:

- Identify the intended EM environment
- Specify the FWP of the EUT
- Specify the evaluation tier to be used for assessing the FWP
- Choose a test method
- Specify the intended signal
- Specify the unintended signals

5.2 Intended EM environment

The intended EM environment of the EUT shall be identified in the test plan and test report. Other RF protocols that are likely to operate in the intended EM environment of the EUT shall be documented in the test plan. Based on the evaluation tier of the EUT (see 5.4), the list should include the applicable RF protocols that operate in the co-channel, adjacent channels, and adjacent bands of the EUT. Other emitters of EM energy into the intended band should also be included.[14]

5.3 Functional wireless performance

5.3.1 General

FWP is the subset of the total functionality of the EUT that will be evaluated for coexistence. Identification of the FWP begins with a review of the total functionality of the EUT and identification of the subset of the total functionality that could result in unexpected responses during coexistence testing or unacceptable consequences if degraded or disrupted during use. This subset of the total functionality is further reduced to the portion that uses the wireless capabilities of the EUT and for which degradation could result in unacceptable consequences. This final subset is the FWP.

The FWP of the EUT shall be identified and documented in the test plan and test report. For each function of the FWP, a threshold shall be determined that differentiates between acceptable and unacceptable performance.

The method for monitoring the FWP during the testing shall be identified along with a suitable method for exercising each function. Monitoring can be accomplished through the use of built-in-test, visual displays, aural outputs, or other measurements of signal output. Monitoring the EUT by special circuits is permissible; however, these modifications shall not influence the FWP or test results.

The time required to complete a pass through all of the functionality to be evaluated shall also be estimated. It is important that all evaluated functionality is exposed to each spectrum presentation used to evaluate the

repeated several times to confirm that the same result is obtained or the transmitting units should be controlled to prevent automatic changes of the transmitted signal.

[14] Microwave ovens are an example of other emitters.

EUT. The time for the evaluation will be largely determined by the time required to exercise all the functionality to be evaluated multiplied by the number of spectral presentations used in the evaluation.

In some cases, it will be appropriate to identify actions that the EUT should not take as well as actions the EUT should take under specified circumstances.

5.3.2 Key performance indicators

The KPIs monitored shall be identified and documented for each FWP function in the test plan.[15] The KPIs shall be selected to provide a realistic assessment of the FWP function being evaluated. Examples of common KPIs are latency, jitter, throughput, error vector magnitude (EVM), non-acknowledgement requests, lost packets, number of retransmissions, and time to complete requests. KPIs can also be specified on the application layer, such as completing a task.

5.3.3 KPI thresholds

The KPI thresholds shall be identified and documented for each KPI in the test plan.[16] KPI thresholds are defined to be the failure criteria and the levels of degradation in performance that differentiate between acceptable and unacceptable performance.[17]

KPI thresholds can have binary characteristics, where a function either performs or it does not. Some FWP functions, such as audio or video, can have a range of performance, measured by different KPIs, often without clear boundaries differentiating acceptable and unacceptable performance. One purpose of the test plan is to provide clear thresholds to differentiate acceptable performance from unacceptable performance.[18]

5.3.4 RF bands and protocols

5.3.4.1 General

The RF protocols, operational bands, channels, and channel bandwidths supported by the EUT shall be identified and documented in the test plan. The use of each RF protocol and frequency band shall be identified and documented with the functionality to be evaluated. Some EUTs will use one RF band and RF protocol for one purpose and another RF band and protocol for other purposes.[19]

If applicable, verify that the coexistence mechanisms included in the RF protocols are correctly implemented by creating test environments that adequately evaluate the coexistence mechanisms.[20] Examples include: adaptive frequency hopping (AFH), clear channel assessment (CCA), listen-before-talk (LBT), and least-interfered-channel (LIC) selection.

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[15] KPIs can exist on multiple levels. Some operate at the RF level, for example evaluating the potential impact of out-of-band emissions (OOBE) from one device on the signal quality of another. Other KPIs function at the operational level. For some evaluations, it is important to select KPIs from multiple levels. This is often helpful in understanding how much margin exists before a high level function is disrupted.

[16] Acceptable KPI thresholds can be determined by the party supervising the test, the manufacturer of the EUT, or other organizations that have set thresholds based on the required performance of the EUT.

[17] For example, if the EUT is capable of operating at multiple data rates, it can be desired that the threshold of interference (ToI) for each data rate be recorded, as well as the ToI at which communication is lost.

[18] With voice signals, it is possible to develop thresholds based on established speech recognition levels, as is done in ANSI C63.19, which establishes acceptable audio performance as being an input-referenced interference level (IRIL) < 55 dB and < 6 dB of gain compression. Similar thresholds can be established for video signals. ATSC A/54a defines threshold of visibility (ToV) as the level at which there are 2.5 data segment errors per second.

[19] An example is a mobile phone that uses the 2.4 GHz ISM band to connect to a Bluetooth headset and one of the cellular bands to connect to the cellular network.

[20] This can mean that an entire frequency band should be populated to adequately represent the kinds of environments that will be encountered and to verify that interference management mechanisms are functioning as intended.

If the EUT supports simultaneous transmission on different bands, from different antennas, or with different RF protocols, the test plan shall include this information and specify how simultaneous transmissions on different bands will be evaluated.

NOTE—When performing testing in an open laboratory, under some circumstances an FCC experimental license might be required.[21, 22]

5.3.4.2 EUT operating frequencies for spread spectrum equipment

For EUTs that use spread spectrum techniques, EUT operation shall be as follows:

a) Frequency hopping: The EUT shall frequency hop in the same way a production model would.

b) Direct sequence: Measurements shall be performed with the EUT processing data at the highest supported data transfer rate.

5.3.4.3 EUT operating frequencies for channelized radios

The test plan shall indicate which frequencies/channels the EUT shall be tested on during coexistence testing. The test frequencies/channels shall be recorded in the test report.

5.4 Evaluation tiers

5.4.1 General

Three tiers are specified in this document for EUT coexistence evaluation. An evaluation tier is determined based on the test deliverables and the consequences of FWP failure. The three tiers are designed to provide corresponding levels of thoroughness, therefore matching the coverage and the confidence level provided by the testing to the potential consequences of lack of coexistence.

- Tier 1 is the most thorough level of evaluation. It is intended for use where the consequences of unacceptable performance are most severe or where the highest levels of evaluation certainty are required.
  - A more rigorous set of unintended test signals and scenarios are used in the evaluation.
  - The potential for interfering signals in adjacent bands are more rigorously evaluated.
- Tier 2 is a more thorough level of testing than Tier 3.
  - The number of unintended test signals used is increased (from Tier 3) to extend the evaluation sample set and increase the confidence level of the evaluation outcome.
  - The potential for interfering transmission in some adjacent bands is evaluated.
- Tier 3 is a selection of test cases to give the greatest confidence in the evaluation for the minimum amount of testing.
  - The number of unintended test signals that the EUT is exposed to is limited to the minimum set, selected to provide the greatest insight to the EUT coexistence capabilities for the most limited amount of testing.

[21] Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.
[22] See FCC OET Experimental Licensing website for additional information and 47 Code of Federal Regulations Part 5 rules: FCC Experimental Licensing System: https://apps.fcc.gov/oetcf/els/index.cfm.

5.4.2 Band-specific test guidance

Annex A provides RAT and band-specific test guidance for some of the most commonly used RATs and frequency bands. Coexistence testing is similar among the same RAT operating in the same band. If a RAT used by the EUT is not included in Annex A, then the test plan shall describe how the EUT will be tested with an appropriate level of rigor. This edition of the standard provides guidance for the following:

- Bluetooth devices operating in the 2.4 GHz ISM band (2400 MHz to 2483.5 MHz)
- Wi-Fi devices operating in the 2.4 GHz ISM band (2400 MHz to 2483.5 MHz)
- Wi-Fi devices operating in the Unlicensed National Information Infrastructure (UNII) and ISM bands (5150 MHz to 5850 MHz)
- DECT (1920 MHz to 1930 MHz)

5.5 Test method selection

5.5.1 General

The test plan shall document the coexistence test method to be used. The test methods supported in this standard and the associated annex with guidance on the test setup, verification, and test procedure are listed in Table 1.

Table 1—Coexistence test methods

1)	Conducted RF test method	Annex B
2)	Multiple chamber test method	Annex C
3)	Radiated anechoic chamber (RAC) test method	Annex D
4)	Radiated open environment (ROE) test method	Annex E

Each coexistence test method consists of the following processes:

- Set up the test
- Verify the test setup
- Establish the intended RF communication of the EUT in an appropriate RF channel
- Verify the unintended signal
- Expose the EUT to the unintended signal
- Evaluate the ability of the EUT to maintain its FWP under the conditions of the test and assess the effect of the EUT communication of the unintended signals

Coexistence testing can be implemented using manual or automated methods.

Each test method has different strengths and weaknesses that should be considered when selecting the best method for use in evaluating a specific EUT. From a test repeatability viewpoint, the test methods in Table 1 are ordered in terms of increasing variability. Conducted RF measurements are generally found to be the most repeatable measurements, and radiated open environment testing are the least repeatable. When test repeatability is a significant consideration, methods should be given preference based on the order shown in Table 1.

From a practical performance perspective, the reverse order applies. Conducted measurements, while repeatable, have the largest number of additional variables introduced between the test and use environments. Notably, antennas are not involved in conducted testing, whereas the characteristics of the antennas can have an impact on the performance of the EUT.

Test time is also a consideration, with conducted tests generally being faster than radiated methods. This is true because with conducted testing, there is no need to find the position of optimal signal reception.

5.5.2 EUT special functionality

The EUT could have special functionality to enhance its capabilities, such as multiple-input, multiple-output (MIMO), beam forming, or simultaneous transmissions that need to be tested for coexistence, which require special methods to test these systems. Multiple antenna usage by EUTs should be tested in both line-of-sight (LOS) and non-line-of-sight (NLOS), where EUTs can mitigate LOS interference by using NLOS paths, and vice versa. ROE test methods are the preferred method, implementing NLOS and LOS. Conducted methods can be implemented; however, phasing of the two or more antennas with interference and signals can become complex. Knowing whether the EUT has MIMO and understanding how this can mitigate interference can help in test method selection.

Multipath of the wireless communication signal should be taken into account during coexistence testing, especially for multiple antenna wireless technologies such as IEEE 802.11n. The use of multiple antennas offers extended range, improved reliability, and higher throughputs than conventional single-antenna communication systems. Other antenna-based systems use multiple transmit and receive antennas to provide diversity gain in a fading (multipath) environment, antenna gain, and interference suppression. These gains translate into improvement of the spectral efficiency, range, and reliability of wireless networks. Neglecting multipath in coexistence testing reduces the depth of the evaluation of the EUT.

5.6 Intended signal transmission

5.6.1 Intended signal level

The test plan shall specify the intended signal level at the EUT and the EUT companion device (if applicable) for coexistence testing. The intended signal level shall be documented in the test report, typically in dBm or dBm/MHz, and verified by measurement during testing. To reduce the number of test runs, it is suggested that the intended signal level be selected for a reasonable worst-case scenario. The intended signal level can be related to the operational distance between the EUT and its companion device if the path loss between them can be determined; see 6.2.3 for further discussion of path loss.

The frequencies, modulations, RF transmit power levels, and power control of the EUT shall be documented in the test plan.

5.6.2 Signal quality

The signal level and signal quality shall be specified and documented in the test plan. The test plan shall identify the process that will be used to measure the signal quality.[23]

5.6.3 Transmission bandwidth

The test plan and test report shall document the transmission bandwidth of the RATs used during testing. For RATs that support and have the ability to control the transmission bandwidth, the test plan shall specify the transmission bandwidth for both transmit and receive operations. It is suggested that the maximum allowable bandwidth of operation for the transmit and receive operations be used.

[23] EVM, or another appropriate measure of signal quality should be used.

5.7 Unintended signals

The test signals are the unintended signals (see Figure 2) to be used in evaluating the ability of the EUT to coexist with devices using such signals. Test signals (unintended signals) shall be selected based on the RAT, operating frequency of the EUT, and the intended use environment. The test signals to be used shall be documented in the test plan. If the unintended signals are similar to the signals of the EUT, measures shall be taken to prevent the EUT from receiving and processing the unintended signals, because this can affect test results. Transmission parameters of the unintended signals shall be documented in the test plan and test report, such as frequency, bandwidth utilization, transmission power, and channel utilization.

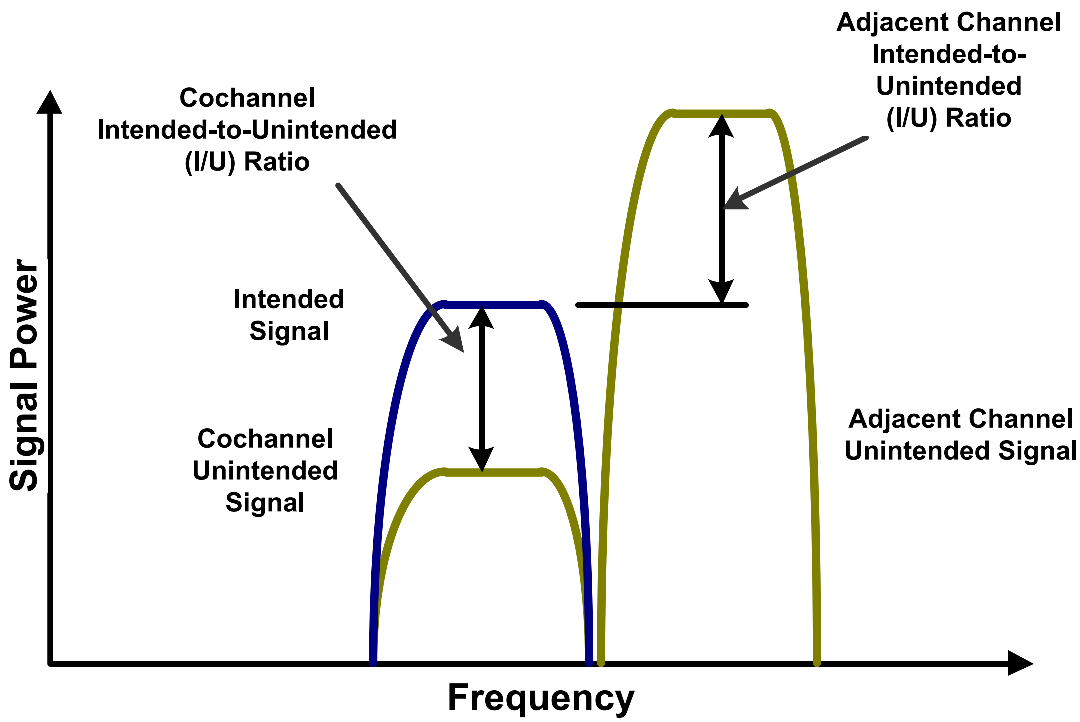

Figure 2—I/U ratio for co-channel and adjacent channel interference

The failure characteristics of the EUT shall be used in selecting the unintended signals to be used. Where there are several differing sets of failure modes or the characteristics of the failure modes are unknown, a wider variation in the test signals might be necessary to ensure that there is a high probability that a weakness will be detected by the testing. In some cases, the failure characteristics of the EUT are well known and can be used in planning a test. However, it is common that exploratory testing is useful and part of the test plan development process. Exploratory testing is useful for refining the specific details of the evaluation and getting experience with the EUT. In some cases, the failure characteristics will become evident during the exploratory testing process and can support the development of a more effective test plan. In this process, the three basic coexistence parameters (frequency, range, and time) of the unintended signal can be varied to identify the failure characteristics. For example, 1) the channel utilization of the unintended signal can be increased until the EUT is unable to coexist, 2) the intended-to-unintended signal (I/U) ratio (of the EUT signal to the unintended signal) can be decreased until the EUT is unable to coexist, or 3) the separation of the carrier frequencies between the EUT signal and unintended signal can be decreased until the FWP is unable to be maintained by the EUT.

Annex A provides RAT and band-specific test guidance for some of the most commonly used RATs and frequency bands. The carrier frequency of the EUT and unintended signal are fixed to decrease test variables and limit test time.[24] The test plan shall specify the coexistence parameters of the unintended signals to investigate during testing. The two possible parameters to determine in coexistence testing are 1) the I/U ratio and 2) the channel utilization of the unintended signal. The intended test deliverables will determine the combination of the test parameters to investigate. In some cases, only one parameter will need to be changed for the FWP to maintained acceptable performance.

For example, if the test deliverable is to find the I/U ratio for coexistence (or minimum separation distance) between the EUT and the unintended signal, the channel utilization of the unintended signal is set to its maximum, and the I/U ratio is found experimentally such that the FWP can maintain acceptable performance. If the test deliverable is to find the channel utilization of the unintended signal, the I/U ratio is fixed, and the channel utilization of the unintended signal is decreased until the FWP can maintain acceptable performance.

Figure 2 illustrates the relationship between an intended signal and an unintended signal in the co-channel and adjacent channel I/U ratios.

Characteristics of the unintended signals shall be documented in the test plan and test report. Communication systems can often operate in multiple modulation and coding states (MCS), and the test plan shall document the MCS for both the intended signals and the unintended signals. It is important to know the failure responses of the EUT for each MCS, or to know that the unintended signals will maximize the probability of detecting susceptibility, should one exist.

The unintended signals shall be monitored during testing, and the method of monitoring shall be documented in the test report. The method of monitoring the unintended signals shall be adequate to ensure that the signal amplitude, channel utilization rate, and other parameters are compliant with the test plan. In addition, if the unintended signals are generated by a wireless network, the unintended signals shall be monitored based on relevant KPIs. The purpose is to measure the change in performance of the unintended communication link during coexistence testing. Examples of commonly monitored KPIs for the unintended signals are as follows:

- Throughput
- Latency (one-way delay)
- Jitter (latency variation)
- Packet error rate (PER)

Two general test cases shall be considered in the test plan:

a) The unintended signal is closer to the EUT and therefore impacts the EUT reception or transmission (see Figure 3).

b) The unintended signal is closer to the EUT companion device, and therefore impacts the EUT companion device reception or transmission (see Figure 4).

Various phenomena occur, depending on the spatial arrangement of the unintended signals and the EUT. A receiver surrounded by unintended signals can experience increased packet collision, i.e., the hidden terminal (hidden node) effect. In contrast, when a transmitter is surrounded by unintended signals, available channel utilization is decreased, i.e., the exposed terminal effect.

Testing with FDD and TDD signal types should be considered based upon the intended EM environment of the EUT specified in the test plan.

[24] If the purpose of coexistence testing is to identify the failure points of the EUT through exploratory testing, the separation between the carrier frequency of the EUT and the unintended signal can be explored.

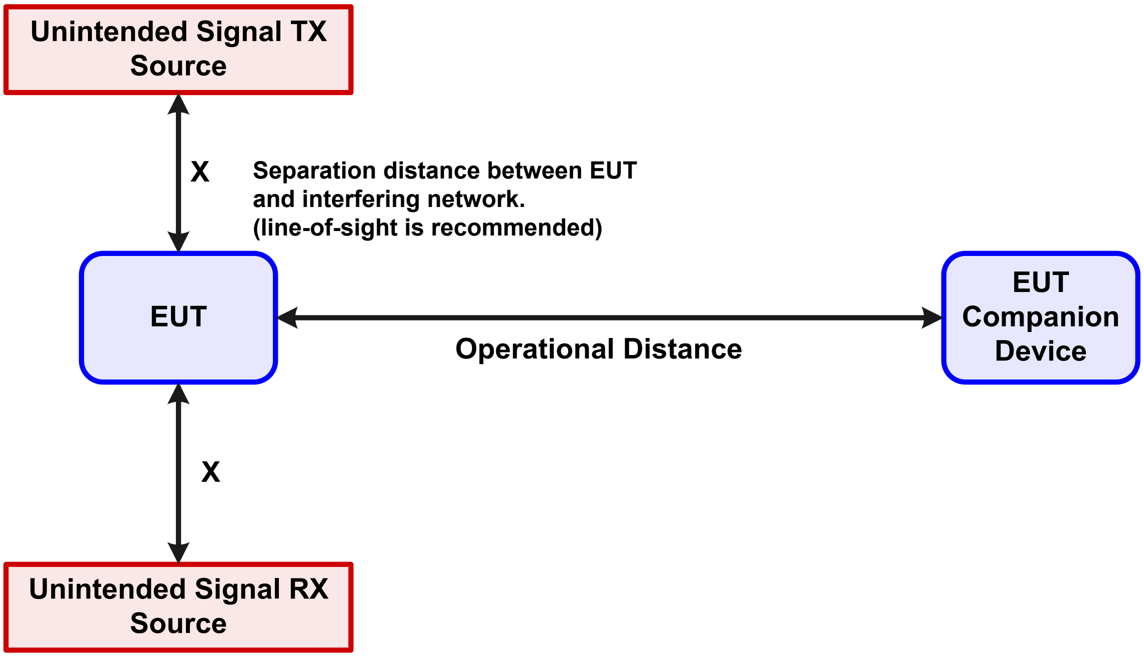

Figure 3—Test setup where primarily the EUT is exposed to the unintended signal

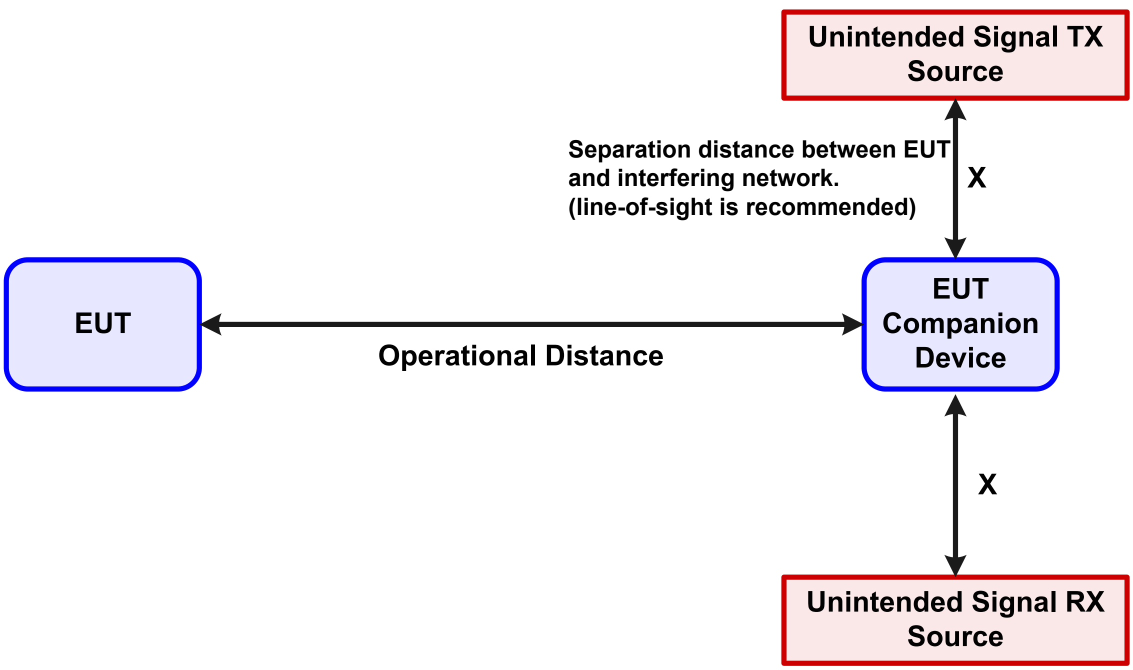

Figure 4—Test setup where primarily the EUT companion device is exposed to the unintended signal

5.8 Test monitoring and criteria

5.8.1 General

The coexistence test shall be monitored to ensure that the intended and unintended signals are as specified. The methods used to monitor the coexistence test shall be included in the test plan. The test plan shall quantify the minimum requirements for a valid monitoring system.

5.8.2 Test criteria

Clear acceptable performance criteria shall be determined for the FWP and documented in the test plan.

5.9 Test plan contents

The test plan shall specify the following:

— The intended EM environment of the EUT
— The FWPs of the EUT to be tested
— The KPIs to be monitored for each FWP function during testing
— The KPI thresholds to differentiate between acceptable and unacceptable FWP
— The RF bands and protocols used for each FWP function to be tested
— The evaluation tier to be used for each FWP function
— The test method to be used
— The intended signal transmission and received signal parameters
— The unintended signal parameters (frequency, transmission power, channel utilization)
— The method to monitor the unintended signals during testing

6. Test methodology

6.1 Overview

The coexistence testing specified in this standard is intended to assess the ability of the EUT to maintain its FWP in the intended EM environment. The test procedures in Annex B through Annex E incorporate the following general methodology:

— Verify the test setup
— Baseline the FWP of the EUT in the test environment
— Baseline the performance of the unintended signals in the test environment
— Test the FWP of the EUT in the presence of the unintended signals

6.2 Test setup verification

6.2.1 General

An end-to-end verification shall be performed of the test setup before coexistence testing is performed. This verification shall take into account the ambient EM noise level, the RF propagation channel, and other factors that have the potential for significantly impacting test results. Test setup verification shall be performed as often as is necessary to ensure that the test setup is operating properly.

Critical values of the test setup shall be measured. These values are described for each test method in the corresponding annex. Test instruments shall be calibrated by an appropriately accredited calibration laboratory. The calibration shall be directly applicable to the critical values being measured and shall provide uncertainty values that can be used when estimating the total MU of each test setup. Verification checks shall be performed to verify that all equipment and instrumentation is operating as specified in the test plan.

6.2.2 Ambient noise level

The ambient noise level of the test setup environment shall not affect the EUT or the unintended signals during testing. The test setup should be designed to provide an interference-free environment with accurate signal levels. It is suggested that the ambient noise level is less than the receiver sensitivity of the EUT minus the signal-to-noise ratio (SNR) required to demodulate the intended signal. This applies to the ambient noise level across the frequencies of operation of the EUT. The ambient noise level shall be reported in the coexistence test report. The measurement equipment should be sufficient to measure the noise level in the frequency bands of interest.

6.2.3 RF propagation channel

The RF propagation channel and path loss shall be measured between the EUT and its companion device. The propagation parameters measured shall be documented in the test report. The RF propagation parameters measured may vary based on the test method. The test plan shall specify each applicable RF propagation channel and path loss use case for the EUT. The RF propagation channels during coexistence testing should reflect each use case of the EUT. The RF path loss between the EUT and its companion device should reflect each use case of the device for which the performance of the FWP of the EUT is acceptable under the conditions of the maximum RF path loss. If the FWP is not acceptable during coexistence testing, one possibility is to decrease the maximum RF path loss between the EUT and its companion device. The maximum RF path loss is chosen as a test variable to test for the reasonable worst-case scenario and to reduce test time. Additional RF path losses can be tested to further characterize the coexistence of the EUT.

The path loss is documented as a dB value. Additionally, the RF path loss can be expressed as a corresponding operational distance between the EUT and its companion device. Depending on the use cases of the EUT, this operational distance can be expressed as a LOS or NLOS deployment distance. The maximum RF path loss and maximum operational distance are output parameters that are included in the coexistence test report.

The EUT and the EUT companion device are placed in the test setup to verify the intended signal level at: 1) the EUT, 2) the EUT companion device, or 3) both. The intended signal level shall be documented in the test report, typically in dBm, and verified experimentally during testing. To reduce the number of test runs, it is suggested to select the intended signal level for a reasonable worst-case scenario.

It is suggested that the EUT and the EUT companion device measure and report the intended signal level. The monitoring device should also simultaneously measure and report the intended signal level. Providing the intended signal level at the EUT and the EUT companion device increases reproducibility from one test to another. Additionally, the distance between the EUT and the EUT companion device should be measured to correlate with the intended signal level. The intended signal level at the EUT and the EUT companion device should be included in the coexistence report.

6.3 Test procedure

6.3.1 Baseline the FWP of the EUT in the test environment

Baseline the FWP of the EUT without the presence of the unintended signals, confirming it performs in the test setup at the received signal strength (RSS) specified in the pre-test plan. It should be demonstrated that the EUT can pass the KPI threshold (5.3.3) of the FWP (5.3) specified in the pre-test plan. The baseline results shall be documented in the test report.

The intended signal shall be measured in the test setup, before the unintended signal is applied, and documented in the test report. The signal amplitude and signal quality shall be confirmed to be within the range specified in the test plan.

For some devices, it is important that unwanted responses do not occur; also that, when appropriate, wanted responses do happen. Methods to exercise the EUT and monitor its functioning for both wanted and unwanted responses related to its FWP shall be used in the testing and described in the test report.

The test procedure along with the test criteria are used to verify the ability of the EUT to coexist with other transmitters or transceiver devices in the operational band and in the adjacent band.

6.3.2 Introduce the unintended signals

6.3.2.1 General

The unintended signals shall be generated by equipment that can either directly produce or simulate protocols, transmission levels, channels, modulations, and bandwidth that have been selected for use in the evaluation. The unintended signals shall be baselined (measured without the intended signals) in the test setup and documented in the test report. Both KPIs and RF parameter changes shall be measured for the unintended signals, during the baseline and during coexistence testing, and shall be documented in the test report.

The unintended signals shall be monitored during testing. The method of monitoring the unintended signals shall be adequate to ensure that the signal amplitude, channel utilization rate, and other parameters are as specified in the test plan. The method of monitoring the unintended signals shall be recorded in the test report.

Acceptable FWP is determined through an iterative process during coexistence testing, where the minimum path loss (attenuation) between the unintended signals and the EUT is determined, which equates to the I/U ratio for the EUT. The minimum path loss is documented as a dB value. Additionally, the path loss can be expressed as a corresponding minimum separation distance between the EUT and the unintended signals. Depending on the use case of the EUT, this minimum separation distance can be expressed as a LOS or NLOS distance. The minimum path loss and minimum separation distance, where the EUT has an acceptable level (pass) of FWP, are output parameters that are included in the coexistence test report.

6.3.2.2 Monitoring the unintended signals

If the unintended signals are generated by a wireless network, the unintended signals shall be monitored based on relevant KPIs. The method of monitoring the unintended signals shall be documented in the test report. The unintended signals shall be baselined (measured without the intended signals of the EUT) in the test setup and monitored during testing. The purpose is to measure the change in performance of the unintended communication link during coexistence testing with the EUT. Examples of commonly monitored KPIs for the unintended signals are:

— Throughput
— Latency (one way delay)
— Jitter (latency variation)
— PER

6.3.3 Test the FWP of the EUT

6.3.3.1 General

Test and measure the FWP of the EUT in the presence of the unintended signals. Depending on the FWP of the EUT tested, the connection between the EUT and its corresponding node or base station can be established before or after the unintended signals are turned on.

6.3.3.2 Interference thresholds

All susceptibilities and anomalies observed during the test shall be documented. One of the primary purposes of the coexistence test is to discover the thresholds at which the EUT can no longer maintain its FWP. When susceptibility indications are noted in the EUT operation, a threshold level shall be determined where the susceptible condition is no longer present. Determine the I/U ratio of the EUT where the device goes from being unable to pass the KPI threshold to being able to pass the KPI threshold during coexistence testing. The I/U ratio for each FWP of the EUT shall be recorded in the test report.

If the test plan calls for multiple criteria to be monitored, the I/U ratio, for each criteria, shall be recorded. The I/U ratio is found by taking the RSS (dBm) of the EUT, measured by the monitoring device, and subtracting the signal power of the unintended signals (dBm). The I/U ratio is expressed in dB. The I/U ratio can be different for different wireless functions of the EUT.

6.3.3.3 Susceptibility monitoring

The FWP of the EUT shall be monitored during testing for indications of degradation or failure. The test plan shall specify the KPIs of the FWP to monitor and the KPI thresholds to be maintained during testing. Degradations or failures of the FWP to maintain the specified KPIs shall be recorded.

Installation of special circuitry in the EUT for monitoring purposes is permissible, provided the modifications do not influence the test results.

6.4 Testing with non-adaptive protocols

The coexistence testing process for non-adaptive protocols follows the same steps specified in 6.1, 6.2, and 6.3 (see Figure 5). For an in-depth discussion of non-adaptive, adaptive, and cognitive radios, refer to Annex B of IEEE 1900.1:2008 [B28]. In general, a non-adaptive protocol does not use adaptive modulation,[25] dynamic channel assignment,[26] dynamic spectrum management,[27] AFH, or additional adaptive techniques to access the radio spectrum.

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[25] Adaptive modulation is a radio system function for adjusting the modulation format.(IEEE Std 1900.1:2008 [B28])

[26] Dynamic channel assignment is: a) The process of selecting and assigning different channels in real time to various entities/devices by making use of the available data regarding the operating environment to enhance performance; b) The transient radio frequency channel assignments created by radios, radio networks, or other spectrum-dependent systems that engage in dynamic spectrum access. Dynamic channel assignment contrasts with the static channel assignments that result from the traditional static spectrum management process, where radio devices operate in one predefined frequency range. (IEEE Std 1900.1:2008 [B28])

[27] Dynamic spectrum management is a system of spectrum management that dynamically adapts the use of spectrum in response to information about the use of that spectrum by its own nodes and other spectrum-dependent systems. NOTE—Dynamic spectrum

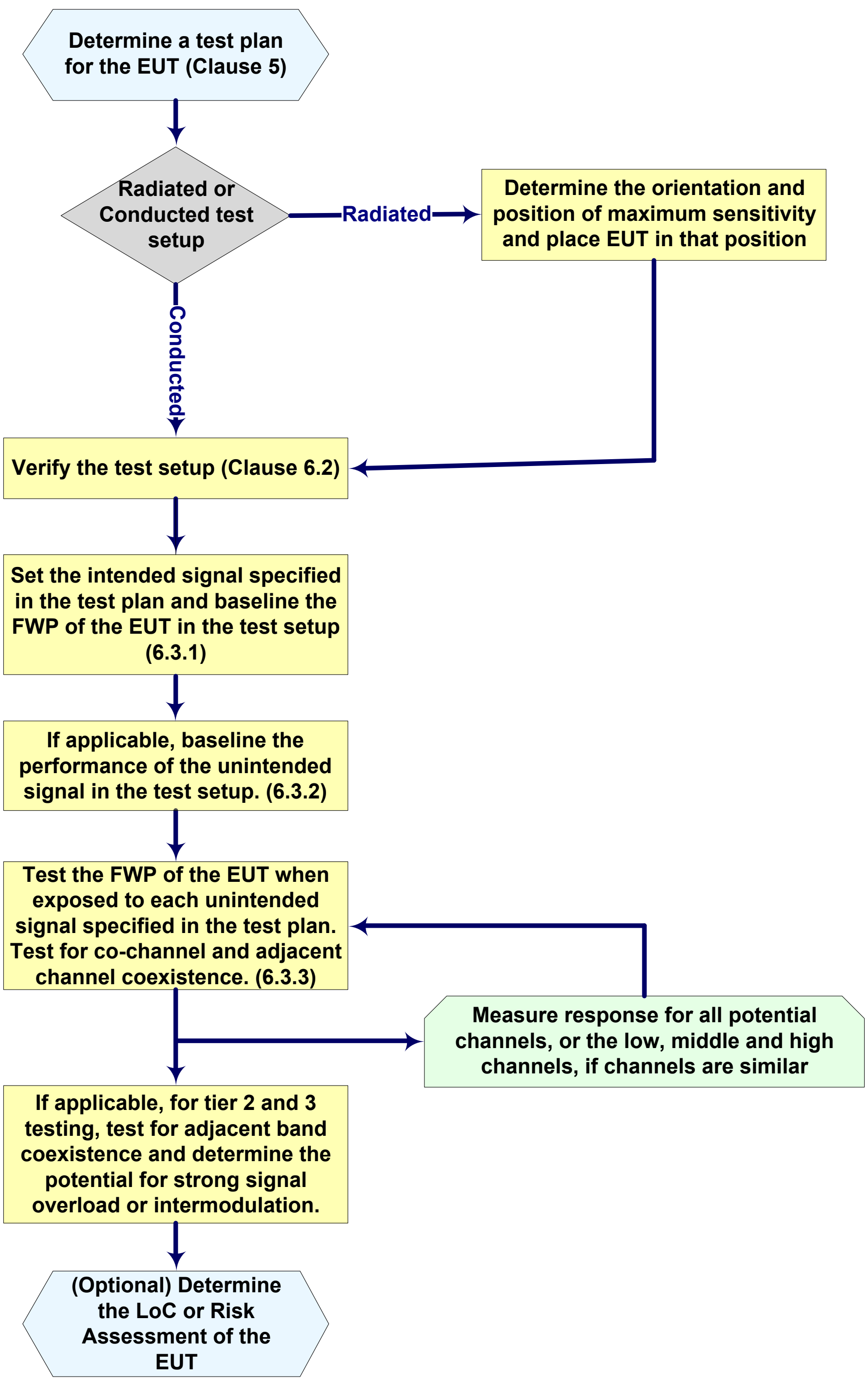

Figure 5—Test flowchart for non-adaptive protocol coexistence testing

management helps to address the inherent inflexibility of static band allocations and the ability of future networks to carry traffic simultaneously that corresponds to multiple radio communications services. (IEEE Std 1900.1:2008 [B28])

7. Analysis and summarization of test results

7.1 General

There are a number of possible objectives for performing coexistence testing. Coexistence test results can be the final output, or optional additional analysis can be performed, such as that specified in Clause 7. It is important to understand that the application of the FWP of the EUT will guide the type of post-test analysis. The results of coexistence testing can be used in connection with, but application is not limited to, the following processes and standards:

— 7.2 Likelihood of coexistence

— 7.3 Medical device risk

Extrapolating test data to predict field performance brings together test results with an understanding of the EM environments into which an EUT will be placed. The testing quantifies the ability of an EUT to operate in the presence of other transmitters and other EM emitters. That data must then be analyzed against what is known about the EM environments in which the EUT will operate.

When the specific device being tested connects to a network, assumptions about the network configuration and its specifications shall be clearly stated. Often the quality and configuration of the network will have a significant impact on coexistence. The device being tested cannot control either the equipment a network administrator will install or the network configuration. However, in evaluating the test results the impact of these factors can be identified and included in the analysis. Assumptions about the network and its equipment shall be clearly stated so that the recipient can be aware of network dependencies.

When a device can be connected to networks with a variety of configurations or levels of companion equipment performance, the anticipated variation in performance due to these factors should be discussed in the evaluation of the test results.

7.2 Estimating the likelihood of coexistence

7.2.1 General

Information about the EM environment and coexistence test data of the EUT can be used to estimate the LoC. One or more KPIs for the FWP of the EUT can be identified. Coexistence testing identifies the I/U ratios that set the boundaries for the ability of the EUT to deliver its FWP given a specified KPI. There will be a set of I/U ratios that could include a co-channel undesired signal and one or several adjacent channel signals with individual frequency separations from the desired signal.

The LoC is an estimate of the probability that an EUT will encounter conditions equal to (and less than) the I/U ratios within the limits of its ability to maintain its FWP.

The validity of the LoC is dependent on both the quantity and quality of measured EM environment data. Confidence in an estimate increases as the amount of sampled data increases. The quality of the EM environmental data is critically important. It is necessary that the EM environmental measurements used to calculate the LoC are sufficiently sampled, and representative of the intended use environments of the EUT.

If the EUT has been submitted for coexistence evaluation as part of a total risk assessment, then an estimation of the LoC can be integrated into that risk assessment.

Determination of the LoC requires information about the following:

- The strength of the intended signal
- The signal quality of the intended signal
- The EM fields the EUT will encounter in its operational environments
- For equipment connecting to a network, variations in the network that can be anticipated

When the EM environments are expected to be stable and measurements of them are of sufficient quality, an estimation of LoC can be made. Alternatively, if the EM environment is expected to be changing, for example because a new technology is being introduced into the band or the band rules are changing, the estimation of LoC will be done using an analysis of the EM characteristics of the new technology.

There can be several LoC estimates if there are multiple KPIs specified in the test plan.[28] There can be different LoC estimates for different EUT functions. There can also be different LoC estimates for the ability of an EUT to provide peak performance versus its ability to provide minimal performance. Separate LoCs shall be calculated and reported for each function and KPI tested.[29]

When it is useful to the purposes of the test, separate LoCs should be calculated and reported for each FWP tested against separate unintended signals.[30]

If a FWP can operate on multiple bands, separate LoCs should be calculated and reported for each FWP for each band.[31]

If a FWP can operate over multiple RATs, separate LoCs should be calculated and reported for each FWP over each wireless technology.[32]

If the EUT has the ability to change bands or RATs, then a summary LoC should be reported, which is the likelihood that it will find at least one band or RAT that enables it to provide the FWP. The summary LoC will be the scalar product of the probabilities of the individual LoCs.

The variables included in the assessment shall be stated, as well as those variables that were considered but determined to be insignificant to the analysis. Examples of variables that can be considered in the LoC estimate are discussed in the subclauses below.

7.2.2 Concurrent operation

Many devices operate only some of the time. Even while operating, devices often only transmit a portion of the time they are in use. Interference can only occur when an unintended signal is present while an intended signal is being received. The likelihood of concurrent operation is a factor that can be included in a LoC estimate.

7.2.3 Relative positioning

The effect of antenna pattern and relative positioning shall be considered in the LoC estimate.

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[28] For example, one analysis can focus on the likelihood that a communication link will be lost. Another could consider the likelihood that a communication link will be lost and cannot be reestablished in a specified amount of time. A third analysis could be interested in the likelihood that the EUT will change its modulation and coding state, reducing data throughput, due to interference.

[29] For example, the EUT can have multiple functions, each with a separate KPI.

[30] For example, the FWP of the EUT can be tested against IEEE 802.11n and IEEE 802.11g.

[31] For example, a FWP can use the 2.4 GHz band and the 5 GHz band for IEEE 802.11n.

[32] For example, a FWP can use IEEE 802.11n and LTE.

The effect of antenna patterns and the degree of antenna cross polarization can be summarized using a cumulative gain distribution (CGD). When using CGD, a single cumulative gain is used in the calculations.

When MIMO, beam forming, or similar techniques are used and their efficacy can be quantified, the impact of these factors should be included in the interference probability estimate.

7.2.4 Channel loss

Differing propagation models can result in a wide variation in estimates of the channel loss for both the intended and unintended signal. The assumptions made in developing channel loss estimates shall be clearly stated in the test report section describing how the LoCs were estimated.

7.2.5 Use of measured EM environmental data

The calculation of LoC requires the use of measured data obtained from a representative EM environment, and thus care must be taken to account for the measurement uncertainties as they propagate through the estimation of LoC. To aid in the interpretation of the results, a thorough description of how the environmental data were acquired is needed. When the LoC is given in a test report, the following shall also be documented:

- The physical environment where the measured data were acquired. This description shall include enough descriptors to enable repeat measurements in the same type of physical environment.
- The data acquisition setup and method. This shall include a description or diagram of all antennas, cables, passive devices (e.g., attenuators), active devices (e.g., amplifiers), and receivers used in the acquisition of data. Key receiver parameters shall be identified. These parameters include but are not limited to: the signal duration required for 100% probability of intercept, the measurement bandwidth, and the dynamic range of the measurement system.
- The calibration method for the devices used in the data acquisition. This includes antenna patterns, antenna mismatch/ voltage standing wave ratio (VSWR) across the frequency range of interest, cable losses, and calibration of the receiver itself.
- Measurement uncertainties shall accompany the environmental data used in the calculation of LoC. This uncertainty analysis shall follow the guidelines specified in Clause 8.
- How the data are processed to obtain the characteristics of the environment EM profile. This description shall also include any protocols or technologies that were explicitly identified in the environmental data and the methods used to identify them.
- How the resulting profile relates to the coexistence test performed on the EUT.

7.3 Medical device risk

AAMI TIR 69 provides guidance for using the test results in this standard in a risk assessment for a medical device. The AAMI TIR address the issues that arise when test results are used in a medical device risk assessment to ISO 14971:2007 or a health care delivery risk assessment to IEC TR 80001-2-2:2012. This purpose uses the test results in combination with an understanding of their clinical significance for the health care delivery functions of the device. The objective is to first quantify the risk and then mitigate it to acceptable levels.

8. Estimating MU

All uncertainty calculations and estimates shall follow the guidance of ISO/IEC guide 98-1 or JCGM 104:2009 and ISO/IEC 98-3 or JCGM 100:2008 (including ISO/IEC 98-3 Supplement 1 and ISO/IEC 98-3 Supplement 2 or JCGM 101:2008 and JCGM 102:2011).

The test plan shall identify and attempt to quantify measurement uncertainties associated with the coexistence test of the EUT.

Regardless of the test method used, all coexistence test reports shall include a list of the individual components accounted for in the MU analysis, a value for the combined standard uncertainty of the measurement, and a final expanded uncertainty value (utilizing a minimum coverage factor of $k=2$).[33] Uncertainty analyses shall include, where appropriate, both Type A and Type B components.

For any coexistence test, the accuracy of the test relies, in part, on the ability to measure the following parameters, of the intended and unintended signals: amplitude (or power), frequency, and duration. In addition to those six parameters the uncertainty of the operator's ability to measure/monitor the FWP of the EUT must also be considered. The uncertainty of each of these parameters contributes to the final expanded uncertainty of the measurement.

Each test lab shall determine the test-to-test measurement repeatability by repeating a verification test a minimum of five times for each time the measurement setup (exclusive of the EUT) is changed. The statistical variance of these measurements is one of the components of each MU calculation for each subsequent EUT measured with this setup.

The repeatability of a test setup and the test method (Annex B through Annex E) used to test the EUT can be significant factors in the combined standard uncertainty of a measurement.

9. Test report

Each test report shall include at least the following information:

a) Name and location of the test laboratory and, if different, the location where the test was performed

b) Names and functions or equivalent identification of the persons performing the test and those authorizing the test report

c) Description of the wireless technology of the EUT, including the transmission frequencies, transmission bandwidths, etc.

d) Description of the basic functions of the EUT, including which functions are considered the FWP, and how they were monitored during the test

e) Version of the EUT, both hardware and software (additionally, the relationship of the model tested to production models shall be described)

f) Description of the intended EM environment of the EUT (including prevalent modulations, data rates, and signal frequencies)

g) Description of the test procedure used, including a description of the unintended signal used [34]

[33] If the combined standard uncertainty is normally distributed, a coverage factor of $k=2$ is equivalent to a 95% confidence interval.

[34] This test procedure description could be as simple as citing one of the annexes of this document, or more elaborate if significant deviations from test methods in the standard are being made.

h) Identification and definition of KPIs, the threshold between acceptable and unacceptable performance, and how they were monitored during the test

i) Criteria for determining whether FWP was maintained or failed

j) EUT configuration (hardware and software) used during the test (including a block diagram)

k) Description and position of interconnecting cables to/from the EUT (the layout of excess cable shall be noted)

l) Test equipment used to perform the test, including versions of hardware and software, calibration, and maintenance dates

m) Test equipment configuration and parameters used (including frequencies, dwell time, and MCS tested)

n) Test equipment configuration when a device can be connected to a network with a variety of configurations or levels of EUT companion device performance, and the anticipated variation in performance due to these factors should be discussed

o) Description of the ambient signals observed during the coexistence test (if applicable to the test method used)

p) Description of methods used to reduce the effects of ambient noise/RF signals

q) The maximum operational distance of the EUT

r) The minimum separation distance between the EUT and the unintended signal or the minimum I/U ratio at the EUT in which the EUT has an acceptable level (pass) of FWP

s) Description of any modifications made to the EUT hardware or software to enable monitoring or facilitating the coexistence test

t) Effects on the EUT that were observed during or after the application of the unintended signals and the duration for which these effects persisted

u) Photographs of each test setup, including the EUT, all peripherals, and all auxiliary equipment used to conduct the test

v) The results of the test monitoring

w) Test MU calculations

x) Summary of test results

Additional information can be added to the test report as necessary. The report requirements in this clause expand on 5.10 of ISO/IEC 17025:2005, and contain additional input from IEC 60601-1-2:2014 [B22].

Annex A

(normative)

Band-specific test guidance

A.1 Overview

This annex provides specific guidance (frequency, signal amplitude,[35, 36] and channel utilization) for testing some of the most common RATs and frequency bands.

It is recognized that there are wireless technologies other than those addressed in this annex. The technologies in this annex have been addressed because of their use in a wide variety of products.

A.2 Bluetooth® wireless technology and Bluetooth low energy EUTs[37]

A.2.1 General

This annex provides focused guidance for testing Bluetooth and Bluetooth Low Energy devices operating in the 2.4 GHz ISM band.

Tier 3 testing is performed with a single IEEE 802.11n transmission as the unintended signal.

Tier 2 testing has two sets of tests: 1) two IEEE 802.11n transmissions as the unintended signal, and 2) two-adjacent band LTE (long term evolution) signals as the unintended signal.

Tier 1 testing has two sets of tests: 1) three IEEE 802.11n transmissions as the unintended signal, and 2) two-adjacent band LTE signals as the unintended signal.

A.2.2 Tier 1 test recommendations

A.2.2.1 Unintended IEEE 802.11n signals

A.2.2.1.1 IEEE 802.11n frequency

Three-channel testing shall be performed using an IEEE 802.11n, 20 MHz bandwidth signal, centered at 2412 MHz, 2437 MHz, and 2462 MHz (Wi-Fi channels 1, 6, and 11).

A.2.2.1.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup. All three IEEE 802.11n unintended signals shall have equal power at the EUT.

[35] Unless otherwise noted, all power levels shall be interpreted as EIRP.

[36] For the conducted test setup (Figure B.1), it is assumed that there is 40 dB of attenuation between the EUT and unintended signal (20 dB attenuation in front of the EUT and 20 dB attenuation in front of each unintended signal). 40 dB of attenuation is equivalent to a separation distance of 1 m.

[37] Bluetooth is a registered trademark owned by Bluetooth SIG, Inc.

A.2.2.1.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at a 64 quadrature amplitude modulation (QAM) modulation MCS.

A.2.2.2 Unintended LTE signals

A.2.2.2.1 LTE frequency

Two-adjacent-band LTE transmission testing shall be performed using a LTE 10 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The lower adjacent band LTE downlink signal shall be FRC R.7 TDD centered on EARFCN 39600, 2395 MHz.[38] The lower adjacent band LTE uplink signal shall be FRC A.5-5 TDD centered on EARFCN 39600, 2395 MHz.[39] The upper adjacent band LTE shall use the same RFCs as the lower adjacent band but centered on EARFCN 39700, 2501 MHz. See Figure A.1

A.2.2.2.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 23 dBm total radiated power (TRP) or −17 dBm at the EUT in the conducted test setup at the EUT.

A.2.2.2.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.2.3 Tier 2 test recommendations

A.2.3.1 Unintended IEEE 802.11n signals

A.2.3.1.1 IEEE 802.11n frequency

Two-channel testing shall be performed using two IEEE 802.11n, 20 MHz bandwidth signals, centered at 2412 MHz and 2462 MHz (Wi-Fi channels 1 and 11).

A.2.3.1.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or −20 dBm at the EUT in the conducted test setup. All IEEE 802.11n unintended signals shall have equal power at the EUT.

A.2.3.1.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

[38] FRC R.7 TDD is specified in 3GPP TS 36.101 v13.2.1 (2016-01) Table A.3.4.1-3.

[39] FRC A5-5 TDD is specified in 3GPP TS 36.104 v13.2.0 (2016-01) Table A.5-1.

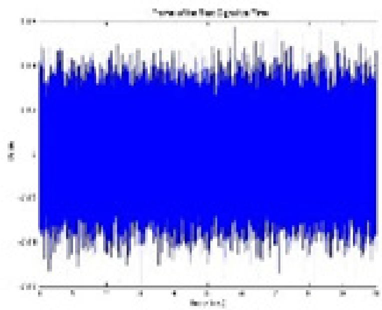
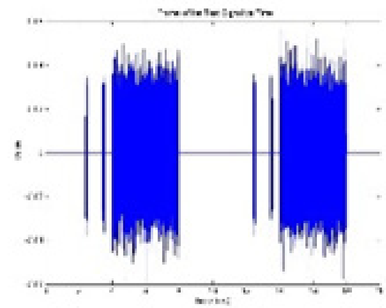
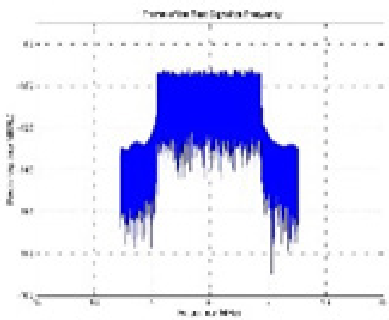
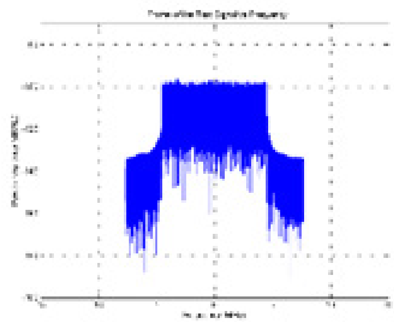
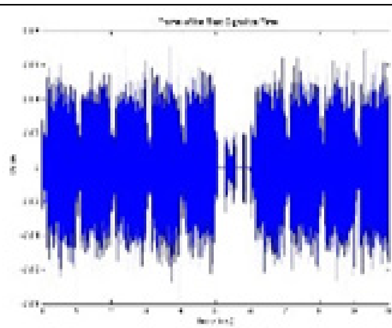
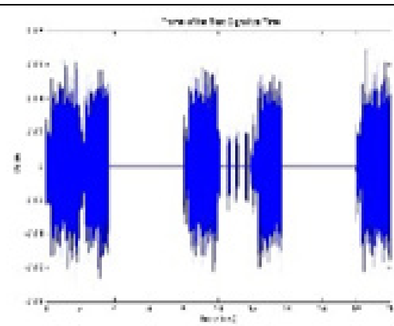
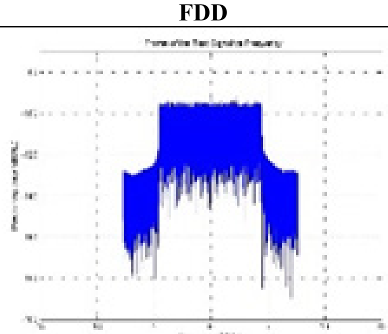
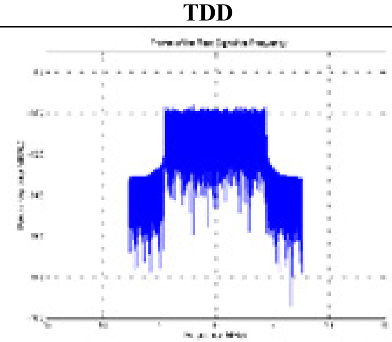
3GPP LTE Waveforms Bandwidth: 10.0 MHz Modulation: 64QAM	
LTE UE Waveform: 3GPP FRC A5-5: Time	
FDD	**TDD**
	
LTE UE Waveform: 3GPP FRC A5-5: Frequency	
FDD	**TDD**
	
LTE Base Waveform: 3GPP FRC R.7: Time	
FDD	**TDD**
	
LTE Base Waveform: 3GPP FRC R.7: Frequency	
FDD	**TDD**
	

Figure A.1—3GPP LTE waveforms

A.2.3.2 Unintended LTE signals

A.2.3.2.1 LTE frequency

Two-adjacent-band LTE transmission testing shall be performed using a LTE 1.4 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The lower adjacent band LTE downlink signal shall be FRC R.7 TDD centered on EARFCN 39600, 2395 MHz.[40] The lower adjacent band LTE uplink signal shall be FRC A.5-5 TDD centered on EARFCN 39600, 2395 MHz.[41] The upper adjacent band LTE shall use the same RFCs as the lower adjacent band but centered on EARFCN 39700, 2501 MHz.

A.2.3.2.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 17 dBm total radiated power in the radiated setup or −23 dBm at the EUT in the conducted test setup. See F.7.2 for the derivation.

A.2.3.2.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.2.4 Tier 3 test recommendations

A.2.4.1 Unintended IEEE 802.11n signal

A.2.4.1.1 IEEE 802.11n frequency

Single-channel testing shall be performed using an IEEE 802.11n, 20 MHz bandwidth signal, centered at 2437 MHz (Wi-Fi channel 6).

A.2.4.1.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signal shall be 20 dBm total radiated power in the radiated setup or −20 dBm at the EUT in the conducted test setup.

A.2.4.1.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.3 Wi-Fi EUT operating in the 2.4 GHz ISM band (2400-2483.5 MHz)

A.3.1 General

This annex provides focused guidance for testing Wi-Fi devices operating in the 2.4 GHz ISM band. See Figure A.2.

Tier 3 testing is performed with a single adjacent band IEEE 802.11n signal as the unintended signal.

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[40] FRC R.7 TDD is specified in 3GPP TS 36.101 v13.2.1 (2016-01) Table A.3.4.1-3.
[41] FRC A5-5 TDD is specified in 3GPP TS 36.104 v13.2.0 (2016-01) Table A.5-1.

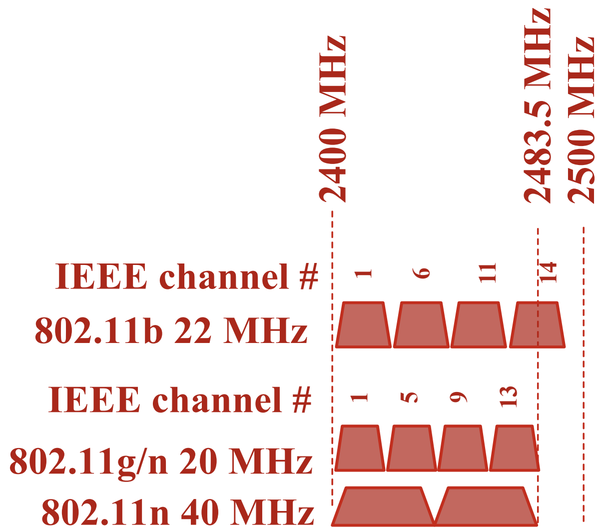

Figure A.2—Non-overlapping 2.4 GHz ISM band Wi-Fi channels

Tier 2 testing has three sets of tests: 1) one co-channel IEEE 802.11n signal as the unintended signal, 2) one adjacent band (lower) LTE signal as the unintended signal, and 3) one adjacent band (upper) LTE transmission as the unintended signal.

Tier 1 testing has three sets of tests: 1) two concurrent adjacent band IEEE 802.11n signals as the unintended signal, 2) one adjacent band (lower) LTE signal as the unintended signal, and 3) one adjacent band (upper) LTE signal as the unintended signal.

A.3.2 Tier 1 test recommendations

A.3.2.1 General

In addition to the testing done for Tier 2 and Tier 3, Tier 1 adds the testing specified in this subclause.

A.3.2.2 Unintended IEEE 802.11n signals

A.3.2.2.1 IEEE 802.11n frequency

Two concurrent IEEE 802.11n unintended signals on the lower and higher adjacent channel shall be used when performing a Tier 1 evaluation of a Wi-Fi device. The EUT shall operate on Wi-Fi channel 6 (centered at 2437 MHz), and one IEEE 802.11n unintended signal shall transmit on channel 1 (centered at 2412 MHz) and another IEEE 802.11n unintended signal shall transmit on channel 11 (centered at 2462 MHz).

A.3.2.2.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup. Both IEEE 802.11n unintended signals shall have equal power at the EUT.

A.3.2.2.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.3.2.3 Unintended LTE signals (lower adjacent band)

A.3.2.3.1 LTE frequency

Single-channel testing shall be performed using a LTE 10 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The lower adjacent band LTE downlink signal shall be FRC R.7 TDD centered on EARFCN 39600, 2395 MHz.[42] The lower adjacent band LTE uplink signal shall be FRC A.5-5 TDD centered on EARFCN 39600, 2395 MHz.[43] The EUT shall operate on Wi-Fi channel 1 (centered at 2412 MHz).

A.3.2.3.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 23 dBm total radiated power in the radiated setup or −17 dBm at the EUT in the conducted test setup. See F.7.2 for the derivation.

A.3.2.3.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.3.2.4 Unintended LTE signals (upper adjacent)

A.3.2.4.1 LTE frequency

Single-channel testing shall be performed using a LTE 10 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The upper adjacent band LTE shall use the same RFCs as the lower adjacent band but centered on EARFCN 39700, 2501 MHz. The EUT shall operate on Wi-Fi channel 11 (centered at 2462 MHz).

A.3.2.4.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 23 dBm total radiated power (TRP) in the radiated setup or −17 dBm at the EUT in the conducted test setup.

A.3.2.4.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.3.3 Tier 2 test guidance

A.3.3.1 General

In addition to the testing done for Tier 3, Tier 2 adds the testing described in this subclause.

[42] FRC R.7 TDD is specified in 3GPP TS 36.101 v13.2.1 (2016-01) Table A.3.4.1-3.
[43] FRC A5-5 TDD is specified in 3GPP TS 36.104 v13.2.0 (2016-01) Table A.5-1.

A.3.3.2 Unintended IEEE 802.11n signal

A.3.3.2.1 IEEE 802.11n frequency

Single-channel testing shall be performed using an IEEE 802.11n, 20 MHz bandwidth signal, Wi-Fi channel 6 (centered at 2437 MHz). The EUT shall operate on Wi-Fi channel 6 (centered at 2437 MHz).

A.3.3.2.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signal shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup.

A.3.3.2.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.3.3.3 Unintended LTE signal (lower adjacent)

A.3.3.3.1 LTE frequency

Single-channel testing shall be performed using a LTE 1.4 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The lower adjacent band LTE downlink signal shall be FRC R.7 TDD centered on EARFCN 39600, 2395 MHz.[44] The lower adjacent band LTE uplink signal shall be FRC A.5-5 TDD centered on EARFCN 39600, 2395 MHz.[45] The EUT shall operate on Wi-Fi channel 1 (centered at 2412 MHz).

A.3.3.3.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 17 dBm total radiated power (TRP) or –23 dBm at the EUT in the conducted test setup.

A.3.3.3.3 LTE channel utilization

The channel occupancy of the unintended LTE signal shall be 100%.

A.3.3.4 Unintended LTE signal (upper adjacent)

A.3.3.4.1 LTE frequency

A single channel testing shall be performed using a LTE 1.4 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan.

The upper adjacent band LTE shall use the same RFCs as the lower adjacent band but centered on EARFCN 39700, 2501 MHz. The EUT shall operate on Wi-Fi channel 11 (centered at 2462 MHz).

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[44] FRC R.7 TDD is specified in 3GPP TS 36.101 v13.2.1 (2016-01) Table A.3.4.1-3.

[45] FRC A5-5 TDD is specified in 3GPP TS 36.104 v13.2.0 (2016-01) Table A.5-1.

A.3.3.4.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 17 dBm total radiated power (TRP) in the radiated setup or −23 dBm at the EUT in the conducted test setup.

A.3.3.4.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.3.4 Tier 3 test guidance

A.3.4.1 Unintended IEEE 802.11n signal

A.3.4.1.1 IEEE 802.11n frequency

A single IEEE 802.11n unintended signal on the lower or higher adjacent channel shall be used when performing a Tier 3 evaluation of a Wi-Fi device. The EUT shall operate on Wi-Fi channel 6 (centered at 2437 MHz), and the IEEE 802.11n unintended signal shall transmit on channel 1 (centered at 2412 MHz) or channel 11 (centered at 2462 MHz).

A.3.4.1.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup. Both IEEE 802.11n unintended signals shall have equal power at the EUT.

A.3.4.1.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.4 Wi-Fi EUT operating in the 5 GHz UNII & ISM bands (5150–5850 GHz)

A.4.1 General

This annex provides focused guidance for testing Wi-Fi devices operating in the 5 GHz UNII and ISM bands. See Figure A.3. The testing is similar to that performed for Wi-Fi in the 2.4 GHz ISM band in A.3, but with changes appropriate to these bands.

Tier 3 testing is performed with a single adjacent band IEEE 802.11n transmission as the unintended signal.

Tier 2 testing is performed with a single co-channel IEEE 802.11n transmission as the unintended signal.

Tier 1 testing is performance with two concurrent adjacent band IEEE 802.11n transmissions as the unintended signal.

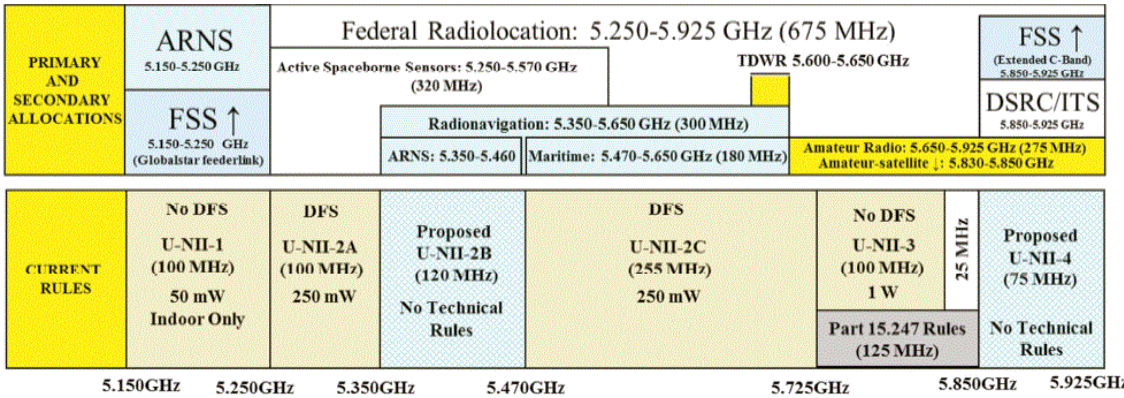

Figure A.3—UNII and ISM band plans[46]

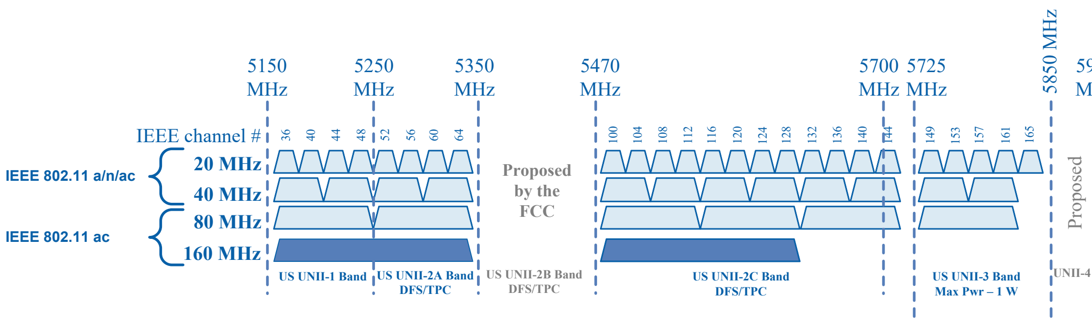

Figure A.4—Wi-Fi channel assignments in the UNII and 5.8 GHz ISM bands[47]

A.4.2 Tier 1 test guidance

A.4.2.1 General

In addition to the testing done for Tier 2 and Tier 3, Tier 1 adds the testing described in this subclause.

A.4.2.2 Unintended IEEE 802.11n signals

A.4.2.2.1 IEEE 802.11n frequency

Two concurrent IEEE 802.11n unintended signals on the lower and upper adjacent channel shall be used when performing a Tier 1 evaluation of a Wi-Fi device. Table A.1 lists the possible channels the EUT (20 MHz bandwidth) can be tested on and the corresponding unintended signal channels. Table A.2 lists the possible channels the EUT (40 MHz bandwidth) can be tested on and the corresponding unintended signal channels. The test plan shall specify the EUT channel of transmission and the unintended signals channel of transmission.

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[46] Illustration from FCC document 14-30, the first report and order for FCC ET Docket 13-49.

[47] FCC KDB 905462 D06 802.11 Channel Plans New Rules v02.

Table A.1—EUT (20 MHz bandwidth transmission) channels and unintended signal channels used in testing

EUT Channel	Unintended Signal (Lower Channel)	Unintended Signal (Upper Channel)
40 (5190-5210 MHz)	36 (5170-5190 MHz)	44 (5210-5230 MHz)
56 (5270-5290 MHz)	52 (5250-5270 MHz)	60 (5290-5310 MHz)
120 (5590-5610 MHz)	116 (5570-5590 MHz)	124 (5610-5630 MHz)
153 (5755-5775 MHz)	149 (5735-5755 MHz)	157 (5775-5795 MHz)

Table A.2—EUT (40 MHz bandwidth transmission) channels and unintended signal channels used in testing

EUT Channel	Unintended Signal (Lower Channel)	Unintended Signal (Upper Channel)
46 (5210-5250 MHz)	38 (5170-5210 MHz)	54 (5250-5290 MHz)
54 (5250-5290 MHz)	46 (5210-5250 MHz)	62 (5290-5330 MHz)
118 (5570-5610 MHz)	110 (5530-5570 MHz)	126 (5610-5650 MHz)
159 (5775-5815 MHz)	151 (5735-5775 MHz)	165 (5815-5835 MHz) (20MHz BW)

A.4.2.2.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup. Both IEEE 802.11n unintended signals shall have equal power at the EUT.

A.4.2.2.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.4.3 Tier 2 test guidance

A.4.3.1 General

In addition to the testing done for Tier 3, Tier 2 adds the testing described in this subclause.

A.4.3.1.1 Unintended IEEE 802.11n signals

A.4.3.1.2 IEEE 802.11n frequency

Single-channel testing shall be performed using a co-channel IEEE 802.11n, operating on the same channel as the EUT and with the same transmission bandwidth (20 MHz of 40 MHz) as the EUT.

A.4.3.1.3 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signal shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup.

A.4.3.1.4 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.4.4 Tier 3 test guidance

A.4.4.1 Unintended IEEE 802.11n signal

A.4.4.1.1 IEEE 802.11n frequency

A single IEEE 802.11n unintended signal on the lower or upper adjacent channel shall be used when performing a Tier 2 evaluation of a Wi-Fi device. Table A.1 lists the possible channels the EUT (20 MHz bandwidth) can be tested on and the corresponding unintended signals channels. Table A.2 lists the possible channels the EUT (40 MHz bandwidth) can be tested on and the corresponding unintended signal channels. The test plan shall specify the EUT channel of transmission and the unintended signal channel of transmission.

A.4.4.1.2 IEEE 802.11n signal amplitude

The signal amplitude of the unintended IEEE 802.11n signals shall be 20 dBm total radiated power in the radiated setup or –20 dBm at the EUT in the conducted test setup. Both IEEE 802.11n unintended signals shall have equal power at the EUT.

A.4.4.1.3 IEEE 802.11n channel utilization

The unintended IEEE 802.11n signal shall operate at 64 QAM.

A.5 DECT EUT operating in the UPCS band (1920-1930 MHz)

A.5.1 General

This subclause provides guidance for testing DECT equipment operating in the UPCS band.

Tier 3 testing is performed with a single IEEE 802.11n transmission as the unintended signal.

Tier 2 testing is performed with a single adjacent band LTE transmission as the unintended signal.

Tier 1 testing is performed with a single adjacent band LTE transmission as the unintended signal.

A.5.2 Tier 1 test guidance

A.5.2.1 General

In addition to the testing done for Tier 2 and Tier 3, Tier 1 adds the testing described in this subclause.

A.5.2.2 Unintended LTE signals

A.5.2.2.1 LTE frequency

Single-channel testing shall be performed using a LTE 1.4 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan. The EUT shall operate on the channel centered at 1923.264 MHz. The adjacent band LTE transmission shall use the uplink frequency for EARFCN 1199, 1909.9 MHz.

A.5.2.2.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 23 dBm total radiated power (TRP) in the radiated setup or –17 dBm at the EUT in the conducted test setup.

A.5.2.2.3 LTE channel utilization

The channel utilization of the unintended LTE signal shall be 100%.

A.5.3 Tier 2 test guidance

A.5.3.1 General

In addition to the testing done for Tier 3, Tier 2 adds the testing described in this subclause.

A.5.3.2 Unintended LTE signals

A.5.3.2.1 LTE frequency

Single-channel testing shall be performed using a LTE 1.4 MHz signal with both a LTE uplink and downlink FRN as the unintended signal. FDD and TDD testing should be considered, based upon the intended EM environment of the EUT specified in the test plan. The EUT shall operate on the channel centered at 1923.264 MHz. The adjacent band LTE signal shall use the uplink frequency for EARFCN 1199, 1909.9 MHz.

A.5.3.2.2 LTE signal amplitude

The signal amplitude of the unintended LTE signal shall be 17 dBm total radiated power (TRP) in the radiated setup or –23 dBm at the EUT in the conducted test setup.

A.5.3.2.3 LTE channel utilization

A LTE unintended signal shall be operated using the 3GPP FRC A5-2 waveform.[48] The channel utilization of the unintended LTE signal shall be 100%.

A.5.4 Tier 3 test guidance

The EUT shall be tested with DECT equipment that is in compliance with the spectrum etiquette requirements of ANSI C63.17-2013. The test report shall include the ANSI C63.17-2013 test results of the DECT to FWP and KPIs of the EUT. Any change or degradation of the KPIs observed while unintended signals are present should be reported in the test report.

[48] See 3GPP 36-104 subclause 5.7.3 and A.5 for further details on this channel assignment and waveform.

Annex B

(normative)

RF conducted test method

B.1 Method overview and principal application

Conducted RF testing is performed by combining the intended and unintended signals and connecting them to an access port next to or in place of the antenna (see Figure B.1). The unintended signal can be generated by transmitters or a signal generator. The signal is monitored at the input to the EUT and at other points in the setup as needed to support adequate control of the system and to allow documentation of the test. If it is not possible to access the antenna port, then a radiated test method shall be used.

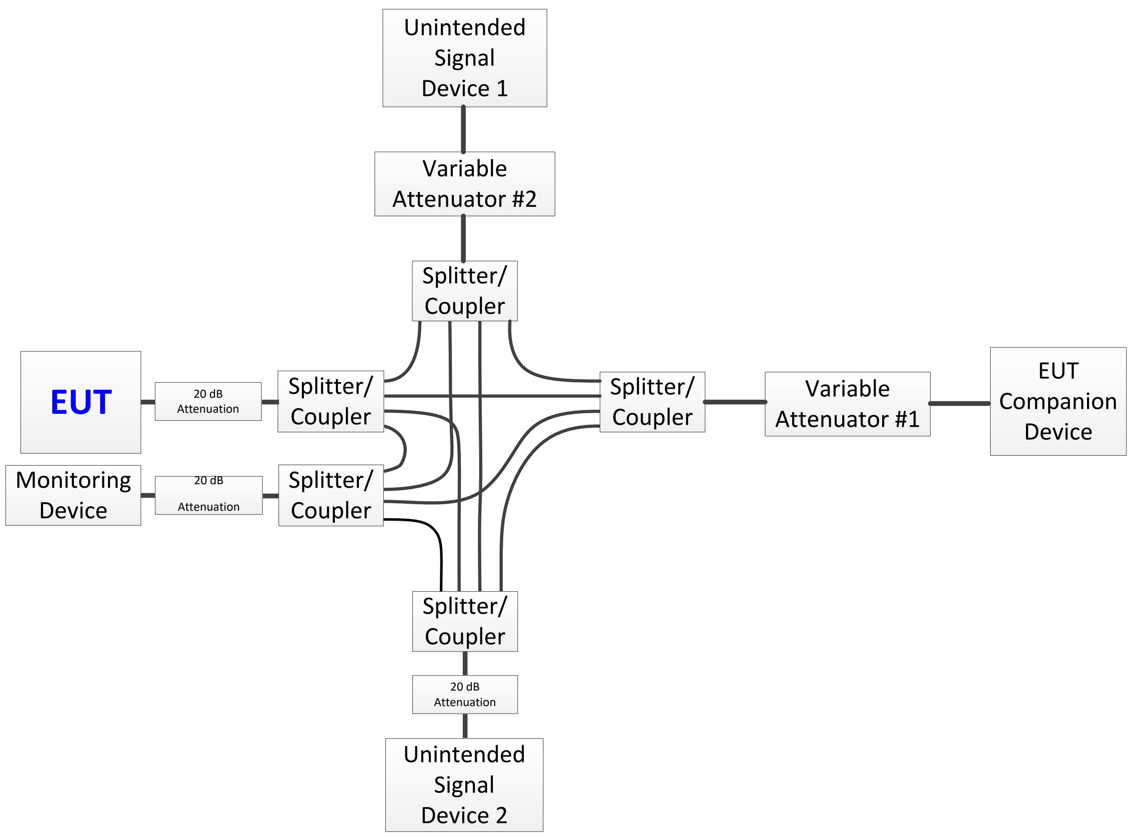

Figure B.1—Basic conducted test setup

The procedures for testing described can be performed manually or using automation.

Conducted test methods can be used for EUTs that use interference management methods such as antenna diversity, beam forming, and MIMO if each antenna port can be accessed and the effect of the method can be simulated or they can be disabled. Otherwise, a radiated test method shall be used.

EUTs that use techniques such as antenna diversity, MIMO, beam forming, and other interference management methods can use conducted test methods where the efficacy of those methods can be quantified.

B.2 Test setup validation

B.2.1 General

See 6.2.1 for details.

B.2.2 Test setup noise floor

See 6.2.2 for details.

It is suggested the noise floor is measured with the monitoring device. The monitoring device specifications are given in 5.8.

B.2.3 RF propagation channel

See 6.2.3 for details.

Path loss with a conducted test is typically measured by placing a spectrum analyzer or other receiving instrument at the point at which the EUT is connected. The loss between each signal source and this point shall be measured and reported in the test report.

Care shall be taken when active devices such as amplifiers are in the transmission path. The specified signals levels in the test plan should be correct during the testing. If there is variation over the dynamic range of the test, the variation shall be included in the test report.

Confirm the path losses are within the acceptable limits specified in the test plan.

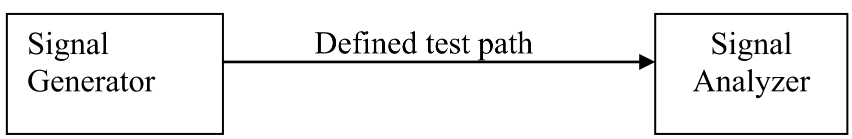

Figure B.2—Setup for conducted path loss verification

B.3 Conducted RF test method

For coexistence testing, conductive communications channels are established between the EUT, the EUT companion device, and the unintended signals. The communication channel is established through a network of power splitters/couplers (see Figure B.1). The communication path loss for each communication channel is adjusted by the attenuation. The technology and parameters of the intended and unintended signals shall be specified in the test plan (see Clause 5). If the EUT and the unintended signal are not expected to interact, the intended signal and unintended signal can be combined with a power combiner and then connected to the EUT.

B.4 Test measurements

B.4.1 Baseline the FWP of the EUT in the test environment

See 6.3.1 for details.

B.4.2 Introduce the unintended signal

B.4.2.1 General

The unintended signals (TX and RX) are connected as shown in Figure B.1.

See 6.3.2.1 for details.

B.4.2.2 Monitoring the unintended signals

See 6.3.2.2 for details.

B.4.3 Test the FWP of the EUT

See 6.3.3.1, 6.3.3.2, and 6.3.3.3 for details.

During coexistence testing, determine the I/U ratio of the EUT where the device goes from being unable to pass the KPI threshold to being able to pass the KPI threshold during coexistence testing.

The I/U ratio can also be expressed as a separation distance between the EUT and the unintended signals. The minimum separation distance between the EUT and the wireless signals can be found theoretically after testing. This is denoted as the minimal separation distance where the EUT can still pass the KPI thresholds determined in the pre-test plan.

The I/U ratio and calculated minimum separation distance for each FWP of the EUT shall be recorded in the test report.

Annex C

(normative)

Multiple chamber test method

C.1 Method overview

In the multiple chamber test method the signals, either or both intended and unintended, are generated by actual equipment, which is placed in a separate chamber to allow control over the signal to which the EUT is exposed. Figure C.1 shows the method implemented with the EUT's companion device in a second chamber and the unintended signal generated by a signal generator. Alternately, a third chamber could contain equipment that generates an undesired signal and it would be combined at the desired level with the intended signal.

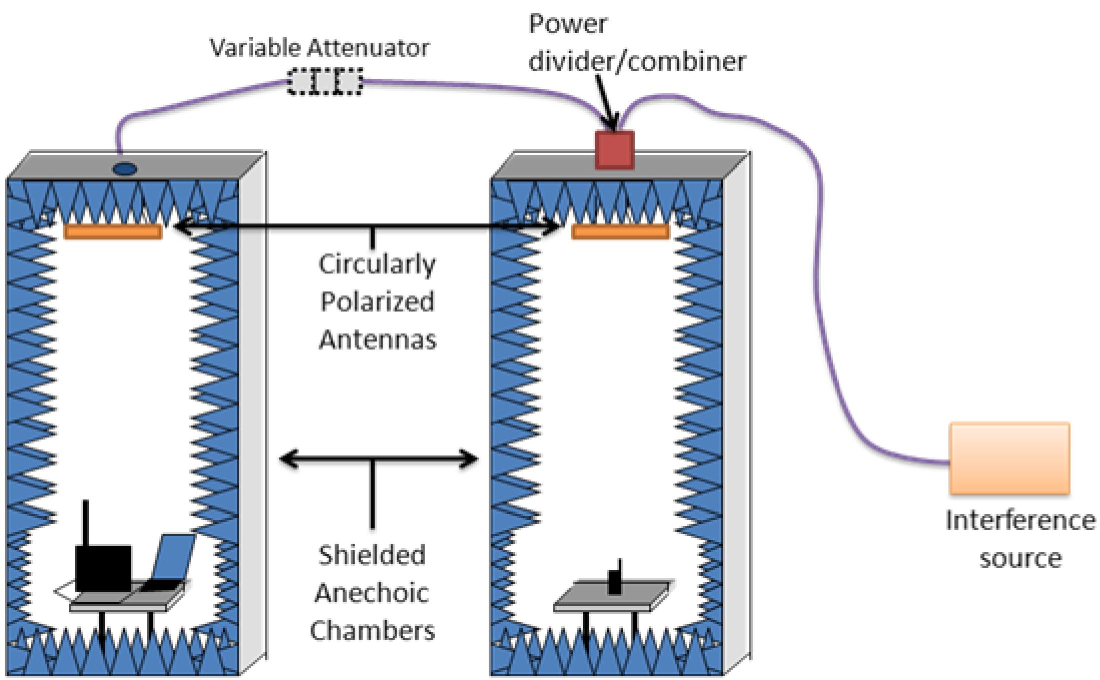

Figure C.1—One-chamber, one-antenna method with a second chamber for the companion device (commonly referred to as the "two-chamber method")

C.2 Test setup

When additional chambers are used to contain the EUT companion device or unintended signal source, this is commonly called the "two-chamber method" (Figure C.1).[49]

Circularly polarized patch antennas can be used to create uniform field levels at the table surfaces that should support the EUT and the EUT companion device. Alternately, linearly polarized antennas can be used but additional efforts shall be made to ensure that testing is performed in the position of maximum sensitivity.

[49] The National Fire Protection Association adopted this basic setup for interference testing in NFPA 1982.

Note that the actual polarization and antenna pattern are not known for many EUTs, so the test procedure should either 1) first determine the orientation that maximizes the power in the RF channel between the EUT and the connected wireless node, or 2) include testing with multiple orientations of the EUT and connected wireless node.

C.3 Test setup validation

C.3.1 General

See 6.2.1 for details.

C.3.2 Ambient noise floor

See 6.2.2 for details.

C.3.3 RF propagation channel

This subclause describes the process for setting the channel path loss between the two reference planes of the connected anechoic chambers in the two-chamber test method. Figure C.2 depicts the setup for a generic path loss measurement. Figure C.3 depicts the setup for the path loss measurement of the path loss between chambers.

The intended signal level shall be reported (typically in dBm) in the test report and experimentally verified during testing. To reduce the number of test runs, it is suggested to test for a reasonable worst-case scenario when selecting the intended signal level. The intended signal level can be related to the operational distance between the EUT and its companion device (e.g., lower signal level corresponds to greater distance.)

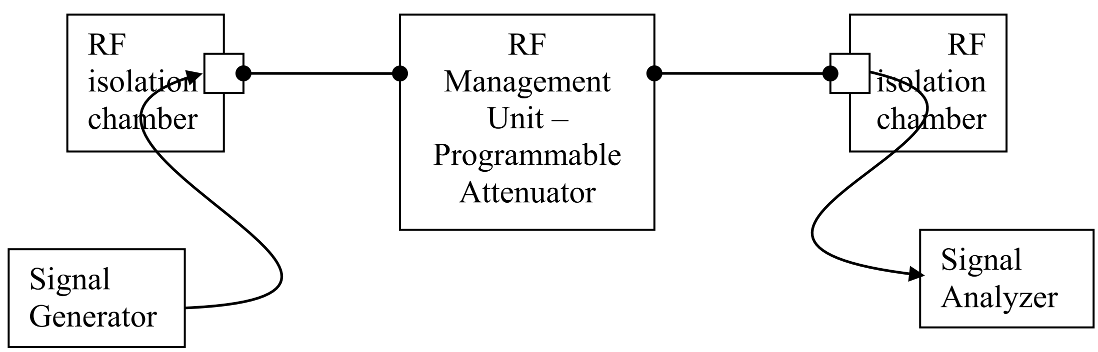

Figure C.2—A generic setup for path loss measurement

The steps for a generic setup for path loss measurement are as follows:

a) The EUT and the EUT companion device are placed on non-conductive tables at equal distance from the circularly polarized antennas, as shown in Figure C.1.

b) Measure and record the signal loss from cables going between the EUT and the EUT companion device.

c) Connect calibration antennas in place of the EUT and the EUT companion device and measure total path loss with the variable attenuator set to 0 dB. The path loss between the location of the EUT and the location of the EUT companion device can then be obtained using the following equation.

Path Loss, 0 dB Atten. = Measured Path Loss - Cable Path Loss + 2 $\times$ Calibration Antenna Gain

d) Set the variable attenuation to achieve a desired channel path loss between the two wireless nodes. The desired channel path loss shall be specified in the test plan (see Clause 5).

Channel Path Loss = Path Loss, 0 dB Atten. + Variable Attenuation

e) Place the EUT in one chamber and its base station or remote connection node in the other chamber and verify that a connection can be established between the two wireless nodes.

If time delay, phase, or similar parameters have the potential to impact the test results, they shall be measured and adequately controlled to ensure test repeatability (see Clause 8). When parameters such as these are important to test repeatability, their values shall be recorded and reported in the test report. If special measures are necessary to maintain them during the test, these measures shall also be described in the test report.

See 6.2.3 for details.

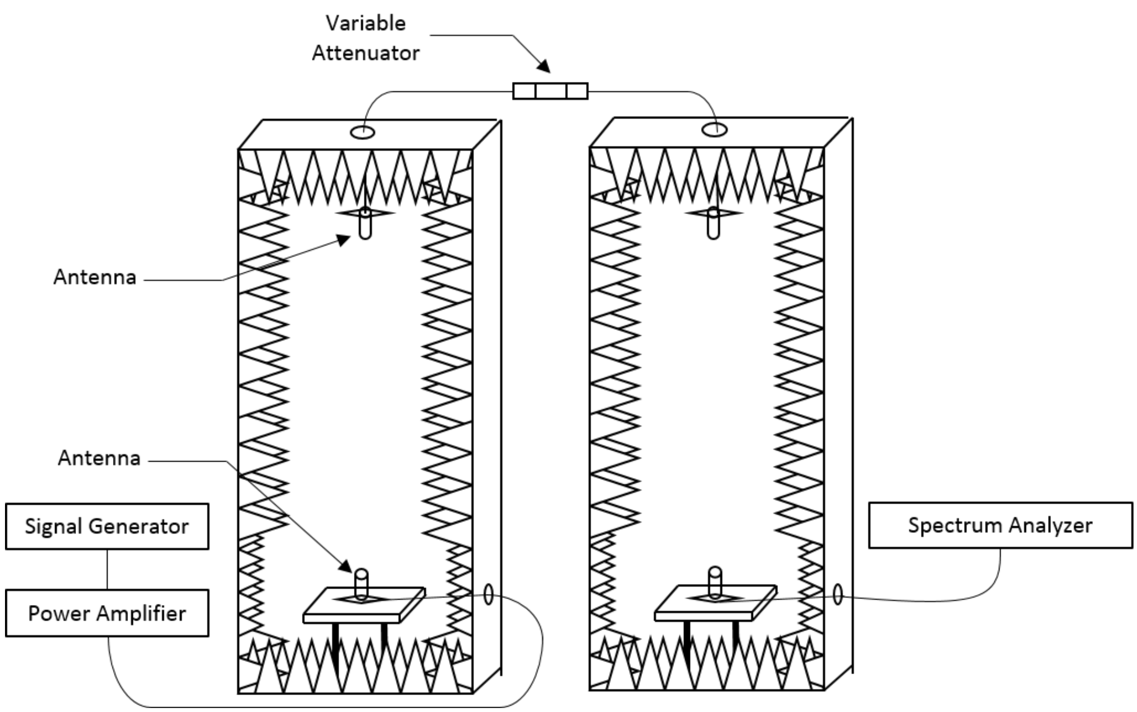

Figure C.3—Setup for path loss measurement between two anechoic chambers

C.3.4 Verification of the unintended signal

The interference signal is introduced into the communication channel via connection to the power combiner/divider that also connects the EUT and the EUT companion device chambers. The characteristics of the unintended signals will depend on the intended environment of deployment.

C.4 Test method

This subclause provides the test method to be used.

C.4.1 Baseline the FWP of the EUT in the test environment

See 6.3.1 for details.

C.4.2 Introduce the unintended signals

The unintended signals (TX and RX) are coupled into the intended signal of the EUT.

See 6.3.2.1 for details.

C.4.3 Monitoring the unintended signals

See 6.3.2.2 for details.

C.4.4 Test the FWP of the EUT

See 6.3.3.1, 6.3.3.2, and 6.3.3.3 for details.

During coexistence testing, determine the I/U ratio of the EUT where the device goes from being unable to pass the KPI threshold to being able to pass the KPI threshold during coexistence testing.

The I/U ratio can also be expressed as a separation distance between the EUT and the unintended signals. The minimum separation distance between the EUT and the wireless signals can be found theoretically after testing. This is denoted as the minimal separation distance where the EUT can still pass the KPI thresholds determined in the pre-test plan.

The I/U ratio and calculated minimum separation distance for each FWP of the EUT shall be recorded in the test report.

Annex D

(normative)

Radiated anechoic chamber (RAC) test method

D.1 Test setup

The radiated anechoic chamber (RAC) method tests the EUT in a radiated test environment within a semi-anechoic or fully anechoic chamber. The purpose of the chamber is to ensure that the environment does not decrease the repeatability of the test results. The basic test setup is shown in Figure D.1.

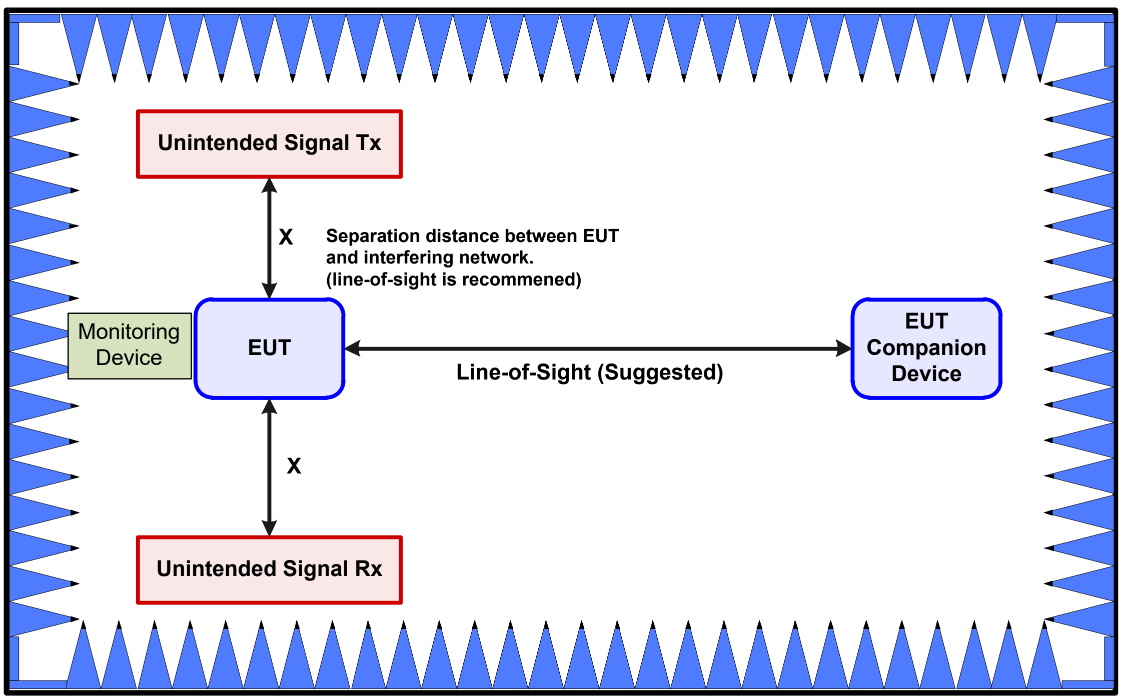

Figure D.1—Setup for the RAC method

It is recommended that the EUT and EUT companion device are placed on non-conductive tables with a height of 1 m. The unintended signals sources and the monitoring device are also placed on non-conductive tables with a height of 1 m.

D.2 Test setup validation

D.2.1 General

See 6.2.1 for details.

D.2.2 Ambient noise floor

See 6.2.2 for details.

D.2.3 RF propagation channel

See 6.2.3 for details.

D.3 Test method

D.3.1 Baseline the FWP of the EUT in the test environment

See 6.3.1 for details.

D.3.2 Introduce the unintended signal

D.3.2.1 General

The unintended signals (TX and RX) are placed on non-conductive tables at equal distance from the EUT.

See 6.3.2.1 for details.

D.3.2.2 Monitoring the unintended signals

See 6.3.2.2 for details.

D.3.3 Test the FWP of the EUT

See 6.3.3.1, 6.3.3.2, and 6.3.3.3 for details.

During coexistence testing, determine the I/U ratio of the EUT where the device goes from being unable to pass the KPI threshold to being able to pass the KPI threshold during coexistence testing.

The I/U ratio can also be expressed as a separation distance between the EUT and the unintended signals. The minimum separation distance between the EUT and the wireless signals can be found theoretically after testing. This is denoted as the minimal separation distance where the EUT can still pass the KPI thresholds determined in the pre-test plan.

The I/U ratio and calculated minimum separation distance for each FWP of the EUT shall be recorded in the test report.

Annex E

(normative)

Radiated open environment (ROE) test method

E.1 Test setup

The ROE method tests the EUT and the EUT companion device in an open environment using a radiated test method without using an anechoic chamber. The test setup is shown in Figure E.1. The ROE method is meant to be able to test any wireless device. The ROE method is versatile to allow the EUT and the EUT companion device to be deployed in a line-of-sight (LOS) or a non-line-of-sight (NLOS) environment, depending on the wireless technology and its typical deployment environment.

NOTE—When performing testing in an open laboratory, an FCC Experimental license might be required under some circumstances.[50]

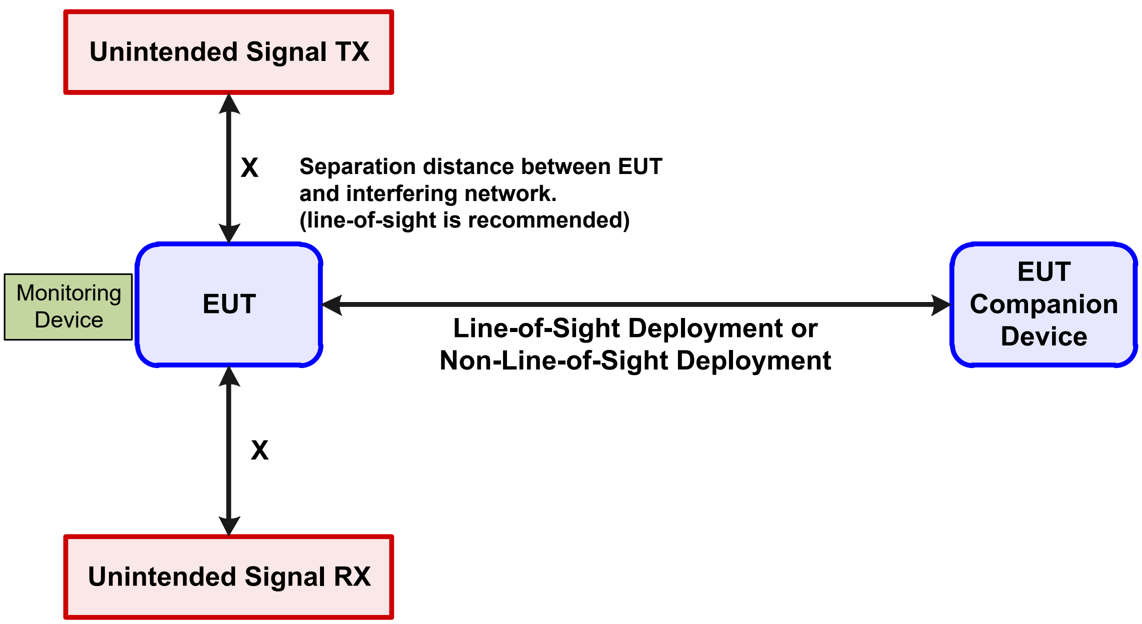

Figure E.1—Setup for the ROE method

E.2 Test setup validation

E.2.1 General

See 6.2.1 for details.

E.2.2 Ambient noise floor

See 6.2.2 for details.

[50] See FCC OET Experimental License Site for additional information at 47 Code of Federal Regulations Part 5 rules or FCC Experimental Licensing System: https://apps.fcc.gov/oetcf/els/index.cfm.

E.2.3 RF propagation channel

See 6.2.3 for details.

E.3 Test method

E.3.1 Baseline the FWP of the EUT in the test environment

See 6.3.1 for details.

E.3.2 Introduce the unintended signal

E.3.2.1 General

The unintended signals (TX and RX) are placed on non-conductive tables at equal distance from the EUT.

See 6.3.2.1 for details.

E.3.2.2 Monitoring the unintended signals

See 6.3.2.2 for details.

E.3.3 Test the FWP of the EUT

See 6.3.3.1, 6.3.3.2, and 6.3.3.3 for details.

During coexistence testing, determine the I/U ratio of the EUT where the device goes from being unable to pass the KPI threshold to being able to pass the KPI threshold during coexistence testing.

The I/U ratio can also be expressed as a separation distance between the EUT and the unintended signals. The minimum separation distance between the EUT and the wireless signals can be found theoretically after testing. This is denoted as the minimal separation distance where the EUT can still pass the KPI thresholds determined in the pre-test plan.

The I/U ratio and calculated minimum separation distance for each FWP of the EUT shall be recorded in the test report.

E.4 Repeatability and reproducibility

Repeatability and reproducibility of the ROE testing method are essential to the validity of the test results. They are achieved by maintaining constant levels of RSS measured next to the EUT device and its companion. The measured strength should be maintained during test repeats, regardless of the testing environment.

Power parameters are as follows:

a) RSS of the EUT at the companion device

b) Interference signal power (average and peak) measured at the EUT

c) Interference signal power (average and peak) measured at the EUT companion device

Annex F

(informative)

Rationale for particular clauses and subclauses

F.1 Overview

This annex provides rationale for the material in the clauses and subclauses of this standard. It is organized by clause number with explanatory material for each clause being provided in the appropriate clause of this annex.

F.2 Clause 4 rationale

The coexistence testing process used in this standard takes a risk based approach. When consequences are less, it is appropriate to do more limited coexistence testing. As the consequences rise in their potential severity the tier of testing required also increases, in order to more fully explore the device's ability to operate reliably in its intended use environment. The standard establishes three tiers of testing with Tier 1 being used for functions where the consequences of failure are most severe. Tier 2 is an intermediate level. Tier 3 is a limited level of testing for use where the consequences of interference are less.

F.3 Clause 5 rationale

F.3.1 Subclause 5.1

The functionality to be evaluated must be established. Not all functions are equally important. The operational reliability of some functions is very important or even critical. However, other functionality might be only for convenience or be of relatively little importance. An early step in planning the evaluation is to identify the functionality to be evaluated. Then it must be determined how that functionality will be monitored and what will be considered a failure.

The RF bands, operational frequency range, channels, and protocols used by the EUT are the next variable to identify in the planning process. Some devices support a number of RF bands and can use a number of modulations, encoding methods, and protocols. Other devices are relatively simple, only using a single RF protocol on a single channel. The RF bands, operational modes, modulation and coding states (MCS), RF protocols, and the purpose they serve must be understood and reflected in the plan of evaluation.

F.3.2 Subclause 5.3.1

For some organizations, particularly hospitals, airports, and other organizations, planning should include the normal operating environment and foreseeable emergency scenarios. In a natural disaster or other emergency situation, the EM environment can be very different from the normal day-to-day environment. For example, police, fire, and other first responders might be in the facility; media; a large number of friends and family, or visitors; and even military might all be in the facility and using their own devices. The resulting EM environment can be predicted but often will not be just an extrapolation of the typical environment. For facilities where emergency planning is important, it is important to test for coexistence under the EM conditions anticipated during an emergency.

When testing for emergency conditions and other infrequent scenarios it might not be desirable or even possible to use the same criteria and performance indicators as are used for the typical environment. The use of systems changes during an emergency; priorities and expectations of performance also change. It can be appropriate to have one set of performance expectations for typical operation and a different set of expectations for unusual situations.

F.3.3 Subclause 5.3.2

In subclause 5.3.2 direction is given to confirm that the signal quality, as well as signal amplitude, are at levels specified in the test plan. Error vector magnitude (EVM) or similar measures are commonly used to quantify the signal quality. Degradation of signal quality can have a significant impact on coexistence and is a separate variable from the intended signal amplitude.

The minimum field strength that causes interference or degradation in the data rate, e.g., causes the EUT to change to a different modulation or coding scheme, is the EUT's interference threshold. There will be multiple interference thresholds, based on the frequency relationship between the channel used by the EUT and the unintended signal. Typically the EUT will be most sensitive to co-channel interference and, therefore, the co-channel interference threshold will be the EUT's area of maximum susceptibility. In most cases, the interference threshold will increase as the frequency separation between the access channel and the unintended signal increases.

F.3.4 Subclause 5.5.1

Three of the four different test methods shown in Table 1 use a different radiated test environment: coupled anechoic chambers (Annex C), a single anechoic chamber (Annex D), and an open environment (Annex E). These three radiated test environments are intended to give the end-user a variety of options when planning for a coexistence test. Included in these three methods are the use of formal anechoic chambers or open area test sites (OATS). Both of these types of facilities have formal definitions in standards (e.g., ANSI C63.4 [B5]). Here, we intentionally avoid limiting coexistence testing to these types of formally defined facilities. This is done for two reasons.

First, the nature of coexistence testing is such that there could be instances where NLOS conditions are necessary to determine if the EUT is capable of maintaining its FWP. The ROE method discussed in Annex E is designed for this purpose, but other environments may be modified to replicate a particular deployment environment of interest.

Second, those writing this document acknowledge the desire for a quick but reasonable coexistence test. In these situations, a formal test facility could not be available or necessary given the desired level of rigor. Situations that might fall into this category are 1) proof-of-concept testing where an EUT manufacturer may want a quick check of how their device may perform in a given environment or 2) formal coexistence testing where the EUT manufacturer already has test equipment described in Annex B through Annex E.

Regardless of the test method used during coexistence testing, it is important to ensure that measurement repeatability and reproducibility are achieved to gain confidence that the correct test method was selected. Within each test method, attention was given to ensuring that when properly executed, the method is capable of yielding consistent results. Attention must be given to precise measurement equipment setup (e.g., understand the impact of MU), environment setup regarding intended and unintended signals (e.g., understand proper calibration procedures), and measurement accuracy of KPIs (e.g., understand the limitations of the measurement method that is used).

F.3.5 Subclause 5.5.2

MIMO, in the most general sense, is a technique that uses multiple antennas or transceivers and advanced digital signal processing to increase data rates, improve link quality, reduce sensitivity to interference, and increase network capacity. MIMO features can be implemented in a variety of ways. All methods use antenna diversity and spatial multiplexing to achieve their objectives. From a reliability perspective, the primary contribution of MIMO is to lower the probability of transmission error and, in doing so, improve the reliability of the transmission. Spatial multiplexing increases the data rate by sending multiple data streams over different antennas simultaneously. In most implementations, units supporting MIMO features have multiple antennas and sometimes use them as an antenna array. Two separately coded versions of the same data are sent to each of the transmit antennas. This provides for antenna diversity. The receiver chooses the antenna that is the most interference free and has the best signal quality. Alternatively, advanced signal processing can be used to combine both received signals and improve the effective SNR. If more than one antenna has acceptable signal conditions, then multiple data streams can be sent, multiplying the data rate.

Multi-RAT is increasingly common for devices to be able to use more than one RAT. An example is a device that is equipped to connect to either the Wi-Fi or cellular network. When a device supports multiple RATs, it becomes possible for FWP to be maintained by switching from one RAT, when interference occurs, to another. However, the ability to do this and its effective implementation can be two different things. Therefore, if an EUT is represented as being able to maintain FWP by switching between RATs, the effectiveness of that switching shall be documented.

F.3.6 Subclause 5.6

This subclause specifies the settings for the intended transmission to the EUT from the device or system it is intended to communicate with.

F.3.7 Subclause 5.6.2

Signal amplitude and signal quality are independent variables that affect the sensitivity of an EUT to an unintended signal. As signal quality degrades due to reflections and other multipath phenomena, jitter, or other signal impairments, sensitivity to an unintended signal will generally increase. The result is that for the same intended signal amplitude the sensitivity to unintended signals will typically vary based on the quality of the intended signal. Therefore, it is necessary to monitor both signal amplitude and signal quality and report them in the test report. Failure to do so has the potential to result in large test-to-test or lab-to-lab variation in test results.

F.3.8 Subclause 5.6.3

In subclause 5.6.3 direction is given to set the EUT's firmware settings on the maximum allowable bandwidth of operation (greatest number of channels), for both transmit and receive. This makes the testing faster because these settings will typically be the most sensitive to interference.

F.3.9 Subclause 5.7

LTE and other protocols can be implemented as either FDD or TDD. However, even in FDD mode transmissions are typically not continuous and so a TDD is often a better unintended test signal. The characteristics of LTE or other RF protocols in the band of interest and adjacent bands should be considered when planning a test. When LTE or other RF protocols will be configured as FDD, consideration should be given to testing with both FDD and TDD signals.

F.4 Clause 6 rationale

F.4.1 Subclause 6.2.2

Assuring that the ambient noise level is less than the receiver sensitivity of the EUT minus the SNR required to demodulate the intended signal, the intended signals can be measured in the receiver channel of the EUT without being impacted by any external EM environment in the test setup. In the more variable radiative open air environmental test method, ambient noise can become a significant source of unintended signals. Also in this case, the ambient environment can become the unintended signals and must be documented and treated as such. In this case the open air test can become an in situ test. Ambient noise floor measurement techniques are further described for each test setup in their corresponding annex.

F.5 Clause 7 rationale

F.5.1 Subclause 7.1

Network administrators can choose protocols that require acknowledgement of transmissions and when using these protocols failed packets are retransmitted. If coexistence testing is performed using a protocol that requires acknowledgements, then the results are likely to be worse if a network uses a protocol that does not require positive acknowledgement. Conversely, if coexistence testing is performed without positive acknowledgement of reception then the performance is likely to be better when operating on a network that does require positive acknowledgement.

F.5.2 Subclause 7.2

The distance between devices has a tremendous impact on the path loss and hence the LoC. Their position relative to each other also can have a dramatic impact on the LoC. When devices that are intended to communicate are placed and oriented for maximum coupling efficiency, the potential for interference is minimized because the intended signal is maximized for the situation. Conversely, when the distance or orientation of devices that are intended to communicate is less sub-optimal, the LoC is greatly increased.

Antenna characteristics can have a dramatic impact on the LoC. Antennas have patterns, typically with significant differences in distribution of their EM energy. In a mobile environment, devices seldom are oriented for maximum coupling efficiency, as illustrated in Figure F.1. It is common that their relative orientation is completely random. However, with techniques like beam forming, the coupling efficiency can be improved by steering the signal toward the intended recipient.

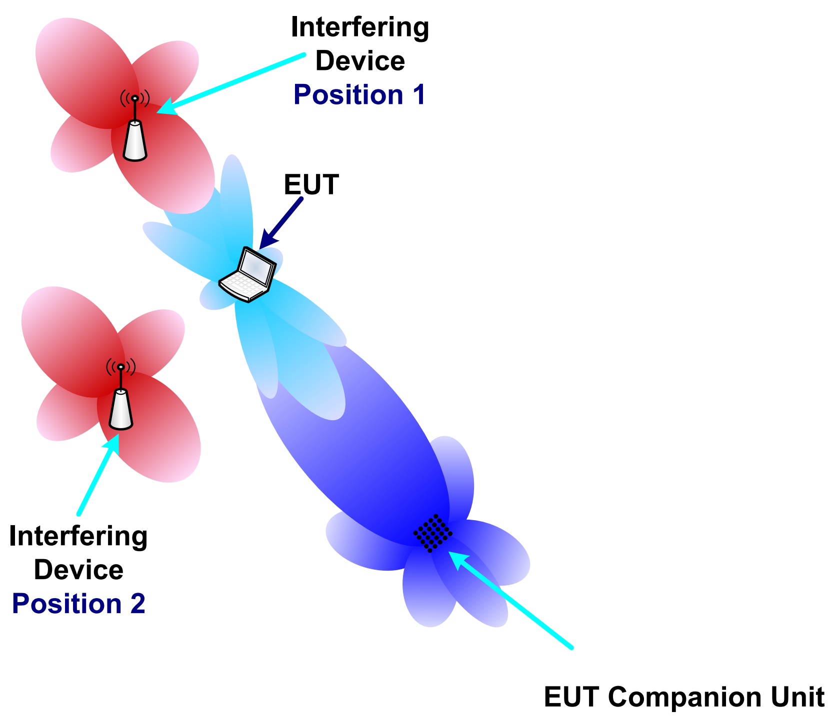

Figure F.1—For mobile devices the relative placement of devices and their antenna patterns tends to be random, which significantly impacts the outcome

For some devices and systems, particularly fixed installations, these variables can be optimized and will remain fixed. With mobile devices this is often not true and the relative position and orientation must be assumed to be random or to vary over a range of possibilities. Increasingly, antenna techniques like antenna diversity and beam forming are being used to support optimization of signal delivery for mobile environments. These and other antenna-related techniques have significant impact on the probability of interference.

F.5.3 Subclause 7.2

The method used to predict field performance depends on the purpose of the analysis and the information available. Information about the EM field environments in which a device will operate is used, with the test data on coexistence performance of the EUT, to predict the LoC. The quality of the estimate will depend on the quality of the environmental and test data used.

Use of field data on EM environments assumes that the EM fields in the future will be similar to those measured. At times it is better to calculate the EM environments that the devices expected to be operating in the future will create and use the resulting estimations of the future EM fields to evaluate LoC.

For less complicated devices, a probability analysis can be performed using parametric test results obtained for the device. Using the EUT's co-channel ToI, the probability of the EUT encountering a co-channel signal above its ToI can be estimated. Then the ToI for a signal in the immediate adjacent channel is used to estimate the probability of encountering a signal above its ToI for a signal in its immediately adjacent channel. If the ToI for more distant adjacent channels or to adjacent band signals is large enough to materially contribute to the LoC, contributing more than 1% to the final probability of interference, those shall be included in the calculation. The result is an estimation of the LoC. This is the cumulative vector sum of the probabilities of encountering a co-channel, adjacent channel, and adjacent band signals that exceed the EUT's ToI.

For EUTs that utilize multiple MCS, the probability of falling below its peak performance can be of interest. If the EUT has multiple MCS and performance levels, additional probabilities can be reported. In order to perform these calculations, the testing must provide the Threshold of Peak Performance (ToPP), which is the level at which an undesired signal forces the EUT to use a lower MCS state and fall below its peak performance. The testing shall also provide the ToI and provide the ToI for additional MCS state changes.

The analysis begins with a specification of the supported levels of signal strength and signal quality for the intended signal. The LoC will be performed based on the EUT receiving the specified minimum amplitude of the intended signal. For efficiency, the anticipated signal strength at the manufacturer's stated maximum recommended separation distance can be used. However, for a more rigorous analysis, the LoC for multiple signal strengths can be calculated and combined for a summary LoC.

The next step is to determine the confidence level for the analysis. A confidence of 95% is typically used but for some purposes 99% confidence level or higher is appropriate.

When EM field data are used, the analysis is significantly simplified because many of the variables that influence the field strength that exposes the EUT are in place and the sampling will record their cumulative effect. Working from the specifications of devices to estimate the EM environments they collectively will create is more complex because the influence of these variables must be properly treated. These variables are often independent but some are mutually dependent and interactive.

When estimating the LoC using EM field data the cumulative probability of encountering a signal co-channel or in any adjacent channel that exceeds the ToI of the EUT is calculated and reported as the estimated LoC.

F.6 Clause 8 rationale

Coexistence testing is often binary; a communication or operation is either successful or not. Further, the relationship of some parameters to the communication or operational success or failure will often be unknown. For example, it will often not be known how increasing or decreasing the channel utilization or small changes in the frequency of the unintended signal will impact the KPI being monitored. However, it is possible to quantify the variability of test parameters and this shall be done. When KPIs are used that allow quantifying the change in intended and unintended signal parameters to the final outcome of the test, then a combined uncertainty should be estimated.

The reference point for evaluating uncertainty shall be the input to the EUT receiver from its antenna, to include factors such as polarization, etc. This is the point at which the intended and unintended signal are brought together, and from this point, their relationship is generally fixed. At the input to the EUT receiver, factors such as channel loss and coupling efficiency between the transmit antenna for the intended and unintended antennas and that of the EUT can and should be included in the estimation.

When testing for a binary outcome, whether an operation succeeds or fails, uncertainty in the test results can be large because it often cannot be known if a device just passed or failed and if small variations in the test might have changed the result. To improve the certainty of the outcome, it is recommended that tests should include an overstress. If an EUT passes the test and then passes the overstress test, the certainty in the test outcome is increased. However, if a EUT passes a test but fails the overstress, then there is greater uncertainty that on retest the EUT would pass again. Potentially the EUT is on the threshold and small differences in the test can move it from passing to failing. Including an overstress in the test plan will improve the certainty of the test outcome by creating an indeterminate region between passing and failing. When it is important to only have passing and failing result, the three categories can be interpreted as failing, passing but close to threshold, and passing with margin.

F.7 Annex A rationale

F.7.1 Subclause A.2.2.1

In A.2.2.1 IEEE 802.11n is specified as the unintended signal. The three most prevalent RATs in the 2.4 GHz ISM band are Wi-Fi, Bluetooth, and ZigBee®[51]. Research has shown that Wi-Fi presents the highest risk of interference to Bluetooth devices. Therefore, testing Bluetooth using either Bluetooth or ZigBee signals for the unintended signal is not required for a Tier 3 evaluation.[52]

It is recognized that there are other, often proprietary, RF protocols used in this band. However, these have not been found to be a significant or different source of interference that is not adequately covered by this subclause. It is recommended that proprietary RF protocols that are identified to operate in the intended environment of the EUT should be considered when testing for coexistence at Tier 2 and Tier 3. Selection and testing with proprietary RF protocols are not covered in this annex.

F.7.2 Subclause A.2.3.2

This is the derivation of an LTE signal level recommended in Annex A.

The maximum allowed mobile transmitter power is +33 dBm (EIRP) (47 CFR 25.50 h (2) [B2]).

[51] ZigBee is a registered trademark of the ZigBee Alliance.
[52] A Bluetooth piconet network is most susceptible to interference from another Bluetooth transmitter. When a new Bluetooth transmitter is operating in discovery mode to join the piconet it is most sensitive to interference from another Bluetooth system. Research has reported that this scenario can produce a PER of up to 1.5%, which some characterize as negligible.

From the Friss narrowband free space propagation approximate attenuation L is specified by the following equation (Moongilan [B35]):

L = 20 $\log_{10}$ (Distance in meters) + 20 $\log_{10}$ (Frequency in MHz) – 27.56 dB.

A typical base station receiver sensitivity level is –93.5 dBm (ETSI TS 136 104 V12.5.0 (2014-10) [B18]).

The highest free space attenuation can be calculated from the above sensitivity level and maximum allowed power as:

–93.5–33.0 = 126.5 dB

The worst case largest distance that can be covered using 33 dBm power is:

20 log (Distance in meters) = 123.5 dB - 20 $\log_{10}$ (2600 MHz) + 27.56 dB
= 19.4 km

If 10 km is assumed to be typical coverage distance, then the attenuation for 10 km is = 120.74 dB.

Therefore, the required power for 10 km coverage is –93.5 dBm + 120.74 = 27.24 dBm (EIRP).

The Friss narrow band free space loss for 1 m distance at 2.6 GHz = 40.73 dB.

Therefore, the radiated power at 1 m = 27.4 -40.73 = –13.5 dBm.

Therefore, the equivalent maximum transmission power for conducted testing is:

23 dBm - 40 dB = -17 dBm.

F.7.3 Subclause A.2.4

See rationale for A.2.3.2.

F.7.4 Subclause A.3

Subclause A.3 provides guidance for testing Wi-Fi devices operating in the 2.4 GHz ISM band. Interference from Wi-Fi transmission has been reported as the most prevalent source of interference in this band. The influence of ZigBee and Bluetooth on Wi-Fi is negligible in most cases (Shuaib, et al [B45]). Therefore, testing Wi-Fi devices using a ZigBee or Bluetooth signal as the unintended signal is a lower priority and not required for a Tier 1 evaluation. What remains is the potential for wireless interference to Wi-Fi when exposed to Wi-Fi in certain cases. Hence, Wi-Fi is the required unintended signal in this subclause. It is recognized that there are other, often proprietary, RF protocols used in this band. In addition, some higher-power ZigBee and Bluetooth devices are on the market, but these have not been found to be significant or different sources of interference than those already included in the recommended testing for Tier 1. However, these may be worth considering when testing to higher tiers.

The signal amplitude of an unintended Wi-Fi transmitter is specified at 17 dBm for Tier 1, but raised to 20 dBm for Tier 2 and Tier 3. These represent a typical value for Tier 1 and testing for exposure to higher-powered Wi-Fi devices at the higher tiers.

Wi-Fi interoperability and backwards compatibility are not considered to be coexistence issues. However, these are important issues for network operators. Wi-Fi interoperability and backwards compatibility are tested during Wi-Fi certification, and replicating those tests here would be redundant as well as beyond the scope of this standard. The Wi-Fi network's capacity is also not stress tested, such as by adding an additional Wi-Fi client to a Wi-Fi local area network. In the 2.4 and 5.0 GHz bands, Wi-Fi clients connected to a Wi-Fi access point must share the spectrum with other clients; thus, there is an inherent overall network throughput limit on wireless traffic that travels through the Wi-Fi access point.

Tier 3 testing is performed with a single Wi-Fi transmission as the unintended signal. This scenario is commonly encountered in all environments due to the widespread use of Wi-Fi communications.

Tier 2 adds testing with three Wi-Fi transmissions, simulating an enterprise deployment with multiple access points distributed through the facility. In addition, testing for sensitivity to an adjacent band LTE transmission is included.

Tier 1 uses the same test scenarios as Tier 2 but increases the signal power of the LTE unintended signal.

F.7.5 Subclause A.4

Subclause A.4 provides guidance for testing Wi-Fi devices operating in the 5.0 GHz UNII and ISM bands. The testing is similar to that performed for Wi-Fi in the 2.4 GHz ISM band but with changes appropriate for these bands. As for the 2.4 GHz ISM band, Tier 3 testing evaluates a single 802.11 transmission, located either co-channel or adjacent channel, as the unintended transmission. At Tier 1 and Tier 2 testing with multiple 802.11 transmissions, representative of an enterprise deployment is added. In addition, testing includes an in-band LTE transmission.

F.7.6 Subclause A.5

ANSI C63.17-2013 provides the test methods for showing compliance with the UPCS band spectrum etiquette. Compliance with ANSI C63.17 is required by the FCC and is the basis for an equipment grant to operate in the UPCS band by the FCC. However, it is necessary that the performance targets for the device’s FWP and the associated KPIs be related to the spectrum etiquette. For many devices, demonstration of compliance with the LBT and least-interfered-channel requirements is adequate to achieve their performance targets for the equipment's FWP. When this is true and stated in the test plan, compliance with FCC's spectrum etiquette for the UPCS band, as demonstrated through testing to the ANSI C63.17-2013 standard, is considered to be an acceptable basis for a claim of compliance with Tier 3 in this standard. For DECT equipment, compliance with the spectrum etiquette requirements of ANSI C63.17 provide a foundation for coexistence. Tier 1 and Tier 2 add testing for sensitivity to LTE operating in the adjacent band.

Tier 2 requires that the DECT equipment be capable of withstanding an LTE signal at 17 dBm, and Tier 1 requires that it be capable of withstanding an LTE at the maximum power specified in the 3GPP specifications for LTE UE, 23 dBm.

Currently the closest deployed frequency for LTE UE is EARFCN 1199, 1909.9 MHz, which is used for this testing.

Some commonly used KPIs for DECT are the receiver quality parameters specified by ETSI EN 301 406 [B16] and required for CE certification. The following parameters are often specified in DECT test plans:

a) Rx Sensitivity - Test method and limits as specified in Clause 5.3.7.1 of EN 301 406

b) Rx Reference Error Rate – Clause 5.3.7.2 of EN 301 406 [B16]

c) Rx Interference Performance – Clause 5.3.7.3 of EN 301 406 [B16]

d) Rx Blocking (Case 1) – Clause 5.3.7.4 of EN 301 406 [B16]

e) Rx Intermodulation Performance - Clause 5.3.7.6 of EN 301 406 [B16]

F.8 Annex B rationale

Conducted testing requires that the EUT have a connection point either replacing the antenna or in parallel with it or that such a connection point can be added.

Generally conducted testing is faster and more repeatable than other methods because the variables introduced with over-the-air (OTA) methods are eliminated. It is also possible to more easily achieve high signal levels because path loss is far less than with OTA methods.

The signal can be monitored at other points in the setup, as needed to support adequate control of the system and to allow documentation of the test. The conducted test setup in Figure B.1 allows the EUT and unintended signal to sense the common channel used by both wireless networks, emphasizing the importance of a coexistence test, as opposed to a wireless interference test. Variable attenuators are used to change the attenuation of the signal and to decrease VSWR between the wireless networks and the coupling network. It is suggested to use four-way splitters/couplers, terminating connections that are not used on each individual splitter/coupler.

Annex G

(informative)

Glossary

Definitions are from the *IEEE Standards Dictionary Online*[53] unless otherwise noted.

adaptive equipment: Equipment operating in an adaptive mode. (ETSI 300 328 v1.9.1)

adaptive frequency hopping (AFH): A mechanism that allows frequency hopping equipment to adapt to its environment by identifying channels that are being used and excluding them from the list of available channels. (ETSI 300 328 v1.9.1)

adaptive mode: A mechanism by which equipment can adapt to its environment by identifying other transmissions present in the band. (ETSI 300 328 v1.9.1)

adjacent channel: A channel whose frequency band is adjacent to that of another channel, known as the reference channel.

adjacent-channel interference (data transmission): Interference, in a reference channel, caused by the operation of an adjacent channel.

adjacent-channel selectivity and desensitization (receiver performance) (receiver): A measure of the ability to discriminate against a signal at the frequency of the adjacent channel. Desensitization occurs when the level of any off-frequency signal is great enough to alter the usable sensitivity.

band: Range of frequency between two defined limits.

beamforming gain: Additional (antenna) gain realized by using beamforming techniques in smart antenna systems.

NOTE—Beamforming gain as used in the present document, does not include the gain of the antenna assembly. (ETSI 300 328 v1.9.1)

clear channel assessment (CCA): A mechanism used by an equipment to identify other transmissions in the channel. (ETSI 300 328 v1.9.1)

channel: A repeated time and spectrum combination used for communications. In 47CFR15.323(c), the FCC uses the description a "combined time and spectrum window." In this standard, channel and access channel have the same meaning. (ANSI C63.17)

co-channel interference: Interference caused in one communication channel by a transmitter operating in the same channel.

frequency hopping spread spectrum: Spread spectrum technique in which the equipment occupies a number of frequencies in time, each for some period of time, referred to as the dwell time

NOTE—Transmitter and receiver follow the same frequency hop pattern. The frequency range is determined by the lowest and highest hop positions and the bandwidth per hop position. (ETSI 300 328 v1.9.1)

harm: Physical injury or damage to the health of people or animals, or damage to property or the environment. (ISO 14971:2007, 2.2)

[53] *IEEE Standards Dictionary Online* is available at: http://dictionary.ieee.org/.

hazard: Potential source of harm. (ISO 14971:2007, 2.3)

listen before talk (LBT): A mechanism by which equipment first applies CCA before using the channel. (ETSI 300 328 v1.9.1)

operating frequency: nominal frequency at which the equipment can be operated; this is also referred to as the operating center frequency. (ETSI 300 328 v1.9.1)

risk: Combination of the probability of occurrence of harm and the severity of that harm. (ISO 14971:2007, 2.16)

Annex H

(informative)

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