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Short Range Devices (SRD) using Ultra Wide Band (UWB); Measurement Techniques

Reference

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Contents

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Foreword

This final draft European Standard (EN) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM), and is now submitted for the Vote phase of the ETSI standards EN Approval Procedure.

Proposed national transposition dates	
Date of latest announcement of this EN (doa):	3 months after ETSI publication
Date of latest publication of new National Standard or endorsement of this EN (dop/e):	6 months after doa
Date of withdrawal of any conflicting National Standard (dow):	6 months after doa

Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Ultra Wide Band (UWB) radio technology enables a new generation of high-speed data devices for short-range communication purposes as well as location tracking and Sensor devices and opens new markets with a variety of innovative applications.

UWB devices may form an integral part of other portable electronic equipment such as future generation cellular phones or laptops equipped with UWB enabled short-range air interfaces.

In addition, UWB devices with an operating bandwidth of several hundreds of MHz up to several GHz allow tens of centimetre-level accuracy real time localization and positioning even in the presence of severe multipath effects caused by walls, furniture or any other harsh radio propagation environments.

Based on the broad variety of different applications and the broad possible frequency range of operation the number of possible deployed physical signal formats can be very large. The existing range of physical signal and modulation formats range from traditional carrier based systems like OFDM over spread spectrum based system to carrier less systems based on base band pulses. The frequency regulation on the other side only defines a single set of transmission limits and values, which have to be fulfilled by all systems under the UWB regulation. Furthermore, the very high channel bandwidth of a UWB signal gives a specific challenge to the needed measurement setup and the procedures. Existing measurement methods need to be extended and new possible techniques should be described in the present document.

1 Scope

The present document summarizes the available information of possible measurement techniques and procedures for the conformance measurement of various UWB signal formats in order to comply with the given transmission limits given in the current regulation.

The present document will be used as a reference for existing and future ETSI standards covering UWB technologies.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TR 100 028 (V1.4.1) (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Uncertainties in the measurement of mobile radio equipment characteristics".

[2] ANSI C63.5 (2006): "American National Standard for Calibration of Antennas Used for Radiated Emission Measurements in Electro Magnetic Interference".

[3] ETSI TS 102 321 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Normalized Site Attenuation (NSA) and validation of a fully lined anechoic chamber up to 40 GHz".

[4] ETSI TS 102 754 (V1.2.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics of Detect-And-Avoid (DAA) mitigation techniques for SRD equipment using Ultra Wideband (UWB) technology".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] ETSI TR 103 181-1: "Short Range Devices (SRD) using Ultra Wide Band (UWB); Technical Report Part 1: UWB signal characteristics and overview CEPT/ECC and EC regulation".

[i.2] ETSI EN 302 065-1: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 1: Requirements for Generic UWB applications".

[i.3] Recommendation ITU-R SM.1754 (2006): "Measurement techniques of ultra-wideband transmissions".

[i.4] ETSI TR 102 070-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Guide to the application of harmonized standards to multi-radio and combined radio and non-radio equipment; Part 2: Effective use of the radio frequency spectrum".

[i.5] EU Project WALTER (Project Number 216312): "Project Deliverable: WALTER report on limitations of test methods to include calibration and measurement uncertainties", July 2009.

[i.6] ETSI TR 102 273 (V1.2.1) (all parts): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Improvement on Radiated Methods of Measurement (using test site) and evaluation of the corresponding measurement uncertainties".

[i.7] Recommendation ITU-R SM 329-10 (2003): "Unwanted emissions in the spurious domain".

[i.8] ETSI EN 302 065-2: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 2: Requirements for UWB location tracking".

[i.9] ETSI EN 302 065-3: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 3: Requirements for UWB devices for ground based vehicular applications".

[i.10] ETSI EN 302 065-4: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU; Part 4: Material Sensing devices using UWB technology below 10,6 GHz".

[i.11] ETSI EN 302 066: "Short Range Devices (SRD); Ground- and Wall- Probing Radar applications (GPR/WPR) imaging systems; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.12] ETSI EN 302 372: "Short Range Devices (SRD); Tank Level Probing Radar (TLPR) equipment operating in the frequency ranges 4,5 GHz to 7 GHz, 8,5 GHz to 10,6 GHz, 24,05 GHz to 27 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.13] ETSI EN 302 729: "Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU".

[i.14] ETSI TR 103 365: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Time Domain Based Peak Power Measurement for UWB Devices".

[i.15] ETSI TS 103 366: "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Time Domain based Low Duty Cycle Measurement for UWB".

[i.16] ETSI TR 103 181-2 (V1.1.1): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD) using Ultra Wide Band (UWB); Transmission characteristics Part 2: UWB mitigation techniques".

[i.17] ECC/DEC/(06)04: "The harmonised conditions for device using Ultra-Wideband (UWB) technology in bands below 10.6 GHz", ECC Decision of 24 March 2006 amended 9 December 2011 on the harmonised conditions for devices using UWB technology in bands below 10.6 GHz.

[i.18] ETSI TS 103 060: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Method for a harmonized definition of Duty Cycle Template (DCT) transmission as a passive mitigation technique used by short range devices and related conformance test methods".

[i.19] ETSI EN 301 489-33: "ElectroMagnetic Compatibility (EMC) standard for radio equipment and services; Part 33: Specific conditions for Ultra-WideBand (UWB) devices; Harmonised Standard covering the essential requirements of article 3.1(b) of the Directive 2014/53/EU".

3 Definitions, symbols and abbreviations

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

avoidance level: maximum amplitude to which the UWB transmit power is set for the relevant protection zone

burst: emitted signal whose time duration (Ton) is not related to its bandwidth

combined equipment: any combination of non-radio equipment and a plug-in radio device that would not offer full functionality without the radio device

cycle time: length of time between subsequent transmissions of the same system at full load

dedicated antenna: removable antenna supplied and tested with the radio equipment, designed as an indispensable part of the equipment

default avoidance bandwidth: portion of the victim service bandwidth to be protected if no enhanced service bandwidth identification mechanisms are implemented in the DAA enabled devices

detect and avoid time: time duration between a change of the external RF environmental conditions and adaptation of the corresponding UWB operational parameters

detection probability: probability that the DAA enabled UWB radio device reacts appropriately to a signal detection threshold crossing within the detect and avoid time

duty cycle: percentage of the transmitter sum of all burst duration "on" relative to a given period

dwell time: duration of a transmission on a particular sub-channel

Effective Radiated Power (E.R.P.): product of the power supplied to the antenna and its gain relative to a half-wave dipole in a given direction (RR 1.162)

Equivalent Isotropically Radiated Power (E.I.R.P.): product of the power supplied to the antenna and the antenna gain in a given direction relative to an isotropic antenna (absolute or isotropic gain) (RR 1.161)

gating: transmission that is intermittent or of a low duty cycle referring to the use of burst transmissions where a transmitter is switched on and off for selected time intervals

hopping: spread spectrum technique whereby individual radio links are continually switched from one subchannel to another

hopping cycle: number of hopping positions for a full frequency hopping sequence

host equipment: any equipment which has complete user functionality when not connected to the radio equipment part and to which the radio equipment part provides additional functionality and to which connection is necessary for the radio equipment part to offer functionality

impulse: pulse whose width is determined by its dc step risetime and whose maximum amplitude is determined by its dc step value

integral antenna: permanent fixed antenna, which may be built-in, designed as an indispensable part of the equipment

maximum avoidance power level: UWB transmit power assuring the equivalent protection of the victim service

minimum avoidance bandwidth: portion of the victim service bandwidth requiring protection

minimum initial channel availability check time: minimum time the UWB radio device spends searching for victim signals after power on, Parameter: $T_{avail,\ Time}$

Non-Interference Mode operation (NIM): operational mode that allows the use of the radio spectrum on a non-interference basis without active mitigation techniques

plug-in radio device: radio equipment module intended to be used with or within host, combined or multi-radio equipment, using their control functions and power supply

pulse: short transient signal whose time duration is nominally the reciprocal of its -10 dB bandwidth

rf carrier: fixed radio frequency prior to modulation

signal detection threshold: amplitude of the victim signal which defines the transition between adjacent protection zones, Parameter: D_{thresh}

NOTE: The threshold level is defined to be the signal level at the receiver front end of the UWB DAA radio device and assuming a 0 dBi receive antenna.

signal detection threshold set: set of amplitudes of the victim signal which defines the transition between adjacent protection zones

stand-alone radio equipment: equipment intended primarily as communications equipment and that is normally used on a stand-alone basis

sweep time: time to tune the LO across the selected span

transmission: sequence of emissions separated by intervals shorter than T_{dis}, ETSI TS 103 060 [i.18]

transmitter timeout functionality: internal functionality that switches off the system in order to reduce power consumption or for regulatory reasons

victim signal: signal(s) of the service to be detected and protected by the DAA mitigation technique

wideband: emission whose occupied bandwidth is greater than the test equipment measurement bandwidth

zone model: flexible DAA concept based on the definition of different zones as defined in ETSI TS 102 754 [4]

3.2 Symbols

For the purposes of the present document, the following symbols apply:

Ω	ohm
λ	wavelength
σ	standard deviation
Θ	elevation angle
Φ	azimuth angle
$C_{\text{ATT total}}$	attenuation from the EUT reference plane to the spectrum analyser
D	detection threshold
dB	decibel
dBi	gain in decibels relative to an isotropic antenna
dBm	gain in decibels relative to one milliwatt
f	frequency
f_c	centre frequency for the filter
f_L	lowest frequency of the operating bandwidth
f_H	highest frequency of the operating bandwidth
f_C	centre frequency of the operating bandwidth
f_M	frequency for peak power measurement
f[t]	filter coefficients at time *t*, centred on f_M
G	gain of the filter
G_{ATT}	attenuator loss
G_{LNA}	gain low noise amplifier
I	isolation in dB
P	power in dBm
$P_{\text{peak,filtered}}$	peak power in filter bandwidth
$P_{\text{peak,max}}$	maximum peak power in filter bandwidth

R distance
$T_{avail\_time\_min}$ minimum initial channel availability check time
T_{avoid} detect and avoid time

NOTE: Actual Detect and Avoid time of a DUT, can be negative.

T_{avoid_max} maximum allowed Detect and avoid time
T time
t discrete time variable
T_{dis} time interval below which interruptions within a transmission are considered part of T_{on} (disregard time), ETSI TS 103 060 [i.18]
T_{obs} reference interval of time (observation period, ETSI TS 103 060) [i.18]
T_{off} time interval between two consecutive bursts when the UWB emission is kept idle

NOTE: T_{off} is defined as "the time duration between two consecutive transmissions", ETSI TS 103 060 [i.18].

T_{on} duration of a burst irrespective of the number of pulses contained

NOTE: T_{on} is defined as "the duration of a transmission".

$V_{peak,filtered}$ peak voltage in filter bandwidth
Z_0 characteristic impedance

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AC Alternating Current
ADC Analogue-to-Digital Converter
BW BandWidth
BWA Broadband Wireless Access
CON Connector
DAA Detect And Avoid
DC Direct Current
DEC DECision
DUT Device Under Test
EC European Commission
ECC European Communication Committee
EIRP Equivalent Isotropically Radiated Power

NOTE: also called e.i.r.p., eirp, E.I.R.P.

EMC Electro Magnetic Compatibility
EN European Norm
ERM Electromagnetic compatibility and Radio spectrum Matters
ESA Economy Spectrum Analyser®
ESD Electro Static Discharge
ETSI European Telecommunications Standards Institute
EU European Union
EUT Equipment Under Test
FC Centre Frequency
FCC Federal Commission for Communications
FH Frequency Hopping
FH-UWB Frequency Hopping-UWB
FMCW Frequency Modulated Continuous Wave
HS Harmonised Standard
IF Intermediate Frequency
ITU International Telecommunications Union
LDC Low Duty Cycle
LNA Low Noise Amplifier

LO	Local Oscillator
NIM	Non-Interference Mode operation
OBW	Operating BandWidth
OE	Other Emissions of the radiated emissions
OFDM	Orthogonal Frequency Division Multiple
PEP	Peak Envelope Power
PPM	Part Per Million
PRF	Pulse Repetition Frequency
PSA	Power Spectrum Analyser®
PSD	Power Spectral Density
RBW	Resolution BandWidth
REC	RECommendation
RF	Radio Frequency
RMS	Root Mean of Squares
RX	Receiver
SNR	Signal to Noise Ratio
TE	Total Emission
TPC	Transmit Power Control
TX	Transmitter
UE	UWB Emissions
UUT	Unit Under Test
UWB	Ultra Wide Band
VBW	Video BandWidth
VSWR	Voltage Standing Wave Ratio

4 Overview

4.1 Basic information

In this clause a short overview over the existing and known UWB signal formats will be given. Based on the presented signal format the main issues of the needed measurement techniques will be derived. A more detailed description of the presented signal formats can be found in the ETSI TR 103 181-1 [i.1].

The present document describes measurements for many different types of UWB technologies used for a variety of different applications. The UWB technologies used for these applications can be broken down into two main groups:

1) Impulse derived (carrier-less) technologies.

2) Frequency modulated/carrier-based.

In general combinations of these systems are possible.

4.2 Impulse derived (carrier-less)

Impulse derived UWB technology consists of a series of impulses. These impulses are created from a pulsed oscillator, or a dc voltage step whose rise time can be modified to provide the maximum useful number of spectral emission frequencies. This derived impulse can then be suitably modified by the use of filters to locate the resulting waveform within a specific frequency spectrum range. This filter can be a stand-alone filter or incorporated into an antenna design to reduce emissions outside the designated frequency spectrum.

Modulation techniques include pulse positioning in time, pulse suppression or other techniques to convey information. The receiver either senses the individual pulses, or sums the energy from multiple pulses to reproduce the transmitted information.

This technology is suitable for direct and non-direct line of sight communications, any reflected or time delayed emissions being suppressed by the receiver input circuits.

Simple short pulses whereby one can modify/modulate by:

- pulseform/pulseshape;
- pulse duration;
- pulse trains (i.e. number of pulses per burst);
- pulse amplitude;
- pulse position/spacing, time/pulse hopping, random pseudo-noise generation, dithering (intentional jitter);
- direct sequence (generates UWB when performed quickly, typically pre-programmed).

Or combinations of the above. In figure 1 some examples of pulse shapes in the time domain and the corresponding spectrum is depicted.

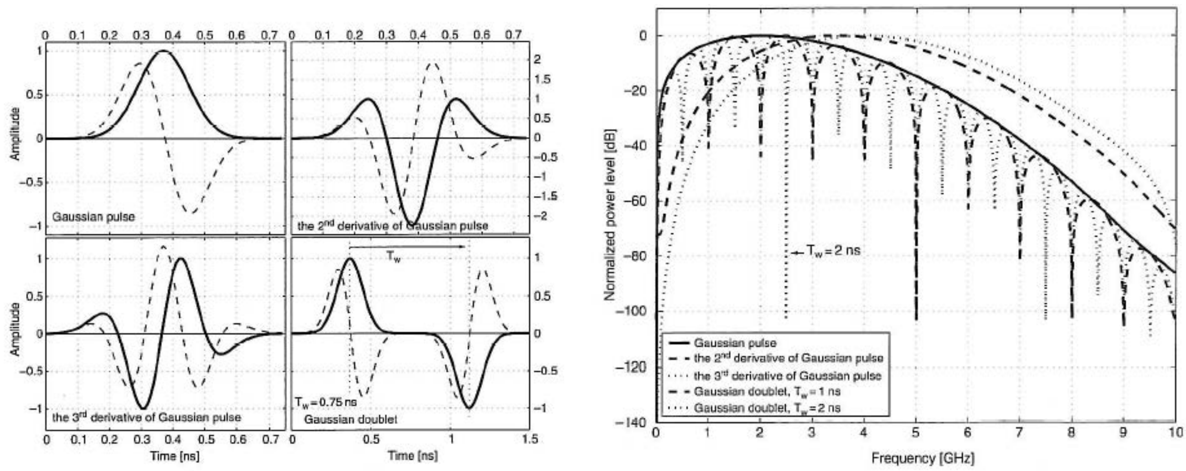


Figure 1: Example of Pulse shapes in time domain and the corresponding spectra

4.3 Frequency modulated/carrier-based

Under this category the following systems can be covered:

- phase shift keying;
- frequency hopping/stepping;
- FMCW, can also be intermittent, i.e. pulsed or gated;
- OFDM and similar (i.e. having multiple carriers/sub-carriers);
- random pseudo-noise generation, dithering or intentional pre-programmed direct sequencing can apply on all these carrier-based modulation schemes.

Or combinations of the above, including complex time- and frequency modulated combinations.

Due to the possible combinations, the above categories are not exhaustive.

5 General Consideration and test requirements

5.1 Overview

In this clause all general considerations for the testing of UWB devices will be given. These considerations and requirements are related to the presentation of the products to be tested (see clause 5.2); the used test modulation (see clause 5.3) and the general test conditions (see clause 5.4).

Details included in following clause:

- Product information (see clause 5.2).
- Test modulation (see clause 5.3).
- Specific Test setup (see clause 5.4).

An overview over the basic flow from a UWB application or device to the right certification measurement is given in figure 2. Based on the UWB application the manufacturer will chose a harmonised standard used for the certification of the devices. In this harmonised standard the regulatory requirements will be covered with a link to the relevant standardization document describing the used mitigation factor, the UWB signal format used and then the corresponding measurement setup for the given specific UWB application. The regulatory limits will be included in the relevant harmonised standard including the requirements for the additional mitigation techniques and factors.

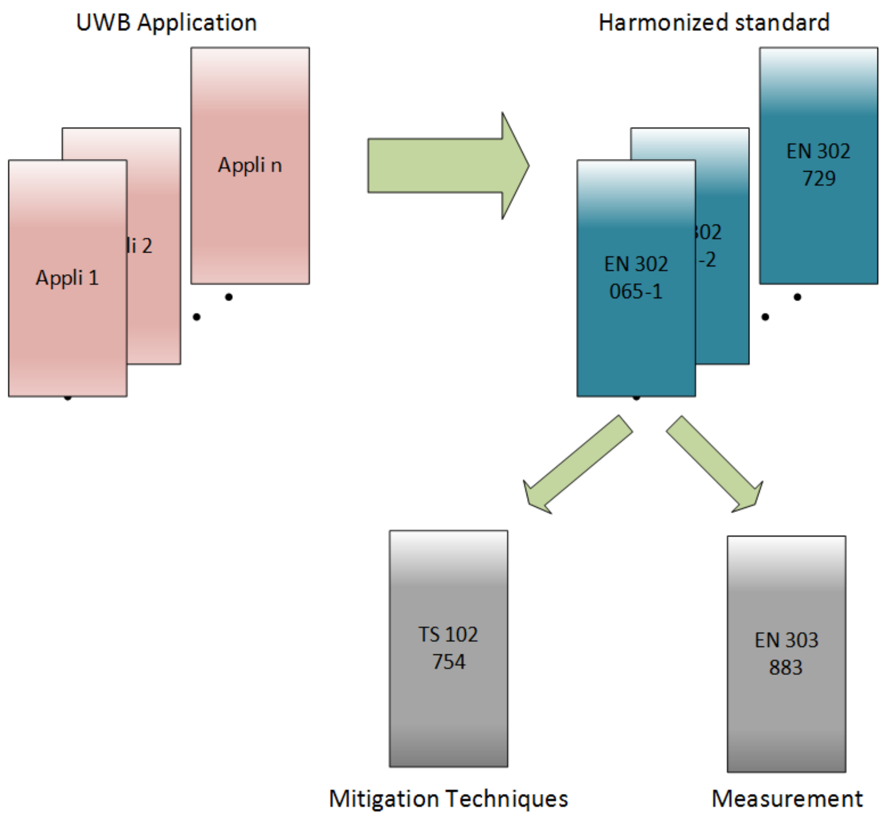


Figure 2: Overview flow for general product information and conformance test settings

As an example the harmonised standard for the generic UWB application ETSI EN 302 065-1 [i.2] is given in figure 2. In the following clause, the requirements for the right declaration of the UWB devices for the preparation of the measurement and the needed measurement setups are presented. The detailed measurements will be included in the clause 7 of the present document.

5.2 Product information

The following product information shall be provided by the manufacturer relevant harmonised standard and environmental conditions of use/intended use:

- the type of UWB technology implemented in the equipment (e.g. carrier-based, impulse, etc.);
- the type of modulation schemes available (e.g. OFDM modulation, pulsed modulation like PPM or Pulse Polarity Modulation or any other type of modulation, etc.);
- for all modulation schemes the modulation parameters need to be provided: for example modulation period, deviation or dwell times within a modulation period (FH systems), rate of modulation (Hz/s), number of carrier for OFDM, modulation bandwidth;
- the operating frequency range(s) of the equipment (see clause 7.4);
- the type of the equipment (e.g. stand-alone equipment, plug-in radio device, combined equipment, etc.), (see also clause 5.6);
- the intended combination(s) of the radio equipment power settings and one or more antenna assemblies and their corresponding e.i.r.p. levels (see also clause 5.5);
- the nominal power supply voltages of the stand-alone radio equipment or the nominal power supply voltages of the host equipment or combined equipment in case of plug-in radio devices;
- the test modulation to be used for testing (see also clause 5.3);
- the inclusion and any necessary implementation details of features such as gating or hopping;
- the inclusion and any necessary implementation details of any mitigation or equivalent mitigation techniques;
- in case of conducted measurements, the antenna impedance as well as maximum antenna gain characteristics (frequency response) over the relevant frequency range covered in the related harmonised standard.

NOTE: For further information on this topic, see related harmonised standards ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12], ETSI EN 302 729 [i.13] and Regulation ECC/DEC/(06)04 [i.17].

5.3 Requirements for the test modulation

The test modulation used should be representative of normal use of the equipment and which results in the highest mean transmit power spectral density which would be available in normal operation.

The highest mean transmit power spectral density is also-likely to be affected by frame/packet length, inter-packet gaps, normal and burst modes. The manufacturer shall declare this information and that the settings were used that are considered to lead to the highest mean transmit power spectral density which would be available in normal operation.

Preferably, the equipment should be capable of continuous RF transmission, so as to minimize the test time required to determine the highest levels of emission from the device. Where the equipment is not capable of continuous RF transmission, the manufacturer shall employ the mode of operation of the equipment which results in the highest transmitter activity consistent with the requirement to measure the highest mean transmit power spectral density which would be available in operation, and should ensure that:

- transmissions occur regularly in time;
- sequences of transmissions can be repeated accurately.

For transmitters that have multi−modulation schemes incorporated, the manufacturer shall declare the modulation scheme to be used for each test.

Implemented transmitter timeout functionality shall be disabled for the sequence of the test suite.

Where radio devices are equipped with LDC, the LDC operation may be disabled for the duration of the test. In any case the mean power measurement shall be performed so as to guarantee the maximum mean power level over 1ms as given in clause 7.2.

The manufacturer shall provide the means to operate the transmitter during the tests.

5.4 Test conditions, power supply and ambient temperatures

5.4.1 Test conditions

Testing shall be performed under normal test conditions.

The test conditions and procedures shall be performed as specified in the following clauses 5.4.2 and 5.4.3.

5.4.2 Power sources

5.4.2.1 Power sources for stand-alone equipment

During testing, the power source of the equipment shall be replaced by a test power source capable of producing normal test voltages as specified in clause 5.4.3.2. The internal impedance of the test power source shall be low enough for its effect on the test results to be negligible. For the purpose of tests, the voltage of the power source shall be measured at the input terminals of the equipment.

Battery operated equipment may be tested with the standard internal battery, or the battery may be removed and replaced with a test power source.

If a test power source is used, it shall be applied as close to the battery terminals as possible. During tests, its voltages shall be maintained within a tolerance of ±1 % relative to the voltage at the beginning of each test. The value of this tolerance is critical to power measurements; using a smaller tolerance will provide better measurement uncertainty values.

5.4.2.2 Power sources for plug-in radio devices

The power source for testing plug-in radio devices shall be provided by test fixture or host equipment.

Where the host equipment and/or the plug-in radio device is battery powered, the battery may be removed and the test power source applied as close to the battery terminals as practicable.

5.4.3 Normal test conditions

5.4.3.1 Normal temperature and humidity

The normal temperature and humidity conditions for tests shall be any convenient combination of temperature and humidity within the following ranges:

- temperature: +15 °C to +35 °C;
- relative humidity: 20 % to 75 %.

When it is impracticable to carry out the tests under these conditions, a note to this effect, stating the ambient temperature and relative humidity during the tests, shall be recorded.

The actual values during the tests shall be recorded.

5.4.3.2 Normal power source

5.4.3.2.1 Mains voltage

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the voltage(s) for which the equipment was designed.

The frequency of the test power source corresponding to the AC mains shall be between 49 Hz and 51 Hz, or between 59 Hz and 61 Hz.

5.4.3.2.2 Lead-acid battery power sources used on vehicles

When radio equipment is intended for operation from the usual, alternator fed lead-acid battery power source used on vehicles, then the normal test voltage shall be 1,1 times the nominal voltage of the battery (6 V, 12 V, etc.).

5.4.3.2.3 Other power sources

For operation from other power sources or types of battery (primary or secondary), the nominal test voltage shall be as stated by the equipment manufacturer. This shall be recorded.

5.5 Choice of equipment for test suites

5.5.1 Choice of model

The tests shall be carried out on one or more production models or equivalent preliminary models, as appropriate. If testing is performed on (a) preliminary model(s), then the corresponding production models shall be identical to the tested models in all respects relevant for the purposes of the present document.

If an equipment has several optional features that are considered to affect directly the RF parameters then tests need only be performed on the equipment configured with the considered worst case combination of features as declared by the manufacturer.

5.5.2 Presentation

Stand-alone equipment shall be tested complete with any ancillary equipment.

Plug-in radio devices may be tested together with a suitable test fixture and/or typical host equipment (see clause 5.6).

5.5.3 Multiple operating bandwidths

Where equipment has more than one operating bandwidth (e.g. 500 MHz and 1 300 MHz), a minimum of two operating bandwidths shall be chosen such that the lower and higher limits of the operating range(s) of the equipment are covered (see clause 7.2.2). All operating bandwidths of the equipment shall be declared by the equipment manufacturer.

5.6 Testing of host connected equipment and plug-in radio devices

5.6.1 General

For combined equipment and for radio parts for which connection to or integration with host equipment is required to offer functionality to the radio, different alternative test approaches are permitted. Where more than one such combination is intended, testing shall not be repeated for combinations of the radio part and various host equipment where the latter are substantially similar.

Where more than one such combination is intended and the combinations are substantially dissimilar, one combination shall be tested against all requirements of the present document and all other combinations shall be tested separately for radiated spurious emissions only (see clause 7.4.5).

5.6.2 The use of a host or test fixture for testing plug-In radio devices

Where the radio part is a plug-in radio device which is intended to be used within a variety of combinations, a suitable test configuration consisting of either a test fixture or typical host equipment shall be used. This shall be representative for the range of combinations in which the radio device may be used. The test fixture shall allow the radio equipment part to be powered and stimulated as if connected to or inserted into the host or combined equipment. Measurements shall be made to all requirements given in the relevant harmonised standards.

NOTE: For further information on this topic, see ETSI TR 102 070-2 [i.4].

5.7 Interpretation of the measurement results

5.7.1 General points on interpretation of the measurement results

The interpretation of the results for the measurements described in the present document shall be as follows:

1) the measured value related to the corresponding limit shall be used to decide whether equipment meets the requirements of the present document;

2) the measurement uncertainty value for the measurement of each parameter shall be recorded;

3) the recorded value of the measurement uncertainty shall be wherever possible, for each measurement, equal to or lower than the figures in table 1, and the interpretation procedure specified in clause 5.7.2 shall be used.

For the test methods, according to the present document, the measurement uncertainty figures shall be calculated in accordance with the guidance provided in ETSI TR 100 028 [1] and shall correspond to an expansion factor (coverage factor) k = 1,96 or k = 2 (which provide confidence levels of respectively 95 % and 95,45 % in the case where the distributions characterizing the actual measurement uncertainties are normal (Gaussian)).

Table 1 is based on such expansion factors.

Table 1: Maximum measurement uncertainty

Parameter	Uncertainty
Radio Frequency	$\pm 1 \times 10^{-5}$
all emissions, radiated	±6 dB (see note)
conducted	±3 dB
temperature	±1 °C
humidity	±5 %
DC and low frequency voltages	±3 %
NOTE: For radiated emissions measurements below 2,7 GHz and above 10,6 GHz it may not be possible to reduce measurement uncertainty to the levels specified in table 1 (due to the very low signal level limits and the consequent requirement for high levels of amplification across wide bandwidths). In these cases alone, it is acceptable to employ the alternative interpretation procedure specified in clause 5.7.3.	

5.7.2 Measurement uncertainty is equal to or less than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits shall be as follows:

a) When the measured value does not exceed the limit value the equipment under test meets the requirements of the present document.

b) When the measured value exceeds the limit value the equipment under test does not meet the requirements of the present document.

c) The measurement uncertainty calculated by the test technician carrying out the measurement shall be recorded in the test report.

d) The measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement untaken. The method used shall be recorded in the test report.

5.7.3 Measurement uncertainty is greater than maximum acceptable uncertainty

The interpretation of the results when comparing measurement values with specification limits should be as follows:

a) When the measured value plus the difference between the measurement uncertainty calculated by the test technician and the maximum acceptable measurement uncertainty does not exceed the limit value, the equipment under test meets the requirements of the present document.

b) When the measured value plus the difference between the measurement uncertainty calculated by the test technician and the maximum acceptable measurement uncertainty exceeds the limit value the equipment under test does not meet the requirements of the present document.

c) The measurement uncertainty calculated by the test technician carrying out the measurement shall be recorded in the test report.

d) The measurement uncertainty calculated by the test technician may be a maximum value for a range of values of measurement, or may be the measurement uncertainty for the specific measurement untaken. The method used shall be recorded in the test report.

5.8 Other emissions

UWB transmitters emit very low power radio signals, comparable with the power of spurious emissions from digital and analogue circuitry. If it can be clearly demonstrated that an emission from the ultra-wideband radio device is not the ultra-wideband emission identified in clause 7.3 (e.g. by disabling the radio device's UWB transmitter or disconnecting and terminating, internally or externally the antenna of the device) or it can clearly be demonstrated that it is impossible to differentiate between other emissions (OE) and the UWB transmitter emissions, that emission or aggregated emissions shall be considered against the transmitter spurious emissions limits defined in the relevant harmonised standard. The EMC emissions of a UWB device will be tested based on ETSI EN 301 489-33 [i.19].

6 Test setups and procedures

6.1 Introduction

In this clause the general setup of a test bed for the test of UWB equipment will be descripted. Two procedures of test will be considered here:

- radiated measurements; and
- conducted measurements.

Both measurements need to be possible for UWB devices due to the very low emission levels to be evaluated. For equipment providing a 50 Ω antenna connectors the conducted measurement is the preferred measurement. More details concerning the conditions are given in clause 6.4.

6.2 Initial Measurement steps

In a first step the relevant frequency band for the measurement of the System under test has to be identified by using the manufacturer's declaration (see clause 5.2) and a coarse peak power measurement using a spectrum analyser. After the identification of the relevant band of the UWB system the further measurement steps can be performed. The identification step is independent of the system to be measured and the measurement to be performed (mean power or peak power, radiated or conducted).

The settings of the instrument have to be chosen based on the description of the signal provided, so as to ensure that the highest values of peak power and mean PSD are captured. This is particularly important for a scanning instrument (spectrum analyser) and a signal that has complex variation in time or over frequency. It is suggested that the signal should initially be observed with both peak and mean measuring modes, over its full bandwidth, to confirm the description and to establish where the highest values can and cannot be in RF. This will permit subsequent measurements to be made with a narrower RF span. Where there is any doubt about the effect of frequency scanning, a measurement at a single RF (zero spans) will provide confirmation.

The measurements shall be repeated for radio devices with TPC implemented within the UWB radio device configured at the lowest power spectral density setting.

6.3 Radiated measurements

6.3.1 General

The test site, test antenna and substitution antenna used for radiated measurements shall be as described in clause 6.3.2.

For guidance on use of radiation test sites, coupling of signals and standard test positions used for radiated measurements, see clauses 6.3.3 to 6.3.5.

Detailed descriptions of radiated measurement arrangements for UWB radio devices can be found in Recommendation ITU-R SM.1754 [i.3].

All reasonable efforts should be made to clearly demonstrate that emissions from the UWB transmitter do not exceed the specified levels, with the transmitter in the far field. To the extent practicable, the radio device under test shall be measured at the distance specified in clause 6.3.3.5 and with the specified measurement bandwidths. However, in order to obtain an adequate signal-to-noise ratio in the measurement system, radiated measurements may have to be made at distances less than those specified in clause 6.3.3.5 and/or with reduced measurement bandwidths.

The revised measurement configuration should be stated on the test report, together with an explanation of why the signal levels involved necessitated measurement at the distance employed or with the measurement bandwidth used in order to be accurately detected by the measurement equipment and calculations demonstrating compliance.

Where it is not practical to further reduce the measurement bandwidth (either because of limitations of commonly-available test equipment or difficulties in converting readings taken using one measurement bandwidth to those used by the limits given in the relevant harmonised standard, and the required measurement distance would be so short that the radio device would not clearly be within the far field, the test report shall state this fact, the measurement distance and bandwidth used, the near field/far field distance for the measurement setup (see clause 6.3.3.5), the measured radio device emissions, the achievable measurement noise floor and the frequency range(s) involved.

6.3.2 Test sites and general arrangements for measurements involving the use of radiated fields

6.3.2.1 General

This clause introduces the test site which may be used for radiated tests. The test site is generally referred to as a free field test site. Both absolute and relative measurements can be performed in these sites. Where absolute measurements are to be carried out, the chamber should be verified. A detailed verification procedure is described in ETSI TS 102 321 [3].

6.3.2.2 Anechoic chamber

An anechoic chamber is the preferred test site to be used for radiated testing in accordance with the present document above 1 GHz. However, an anechoic chamber with ground plane as described in clause 6.3.2.3 may be used above 1 GHz providing that suitable anechoic material is placed on the chamber floor to suppress any reflected signal.

An anechoic chamber is an enclosure, usually shielded, whose internal walls, floor and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. The chamber usually contains an antenna support at one end and a turntable at the other. A typical anechoic chamber is shown in figure 3.

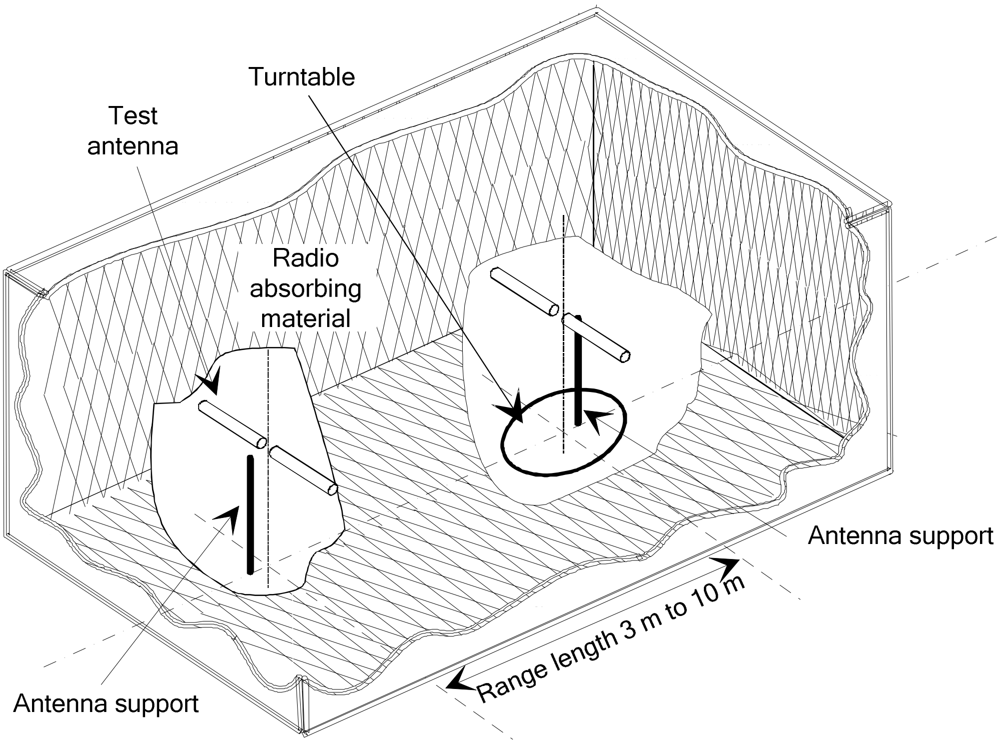


Figure 3: A typical anechoic chamber

The chamber shielding and radio absorbing material work together to provide a controlled environment for testing purposes. This type of test chamber attempts to simulate free space conditions.

The shielding provides a test space, with reduced levels of interference from ambient signals and other outside effects, whilst the radio absorbing material minimizes unwanted reflections from the walls and ceiling which can influence the measurements. In practice it is relatively easy for shielding to provide high levels (80 dB to 140 dB) of ambient interference rejection, normally making ambient interference negligible.

A turntable is capable of rotation through 360° in the horizontal plane and it is used to support the test sample (EUT) at a suitable height (e.g. 1 m) above the ground plane. The chamber shall be large enough to allow the measuring distance of at least 3 m or $2(d_1 + d_2)^2/\lambda$ (m), whichever is greater (see clause 6.3.3.5). However, it shall be noted that due to the low radiated power density for UWB equipment, its transmit spectrum can be measured at approximately 1 m to improve measurement sensitivity. The distance used in actual measurements shall be recorded with the test results. Practical tests have shown that larger measurements distances of up to 3 meters at the frequencies below 1 GHz and shorter measurement distances of less than 1 meter at frequencies above 10 GHz can be conducted as long as the far field conditions are still fulfilled.

The anechoic chamber generally has several advantages over other test facilities. There is minimal ambient interference, minimal floor, ceiling and wall reflections and it is independent of the weather. It does however have some disadvantages which include limited measuring distance and limited lower frequency usage due to the size of the pyramidal absorbers. To improve low frequency performance, a combination structure of ferrite tiles and urethane foam absorbers is commonly used.

All types of emission testing can be carried out within an anechoic chamber without limitation.

6.3.2.3 Anechoic chamber with a conductive ground plane

An anechoic chamber with a conductive ground plane shall be used for radiated testing in accordance with the present document below 1 GHz.

An anechoic chamber with a conductive ground plane is an enclosure, usually shielded, whose internal walls and ceiling are covered with radio absorbing material, normally of the pyramidal urethane foam type. The floor, which is metallic, is not covered and forms the ground plane. The chamber usually contains an antenna mast at one end and a turntable at the other. A typical anechoic chamber with a conductive ground plane is shown in figure 4.

This type of test chamber attempts to simulate an ideal Open Area Test Site whose primary characteristic is a perfectly conducting ground plane of infinite extent.

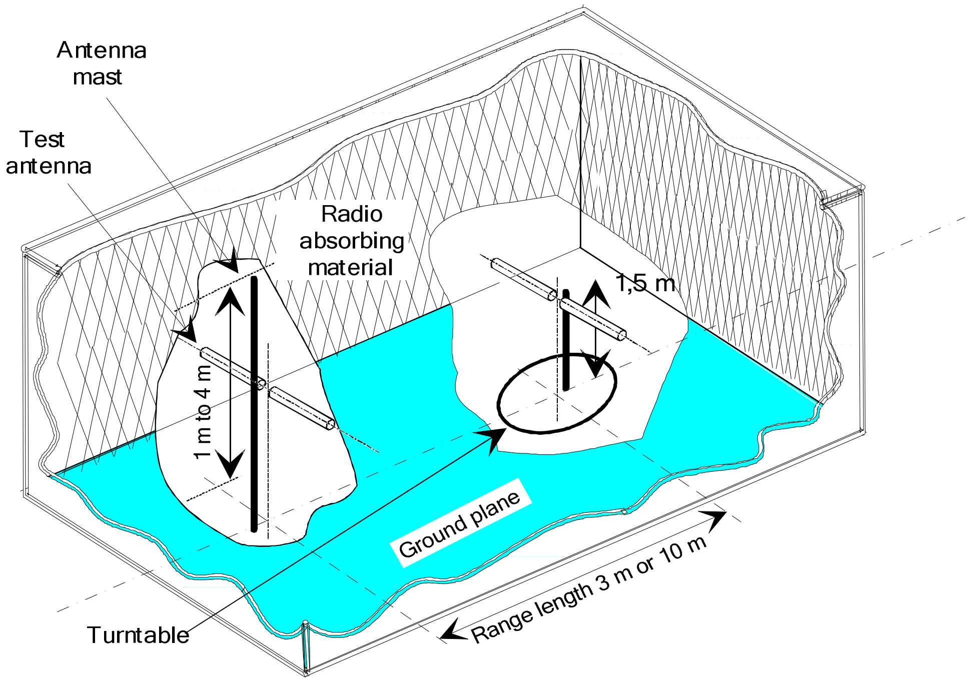


Figure 4: A typical anechoic chamber with a conductive ground plane

In this facility the ground plane creates the wanted reflection path, such that the signal received by the receiving antenna is the sum of the signals from both the direct and reflected transmission paths. This creates a unique received signal level for each height of the transmitting antenna (or EUT) and the receiving antenna above the ground plane.

The antenna mast provides a variable height facility (from 1 m to 4 m) so that the position of the test antenna can be optimized for maximum coupled signal between antennas or between a EUT and the test antenna.

A turntable is capable of rotation through 360° in the horizontal plane and it is used to support the test sample (EUT) at a specified height, usually 1,5 m above the ground plane. The chamber shall be large enough to allow the measuring distance of at least 3 m or $2(d_1 + d_2)^2 /\lambda$ (m), whichever is greater (see clause 6.3.3.5). However, it shall be noted that due to the low radiated power density for UWB equipment its transmit spectrum can be measured at approximately 1 m. The distance used in actual measurements shall be recorded with the test results.

Emission testing involves firstly "peaking" the field strength from the EUT by raising and lowering the receiving antenna on the mast (to obtain the maximum constructive interference of the direct and reflected signals from the EUT) and then rotating the turntable for a "peak" in the azimuth plane. At this height of the test antenna on the mast, the amplitude of the received signal is noted. Secondly the EUT is replaced by a substitution antenna (positioned at the EUT's phase or volume centre), which is connected to a signal generator. The signal is again "peaked" and the signal generator output adjusted until the level, noted in stage one, and is again measured on the receiving radio device.

Receiver sensitivity tests over a ground plane also involve "peaking" the field strength by raising and lowering the test antenna on the mast to obtain the maximum constructive interference of the direct and reflected signals, this time using a measuring antenna which has been positioned where the phase or volume centre of the EUT will be during testing. A transform factor is derived. The test antenna remains at the same height for stage two, during which the measuring antenna is replaced by the EUT. The amplitude of the transmitted signal is reduced to determine the field strength level at which a specified response is obtained from the EUT.

6.3.2.4 Test antenna

A test antenna is always used in radiated test methods. In emission tests (i.e. effective radiated power, spurious emissions) the test antenna is used to detect the field from the EUT in one stage of the measurement and from the substitution antenna in the other stage. When the test site is used for the measurement of receiver characteristics (i.e. sensitivity and various immunity parameters) the antenna is used as the transmitting radio device.

The test antenna should be mounted on a support capable of allowing the antenna to be used in either horizontal or vertical polarization which, on ground plane sites (i.e. anechoic chambers with ground plane) should additionally allow the height of its centre above the ground to be varied over the specified range (usually 1 m to 4 m).

In the frequency band 30 MHz to 1 000 MHz, dipole antennas (constructed in accordance with ANSI C63.5 [2]) are generally recommended. For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. For spurious emission testing, however, a combination of bicones and log periodic dipole array antennas (commonly termed "log periodic") could be used to cover the entire 30 MHz to 1 000 MHz band. Above 1 000 MHz, waveguide horns are recommended although, again, log periodic could be used.

NOTE: The gain of a horn antenna is generally expressed relative to an isotropic radiator.

6.3.2.5 Substitution antenna

The substitution antenna is used to replace the EUT for tests in which a transmitting parameter (i.e. frequency error, effective radiated power, spurious emissions and adjacent channel power) is being measured. For measurements in the frequency band 30 MHz to 1 000 MHz, the substitution antenna should be a dipole antenna (constructed in accordance with ANSI C63.5 [2]). For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. For measurements above 1 000 MHz, a waveguide horn is recommended. The centre of this antenna should coincide with either the phase centre or volume centre.

6.3.2.6 Measuring antenna

The measuring antenna is used in tests on a EUT in which a receiving parameter (i.e. sensitivity and various immunity tests) is being measured. Its purpose is to enable a measurement of the electric field strength in the vicinity of the EUT. For measurements in the frequency band 30 MHz to 1 000 MHz, the measuring antenna should be a dipole antenna (constructed in accordance with ANSI C63.5 [2]). For frequencies of 80 MHz and above, the dipoles should have their arm lengths set for resonance at the frequency of test. Below 80 MHz, shortened arm lengths are recommended. The centre of this antenna should coincide with either the phase centre or volume centre (as specified in the test method) of the EUT.

6.3.3 Guidance on the use of a radiation test site

6.3.3.1 General on guidance on the use of a radiation test site

This clause details procedures, test equipment arrangements and verification that should be carried out before any of the radiated tests are undertaken.

6.3.3.2 Verification of the test site

No test should be carried out on a test site which does not possess a valid certificate of verification. The verification procedures for the different types of test sites described in annex A (i.e. anechoic chamber and anechoic chamber with a ground plane) are given in the relevant parts of ETSI TR 102 273 [i.6] or equivalent.

6.3.3.3 Preparation of the EUT

The manufacturer should supply information about the EUT covering the operating frequency, polarization, supply voltage(s) and the reference face. Additional information, specific to the type of EUT should include, where relevant, carrier power, channel separation, whether different operating modes are available (e.g. high and low power modes) and if operation is continuous or is subject to a maximum test duty cycle (e.g. 1 minute on, 4 minutes off).

Where necessary, a mounting bracket of minimal size should be available for mounting the EUT on the turntable. This bracket should be made from low conductivity, low relative dielectric constant (i.e. less than 1,5) material(s) such as expanded polystyrene, balsawood, etc.

6.3.3.4 Power supplies to the EUT

Where possible, all tests should be performed using power supplies, including tests on EUT designed to include battery-only use. However, devices may be tested with internal batteries in that casing materials, components, and sealants used for assembly, can affect test results.

If a battery supply is used, fully-charged batteries shall be used. The batteries used shall be as supplied or recommended by the manufacturer. If internal batteries are used, at the end of each test the voltage shall be within a tolerance of ±5 % relative to the voltage at the beginning of each test. If the battery is not accessible (for example, it is internal to a sealed unit), then it is acceptable to determine the battery voltage at the start and end of the test by indirect means (e.g. battery health messages sent from the unit itself). In all cases, in which power leads are used, they should be connected to the EUT's supply terminals (and monitored with a digital voltmeter) but the battery should remain present, electrically isolated from the rest of the equipment, possibly by putting tape over its contacts.

The presence of these power cables can, however, affect the measured performance of the EUT. For this reason, they should be made to be "transparent" as far as the testing is concerned. This can be achieved by routing them away from the EUT and down to either the screen, ground plane or facility wall (as appropriate) by the shortest possible paths. Precautions should be taken to minimize pick-up on these leads (e.g. the leads could be twisted together, loaded with ferrite beads at 0,15 m spacing or otherwise loaded).

6.3.3.5 Range length

The range length for all these types of test facility should be adequate to allow for testing in the far field of the EUT i.e. it should be equal to or exceed:

$$\frac{2(d_1 + d_2)^2}{\lambda} \tag{1}$$

Where:

d_1 is the largest dimension of the EUT/dipole after substitution (m);

d_2 is the largest dimension of the test antenna (m);

λ is the test frequency wavelength (m).

It should be noted that in the substitution part of this measurement, where both test and substitution antennas are half wavelength dipoles, this minimum range length for far-field testing would be:

$$2\lambda \tag{2}$$

It should be noted in test reports when either of these conditions is not met so that the additional measurement uncertainty can be incorporated into the results.

NOTE 1: For the fully anechoic chamber, no part of the volume of the EUT should, at any angle of rotation of the turntable, fall outside the "quiet zone" of the chamber at the nominal frequency of the test.

NOTE 2: The "quiet zone" is a volume within the anechoic chamber (without a ground plane) in which a specified performance has either been proven by test, or is guaranteed by the designer/manufacturer. The specified performance is usually the reflectivity of the absorbing panels or a directly related parameter (e.g. signal uniformity in amplitude and phase). It should be noted however that the defining levels of the quiet zone tend to vary.

6.3.3.6 Site preparation

The cables for both ends of the test site should be routed horizontally away from the testing area for a minimum of 2 m and then allowed to drop vertically and out through either the ground plane or screen (as appropriate) to the test equipment. Precautions should be taken to minimize pick up on these leads (e.g. dressing with ferrite beads, or other loading). The cables, their routing and dressing should be identical to the verification set-up.

Calibration data for all items of test equipment should be available and valid. For test, substitution and measuring antennas, the data should include gain relative to an isotropic radiator (or antenna factor) for the frequency of test. Also, the VSWR of the substitution and measuring antennas should be known.

The calibration data on all cables and attenuators should include insertion loss and VSWR throughout the entire frequency range of the tests. All VSWR and insertion loss figures should be recorded in the logbook results sheet for the specific test.

Where correction factors/tables are required, these should be immediately available.

For all items of test equipment, the maximum measurement uncertainty they exhibit should be known along with the distribution of the uncertainty.

At the start of measurements, system checks should be made on the items of test equipment used on the test site.

6.3.4 Coupling of signals

6.3.4.1 General

The presence of leads in the radiated field may cause a disturbance of that field and lead to additional measurement uncertainty. These disturbances can be minimized by using suitable coupling methods, offering signal isolation and minimum field disturbance (e.g. optical and acoustic coupling).

6.3.4.2 Data Signals

Isolation can be provided by the use of optical, ultrasonic or infrared means. Field disturbance can be minimized by using a suitable fibre optic connection. Ultrasonic or infrared radiated connections require suitable measures for the minimization of ambient noise.

6.3.5 Standard test methods

6.3.5.1 General information on test methods

Two methods of determining the radiated power of a radio device are described in clause 6.3.5.2 (calibrated setup) and clause 6.3.5.3 (substitution method).

6.3.5.2 Calibrated setup

The measurement receiver, test antenna and all associated equipment (e.g. cables, filters, amplifiers, etc.) shall have been recently calibrated against known standards at all the frequencies on which measurements of the equipment are to be made. A suggested calibration method is given in clause 6.3.6.

On a test site according to clause 6.2, the equipment shall be placed at the specified height on a support, and in the position closest to normal use as declared by the provider.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser via whatever (fully characterized) equipment is required to render the signal measurable (e.g. amplifiers).

The transmitter shall be switched on, if possible without modulation, and the spectrum analyser shall be tuned to the frequency of the transmitter under test.

The test antenna shall be raised and lowered through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The transmitter shall then be rotated through 360° in the horizontal plane, until the maximum signal level is detected by the spectrum analyser.

The test antenna shall be raised and lowered again through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The maximum signal level detected by the spectrum analyser shall be noted and converted into the radiated power by application of the pre-determined calibration coefficients for the equipment configuration used.

NOTE: The calibration procedure is to be performed with both polarizations: vertical and horizontal.

6.3.5.3 Substitution method

On a test site, selected from clause 6.3.2, the equipment shall be placed at the specified height on a support, as specified in clause 6.3.2, and in the position closest to normal use as declared by the provider.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser.

The transmitter shall be switched on, if possible without modulation, and the measuring receiver shall be tuned to the frequency of the transmitter under test.

The test antenna shall be raised and lowered through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The transmitter shall then be rotated through 360° in the horizontal plane, until the maximum signal level is detected by the spectrum analyser.

The test antenna shall be raised and lowered again through the specified range of height until a maximum signal level is detected by the spectrum analyser.

The maximum signal level detected by the spectrum analyser shall be noted.

The transmitter shall be replaced by a substitution antenna as defined in clause 6.3.2.5.

The substitution antenna shall be orientated for vertical polarization and the length of the substitution antenna shall be adjusted to correspond to the frequency of the transmitter.

The substitution antenna shall be connected to a calibrated signal generator.

If necessary, the input attenuator setting of the spectrum analyser shall be adjusted in order to increase the sensitivity of the spectrum analyser.

The test antenna shall be raised and lowered through the specified range of height to ensure that the maximum signal is received. When a test site according clause 6.3.2.2 is used, the height of the antenna shall not be varied.

The input signal to the substitution antenna shall be adjusted to the level that produces a level detected by the spectrum analyser, that is equal to the level noted while the transmitter radiated power was measured, corrected for the change of input attenuator setting of the spectrum analyser.

The input level to the substitution antenna shall be recorded as power level, corrected for any change of input attenuator setting of the spectrum analyser.

The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

The measure of the radiated power of the radio device is the larger of the two levels recorded at the input to the substitution antenna, corrected for gain of the substitution antenna if necessary.

NOTE: Details for all standard test setups are described in clause A.4.

6.3.6 Standard calibration method

The calibration of the test fixture establishes the relationship between the detected output from the test fixture, and the transmitted power (as sampled at the position of the antenna) from the EUT in the test fixture. This can be achieved (at higher frequencies) by using a calibrated horn with a gain of equal to or less than 20 dB, fed from an external signal source, in place of the EUT to determine the variations in detected power over frequency.

The calibration setup is shown in figure 5.

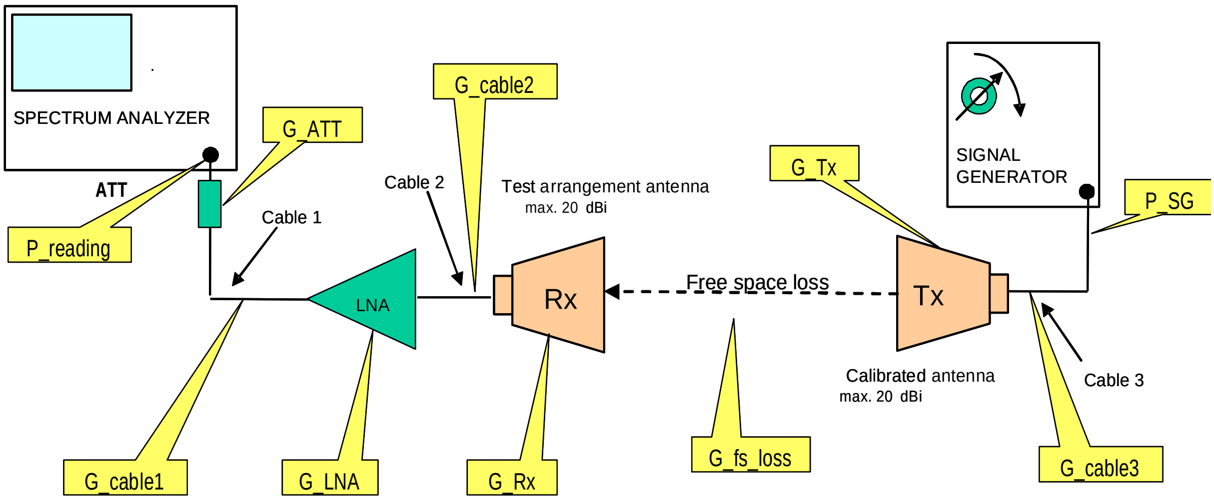


Figure 5: Calibration set-up configuration

The calibration of the test fixture shall be carried out by either the provider or the accredited test laboratory. The results shall be approved by the accredited test laboratory.

It is the responsibility of the tester to obtain enough measurement accuracy. The following description is an example of a proven and accurate calibration method:

a) Calibrate all instruments using usual calibration routines.

b) Remove the EUT from the test fixture and replace the EUT by a calibrated antenna. Carefully orientate the calibration antenna in the test fixture towards the test arrangement antenna. The reference plane of the calibration antenna shall coincide with the EUT reference plane. The distance between the calibration antenna and the test arrangement antenna shall be between 0,5 m to 1 m.

c) Connect a signal generator to the calibrated antenna in the test fixture.

d) Connect a 10 dB attenuator to the test arrangement antenna to improve the VSWR. If SNR of the test arrangement is low it might be necessary to omit the attenuator.

e) Connect a power meter to the test arrangement antenna including a 10 dB attenuator, if required, and apply, by means of a signal generator, a frequency and power level to the same as the expected value from the EUT output to the calibration antenna in the test fixture.

f) Take into account the gain from both the calibration and the test arrangement antenna, the losses from the attenuator and all cables in use and the gain of a LNA, if required.

g) Note the absolute reading of the power meter.

h) Replace the power meter with a spectrum analyser. Adjust the frequency and power level of the signal generator to the same as the expected value from the EUT output. Apply this signal to the calibration antenna.

i) Take into account the gain from both the calibration and the test arrangement antenna, the losses from the attenuator and all cables in use and the gain of a LNA, if required. Instead of an external attenuator the built-in attenuator of the spectrum analyser may be used.

j) Set the spectrum analyser detector in RMS mode with a RBW and VBW at least as large as the signal generator output signal bandwidth with an appropriate spectrum analyser sweep rate. Note the absolute reading of the spectrum analysers input signal.

k) The noted absolute power reading of the power meter and the spectrum analyser shall not differ more than the specified uncertainty of the used measurement equipment's.

l) Calculate the total attenuation from the EUT reference plane to the spectrum analyser as follows:

$P_{reading}$ = the absolute power level (in e.g. dBm) noted from the power meter/spectrum analyser.

G_{Tx} = antenna gain in dB of the calibrated antenna in the test fixture.

G_{Rx} = antenna gain in dB of the test arrangement antenna.

G_{ATT} = the 10 dB attenuator loss (0 dB, if attenuator not used).

G_{cable} = the total loss in dB of all cables used in the test setup.

G_{LNA} = the gain in dB of the low noise amplifier (0 dB, if LNA not used).

G_{fs_loss} = the free space loss in dB between the calibrated antenna (Tx) in the test fixture and the test arrangement antenna (Rx).

C_{ATT} = calculated attenuation in dB of all losses with referenced to the EUT position.

P_{abs} = the absolute power (in e.g. dBm) of the EUT (e.i.r.p.).

C_{ATT} = $G_{fs\_loss} - G_{Rx} + G_{cable2} - G_{LNA} + G_{cable1} + G_{ATT}$.

P_{abs} = $P_{reading} - C_{ATT}$.

The calibration should be carried out at a minimum of three frequencies within the operating frequency band.

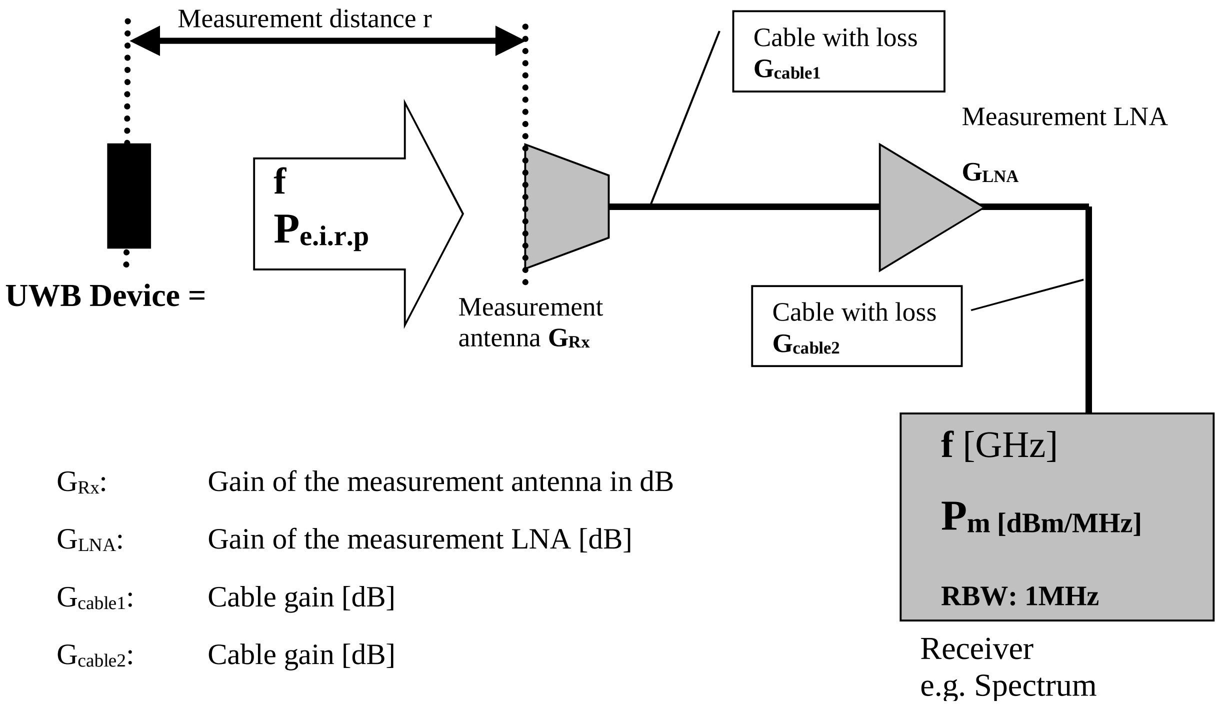


Figure 6: Test set-up for measuring the operating frequency range

Equation (Values [dB]):

$$P_{e.i.r.p} = P_m - G_{Rx} - G_{cable\,1} - G_{cable\,2} - G_{LNA} + 20 \cdot \log\left(\frac{4\pi r}{\lambda}\right) \quad \text{[dBm/MHz]} \qquad (3)$$

The values of the cable gain G_cable1 and G_cable2 are negative.

A test site such as one selected from annex A (i.e. indoor test site or open area test site), which fulfils the requirements of the specified frequency range and undisturbed lowest specified emission levels of this measurement shall be used.

6.4 Conducted measurements

Radiated measurements of transmitted UWB signals meeting the extremely low UWB transmitter emissions limits are very difficult to perform, and it may not be possible to measure such emissions via radiated setups in a reliable manner, EU Project WALTER [i.5].

Thus, conducted measurements are permitted when specific prerequisites are fulfilled:

- Conducted measurements may be taken of equipment provided (permanently or temporarily) with a 50 Ω transmitter output connector.
- The maximum gain characteristics (across all directions) of the integral or dedicated antenna shall be provided as a function of frequency over the complete frequency range of measurement. If accurate measurement of the complete frequency range is impractical, then peak radiated EIRP compared to peak conducted power may be used as a gain value.
- The Voltage Standing Wave Ratio (VSWR) at the 50 Ω connector shall be measured and provided as a function of frequency over the complete frequency range of measurement.
- All ancillary equipment (e.g. amplifiers, cables) used in the measurement shall be calibrated over the complete frequency range of measurement.

In this case, the measured maximum antenna gain of the integral or dedicated antenna and any gains/losses (including those from impedance matching mismatch, see below) due to measurement equipment (e.g. amplifiers, cables) at each measurement frequency should be added to the conducted measurement to compute a radiated emission power level for each frequency which can be compared with the permitted limits given in the relevant standards, as below:

Computed radiated level for frequency *f* =	Measured conducted level at frequency *f* + Measured maximum antenna gain at frequency *f* + Mismatch loss at frequency *f* + (∑ Loss of cable(s) [if any] at frequency *f*) – (∑ Gain of amplifier(s) [if any] at frequency *f*)

The mismatch loss at a particular frequency between the EUT and the measurement equipment can be determined from the measured VSWR at that frequency, as follows:

$$\rho = \frac{\Gamma - 1}{\Gamma + 1} \quad (4)$$

$$L = -10 \log_{10}(1 - \rho^2) \quad (5)$$

where:

$$\Gamma = VSWR \quad (6)$$

$$L = Mismatch\ loss\ in\ dB$$

Note that the above approach assumes that the antenna's gain characteristics have been determined as part of a 50 Ω system. In more complex cases where the antenna has not been characterized as a 50 Ω system, the mismatch calculations may be more involved - in these situations, full calculations and justification for those calculations shall be given in the test report.

7 Test procedures for essential radio test suites

7.1 General

This clause describes methods of measurement for the following transmitter and receiver parameters:

- the operating bandwidth(s);
- the maximum mean power spectral density (e.i.r.p.);

- the maximum peak power (e.i.r.p.);
- other Emissions (OE); and
- the receiver spurious emissions;
- power control;
- detect and avoid;
- duty cycle.

The following methods of measurement shall apply to the testing of stand-alone units and to the equipment configurations identified in clause 5.6. More explanations and descriptions covering the topic of frequency domain measurements can be found in annex A.

For the operating bandwidth, the receiver spurious emissions and the other emissions limits are given in the present document. The maximum mean power spectral density and the maximum peak power limits are given in the relevant harmonised standards.

7.2 Definitions

7.2.1 Introduction

In this clause the needed definitions of the measured parameters of a UWB device are descripted.

7.2.2 Operating bandwidth

The operating bandwidth is the -10 dBc bandwidth(s) of intended UWB signal(s) transmitted by the equipment.

The operating bandwidth shall be inside the permitted range(s) of operation, see related harmonised standards ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13].

7.2.3 Maximum mean power spectral density

The maximum mean power spectral density (specified as e.i.r.p.) of the radio device under test, at a particular frequency, is the average power per unit bandwidth (centred on that frequency) radiated in the direction of the maximum level under the specified conditions of measurement.

7.2.4 Maximum peak power

The maximum peak power specified as e.i.r.p. contained within a 50 MHz bandwidth at the frequency at which the highest mean radiated power occurs, radiated in the direction of the maximum level under the specified conditions of measurement.

7.2.5 Emissions

The emission levels of a UWB device are characterized by the maximum mean spectral power density and by the maximum peak power. The following emission definitions are equally valid for both values (maximum mean spectral density and maximum peak power).

The total measured emissions in transmit mode (TE mean power spectral density, TE peak power) of the equipment are the sum of:

1) UWB Emissions (UE) from the transmitter.
2) Other Emissions (OE) from the transmitter, receiver and other analogue or digital circuitry.

The UWB emissions (UE) are the UWB emissions into free space during the transmit mode operation and is equivalent to the mean power spectral density or peak power depending on the deployed measurement procedure, see clauses 7.4.2 and 7.4.3.

The UWB emissions cannot be measured directly because the Other Emissions (OE) (e.g. narrow-band spurious emissions and the analogue or digital control circuitry emissions) are simultaneously present and emitted.

UE and OE from the equipment for the purpose of the test are defined as the total emissions (TE).

The Other Emissions OE can be determined by disabling the UWB emissions. The UWB device is operating in the transmit mode. The TE is measured and recorded.

In the case that the TE measurement fulfils the limits given for the corresponding UE maximum values within the operating bandwidth given in the relevant harmonised standards (ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13]) TE can be declared as UE.

If the recorded TE emission of the UWB device exceeds the corresponding UE limits within the operating bandwidth given in the relevant harmonised standards (ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13]) the UWB device is then tested with UWB emissions disabled and now the OE is measured and recorded within the operating bandwidth.

For a more detailed procedure see clause 7.3.2.

In some frequency ranges the regulated UWB emissions UE are very low power radio signals, comparable to the power limits of emissions from digital and analogue circuitry. If it can be clearly demonstrated that an emission from the UWB device is not the UWB emission UE limited in the relevant harmonised standards or it can clearly be demonstrated that it is impossible to differentiate between other emissions OE and the UWB emissions UE within the measurement uncertainty the emission shall be considered as other emissions OE.

If after optimization of the measurement set-up, it is not possible to identify any OE or UE emission above the noise floor of the measurement system, it is considered that the UE limits are fulfilled.

7.2.6 Receiver spurious emissions

Receiver spurious emissions are emissions at any frequency when the equipment is in receive mode. Consequently, receiver spurious emission testing applies only when the equipment can work in a receive-only mode or is a receive only device.

7.2.7 Power control

Transmit Power Control (TPC) is a mechanism to be used to ensure an interference mitigation on the aggregate power from a large number of radio devices. The TPC mechanism shall provide the full range from the highest to the lowest power level of the radio device ETSI TR 103 181-2 [i.16].

7.2.8 Detect and avoid

The detect and avoid mechanism is an active mitigation technique for the protection of sensitive potential victim systems in the vicinity of the UWB device based on a sensing approach including an active reduction of the interference potential if required (see ETSI TR 103 181-2 [i.16] and ETSI TS 102 754 [4]).

7.2.9 Duty Cycle

Duty Cycle (DC) is a passive mitigation technique often used in radio regulation and harmonised standards in order to enable spectrum sharing between different radio devices and/or radio applications. A duty cycle regulation is normally stated as a limitation to activity of a transmitter within certain time and power boundaries, e.g. allowing a defined percentage of transmission activity at some predefined levels of transmitted power (see ETSI TR 103 181-2 [i.16]).

7.3 Method of measurements of the UE

7.3.1 Introduction

In this clause the method of measurement for the UE will be given in a stepwise approach.

7.3.2 Emission Measurements steps

7.3.2.1 First step

The Total Emissions (TE) including the UWB Emission (UE) and Other Emissions (OE) shall be measured using the mean power spectral density, see clause 7.4.2 and peak power measurement procedure, see clause 7.4.3. The results shall be recorded. In the case that the TE measurement fulfils the limits given for the corresponding UE maximum values within the operating bandwidth given in the relevant harmonised standard TE can be declared as UE. If the recorded TE emission of the UWB device exceeds the corresponding UE limits within the operating bandwidth given in the relevant harmonised standard the UE shall be evaluated using second step, see clause 7.3.2.2.

The principle of this measurement process is illustrated for such a case in figure 7.

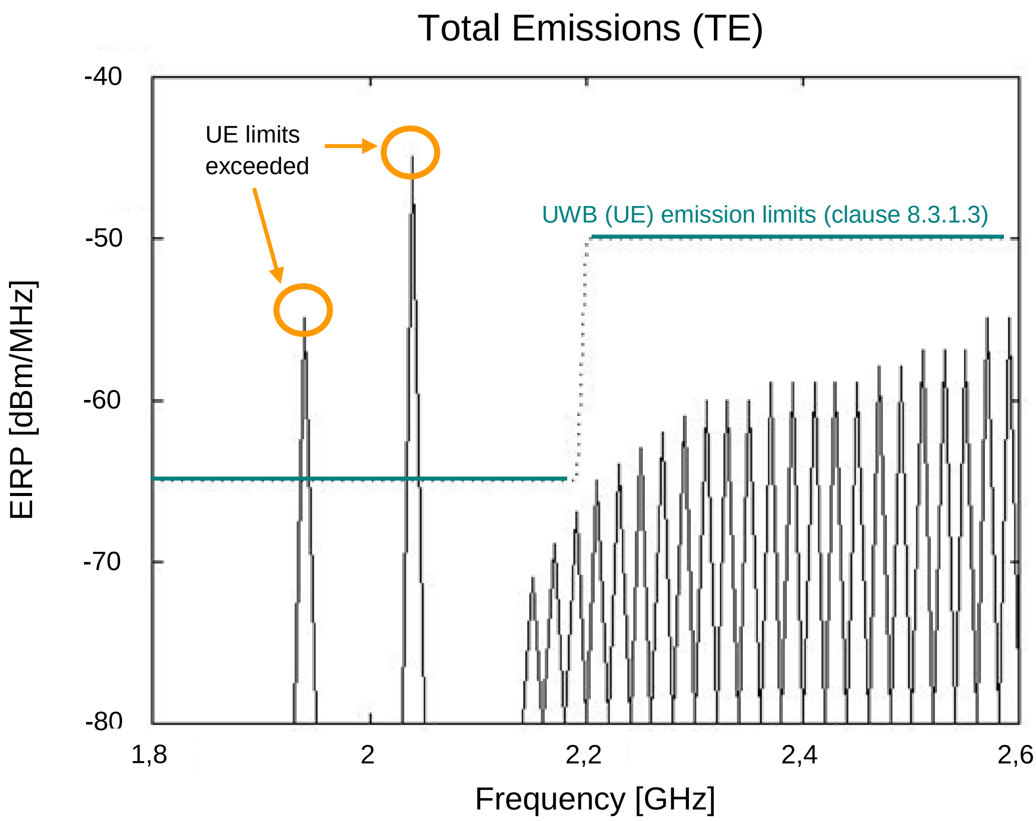


Figure 7: Example for a TE measurement in the frequency range 1,8 GHz to 2,6 GHz

7.3.2.2 Second step

The second step is mandatory if the recorded TE emission of the UWB device exceeds the corresponding UE limits within the operating bandwidth given in the relevant harmonised standard.

For the frequency ranges, where the Total Emissions (TE) exceed the limits of the UE limits given in the relevant harmonised standard, the Other Emissions (OE) shall be measured by disabling the UWB transmitter, or removing the antenna and terminating the transmitter. The rest of the UWB device shall be set into the transmit mode.

Emissions that are present in OE as well as in TE with the similar amplitude within the measurement uncertainty are considered to be OE. This OE measurement shall be performed using the measurement procedure given in clauses 7.4.2 and 7.4.3.

The principle of this measurement process is illustrated for such a case in figure 8.

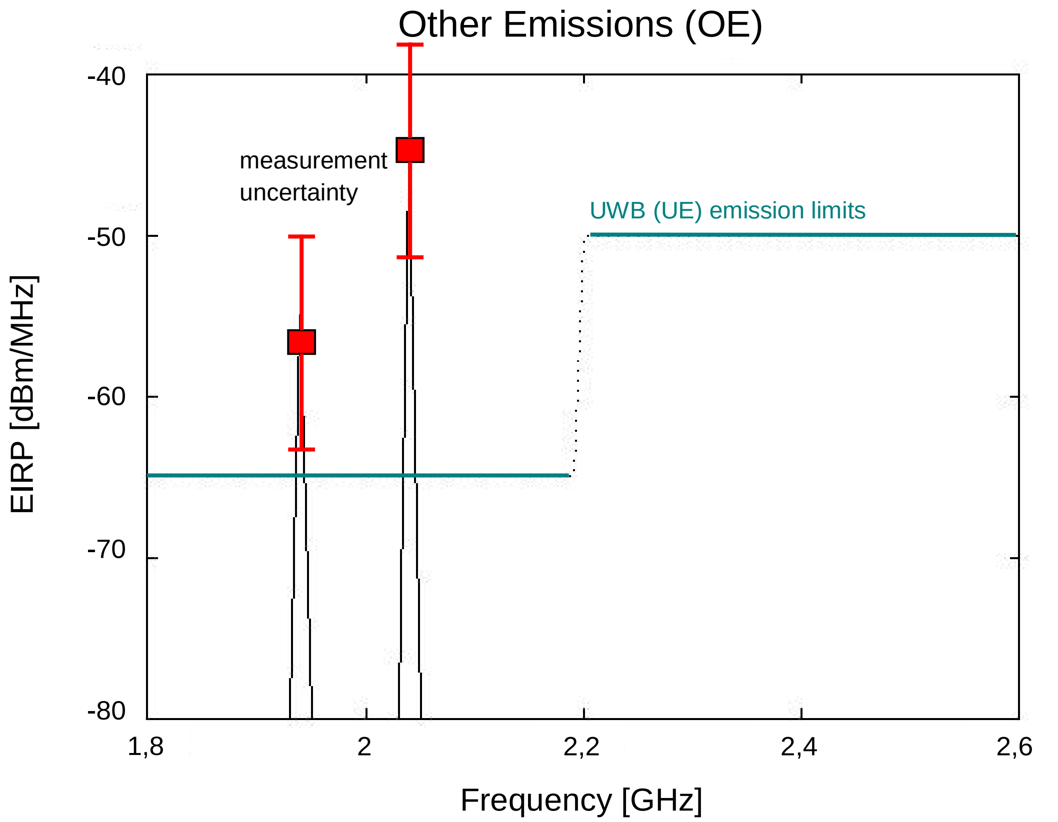


Figure 8: Example for a OE measurement in the frequency range 1,8 GHz to 2,6 GHz

The recorded OE mean power spectral density measurement results can be used as inputs to the EMC homologation according to ETSI EN 301 489-33 [i.19].

7.4 Detailed measurement procedure

7.4.1 Introduction

In this clause the detailed measurement procedures and settings for the measurements of the operating bandwidth, the mean power spectral density and the peak power will be presented. The measurement procedure for the mean power spectral density and the peak power are used for the methods of measurement given under clause 7.3.

7.4.2 Operating bandwidth

Using the recorded results from the mean power spectral density measurements steps given in clause 7.4.3 the operating bandwidth of the equipment shall be evaluated.

The bandwidth procedure shall be as follows:

- use the recorded results of the TE and OE to specify the UE over the complete frequency range given in the relevant harmonised standard;
- find the lowest frequency (f_L) below the operating bandwidth at which UE decreases to the level defined in clause 7.2.2. This frequency shall be recorded;

- find the highest frequency (f_H) at which the UE decreases to the level defined in clause 7.2.2. This frequency shall be recorded;
- find the frequency (f_M) at which the highest emission level occurs, this frequency shall be recorded and used for the peak power measurement of clause 7.4.4;
- the difference between the lowest frequency (f_L) and highest frequency (f_H) is the operating bandwidth (OBW) which shall be recorded:

$$OBW = f_H - f_L \quad (7)$$

- the addition of the lowest frequency and highest frequency divided by two is the centre frequency (F_C) which shall be recorded:

$$F_C = (f_L + f_H)/2 \quad (8)$$

NOTE: This evaluation steps are to be repeated for each operating bandwidth as declared by the manufacturer.

The results for the frequency ranges obtained shall be compared to the limits defined in the related harmonised standards ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13].

7.4.3 Mean power spectral density measurements

7.4.3.1 General on mean power spectral density measurement

The maximum mean power spectral density shall be determined and recorded.

The following measurements shall be applied to the combination(s) of the radio device and its intended antenna(s). In the case that the RF power level is user adjustable, all measurements shall be made with the highest power level available to the user for that combination.

Measurements shall be carried out over the frequency ranges as shown in the relevant harmonised standards.

There are three different measurement methods available, see figure 9.

For UWB devices which are intended to operate at a mean power spectral density of -65 dBm/MHz or less, the test shall be performed using a conducted test procedure as given in clause 6.4. In all other cases, the test shall be performed using a radiated test procedure as specified in clause 6.3.

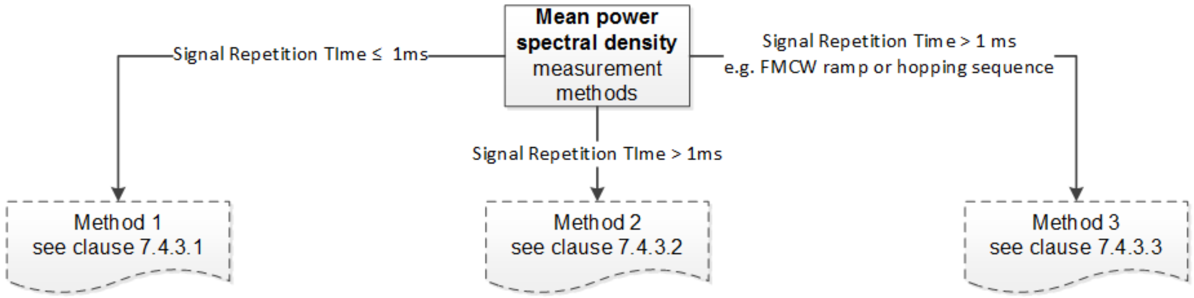


Figure 9: Overview mean power spectral density measurement methods

See clause 5.4 for the test conditions.

Definition of signal repetition time: The signal repetition time defines a time frame that is continuously repeated. Each time frame consists of the same signal waveform. This ensures that the same mean power spectral density is measured independently of which one of the time frames is captures by the measurement instrument. Even if the captured time frame is shifted in time (what will happen for real measurements without synchronization) the same result will be measured.

EXAMPLES: For signal repetition time:

EXAMPLE 1: Stepped-frequency / frequency hopping signal, see figure 10.

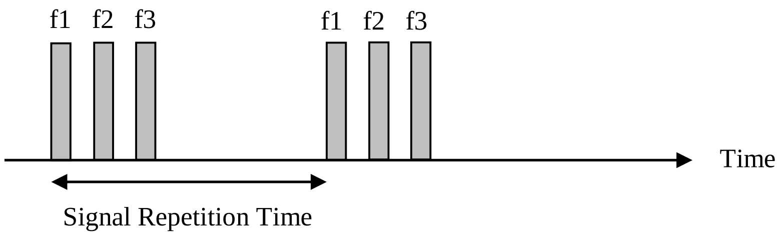


Figure 10: Example for signal repetition time of a frequency-hopping signal

EXAMPLE 2: FMCW signal, see figure 11.

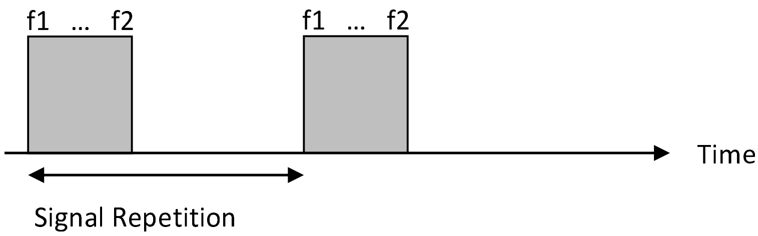


Figure 11: Example for signal repetition time of a FMCW signal

EXAMPLE 3: Any other signals with frequency and/or amplitude variations over time, see figure 12.

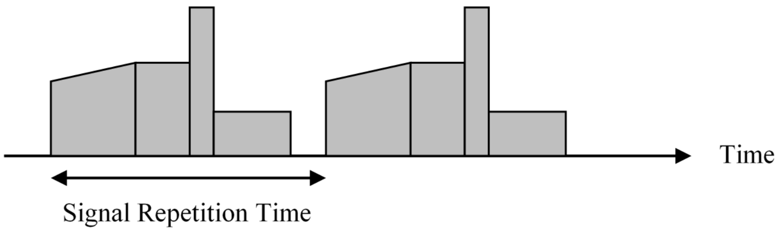


Figure 12: Example for signal repetition time of a generic signal

7.4.3.2 Mean power spectral density measurement: Method 1

When measuring maximum mean power spectral density from the radio device under test, the spectrum analyser or equivalent shall be configured as follows unless otherwise stated (flowchart see figure 13):

Resolution Bandwidth: 1 MHz

Video Bandwidth: Not less than the resolution bandwidth

Detector Mode: RMS Average Power

Display Mode: Max. Hold

Average Time: 1 ms or less per sweep point

NOTE: "Average Time" may not be an explicit setting. In some cases it may be determined by setting the number of measurement points and the time taken for a sweep.

Frequency Span: Equal to or less than the number of sweep points multiplied by the resolution bandwidth, preferably less than half as much.

Sweep Time: Time for spectrum analyser sweep (over one span). Appropriate settings shall be calculated with the following formulas:

$$Number\ of\ Measurement\ Points = \frac{Frequency\ Span}{RBW} \quad (9)$$

$$Sweep\ Time\ (SWT) \leq Number\ of\ Measurement\ Points\ \times 1\ ms \quad (10)$$

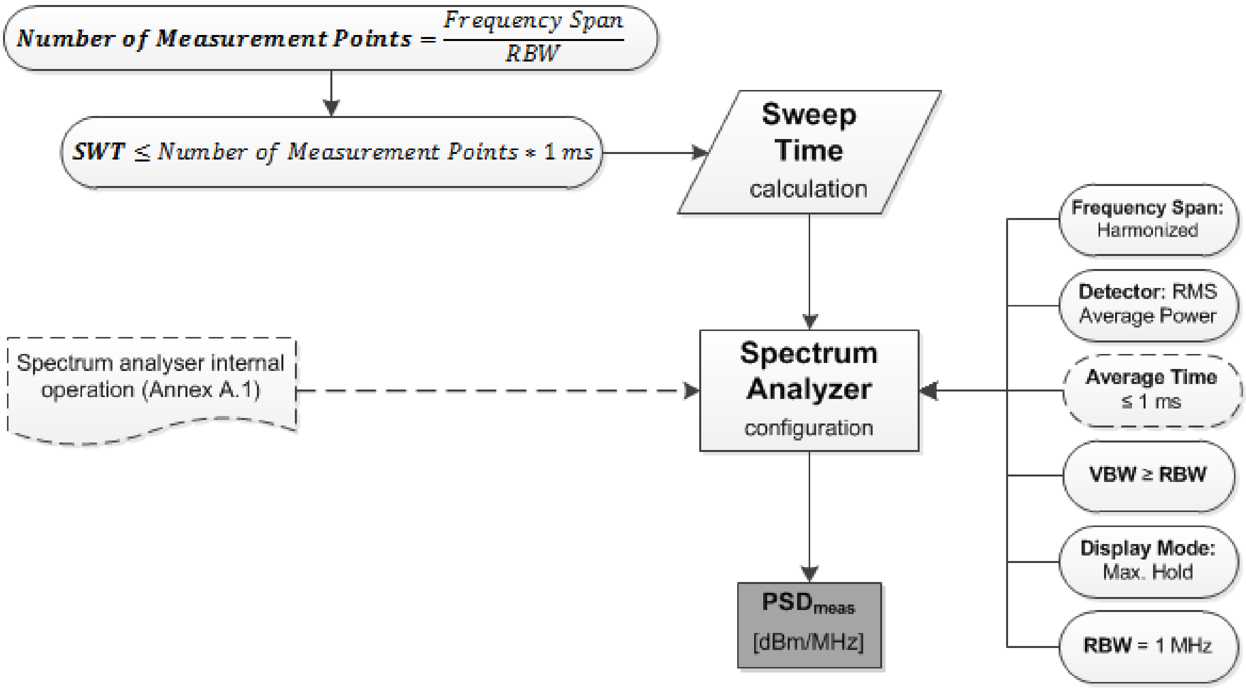
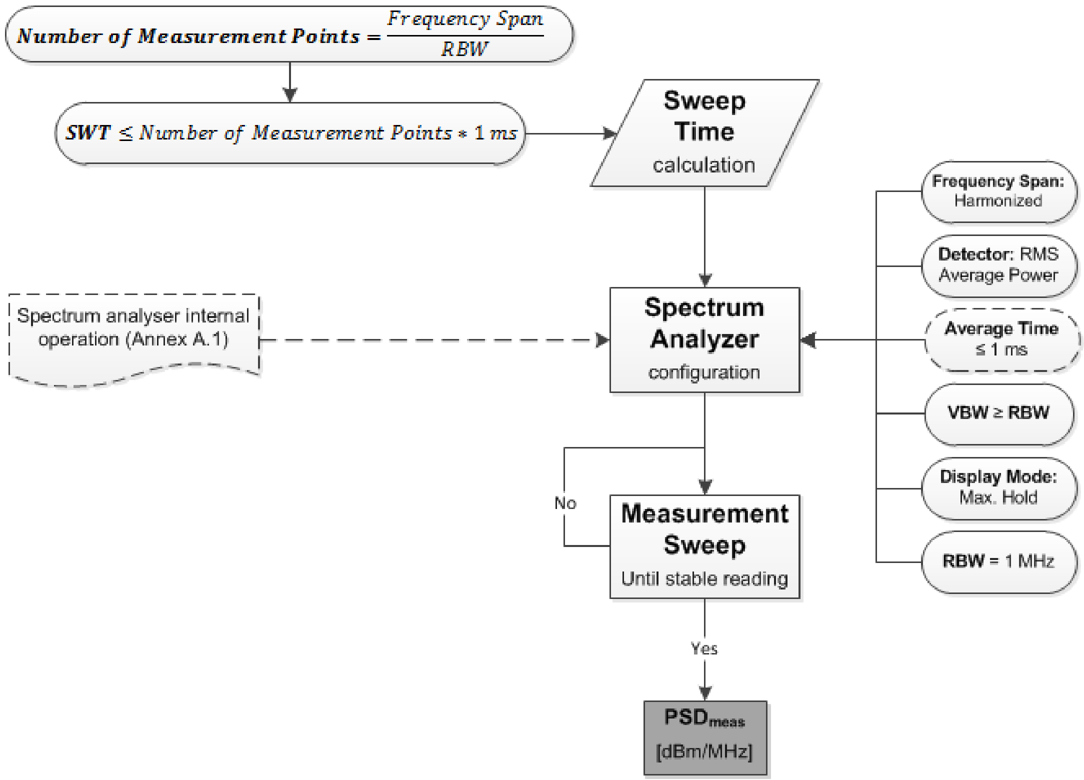


Figure 13: Test Procedure for Mean Power Spectral Density, Method 1

The measurement results shall be determined and recorded over the specified frequency ranges given in the relevant harmonised standards.

7.4.3.3 Mean power spectral density measurement: Method 2

Follow the procedure described under method 1. Wait for each measurement until the reading in the display is stable. For a flowchart, see figure 14.



NOTE: As the maximum averaging time is 1 ms, in case of signal with a repetition rate greater than 1 ms the initial measurement sweep will not give the final result. Therefore several sweeps with display mode "max hold" are necessary to get the final result. As the number of sweeps depends on the timing between signal and spectrum analyser sweep the number of sweeps necessary cannot be predicted. Therefore this method should only be used with an operator. It is the responsibility of the operator that the final measurement result was a stable reading.

Figure 14: Test Procedure for Mean Power Spectral Density, Method 2

7.4.3.4 Mean power spectral density measurement: Method 3

When measuring maximum mean power spectral density from the radio device under test, the spectrum analyser or equivalent shall be configured as follows unless otherwise stated (flowchart, see figure 15):

Resolution Bandwidth: 1 MHz

Video Bandwidth: Not less than the resolution bandwidth

Detector Mode: RMS Average Power

Display Mode: Max. Hold

Average Time: > 1 ms per sweep point

NOTE: "Average Time" may not be an explicit setting. In some cases it may be determined by setting the number of measurement points and the time taken for a sweep.

Frequency Span: Equal to or less than the number of sweep points multiplied by the resolution bandwidth, preferably less than half as much.

Sweep Time: Time for spectrum analyser sweep (over one span). Appropriate settings shall be calculated with the following formulas.

$$Sweep\ Time\ (SWT) \geq \text{Signal Repetition Time} \times \frac{Frequency\ Span}{RBW} \quad (11)$$

Signal Repetition Time: UWB signal time, e.g. FMCW ramp time or hopping sequence

EXAMPLES: See clause 7.4.3.

Based on the longer averaging time than 1 ms, there is a need to correct the measured and recorded values with the following formulas:

$$Sweep\ Time\ Per\ Measurement\ Ppoint = \frac{Sweep\ Time}{Measurement\ Points} \qquad (12)$$

$$Correction\ [db] = 10\log\left(\frac{Sweep\ Time\ for\ Measurement\ Point}{1\ ms}\right) \qquad (13)$$

$$PSD_{real}\left[\frac{dBm}{MHz}\right] = PSD_{meas}\left[\frac{dBm}{MHz}\right] + Correction[dB] \qquad (14)$$

The radiation measured values (PSD_{meas}) shall be corrected with the calculated correction factor (PSD_{real}) and has to comply with the related limits in the relevant harmonised standard.

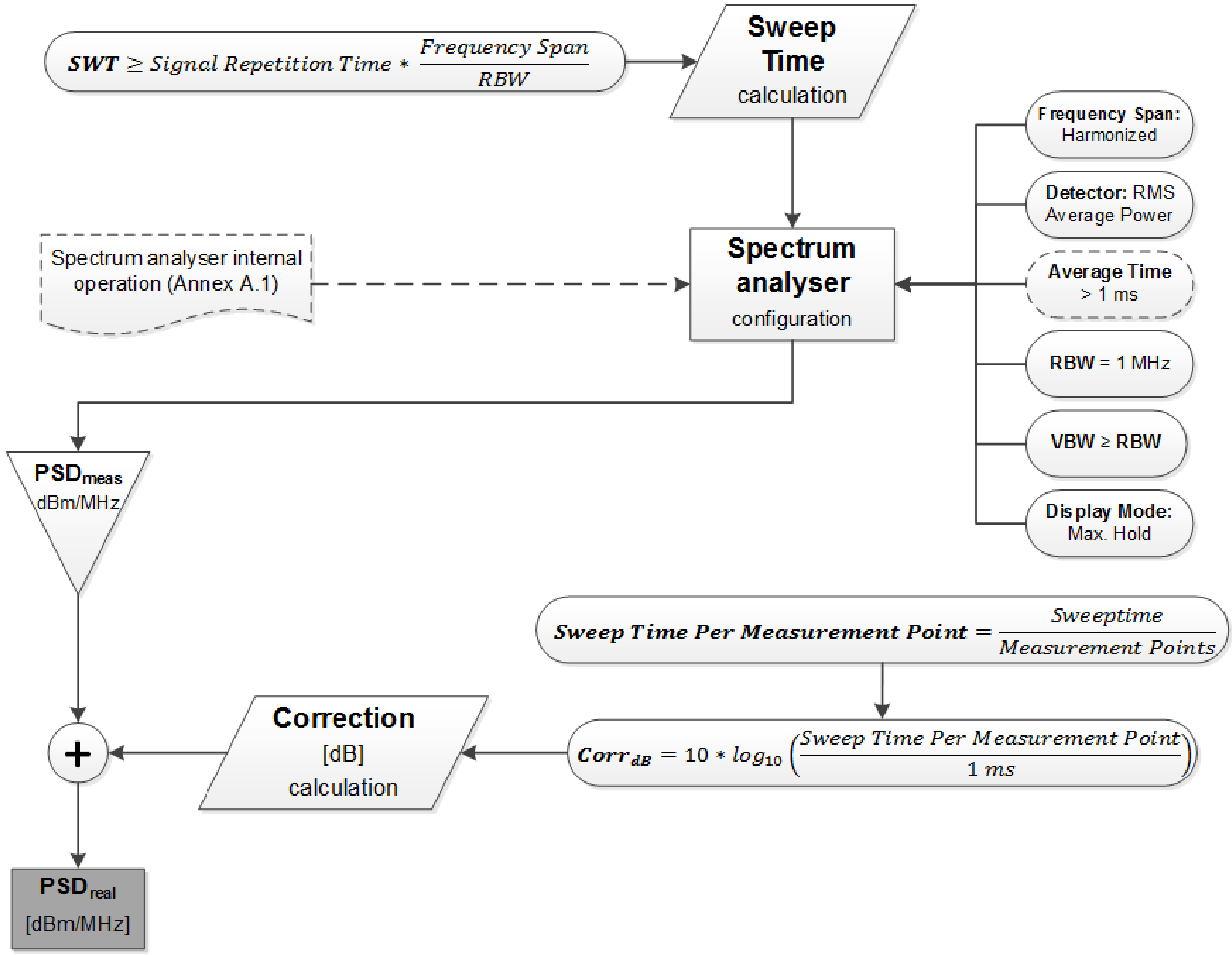


Figure 15: Test Procedure for Mean Power Spectral Density, Method 3

The measurement results shall be determined and recorded over the specified frequency ranges given in the relevant harmonised standards.

7.4.4 Peak power measurements

7.4.4.1 General on peak power measurement

For the peak power spectral density measurements there are three different measurement methods available. Some methods may be restricted to certain signal characteristics.

The different methods may overestimate the peak power differently dependent on the signal characteristics, see figure 16.

For all UWB modulations the maximum peak power (e.i.r.p.) shall be measured at the frequency of the maximum mean power spectral density as recorded under clause 7.4.3. Radiated measurements shall be made using one of the techniques presented in clause 6.3.5. Measurements shall be carried out over the frequency range from 30 MHz to 18 GHz.

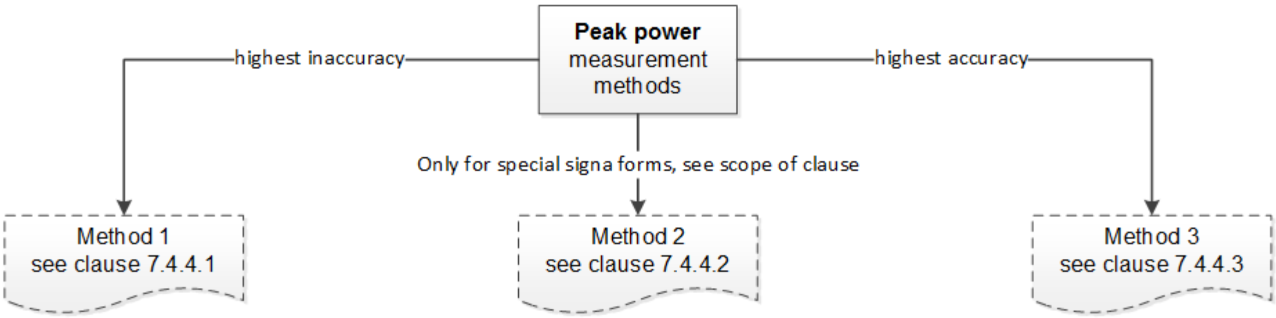


Figure 16: Overview peak power measurement methods

7.4.4.2 Peak power measurement: Method 1

This method gives the maximum overestimation for the peak power result of all presented methods. However, it is the simplest and most common one of all methods.

When measuring maximum peak power from the radio device under test, the spectrum analyser used should be configured as follows (for a flowchart, see figure 17):

Resolution Bandwidth: Bandwidth equal or greater than 3 MHz and less or equal than 50 MHz

NOTE: It is recommended to use the highest available bandwidth for the signal to be measured because choosing a lower bandwidth could lead to an overestimate of the peak power.

Video Bandwidth: Not less than the resolution bandwidth

Detector Mode: Peak

Display Mode: Max. Hold

- Measurements shall be continued with the transmitter emitting the normal signal (see clause 5.2) until the displayed trace no longer changes.

When measurement are performed using a lower bandwidth then 50 MHz a correction factor shall to be used to calculate the peak power limits given in the relevant harmonised standards.

$$\boldsymbol{Corr_{dB}} = 20 \times log_{10}\left(\frac{50\ MHz}{RBW_{used}}\right) \quad (15)$$

For a more detailed discussion, please refer to clause A.3.

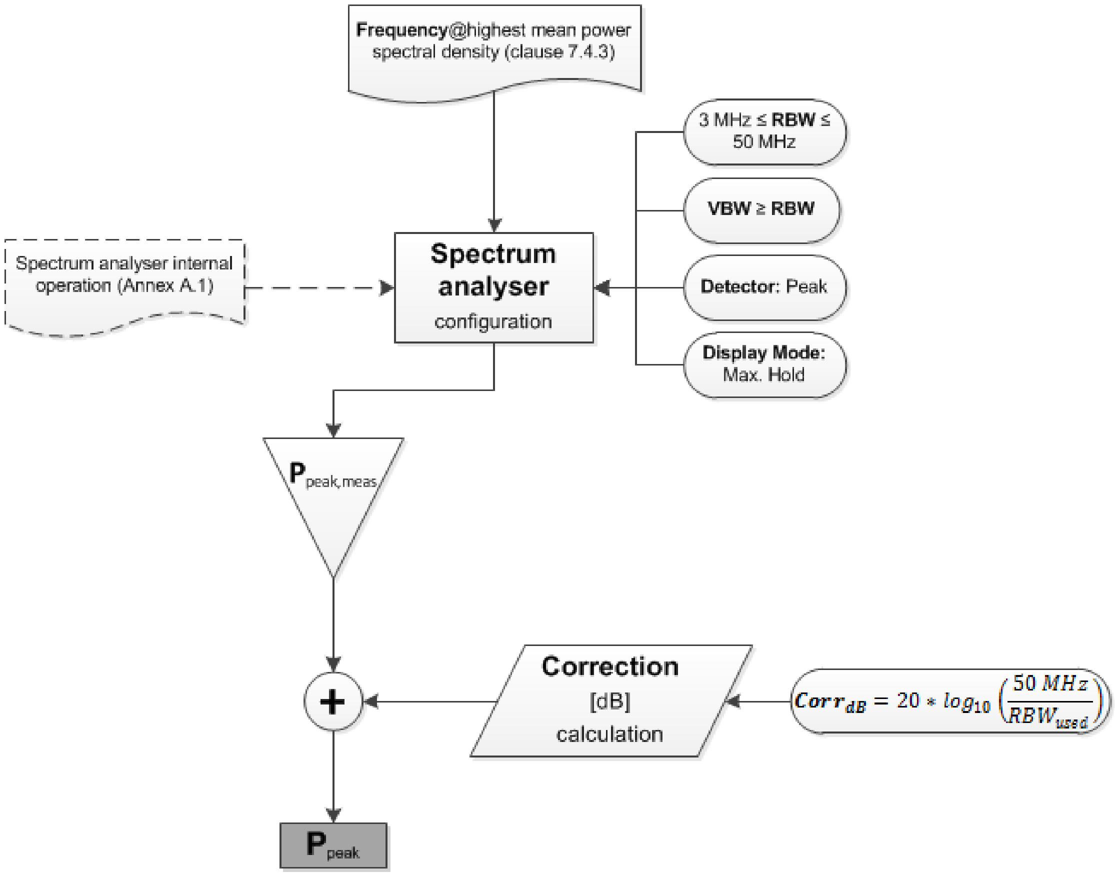


Figure 17: Test Procedure for Peak Power Measurement Method 1

7.4.4.3 Peak power measurement: Method 2

Restriction:

This method can only be applied, if there is only one spectral line in 50 MHz bandwidth at one time and the bandwidth of the spectral line is smaller than the smallest RBW used for the measurements.

EXAMPLES:

- Pulse signal with PRF > 50 MHz and bandwidth of spectral lines < smallest RBW used for measurement.
- Stepped-frequency signal with bandwidth of spectral lines < smallest RBW used for measurement. The distance of the spectral lines may be smaller than 50 MHz, if only one spectral line is emitted at one time.

When measuring maximum peak power from the radio device under test, the spectrum analyser used should be configured as follows (flowchart, see figure 18):

Resolution Bandwidth: Maximum available bandwidth equal or greater than 3 MHz and less or equal 50 MHz

Video Bandwidth: Not less than the resolution bandwidth

Detector Mode: Peak

Display Mode: Max. Hold

- Measurements shall be continued with the transmitter emitting the normal signal (see clause 5.2) until the displayed trace no longer changes.
- The following measurement steps are necessary to perform to get proper extrapolation results:
  - Measure with maximum available resolution bandwidth $RBW_{used,1}$ to get the resulting peak power $P_{peak,1}$.

- Measure with smaller resolution bandwidth $RBW_{used,2}$ to get the resulting peak power $P_{peak,2}$.
- Extrapolate $P_{peak,1}$ and $P_{peak,2}$ to estimate the final peak power $P_{peak,final}$ at a RBW of 50 MHz.

NOTE: The smaller the second resolution bandwidth $RBW_{used,2}$ is chosen, the bigger the overestimation of the final peak power $P_{peak,final}$ will be.

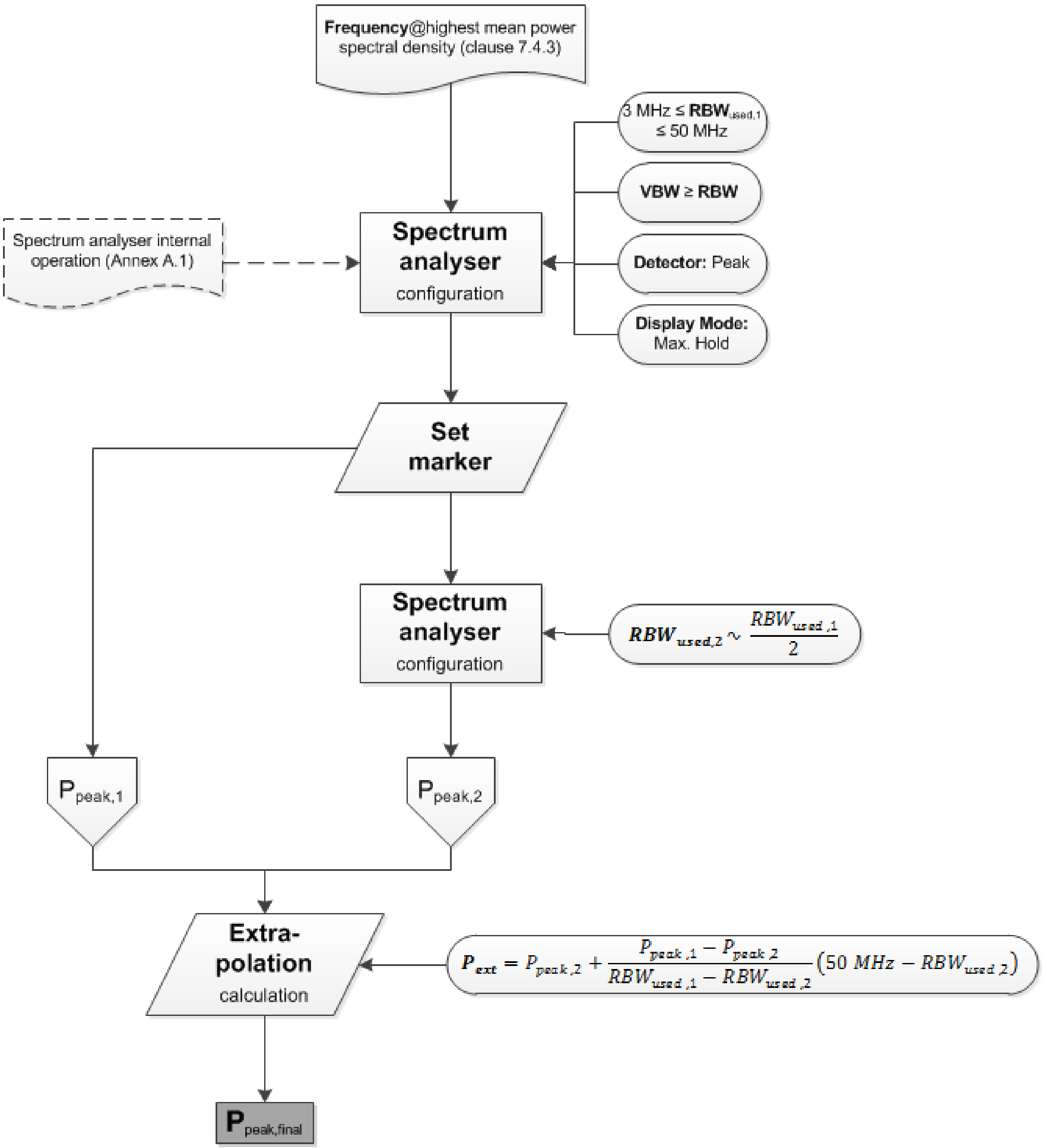


Figure 18: Test Procedure for Peak Power Measurement, Method 2

7.4.4.4 Peak power measurement: Method 3

7.4.4.4.1 Description

The proposed procedure is applicable to all UWB signal types. It provides more accurate results compared to the frequency domain measurement in case a correction factor needs to be applied for frequency domain measurements with RBW smaller than 50 MHz. More information is provided in ETSI TR 103 365 [i.14].

The test procedure can be summarized as follows:

- Capture the time domain waveform with a high speed sampling oscilloscope.
- Apply a Gaussian filter to the captured waveform.
- Calculate the power for each sample of the filter output.
- Search for the maximum power.
- Compare with the limit in the relevant harmonised standard.

Details of the measurement procedure can be found in the clauses 7.4.4.4.2 and 7.4.4.4.3.

7.4.4.4.2 Signal acquisition

Oscilloscope specification and settings:

- Input bandwidth > $f_{H.}$
- Sampling frequency > 2 × $f_{H.}$
- Dynamic range set to the maximum value that still allows complete display of the waveform without clipping.

Where, in order to satisfy the Nyquist criterion, f_H is the highest frequency as determined in clause 7.4.2, i.e. the upper boundary to the operating bandwidth.

Length of data acquisition and storage:

A sufficiently long portion of the signal needs to be captured to ensure that the peak power occurs within the acquired portion. Often, the position of the signals causing the maximum peak power will be known to the manufacturer, who can provide a dedicated test peak power mode to speed up the measurements and post-processing.

7.4.4.4.3 Post-Processing

The captured time domain signal needs to be filtered with the resolution bandwidth filter whose time domain impulse response is defined in the formulas (16) to (22). This assumes that the convolution will be performed in the time domain. Chapter 3 of Recommendation ITU-R SM.1754 [i.3] details an equivalent frequency domain convolution method.

As defined in clause 7.4.4, the filter shall be centred on the frequency of the maximum mean power spectral density.

Definition of the resolution bandwidth filter:

The resolution bandwidth filter shall have a Gaussian impulse response. The standard deviation σ of the Gaussian is related to the desired -3 dB resolution bandwidth *RBW* via:

$$\sigma = \frac{\sqrt{\ln(2)}}{\pi \times RBW} \qquad (16)$$

Assuming the resolution bandwidth *RBW* is specified in Hz, the unit of the standard deviation is seconds. For a resolution bandwidth of 50 MHz, the resulting standard deviation is 5,3 ns.

The baseband filter coefficients are then generated using:

$$f_{BB}[t] = \frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{t^2}{2\sigma^2}\right) \qquad (17)$$

where the (discrete) time variable *t* ranges from -6 σ to +6 σ in order to truncate the filter response while containing the significant part of the response.

The passband equivalent of the filter, centred on a frequency f_M, (see clause 7.4.2) is obtained via:

$$f[t] = f_{BB}[t]\cos(2\pi f_M t) \tag{18}$$

To maintain the power of the passband signal, the filter is normalized by the gain G of the filter at the centre frequency f_M. Therefore, the gain of the filter shall be calculated using:

$$G = \sum f[t]\exp(-j2\pi f_M t) \tag{19}$$

and the normalized filter coefficients are obtained by dividing $f[t]$ by $|G|$.

To verify the filter, it is useful to note that the equivalent noise bandwidth of a Gaussian filter equals 1,064 times its -3 dB bandwidth.

Maximum peak power determination:

The result of the post-processing is a filtered waveform with a peak amplitude $V_{peak,filtered}$. The corresponding instantaneous power is calculated using:

$$P_{peak,filtered} = \frac{V^2_{peak,filtered}}{2Z_0} \tag{20}$$

where Z_0 is the characteristic impedance of the oscilloscope.

The maximum peak power is then simply:

$$P_{peak,\max} = \max\left(P_{peak,filtered}\right) \tag{21}$$

7.4.4.4.4 Limit

The limit on the maximum peak power is defined in the relevant harmonised standard.

Assuming $V_{peak,filtered}$ is recorded in volts, $P_{peak,max}$ is in watts. It can be converted in dBm using:

$$30 + 10\log_{10}\left(P_{peak,\max}\right) \tag{22}$$

for comparison with the limit defined in the relevant harmonised standard (ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13]).

7.4.5 Receiver spurious emissions

See clause 5.4 for the test conditions.

The level of spurious emissions radiated by cabinet and antenna shall be measured.

The following method of measurement shall apply:

- Above 1 GHz a full anechoic test site as described in clause 6.3.2.2 is preferred for measurement. The spurious emissions as defined in clause 7.2.6 shall be measured and recorded.
- Where an anechoic chamber is not available, the test site described in clause 6.3.2.3 may be used with suitable anechoic material placed on the floor of the chamber.
- Below 1 GHz the method and site characteristics described in Recommendation ITU-R SM 329-10 [i.7] shall be used (see clause 6.3.2.3). The spurious emissions as defined in clause 7.2.6 shall be measured and recorded.

The measurement procedure shall be as follows:

- With the equipment in the receive mode, the applicable spectrum shall be searched for emissions that exceed the limit values given in the relevant standard or that come to within 6 dB below the limit values given in the relevant standard. Each occurrence shall be recorded.

Measurements shall be carried out over the frequency range from 30 MHz to 40 GHz.

The measurements shall be performed only under the following conditions:

- The equipment shall be tested in the standby/receive mode among frequencies as defined in clause 7.3.1.

Where these measurements are made with a spectrum analyser, the following settings shall be used for narrowband emissions:

- resolution BW: 100 kHz for final measurements; wider resolution bandwidths may be used during searches;
- video BW: 3 × resolution BW;
- detector mode: positive peak;
- averaging: off;
- span: preferably, less than or equal to 100 MHz; wider spans may be used as long as the number of scan points on the spectrum analyser is no less than (span / resolution BW);
- amplitude: adjust for middle of the instrument's range;
- sweep time: auto.

For measuring emissions that exceed the level of 6 dB below the applicable limit, the resolution bandwidth shall be switched to 30 kHz and the span shall be adjusted accordingly. If the level does not change by more than 2 dB, it is a narrowband emission; the observed value shall be recorded. If the level changes by more than 2 dB, the emission is a wideband emission and its level shall be measured and recorded. The measurement result for wideband spurious emissions has to be recalculated for 1 MHz bandwidth.

The results obtained shall be compared to the limits given in the harmonised standard in order to prove compliance with the requirement.

7.4.6 Power control

TPC tests to assess the highest and lowest power spectral density level shall be measured using a radiated test procedure (see clause 7.4.3).

7.4.7 Test procedures for detect and avoid mechanisms

7.4.7.1 Introduction

In the present clause the test procedure for the DAA test is depicted. The UWB DAA radio device under test shall be verified under normal operational conditions.

The DAA test is split into two main test conditions:

- start-up test with and without victim test signal; and
- in-operation test.

The start-up test verifies the operation of the UWB DAA radio device during the initial start-up when the DAA UWB radio device intends to operate directly in a non NIM. Thus the UWB DAA radio device need to be set in an operational condition in which this is guaranteed. The test verifies that the UWB DAA radio device respects the defined *Minimum Initial Channel availability Check Time*.

The in-operation test is intended to verify the dynamic behaviour of the UWB DAA radio device under test. During this test the UWB DAA radio device under test shall operate in a normal dynamic operational mode. The manufacturer has to declare this normal operational mode taking into account the zone model given in ETSI TS 102 754 [4].

The radiated test configuration is shown in figure 19 and the conducted test configuration is shown in figure 20.

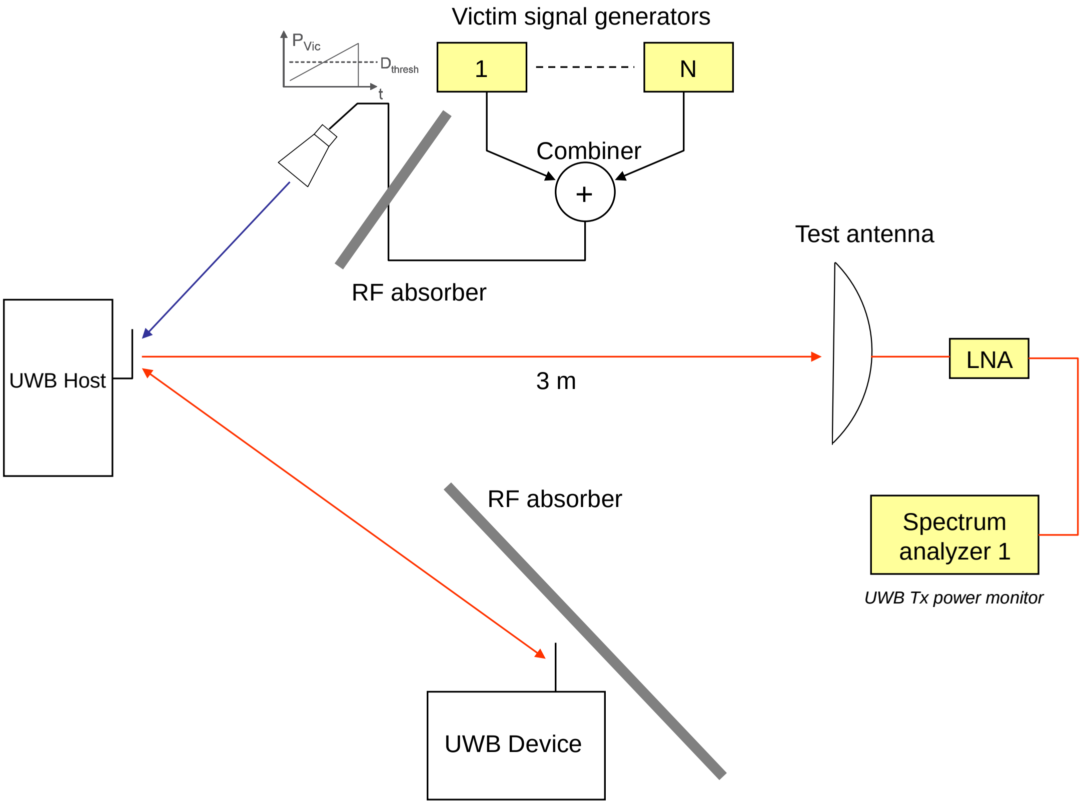


Figure 19: Example Setup for radiated DAA measurements

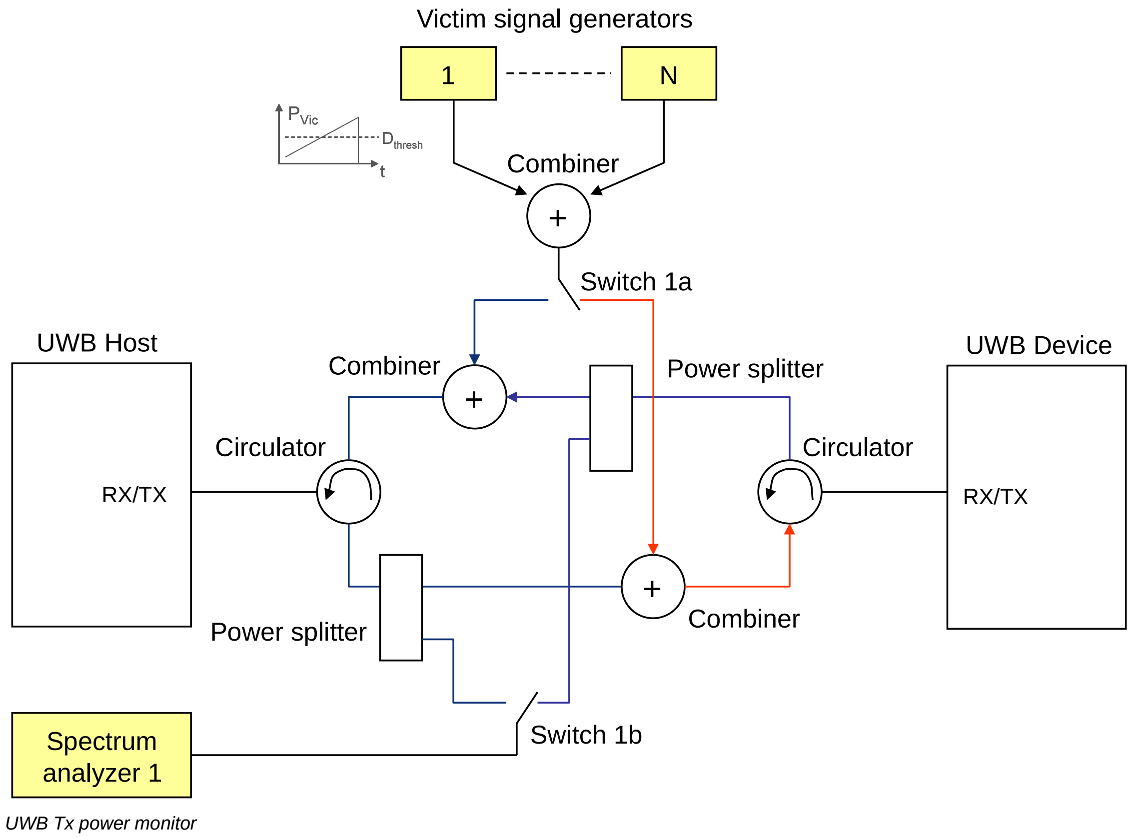


Figure 20: Example Setup for conducted DAA measurements

7.4.7.2 Initial start-up test

7.4.7.2.1 Start-up procedure

The clauses below define the procedure to verify the *Minimum Initial Channel Availability Check* by ensuring that the UWB DAA radio device is capable of detecting victim system signals at the beginning and at the end of the *Minimum Channel Availability Check Time*. Furthermore, one initial test shall guarantee that the UWB radio device does not switch into a NIM operation before the end of the *Minimum Initial Channel Availability Check time*. $T_{avail\_time\_min}$.

7.4.7.2.2 Test without a victim test signal during the *Minimum Initial Channel Availability Check Time*, $T_{avail\_time\_min}$

Summary:

Verify the UWB DAA radio device will not start transmitting in a non NIM operation before the end of the *Minimum Initial Channel Availability Check Time* when no victim test signal is present. This is illustrated for a radiolocation signal in figure 21.

Pre-test Condition:

- UWB radio device supporting DAA.
- UWB radio device switched off.

Test sequence:

a) The UWB DAA radio device will be switched off. No signal generator is connected to the test setup or the signal generator is switched off.

b) The UWB DAA radio device is powered on at T_0. T_1 denotes the instant when the UWB DAA radio device has completed its power-up sequence (T_{power_up}), enters into the operational mode defined in the relevant harmonised standard and is ready to start the victim signal detection.

CON-1: The UWB DAA radio device shall not switch into a mode other than a NIM before the end of $T_1 + T_{avail\_time\_min}$ after switch on of the radio device, where the NIM operation is either the LDC mode or the power level defined in relevant harmonised standards for the relevant victim band.

NOTE: Additional verification may be needed to define T_1 in case it is not exactly known or indicated by the UWB DAA radio device.

CON-2: A timing trace or description of the observed timing and behaviour of the UWB DAA radio device shall be recorded.

c) Repeat a) and b) for *n* times in a row. The values for *n* shall be defined in the relevant harmonised standard.

CON-3: CON-1 and CON-2 shall be fulfilled in all *n* tests. If one failure occurs go to d). For more than one failure the test has not been passed.

d) Repeat a) and b) for *m* times in a row. The values for *m* shall be defined in the relevant harmonised standard.

CON-4: CON-1 and CON-2 shall be fulfilled in all *m* tests.

e) End of test.

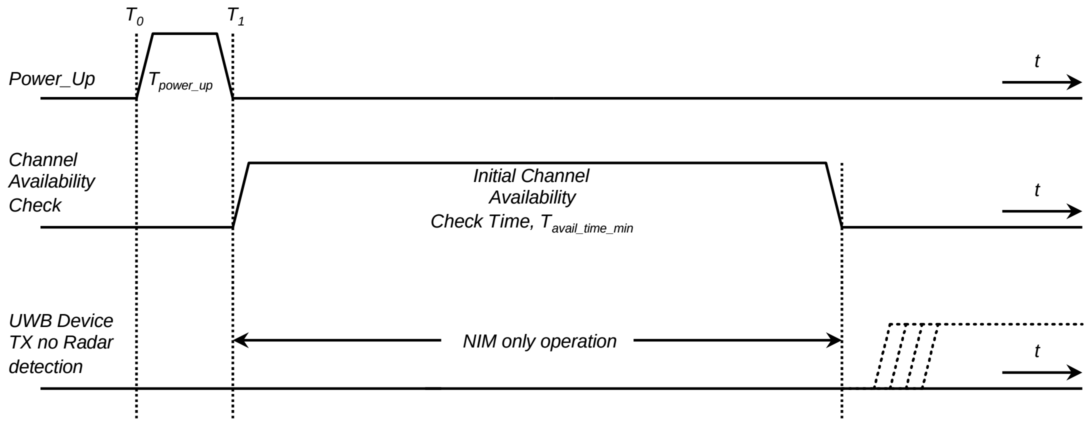


Figure 21: Example of timing for a radiolocation testing of the Minimum Initial Channel Availability Check Time Tavail_time, UWB DAA devise intent to operate in a non NIM mode

7.4.7.2.3 Test with a victim test signal at the beginning of the *Minimum Initial Channel Availability Check Time, T*$_{avail\_time\_min}$

Summary:

Verify the victim signal detection and avoidance capability for the selected UWB operational frequency when a victim signal occurs at the beginning of the *Minimum Initial Channel Availability Check Time*. This is illustrated for a radio location victim signal in figure 22.

Pre-test Condition:

- UWB radio device supporting DAA.
- UWB radio device switched off.

Test Sequence:

a) The UWB DAA radio device will be switched off. The signal generator used to generate the test patterns defined in the relevant harmonised standard will be connected to an antenna of suitable characteristics to permit the UWB DAA radio device to be illuminated with a field equal to the threshold detection limit or connected to the corresponding connectors in the case of a conducted measurement setup.

b) The UWB DAA radio device is powered on at T_0. T_1 denotes the instant when the UWB DAA radio device has completed its power-up sequence (T_{power_up}), enters into the operational mode defined in the relevant harmonised standard and is ready to start the victim signal detection.

c) The victim system test signal will be switched on at T_0 with the test pattern, timing behaviour and power levels in accordance with the relevant harmonised standard.

CON-1: The *Minimum initial Channel Availability Check* is expected to commence at T_1 and is expected to end no sooner than $T_1 + T_{avail\_time\_min}$ unless a victim signal is detected sooner.

NOTE: Additional verification may be needed to define T_1 in case it is not exactly known or indicated by the UWB DAA radio device.

CON-2: It shall be recorded if the victim test signal was detected. This can be done by verifying that the UWB DAA radio device is switched into an avoid operation corresponding to the investigated threshold level in the relevant operational band or stays in a corresponding NIM operation. The following avoid operation parameter shall be verified:

- *default avoidance bandwidth* for the victim system service identified and where relevant;
- *optional avoidance mechanisms* identified by the manufacturer for the victim system service identified;
- LDC operational parameter if applicable.

CON-3: A timing trace or description of the observed timing and behaviour of the UWB DAA radio device shall be recorded for each avoidance mechanism.

d) Repeat a) to c) for *n* times in a row. The values for *n* shall be defined in the relevant harmonised standard.

CON-4: CON-1, CON-2 and CON-3 shall be fulfilled in all *n* tests. If CON-3 is fulfilled go to f). If one failure occurs go to e). For more than one failure the test has not been passed.

e) Repeat a) to c) for *m* times in a row. The values for *m* shall be defined in the relevant harmonised standard.

CON-5: CON-1, CON-2 and CON-3 shall be fulfilled in all *m* tests.

f) Repeat b) to e) for each of the relevant victim test signals for the UWB operational frequency range as defined in the relevant harmonised standard at a level of 10 dB above the defined threshold level as defined in the relevant harmonised standard and at exactly the threshold levels as defined in the relevant harmonised standard.

CON-6: A timing trace or description of the observed timing and behaviour of the UWB DAA radio device shall be recorded.

g) Repeat c) to f) for each of the identified victim system operational frequency.

h) If the UWB radio device has optional avoidance mechanisms, repeat a) to g) for each optional avoidance mechanism identified.

i) If the UWB radio devices have Victim Service Identification implemented, re-establish the victim service as an Up-link down-link pair as identified in the relevant harmonised standard and repeat steps a) to h) for each of the associated victim service identification avoidance mechanisms.

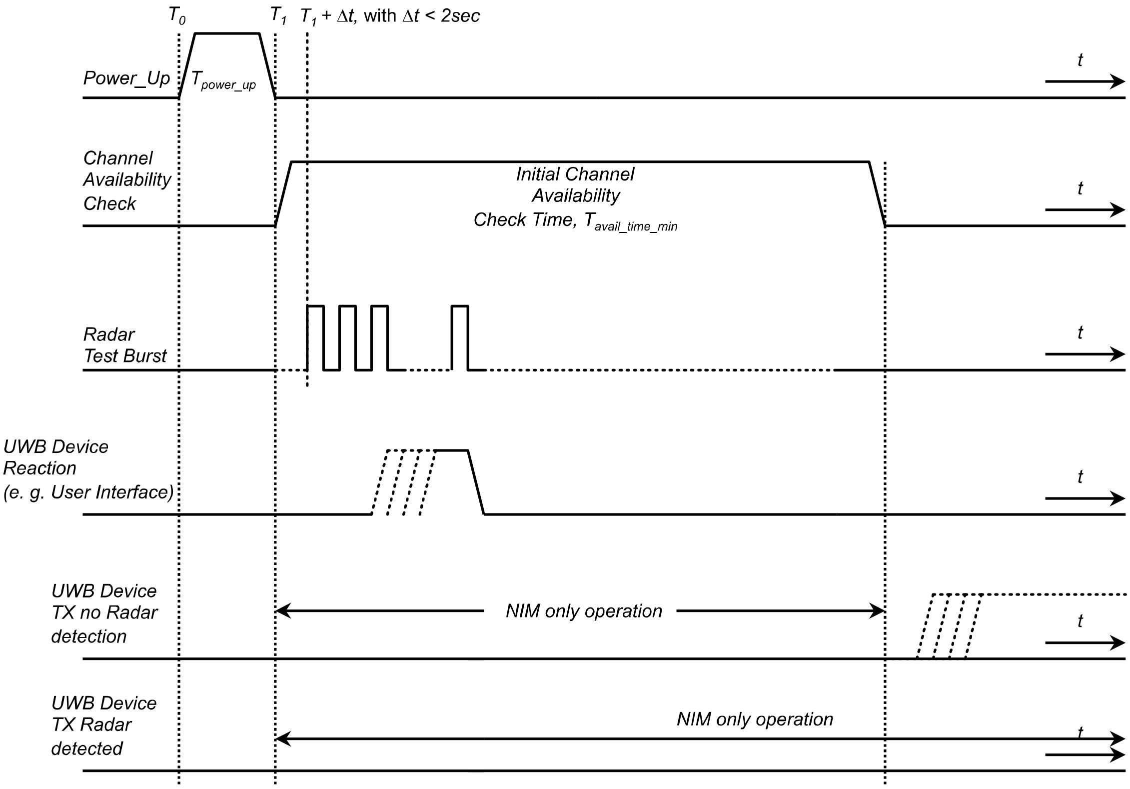


Figure 22: Example of timing for radiolocation testing at the beginning of the Minimum Initial Channel Availability Check Time, UWB DAA radio device intent to operate in a non-NIM mode

7.4.7.2.4 Test with a victim test signal at the end of the *Minimum Initial Channel Availability Check Time, $T_{\text{avail\_time\_min}}$*

Summary:

Verify the victim signal detection and avoidance capability for the selected UWB operational frequency when a victim signal occurs at the end of the *Minimum Initial Channel Availability Check Time*. This is illustrated for a radio location victim signal in figure 23.

Pre-test Condition:

- UWB radio device supporting DAA.
- UWB radio device switched off.

Test Sequence:

a) The UWB DAA radio device will be switched off. The signal generator used to generate the test patterns given in the relevant harmonised standard will be connected to an antenna of suitable characteristics to permit the UUT to be illuminated with a field equal to the threshold detection limit or connected to the corresponding connectors in the case of a conducted measurement setup.

b) The UWB DAA radio device is powered up at T_0. T_1 denotes the instant when the UWB DAA radio device has completed its power-up sequence ($T_{\text{power\_up}}$), enters into the operational mode defined in the relevant harmonised standard and is ready to start the victim signal detection.

   CON-1: The *Minimum Initial Channel Availability Check* $T_{\text{avail\_time}}$ is expected to commence at instant T_1 and is expected to end no sooner than $T_1 + T_{\text{avail\_time}}$ unless a victim signal is detected sooner.

NOTE: Additional verification may be needed to define T_1 in case it is not exactly known or indicated by the UWB DAA radio device.

c) The victim system test signal will be switched on at T_0 with the test pattern, timing behaviour and power levels in accordance with the relevant harmonised standard.

CON-2: It shall be recorded if the victim test signal was detected. This can be done by verifying that the UWB DAA radio device is switched into an avoid operation corresponding to the investigated threshold level in the relevant operational band or stays in a corresponding NIM operation. The following avoid operation parameter shall be verified:

- *default avoidance bandwidth* for the victim system service identified and where relevant.
- *optional avoidance mechanisms* identified by the manufacturer for the victim system service identified.
- LDC operational parameter if applicable.

CON-3: A timing trace or description of the observed timing and behaviour of the UWB DAA radio device shall be recorded for each avoidance mechanism.

d) Repeat a) to c) for *n* times in a row. The values for *n* shall be defined in the relevant harmonised standard.

CON-4: CON-1, CON-2 and CON-3 shall be fulfilled in all *n* tests. If CON-3 is fulfilled go to f). If one failure occurs go to e). For more than one failure the test has not been passed.

e) Repeat a) to c) for *m* times in a row. The values for *m* shall be defined in the relevant harmonised standard.

CON-5: CON-1, CON-2 and CON-3 shall be fulfilled in all *m* tests.

f) Repeat a) to e) for each of the relevant radar test signals for the UWB operational frequency range as defined in the relevant harmonised standard at a level of 10 dB above the defined threshold level given in the relevant harmonised standard and at exactly the threshold levels given in the relevant harmonised standard.

CON-6: A timing trace or description of the observed timing and behaviour of the UWB DAA radio device shall be recorded.

g) Repeat a) to f) for each of the identified victim system frequencies.

h) If the UWB radio device has optional avoidance mechanisms, repeat a) to g) for each optional avoidance mechanism identified.

i) If the UWB radio devices have Victim Service Identification implemented, re-establish the victim service as an Up-link down-link pair as identified in the relevant harmonised standard and repeat steps a) to h) for each of the associated victim service identification avoidance mechanisms.

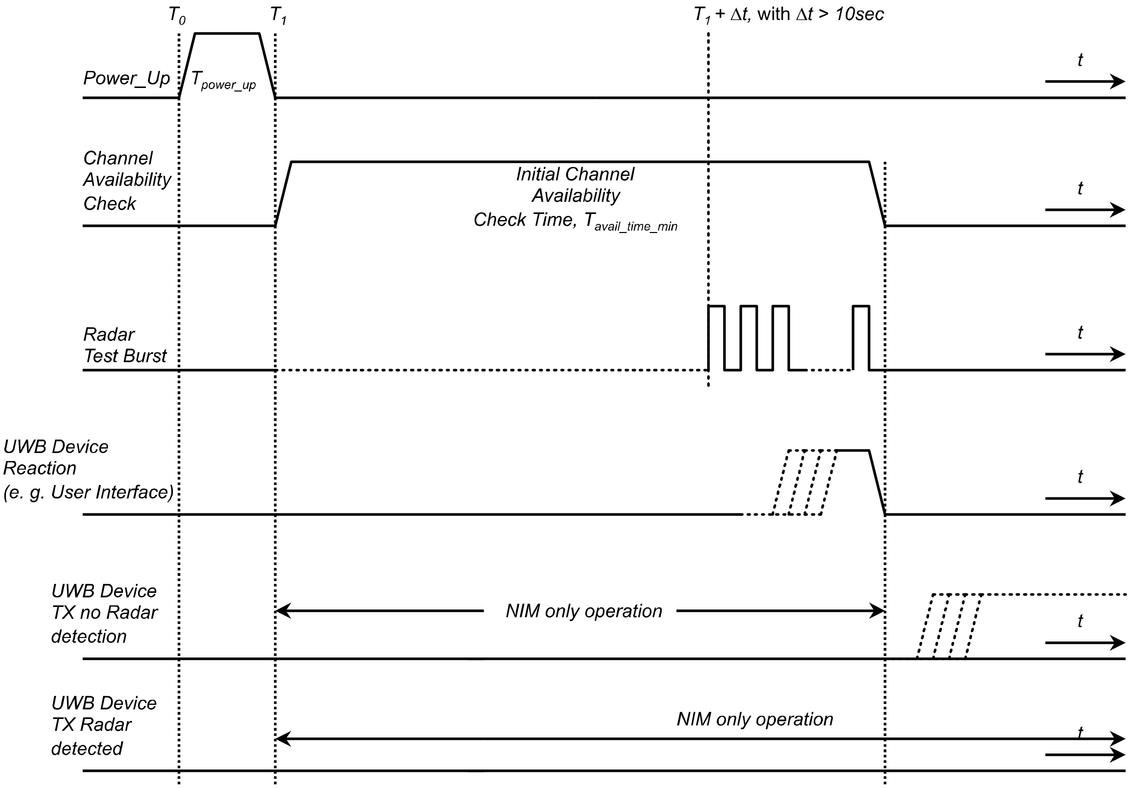


Figure 23: Example of timing for radiolocation victim testing at the end of the Minimum Initial Channel Availability Check Time, UWB DAA radio device intent to operate in a non-NIM mode

7.4.7.3 In-operation test

7.4.7.3.1 General points for In-operation test

This series of tests evaluates the UWB radio device's response to the presence of different payload types which the victim service may carry. The relevant services are defined in the relevant harmonised standards.

In the in-operation test set up the UWB pair will be actively exchanging data under the presents of a victim signal as defined in the relevant standards. In this test the *Detect and Avoid time* will be recorded and the corresponding avoidance operation will be verified.

During the test, the existing data link might be disrupted. This should then not lead to an uncontrolled operation but to an operation equivalent to the NIM mode.

Depending on the test pattern definition in the relevant harmonised standards a power ramping of the victim signal might be necessary. An example for that ramming is given in figure 24.

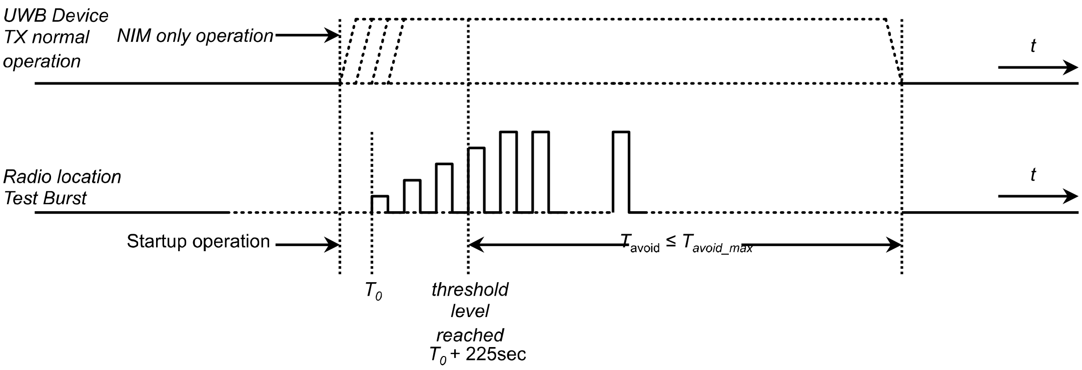


Figure 24: Example of timing for victim signal in-operation testing of the Detect and Avoid Time, here with increasing Radiolocation test signal

7.4.7.3.2 In-operation test procedure

Summary:

The procedure below verifies the victim signal detection and avoidance capability for the selected UWB operational frequency in normal UWB operation using an increasing victim test signal level. In this test the *Detect and Avoid time* and the corresponding avoidance operation will be verified.

Pre-test Condition:

- Two UWB radio devices at least one supporting DAA.
- Both UWB radio devices switched on.
- UWB radio device in normal communication mode with a channel load of 50 %.

Test Sequence:

a) Both UWB DAA radio devices shall be switched on and in a stable operational mode as defined in relevant harmonised standard. The signal generator used to generate the test patterns given in the relevant harmonised standard will be connected to an antenna of suitable characteristics to permit the UUT to be illuminated with a field equal to the threshold detection limit or connected to the corresponding connectors in the case of a conducted measurement setup.

b) The victim system test signal will be switched on at T_0 with the test pattern, timing behaviour and power levels in accordance with the relevant harmonised standard.

CON-1: The measurement of the actual "Detect and Avoid Time" T_{avoid} of the DUT is expected to commence at an instant after T_0 as given in the relevant harmonised standard. The actual detect and avoid time of the radio device under test shall be smaller or equal to the Maximum Detect and Avoid time T_{avoid_max} as defined in the relevant harmonised standard. The actual Detect and Avoid time T_{avoid} of the radio device under test can be negative. The following avoid operations shall be verified:

- *default avoidance bandwidth* for the BWA service identified and where relevant.
- *optional avoidance mechanisms* identified by the manufacturer for the BWA service identified.
- LDC operational parameter if applicable.

CON-2: It shall be recorded if the victim test signal was detected before the time instance given in the relevant harmonised standard.

c) Repeat a) and b) for *n* times in a row. The values for *n* shall be defined in the relevant harmonised standard.

CON-3: CON-1 and CON-2 shall be fulfilled in all *n* tests, then go to e). If one failure occurs go to d). For more than one failure the test has not been passed.

d) Repeat a) and b) for *m* times in a row. The values for *m* shall be defined in the relevant harmonised standard.

CON-4: CON-1 and CON-2 shall be fulfilled in all *m* tests.

e) Repeat b) to d) for each threshold given in the relevant harmonised standard.

NOTE: Instead of repeating the test for each threshold, continuous testing for the different thresholds can also be performed. Depending on the implemented avoidance strategy, some threshold tests may be redundant, i.e. one test already covers another case.

f) Repeat b) to e) for each of the relevant victim test signals for the UWB operational frequency range and threshold levels as defined in the relevant harmonised standard.

g) Repeat a) to f) for each of the victim systems operation frequencies as defined in the relevant harmonised standard.

h) If the UWB radio device has optional avoidance mechanisms, repeat a) to g) for each *optional avoidance mechanism* identified.

i) If the UWB radio devices have Victim Service Identification implemented, re-establish the victim service as an Up-link down-link pair as defined in the relevant harmonised standard and repeat steps a) to h) for each of the *associated victim service identification avoidance mechanisms*.

7.4.8 Test procedures for Low Duty Cycle

7.4.8.1 Test procedure for T_{on}/T_{off}, Method 1

When measuring Low Duty Cycle from the radio device under test, the spectrum analyser or equivalent shall be configured as follows unless otherwise stated:

Resolution Bandwidth: Maximum available bandwidth equal or greater than 3 MHz and less or equal 50 MHz

NOTE: Use always the highest available bandwidth for the signal to be measured.

Video Bandwidth: Not less than the resolution bandwidth

Frequency Span: Measuring in Zero Span Mode and take the centre frequency determined at highest mean power spectral density.

Sweep Time: Time for spectrum analyser sweep (over one span). Appropriate settings shall be calculated with following formulas.

The first sweep should be an overview about pulse frame timing. Manufacturer should also declare this timing. Choose a pulse frame with maximum T_{on} and minimum T_{off} time for further measurements. One package includes onetime T_{on} and onetime T_{off} regarding T_{dis} (Disregard Time see ETSI TS 103 060 [i.18]). Frame periods may vary because of different coding schemes.

The second sweep focus on one selected pulse frame period including maximum T_{on} and minimum T_{off} time.

For measuring T_{on} set the transmission start marker at first rising edge of pulse frame. Set end marker at last falling edge of pulse frame. Take Disregard-Time T_{dis} into account for choosing correct end of active transmission T_{on}. Calculate T_{on} from start marker to end marker position.

For measuring T_{off} set the transmission start marker at the first rising edge of pulse frame. Set end marker at the next transmission start first rising edge of pulse frame. Calculate the sum of T_{on} and T_{off} from both marker positions. For calculating T_{off} subtract T_{on} time from this result.

Maximum sweep times are limited in different specific EN because they correlate with maximum T_{on} and minimum T_{off} periods.

A flow chart is provided in figure 25.

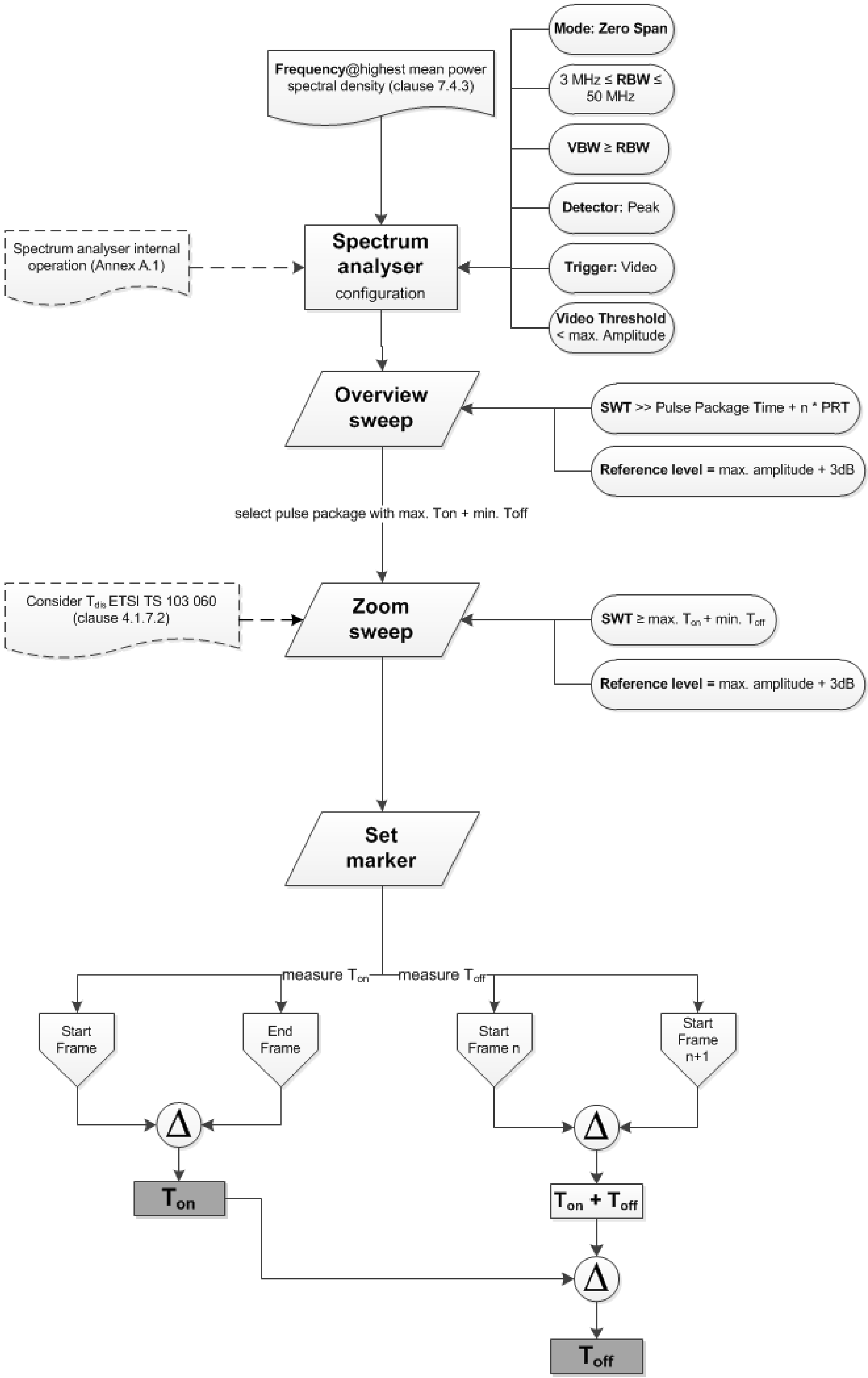


Figure 25: Test Procedure for Low Duty Cycle Measurement

The measurement results shall be determined and recorded over the specified frequency ranges given in the relevant harmonised standards.

7.4.8.2 Test procedure for T_{on}/T_{off}, Method 2

7.4.8.2.1 Description

Alternative time domain method, for details see ETSI TS 103 366 [i.15].

7.4.8.2.2 General test setup

The following tools shall be used to execute the time domain procedure for DC measurement:

- One 50 Ω cable.
- One Oscilloscope with the following minimum requirements:
    - Sampling frequency > 2 B (where *B* is the pulse bandwidth): this requirement is enough to detect the envelope of the signal and ensure the correct operation of the measurement procedure.
    - Input bandwidth > f_H (where f_H is the highest frequency, i.e. the upper boundary to the operating bandwidth).
- One Personal Computer with installed a Post Processing Tool.

Conducted emission:

Figure 26 illustrates the general test setup to execute the time domain procedure for DC measurement in the case of conducted emission.

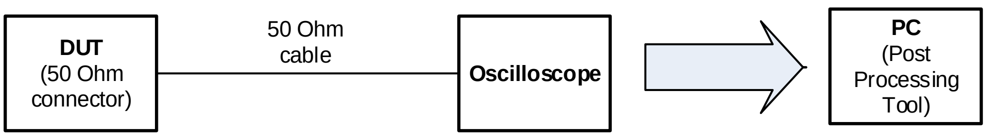


Figure 26: General test setup to execute the time domain procedure for DC measurement in the case of conducted emission

Radiated emission:

Figure 27 illustrates the general test setup to execute the time domain procedure for DC measurement in the case of radiated emission.

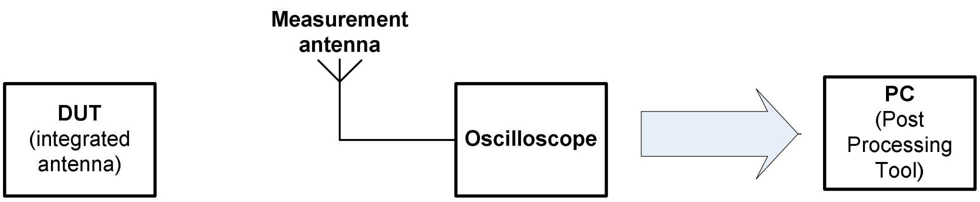


Figure 27: General test setup to execute the time domain procedure for DC measurement in the case of radiated emission

7.4.8.2.3 Time domain procedure for DC measurement

In order to calculate the T_{off} periods, it shall be taken into account the value of the T_{dis} parameter. In fact, given the definition of **Duty Cycle** reminded in clause 3.1 (i.e. "the percentage of the transmitter sum of all burst duration "on" relative to a given period"), it is possible to consider as T_{off} periods only the inter-burst intervals greater than T_{dis}.

The Time Domain Procedure for DC Measurement is illustrated in figure 28. The procedure consists of the following steps:

1) Configure the oscilloscope as follows:

   a) Set the signal sampling frequency f_c of the Oscilloscope ($f_c > 2B$, where B is the pulse bandwidth).

   b) Adjust the time division in accordance with the memory storage of the oscilloscope.

   c) Adjust the vertical amplitude of the Oscilloscope (set the vertical scale of the oscilloscope to display the entire dynamic range of the waveform).

   d) Set the trigger time of the Oscilloscope at the time zero $\langle Ttrig = 0 \rangle$ **Error! Digit expected.**

2) Consider the T_{obs} time and check if the Oscilloscope is capable to acquire and store the whole observation period:

   a) If it is the case, save the signal acquired during the whole T_{obs} time, and go to step 3.

   b) Otherwise:

      i) Save the signal that the Oscilloscope can acquire and store.

      ii) Record the time $\langle Tspan \rangle$ of the acquired signal.

      iii) Set the new trigger time as: $Ttrig = Ttrig + Tspan$ $\mathrm{Ttrig} = \mathrm{Trig} + \mathrm{Tspan}$.

      iv) Check if the new trigger time is less or equal than the T_{obs} time:

         - If it is the case, repeat the steps from i) to iv).

         - Otherwise, go to step 3 (post processing of all acquired and stored signal during T_{obs}).

3) Load in the Post Processing Tool ([i.15]) all the points acquired by the Oscilloscope and relative to T_{obs}.

4) Inside T_{obs}, identify only the bursts. In accordance with the definition of burst in ETSI TS 103 366 [i.15] (i.e. "an emitted signal whose time duration (T_{on}) is not related to its bandwidth"), and the definition of disregard time T_{dis} in ETSI TS 103 366 [i.15] (i.e. "the time interval below which interruptions within a transmission are considered part of T_{on}"), consider each burst as T_{on} time.

5) Calculate the sum of all $T_{on(bursts)}$ (sum all T_{on} identified in step 4) inside T_{obs}: $\sum T_{on(bursts)}^{Tobs}$.

6) Calculate the DC measurement in T_{obs} as a percentage with formula (23):

$$DC = \frac{\sum T_{on(bursts)}^{Tobs}}{T_{obs}} \qquad (23)$$

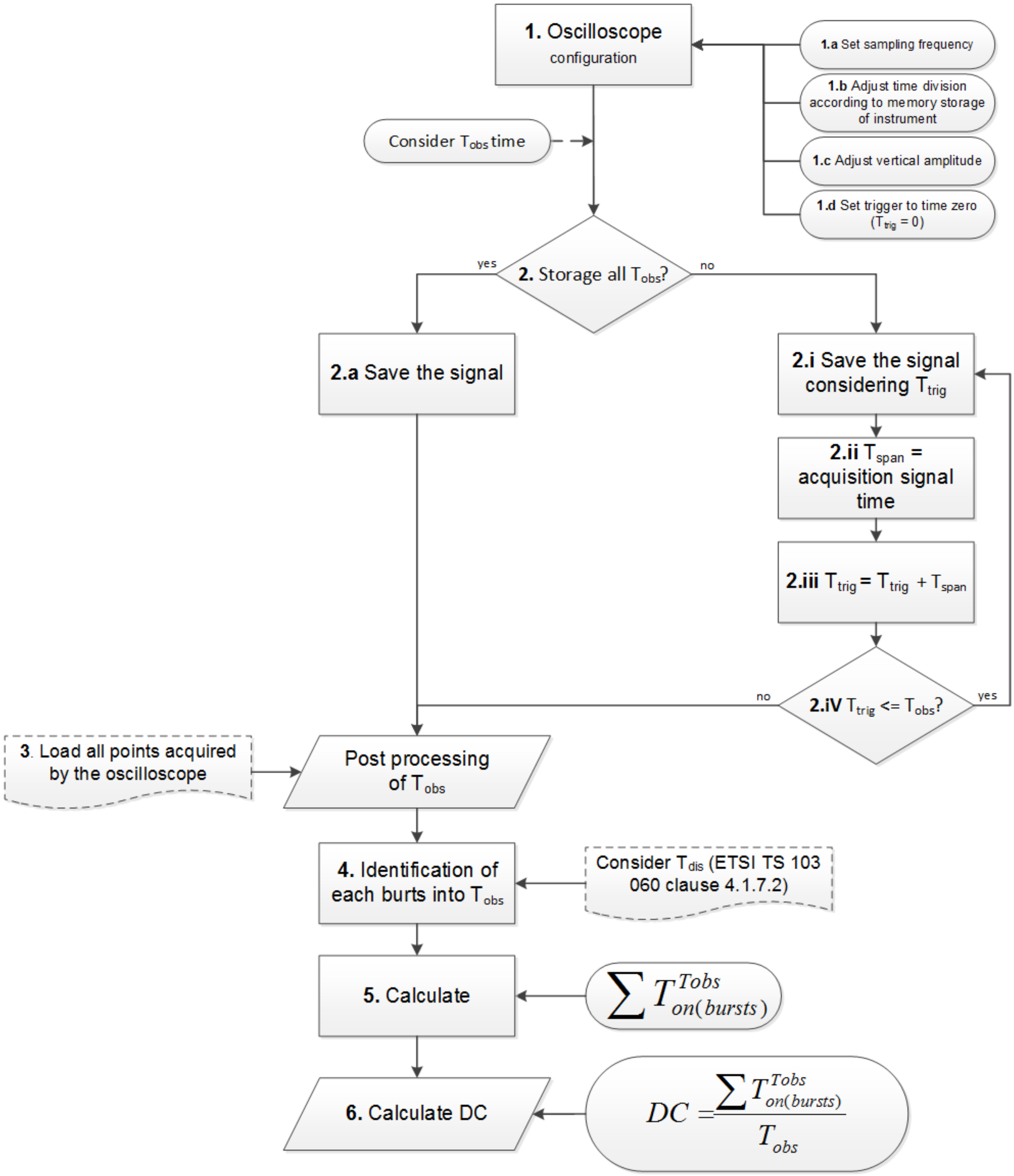


Figure 28: Flow chart of time domain procedure for DC measurement by using an oscilloscope

7.5 Limits

The limits for the measured parameters and limits are provided in the relevant harmonised standard ETSI EN 302 065-1 [i.2], ETSI EN 302 065-2 [i.8], ETSI EN 302 065-3 [i.9], ETSI EN 302 065-4 [i.10], ETSI EN 302 066 [i.11], ETSI EN 302 372 [i.12] and ETSI EN 302 729 [i.13].

7.6 Maximum allowable measurement uncertainty

In all cases the maximum allowable measurement uncertainty is given in table 1.

Annex A (normative): Frequency domain measurements using spectrum analyser

A.1 Spectrum analyser internal operation

It is necessary to have a detailed knowledge of how both modern and older "classical" spectrum analysers work. One is the obvious one: so that the measurement being made is what is intended. The form of the signal, and in particular its envelope, interacts with the scanning process in the analyser and with its other internal processes as well. The importance of the classical analyser is that some of the labels used for internal processing functions have been retained from those older instruments, even though they are now not really appropriate.

The front end of a spectrum analyser is very similar in both the older analogue and current digital instruments; at least as far as the signal path is concerned. Several stages of frequency conversion (usually up as well as down) and wideband filtering, involving at least one swept local oscillator, feed a final IF stage. Synthesised Los improve the accuracy and stability of the conversions, but the signal path through mixers and filters is much the same. The overall effect is that of measuring receiver with a swept centre frequency at the front end.

Modern spectrum analysers digitize the signal at IF, though exactly where they do this varies between designs. Typically, there will be an analogue filter right before the digitizer. This may only be there to suppress aliasing, or it may be switchable to select the widest resolution bandwidths (RBW). After the digitizer everything is digital: the RBW filters, the "detector" functions, and the rest of the processing, including down-sampling as appropriate. However, the terminology used to describe their functions still reflects the earlier analogue analysers.

In the "classical" analogue analyser, the RBW filters were all switched analogue ones, and then there was a logarithmic envelope detector, and subsequent processing used actual voltages representing logarithmic power or (having been converted) representing power or amplitude. Note that analogue filters (in this context "video" filters) operate on a voltage signal, which initially was always the logarithmic power, but in later analogue models this could be selected to represent the input spectrum power, voltage, or logarithmic power density. The filtering effect on noise is different in all these cases, and there are corrections factors between the resulting on-screen level and (for example) the mean power density input. Digital analyser's process numbers and the number can be power, voltage, or decibels as what they are.

Different makers, and different models of analyser, vary quite a lot in how they operate, in the controls available, and how much information is available about both of these. For example, in the Agilent 4440A PSA® spectrum analyser, all the RBW filters are provided as digital functions, which means that many more bandwidths can be selected. The Rohde and Schwarz PSA® has a few analogue RBW filters before digitization, which only permits much wider steps of available values, but also means it has much wider RBWs, up to 50 MHz (it is the only analyser that can do this). In the Agilent 440x series (ESA®) there is one "Video/RMS" selection for both the detector type and scan-scan averaging, though these are quite distinct parts of the processing. At least the manual is quite explicit about its functions. The Rohde and Schwarz FSP® is similar to the ESA®, but differs in many details - and its manual is not so explicit about some of the details that are important for these measurements.

NOTE 1: Agilent 4440A PSA® spectrum analyser is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

NOTE 2: The Rohde and Schwarz FSP® is an example of a suitable product available commercially. This information is given for the convenience of users of the present document and does not constitute an endorsement by ETSI of this product.

One term that can cause a lot of confusion is "average", and its variant "RMS average". Most analysers can do scan-to-scan averaging of trace levels, and some can convert the trace (e.g. from dB to power) before doing so. This kind of averaging is not called for in any of these procedures. Averaging as a detector mode implies averaging all the numbers that are collected for one bin (or bucket, or point - the term used varies) of a sweep. This may not be the same as one display pixel. Again, the averaging may be done on the alternative signal level measures. Finally, there may be the option to average for a specified time. This has an obvious meaning in zero spans, where the stream of measurements is for the same unchanging RF. When scanning, it may do one of several things, and it is important to know what it does in any instrument. Note that if it means setting the time to sweep across one bin, there will now be a non-uniform gain (or amplitude) during the average due to the RBW being swept past the signal. This should be considered to see if it alters the meaning of the average measured.

It is useful to understand this process, for those doing the measurements to show compliance with EC rules and the HS (Harmonised Standard), but more so for those who define the rules and standards. Further specific instances of instrument operation are given below, where they are relevant.

A.2 UWB power measurement procedures

A.2.1 Introduction

There are two main measurements that have been used right through from the original FCC regulations to the former harmonised standard in ETSI for the measurement of mean and peak power. These will be considered in more detail in this clause and the next. However, it is important to note first that all spectrum analysers down-convert the signal, select one RF by the RBW filter, and then measure its short-term carrier amplitude (voltage) repetitively, and process this stream of measurements. The physical quantity being measured may be a power, power spectral density, or something else, for which the analyser's observations are evidence and can be converted to give a measure of the required quantity. However, the analyser cannot actually be set up to measure a power spectral density or a power by distinct processes.

A.2.2 Maximum mean power spectral density

A.2.2.1 General

The limit on mean power (in fact EIRP, which can be related to measured power) is defined as a power spectral density, but this is a mathematical abstraction and cannot be directly observed by an instrument. For measurement purposes with a spectrum analyser the measurement may be defined to be done including the processing details. Meaning "processing": the steps that turn a stream of many internal measurements into a single PSD estimate, which can usually be done internally using standard functions of a digital analyser, but may be possible by manual post-processing for an older analogue analyser. It has been decided that a good estimate of the PSD is obtained by measuring the power in a 1 MHz bandwidth filter, and using the PSD implied (as measured power ÷ RBW). From now on the fact that a PSD is being estimated can be ignored, to concentrate on measuring the power in a 1 MHz filter. The RBW filter with a 1 MHz nominal bandwidth may have a slightly different bandwidth in practice, in which case this can substituted if it can be found (it should be the "power", "noise", or "RMS" bandwidth).

According to the rules, mean power is to be measured with a 1 MHz resolution bandwidth and an averaging time of no more than 1 ms. The description will assume 1 ms averaging from now on, but note that shorter times are allowed. The limit applies to the highest value found for this power (converted to an EIRP) over all frequencies and times and operating modes. It is also the highest value found over all directions, either as part of the EIRP measurement method or by using the maximum antenna gain with a conducted power measurement. The critical measurement should be made at the frequency where the highest level is found (Fhighest), which implies doing a very wide-band scan. The measurement rules and standards often do not make the required method very clear.

Averaging a power measurement for a specific time means integrating the power, to give energy, and dividing by the time. Does the time always have to be one contiguous interval, or could it be a series of shorter times with gaps between them? Probably not, or at least that would be so unusual as an interpretation that it would need to be explicitly stated, and if not it cannot be interpreted in that way. In any case, it is not likely that an analyser would perform such as measurement as part of its basic repertoire of measurements.

For all mean power measurements the RBW should be 1 MHz and the VBW at least as big - the PSA® has a 50 MHz VBW setting that in effect disables video filtering, which is to be preferred. For the "averaging" the carrier power should be integrated for 1 ms as the first processing step, rather than averaged from scan to scan, and this is part of the "detector/average" function (not "BW/average") in Agilent terms. Set this detector function as RMS (i.e. operate on power itself not voltage or log power) and the averaging time as 1 ms. In the PSA®, set the sweep time to define the time per point, the detector as "average", and the average type as "Pwr Avg (RMS)".

Finding the "highest of" this mean power over a sensible length of time can be done by the second, scan-scan, selection of peak/average functions. In the PSA® this is called "Trace/view", and can be set to "Max hold", and of course it applies per trace point. Finding the maximum over a whole scan can be done with the "marker > peak" operation.

In these modern digital analysers, the averaging is done by taking samples at the full ADC rate and processing them digitally. The number of samples per measurement points "Agilent say per "bucket"") can be large. In many analysers, there can be more "points" (or measurements) per scan than the screen can show - this makes more sense if they are transferred to a computer for further processing. Thus it is necessary to distinguish "screen point" or pixel from measurement point, "bucket", or "sweep point".

The PSA® analyser has 601 displayed points on its screen by default (401 in the ESA®), so the span is 600 times the nominal spacing. The number of points per sweep can be set to anything from 101 to 8 192, and is indicated permanently on the screen. The similar Rohde and Schwarz FSP® analyser has 501 as default, and can vary this in factors of two from 125 to 8 001, but does not report the current value on-screen (one has to go and look for it via the menus).

Of course the screen cannot show all of these measurements, and it is not clear what it does choose to show. This should be explained in the manuals, but has not been found in any. One likely behaviour is that it processes all the points as if they could be displayed (and they could be viewed or processed externally), and it can search this full sweep for the peak ("marker>peak" function) and display the peak RF on this finer grid. For display, it then down-samples (most likely by a simple algorithm like pick-the-nearest-to-the-pixel-centre or show-the-highest). If this is right, the approach given below of scanning over the full band is OK. Otherwise, it would be safer to keep to one pixel per 1 MHz.

Other analysers (older ones in particular) do not allow the same level of control over the points per scan, and it can be hard to find out how many points (pixels or samples) there are. So the one nominal pixel per 1 MHz method may be needed for them.

A.2.2.2 Average mean power: Finding highest

The rules say that both mean and peak power should be measured at the RF at which the average mean power is highest. The most convenient way to find this is in a single sweep over the whole bandwidth. Note that the absolute accuracy of power measurement is not important while finding this frequency.

It should be possible to set a scanning measurement so that the RBW is 1 MHz and the dwell time per MHz is 1 ms, as it scans across each frequency. This may or may not be the same as a true 1 ms averaging time: it depends on whether the LO jumps from one screen display frequency to the next or sweeps in steps much smaller than 1 MHz. There may be some effects due to sweeping over part of the RBW filter shape; however, it should be good enough to find the peak in either case. To set this mode on a simpler analyser with X (400 to 600) measurement intervals per scan, the span is set explicitly at X MHz and the scan time at X ms. This X MHz span has to be moved manually (by varying the centre RF) across the full range of the UWB signal, or even over 1 GHz to10 GHz, which is a bit laborious but not excessively so.

Assuming X (typically 500) pixels or measured points per scan:

Centre frequency:	Scanned manually - see text
RBW:	1 MHz
VBW:	≥ 1 MHz, or off (e.g. 50 MHz)
Samples per scan:	X (500)
Span:	X (500) MHz
Sweep:	Exactly X (500) ms for 1 ms averaging
Detector:	Average, Type: Pwr Avg (RMS)
Scan/View:	Max Hold
Amplitude scale:	1 dB or 2 dB/div for convenience
Input attenuation:	Reduce to give noise level at least 20 dB below measured peak

Use marker > peak to find Fhighest. Most analysers will clear the max hold store when the centre RF is moved, as otherwise it is meaningless. If there are spurious peaks above the UWB PSD, and if they can be disregarded when finding Fhighest, then the marker > peak search cannot be used (apart from stepping through peaks in turn until the right one is reached).

It would be more convenient to scan over the whole UWB signal, if the analyser will do this. With a 1 MHz RBW, one should aim for at least one sample per 1 MHz of span. If there is more than one sample per 1 MHz, one can scan less of the RBW filter during one measurement dwell, which ought to be more accurate. Most recent analysers will allow this - it is possible to select a 2 GHz span, 4 001 samples, and a sweep time of 4 s.

Note that these settings may be coupled, so they have all to be rechecked to make sure they are right, and set again if they have changed. In some cases a combination may be not allowed, for internal reasons that are not always obvious. No doubt there is a right order to do the settings for each instrument, but in any case there should be a save and re-load facility somewhere (to be found and documented).

Centre frequency:	At centre of UWB signal
Span:	Y (e.g. 2 000) MHz
Samples per scan:	Z ≥ Y (e.g. 4 001 for 4 000 intervals)
RBW:	1 MHz
VBW:	≥ 1 MHz, or off (e.g. 50 MHz)
Sweep:	Exactly Z ms (e.g. 4 s) for 1 ms averaging
Detector:	Average, Type: Pwr Avg (RMS)
Scan/View:	Max Hold
Amplitude scale:	Can be left on 10 dB/div
Input attenuation:	Reduce to give noise level at least 20 dB below measured peak

Use marker > peak to find Fhighest.

To find the highest peak at all frequencies, one might use max hold (a scan-scan function) and then use the marker to find the peak. The peak should be pretty flat, so 10 dB/division will not show the peak at all easily and an expanded scale is better. The input attenuation can safely be reduced to a low level, as the full-band power is not likely to exceed even a 20 dBm limit (and most analysers can cope with more than this).

A.2.3 Maximum peak power (e.i.r.p.) measurement procedure

"Power" in this case (as for all RF measurements) means the power delivered by the signal with the carrier cycles smoothed out. This corresponds to "envelope power" of which the peak value is "PEP", and it is PEP that is to be measured here. It is also the kind of power always shown by spectrum analysers. Note that the highest level of mean power found at any RF, direction, or any other domain can also be labelled as a "peak", which causes confusion.

The peak power is to be measured in a 50 MHz bandwidth, representing the widest potential victim receiver bandwidth that is to be considered. However, it appears that only a limited number of spectrum analysers offer such a bandwidth as standard. There is a scaling rule (power proportional to bandwidth squared) that allows a narrower bandwidth to be used, but it is only correct for very short pulses.

Pulse UWB fills its band for any length of transmission, and with only one pulse type only the timing of pulses can be altered. Since pulses are so short, each contains very little energy, and many should be integrated into a single detection for all but the shortest range. If the pulses are regular in time, the spectrum will have lines. Since the mean PSD limit applies to the highest level in the spectrum, this is a very poor choice. Pulse times are always modulated or dithered (intentionally jittered) to spread the spectral power density more evenly. It is thus likely to be the case that the pulse timing will have its own spectrum that is much wider than 1 MHz, but narrow than the single-pulse ESD. The effect of this is that the signal PSD is just a little wider than the ESD, and nearly the same shape.

For peak power, the simple formula now enshrined in the regulations applies strictly speaking to this kind of situation. The reasoning is as follows:

- Take the voltage trace of one pulse, and Fourier transforms it to a finite-time complex spectrum.
- Set a 50 MHz wide filter transfer function at some point on the much wider pulse spectrum. Its shape is not important, provided it is reasonable.

- Apply the filter response to the pulse spectrum (i.e. a complex multiply), to give the filtered pulse spectrum.
- Inverse Fourier transforms this, to give the voltage trace of the filtered pulse.
- Now the instantaneous power is the square of this voltage. Its peak is the peak instantaneous power. Usually the meaning of peak carrier power: the peak of the mean of the oscillations imposed by the filtering.
- This power is the transform of the autocorrelation (with conjugation) of the filtered pulse spectrum.
- If the pulse spectrum was purely real, the filtered pulse spectrum will be just the filter's own spectrum, scaled.
- The filter's amplitude response shall be nearly symmetrical and a normal humped shape, so its impulse response (its envelope, where it has a carrier) will be similarly symmetrical and humped.

If the is no image the filter bandwidth shall be changed, using the same shape (in full complex form) and keeping the band-centre gain at unity. Its transform (impulse response) changes inversely, and so does its peak:

- So if the filter gets wider by a factor k (H2 is wider than H1), its impulse response gets narrower by the same factor and is scaled up by a factor of k in voltage terms.
- The peak power, in either definition, can now be seen to rise by a factor of k2.
- With symmetrical functions, the peak will be at the centre.
- Similar procedure can be done with the pulse spectrum; so its linear phase term vanished at the filter band centre.
- It can be concluded that this simple approach is going to work if the remaining phase in the pulse spectrum (i.e. after constant and linear terms are removed) is close to zero across the widest filter, i.e. 50 MHz.
- If this is not the case, the calculation has to be executed.
- All of this assumes implicitly that successive pulses do not overlap. As filtered pulses get longer when the filter is narrower, this lowers the maximum PRF for which this rule applies. It is thus possible for a stream of pulses that would not overlap with 50 MHz filtering to do so with a measurement bandwidth of 3 MHz, leading to a higher peak power than the rule would give and so to an overestimate of the power in 50 MHz when the correction is applied.

For FH-UWB or OFDM signals this overestimates the power in 50 MHz, so ideally the measurement should be done in as close to 50 MHz as possible. For OFDM a different scaling law is used (power proportional to bandwidth).

For rf carrier based modulation using multi-tone carriers and not having gating techniques implemented, the maximum peak power limit shall be scaled down by a different factor of 10 log(50/X), where X represents the measurement bandwidth used.

Resolution bandwidth (peak): Equal to or greater than 3 MHz but not greater than 50 MHz for impulsive technology or equal or greater than 10 MHz but not greater than 50 MHz for rf carrier based technology.

Most mid-range current analysers can only reach 10 MHz at most with their RBW filters, where these are digital in all cases. The PSA® analyser will only allow the RBW to be increased as far as 8 MHz, and the ESA® only 5 MHz, which is not high enough. The FSP® was advertised as 50 MHz but can now only do 10 MHz.

So, in this case when signal will be filtered to 5 MHz, 8 MHz, 10 MHz (or when possible to 50 MHz), envelope detected, and then the maximum value seen over a reasonably long time interval retained - a few seconds should suffice. The rules specify that this should be done at same RF for which the mean power was found to be highest, so no new search for a maximum is needed, and a zero span measurement can be done directly.

Centre frequency:	Highest - see text
RBW:	The highest on offer up to 50 MHz
VBW:	≥ RBW, or off (e.g. 50 MHz)
Span:	Zero
Sweep:	Not critical

Detector: Peak

Scan/View: Direct and then Max Hold

The peak hold display should be flat - if not, find out why and remove the cause. This will probably involve disabling Max Hold so that the power vs. time can be displayed, which should show how the envelope may be affecting the measurement.

A.3 Calculation of peak limit for 3 MHz measurement bandwidth

For impulsive modulation schemes the present document specifies a fixed maximum limit for average power in a 1 MHz bandwidth. The relationship between the PRF and the peak power to average power ratio is given in figure A.1.

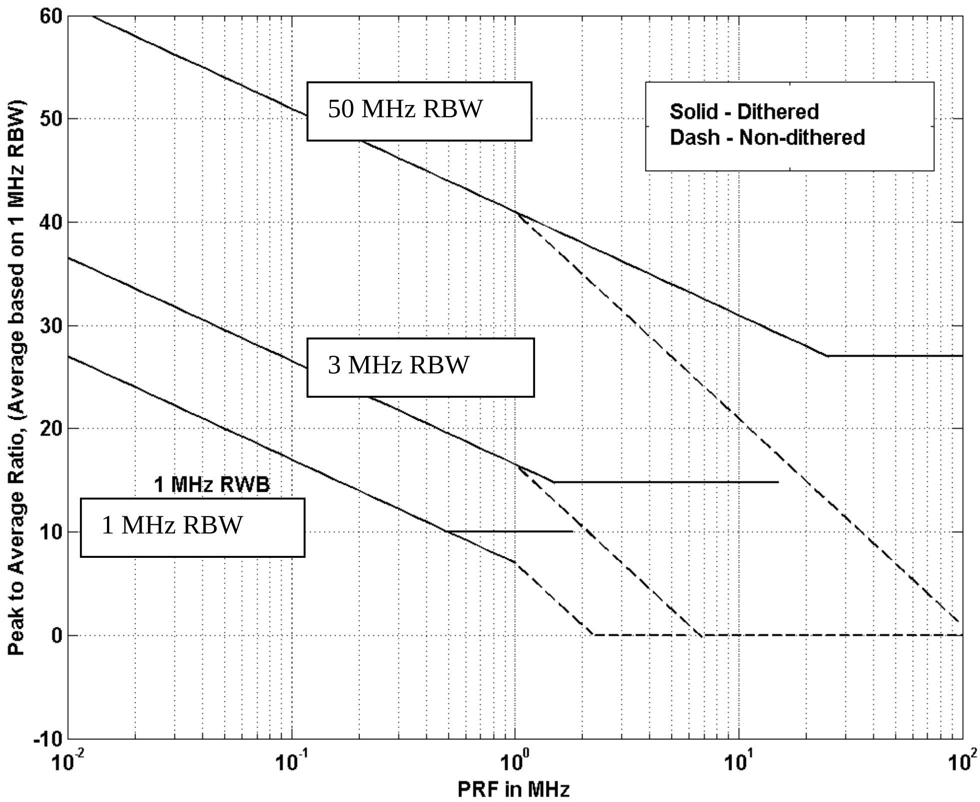


Figure A.1: Peak to average power versus PRF

For a noise like signal (e.g. dithered pulses) the roll-off rate is -10 dB/decade with a break point at half of the resolution bandwidth. Consequently, the breakpoints for 50 MHz, 3 MHz and 1 MHz resolution bandwidths are 25 MHz, 1,5 MHz and 0,5 MHz respectively.

As a peak measurement using a 50 MHz resolution bandwidth is difficult to impossible to conduct, the peak power is measured with a 3 MHz resolution bandwidth.

The curve for 3 MHz resolution bandwidth is 20log(BW 50 MHz/BW 3 MHz) = 24,4 dB lower than for a 50 MHz resolution bandwidth. A peak limit of 0 dBm at 50 MHz will consequently be reduced correspondingly by 24,4 dB to -24,4 dBm.

As the dithered limit values are almost identical below and above 1 MHz PRF (within ±1 dB). For a 3 MHz measuring bandwidth the peak limit is adjusted to -25 dBm within the entire range for PRF.

The resulting Peak limit is shown in figure A.2.

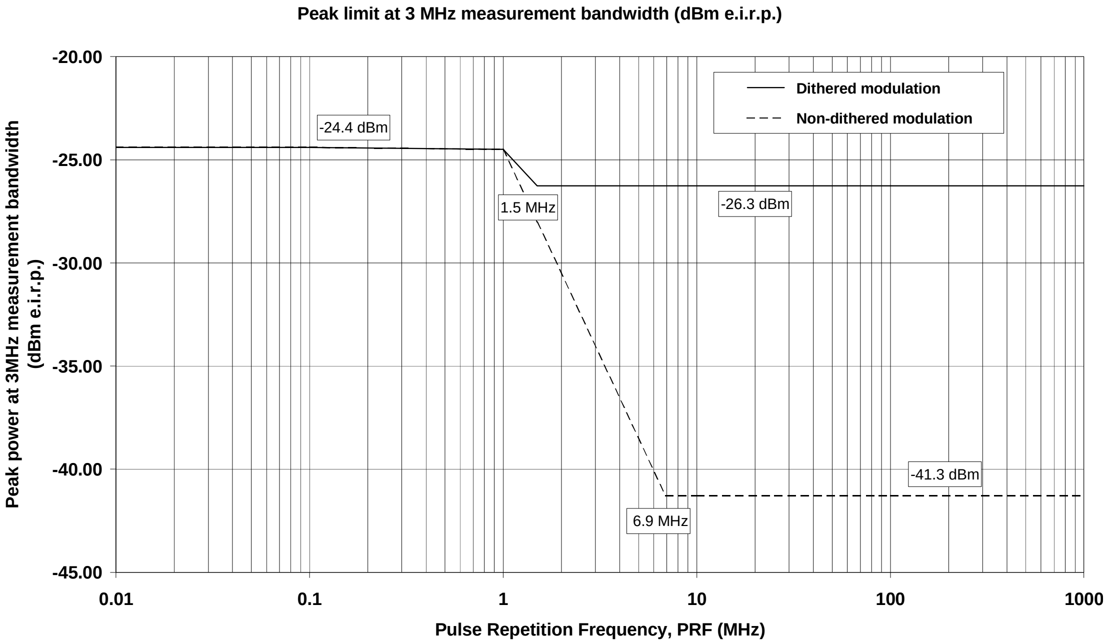


Figure A.2: Peak power limit in a 3 MHz bandwidth

Non-dithered modulation does not have the characteristics of a noise like spread spectrum but contains instead higher level non-spread spectrum lines. To protect against these non-dithered spectrum lines the Peak limit is reduced further for PRF frequencies above 1 MHz by an additional 20 dB/decade roll-off until the peak to average ratio is zero. The resulting peak limit at 3 MHz is identical to the average limit in 1 MHz bandwidth for PRF above approximately 6,9 MHz.

A.4 Detailed Information to standard test methods

A.4.1 Spherical scan with automatic test antenna placement

A.4.1.1 General

Figure A.3 shows the spherical measurement method using automatic test antenna placement. The RX antenna moveable and it is mounted for example on an automatic arm, which moves the antenna stepwise on a sphere around the DUT.

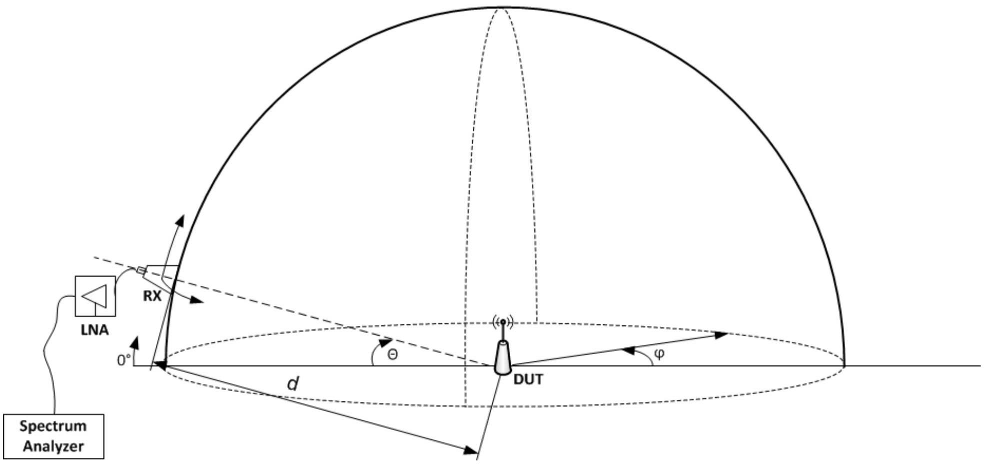


Figure A.3: Spherical scan setup using automatic test antenna placement

The maximum measurement step size for the azimuth angle φ and for the elevation angle Θ is smaller or equal to 5°. In a half sphere scan φ is varied from 0° to 360° and Θ is changed from 0° to 90°. Therefore the DUT has to be mounted according to the typical usage in the application. If a full sphere scan shall be performed, then the device can be tilted by 180° and the half sphere shall be measured again. The scan shall be performed at a distance given by clause 6.3.3.5.

NOTE: Another relation of the angles is possible, but the coverage of the whole spheres should be ensured.

A.4.1.2 Calibrated setup

The measurement receiver, test antenna and all associated equipment (e.g. cables, filters, amplifiers, etc.) shall have been recently calibrated against known standards at all the frequencies on which measurements of the equipment are to be made. A suggested calibration method is given in clause 6.3.6.

If an anechoic chamber with conductive ground plane is used, the ground shall be covered by absorbing material in the area of the direct ground reflection from the DUT to the test antenna.

The equipment shall be placed in an anechoic chamber (compare clauses 6.3.2.2 and 6.3.2.3), which allows the spherical scan. The DUT shall be placed closest to the orientation of normal operation.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser via whatever (fully characterized) equipment is required to render the signal measurable (e.g. amplifiers).

The transmitter shall be switched on, if possible without modulation, and the spectrum analyser shall be tuned to the frequency of the transmitter under test.

The RX antenna shall be moved stepwise on the sphere and in each location the signal level shall be noted.

After all locations have been reached, the measurement procedure shall be repeated for horizontal polarized test antenna orientation.

The maximum signal level detected by the spectrum analyser shall be noted and converted into the radiated power by application of the pre-determined calibration coefficients for the equipment configuration used.

A.4.1.3 Substitution method

The equipment shall be placed in an anechoic chamber, which allows the spherical scan (compare clauses 6.3.2.2 and 6.3.2.3). The DUT shall be placed closest to the orientation of normal operation.

If an anechoic chamber with conductive ground plane is used, the ground shall be covered by absorbing material in the area of the direct ground reflection from the DUT to the test antenna.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser.

The transmitter shall be switched on, if possible without modulation, and the measuring receiver shall be tuned to the frequency of the transmitter under test.

The RX antenna shall be moved stepwise on the sphere and in each location the signal level and its coordinates shall be noted.

After all locations have been reached, the maximum signal level and its coordinates shall be determined.

The transmitter shall be replaced by a substitution antenna as defined in clause 6.3.2.5.

The substitution antenna shall be orientated for vertical polarization.

The substitution antenna shall be connected to a calibrated signal generator.

If necessary, the input attenuator setting of the spectrum analyser shall be adjusted in order to increase the sensitivity of the spectrum analyser.

If an anechoic chamber with a conductive ground plane is used, then the substitution antenna shall be moved to the position of the previous maximum. The test antenna shall be moved around this position of the substitution antenna within at least five times the wavelength of the centre frequency on the sphere to find the local maximum.

The input signal to the substitution antenna shall be adjusted to the level that produces a level detected by the spectrum analyser, that is equal to the level noted while the transmitter radiated power was measured, corrected for the change of input attenuator setting of the spectrum analyser.

The input level to the substitution antenna shall be recorded as power level, corrected for any change of input attenuator setting of the spectrum analyser.

The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

The measure of the radiated power of the radio device is the larger of the two levels recorded at the input to the substitution antenna, corrected for gain of the substitution antenna if necessary.

A.4.1.4 Spherical scan with rotating device

A.4.1.4.1 General

Instead of using an automatic arm, it is also possible to rotate and tilt the DUT (see figure A.4). Thus, the same sphere can be measured as with the automatic arm. In contrast to the previous method Θ is changed from 0° to -90° for the half sphere measurement. The distance d is given by clause 6.3.3.5.

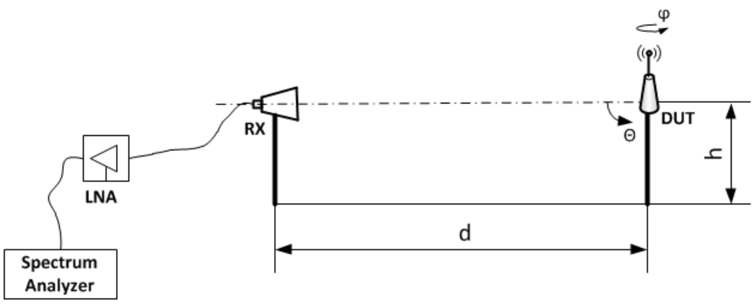


Figure A.4: Spherical scan setup with rotation and tilt of the DUT

A.4.1.4.2 Calibrated setup

The measurement receiver, test antenna and all associated equipment (e.g. cables, filters, amplifiers, etc.) shall have been recently calibrated against known standards at all the frequencies on which measurements of the equipment are to be made. A suggested calibration method is given in clause 6.3.6.

If an anechoic chamber with conductive ground plane is used, the ground shall be covered by absorbing material in the area of the direct ground reflection from the DUT to the test antenna.

The equipment shall be placed in an anechoic chamber (compare clauses 6.3.2.1 and 6.3.2.2), which allows the rotation and tilt of the DUT. The DUT shall be placed closest to the orientation of normal operation.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser via whatever (fully characterized) equipment is required to render the signal measurable (e.g. amplifiers).

The transmitter shall be switched on, if possible without modulation, and the spectrum analyser shall be tuned to the frequency of the transmitter under test.

The TX antenna shall be stepwise rotated and tilted that the sphere of interest is covered. The signal level shall be noted in each location.

After all locations have been reached, the measurement procedure shall be repeated for horizontal polarized test antenna orientation.

The maximum signal level detected by the spectrum analyser shall be determined and converted into the radiated power by application of the pre-determined calibration coefficients for the equipment configuration used.

A.4.1.4.3 Substitution method

The equipment shall be placed in an anechoic chamber, which allows the rotation and tilt of the DUT. The DUT shall be placed closest to the orientation of normal operation.

The test antenna shall be oriented initially for vertical polarization and shall be chosen to correspond to the frequency of the transmitter.

The output of the test antenna shall be connected to the spectrum analyser.

The transmitter shall be switched on, if possible without modulation, and the measuring receiver shall be tuned to the frequency of the transmitter under test.

The TX antenna shall be stepwise rotated and tilted that the sphere of interest is covered. The signal level shall be noted in each orientation.

After all locations have been reached, the maximum signal level and the orientation of the DUT shall be noted.

The transmitter shall be replaced by a substitution antenna as defined in clause 6.3.2.5.

The substitution antenna shall be orientated for vertical polarization and the length of the substitution antenna shall be adjusted to correspond to the frequency of the transmitter.

The substitution antenna shall be connected to a calibrated signal generator.

If necessary, the input attenuator setting of the spectrum analyser shall be adjusted in order to increase the sensitivity of the spectrum analyser.

If an anechoic chamber with a conductive ground plane is used, then the test antenna shall be raised and lowered through the specified range of height that the maximum signal level is received.

The input signal to the substitution antenna shall be adjusted to the level that produces a level detected by the spectrum analyser, that is equal to the level noted while the transmitter radiated power was measured, corrected for the change of input attenuator setting of the spectrum analyser.

The input level to the substitution antenna shall be recorded as power level, corrected for any change of input attenuator setting of the spectrum analyser.

The measurement shall be repeated with the test antenna and the substitution antenna orientated for horizontal polarization.

The measure of the radiated power of the radio device is the larger of the two levels recorded at the input to the substitution antenna, corrected for gain of the substitution antenna if necessary.

A.4.1.5 Spherical scan other methods

Other methods for spherical scans are allowed but it has to be ensured that the relevant sphere is full covert. Then again the calibrated or substitution method shall be applied. The exact method for the scanning shall be described in the measurement report.

Annex B (informative): Measurement antenna and preamplifier specifications

The radiated measurements set-up in clause 5.6 specifies the use of a horn antenna and a wide-band, high gain preamplifier above 1 GHz in order to measure the very low radiated power density level from UWB equipment.

Table B.1 gives examples of recommended data and features for the horn antenna and preamplifier to be used for the test set-up.

Table B.1: Recommended performance data for preamplifier and horn antenna

Pre-amplifier	
Parameter	**Data**
Bandwidth	< 1 GHz to > 15 GHz
Noise figure	< 2 dB
Output at 1 dB compression	> +10 dBm
Gain	> 30 dB (see note)
Gain flatness across band	±1,5 dB
Phase response	Linear across frequency range
Impulse response overshoot	< 10 %
Impulse response damping ratio	0,3 to 0,5
VSWR in/out across band	2:1
Nominal impedance	50 Ω
Horn antenna	
Parameter	**Data**
Gain	> 10 dBi (see note)
3 dB bandwidth	< 1 GHz to > 15 GHz
Nominal impedance	50 Ω
VSWR across band	< 1,5:1
Cross polarization	> 20 dB
Front to back ratio	> 20 dB
Tripod mountable	Yes
Robust precision RF connector	Yes
NOTE: The combination of preamplifier and horn antenna should give an overall equivalent gain of about 40 dB without overloading the spectrum analyser. The noise floor of the combined equipment should be at least 6 dB below the limits specified in the radiated tests given in the present document.	

Annex C (informative): Bibliography

- CEPT/ERC Recommendation 70-03: "Relating to the use of Short Range Devices (SRD)".
- EC/EFTA Mandate M/407: "Ultra-WideBand equipment".
- Recommendation ITU-R SM.1538: "Technical and operating parameters and spectrum requirements for short-range radio-communication devices".
- CEPT ECC/DEC/(06)12 amended of 31 October 2008 on the harmonised conditions for devices using Ultra-Wideband (UWB) technology with Low Duty Cycle (LDC) in the frequency band 3.4-4.8 GHz.
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- CEPT ECC/DEC/(06)04 of 24 March 2006 amended 6 July 2007 at Constanza on the harmonised conditions for devices using Ultra-Wideband (UWB) technology in bands below 10.6 GHz.
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- ETSI TR 101 994-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 1: Communications applications".
- ETSI TR 101 982: "Electromagnetic compatibility and Radio spectrum Matters (ERM);Radio equipment to be used in the 24 GHz band; System Reference Document for automotive collision warning Short Range Radar".
- ETSI TR 102 263: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Road Transport and Traffic Telematics (RTTT); Radio equipment to be used in the 77 GHz to 81 GHz band; System Reference Document for automotive collision warning Short Range Radar".
- ETSI TR 102 495-1: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 1: Building material analysis and classification applications operating in the frequency band from 2,2 GHz to 8 GHz".
- ETSI TR 102 495-2: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 2: Object discrimination and characterization applications".
- ETSI TR 102 495-3: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 3: Location tracking applications operating in the frequency band from 6 GHz to 9 GHz".
- ETSI TR 102 495-4: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 4: Object identification for surveillance applications".
- ETSI TR 102 495-5: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 5: Location tracking applications type 2 operating in the frequency band from 6 GHz to 9 GHz for indoor and outdoor usage" (under development).

- ETSI TR 102 495-6: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 6: Object Detection for mobile, construction, agriculture and off-road applications operating in the frequency band from 6 GHz to 7,25 GHz" (under development).
- ETSI TR 102 495-7: "Electromagnetic compatibility and Radio spectrum Matters (ERM); Short Range Devices (SRD); Technical characteristics for SRD equipment using Ultra Wide Band technology (UWB); Part 7: Location tracking and sensor applications for automotive and transportation environments operating in the frequency bands from 3,1 GHz to 4,8 GHz and 6 GHz to 8,5 GHz".
- ETSI TR 102 834: "Electromagnetic compatibility and Radio spectrum Matters (ERM);System Reference Document; Technical Characteristics for airborne Ultra-WideBand (UWB) applications operating in the frequency bands from 3,1 GHz to 4,8 GHz and 6 GHz to 8,5 GHz".
- ETSI TR 102 892: "Electromagnetic compatibility and Radio spectrum Matters (ERM); SRD radar equipment using Wideband Low Activity Mode (WLAM) and operating in the frequency range from 24,05 GHz to 24,50 GHz; System Reference Document SRDoc for 24 GHz - WLAM SRR".
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