



American National Standard for Evaluation of Wireless Coexistence

C63[®]

USEMCSC C63[®] Committee on Electromagnetic Compatibility –
an ANSI-Accredited Standards Developer

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American National Standards Institute

ANSI/USEMCSC C63.27-2021
(Revision of ANSI C63.27-2017)

STANDARDS

American National Standard for Evaluation of Wireless Coexistence

USEMCSC C63® Committee on Electromagnetic Compatibility

Accredited by the

American National Standards Institute

Secretariat

Institute of Electrical and Electronics Engineers, Inc.

Approved 29 November 2021

American National Standards Institute

C63®

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 radiofrequency environments.

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

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PDF: ISBN 978-1-5044-8637-8 STD25368
Print: ISBN 978-1-5044-8638-5 STDPD25368

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Introduction

This introduction is not part of ANSI/USEMCSC C63.27-2021, 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 electromagnetic compatibility (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. The application of this standard is not limited to the technologies discussed in Annex A. The test process and methods may be used to evaluate any set of technologies or protocols.

This document has been revised to clarify the procedures set forth in the 2017 version. In particular, the testing requirements for each tier of testing have been streamlined, enabling more concise testing. Additional guidance was added to Annex A to address the testing of unlicensed LTE and IEEE 802.11 devices. The guidance surrounding the Likelihood of Coexistence calculation was expanded and is now featured in its own Annex.

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 on the guidance of IEEE Std 1900.2™-2008, *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.

Soon after the first version was released in 2017, Subcommittee 7 formed a new working group to gather feedback from those using the standard and begin working on a revision. During the writing of the 2017 version of the standard, several items were tabled for future work in an effort to get the standard published in a timely manner. Once Subcommittee 7 formed a new working group, these items, along with others could be considered as part of the revised standard.

Acknowledgments

This revision of ANSI/USEMCSC C63.27 is dedicated to the memory of Dr. Vladimir Bazhanov (1951–2019) and Dr. Dheena Moongilan (1949–2019). Both gentlemen made significant contributions to this standard, and to the broader fields of EMC and wireless communications. Their presence, contributions, and personalities on the C63 committees will be dearly missed, and we owe our gratitude for their service.

Dr. Bazhanov served as the SC7 Chair from 2016 until his passing in 2019. His leadership provided essential guidance to the first version of C63.27 as it worked its way through the balloting and publication process. Prior to his service as SC7 Chair, Dr. Bazhanov was an active member of the C63.27 working group and shared his industry perspective with the group. This made the standard stronger and the external community benefited from his work.

Dr. Moongilan was an active member of the C63.27 working group and SC7 for several years. He made distinct contributions to the working group and had a keen eye for the future of communications technology. Dr. Moongilan's ability to identify future trends was an extremely valuable asset within the C63.27 working group and subcommittee as it ensured the work everyone was doing would be relevant for many years.

Both gentlemen did not hesitate to share their humor, friendship, and hospitality with their colleagues. Each was a true expert in his own right. We are all stronger professionals for having spent part of our careers working alongside them.

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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 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall* equals *is required to*).^{6, 7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should* equals *is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may* equals *is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can* equals *is able to*).

1.4 Interference, coexistence, and immunity

Interference, immunity, and coexistence are related concepts.

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

Interference as used in this standard is the degradation in the performance of equipment or transmission channel or a system caused by an electromagnetic disturbance.⁸ Usually, interference refers to unintentional effects of electromagnetic (EM) disturbances in equipment that might or might not be intended to receive RF EM energy. 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, usually in intentional receivers of RF EM energy. Accordingly, wireless coexistence evaluation is performed at the system level to understand the underlying features that can impact coexistence, including the mitigation of interference that is primarily caused by other users of a shared spectrum frequency band.

Immunity to a disturbance is the ability of a device, equipment or system to perform without degradation in the presence of an EM disturbance.⁹ Immunity evaluation checks for degradation due to various forms of EM disturbance (e.g., immunity to electrostatic discharge [ESD], immunity to conducted disturbances induced by RF fields, and immunity to radiated RF EM fields, etc.) and assesses the overall performance degradation of or damage to an equipment. Coexistence evaluation involves assessing the mutual effects of coexisting systems, whereas immunity testing does not. Furthermore, coexistence evaluation is specific to the functional wireless performance of an equipment when using a shared spectrum band with other users. Therefore, the unintended signals used in a wireless coexistence evaluation are determined according to the characteristics (i.e., transmission power, frequency allocation, and channel utilization) of the users of that band and those in adjacent bands that can impact the functional wireless performance of the equipment.

2. Normative references

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

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).¹⁰

3GPP TS 36.101 V14.3.0 (2017-04), 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 14).

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 TIR69:2017, Risk Assessment of Radio-Frequency Wireless Coexistence for Medical Devices and Systems.¹¹

ANSI C63.14-2014, American National Standard Dictionary for Electromagnetic Compatibility (EMC) including Electromagnetic Environmental Effects (E3).¹²

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

⁸ IEC 60050-161:1990, 161-01-06

⁹ IEC 60050-161:1990, 161-01-20

¹⁰ 3GPP publications are available from the 3rd Generation Partnership Project (<https://www.3gpp.org/>).

¹¹ AAMI publications are available from the Association for the Advancement of Medical Instrumentation (<https://www.aami.org/>).

¹² ANSI C63 publications are available from The Institute of Electrical and Electronics Engineers (<https://standards.ieee.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

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.¹³

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.¹⁴

ISO 14971:2019, Medical devices – Application of risk management to medical devices.¹⁵

ISO/IEC 17025:2017, General requirements for the competence of testing and calibration laboratories, third 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, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) – Supplement 1: Propagation of distributions using a Monte Carlo method.

ISO/IEC Guide 98-3:2008/Suppl 2:2011, Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) – Supplement 2: Extension to any number of output quantities.

ISO/TR 24971:2020, Medical devices – Guidance on the application of ISO 14971.

JCGM 100:2008, Evaluation of measurement data – Guide to the expression of uncertainty in measurement.¹⁶

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 standard, the following terms and definitions apply. The *IEEE Standards Dictionary Online*¹⁷ and ANSI C63.14-2014¹⁸ should be consulted for terms not defined in this clause. Unless otherwise noted, the definitions of this clause apply throughout this standard.

¹³ ETSI publications are available from the European Telecommunications Standards Institute (<https://www.etsi.org/>).

¹⁴ IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

¹⁵ ISO publications are available from the International Organization for Standardization (<https://www.iso.org/>) and the American National Standards Institute (<https://www.ansi.org/>).

¹⁶ JCGM publications are available from BIPM (<https://www.bipm.org/en/publications/guides/gum.html>).

¹⁷ *IEEE Standards Dictionary Online* is available at <https://dictionary.ieee.org/>. An IEEE Account is required for access to the dictionary, and one can be created at no charge on the dictionary sign-in page.

¹⁸ Information on references can be found in Clause 2.

3.1 Definitions

channel utilization: The fraction of time a channel is actively used by a system for transmission in a specified observation period.

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 [B38]) (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 [B36]) (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 [B37]) (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 [B24])

EUT companion device: The corresponding wireless node that is wirelessly communicating with the EUT (e.g., of a 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.

intended signal: The wireless communications signal(s) the EUT uses to implement its functional wireless performance.

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

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

test deliverable: The output of a coexistence test per the test plan.

NOTE—For example, if the test plan is designed to determine the acceptable signal loss for reliable EUT operation, then the intended/unintended signal ratio is varied during the test, and the output could become the ratio at which the FWP fails.¹⁹

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
5G	fifth generation

¹⁹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement this standard.

AAMI	Association for the Advancement of Medical Instrumentation
AFH	adaptive frequency hopping
AMC	adaptive modulation and coding
ANSI	American National Standards Institute
ASC	accredited standards committee
CCA	clear channel assessment
CFR	Code of Federal Regulations
CGD	cumulative gain distribution
CSMA/CA	carrier sense multiple access/collision avoidance
CTIA	Cellular Telecommunications & Internet Association
CTS	clear to send
dB	decibel
dBm	decibels referenced to 1 mW
DECT	Digital Enhanced Cordless Telecommunications
DOP	delay outage probability
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: $g_{\text{eff}}(f) [\text{dB}] = \text{EIRP}(f) [\text{dBm}] - \text{TRP}(f) [\text{dBm}]$
GUM	Guide to the Expression of Uncertainty in Measurement
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IFS	inter-frame space
IM	intermodulation
IRIL	input-referenced interference level
ISM	industrial, scientific, medical
I/U	intended-to-unintended signal ratio
ITU	international telecommunication union
KPI	key performance indicator
LAA	license assisted access

LBT	listen-before-talk
LIC	least interfered channel
LTE	long term evolution ²⁰
LoC	likelihood of coexistence
LOS	line-of-sight
LUT	look-up table
MAC	media access control
MCS	modulation and coding schemes
MIMO	multiple-input, multiple-output
ML	machine learning
MU	measurement uncertainty
NLOS	non-line-of-sight
OBE	out-of-band emissions
OTA	over-the-air
PER	packet error rate
QAM	quadrature amplitude modulation
QoS	quality of service
RAC	radiated anechoic chamber
RAT	radio access technology
RF	radio frequency
RFID	radio frequency identification
ROE	radiated open environment
RSS	received signal strength
RTS	request to send
RX	receive or receiver
SNR	signal-to-noise ratio
ToI	threshold of interference
ToPP	threshold of peak performance
ToV	threshold of visibility
TRP	total radiated power
TX	transmit or transmitter
UE	user equipment
UNII	Unlicensed National Information Infrastructure
USEMCSC	United States Electromagnetic Compatibility Corporation Standards Committee
VSWR	voltage standing wave ratio
Wi-Fi	wireless fidelity
WLAN	wireless local area network
WPAN	wireless personal area network
Z ₀	free space impedance ($Z_0 = 377 \Omega$)

²⁰ LTE is a trademark of European Telecommunications Standards Institute (ETSI).

4. Process overview

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

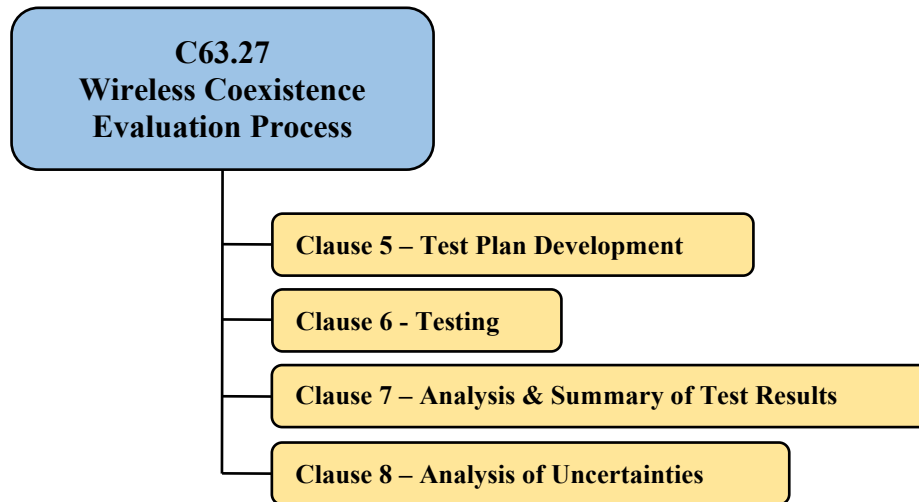


Figure 1—Evaluation process overview

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 path losses between communicating EUT nodes and the minimum recommended path losses to sources of unintended signals that has the potential to cause loss of EUT FWP. The path losses can be exchanged with separation distances using a relevant radio propagation model.²¹
- *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 uncertainty 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.

²¹ Throughout this document, the word “distance” is used in a variety of contexts. In most cases, signal levels can be translated into the distance between the transmitter and receiver (e.g., between the EUT and the unintended signal transmitter). The use of the term distance is typically preferred by the medical device community, in part because distances can be included in end-user documentation. For example, a user manual might instruct the user to stay 1 m away from a wireless access point. In this example, the use of distance is more meaningful than instructing the user to stay far enough away from an access point such that the signal levels don’t exceed a threshold.

- *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) distance, 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.²²

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 for monitoring 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 for monitoring 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 14971:2019 and ISO/TR 24971:2020
- IEC TR 80001-2-2:2012
- AAMI TIR69:2017

²² 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.

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.²³

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 test plan 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.²⁴

The intended EM environment could further be illustrated by performing a spectrum occupancy measurement survey of an exemplary EUT use environment. The outcome of this survey should clarify the distribution of channel occupancy observations during the survey period and can be helpful in estimating LoC.

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.

²³ 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 repeated several times to confirm that the same result is obtained, or the transmitting units controlled to prevent automatic changes of the transmitted signal.

²⁴ Microwave ovens are an example of other emitters.

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 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 EUT for a duration that permits adequate assessment of the functionality. 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 and test report.²⁵ 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.²⁶ KPI thresholds are defined to be the failure criteria and the levels of degradation in performance that differentiate between acceptable and unacceptable performance.²⁷

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.²⁸

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 and test report. The use of each RF protocol and frequency band

²⁵ 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.

²⁶ 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.

²⁷ 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.

²⁸ With voice signals, it is possible to develop thresholds based on established speech recognition levels, as is done in ANSI C63.19-2019 [B10], 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 [B14] defines threshold of visibility (ToV) as the level at which there are 2.5 data segment errors per second.

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.²⁹

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.³⁰ Examples include: adaptive frequency hopping (AFH), clear channel assessment (CCA), listen-before-talk (LBT), and least-interfered-channel (LIC) selection.

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, some regulators may require an experimental license to operate on specific frequencies.^{31, 32}

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 on which frequencies/channels the EUT shall be tested 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 standard 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 when the consequences of unacceptable performance are most severe or when 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 is 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.

²⁹ 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.

³⁰ 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.

³¹ Notes in text, tables, and figures of a standard are given for information only and do not contain requirements needed to implement the standard, including this standard.

³² For example, 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>.

- 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.

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 this 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 and LTE-LAA devices operating in the 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 specified 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 on 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 ROE testing to be 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 functionality³³

The EUT could have special functionality to enhance its capabilities, such as multiple-input, multiple-output (MIMO), beamforming, 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. When testing these special functionalities, ROE test methods that implement NLOS and LOS are preferred over the conducted method. Conducted methods can be implemented; however, phasing of the two or more antennas with interference and signals can become complex. It can also be difficult to implement conducted testing that captures certain special features like antenna beamforming. 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 recommended 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.

³³ Many of the features described in this clause are also part of a larger feature set found in “5G” or other emerging wireless communications systems. At the time of publication of this standard, 5G technologies were not in widespread use; therefore, specific guidance on testing with them is not provided in Annex A. However, nothing prevents the framework set forth in this standard from being used to test 5G or emerging systems in the future. This applies to lower-frequency systems (sub 6 GHz) as well as higher-frequency systems (e.g., mm-Wave).

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.³⁴

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 recommended that the maximum allowable bandwidth of operation for the transmit and receive operations 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.

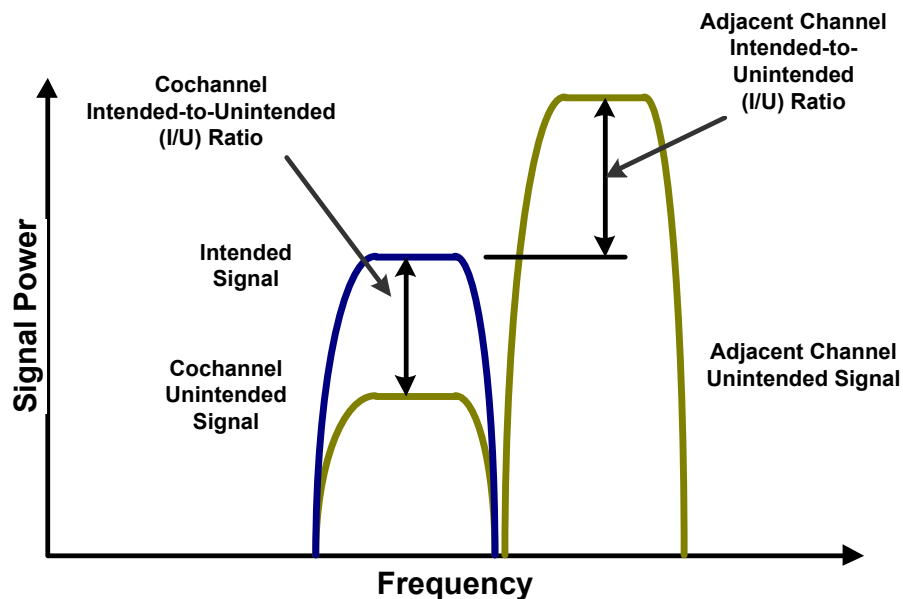


Figure 2—I/U ratio for co-channel and adjacent channel interference

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 help 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,

³⁴ EVM, or another appropriate measure of signal quality should be used.