ETSI TS 103 941 V1.1.1 (2024-01)

**Short Range Devices (SRD) and Ultra Wide Band (UWB);
Measurement setups and specifications
for testing under full environmental profile
(normal and extreme environmental conditions)**

Reference

DTS/ERM-TGUWB-620

Keywords

environment, measurement, radio measurement, SRD, UWB

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Sous-Préfecture de Grasse (06) N° w061004871

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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Electromagnetic compatibility and Radio spectrum Matters (ERM).

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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1 Scope

The purpose of the present document is to explain and to provide a justification for an additional (radiated or conducted) test (procedure and test sept up arrangement) for devices and applications under the complete (normal and extreme) conditions of the environmental profile. This requirement is proposed to name as "TX behaviour under extreme environmental profile conditions".

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 https://docbox.etsi.org/Reference/.

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

Not applicable.

2.2 Informative references

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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 TS 103 789 (V1.1.1): "Short Range Devices (SRD) and Ultra Wide Band (UWB); Radar related parameters and physical test setup for object detection, identification and RCS measurement".

[i.2] IEC 60068-3-5:2018: "Environmental testing - Part 3-5: Supporting documentation and guidance - Confirmation of the performance of temperature chambers".

[i.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".

[i.4] R&S ATS-TEMO: "Temperature Option for R&S ATS 1000", order no. 1533.8147.02.

[i.5] EDN: "Near field or far field" C. Capps, August 16, 2001, pp. 95-102.

[i.6] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC (RED).

[i.7] Günter Pfeifer and Benoit Derat: "Optimized Air Flow and Thermally Efficient Test System Enables 3D OTA Measurements Over Temperature", Microwave Journal, January 2023.

[i.8] R&S®ATS1800C compact 3GPP compliant ota chamber for 5g nr mmwave signals.

[i.9] ETSI EN 302 065-4-1 (V2.1.0): "Short Range Devices (SRD) using Ultra Wide Band technology (UWB); Harmonised Standard for access to radio spectrum; Part 4: Material Sensing devices; Sub-part 1: Building material analysis below 10,6 GHz".

[i.10] ETSI EN 302 065-2 (V2.1.1): "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 2: Requirements for UWB location tracking".

[i.11] IEC 60068-2-1:2007: "Environmental testing - Part 2-1: Tests - Test A: Cold".

[i.12] IEC 60068-2-2:2007: "Environmental testing - Part 2-2: Tests - Test B: Dry heat".

[i.13] ETSI EN 302 729 (V2.1.1): "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".

3 Definition of terms, symbols and abbreviations

3.1 Terms

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

absolute measurement: values of a requirement as measured with an instrument within a calibrated test set-up

NOTE: The measurement can be reproduced irrespective of the laboratory or instrument manufacturer.

environmental profile point (T_{step}): measurement requirement (e.g. temperature, voltage) under the specified environmental profile to assess the TX behaviour at this point

relative measurement: measurement of changes/behaviour of values compared to a reference value

NOTE: The measurement of the behaviour can be reproduced irrespective of the laboratory or instrument manufacturer but there is no possibility to provide information of the absolute measurement result over laboratories or instruments.

temporary antenna connector: EUT hardware design provide connector mounting option (e.g. landing pads on PCB)

NOTE: The connector is either a standardized coaxial or a hollow waveguide connector and the necessary information how to install the connector should be in the technical documentation of the EUT.

3.2 Symbols

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

°C	Celsius
λ	wavelength
Adjusted_RL	adjusted regulated limit to assess TX-behaviour on each environmental profile point
$Adjusted\_RL_{SX}$	adjusted regulated limit to assess TX-behaviour on each environmental profile point and for each range of the UWB emission which is overlapping with the OFR
c	the velocity of light [m/s]
CON_{abs}	max emission assessed in the "connected" measurement
d	Measurement distance (distance between EUT and measurement antenna)
d_m	thickness material
D_{ap}	aperture size (the maximum dimension of the antenna orthogonal to the direction of propagation)
deg	degree [°C]
dB	decibel
dBi	gain in decibels relative to an isotropic antenna
dBm	gain in decibels relative to one milliwatt
$DELTA_{power}$	difference between RL and $NORM_{abs}$

$DELTA_{fH}$ difference between the high frequency of the OFR to the upper edge of the permitted frequency range
$DELTA_{fL}$ difference between the low frequency of the OFR to the lower edge of the permitted frequency range
$DELTA_{SX}$ difference between RL_{SX} and $NORM_{SX}$
$di_{\varphi,\theta}$ measurement direction in polar coordinates in relation to the EUT
f_L lowest frequency of the EUT OFR
f_{H_abs} higher edge of the OFR within the absolute measurement under normal conditions
f_{H_REF} higher edge of the OFR within the relative measurement under normal conditions
f_{H_step} higher edge of the OFR within the relative measurement at one environmental profile point
$f_{L,abs}$ lower edge of the OFR within the absolute measurement under normal conditions
f_{L_REF} lower edge of the OFR within the relative measurement under normal conditions
f_{L_step} lower edge of the OFR within the relative measurement at one environmental profile point
f_{PER_H} higher edge of the regulated permitted frequency range
f_{PER_L} lower edge of the regulated permitted frequency range
g_{AEUT} gain of the antenna under test in main beam direction in the respective plane [dBi]
K kelvin

NOTE: The numerical value of a temperature difference is the same for kelvin and Celsius (°C).

$NORM_{abs}$ max emission assessed in the "absolute" measurement
$NORM_{SX}$ max emission assessed in the "absolute" measurement for each range of the UWB emission which is overlapping with the OFR
P_{step} measured emission level (at each environmental profile point)
REF_{power} measured relative reference
REF_{SX} measured relative reference for each range of the UWB emission which is overlapping with the OFR
REF_{fL} measured relative reference for f_L
REF_{fH} measured relative reference for f_H
RL regulated limit
RL_{SX} regulated limit for each range of the UWB emission which is overlapping with the OFR
t_{low} lowest value of the environmental profile
t_{high} highest value of the environmental profile
t_{steps} steps in deg [°C or kelvin] from one to the next environmental profile point
T_{step} environmental profile point

3.3 Abbreviations

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

CATR Compact Antenna Test Ranges
d measurement distance
DFF Direct Far Field
DoC Declaration of Conformity
DRH Double Ridged Horn
e.i.r.p. equivalent isotopically radiated power

NOTE: Based on kind of power, e.g. mean power, peak power or mean power spectral density.

EUT Equipment Under Test
FMCW Frequency Modulated Continuous Wave
HF high frequency
HS Harmonised Standard
LNA low noise amplifier
LPR Level Probing Radar
MU measurement uncertainty
OFR Operating Frequency Range
OTA far-field Over-The-Air
PCB Printed Circuit Board
PSD power spectral density
QZ Quiet Zone
RBW Resolution bandwidth

RCS	Radar Cross Section
RL	Regulated Limit
RMS	Root Mean Square
RX	Receiver
SGH	Standard Gain Horn
SX	Index for a frequency segment for the assessment
TC	Technical Committee
TG	Task Group
TLPR	Tank Level Probing Radar
TR	Technical Report
TX	Transmitter
UWB	Ultra Wide Band
VBW	Video Bandwidth
VSWR	Voltage standing Wave Ratio

4 Radiated environmental profile measurements

4.1 Background

Requirements of radio equipment according to article 3.2 of the RED [i.6] are clearly to be compliant under all circumstances, including the environmental conditions.

However, radiated conformance tests to demonstrate compliance against a requirement are mostly not possible to execute under all circumstances/environmental conditions:

- Not possible to adjust temperature and humidity in a common standard test site (fully anechoic chamber, semi anechoic chamber, open area test site) as such chambers are not available in the market. This would lead to immense/unrealistic costs and used for extreme environmental tests, this would lead to damages at the site itself.
- Small climate chambers are available in the market, but calibrated, radiated measurements are not possible applying such.
- Measurements over the complete environmental profile is possible for equipment with permanent antenna connector (tests within a temperature chamber) but challenging for equipment with integral antennas without antenna connector (and where no provision is made in the EUT design for a temporary antenna connector, e.g. connector landing pads).

There is discussion ongoing in ETSI on how much effort in harmonised standards is needed to demonstrate, that the requirements are fulfilled over the entire environmental profile.

The current common understanding in ETSI is the following:

- A HS should define the environmental profile, if possible.
- If a HS cannot define the environmental profile (e.g. scope too broad, too many different profiles, only manufacturer knows the profile, too many different markets), then the declaration for the tests is possible, but the data needs to be objectively verifiable (e.g. within the EUT manual or DoC).
- Tests for specified requirements in the related standards shall be made under normal environmental conditions (e.g. within 20 °C to 25 °C).
- For equipment with integral antenna a HS should specify one or two requirements (e.g. radiated power or frequency stability) relative to measurements in a climate chamber over the complete profile (e.g. using test fixture, temperature chamber with radio transparent window) to give some confidence. The connection/calibration of relative measurement with absolute measurement should be made at normal temperature.

NOTE: The risk assessment of the manufacturer may be able to fill the gap which the limited radiated conformance measurements have left, e.g. by providing simulation results and calculations, and/or by making relative conducted measurements (using a temporary connection if necessary for internal antenna equipment), over the complete profile.

4.2 State of the art of radiated measurements over environmental profile

Today widespread available are (semi-) anechoic-chambers which do not provide a temperature-chamber function and are typically used at ambient environmental conditions of +5/+10 °C to +35/+40 ºC and 30 % to 60 %/70 % humidity. Such solutions are state of the art for radiated emission tests.

The following technical reasons, why it is difficult for a typical a (semi-) anechoic chamber, to execute radiated tests over a complete environmental profile (extreme conditions):

- Huge energy consumption, costs and time to heat up and cool down the chamber space (considering thermal balance).
- Large temperature changes could lead to condensation of water and water (behind absorbers) could lead to gridiron (steel parts) and could form verdigris (at copper) which would lead to deterioration of the shielding parts and the bonding of the absorbers will be reduced.
- In addition, temperature changes would also lead to expansion of the shielding structure causing changes that would create leakage problems and could create gaps between ferrite tiles.
- The temperature changes could also "destroy the fitting of the absorbers and this could lead to absorber damages (falling down).
- Absorbing material (attenuation) is only specified for a limited range of temperature and humidity, e.g. +5 °C to +90 °C and 30 % to 60 %/70 % for humidity, more information are provided in clause Annex A.
- All this possible changes in shielding and absorption parameter could lead to a higher maintenance effort and additional certification measures of the (semi-) anechoic chambers (worst case: re-certification).
- In addition, the specified environmental behaviour of "supporting structure", measurement equipment and "turntable/positioner" inside the (semi-) anechoic chambers could limit the possible operational temperature range for the testing as well.

4.3 Possibilities to measure over environmental profile

4.3.1 General

Tx parameters of EUTs shall be tested with regard to the ambient condition's temperature and supply voltage. For this purpose, the ambient temperature of the EUTs shall be changed via temperature chambers, for example.

The chamber size for temperature tests shall be selected depending on the size of the EUT, its frequency range and whether the EUT has an antenna connector or not.

A further distinction is made here as to whether the EUT's antenna is connected via a standardized antenna connector or whether the antenna is an integral part of the EUT.

If EUTs have a detachable antenna, the signal from the EUT can be fed out of the temperature chamber and to the measurement receiver via its permanent antenna connector using a cable. This is also possible if the antenna is not detachable, but a temporary antenna connector is provided in the EUT design (landing pads).

For EUTs with integral antennas three possibilities to measure the Tx parameters are available.

Test equipment manufacturers are working on solutions of radiated temperature tests, such as a radio transparent dome which covers a temperature-controlled volume (clause 4.3.3). Such test sides are under development and a few solutions are already available on the market. With these systems, depending on availability, the entire measurements can be carried out in an anechoic chamber. Here, even absolute measurements can be carried out after calibrating the entire system.

If such a solution is not available, temperature chambers (clause 4.3.2) shall be used, and relative measurements shall be carried out.

Measurements from clause B.4 show that also for low gain antennas and small temperature chamber sizes compared to the wavelength of the EUT's RF signal an absorbing box (clause 4.3.4) can be used to conduct the measurement inside the temperature chamber.

Further measurements from clause B.2 show that with sufficient chamber size and high gain antennas, EUTs whose antenna is an integral part of the device can be measured in the near field of the measurement antenna and inside the chamber.

As an alternative, the temperature chamber can be equipped with a radio transparent door through which the EUT can be measured.

Figure 1 gives guidance which test solution shall be used to conduct the measurement.

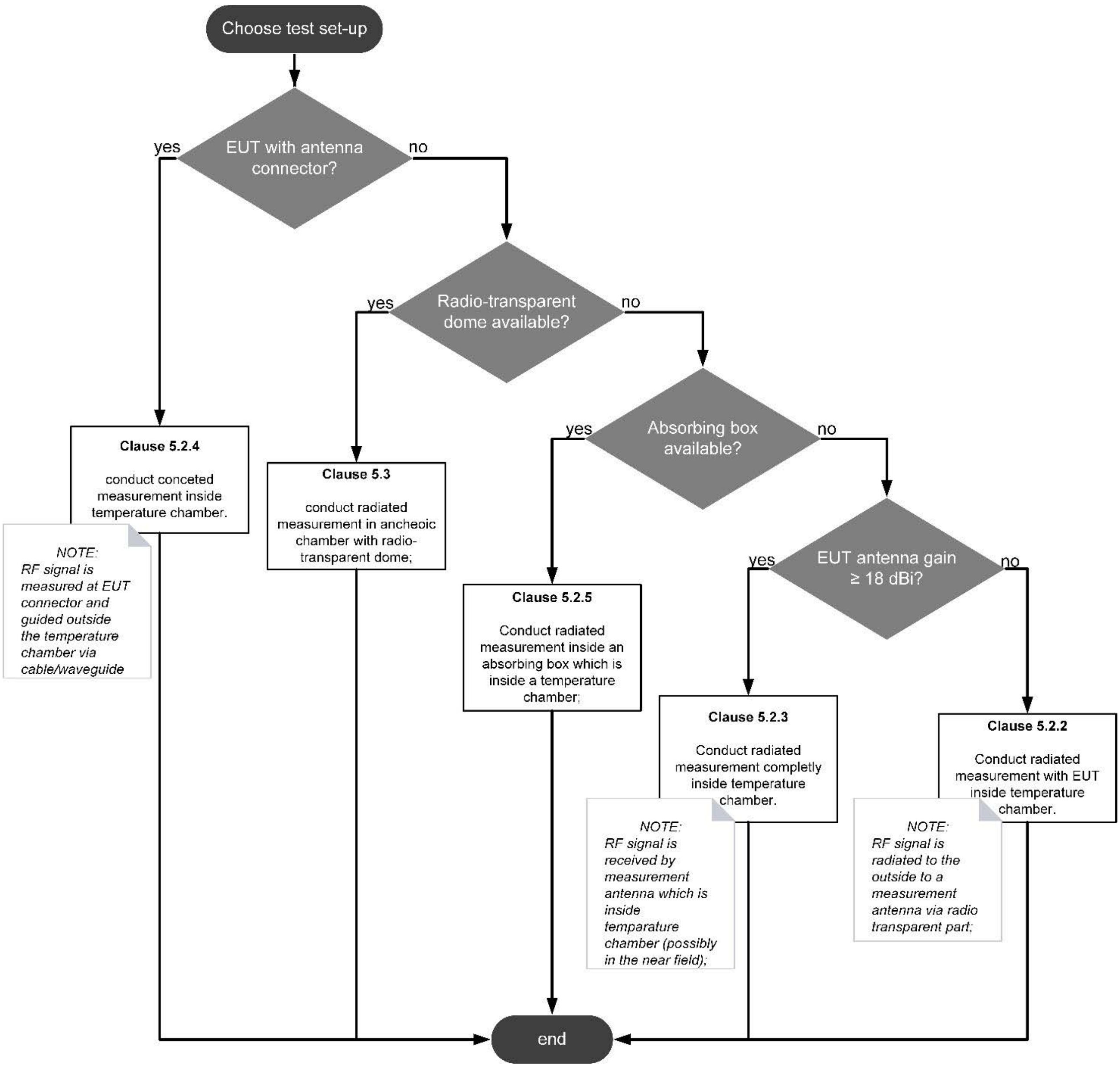


Figure 1: Guidance to choose the right measurement set-up in clause 5

4.3.2 Temperature chamber

Tests and performance requirements of temperature chambers are described in IEC 60068-2-1 [i.11] (cold testing), IEC 60068-2-2 [i.12] (dry heat testing) and IEC 60068-3-5 [i.2] (Confirmation of the performance of temperature chambers).

4.3.3 Radio transparent dome

4.3.3.1 General

Radio transparent dome within (semi-) anechoic chamber, see clause 5.3. Such set-up is also named as Temperature Bubble for environmental RF testing, see [i.4], [i.7] and [i.8].

The measurement methodology relies on far-field Over-The-Air (OTA) assessments in Compact Antenna Test Ranges (CATR). For OTA measurements in temperature conditions ranging from -10 °C to +55 °C and extended temperature ranges from -40 °C to +85 °C an innovative realization of a CATR with an embedded thermal compartment meeting conformance and compliance testing needs is presented [i.7].

The Equipment Under Test (EUT) is enclosed in a thermal compartment within the OTA chamber, which contains the cold or hot air as hermetically as possible. The rest of the chamber is ventilated to maintain close to the ambient temperature.

As a prerequisite, the thermal enclosure should be sufficiently RF transparent to minimize any impact on Quiet Zone (QZ) uniformity and EUT radiation. Yet the enclosure should to be stable and withstand the increase in inner air pressure from the temperature air flow while isolating the hot and cold air flow from the surrounding environment. All mechanical parts of the thermal enclosure, as well as the air pipes which connect to it, has to support full 3D movement of the dual-axis positioner - hence the EUT - while being airtight. The air hoses run in and out of the chamber through RF shielded walls without compromising the shielding effectiveness.

The measurement chamber and temperature supply are shown in figure 2. The compressed dry air at the desired temperature is provided by an external climate machine called a "thermostream". Connected to power and the central compressed air supply, it provides the required air volume between the minimum and maximum air temperatures to the air inlet of the anechoic chamber. Running the air pipes through the shielded chamber walls requires RF filtered air feedthroughs, which comprise multiple metal pouches filled with absorber, guiding the air through winding pipes to the inside of the chamber. Inside the shielded chamber, the hoses connect to an air rotary joint. It separately supports airflow in both directions (supply and exhaust) through the elevation axis of the combined azimuth-over-elevation positioner, while not limiting its angular movement capabilities.

Figure 2: OTA chamber with the thermal compartment (left side) and the inside of the OTA chamber with the RF transparent compartment (right side) (source: ROHDE & SCHWARZ GmbH & Co.KG)

The inside of the chamber with the Rohacell® RF transparent compartment is shown in figure 3.

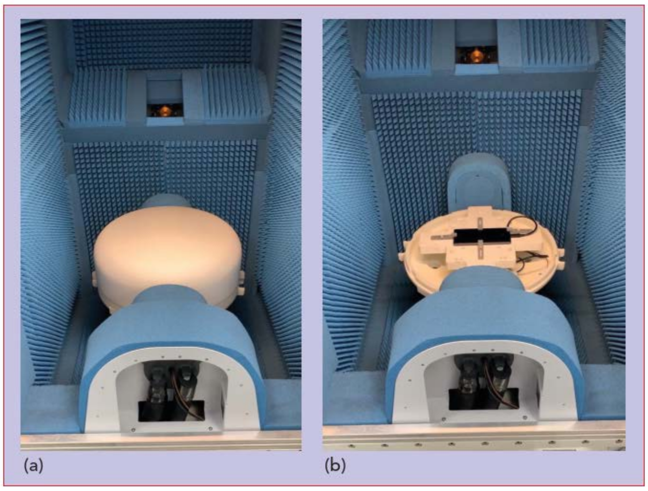


Figure 3: Inside of the OTA test system with 35 l Rohacell and thermal enclosure closed (a) and open showing a EUT (b) (source: ROHDE & SCHWARZ GmbH & Co.KG)

4.3.3.2 Performance

- The positioning system can cover azimuth range from ± 180° and an elevation range from ±120° and is not reduced by the air pipes or other ETC requirements on the positioner.
- Spherical measurements with the device temperature from -10 °C to +55 °C can be performed.
- An extended temperature range of -40 °C to +85 °C (for stress tests) is available.
- 30 cm diameter QZ during extreme temperature conditions testing, with an uncertainty better than 0.9 dB
- Chamber shielding > 70 dB, not degraded by air injection pipes.
- Flow rate up to 700 l/minute realizes temperature change from +85 °C to -40 °C is possible in 10 to 14 minutes within a 50 litre compartment.
- 30 litre or 50 litre compartment available.

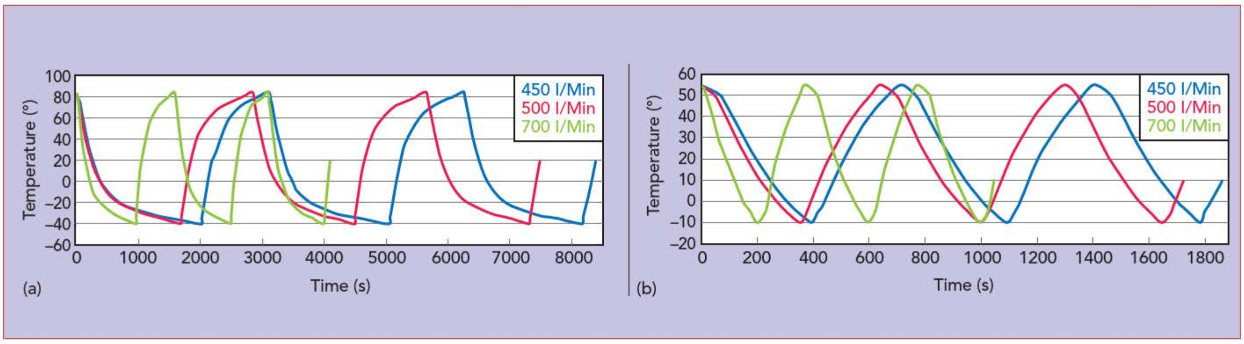


Figure 4: DUT temperature cycling times in 50 l enclosure at 450, 500 and 700 l/min air flow rates: -40 °C to +85 °C (a) and 3GPP (source: ROHDE & SCHWARZ GmbH & Co.KG)

Frequency Ranges

The frequency range that is covered by the system is mainly defined by the chamber itself as well as the chosen feed antenna. The size of the chamber and the desired quiet zone quality and size are one important aspect if antenna pattern or out-of-band power measurements need to be done.

In case of an R&S ATS1800C [i.8], the chamber itself covers 6 GHz to 92 GHz. However, given the chamber size and other aspects, antenna pattern can be measured in frequency ranges starting at 12 GHz, and for example out-of-band power measurements are also covered in 6 GHz to 12 GHz frequency range. For frequency ranges below 6 GHz, other shielded chambers, like Direct Far Field (DFF) chambers are required.

The temperature-controlled compartment itself can cover the entire frequency range. However, the size of the compartment (up to 50 litres) defines the size of the EUT and the possibilities to feed the pipes through shielded environments outside of a shielded chamber dictates the possible setups and lowest frequency and temperature range that can be covered.

4.4 Procedure for Tests at Extreme Temperatures

For a temperature measurement it is necessary that the temperature surrounding the EUT has also reached the inside of the unit. The state shall be steady.

Since temperature changes are very slow processes, it is necessary to wait a certain time after setting a new temperature level until a measurement of the transmission power can be carried out.

The time until a device is in a steady state depends on its construction. The thermal conductivity of the materials used, the volume and the weight of the device play a decisive role.

For example, electronic units of EUTs can be filled with a potting compound that is intended to protect the electronics from environmental influences. If such a potting compound is used, the time until the EUT is warmed through is prolonged.

After temperature changes in a temperature chamber, a certain amount of time passes until the temperature display is stable. Depending on whether additional absorbers, an absorbing box or a radio transparent door is used, a longer time will pass until the temperature next to the EUT shows the same temperature as the display of the temperature chamber. This should also be taken into account and an additional thermometer probe next to the EUT shall be used.

When the displayed temperature value after a change in temperature of the chamber is stable a certain amount of time shall be waited until the EUT is warmed through.

If not otherwise specified in the related standard, the following time (after stable reading in the thermometer probe) shall be waited until the TX-measurement is conducted:

- half an hour for temperature steps ≤ 10 K
- one hour for temperature steps > 10 K and ≤ 20 K
- one and a half hour for temperature steps > 20 K and ≤ 30 K
- two hours for temperature steps > 30 K

During the TX-measurement the fans of the chamber and the absorbing box shall be switched off to avoid any kind of interference.

4.5 Test Conditions, Power Supply and Ambient Temperatures

4.5.1 General

The equipment has to comply with all the technical requirements as identified in annex A of the related harmonised standards at all times when operating within the boundary limits of the declared operational environmental profile.

However, practical measurements are usually not realistic to be done at each and every possible combination of the environmental profile due to the huge time required.

The key is here to carry out tests under a sufficient variety of environmental conditions (within the boundary limits of the specified environmental profile within the related standard or declared operational environmental profile by the manufacturer) to give confidence of compliance for the affected technical requirements under the complete environmental profile. The following procedure would be reasonable to achieve the compliance for the affected technical requirements over the specified or declared operational environmental profile of the equipment based on the intended use :

- If not otherwise specified in the related standard, the manufacturer could declare the environmental profile of the equipment in the DoC or EUT manual.
- Representative points within the boundary limits of the specified or declared operational environmental profile, if not otherwise specified in the related standard, should be selected for the measurements (e.g. lowest and highest values); it should be noted that dependent on the size of the EUT the test might only be possible at the environmental condition at the test site.

  The manufacturer could provide in the technical documentation file (see article 21 of Directive 2014/53/EU [i.6]) other information which shows that the equipment is expected to fulfil the conformance requirements over the complete environmental profile, e.g. simulation results, measurements at the board, data sheets.

4.5.2 Power Sources

4.5.2.1 Power Sources for Stand-Alone Equipment

During testing, the power source of the equipment may be replaced by a test power source capable of producing normal test voltages as specified in the related standard. 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 range 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.

4.5.2.2 Power sources for plug-in radio devices

The power source for testing plug-in radio devices shall be provided by external power supply 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.

4.5.3 Normal and Extreme Test Conditions

4.5.3.1 Normal Test Conditions

4.5.3.1.1 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.

4.5.3.1.2 Normal Power Source

4.5.3.1.2.1 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.

4.5.3.1.2.2 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.).

4.5.3.1.2.3 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.

4.5.3.2 Extreme Conditions

4.5.3.2.1 Extreme Temperatures

4.5.3.2.1.1 Procedure and test set-ups for tests under extreme conditions of the environmental profile

Procedures as specified in the related standard and for guidance see present document, clause 6.

Test set-ups for measurements under the extreme conditions of the environmental profile shall be as used as specified in the related standard, for guidance see clause 5.

4.5.3.2.1.2 Extreme Temperature Ranges

Extreme conditions shall be as defined in the related standard with a temperature range varying between -X1 °C to +X2 °C. The specified range shall consider the EUT category and the wanted technical performance (intended use) of the EUT.

For tests at extreme temperatures, measurements shall be made in accordance with the procedures specified in the related standard (see clause 5 and clause 6 for guidance), at the upper, lower and specified steps of the environmental profile of the EUT (see related standard). For guidance see clause 4.5.4.

The test report shall state which environmental profile points were assessed, see clause 4.5.4.

4.5.3.2.2 Extreme Test Source Voltages

4.5.3.2.2.1 Mains Voltage

The extreme test voltages for equipment to be connected to an AC main source shall be the nominal mains voltage ±10 % if nothing different is specified in the related standard.

4.5.3.2.2.2 Other Power Sources

For equipment using other power sources, or capable of being operated from a variety of power sources, the extreme test voltages shall be those that are specified in the technical documentation file. These shall be recorded in the test report.

4.5.4 Complete environmental profile test conditions and procedure in general

The complete environmental profile test conditions include both the normal (see clause 4.5.3.1) and extreme conditions (see clause 4.5.3.2). As explained the profile could either be specified in the related standard and/or provided (specified) by the manufacturer in the EUT manual or EUT DoC.

The test report records which environmental profile and the related environmental profile points were assessed.

The complete assessment procedure is shown in figure 5. If not otherwise specified in the related standard, for the assessment procedure over the environmental profile (per environmental steps) for the TX-behaviour within the relative test set-up the procedure as shown in figure 6 shall be used.

Before starting the emission measurement on one environmental step point (T_{step}) sufficient time need to consider to reach the thermal balance inside the relative conformance test set-up, see clause 4.4.

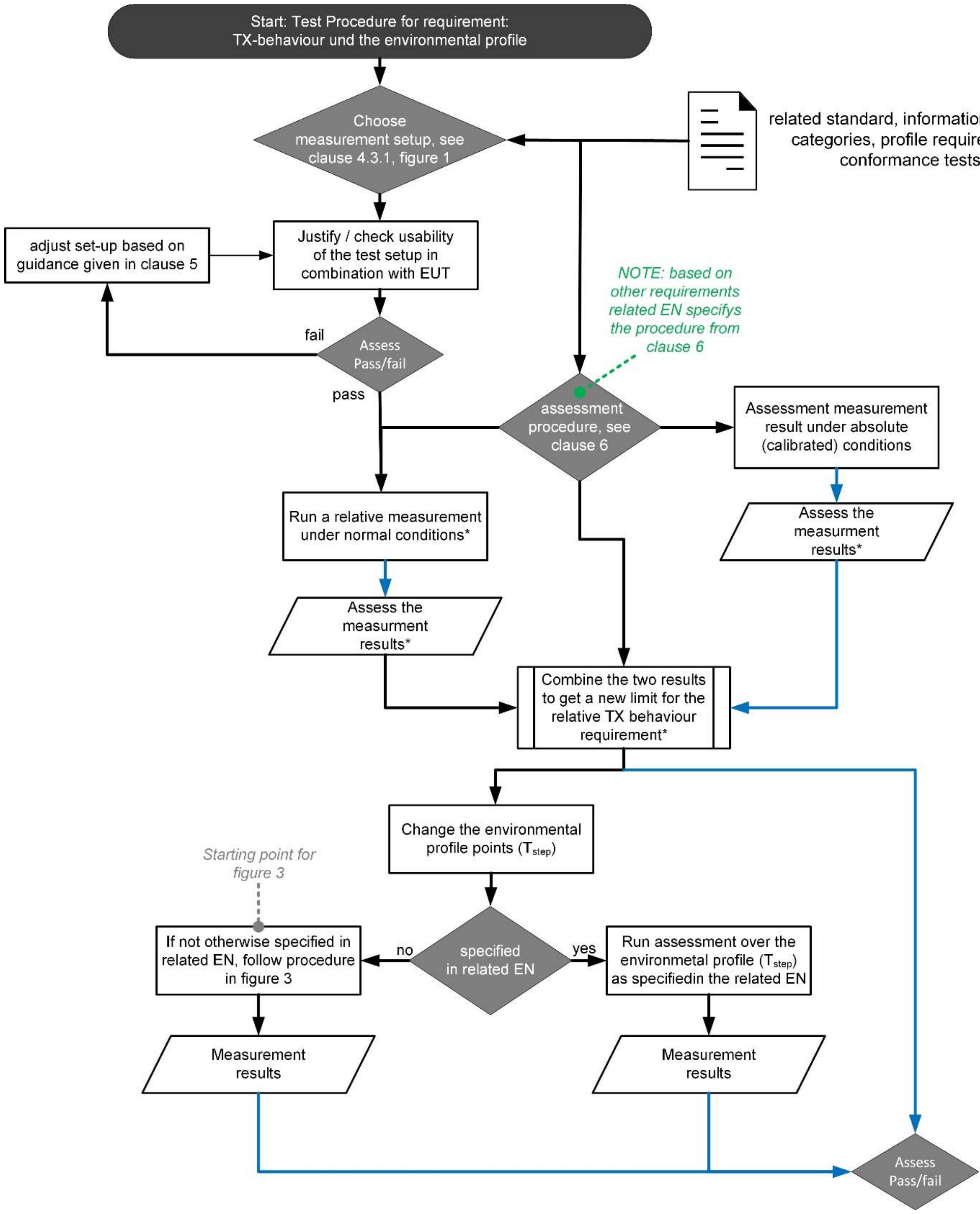


Figure 5: General assessment procedure

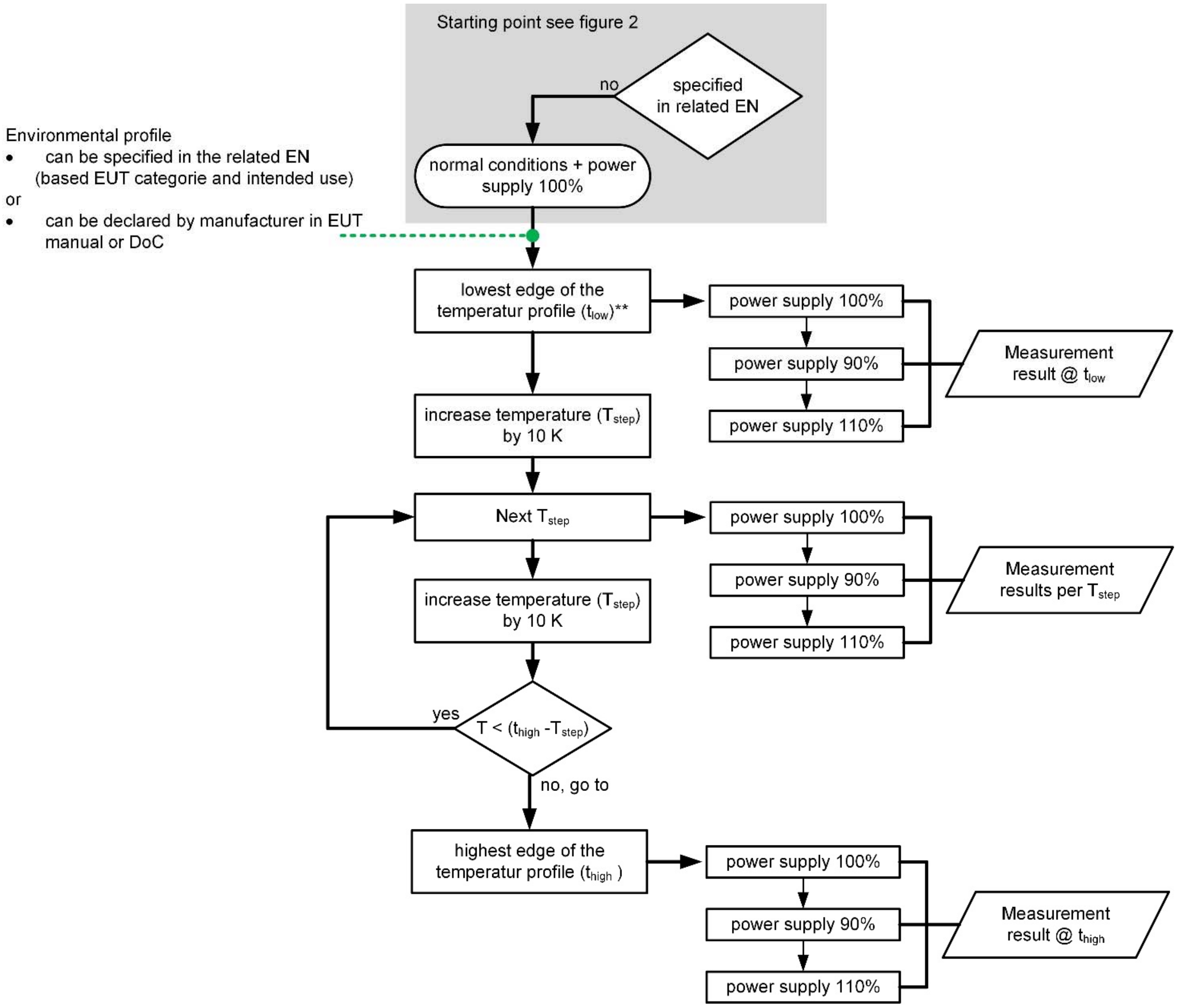


Figure 6: Assessment procedure over environmental profile (per T_{step}) within the related test set-up

5 Test solutions for TX-behaviour under environmental profile

5.1 General

As still explained the most widespread solution to assess the behaviour of an EUT is the usage of a temperature chamber, see clause 5.2. The usage of a radio transparent dome is very difficult (based on the mechanical realization) or limited in the usability (size and frequency range, see clause 5.3).

Based on that the TX-behaviour could only be realized based on a relative assessment (see clause 4.1 and the test set-ups in clauses 5.2.2, 5.2.3 and 5.2.5) of the EUT emissions therefore, such set-up shall be realized within a full or semi-anechoic chamber or a radio quiet environment. The environment (full, semi and quiet) is only necessary to reduce the impact from other radio sources. These other radio sources would make it more difficult to assess the TX-behaviour (EUT related TX emissions) and not to consider emissions at frequencies which would be radiated from other sources. This could be checked by a simple emission assessment of the environment (measurement of other present emissions in the frequency range under interest).

The related standard shall specify parameters/requirements to choose either the relative set-up (see clauses 5.2.2, 5.2.3 and 5.2.5) and the absolute set-up (clauses 5.2.4 and 5.3) and the related assessment procedure in clause 6 or clause 7.

Based on this there are several test environment and test set-ups, more detailed solutions described in:

- Clause 5.2.2: for the case if EUT is inside a temperature chamber and radiated through a radio transparent door/part of the temperature chamber to the measurement antenna.
- Clause 5.2.3: for the case that EUT and the measurement antenna are both inside the temperature chamber.
- Clause 5.2.4: EUT emission will be assessed based on a conducted solution and the EUT inside the temperature chamber.
- Clause 5.2.5: with use of an absorbing box inside the temperature chamber.
- Clause 5.3: the use of a temperature dome inside an anechoic test environment.

5.2 Assessment within temperature chamber

5.2.1 General considerations for radiated test set-up and EUT inside a temperature chamber

Some general considerations for radiated test set-up and EUT inside a temperature chamber.

- The retainer to fix the EUT inside the temperature chamber shall not have an impact on the radiation, therefore, non-metalized material shall be used. The use of metalized flat grids (typical available inside temperature chambers) shall be avoided. If metallized girds cannot be "removed" the EUT shall be placed on an isolating and absorbing material with an attenuation if minimum 20 dB.
- Based on the antenna pattern of the EUT (e.g. more spherical radiation pattern) is important that to be outside of the reactive nearfield of the antennas (mainly EUT), the following distances have to be met:
  - The distance between measurement antenna and EUT antenna should be greater than 10λ.
  - The distance from measurement antenna to the temperature chamber walls should be greater than 10λ.
  - The distance from EUT antenna to the wall of the temperature chamber should be greater than 10λ.

With: λ is the wavelength of the lowest frequency (f_L) of the EUT OFR (see OFR requirement in the related standard), see equation (1)

$$\lambda\,[m] = \frac{c\left[\frac{m}{s}\right]}{f_L[Hz]} = \frac{299792458\,[\frac{m}{s}]}{f_L[Hz]} \qquad (1)$$

If the distances are not possible the usage of additional absorbing material (see clause clause A.3) between the EUT and the temperature chamber walls shall be used. The attenuation/absorption shall be in minimum 20 dB for the OFR frequency range of the EUT.

The use of absorbing material will have impact on the temperature adjustment inside the temperature chamber and could lead to a temperature difference at the EUT position and the shown temperature on the temperature chamber user interface. In such cases a thermometer shall be place close to the EUT. To reduce the impact of the thermometer on the EUT emissions it shall be switched of during the emission assessment and it shall be place at directions of the EUT with low or no measurable emissions (consideration of the absolute e.i.r.p. measurements, see related standard).

The environmental profile behaviour (change in attenuation, etc.) of the material used as radio transparent, or dome/box shall be known or assessed similar the set-up described in clause A.4.

The heating functionality of the temperature chamber shall be switched during the emission measurement to limit the interference on the measurement results to a minimum.

5.2.2 In Detail: radiated set-up with radio transparent part of the temperature chamber

5.2.2.1 Set-up Description

The first arrangement is with the measurement antenna outside the temperature chamber and the EUT related emission will be measured through a radio transparent part of the temperature chamber door, or the temperature chamber door will be replaced by possible material. This test set-up is shown in figure 7.

NOTE: measurements have shown that glass windows (typical available in temperature chambers) are not usable as radio transparent parts. Main reason is that these windows are metalized to increase the temperature stability of the temperature chamber. For that reason, it is a better solution to use a replacement of the door by radio transparent material and bridge the "door closing contact" of the temperature chamber.

Figure 7 shows a basic test set-up of a temperature chamber.

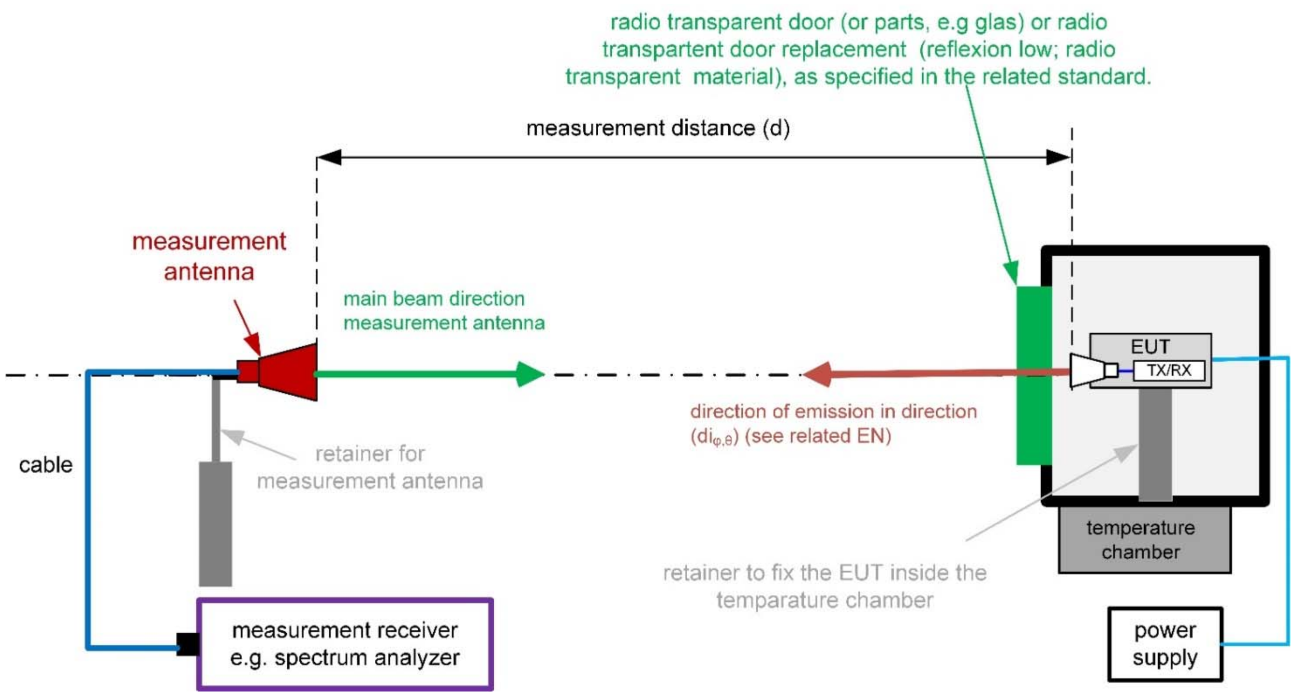


Figure 7: Basic radiated set-up with temperature chamber within full anechoic chamber

Additional points for consideration.

- A measurement antenna with an antenna gain of minimum 18 dBi for the assessed frequency range is proposed. If such measurement antenna is not available (e.g. based on necessary bandwidth) an antenna with lower gain can be used, but in such cases, there is a need to assess the emission measurement on plausibility (see for example clause B.3 and clause B.5)

NOTE 1: For justification, see measurements in clause B.3 and clause B.5

- For the EUT adjustment inside the temperature chamber it is necessary to consider that the direction of the emission which shall be assessed, shall radiated perpendicular to the radio transparent material.

- For this set-up it is very likely that the shown temperature on the temperature chamber interface will be not the same than at the location of the EUT inside. Therefore, it is proposed to monitor the temperature at the EUT (with an additional temperature sensor) during the temperature settlement process.

- The used radiotransparent material (see figure 7) shall cover in minimum the door opening of the temperature chamber and temperature insolation of the radio transparent material shall limit the temperature drift during the emission measurement (heating function of the temperature chamber is off to reduce interference to the measurement) < 2 K.

NOTE 2: The temperature insolation of the material is given in the material datasheet or if not know the thickness could be increased and the set-up could be assessed.

5.2.2.2 Justification of the impact on the radio emissions in the set-up

To Justify the test set-up/arrangement it is proposed before running an TX-behaviour assessment over the complete environmental there shall be a comparison of the e.i.r.p. measurement (absolute emission test) and an emission measurement based on the arranged relative set-up (see figure 8).

If the emission looks completely different (in frequency and/or emission power levels) or the shape of the power envelope of the emissions is completely different than the set-up shall be adjusted by e.g.:

- use of larger temperature chamber (more space between EUT and temperature chamber wall); and/or
- adding absorbers inside the temperature chamber; and/or
- change of the material used as radio transparent (or assess material if there are impacts); and/or
- change of the set-up in principle (e.g. measurement antenna from the inside to the outside, etc.);
- change measurement antenna e.g. with smaller antenna gain to reduce the antenna size, etc.

NOTE: To get as stable/reproduceable set-up a realization of an absorbing box which would fit into a temperature chamber would reduce the justification effort. Such absorbing box solution is descripted in clause 5.2.5.

5.2.3 In Detail: radiated with measurement antenna inside the temperature chamber

5.2.3.1 Set-up Description

The second set-up arrangement is with the measurement antenna inside the temperature chamber. This test set-up is shown in figure 8.

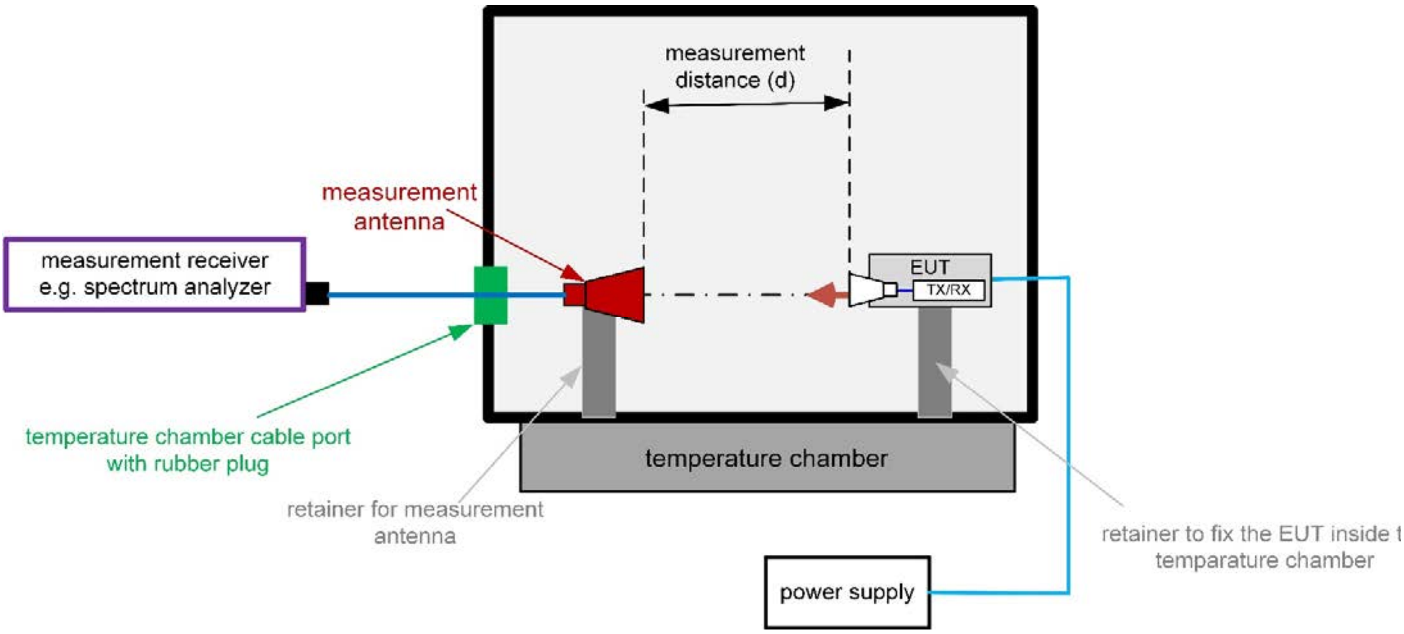


Figure 8: The basic arrangement for measurement antenna inside the temperature chamber

Additional points for consideration.

- A measurement antenna with an antenna gain of minimum 18 dBi for the assessed frequency range shall be used.

NOTE: For justification, see measurements in clause B.2.

- The measurement receiver is connected directly to the measurement antenna via a cable or waveguide, which is brought inside the temperature chamber through an opening which is sealed with a rubber plug.
- The measurement antenna is oriented in boresight direction with respect to the EUT antenna or the direction of emission for the assessment (e.g. direction of the highest emission).

5.2.3.2 Justification of the impact on the radio emissions in the set-up

To justify the test set-up/arrangement it is proposed before running an TX-behaviour assessment over the complete environmental there shall be a comparison of the e.i.r.p. measurement (absolute emission test) and an emission measurement based on the arranged relative set-up (see figure 8).

If the emission looks completely different (in frequency and/or emission power levels) or the shape of the power envelope of the emissions is completely different than the set-up shall be adjusted by e.g.:

- use of larger temperature chamber (more space between EUT and temperature chamber wall); and/or
- adding absorbers inside the temperature chamber; and/or
- change of the material used as radio transparent (or assess material if there are impacts); and/or
- change of the set-up in principle (e.g. measurement antenna from the inside to the outside, etc.);
- change measurement antenna (e.g. with smaller antenna gain to reduce the antenna size, etc.).

NOTE: To get as stable/reproduceable set-up a realization of an absorbing box which would fit into a temperature chamber would reduce the justification effort. Such absorbing box solution is descripted in clause 5.2.5.

5.2.4 In Detail: connected if EUT has permanent antenna connector (inside the temperature chamber)

5.2.4.1 Set-up Description

The third arrangement is a conducted measurement. This test set-up is shown in figure 9.

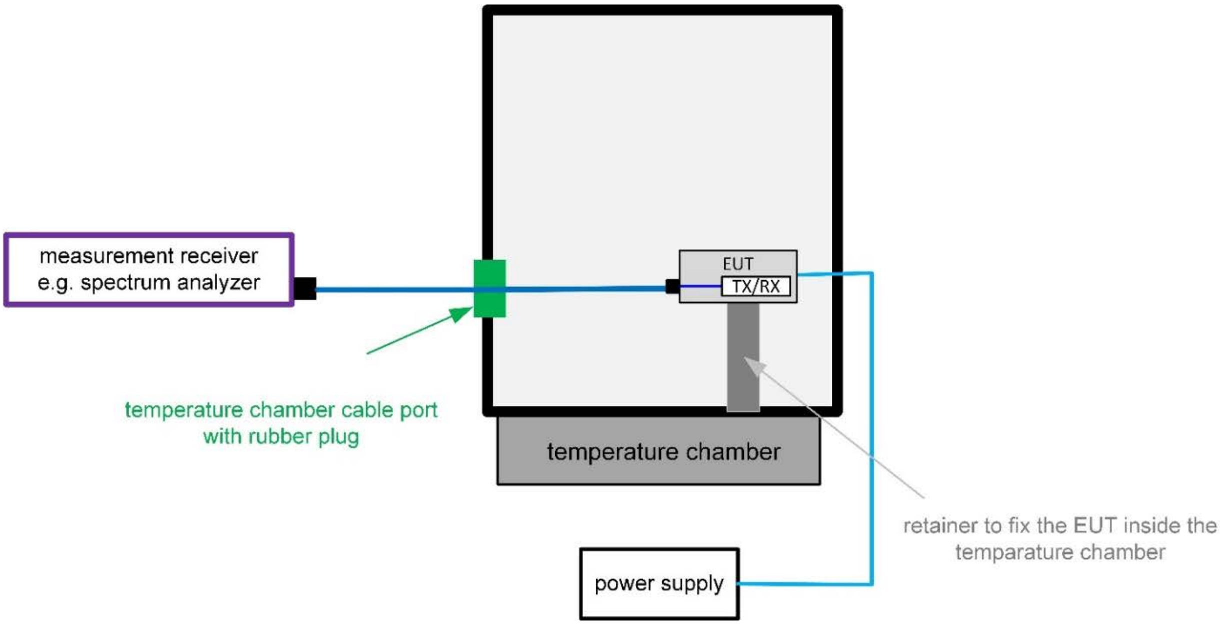


Figure 9: The basic arrangement for conducted measurement set-up

Additional points for consideration.

- This test set-up shall be only considered if the EUT could over a specified antenna connector or if a temporary antenna connector is foreseen in the hardware design.

NOTE: Absolute measurement possible, related assessment procedure see clause 7.

5.2.4.2 Justification of the impact on the emissions in the set-up

The justification of the test set-up/arrangement is only necessary if a temporary antenna connector will be attached to the device. In such cases the emission measured via the temporary antenna connector show a plausible emission characteristic compared to the radiated emission (power levels and shape). This is necessary to justify if the mounting was correct (as foreseen in the EUT hardware).

5.2.5 In Detail: with absorbing box inside a temperature chamber

5.2.5.1 Set-up Description

The fourth arrangement is a radiated measurement solution with an absorbing box within the temperature chamber. This test set-up is shown in figure 10.

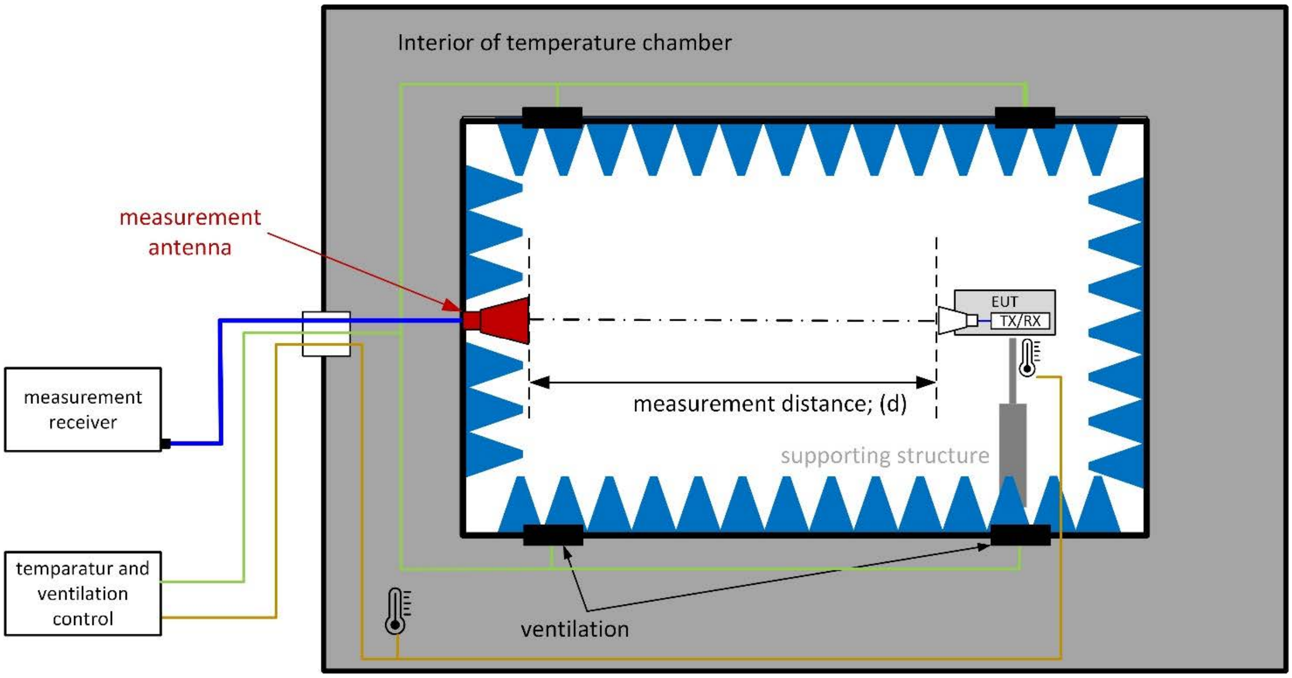


Figure 10: The basic arrangement for a measurement set-up with absorbing inside the temperature chamber

Additional points for consideration.

- The box dimension shall be large enough to reach in minimum a measurement distance (d) that is further than the $2D_{ap}^2/\lambda$ far field distance of the measurement antenna, where D_{ap} represents the maximum dimension of the antenna orthogonal to the direction of propagation, see [i.5].
- Additional ventilation and temperature sensors shall be considered to get a good thermal balance and distribution in the absorbing box. The ventilation and temperature measurement shall be switched off during the radiated emission testing unless the measurement is otherwise validated.

5.2.5.2 Justification of the impact on the emissions in the set-up

For more details see clause clause B.4

- In clause B.4.1, there is more information on one method for building up an absorbing box.
- In clause B.4.2, there is information on ways to verify the performance of an absorbing box.
- In clause B.4.3, there is an example measurement performed in such an absorbing box.

5.3 (Semi-) anechoic chamber and transparent dome

Figure 11 shows a basic test set-up of a radio transparent dome/box around the EUT and inside a full anechoic chamber. Such test set-ups are not widespread and typically only available as purchase (as a complete test set-up) for some specific cases, e.g. to test mobiles, see clause 4.3.3 and figure 11.

If such a set-up is available as a certified solution (see [i.4] and [i.8] the environmental test can be performed as an absolute measurement. Therefore, the set-up needs to be calibrated, see related manual of the test set-up.

If there is not a completely test set-up available, in other words the dome/box needs to build up for the testing, additional points shall be considered:

- The size of the dome/box shall be large enough not impact the radiation but as small enough to reduce the effort to change the environmental profile inside the dome/box.

- The dome/box shall allow an EUT orientation inside that the direction of interests will be perpendicular to the walls of the dome/box (see angular requirements in ETSI TS 103 789, clause A.2.2 [i.1]).

NOTE: This is necessary of the dome as no spherical structure.

- It could be difficult to proof the dome/box against the rest of the chamber.
- This could lead to limitations of the possible assessable temperature range, and it is necessary to monitor the environmental profile at the EUT location.
- The equipment for the environmental profile creation shall be placed in such a way that it will not create any impact/interference to the assessment (e.g. based on emissions).

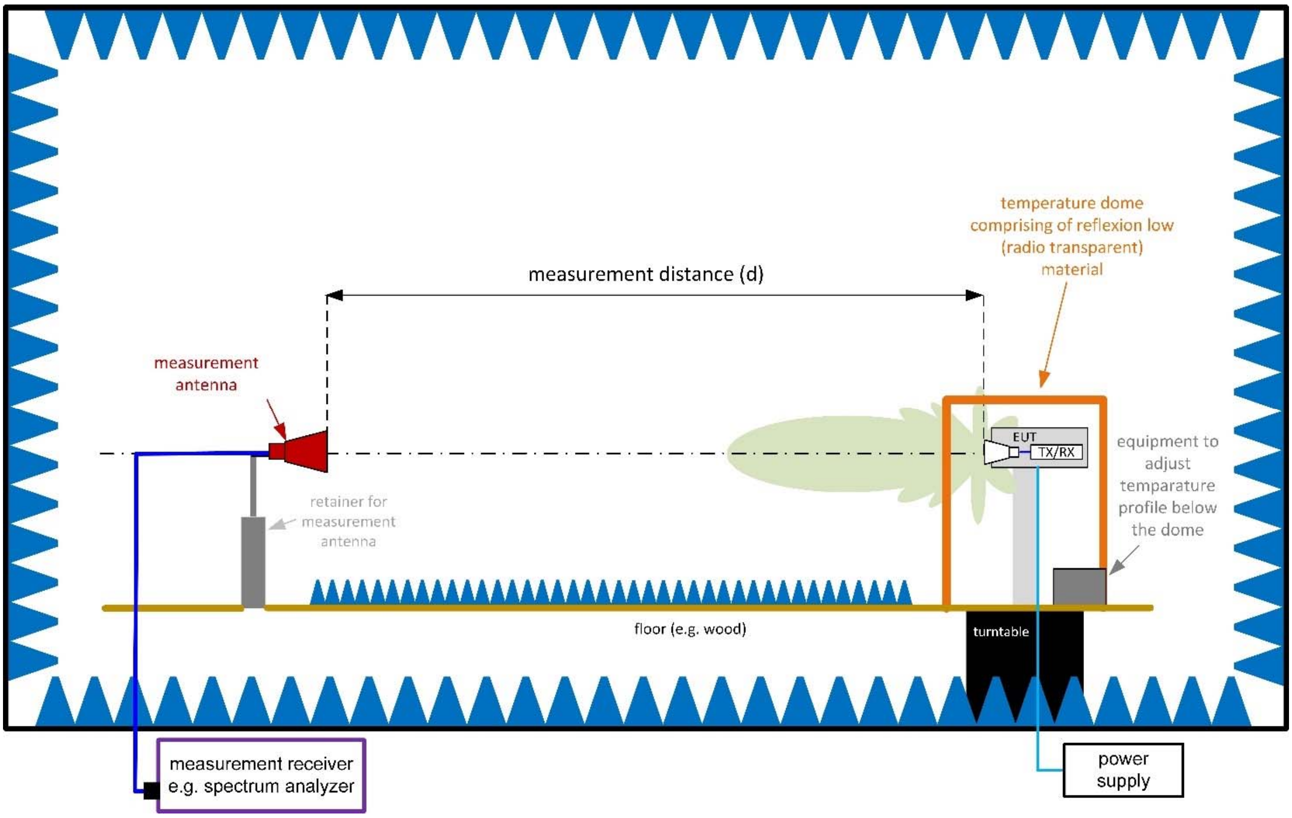


Figure 11: Schematic figure to show a radio transparent dome within a full anechoic chamber

5.4 Considering's for settings of the measurement receiver

The power shall be measured with the same measurement receiver settings (number of measurement points, RBW/VBW, sweep time) as for the absolute power measurement under normal conditions (calibrated test set-up), see related standard.

6 Assessment procedures over environmental profile

6.1 General on assessment procedures

The general basics for the assessment procedure is still explained in clause 4 and a general overview on the procedure is provided in clause 4.5.4 and the figures 2 and 3.

The assessment procedures descripted in the clauses 6.2, 6.3, 6.4 and 6.5 are based on radiated test set-ups, because the assessment shall be performed in the direction of the highest EUT emission (or sufficient emission level to have sufficient dynamic in the measurement system).

For conducted tests will be in any case in the direction of the highest emission and therefore the assessment procedures can be used as well.

For all assessment procedures the step 1 and step 2 is performed in the "absolute" calibrated conformance test set-up (see related standard) and the assessment itself (read out of the emissions levels,..) has to be done in the direction(s) of the highest emissions (e.i.r.p.). The directions could be different for each frequency depending on the EUT and the use-case (e.g. EUT is operating close to material, within an scenario).

All the other steps of the assessment procedures are within the "relative" test set-ups and descripted in clause 5 and specified in the related standard

Currently the present document provides four procedures to assess the TX-behaviour of the environmental profile:

- Clause 6.2: based on a simple radiated power measurement and Mean e.i.r.p. or Peak e.i.r.p. requirement.
- Clause 6.3: based on a power and OFR measurement and a Mean e.i.r.p. or Peak e.i.r.p. requirement and the frequencies shall still within the permitted range.
- Clause 6.4: based on a power spectral density measurement over the EUT OFR.
- Clause 6.5: specific procedure for EUT operating within a scenario, Assessment is over the EUT - OFR and based on Mean e.i.r.p. Spectral Density requirement.

6.2 Assessment of the radiated power (Mean e.i.r.p. or Peak e.i.r.p.)

6.2.1 Procedural steps

6.2.1.1 Step 1: EUT OFR and regulated TX requirements

The starting point is the calibrated/absolute measurement result of the mean e.i.r.p. [dBm] or peak e.i.r.p. power [dBm] requirement under normal conditions.

Action 1: Read out and record the Mean/Peak e.i.r.p. power ($NORM_{abs}$) from a calibrated measurement.

Action 2: Record the related Regulated Limit ((RL), either Mean/Peak e.i.r.p.) which is required for the EUT in the permitted frequency range.

6.2.1.2 Step 2: Assessment absolute measurement

Action 1: Calculate the $DELTA_{power}$ between the regulated limit (RL) and the measured value ($NORM_{abs}$), see step 1 (see clause 6.2.1.1) above and calculate, with equation (2):

$$DELTA_{power} = RL - NORM_{abs} \qquad (2)$$

6.2.1.3 Step 3: Test set-up TX-behaviour environmental profile

Now place the EUT into one of the environmental profile test set-ups from clause 5 using the guidance from clause 4.3.

For the EUT arrangement the same direction as assesses out of the absolute measurement see step 1 (see clause 6.2.1.1) and step 2 (see clause 6.2.1.2) needs to be considered.

NOTE: For radiated tests the direction with highest emission could guarantee sufficient dynamic for the following steps. But if the mounting inside the set-up is not possible (space, size of the EUT, etc.), other emission directions could be used as well for the relative measurements if this position is kept for all the relative measurements. Therefore, it is only important to have sufficient dynamic range in the measurement. This is possible because only the relative changes in the emissions will be considered in this procedure.

6.2.1.4 Step 4: Relative reference measurement at normal conditions

Action 1: Run a measurement based on the set-up and arrangement out of step 3 (see clause 6.4.1.3) under normal conditions and record the related environmental conditions. For the measurement the same measurement receiver settings (RBW, span, measurement time) used to get the absolute measurement in step 2 (see clause 6.2.1.2) shall be chosen.

Action 2: Read out and record the measured emission level as REF_{power}

6.2.1.5 Step 5: Calculate an adjusted limit for the TX-behaviour testing under environmental profile

Here an adjusted limit for the following relative measurement is calculated. For the adjustment the measured reference emission (REF_{power}) from step 4 (see clause 6.4.1.4) and the related $DELTA_{power}$ (out of step 2, see clause 6.2.1.2) are needed. This calculation will provide an new environmental profile limit for the emission over the environmental test (Adjusted_RL).

Action: Calculate with equation (3):

$$\text{Adjusted\_RL [dBm]} = REF_{power}\text{ [dBm]} + DELTA_{power}\text{ [dBm]} \quad (3)$$

NOTE: If in the following steps the emissions over the environmental profile would be now below the "new" limit (environmental profile limit (Adjusted_RL)) it could be guaranteed that also under the "absolute" case the emissions would below the regulated emission limits.

6.2.1.6 Step 6: Relative measurement over environmental profile

Action 1: Run the same measurement as under step 4 (action 1) on all environmental profile points T_{step} as specified in the related harmonised standard.

Action 2: Read out and record for each measurement (for each environmental profile point T_{step}) and note the emission level (P_{step}) for each environmental profile point.

NOTE: The environmental profile points can include for example temperature and voltage. Table 1 shows an example of possible environmental steps for the tests.

Table 1: Proposal for T_{steps} and the changes in temperature and voltage (per step)

T_{step}	Temperature	Voltage
1	Normal (20 °C)	Nominal
2	Normal (20 °C)	Minimum
3	Normal (20 °C)	Maximum
4	Minimal	Nominal
5	Minimal	Minimum
6	Minimal	Maximum
…..	Related standards specify the steps in temperature from minimal to maximal temperature	
	Maximum	Nominal
	Maximum	Minimum
	Maximum	Maximum

A detailed assessment procedure of the measurement results at each T_{step} is described in clause 6.2.1.7.

6.2.1.7 Step 7: Assessment procedure

The assessment procedure for step 6 in clause 6.4.1.6 is as follows:

Action 1: Assess at each profile points T_{step} (as specified in related standard) the measured emission level (P_{step}) against the new environmental profile limit Adjusted_RL, see figure 12.

The EUT would pass the assessment at T_{step} if: for each environmental profile point (T_{step}) the emission level (P_{step}) is below the calculated environmental profile limit (Adjusted_RL), see figure 12.

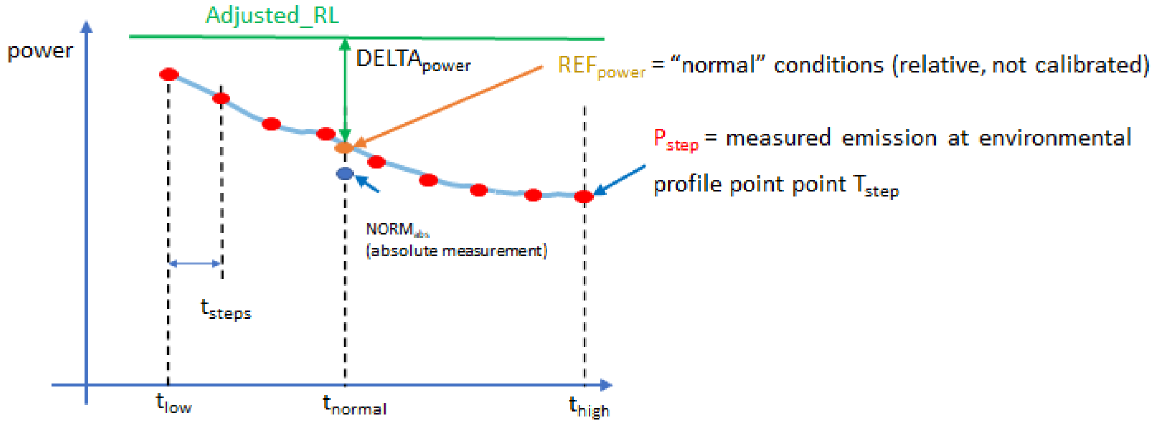


Figure 12: Relationship of the measured, calculated and assessed parameter

6.2.2 Overview on recorded values (measured/calculated)

Table 2 provides an overview on all measured, calculated and assessed requirements/parameter.

Table 2: Overview the recorded parameter for procedure in clause 6.2

		Requirement/parameter	Assessment step
		Permitted frequency range	From measurement, step 1, clause 6.2.1.1
Calibrated measurement with the environmental conditions	Regulated limit	RL [dBm]	From measurement, step 1, clause 6.2.1.1
	Reference points	$NORM_{power}$ [dBm]	From measurement, step 2, clause 6.2.1.2
	Delta	$DELTA_{power}$ [dBm]	Calculated, step 2, clause 6.2.1.2
	Reference Limit	REF_{power} [dBm]	Normal conditions, measurement step 4, clause 6.2.1.4
	Environmental profile limit	Adjusted_RL [dBm]	Calculate step 5, clause 6.2.1.5
	Emission level @ T_{step}	P_{step} [dBm] at each T_{step}	From measurement step 6, clause 6.2.1.6

6.3 Assessment of the radiated power (Mean e.i.r.p. or Peak e.i.r.p.) and frequencies within the permitted range

6.3.1 Procedural steps

6.3.1.1 Step 1: EUT OFR and regulated TX requirements

The starting point is the calibrated/absolute measurement result of the mean e.i.r.p. [dBm] or peak e.i.r.p. power [dBm] requirement under normal conditions.

Action 1: Read out and record out the Mean/Peak e.i.r.p. power ($NORM_{abs}$) and the two frequencies for the OFR ($f_{L,abs}$ and f_{H_abs}) from a calibrated measurement.

Action 2: Record the related regulated limit ((RL), either Mean/Peak e.i.r.p.) which is required for the EUT in the permitted frequency range (specified with f_{PER_L} and f_{PER_H}), see related standard

6.3.1.2 Step 2: Assessment absolute measurement

Action 1: Calculate with equation (4) the difference ($DELTA_{power}$) between the Regulated Limit (RL) and the measured value ($NORM_{abs}$).

$$DELTA_{power} = RL - NORM_{abs} \quad (4)$$

Action 2: Calculate with equations (5) and (6) the difference between the OFR boarders to the edges of the permitted frequency range.

$$DELTA_{fL} = f_{L\_abs} - f_{PER\_L} \quad (5)$$

$$DELTA_{fH} = f_{PER\_H} - f_{H\_abs} \quad (6)$$

6.3.1.3 Step 3: Test set-up TX-behaviour environmental profile

Now place the EUT into one of the environmental profile test set-ups from clause 5 using the guidance from clause 4.3.

For the EUT arrangement the same direction ("highest" emission) as assesses out of the absolute measurement (see step 2, clause 6.3.1.2) needs to be considered.

NOTE: For radiated tests the direction with highest emission could guarantee sufficient dynamic for the following steps. But if the mounting/poisoning inside the set-up is not possible (space, size of the EUT, etc.), other emission directions could be used as well. Therefore, it is only important to have sufficient dynamic range in the measurement. This is possible because only the relative changes in the emissions will be considered in this procedure.

6.3.1.4 Step 4: Relative reference measurement at normal conditions

Action 1: Run a measurement based on the set-up and arrangement out of step 3 (see clause 6.3.1.3) under normal conditions and note the related environmental conditions. For the measurement the same measurement receiver settings (RBW, span, measurement time) used to get the absolute measurement in step 2 (see clause 6.3.1.2) shall be chosen.

Action 2: Read out and record the radiated emissions (REF_{power}) [dBm].

Action 3: Read out and record (f_{L_REF} and f_{H_REF}) [Hz].

with:

- f_{L_REF}: lower edge of the OFR in the environmental set-up, see step 3 (clause 6.3.1.3).
- f_{H_REF}: higher edge of the OFR in the environmental set-up, see step 3 (clause 6.3.1.3).

6.3.1.5 Step 5: Calculate an adjusted limit for the TX-behaviour testing under environmental profile

Here an adjusted limit for the following relative measurement is calculated. For the adjustment the measured reference emission (REF_{power}) from step 4 (see clause 6.3.1.4) and the related $DELTA_{power}$ (out of step 2, see clause 6.3.1.2) are needed. This calculation will provide an new environmental profile limit for the emission over the environmental test (Adjusted_RL).

Action 1: Calculate with equation (7).

$$Adjusted\_RL\ [dBm] = REF_{power}\ [dBm] + DELTA_{power}\ [dBm] \quad (7)$$

NOTE: If in the following steps the emissions over the environmental profile would be now below the "new" limit (environmental profile limit (Adjusted_RL)) it could be guaranteed that also under the "absolute" case the emissions would below the regulated emission limits.

Action 2: Calculate with equations (8) and (9) the offsets from the OFR frequencies to edges of the permitted frequency range.

$$REF_{fL} = f_{L\_REF} - f_{PER\_L} \quad (8)$$

$$REF_{fH} = f_{PER\_H} - f_{H\_REF} \quad (9)$$

6.3.1.6 Step 6: Relative measurement over environmental profile

Action 1: Run the same measurement as under step 4 (clause 6.3.1.4, action 1) on all environmental profile points T_{step} as specified in the related harmonised standard.

Action 2: Read out and record for each measurement (for each environmental profile point T_{step}) and note the emission level (P_{step}) and values for f_{L_step} and f_{H_step} for each environmental profile point.

NOTE: The environmental profile points can include for example temperature and voltage. Table 3 shows an example of possible environmental steps for the tests.

Table 3: Proposal for T_{steps} and the changes in temperature and voltage (per step)

T_{step}	Temperature	Voltage
1	Normal (20 °C)	Nominal
2	Normal (20 °C)	Minimum
3	Normal (20 °C)	Maximum
4	Minimum	Nominal
5	Minimum	Minimum
6	Minimum	Maximum
…..	Related standards specify the steps in temperature from minimal to maximal temperature	
	Maximum	Nominal
	Maximum	Minimum
	Maximum	Maximum

A detailed assessment procedure of the measurement results at each T_{step} is described in clause 6.3.1.7.

6.3.1.7 Step 7: Assessment procedure

The assessment procedure for step 6 in clause 6.3.1.6 is as follows:

Action 1: Assess at each profile points T_{step} (as specified in related standard) the measured emission levels (P_{step}) against the new environmental profile limit Adjusted_RL, see figure 13.

The EUT would pass the assessment at T_{step} if:

- For each environmental profile point (T_{step}) the emission levels (P_{step}) is "below" the calculated environmental profile limit (Adjusted_RL), see figure 13 and requirement in equation (10).

$$DELTA_{power} \geq P_{step} - REF_{power} \quad (10)$$

- For each environmental profile point (T_{step}) the changes of the OFR frequencies (f_{L_step} and f_{H_step}) are smaller than the offset from step 2 (see figure 14 for f_H and figure15 for f_L) and the related requirements in equation (11) and (12).

$$DELTA_{fH} \geq f_{H\_step} - REF_{fH} \quad (11)$$

$$DELTA_{fL} \geq REF_{fL} - f_{L\_step} \quad (12)$$

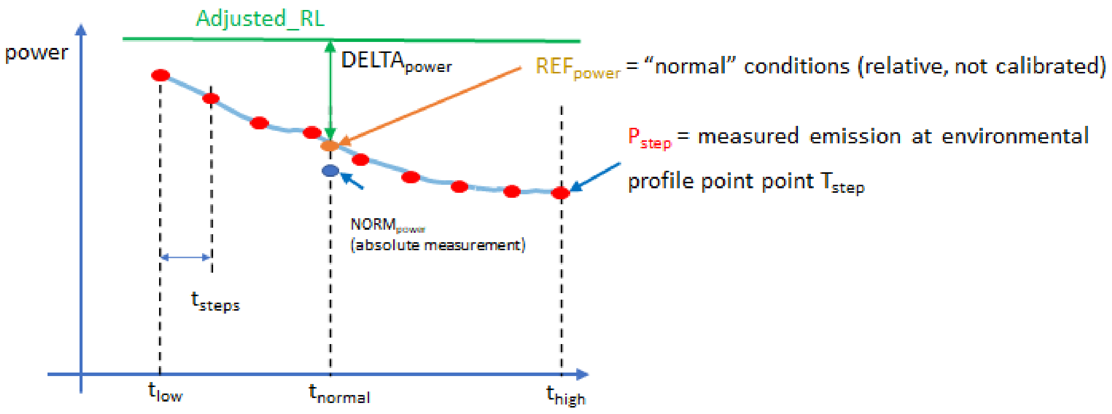


Figure 13: Relationship of the measured, calculated and assessed power parameter

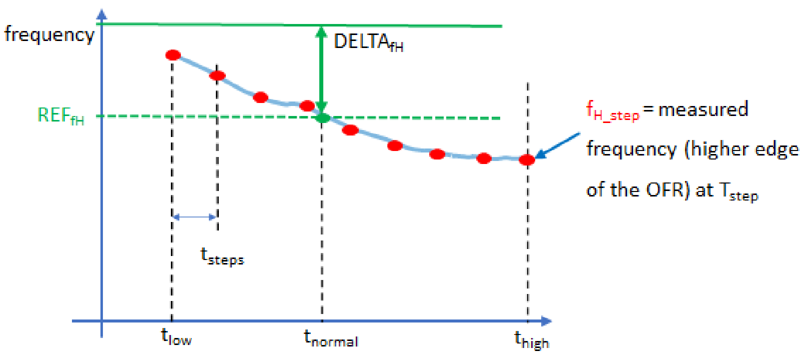


Figure 14: Relationship of the measured, calculated and assessed f_H parameter

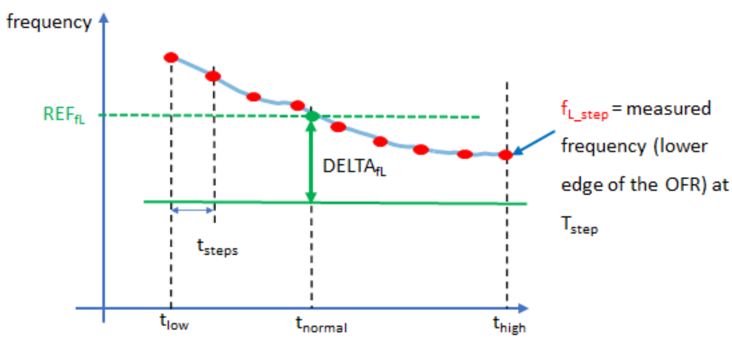


Figure 15: Relationship of the measured, calculated and assessed f_L parameter

6.3.2 Overview on recorded values (measured/calculated)

Table 4 provides an overview on all measured and assessed requirements.

Table 4: Overview the recorded parameter for procedure in clause 6.3

		Requirement/parameter	Assessment step
		Permitted frequency range	From measurement, step 1, clause 6.3.1.1
Calibrated measurement with the environmental conditions	OFR	with OFR = f_{H_abs} - f_{L_abs}	From measurement, step 1, clause 6.3.1.1
	Regulated limit	RL [dBm]	From measurement, step 1, clause 6.3.1.1
	Reference points	$NORM_{power}$ [dBm]	From measurement, step 2, clause 6.3.1.2
	Delta	$DELTA_{power}$ [dBm] $DELTA_{fL}$ [Hz] $DELTA_{fH}$ [Hz]	Calculated, step 2, clause 6.3.1.2
Relative measurement	Reference Limit	REF_{power} [dBm] REF_{fL} [Hz] REF_{fH} [Hz]	Normal conditions, measurement step 4, clause 6.3.1.4
	Environmental profile limit	Adjusted_RL [dBm]	Calculated, step 5, clause 6.3.1.5
	Emission level @ T_{step}	P_{step} [dBm] at each T_{step} f_{L_step} at each T_{step} f_{H_step} at each T_{step}	From measurement step 6, clause 6.3.1.6

6.4 Full assessment over OFR & Mean e.i.r.p. Spectral Density

6.4.1 Procedural steps

6.4.1.1 Step 1: EUT OFR and regulated TX requirements

The starting point is the calibrated measurement result of the mean e.i.r.p. power spectral density [dBm/MHz] under normal conditions.

Action 1: Read out and record out from a calibrated mean e.i.r.p. power spectral density measurement the two frequencies left and right from the maximum e.i.r.p. value, where the mean e.i.r.p. is 10 dB below the maximum. These frequencies shall be recorded as $f_{L,abs}$ and f_{H_abs} and calculate OFR=f_{H_abs} - f_{L_abs} (see figure 16).

Action 2: Assessment of whether different regulatory limits apply between $f_{L,abs}$ and f_{H_abs} ; record the frequency ranges with related limits as RL_{SX} (see figure 16).

NOTE: If the EUT OFR is overlapping with different frequency ranges (UWB emission mask) the ranges can be (for example) numbered consecutively with X=1,2,… from the lower to the higher frequencies.

6.4.1.2 Step 2: Assessment absolute measurement

For each limit segment (e.g. if the EUT OFR is overlapping with frequency ranges having different regulatory limits RL_{RX}, see figure 16) one data point with highest emission (mean e.i.r.p.) and its frequency shall be recorded as f_{SX} and $NORM_{SX}$ (e.g. X=1 if only one limit applies over OFR).

Action 1: Read out and record for each limit segment one data point with the highest emission (mean e.i.r.p.) and its frequency shall be recorded from a calibrated mean e.i.r.p. power spectral density measurement as f_{SX} and $NORM_{SX}$ (e.g. X=1 if only one limit applies over OFR).

NOTE: Figure 16 shows an example; with two data points: f_{S1}/$Norm_{S1}$ and f_{S2}/$Norm_{S2.}$

Action 2: For each limit segment: Calculate the difference between the regulated limit (RL) and the related results from action 1 within this step 2. These differences at each f_{SX} [MHz] are noted as $DELTA_{SX}$ [dBm/MHz].

$DELTA_{SX}$ is calculated with equation (13):

$$DELTA_{SX}\ [dBm/MHz] = RL_{SX}\ [dBm/MHz] - NORM_{SX}\ [dBm/MHz] \qquad (13)$$

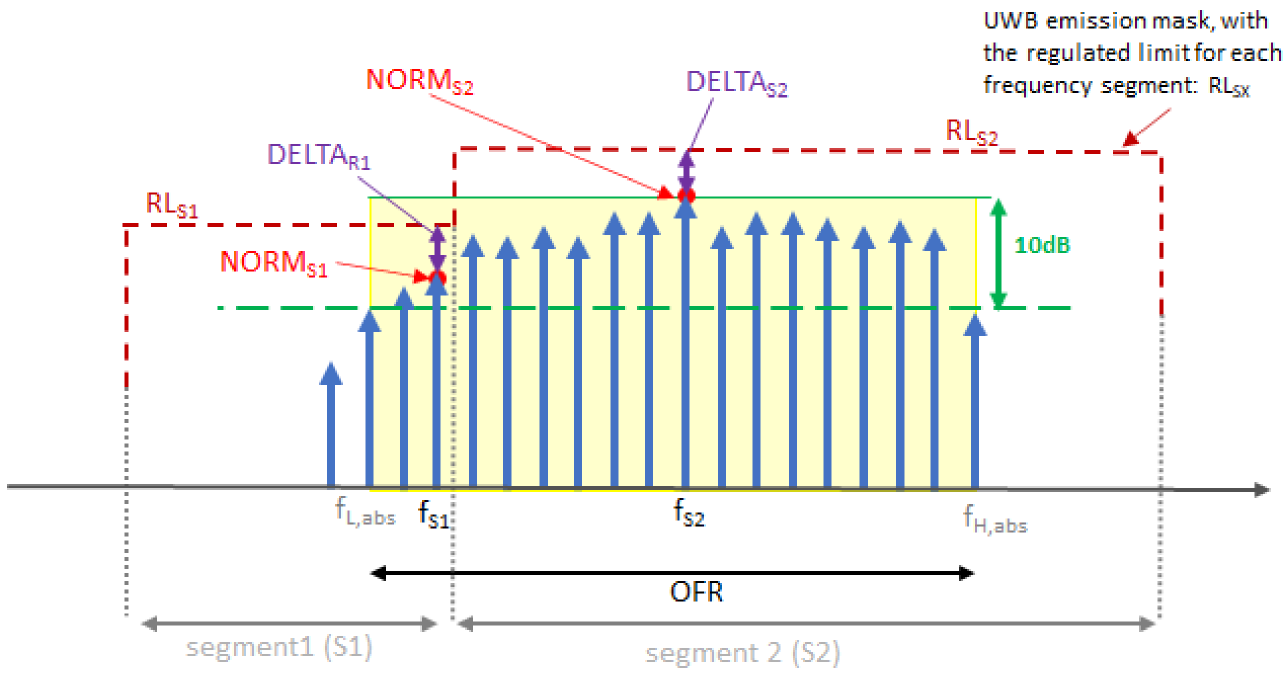


Figure 16: Example calibrated mean e.i.r.p. power spectral density measurements with limit mask and data points (OFR is overlapping with two frequency limit segments)

6.4.1.3 Step 3: Test set-up TX-behaviour environmental profile

Now place the EUT into one of the environmental profile test set-ups from clause 5 using the guidance from clause 4.3.

For the EUT arrangement the same direction ("highest" emission) as assesses out of the absolute measurement (see step 2, clause 6.4.1.2) needs to be considered.

6.4.1.4 Step 4: Relative reference measurement at normal conditions

Action 1: Run a measurement based on the set-up and arrangement out of step 3 (see clause 6.4.1.3) under normal conditions and note the related environmental conditions. For the measurement the same measurement receiver settings (RBW, span or frequency range, measurement time) used to get the absolute measurement in step 2 (see clause 6.4.1.2) shall be chosen.

Action 2: Read out and record the highest emissions (REF_{SX}) at the frequencies f_{SX} from step 2 (see clause 6.4.1.2). The emissions levels are noted as REF_{S1}, REF_{S2},… [dBm/MHz], see figure 17.

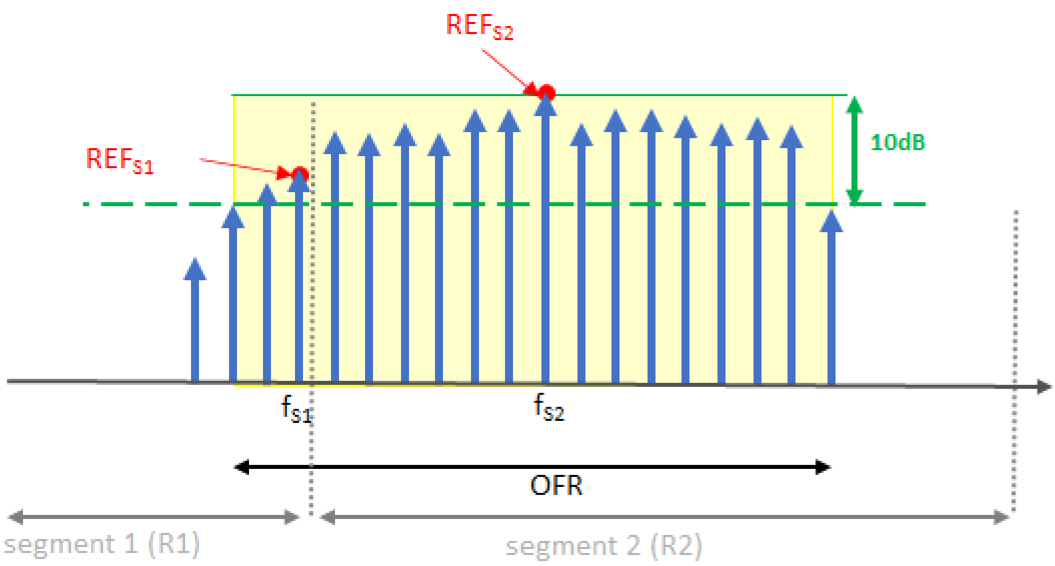


Figure 17: Example relative mean e.i.r.p. power spectral density measurement with data points (OFR is overlapping with two frequency limit segments)

6.4.1.5 Step 5: Calculate an adjusted limit for the TX-behaviour testing under environmental profile

Here an adjusted limit for the following relative measurement is calculated. For the adjustment the highest emission levels (REF_{SX}) for each frequency range (out of step 4, see clause 6.4.1.4) and the related $DELTA_{SX}$ (out of step 2, see clause 6.4.1.2) for each frequency range (RX) are needed. This leads to an new environmental profile limit for each frequency range ($Adjusted\_RL_{SX}$), see figure 18.

Action: calculate for each frequency range with equation (14):

$$Adjusted\_RL_{SX}\ [dBm/MHz] = REF_{SX} + DELTA_{SX}\ [dBm/MHz] \quad (14)$$

NOTE: If in the following steps the emissions over the environmental profile would be now below the "new" mask (environmental profile limit ($Adjusted\_RL_{RX}$)) it could be guaranteed that also under the "absolute" case the emissions would below the regulated emission limits.

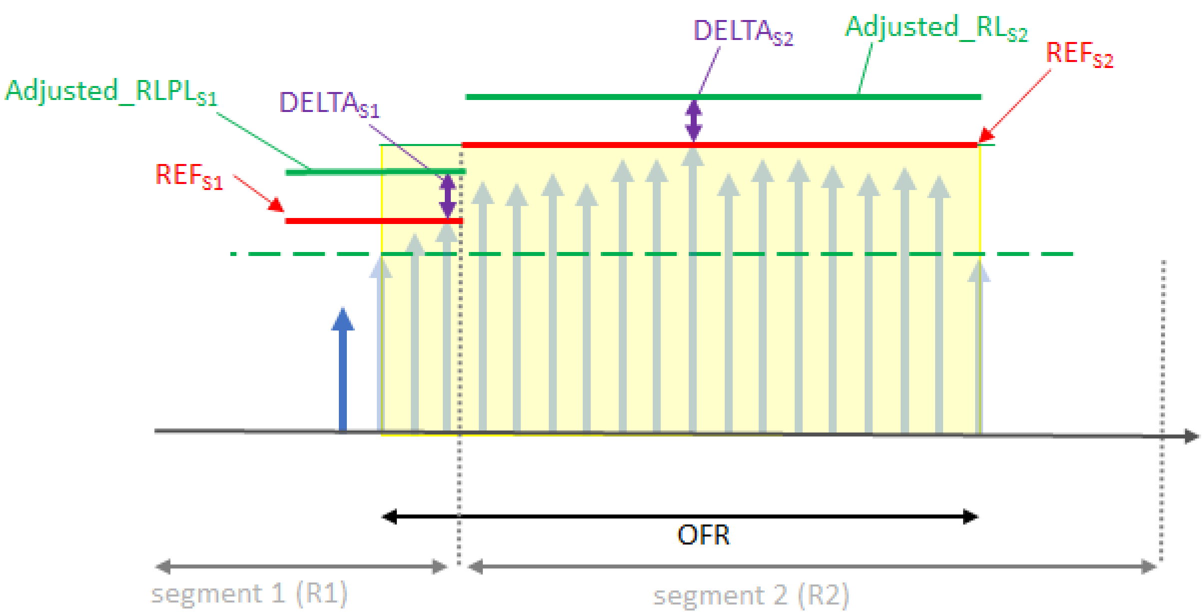


Figure 18: Example for the parameter relationship in step 5

6.4.1.6 Step 6: Measurement on one environmental profile point

Action 1: Run the same measurement as under step 4; action 1 on all environmental profile points T_{step} as specified in the related harmonised standard.

NOTE: The environmental profile points can include for example temperature and voltage. Table x shows an example of possible environmental steps for the tests.

Table 5: Proposal for T_{steps} and the changes in temperature and voltage (per step)

T_{step}	Temperature	Voltage
1	Normal (20 °C)	Nominal
2	Normal (20 °C)	Minimum
3	Normal (20 °C)	Maximum
4	Minimal temperature	Nominal
5	Minimal temperature	Minimum
6	Minimal temperature	Maximum
…..	Related standards specify the steps in temperature from minimal to maximal temperature	
	Maximal temperature	Nominal
	Maximal temperature	Minimum
	Maximal temperature	Maximum

A detailed assessment procedure of the measurement results at each T_{step} is described in clause 6.4.1.7.

6.4.1.7 Step 7: Assessment procedure

The assessment procedure for step 6 in clause 6.2.1.6 is as follows:

- The EUT would pass the assessment at T_{step} if:
  - for each environmental profile point (T_{step}) the measured emissions is equal or below the calculated Adjusted_RL_{SX} from step 5 (see clause 6.4.1.5).
- The device would fail the assessment at T_{step} if:
  - at any frequency an emission is above the Adjsuted_RL_{RX} limit. The level by which each individual emission exceeds the Adjusted_RL_{SX} limit shall be referred to as $FAIL_{SX,}$ see figure 19.

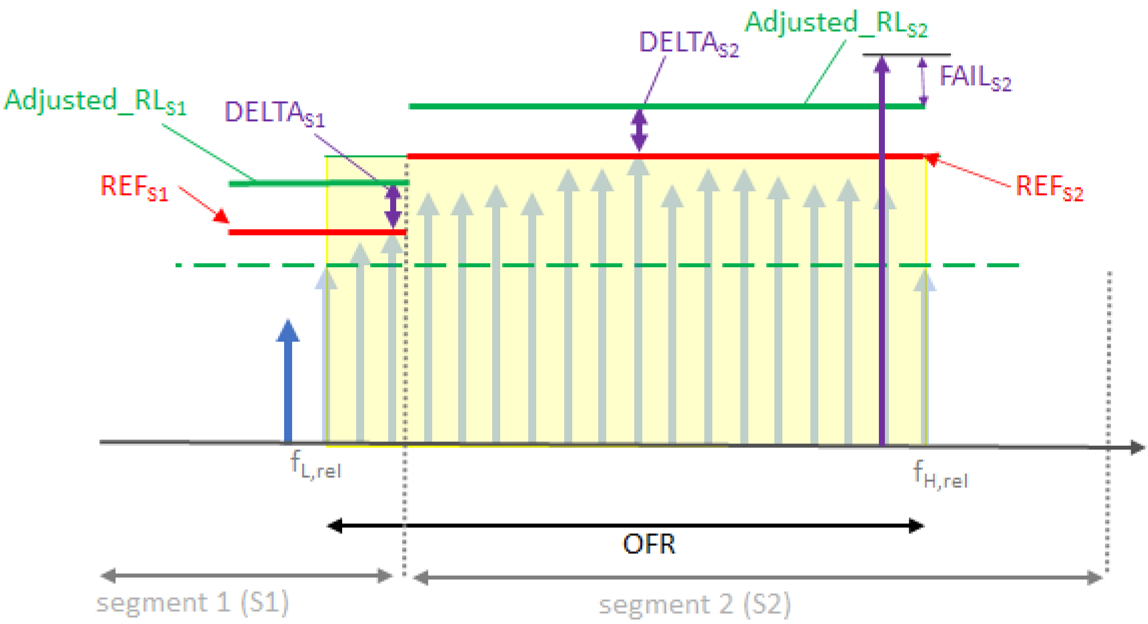


Figure 19: Example for the parameter relationship and an assessment fail in step 7

To confirm within a "fail" case that there is no other influence on the measurement (emission from another source, errors based on the relative testing, etc.) it could be possible (via a risk assessment) to assess if:

- f_{FAIL} is more than Y [MHz] away from one of the reference frequencies f_{SX} which were considered for the ascertainment of the environmental profile limit (Adjusted_RL_{RX}) in the absolute measurement (step 2 in clause 6.4.1.2) the $DELTA_{SX}$ values were calculated, see figure 16.

NOTE 1: Y to be specified by considering RBW of the PSD measurement and typical frequency drift of the UWB EUT TX). This needs to be specified in related standard.

In addition, it is necessary to assess the "$DELTA_{FAIL}$" at the frequency f_{FAIL} the under the calibrated set-up, see figure 20.

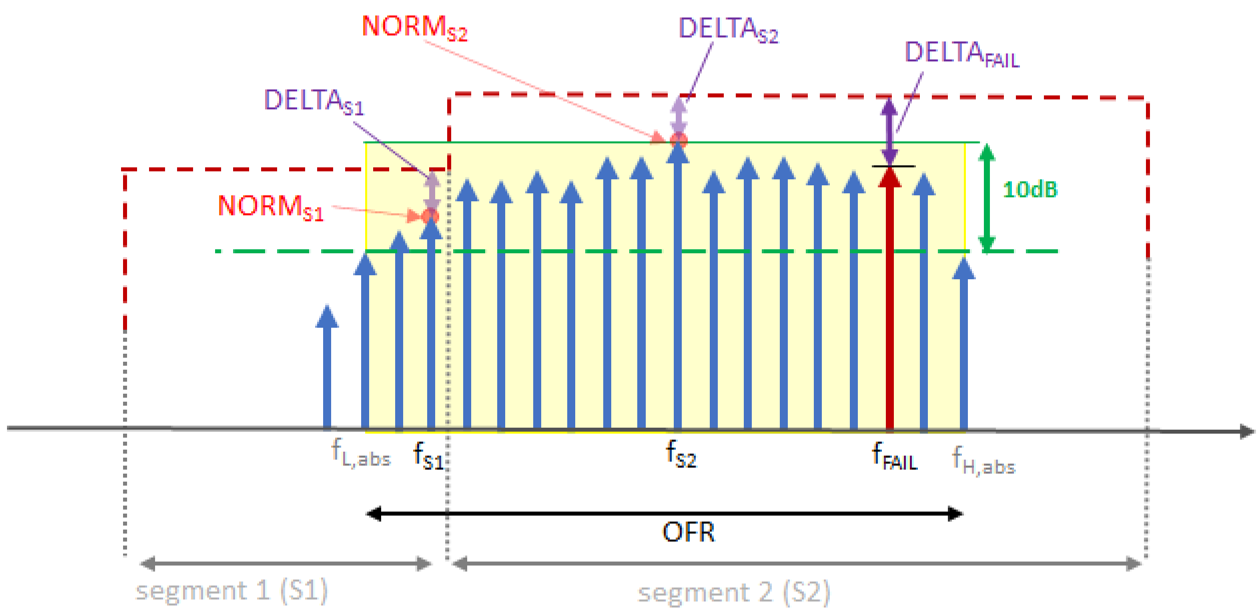


Figure 20: Example for the parameter relationship and an assessment to check if the result "fail" could be an error

For the risk assessment: if the requirement for $DELTA_{FAIL}$ in equation (15) is fulfilled:

$$DELTA_{FAIL}\,[dBm/MHz] > DELTA_{SX}\,[dBm/MHz] + FAIL_{SX}\,[dBm/MHz] \qquad (15)$$

- Then it could be that the "failing" is based on the set-up (not calibrated, impact from other kind of used material to simulate the scenario) or based on measurement error or based on other emissions from the environment.
- In addition the behaviour of the other spectral lines shall be assessed (over all T_{steps}) and if for this other lines the changes from one T_{step} to the next T_{step} is much more different (smaller) than for f_{FAIL}.

For such cases the assessment could be determined to be passing.

NOTE 2: For each T_{step} to the next T_{step} it is typical that all spectral lines have the same behaviour → all going down or up in power and/or frequency.

But if for $DELTA_{FAIL}$ in with equation (16) the requirement is fulfilled.

$$DELTA_{FAIL}\,[dBm/MHz] < DELTA_{SX}\,[dBm/MHz] + FAIL_{SX}\,[dBm/MHz] \qquad (16)$$

- For such a case the requirement (TX-behaviour of the environmental profile) is failed for this T_{step}

6.4.2 Overview on recorded values (measured/calculated)

Table 6 provides an overview on all measured and assessed requirements.

Table 6: Overview the recorded parameter for procedure in clause 6.4

		Requirement			Assessment step
		Frequency range 1 limit segment (S1);	Frequency range2 limit segment(S2); …	Frequency range (X limit segment (SX)	from measurement, step 1, clause 6.4.1.1
Calibrated measurement with the environmental conditions	OFR	with OFR = f_{H_abs} - f_{L_abs}			from measurement, step 1, clause 6.4.1.1
	Regulated limit	RL_{S1} [dBm/MHz]	RL_{S2} [dBm/MHz] …	RL_{SX} [dBm/MHz]	from measurement, step 1, clause 6.4.1.1
	Reference points	$NORM_{S1}$ [dBm/MHz] at f_{S1} [MHz]	$NORM_{S2}$ [dBm/MHz] at f_{S2} [MHz] …	$NORM_{SX}$ [dBm/MHz] at f_{SX} [MHz]	from measurement, step 2, clause 6.4.1.2
	Delta	$DELTA_{S1}$ [dBm/MHz]	$DELTA_{S2}$ [dBm/MHz] …	$DELTA_{SX}$ [dBm/MHz]	calculated, step 2, clause 6.4.1.2
Relative measurement					
	Reference limit	REF_{S1} [dBm/MHz]	REF_{S2} [dBm/MHz] …	REF_{SX} [dBm/MHz]	Normal conditions, measurement step 4, clause 6.4.1.4
	Environmental profile limit	$Adjusted\_RL_{S1}$ [dBm/MHz]	$Adjusted\_RL_{S2}$ [dBm/MHz]	$Adjusted\_RL_{SX}$ [dBm/MHz]	calculate step 5, clause 6.4.1.5

6.5 Assessment over OFR and based on Mean e.i.r.p. Spectral Density

6.5.1 Procedural steps

6.5.1.1 Step 1: Assessment mean e.i.r.p. power spectral density measurement

The starting point is the assessment of the measurement result of the mean e.i.r.p. power spectral density measurement. For a better dynamic in the TX-behaviour assessment the direction with highest emission shall be chosen. This absolute measurement is based one normal conditions withing a calibrated set-up. The detailed conditions shall be noted, see requirement and conformance test in the related standard.

Action 1: Assessment of the absolute mean e.i.r.p. power spectral density measurement (calibrated test) and note the frequency f_{max} with the highest emission (see figure 21).

NOTE 1: For large OFR (> 1 GHz) more than one frequency could the specified in the related standard to run the assessment.

And in addition, assess and record:

- the regulated power limit for each segment and note as RL_{SX} [dBm/MHz].
- the frequencies at which there is a step up in the regulated power limit (from a lower to a higher limit, boarder between two ranges) and note as $f_{boarder\_up\_X}$.
- the frequencies at which there is a step down in the regulated power limit (from a higher to a lower limit, boarder between two ranges) and note as $f_{boarder\_down\_X}$.

NOTE 2: This information is still known. The frequency with the highest emission is necessary to assess and calculate the EUT OFR. The related requirements for this step are named in the related standard as OFR and mean e.i.r.p. spectral density or indirect emission.

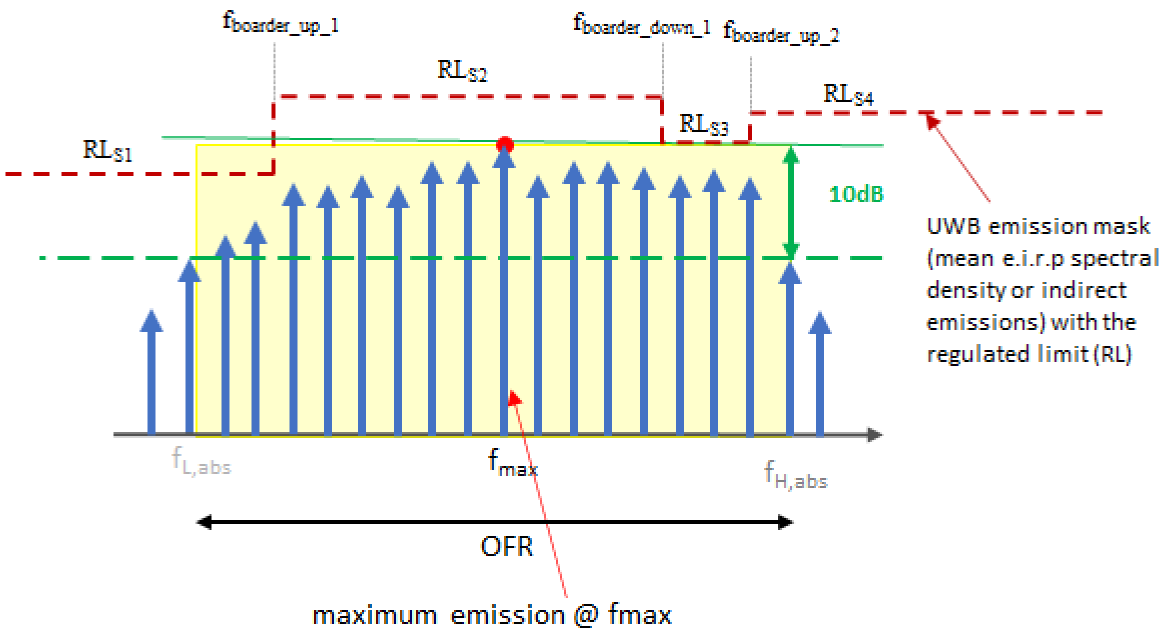


Figure 21: The principle of the assessment for step 1

Action 2: Prepare an overview of the max (UWB) emissions at each frequency within OFR including the direction, for example see clause B.3.4.1, figure B.37.

6.5.1.2 Step 2: Test set-up TX-behaviour environmental profile

Now place the EUT into the specified set-up (related standard) for the assessment of the TX-behaviour under the environmental profile. Basis are described in clause 5. For the arrangement a direction with sufficient radiated power shall be chosen (e.g. in direction of "measurement focus of the EUT").

Action 1: The EUT shall be placed into the specified set-up to assess the TX behaviour (see clause 5 and related standard). For the placement following points shall be considered.

NOTE: It need to be considered that for EUT which are normally tested within a scenario (indirect emissions) : that such scenario cannot be realized within a temperature chamber. Therefore, and based on the relative testing basis, the EUT can be installed "without" the material inside e.g. a temperature chamber.

Based on that the EUT will be tested without a material (or another material than for the absolute test) it could be that the direction with the highest emissions changes. In such a case a practical arrangement with sufficient dynamic should be taken. This is possible, because only the behaviour (changes) of the emission is relevant (TX-behaviour over the environmental profile). This simplification would also reduce measurement uncertainties based of unknown test material behaviour under the environmental profile.

The material has typically an impact on the emission level around the EUT (based attenuation, focusing effect, etc.) but has no impact on the frequencies of the emissions or the "changes" in radiated power over the profile → these requirements are only related to the TX-hardware.

6.5.1.3 Step 3: Relative reference measurement

In this step a relative reference measurement will be executed. Therefore, run a measurement based on the set-up and arrangement out of step 2 (clause 6.5.1.2) under normal conditions and note the related environmental conditions.

For the measurement the same measurement receiver settings (RBW, span, measurement time) used to get the absolute measurement in step 1 (see clause 6.5.1.1) shall be chosen.

Action: Run a measurement at normal conditions in the adjusted EUT direction (see step 2, clause 6.5.1.2) and read out the emission level [dBm/MHz] at f_{max} as a reference emission (REF_f), see figure 22.

The emission level at f_{max} (REF_f) [dBm/MHz] and the normal conditions shall be recorded.

NOTE: if the related standards specifies more than one f_{max}, they could be simply numbered as f_{max_x} and similar for the related emission REF_{f_x}

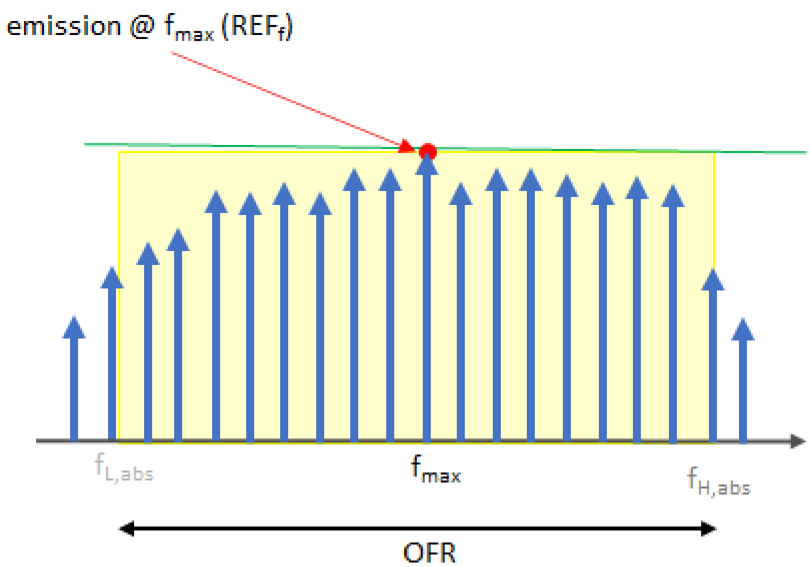


Figure 22: Example for the assessment in step 3

6.5.1.4 Step 4: Measurement on one environmental profile point

In this step the following actions shall be taken at one single environmental profile point.

The measurement scenario is adjusted to the environmental profile point requirement (temperature, voltage) as specified.

For the measurement the same measurement receiver settings (RBW, span or frequency range, measurement time) used to get the absolute measurement in step 3 (see clause 6.5.1.3) shall be chosen.

Action: Run at the profile points T_{step} (as specified in the related standard) and track the spectral line at f_{max} and note the changes in the emission power level (P_{step}) [dBm/MHz] and frequency (f_{step}) [MHz] for this profile point.

6.5.1.5 Step 5: next environmental profile point

The related standard will specify the changes in environmental conditions and voltage from one to next environmental profile point, see also clause 4.3.2.

It is important that the environmental conditions are reached (temperature, …) before going back to step 4 (see clause 6.5.1.4).

The measurement in step 4 shall be iterated until the final T_{step} is reached.

6.5.1.6 Step 6: Calculate changes of the emission over the environmental profile

Now all noted results for emission power level ($P_{step)}$ [dBm/MHz] and frequency (f_{step}) [MHz] will be assessed.

Action 1: Calculate for each profile point (T_{step}) the changes in the emission power level (ΔP_{step}, see equation (18) and changes in the frequency (Δf_{step}, also named frequency shift, see equation (17)):

$$\Delta f_{step} = f_{step} - f_{max} \tag{17}$$

with:

- f_{step} is the measured frequency at T_{step}

$$\Delta P_{step}\text{: } REF_f + \Delta P_{step} = P_{step} \tag{18}$$

with:

- P_{step} is the measured power level at T_{step}

Action 2: Assess the extreme changes over the specified environmental profile. Therefore, figure out:

- the maximum delta for ΔP_{step} (positive values) (see figure 23); and
- the maximum Δf_{step} (increase and decrease) (see figure 24).

NOTE: If based on the measurement receiver setting no frequency shift $\Delta f_{step,increase}$ or $\Delta f_{step,decrease}$ is observed, no frequency shift needs to be considered.

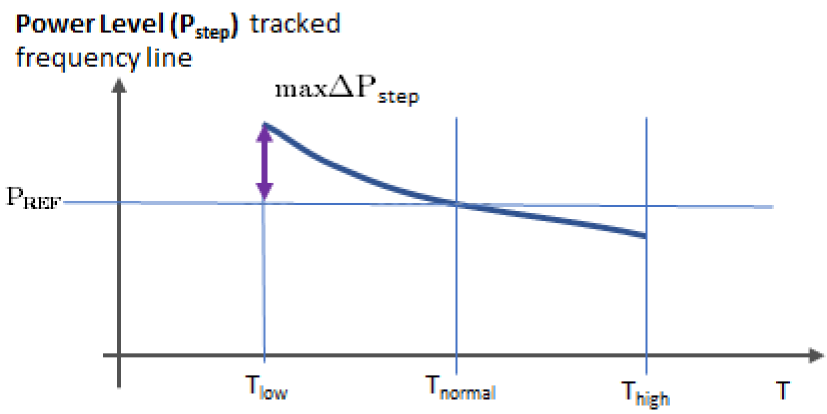


Figure 23: Example for the change of ΔP_{step} over the temperature range of the environmental profile

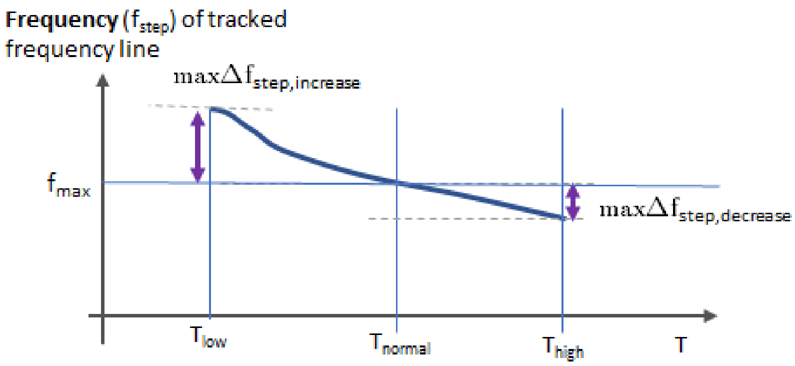


Figure 24: Example for the change of Δf_{step} over the temperature range of the environmental profile

6.5.1.7 Step 7: Assess the changes over specified profile

This addition step is necessary to consider the OFR of the device. This could for UWB EUT several GHz. Therefore, according to determined $\max\Delta P_{step}$ (see figure 23), $\max\Delta f_{step,increase}$ *and* $\max\Delta f_{step,decrease}$ (see figure 24), for UWB devices (large OFR) the changes in frequency ($\max\Delta f_{step)}$ shall be considered on a relative level.

Action: Calculate the relative changes for the frequency shift with equations (19) and (20):

$$\max\Delta f_{step,\ increase\_rel} = (\max\Delta f_{step,increase}/f_{max}) \quad (19)$$

$$\max\Delta f_{step,\ decrease\_rel} = (\max\Delta f_{step,decrease}/f_{max}) \quad (20)$$

6.5.1.8 Step 8: Adjust emission levels for the TX-behaviour testing under environmental profile

Adjust the regulated UWB mask used for the absolute assessment (e.g. Mean e.i.r.p. spectral density/indirect emissions) by the following procedure:

Action 1: Adjustment of the emission power levels:

- each emission power limits [dBm/MHz] (for each range, RL_{RX}) shall reduce by:

  $\max\Delta P_{step}$ (see in figure 25)

Action 2: Adjustment of the frequencies between one frequency range and another one:

- at each "step down" (frequency ($f_{boarder\_down}$) of the UWB emission mask/from a higher to a lower limit) the frequency boarder shall be decreased by $\max\Delta f_{step,increase\_borader}$ (see in figures 25 and 27), with equations (21) and (22):

$$\max\Delta f_{step,\ increase\_boarder} = (\max\Delta f_{step,increase\_rel} \times f_{boarder\_down}) \quad (21)$$

$$f_{boarder\_increase} = f_{boarder\_down} - \max\Delta f_{step,\ increase\_boarder} \quad (22)$$

NOTE 1: The frequency shift (increase) is critical at frequencies if the spectral line would move over the environmental profile from a "lower" frequency to a "higher" frequency area with a more stringent level. If the delta from closest emissions (under normal conditions) below such $f_{boarder\_down}$ would be larger than the max increase in frequency over the environmental profile (see figure 18) than it could be considered that there is no issue with the increase of the frequency shift over the environmental profile.

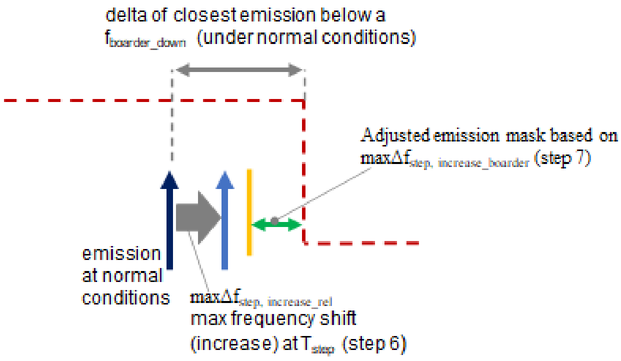


Figure 25: Example to assess the measurement in relation to adjusted frequency at $f_{boarder\_down}$

- at each "step up" (frequency ($f_{boarder\_up}$) of the UWB emission mask from a lower to a higher limit) the frequency boarder shall be increased by $max\Delta f_{step,decrease\_rel}$ (see in figures 26 and 27), with equations (23) and (24):

$$max\Delta f_{step,\ decrease\_boarder} = (max\Delta f_{step,decrease\_rel} * f_{boarder\_up}) \qquad (23)$$

$$f_{boarder\_decrease} = f_{boarder\_up} + max\Delta f_{step,\ decrease\_boarder} \qquad (24)$$

NOTE 2: Similar consideration for the frequency shift (decrease) is similar to the increase case above applies. The delta of closest emission above an $f_{boarder\_up}$ needs to be larger than the $max\Delta f_{step,decrease\_rel}$ over the environmental profile, see figure 26.

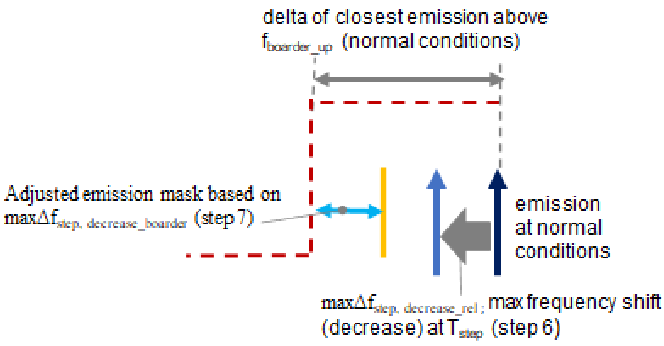


Figure 26: Example to assess the measurement in relation to adjusted frequency requirement at $f_{boarder\_up}$

Figure 27 show an example with all adjustments (power and frequency).

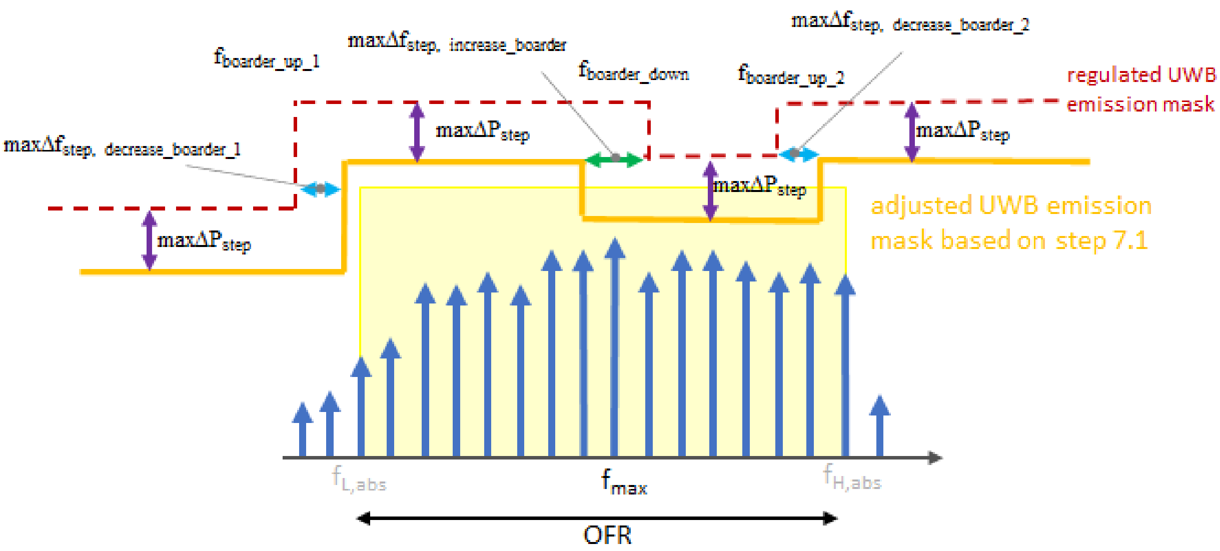


Figure 27: Complete example will complete adjusted limit mask

6.5.1.9 Step 9: Assess absolute emission measurement in in relation to the adjusted UWB emission mask

Action: Assess (see clause 6.5.1.2) the absolute emission measurement results used for step 1 (based on a. Mean e.i.r.p. spectral density [dBm/MHz] or indirect emissions [dBm/MHz] requirement) in relation to the adjusted UWB emission mask from step 8 (see clause 6.5.1.8).

The assessment procedure in detail for step 8 in clause 6.5.1.8 is as follows:

- The device would pass the assessment for the TX-behaviour over the environmental profile if:
  - The absolute measurement results (step1) of the highest emissions, requirement see related standard (e.g. Mean e.i.r.p. spectral density [dBm/MHz] or indirect emission [dBm/MHz]) would be "below" the adjusted UWB emission mask (step 8 in clause 6.5.1.8).

NOTE 1: (For spectrum with clear spectral lines): based on the e.i.r.p. requirement the highest emission for each direction and frequency/spectral line over OFR is known (basis for step 1) and all "highest emissions at each frequency/spectral line could be put together in one plot, see for example figure B.37 in clause B.3.4.1. This would make an assessment for the TX-behaviour much faster.

NOTE 2: If such absolute emission summary could be not provided the assessment should be done for each measurement direction separately.

- The device would fail the assessment if:
  - In minimum at one part (one spectral line) is over the adjusted UWB emission mask (see figure 28).

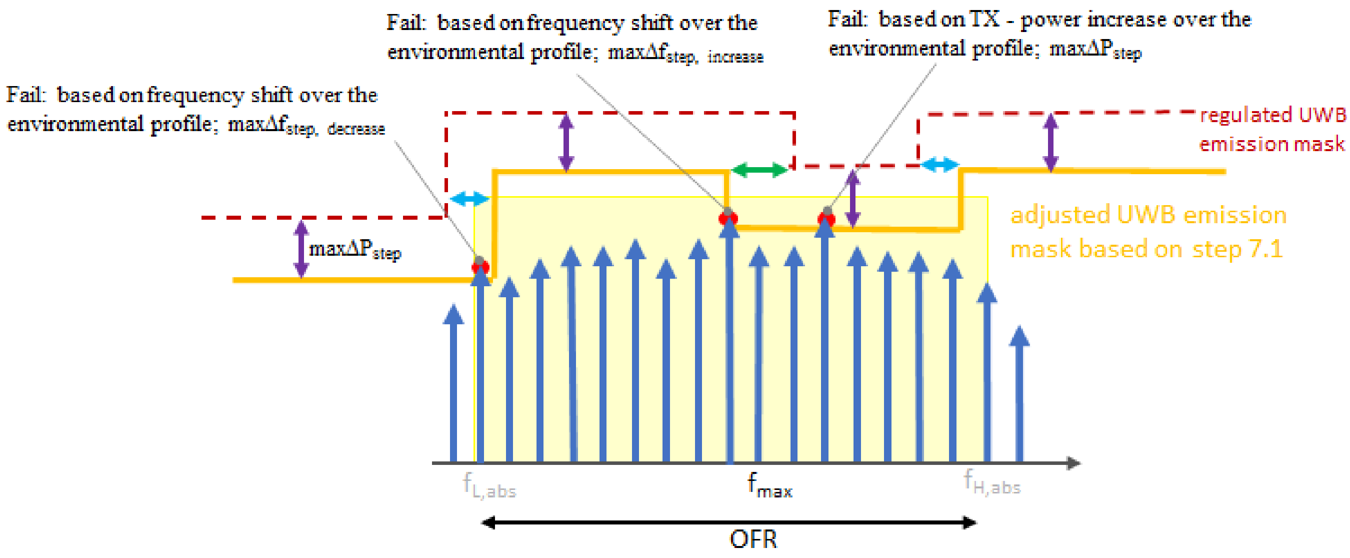


Figure 28: Complete example will complete adjusted limit mask and "fail" results in the assessment

6.5.2 Overview on recorded values (measured/calculated)

Table 7 provides an overview on all measured and assessed requirements.

Table 7: Overview the recorded parameter for procedure in clause 6.5

	Requirement		Assessment step
Calibrated measurement with the environmental conditions	Assessment frequency	f_{max} [MHz] See note 1.	From measurement, step 1, clause 6.5.1.1
	Regulated limit	RL_{SX} [dBm/MHz] (for each emission segment)	From measurement, step 1, clause 6.5.1.1
	Frequencies of steps in power between ranges/segments	$f_{boarder\_up\_X}$ See note 2. $f_{boarder\_down\_X}$ See note 3.	From measurement, step 1, clause 6.5.1.1
Relative measurement	Reference limit	REF_f [dBm/MHz] measured at f_{max}	From measurement, step 3, clause 6.5.1.3
	Measurement at T_{step}	P_{step} [dBm/MHz] and changes in frequency (f_{step}) [MHz] compared to f_{max}	From measurement, step 4, clause 6.5.1.4
	Assess changes over the environmental profile	Δf_{step} [MHz] ΔP_{step}, [dBm/MHz]	From calculation, step 6, clause 6.5.1.6
	Adjust emission limit	$f_{boarder\_increase}$ [MHz] $f_{boarder\_decrease}$ [MHz] $max\Delta P_{step}$ [dBm/MHz]	From calculation, step 7, clause 6.5.1.7 and step 8, clause 6.5.1.8
NOTE 1: The related EN shall specify the number of frequencies the assessment shall be made. NOTE 2: Step up in the regulated power limit (from a lower to a higher limit, boarder between two ranges/segments). NOTE 3: Step down in the regulated power limit (from a higher to a lower limit, boarder between two ranges/segments).			

7 Assessment of power (Mean e.i.r.p. or Peak e.i.r.p.) requirement and frequencies within the permitted range based on a conducted set-up

7.1 General

Under the assumption that the EUT antenna is a passive antenna (passive device) which has no influence on the transmitter requirement (transmitted power, TX bandwidth), the environmental tests can be executed in a conducted way. This is only for EUTs with detachable antenna and/or with standardised antenna connector. Since the antenna parameter (pattern and gain) can be assessed separately (see related standard) the radiated e.i.r.p. emission can be calculated if the conducted peak/mean power is measured at the antenna connector.

This measurement is an absolute measurement where no calibration has to be conducted.

This assessment procedure could be used for two cases:

CASE 1: The EUT has a connector, and the dedicated antennas (with known antenna pattern/antenna gain) are clearly specified (measurable) and the regulated limit is given an e.i.r.p. requirement.

CASE 2: The EUT has a connector, and the regulated limit is given as an TX output or Total Radiated Power requirement.

7.2 Detailed description of the procedure

7.2.1 Step 1: EUT OFR and regulated TX requirements

Assess if the EUT fulfils the regulated limit under normal conditions.

The starting point is the (calibrated/absolute) measurement result of the mean (e.i.r.p.) [dBm] or peak (e.i.r.p.) [dBm] power requirement under normal conditions.

Action 1: Read out and record out the Mean/Peak e.i.r.p. power ($NORM_{abs}$) and the two frequencies for the OFR ($f_{L,abs}$ and f_{H_abs}) from this measurement, see related standard.

Action 2: Consider the related regulated limit ((RL), either Mean/Peak (e.i.r.p.)) which is required for the EUT in the permitted frequency range (specified with f_{PER_L} and f_{PER_H}), see related standard.

For CASE 1

Action 3: Subtract the max antenna gain (g_{AEUT}) from the recorded Mean/Peak e.i.r.p. power ($NORM_{abs}$) and note as (CON_{abs}).

NOTE: For EUT assessed under CASE 2 the parameter $NORM_{abs}$ is the same than for CON_{abs}.

7.2.2 Step 2: Assessment the reference measurement

Action 1: For CASE 1: Calculate with equation (X3) the difference ($DELTA_{power}$) between the regulated limit (RL) and the measured value ($NORM_{abs}$), see equation (25).

$$DELTA_{power} = RL - NORM_{abs} \tag{25}$$

For CASE 2: Calculate with equation (X4) the difference ($DELTA_{power}$) between the regulated limit (RL) and the measured value (CON_{abs}), see equation (26).

$$DELTA_{power} = RL - CON_{abs} \tag{26}$$

7.2.3 Step 3: Test set-up TX-behaviour environmental profile

Place the EUT in the environmental profile test set-up as described in clause 5.2.4.

7.2.4 Step 4: Absolute measurement over environmental profile

Action 1: Run the same measurement as under step 2 (Action 1) on all environmental profile points T_{step} as specified in the related standard.

Action 2: Read out and record for each measurement (for each environmental profile point T_{step}) the emission level (P_{step}) and values for f_{L_step} and f_{H_step}.

NOTE: The environmental profile points can include for example temperature and voltage. Table 8 shows an example of possible environmental steps for the tests.

Table 8: Proposal for T_{steps} and the changes in temperature and voltage (per step)

T_{step}	Temperature	Voltage
1	Normal (20 °C)	Nominal
2	Normal (20 °C)	Minimum
3	Normal (20 °C)	Maximum
4	Minimal temperature	Nominal
5	Minimal temperature	Minimum
6	Minimal temperature	Maximum
…..	Related standards specify the steps in temperature from minimal to maximal temperature	
	Maximal temperature	Nominal
	Maximal temperature	Minimum
	Maximal temperature	Maximum

7.2.5 Step 5: Assessment procedure

The assessment procedure for each recorded value of P_{step}, f_{L_step} and f_{H_step} shall be done as follows:

Action 1: Assess at each profile point T_{step} (as specified in related standard) the measured power level P_{step} and the edges of the OFR f_{L_step} and f_{H_step} against the Regulated Limits (RL).

The EUT will pass the assessment at T_{step} when:

- for each environmental profile point (T_{step}) the power level P_{step} shall fulfil, see equation (27):

$$DELTA_{power} \geq Pstep - CON_{abs} \tag{27}$$

- or for:
  - CASE 1 see figure 29 left and equation (28):

$$RL \geq P_{step} + g_{AEUT} \text{ or } RL - g_{aeut} \geq P_{step} \tag{28}$$

  - CASE 2 see figure 29 right and equation (29):

$$RL \geq P_{step} \tag{29}$$

    - for each environmental profile point (T_{step}) the lower frequency $f_{L\_step} \geq f_{PER\_L}$ (see figure 30);
    - for each environmental profile point (T_{step}) the higher frequency $f_{H\_step} \leq f_{PER\_H}$ (see figure 31).

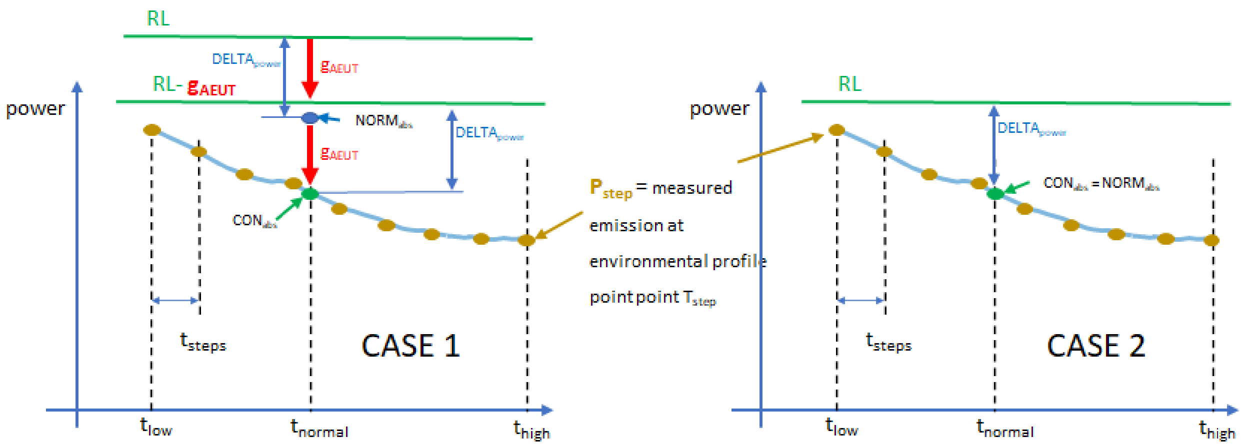


Figure 29: Example for the change of P_{step} and ΔP_{step} over the temperature range of the environmental profile

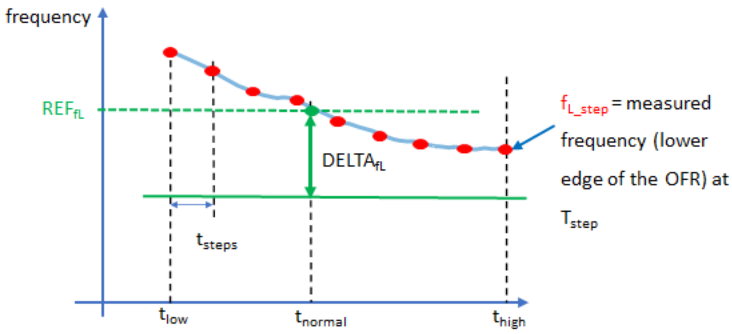


Figure 30: Example for the change of f_L over the temperature range of the environmental profile

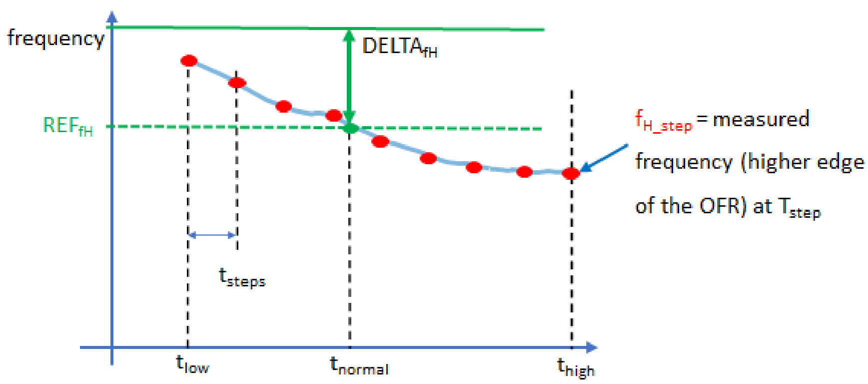


Figure 31: Example for the change of f_H over the temperature range of the environmental profile

Annex A (informative): Additional information for materials used in environmental test set-ups

A.1 General

The information within this annex A are based on ETSI research on the internet and received feedback from companies. The provided links are checked during the preparation of the present document and therefore, dated for (publication date).

It has to be noted that the list of manufacturers and provided information in clauses A.2 and A.3 are not complete.

The provided links and information provide some guidance to choose the possible usable materials for the test set-up dependent of the environmental profile, EUT (size, antenna connector, etc.) and frequency range of operation.

More details for:

- Radio Transparent Material (low dielectric/low attenuated material) in clause A.2.
- Absorbing material/high attenuation in clause A.3.
- And if necessary to validate the attenuation of used material, see clause A.4.

A.2 Radio Transparent Material

The impacts from dielectric material on electromagnetic emissions are well studied.

There are several manufactures, which provide appropriate radio transparent materials.

For choosing an appropriate material to be used a "radio transparent" the following points need to be considered:

- the dielectric constant (relative permittivity) should be as small as possible (for the frequency range under consideration). This would also reduce the risk to run into a special case of total reflections (no emission through the dielectric material). More details see ETSI TS 103 789 [i.1], clauses A.2 and A.3.
- the losses of the used material should be as low as possible. Typical the losses are given as Loss Tangent or as attenuation in dB/distance.
- and finally, the operating temperature (temperature stability) should be similar or larger than the environmental profile temperatures specified in the related standard.

NOTE: If the attenuation is not available, they could be validated based on clause A.4.

A.3 Absorbing Material

There are several manufactures, which provide appropriate absorbing materials (typically named RF or microwave absorbers).

The datasheets of the materials are providing all necessary information (attenuation (reflection coefficient and/or attenuation), mechanical dimensions (hight/thickness), operating frequency and temperature range) for choose the appropriate material depending on the field of application. The field of applications are:

- to prepare absorbing boxes (see clause B.4); or
- to reduce multi path effects (reflections) inside the temperature chamber (see clause B.5);

- to reduce the impact from metalized temperature chamber wall on the EUT (mismatch/detune EUT antenna) inside the temperature chamber (see clause B.5).

A.4 Radio Transparent Material

A.4.1 Procedure to measure the attenuation

The measurement principle to assess material attenuation is shown in figures A.1 and A.2. The measurement of the attenuation of the representative structure should be inside a low radio noise environment, e.g. an anechoic chamber, see ETSI TS 102 321 [i.3], clause 4.

In a first step, calibration is performed using the setup shown in figure A.1.

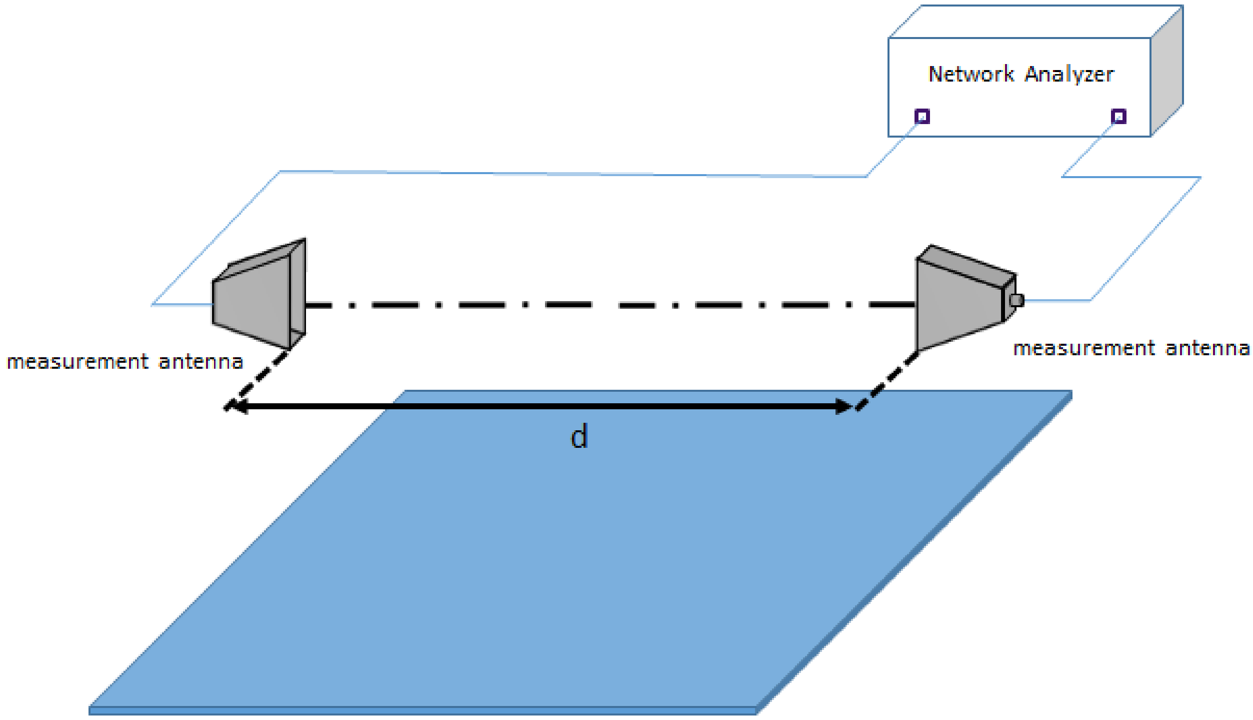


Figure A.1: Calibration setup

It is important that the antenna main beam of both measurement antennas are exactly aligned to each other and the distance (d) between the two identical antennas should be larger than 2 × minimal far field distance (see ETSI TS 102 321 [i.3], clause 4).

The beamwidth "ant_beam" of the measurement antennas is linked with the size of the material and the related consideration is as, see equation (A.1):

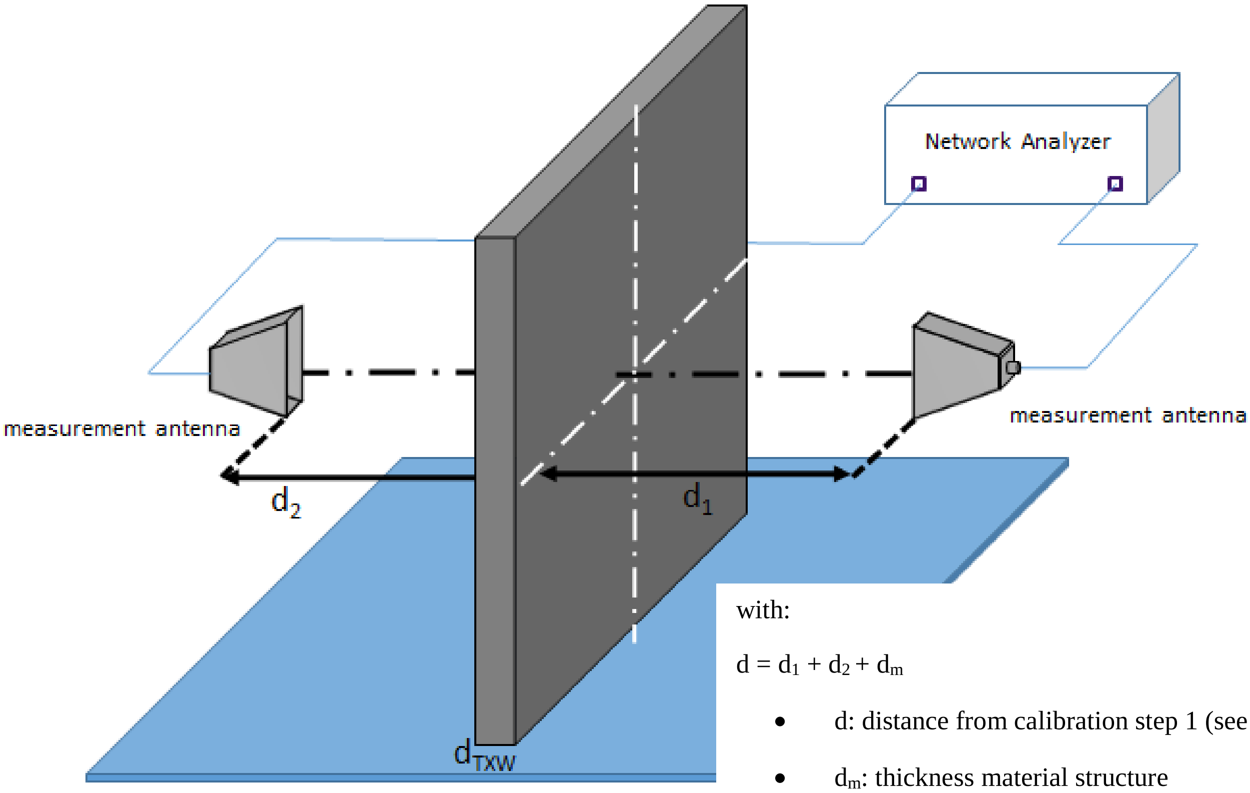
$$ant\_beam < 2 \text{ x } arctan\left(\frac{size\_of\_material}{d}\right) \qquad (A.1)$$

Calibration steps:

1) Set the start and stop frequencies of the network analyser to f_L and f_H as derived from the OFR measurements (see related standard) The frequency range depends on the measurement antennas.

2) Calibrate the system in the S21 Mode.

After calibration of the setup, the material for investigation will be placed between the two antennas, with $d_1 = d_2$, see figure A.2.



with:

$d = d_1 + d_2 + d_m$

- d: distance from calibration step 1 (see figure A.1)
- d_m: thickness material structure

Figure A.2: Attenuation measurement of the wall/material structure

The network analyser shows now the attenuation of the material (g_{mat}) in dB.

For the measurement a network analyser with a time gating option should be used. This is important because with this option it is possible to obtain the necessary signal parts for the attenuation measurement (more signal components or more signal reflexions can yield to wrong results).

Other setups can be used if the presented method in this clause is not feasible for the typical absorbing material used for the measurements of the devices under test.

Annex B (informative): Measurements on TX-behaviour testing under the environmental profile as specified in the present document

B.1 General

The informations in this annex are based on real measurement results provided by ETSI members.

For information the related ETSI contribution for:

- Clause B.2 shows measurements (radiated/connected) for LPR/TLPR devices.
- Clause B.3 shows a measurement for an UWB wall scanning device.
- Clause B.4 shows an assessment with an absorbing box.
- Clause B.5 shows an measurement for an UWB tracking tag.

B.2 Measurement based on LPR and TLPR devices

B.2.1 Introduction

The focus of this measurement trial is based on the radiated test setup which is used to show if a relative measurement of the TX output spectrum can be conducted in the nearfield of the EUT antennas. For comparison reasons the measurement is also executed in a conducted way.

Both procedures have been evaluated in a test setup using two different radar antennas (¾" horn antenna with screw-in thread and a 3" plastic horn antenna) and documented. The EUT is an FMCW radar sensor with an Operating Frequency Range (OFR) between 76 and 84 GHz.

For comparability reasons the same sensor-electronic unit was used for all measurements.

B.2.2 Used EUT and measurement antennas

B.2.2.1 EUT antenna: ¾" horn antenna with screw-in thread

The first antenna which is used for the trial is a ¾" horn antenna (see figure B.1) with screw-in thread which has a circular waveguide with a diameter of 2,6 mm as antenna connector. This antenna is optimized for the usage in closed metallic tanks (TLPR).

- Aperture diameter: d = 19 mm
- Farfield distance: rff = 19,3 cm
- Gain: G = 18 dBi @ 80 GHz
- Opening angle: 14,3° (E-plane); 15,6° (H-plane)

Figure B.1: ¾" horn antenna with screw-in thread (source: VEGA Grieshaber KG)

B.2.2.2 EUT antenna: 3" plastic horn antenna

The second antenna which is used for the experiment is a 3" plastic horn antenna (see figure B.2) with which has a circular waveguide with a diameter of 2,6 mm as antenna connector. This antenna is optimized for the usage in open area applications (LPR).

- Aperture diameter: d = 75 mm
- Farfield distance: rff = 3,0 m
- Gain: G = 34,2 dBi @ 80 GHz
- Opening angle: 3,0° (E-plane); 3,7° (H-plane)

Figure B.2: 3" plastic horn antenna (source: VEGA Grieshaber KG)

B.2.2.3 Measurement antenna: Standard Gain Horn (SGH)

On receiver side a Standard Gain Horn (SGH) from Flann Microwave was used:

- Model No: 26 240 - 20 dB
- Nominal Gain: 20 dBi
- Aperture: a x b = 14,8 mm x 10,8 mm
- Farfield distance: rff = 9,3 cm

B.2.2.4 Nearfield - Far field consideration

According to the range length of test facilities, i.e. the distance between EUT antenna and measurement antenna (see equation (B.1), should be equal or greater than:

$$r_{tf} \geq \frac{2(d_1+d_2)^2}{\lambda} \qquad \text{(B.1)}$$

Where:

- d_1 is the largest dimension of the EUT antenna.
- d_2 is the largest dimension of the measurement antenna.
- λ is the wavelength of the test frequency.

Very often the measurement antenna can be assumed as a "point target" ($d_2 = 0$) whereby above mentioned equation (B.1) is simplified to equation (B.2):

$$r_{ff} \geq \frac{2d_1^2}{\lambda} \qquad \text{(B.2)}$$

This distance is denoted as far field (Fraunhofer) region and is defined as that region of the field of an antenna where the angular field distribution is essentially independent of the distance from the antenna.

According to ETSI TS 103 789 [i.1] the region below $2d_1^2/\lambda$ is denoted as nearfield.

B.2.3 Test set-up and Measurements

B.2.3.1 General

The EUTs were placed in a temperature chamber. Clause B.2.3.2 describes the test-setup for EUTs with antenna connector (conducted test setup, see clause 5.2.4) and clause B.2.3.3 for EUTs with (integral) antennas (radiated test setup, see clause 5.2.3).

The output spectrums were captured with a spectrum analyser from Rohde & Schwarz (measurement receiver) for every temperature step.

The observed temperature range was between -40 °C and +80 °C. 20 K temperature steps between the individual measuring points have been chosen. A settling time of 45 minutes has been chosen between each temperature step to achieve stable temperature conditions for the electronics unit inside the EUT's housing.

The measurement frequency range was between 75 GHz and 85 GHz. The resolution bandwidth RBW was 3 MHz and the corresponding settling time is sufficient to detect the maximum peak power of the FMCW signal which has a sweep time of 2,048 ms and a bandwidth of 8 GHz. The peak detector with the MaxHold function has been chosen.

The case of the mean power measurement was not considered.

The measurement cable between SGH and measurement receiver consisted of a 20 cm WR12 waveguide, a 20 cm coaxial cable with 1 mm connector and an adapter in between with an overall attenuation of around 5 dB.

The captured output spectrums were evaluated at three frequency points indicated by markers:

- Marker 1: lowest frequency f_L of the output spectrum
- Marker 2: highest frequency f_H of the output spectrum
- Marker 3: maximum amplitude of the output spectrum

f_L and f_H were captured at the frequency point where the amplitude is at least 20 dB lower than the maximum amplitude of the output spectrum.

The frequency resolution of the measured spectrum is 10 GHz/1 001 points = 9,9901 MHz/point.

B.2.3.2 EUT with antenna connector

In figure B.3 the conducted test setup is depicted. The measurement receiver is connected directly to the EUT which has an antenna connector to measure the TX output signal. The measurement cable is brought inside the chamber through a rubber plug sealed opening of the chamber. Figure B.4 shows a picture of the setup in the laboratory.

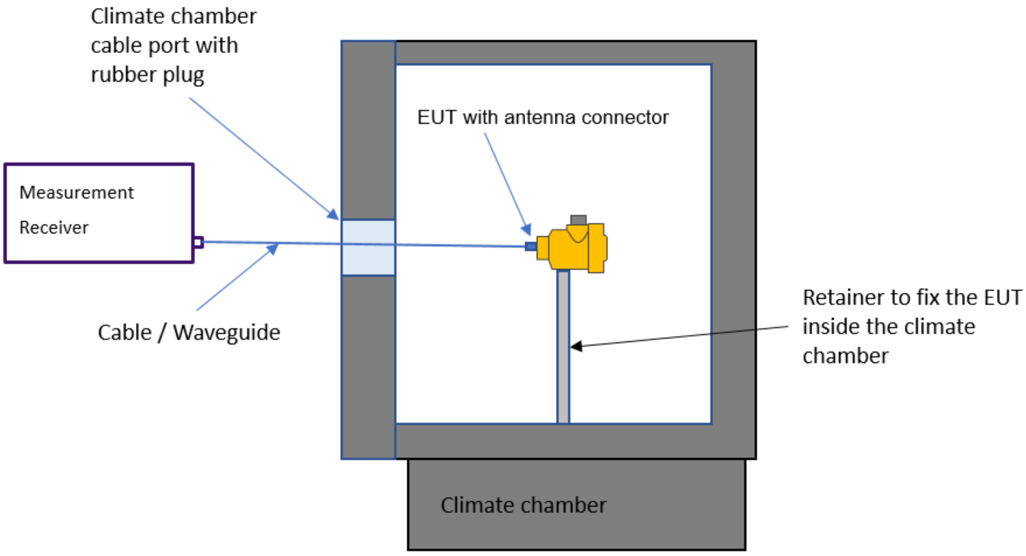


Figure B.3: Conducted test-setup for EUTs with antenna connector (source: VEGA Grieshaber KG)

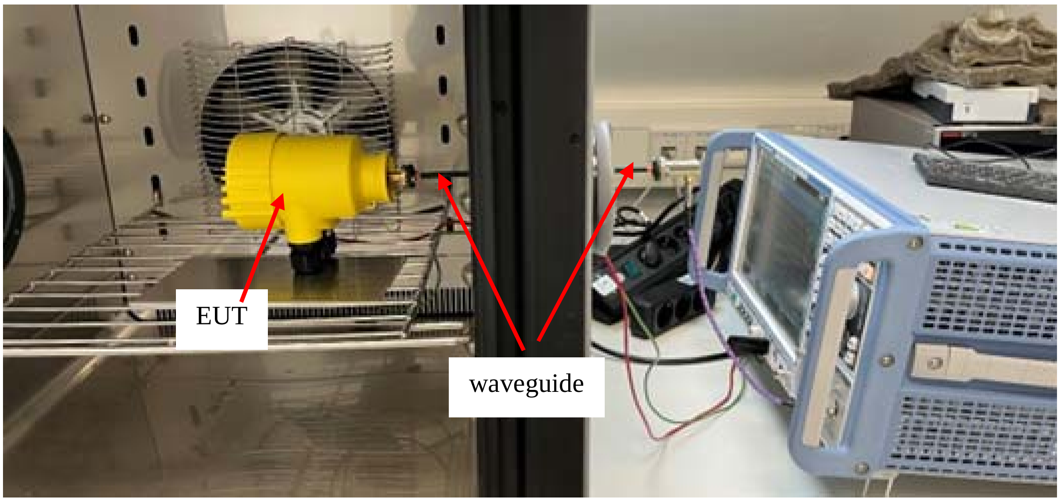


Figure B.4: Picture of the test-setup. EUT with antenna connector (source: VEGA Grieshaber KG)

B.2.3.3 EUT with (integral) antenna

Figure B.5 shows the radiated test setup using a measurement antenna which is placed inside the temperature chamber. The setting in the laboratory is shown in figures B.6, B.7 and B.8. This setup is used for EUTs where the antenna is integral part of the sensor. Nevertheless, the same electronics unit with demountable antenna was used in this trial because of comparability reasons with the first trial with antenna connector.

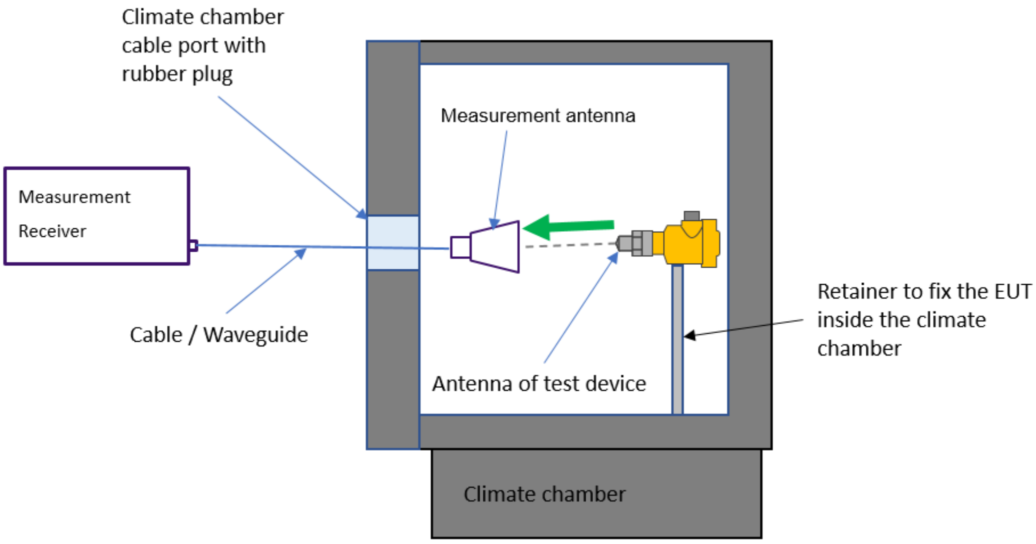


Figure B.5: radiated test-setup for EUTs with integral antenna (source: VEGA Grieshaber KG)

In figures B.6 and B.7 the test-setup of the EUT with a ¾" horn antenna which is placed inside the temperature chamber is depicted. The measurement antenna (SGH) of the receiver is a standard gain horn which is placed in a distance of 10 cm in front of the EUT's ¾" horn antenna in boresight direction.

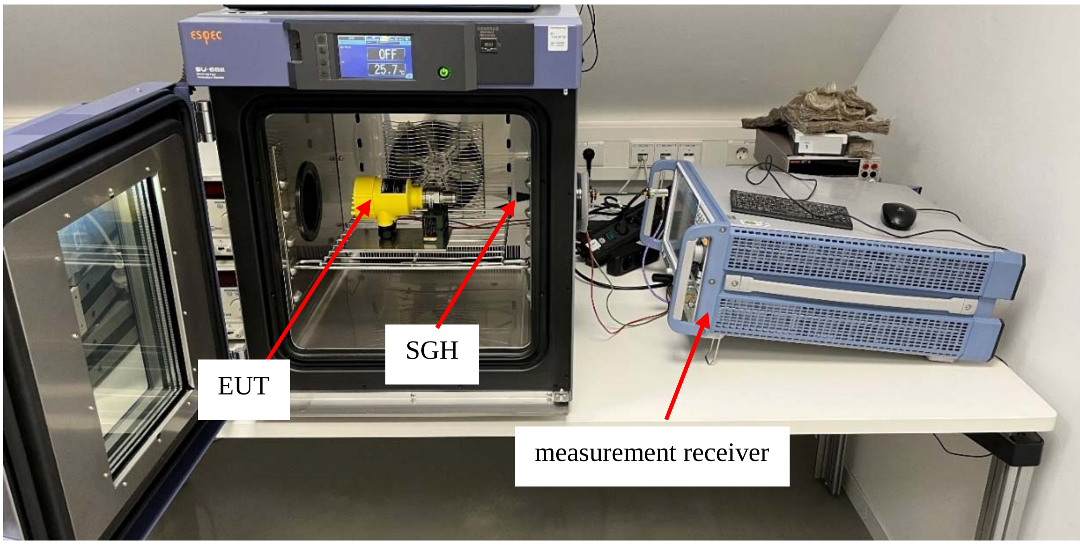


Figure B.6: Picture of the test-setup. EUT with ¾" horn antenna (source: VEGA Grieshaber KG)

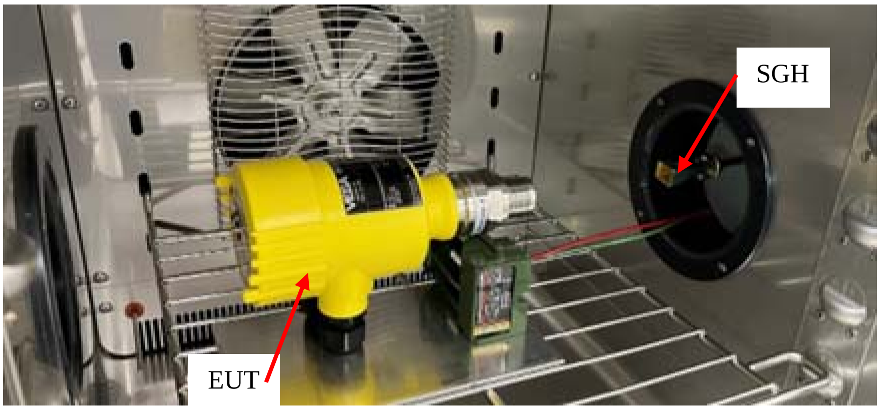


Figure B.7: Picture of test-setup inside the temperature chamber. EUT with ¾" horn antenna (source: VEGA Grieshaber KG)

In figure B.8 the test-setup of the EUT with a 3" plastic horn antenna which is placed inside the temperature chamber is depicted. The measurement antenna of the receiver is a standard gain horn which is placed in a distance of 9 cm in front of the EUT's 3" plastic horn antenna in boresight direction.

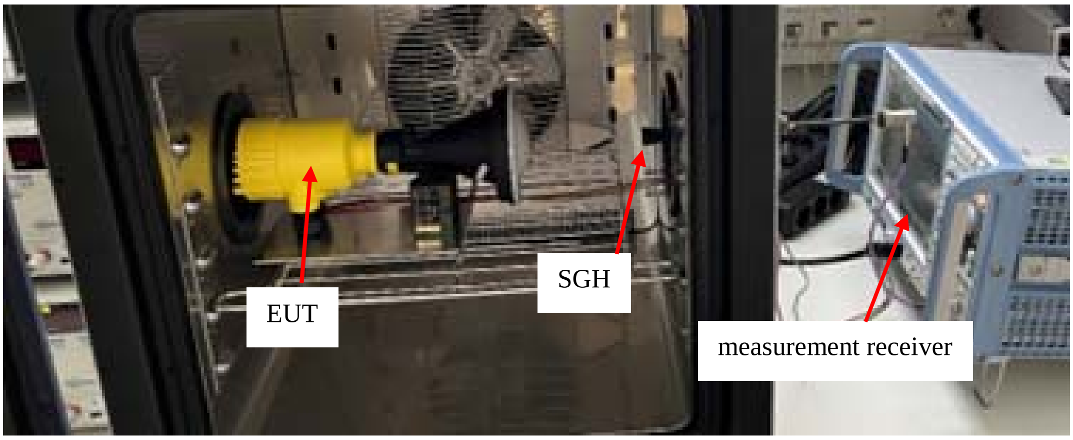


Figure B.8: Picture of the test-setup. EUT with 3" plastic horn antenna (source: VEGA Grieshaber KG)

B.2.4 Measurement Results

B.2.4.1 EUT with antenna connector: conducted measurement

Figure B.9 shows the measured output spectrum of the EUT acquired in the test-setup depicted in figure B.3 at a temperature of 20 °C.

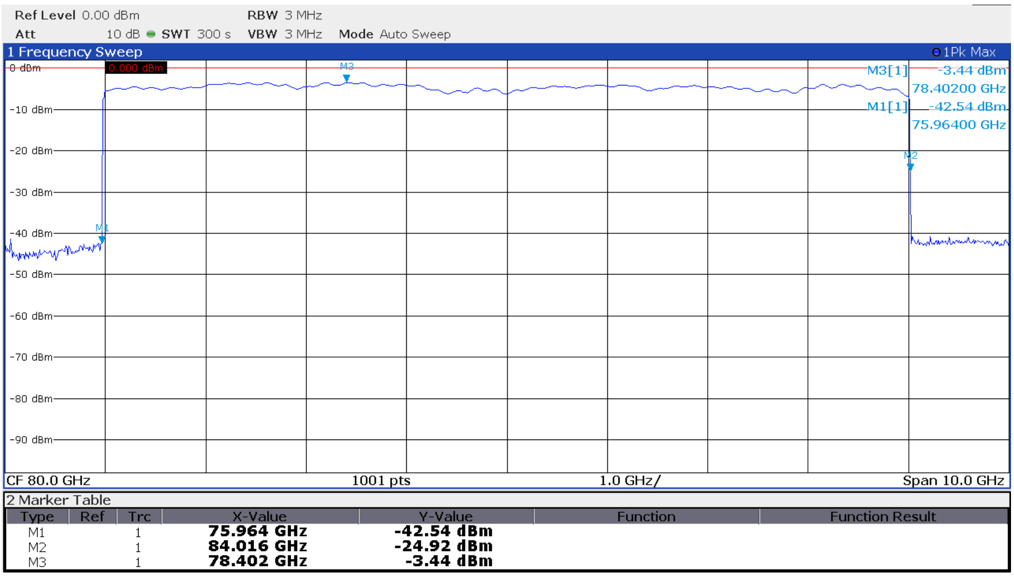


Figure B.9: output spectrum of EUT measured at antenna connector (source: VEGA Grieshaber KG)

The following figures showing the measurements results for:

- Figure B.10: TX spectrum of conducted measurement at -40 °C
- Figure B.11: TX spectrum of conducted measurement at -20 °C
- Figure B.12: TX spectrum of conducted measurement at 0 °C
- Figure B.13: TX spectrum of conducted measurement at 20 °C
- Figure B.14: TX spectrum of conducted measurement at 40 °C
- Figure B.15: TX spectrum of conducted measurement at 60 °C
- Figure B.16: TX spectrum of conducted measurement at 80 °C

Figure B.10: TX spectrum of conducted measurement at -40 °C (source: VEGA Grieshaber KG)

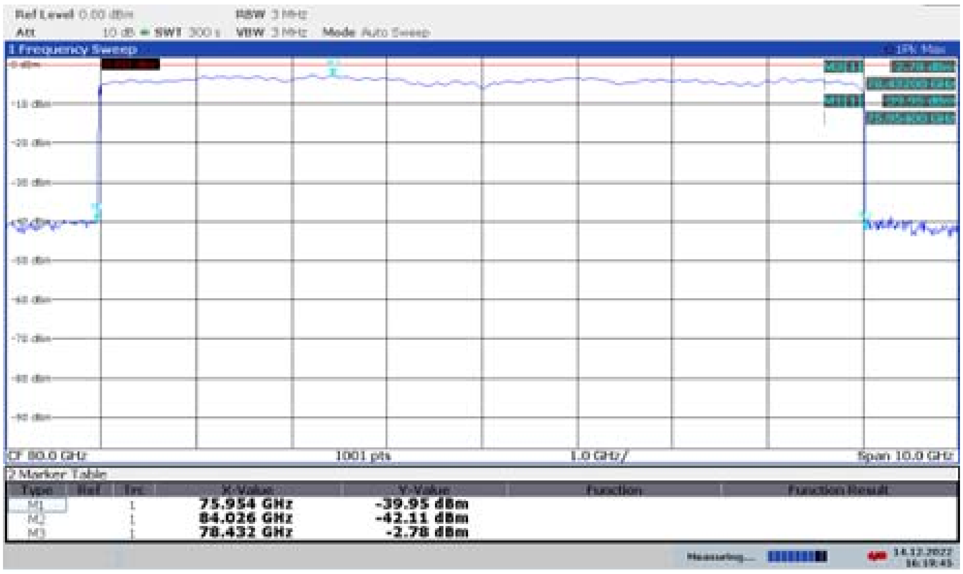


Figure B.11: TX spectrum of conducted measurement at -20 °C (source: VEGA Grieshaber KG)

Figure B.12: TX spectrum of conducted measurement at 0 °C (source: VEGA Grieshaber KG)

Figure B.13: TX spectrum of conducted measurement at 20 °C (source: VEGA Grieshaber KG)

Figure B.14: TX spectrum of conducted measurement at 40 °C (source: VEGA Grieshaber KG)

Figure B.15: TX spectrum of conducted measurement at 60 °C (source: VEGA Grieshaber KG)

Figure B.16: TX spectrum of conducted measurement at 80 °C (source: VEGA Grieshaber KG)

At 20 °C the maximum measured output power is -3,44 dBm. The lower frequency bound of the Operating Frequency Range (OFR) is at 75,964 GHz and the upper frequency bound of the OFR is at 84,016 GHz.

Table B.1 shows all frequency and power value pairs for the different temperature settings.

Table B.1: Measured frequency and power value pairs extracted from the output spectrum of the EUT at the antenna connector

	Marker 1		Marker 2		Marker 3	
Temp.	**Ampl./dBm**	**Freq./GHz**	**Ampl./dBm**	**Freq./GHz**	**Ampl./dBm**	**Freq./GHz**
-40 °C	-38,8	75,954	-39,51	84,026	-2,3	78,432
-20 °C	-39,95	75,954	-42,11	84,026	-2,78	78,432
0 °C	-28,1	75,964	-26,44	84,016	-3,05	78,202
20 °C	-42,54	75,964	-24,92	84,016	-3,44	78,402
40 °C	-27,31	75,974	-39,86	84,016	-3,96	78,191
60 °C	-35,31	75,974	-43,22	84,016	-4,47	78,541
80 °C	-43,24	75,974	-42,89	84,016	-4,99	78,127

- The amplitude drifts from -2,30 dBm at -40 °C to -4,99 dBm at +80 °C which corresponds to a delta of 2,69 dB over the whole temperature range.
- The lower frequency bound drifts from 75,954 GHz to 75,974 GHz which corresponds to a delta of 20 MHz over the whole temperature range.
- The upper frequency bound drifts from 84,026 GHz to 84,016 GHz which corresponds to a delta of 10 MHz over the whole temperature range.

B.2.4.2 EUT with ¾" horn antenna with screw-in thread

Figure B.17 shows the measured output spectrum of the EUT acquired in the test-setup depicted in figure B.5 at a temperature of 20 °C.

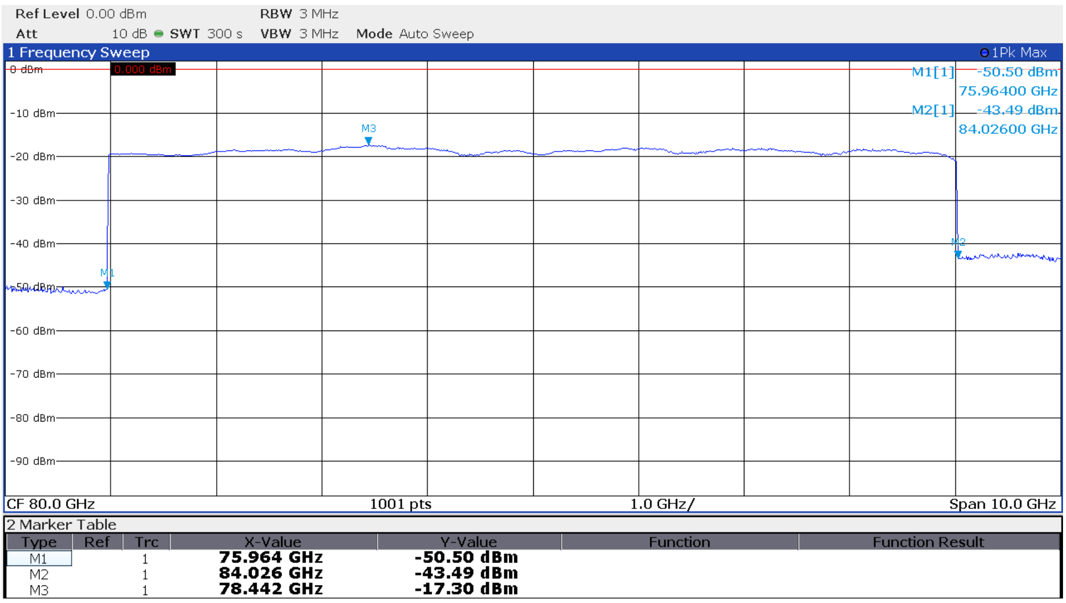


Figure B.17: output spectrum of EUT with ¾" horn antenna at 20 °C (source: VEGA Grieshaber KG)

The following figures showing the measurements results for:

- Figure B.18: TX spectrum of ¾" horn antenna at -40 °C.
- Figure B.19: TX spectrum of ¾" horn antenna at -20 °C.
- Figure B.20: TX spectrum of ¾" horn antenna at 0 °C.
- Figure B.21: TX spectrum of ¾" horn antenna at 20 °C.
- Figure B.22: TX spectrum of ¾" horn antenna at 40 °C.

- Figure B.23 TX spectrum of ¾" horn antenna at 60 °C.
- Figure B.24: TX spectrum of ¾" horn antenna at 80 °C.

Figure B.18: TX spectrum of ¾" horn antenna at -40 °C (source: VEGA Grieshaber KG)

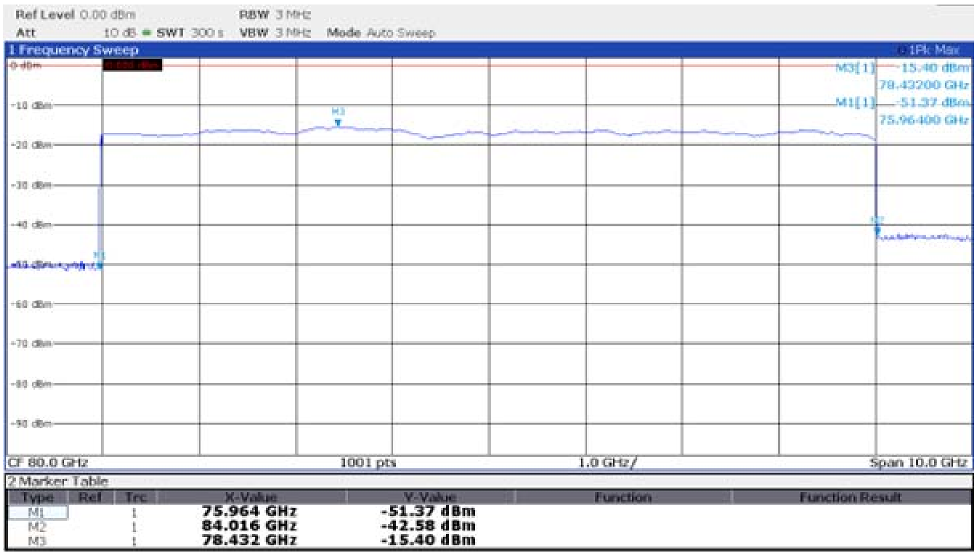


Figure B.19: TX spectrum of ¾" horn antenna at -20 °C (source: VEGA Grieshaber KG)

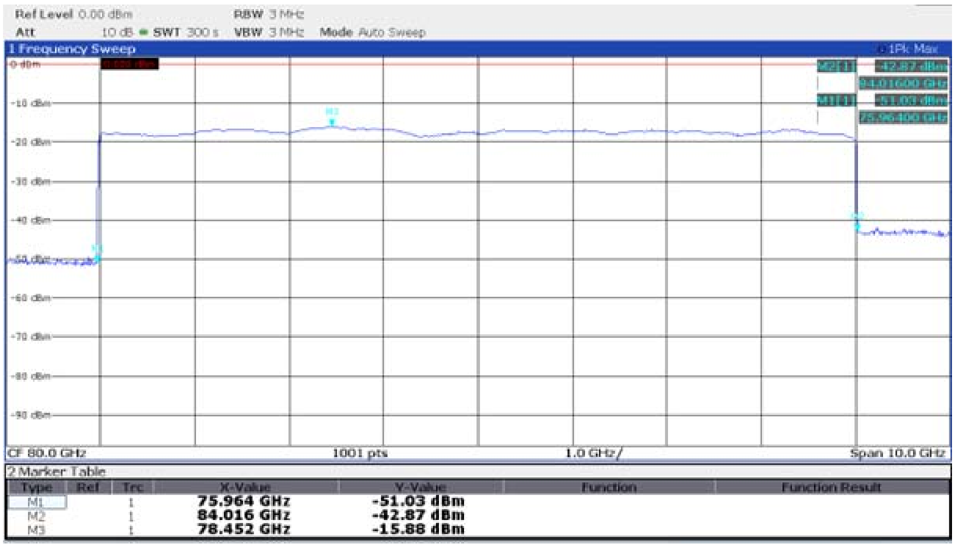


Figure B.20: TX spectrum of ¾" horn antenna at 0 °C (source: VEGA Grieshaber KG)

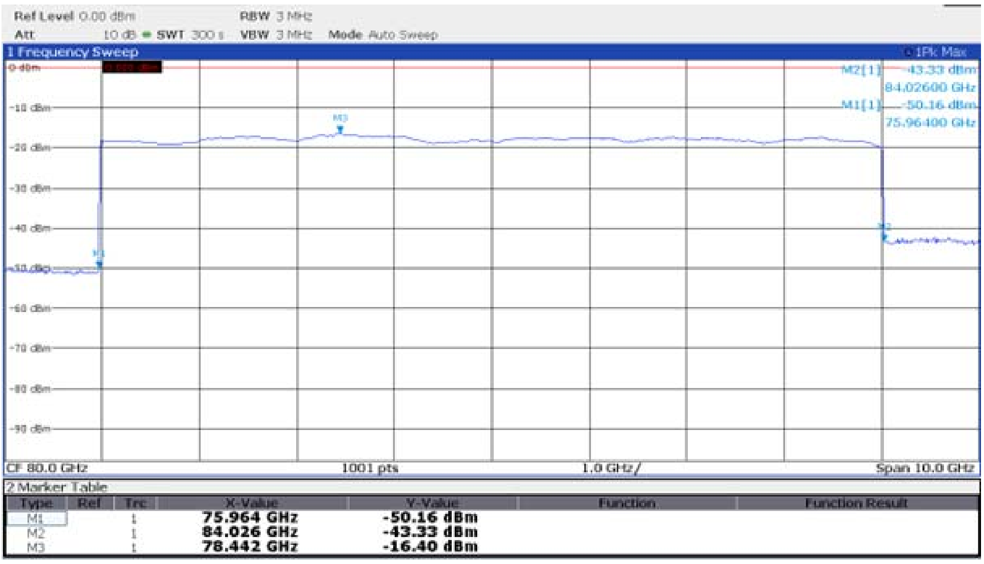


Figure B.21: TX spectrum of ¾" horn antenna at 20 °C (source: VEGA Grieshaber KG)

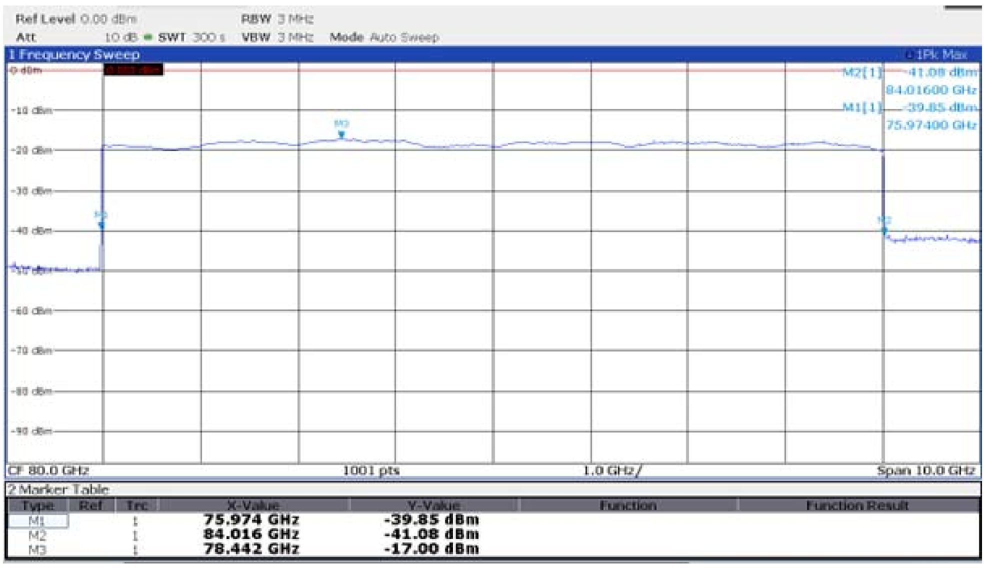


Figure B.22: TX spectrum of ¾" horn antenna at 40 °C (source: VEGA Grieshaber KG)

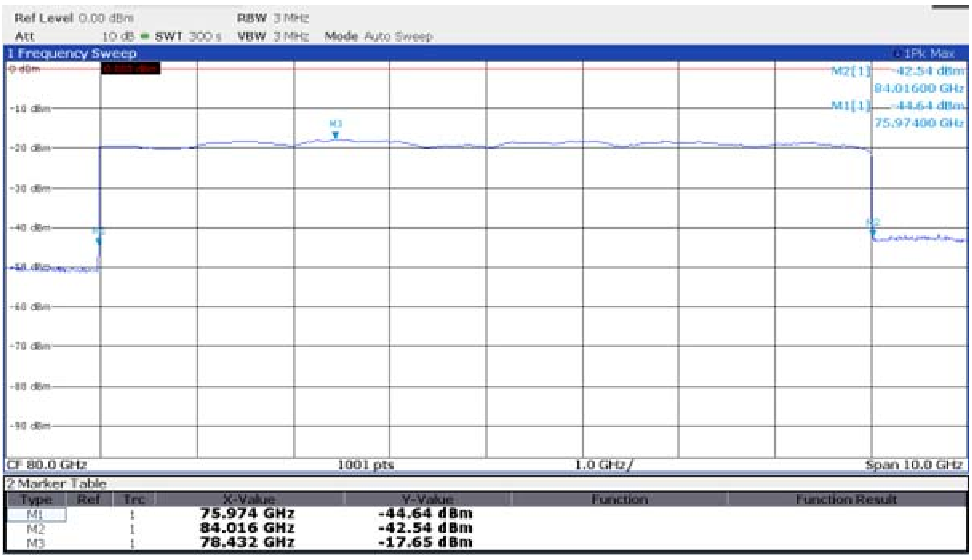


Figure B.23: TX spectrum of ¾" horn antenna at 60 °C (source: VEGA Grieshaber KG)

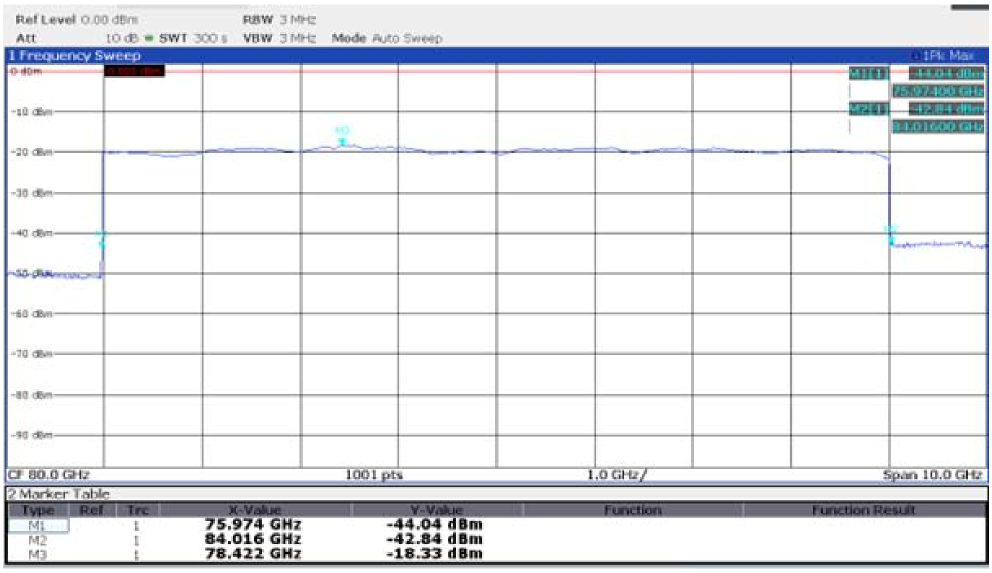


Figure B.24: TX spectrum of ¾" horn antenna at 80 °C (source: VEGA Grieshaber KG)

At 20 °C the maximum measured output power is -17,3 dBm. The lower frequency bound of the Operating Frequency Range (OFR) is at 75,964 GHz and the upper frequency bound of the OFR is at 84,026 GHz.

Table B.2 shows all frequency and power value pairs for the different temperature settings.

Table B.2: Measured frequency and power value pairs extracted from the output spectrum of the EUT with ¾" horn antenna

	Marker 1		Marker 2		Marker 3	
Temp.	**Ampl./dBm**	**Freq./GHz**	**Ampl./dBm**	**Freq./GHz**	**Ampl./dBm**	**Freq./GHz**
-40 °C	-43,96	75,964	-42,72	84,026	-14,85	78,501
-20 °C	-51,37	75,964	-42,58	84,016	-15,4	78,432
0 °C	-51,03	75,964	-42,87	84,016	-15,88	78,452
20 °C	-50,16	75,964	-43,33	84,026	-16,4	78,442
40 °C	-39,85	75,974	-41,08	84,016	-17	78,442
60 °C	-44,64	75,974	-42,54	84,016	-17,65	78,432
80 °C	-44,04	75,974	-42,84	84,016	-18,33	78,422

- The amplitude drifts from -14,85 dBm at -40 °C to -18,33 dBm at +80 °C which corresponds to a delta of 3,85 dB over the whole temperature range.
- The lower frequency bound drifts from 75,964 GHz to 75,974 GHz which corresponds to a delta of 10 MHz over the whole temperature range.
- The upper frequency bound drifts from 84,026 GHz to 84,016 GHz which corresponds to a delta of 10 MHz over the whole temperature range.

B.2.4.3 EUT with 3" plastic horn antenna

Figure B.25 shows the measured output spectrum of the EUT which was measured according to test-setup depicted in Figure B.5 at a temperature of 20 °C.

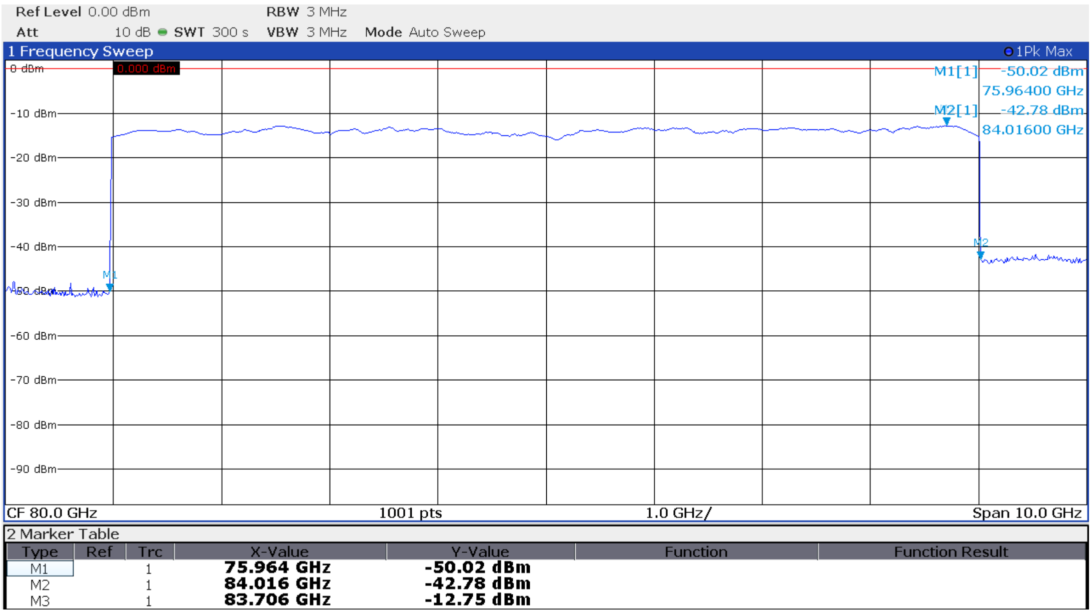


Figure B.25: Output spectrum of EUT with 3" plastic horn antenna at 20 °C (source: VEGA Grieshaber KG)

The following figures showing the measurements results for:

- Figure B.26: TX spectrum of 3" plastic horn antenna at -40 °C.
- Figure B.27: TX spectrum of 3" plastic horn antenna at -20 °C.
- Figure B.28: TX spectrum of 3" plastic horn antenna at 0 °C.
- Figure B.29: TX spectrum of 3" plastic horn antenna at 20 °C.
- Figure B.30: TX spectrum of 3" plastic horn antenna at 40 °C.
- Figure B.31: TX spectrum of 3" plastic horn antenna at 60 °C.
- Figure B.32: TX spectrum of 3" plastic horn antenna at 80 °C.

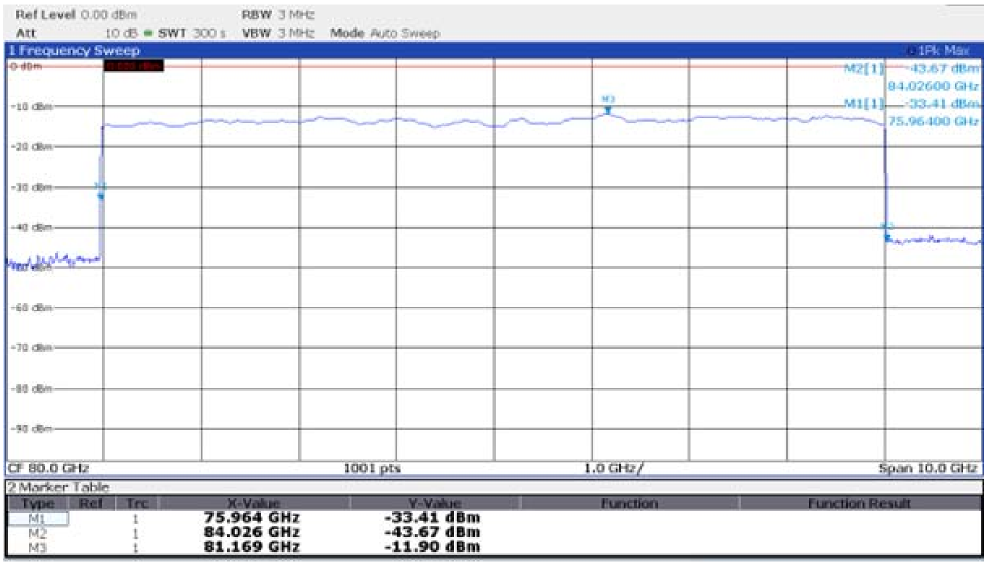


Figure B.26: TX spectrum of 3" plastic horn antenna at -40 °C (source: VEGA Grieshaber KG)

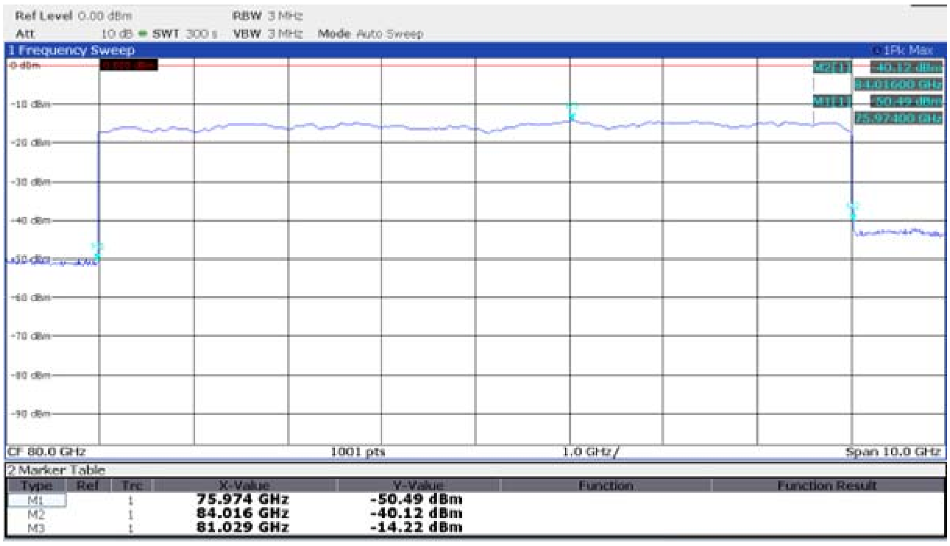


Figure B.27: TX spectrum of 3" plastic horn antenna at -20 °C (source: VEGA Grieshaber KG)

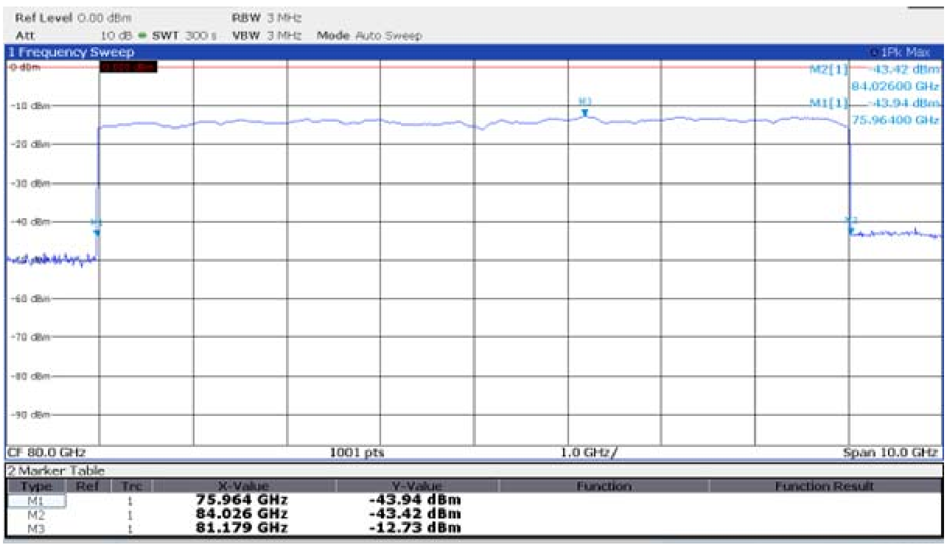


Figure B.28: TX spectrum of 3" plastic horn antenna at 0 °C (source: VEGA Grieshaber KG)

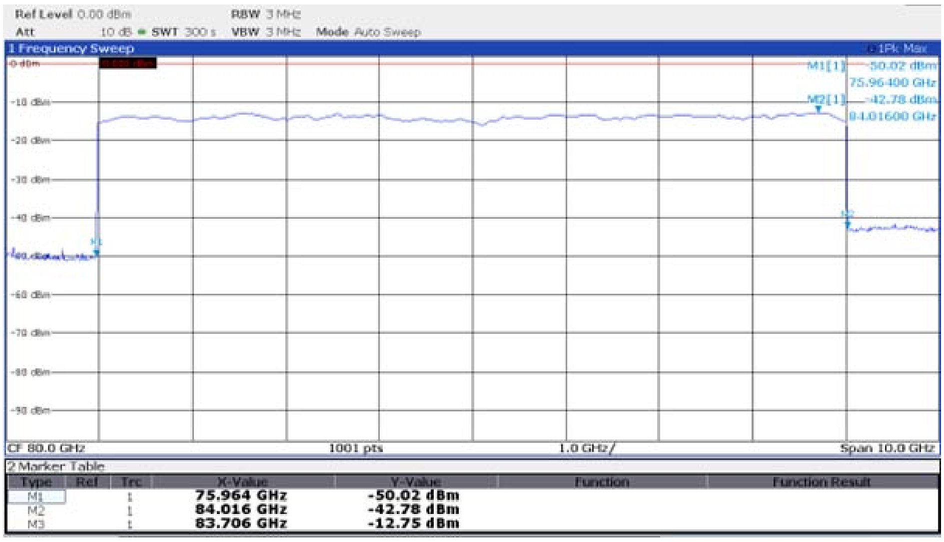


Figure B.29: TX spectrum of 3" plastic horn antenna 20 °C (source: VEGA Grieshaber KG)

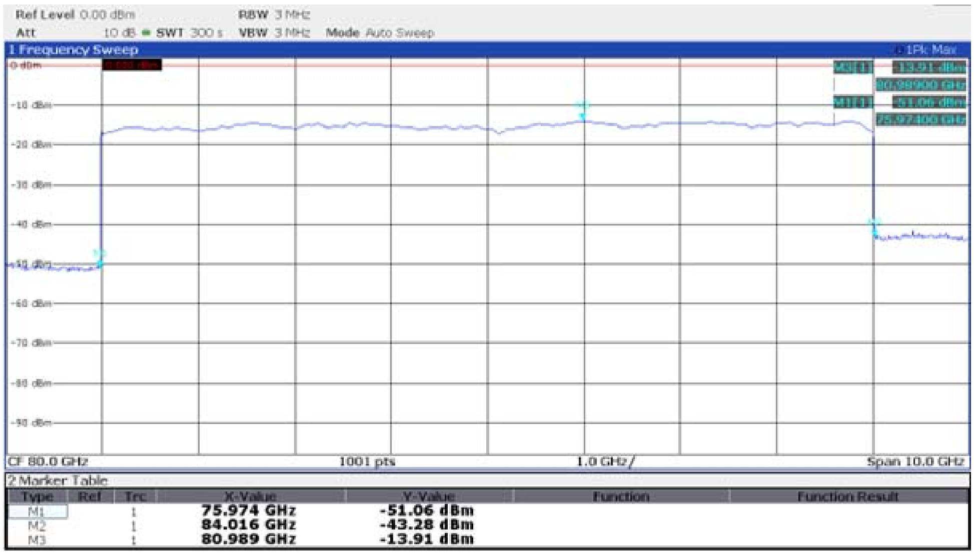


Figure B.30: TX spectrum of 3" plastic horn antenna 40 °C (source: VEGA Grieshaber KG)

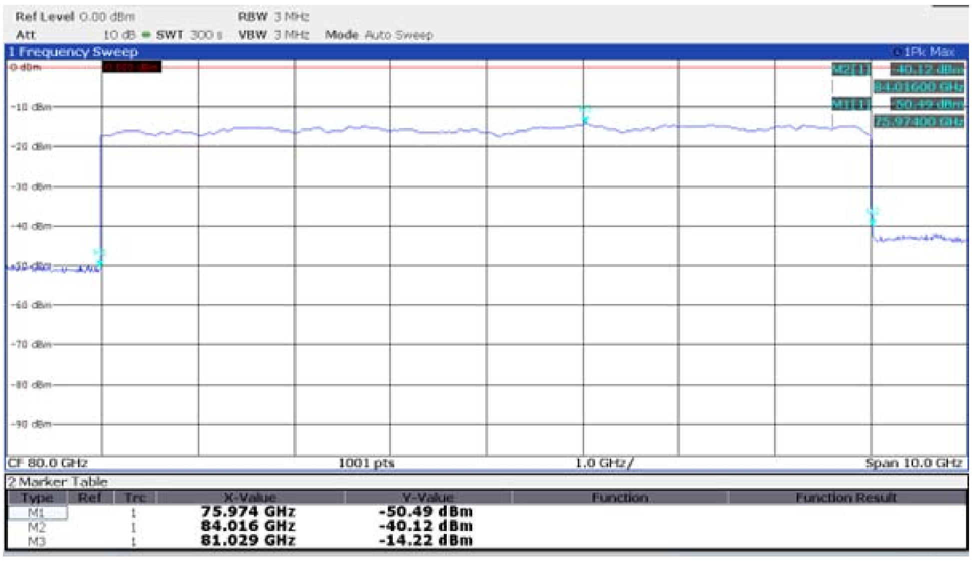


Figure B.31: TX spectrum of 3" plastic horn antenna 60 °C (source: VEGA Grieshaber KG)

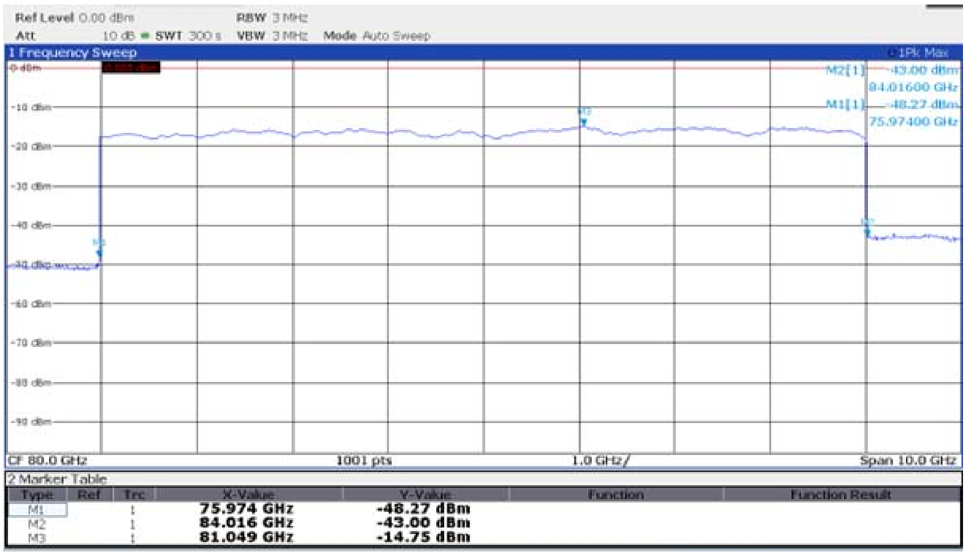


Figure B.32: TX spectrum of 3" plastic horn antenna at 80 °C (source: VEGA Grieshaber KG)

At 20 °C the maximum measured output power is -12,75 dBm. The lower frequency bound of the operating frequency range (OFR) is at 75,964 GHz and the upper frequency bound of the OFR is at 84,016 GHz.

Table B.3 shows all frequency and power value pairs for the different temperature settings

Table B.3: Measured frequency and power value pairs extracted from the output spectrum of the EUT with 3" plastic horn antenna

	Marker 1		Marker 2		Marker 3	
Temp.	Ampl./dBm	Freq./GHz	Ampl./dBm	Freq./GHz	Ampl./dBm	Freq./GHz
-40 °C	-33,41	75,964	-47,63	84,026	-11,9	81,169
-20 °C	-47,63	75,964	-43,92	84,026	-12,38	81,169
0 °C	-43,94	75,964	-43,42	84,026	-12,73	81,179
20 °C	-50,02	75,964	-42,78	84,016	-12,75	83,706
40 °C	-51,06	75,974	-43,28	84,016	-13,91	80,989
60 °C	-50,49	75,974	-40,12	84,016	-14,22	81,029
80 °C	-48,27	75,974	-43	84,016	-14,75	81,049

- The amplitude drifts from -11,90 dBm at -40 °C to -14,75 dBm at +80 °C which corresponds to a delta of 2,85 dB over the whole temperature range.
- The lower frequency bound drifts from 75,964 GHz to 75,974 GHz which corresponds to a delta of 10 MHz over the whole temperature range.
- The upper frequency bound drifts from 84,026 GHz to 84,016 GHz which corresponds to a delta of 10 MHz over the whole temperature range.

B.2.5 Summary and Conclusion

B.2.5.1 Summary

Table B.4 shows the summary of the measured output spectrums with both applied EUT antennas in comparison with the conducted measurement method.

The experiment shows that the amplitude drift of the EUT over the monitored temperature region from -40 °C to +80 °C is below 4 dB. Depending on the measurement method the amplitude drifts between 2,69 dBm in the conducted measurement to 3,48 dBm in the setup with ¾" horn antenna with screw-in thread.

Table B.4: Summary of amplitude and frequency drifts from -40 °C to +80 °C of all three measurement setups

	Conducted	¾" horn antenna with screw-in thread	3" plastic horn antenna
Amplitude Drift	2,69 dB	3,48 dB	2,85 dB
Lower Frequency Boundary Drift	20 MHz	10 MHz	10 MHz
Upper Frequency Boundary Drift	10 MHz	10 MHz	10 MHz

B.2.5.2 Conclusions

All three measurements show the same temperature behaviour. At -40 °C the amplitude is at its maximum and the Operating Frequency Range (OFR) is shifted to lower frequencies. With increasing temperature, the amplitude decreases, and the OFR is shifted to higher frequencies.

The comparison of all three measurement setups shows that the amplitude and frequency drifts over temperature are essentially the same within the prevalent Measurement Uncertainty (MU) at those frequencies (max. MU ±4 dB according to ETSI EN 302 729 [i.13]. The difference of the amplitude drifts of all three trials is below 1 dB and the difference of the frequency drifts is below 1 %.

The measurement trials showed that the relative TX behaviour under extreme environmental conditions can be conducted in a radiated measurement setup inside a temperature chamber under near field conditions of the used directive antennas with sufficient accuracy without a significant increase of the MU or any other adverse effect.

B.3 Measurement based on a UWB wall scanning device

B.3.1 Introduction

With an UWB wallscanner according to ETSI EN 302 065-4-1 [i.9], lab measurements are conducted to test the proposed procedure for the environmental profile. The EUT is working with the OFR within a range of around 2 GHz - 6 GHz.

B.3.2 Used EUT and measurement antennas

As EUT a certified wallscanner, based on ETSI EN 302 065-4-1 [i.9] was used.

On receiver side a Standard Gain Horn (SGH) from Rohde & Schwarz was used:

- Model No: R&S HF 906
- Nominal Gain: 9,9 dBi (at center frequency 3,8 Ghz)
- Aperture: a x b = 250 mm x 160 mm

B.3.3 Test set-up and Measurements

Procedure for environmental profile assessment was followed clause 6.3:

a) Assess the indirect emissions mean spectral EIRP frequency of maximum emissions f_{max}.

b) Conduct relative measurement without absorbing wall where the DUT is placed inside a temperature chamber. The DUT emits through a radio transparent door of the temperature chamber.

c) By varying the environmental profile, evaluate the difference in power level $\max\Delta P_{step}$ and the change in frequency $\max\Delta f_{step,increase}$ and $\max\Delta f_{step,decrease}$ at $f_{max,}$ see figure B.33.

d) Adapt spectral mask for indirect emissions depending on results, check compliance with.

e) Respect to adapted mask, see figure B.34.

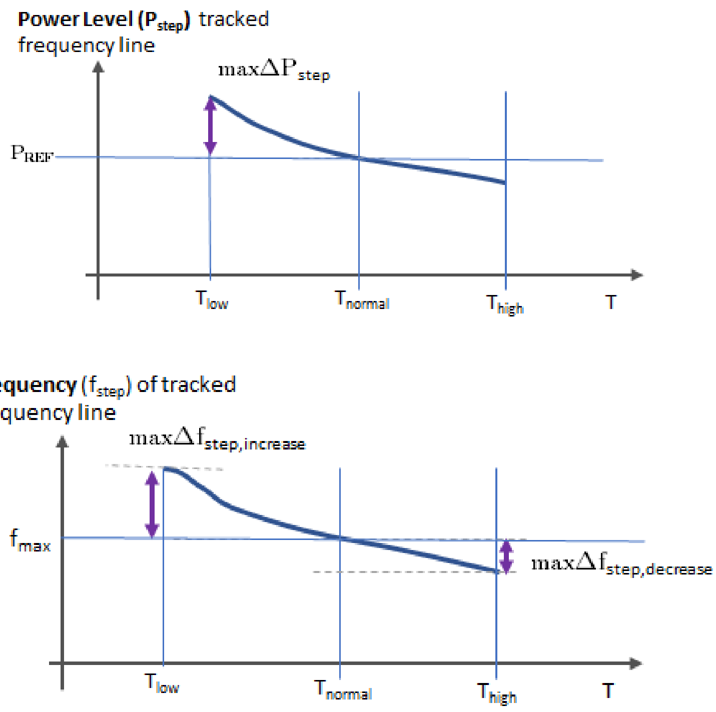
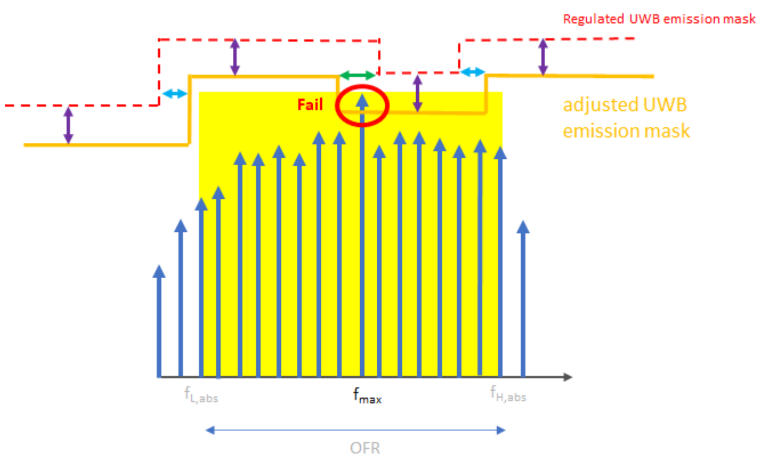


Figure B.33: The measurement was assessed based on the concept in step 6 of clause 6.5.1.6



- Reduce limit by $\max\Delta P_{step}$
- Reduce frequency boarder (at steps "from higher to lower limit levels) by $\max\Delta f_{step,increase}$
- increase frequency boarder (at steps "from lower to higher limits levels") by $\max\Delta f_{step,decrease}$

Figure B.34: The emission mask was adjusted based on step 8 clause 6.5.1.8

Figure 7 in clause 5.2.2.1 shows the in principle used radiated test setup using a measurement antenna which is placed outside the temperature chamber. The setting in the laboratory is shown in figures B.35 and B.36.

The radio transparent cover was made of plastic and replaced the door of the temperature chamber.

The EUT was placed inside the temperature chamber and emits through the transparent cover directly to the measurement antenna. The measurement standard gain horn faces the EUT in the expected direction of maximum emissions in a distance of 50 cm.

The measurement was conducted in a lab environment and not in an anechoic chamber. Thus, an external LNA in-between measurement antenna and spectrum analyser (measurement receiver) was not used, due to strong available services in the 1,8 GHz to 6 GHz range.

The spectrum analyser is configured with the settings as for the indirect emissions mean power e.i.r.p. spectral density measurement (1,8 GHz to 5,8 GHz, RBW = VBW =1 MHz, RMS detector, 4 001 pts measurement points, 1.95ms/pt per measurement point this would lead to a sweep time of 7,802 s).

Specified operating temperature range of EUT: -10 °C to + 50 °C. Test temperatures (including margin): -15 °C, + 20 °C, + 55 °C.

Figure B.35: The EUT within an "radio transparent part" in front of the temperature chamber (source: Robert Bosch GmbH)

Figure B.36: The measurement antenna pointing to the "radio transparent part" which is in front of the temperature chamber (source: Robert Bosch GmbH)

B.3.4 Measurement Results and Assessment

B.3.4.1 Assess f_{max} of the indirect emissions mean power e.i.r.p. spectral density

Based on the procedure for environmental profile assessment in clause 6.3 the measurement result of the calibrated radiated emission test was used as the basis. Therefore, a plot with the max e.i.r.p. emission was used to assess the max emission within the OFR, see figure B.37.

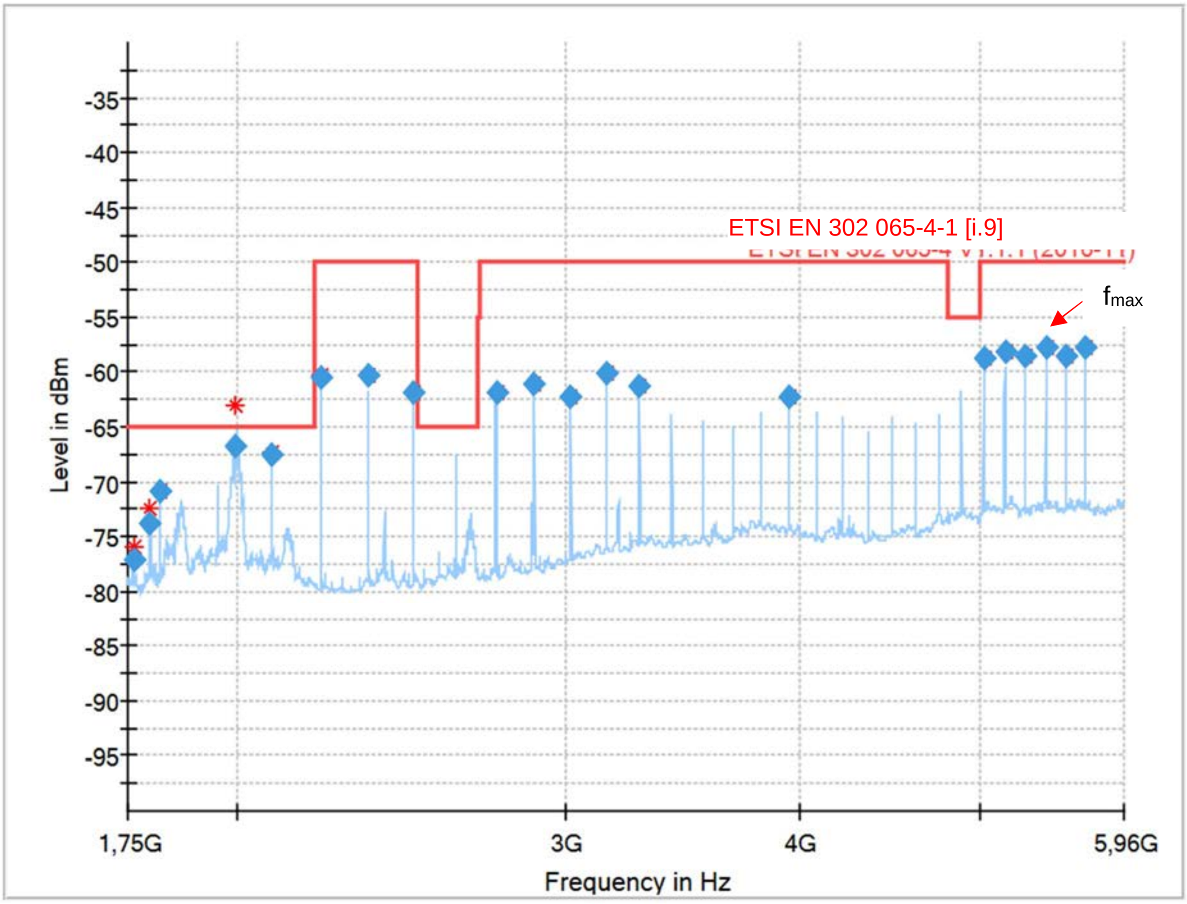


Figure B.37: Maximum e.i.r.p. emissions based on the calibrated set-up (as specified in ETSI EN 302 065-4-1 [i.9]) (source: Robert Bosch GmbH)

The max emission in operating bandwidth was red out at f_{max} = 5 679,523000 MHz.

B.3.4.2 Measurement results and assessment

Figure B.38 shows the measurement with UWB emission "on" and UWB emission "off" under normal environmental conditions (20 °C).

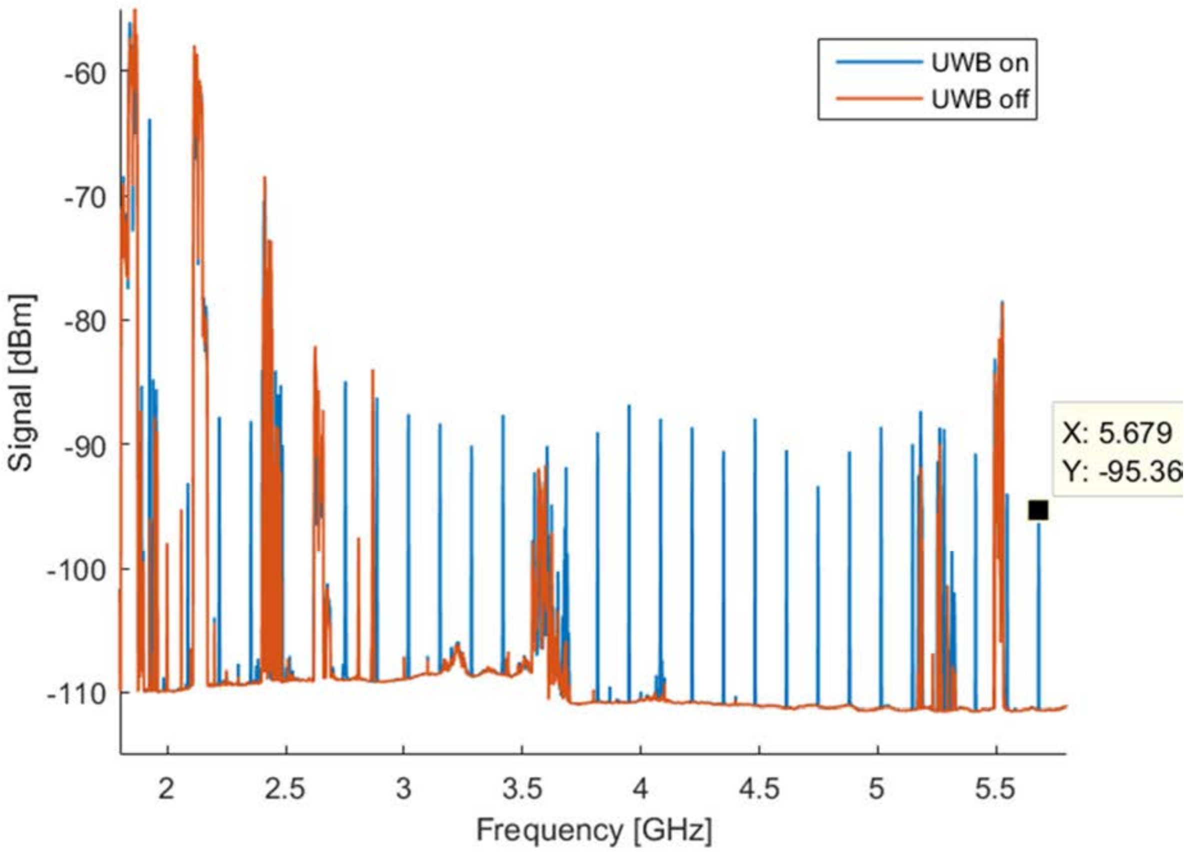


Figure B.38: Measurement at 20 °C, with UWB on vs. UBW off (source: Robert Bosch GmbH)

Figure B.39 shows the measurement with UWB emission "on" under environmental conditions (-15 °C, +20 °C and +55 °C).

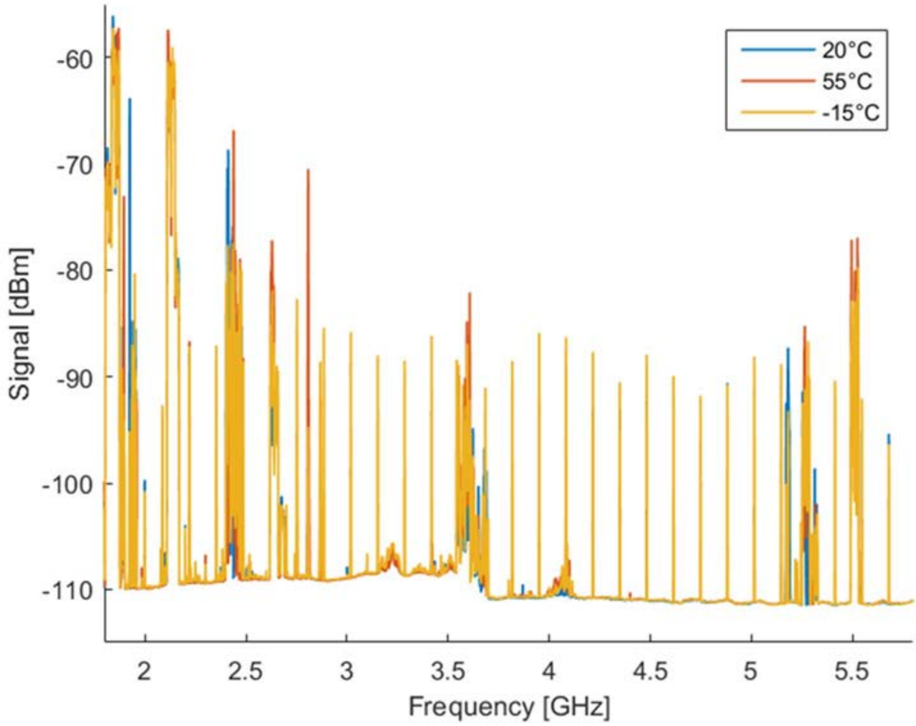


Figure B.39: Measurement at -15 °C, + 20 °C and + 55 °C; with UWB on (Source: Robert Bosch GmbH)

- By comparing "UWB on" with "UWB off", a lot of external services are observed in the observed frequency range.
- At fmax = 5,679 GHz, no external service observed, but absolute power level is lower compared to other frequencies (based on the higher free space attenuation and the emission itself). Thus, 2 additional other different emission frequencies are evaluated at low and mid frequency.

The measurement assessment is shown in table B.5.

Table B.5: Summary of amplitude and frequency drifts from -15 °C to +55 °C

Frequency line @20 °C	Power @20 °C	Frequency shift, -15 °C	Power shift, -15 °C	Frequency shift, +55 °C	Power shift, +55 °C
5,679 GHz	-95,36 dB	+1 MHz	-1 dB	0 MHz	-2,15 dB
3,418 GHz	-87,62 dB	0 MHz	+1,39 dB	0 MHz	-0,97 dB
2,220 GHz	-87,8 dB	+1 MHz	+0,61 dB	+1 MHz	+1,08 dB

Summary for the assessment based on procedure in clause 6.3:

- For frequency shift:
  - $\max\Delta f_{step,increase} = 1$ MHz
  - $\max\Delta f_{step,decrease} = 0$
- For the power increase:
  - $\max\Delta P_{step} = 1,39$ dB

B.3.4.3 Final assessment for TX-behaviour based on procedure in clause 6.3

Limit changes in indirect emissions mean spectral e.i.r.p.

Based on the descripted changes (procedure clause 6.3) for the indirect emission mask, see figure B.37 and the assessed limits for:

- Frequency shift:
  - $\max\Delta f_{step,increase}$ = 1 MHz.
  - $\max\Delta f_{step,decrease}$ = 0.

  Result: frequency shift is too small that no emission would go to a more stringent limit.
- Power increase:
  - $\max\Delta P_{step}$ = 1,39 dB.
  - Requires decrease of limit curve (in red) by 1,39 dB.
- Result:
  - Still all UWB emissions below the adjusted limit curve.
  - The spectral line near 2 GHz can rather be attributed to other emissions.

Therefore, it could be decided that the TX-behaviour test is passed.

B.3.5 Summary and Conclusion

- Without external LNA, additional measures of the spectrum analyser to decrease noise floor and increase repeatability of the measurement need to be used: Noise floor extension, internal preamp, 10x averaging.
- The normal glass door of the temperature chamber shows such high attenuation in the 1,8 GHz to 6 GHz band, that no device emissions could be seen when the device is placed inside the chamber to transmit through the normal glass door.
- Instead of the used extended cover made of thin plastic as radio transparent door of the temperature chamber, a flat cover with isolation would be preferable.
- A lot of external interferers observed, as measurement not done in anechoic chamber, but in normal lab environment.
- It needs to be discussed it the "choosing" only the highest emission at fmax is the best solution or if it is not better to choose three "higher" UWB emissions at frequencies (mid, center, high) within the OFR.

But it was able to show that the test set-up and procedure is usable to assess the TX-behaviour.

B.4 Assessment and Justification Absorbing Box

B.4.1 Guidance to create an absorbing box

This test set-up could be specifically prepared by the manufacturer to reflect the needs for the EUT (size, available temperature chambers, EUT mounting, etc.) and offers the possibility of a longer-term stable test solution for a manufacturer itself. It may not be a practical solution for test houses because, it may prove more expensive for test labs to build such a container for every possible EUT when compared to the other test set-up in clauses 5.2.3 and 5.2.4.

The following points were considered by the preparation of such absorbing box.

For this set-up a non-conducting box (e.g. plastic/wood) used and the inside needs to be covered with RF absorbing material. The absorbing material has had an absorption sufficient to mitigate any effect that the metallic walls of the environmental chamber would have on the frequency or spectral shape of the EUT's emission, which can be verified empirically as seen below in clause B.4.2.3.

NOTE 1: As a guide to selection of absorber 20 dB absorption over the operating frequency of the EUT should be sufficient.

In addition, the measurement antenna should have sufficient gain to estimate a link loss (e.g. 3 dBi) but not so large so as to couple to the EUT and perturb the radiation measurement. The antenna was fixed securely within the non-conducting box such that the box-walls and absorbing material will not impact the radiation pattern of the measurement antenna. A gain of 10 dBi standard gain horn has proven sufficient for this purpose.

In order to achieve faster thermal balance between the inside of the temperature chamber and the inside of the absorbing box additional ventilation could be fixed to the exterior of the box in a "push/pull" configuration. An additional thermometer close to the EUT can be utilized as the control loop thermometer to validate the temperature of the EUT (or the environment inside the box), while the temperature chamber's thermometer can validate the temperature inside the box (or EUT) matches that of the environmental chamber. The ventilation (both for the chamber and box, if installed) and temperature measurement in the box was switched off during the radiation measurement Temperature changes during the radiated measurement is < 0,1 °C are easily achievable in this manner. Powering off ventilation and thermometry during the radiation measurement will reduce the possibility of interfering with the measurement results. Should these functions need to be enabled during the pendency of the measurement, they should be verified not to effect the EUT measurement.

Parameters to be considered for the preparation:

- Box-size: the distance between measurement antenna and EUT should be further than the $2D_{ap}^2/\lambda$ far field distance of the measurement antenna where D represents the maximum dimension of the antenna orthogonal to the direction of propagation, see [i.5].

- The space between EUT and the absorbers should be: sufficiently large so as not to obstruct the direct path between the main beam of the measurement antenna and the EUT (see clause 5.2.5, figure 7) in addition, in no case the proximity of the EUT to the absorber loading the EUT such that the frequency and spectral shape are not significantly different. In minimum the distance should be larger than 1 λ.

NOTE 2: The distance to the absorber on the sides and top of the absorber lined box is not, itself a critical parameter. Because the purpose of the fixture is to provide an environment that mitigates loading effects of the metal walls of the environmental chamber, it is sufficient to demonstrate that the EUT fundamental frequency and spectral shape is not substantially affected. In figures B.8 and B.9 it is evident that the shape and frequency of the fundamental emission is not affected. Small perturbations to the shape or frequency of the spectrum can be compensated for by measurements of the relevant parameters (fundamental frequency, e.g. -23 dB for the OFR definition) both inside and outside the box as seen in figures B.8 and B.9. If an impact will be recognized (during the justification, see clause B.4.2) the distance need to be increased.

- The absorbers should have attenuation sufficient at the frequencies of the EUT to avoid interference effects from the environmental chamber and to reduce multipath interference within the non-conducting box (a minimum of 20 dB is recommended) and the attenuation should be guaranteed (or validated) over the environmental profile.

- The antenna gain of the measurement antenna should be in min 3 dBi over the OFR of the EUT.

- Any active ventilation fans for the box should be mounted exterior to the box with feedthroughs recessed into the absorber such that they are not in the direct path between the EUT and measurement antenna.

- Difference S21 (between free space and in box) should be no larger than 6 dB, see clause B.4.2.2.

The absorbing box used for the assessment is shown in figures B.40, B.41 and B.42.

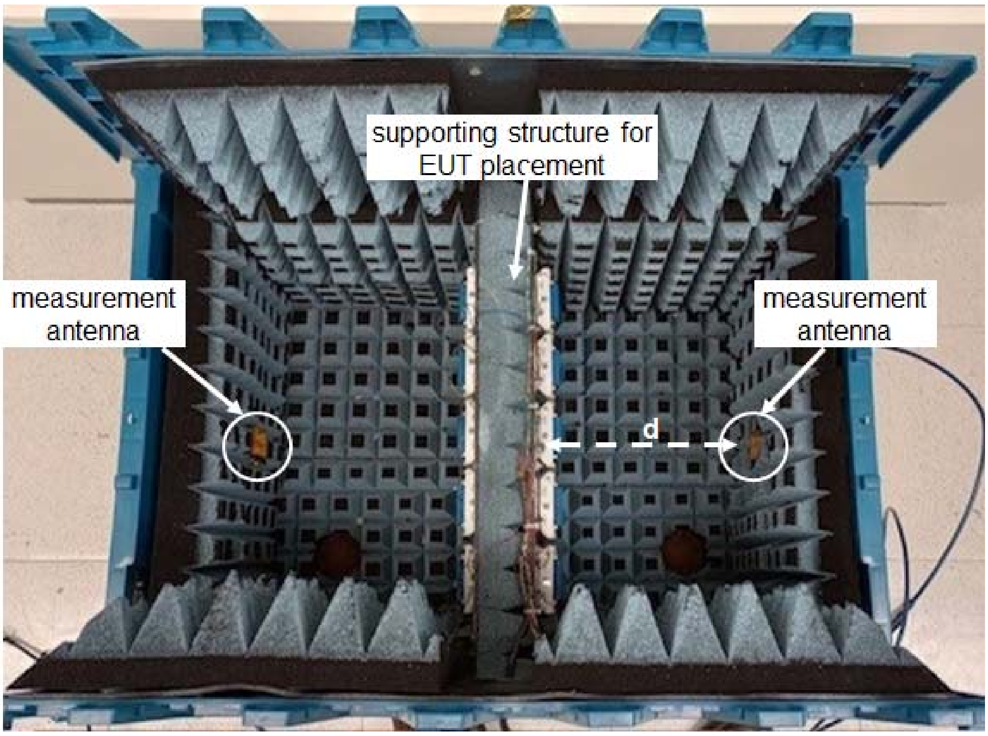


Figure B.40: Open absorbing box with the option to test several EUT in parallel

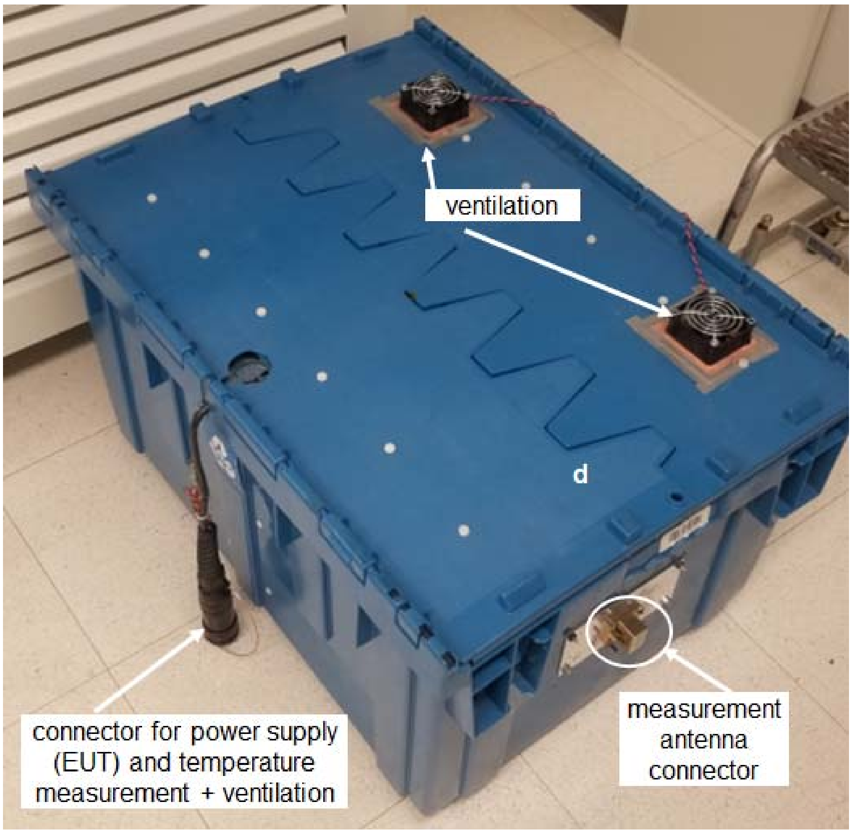


Figure B.41: Closed absorbing box with connectors

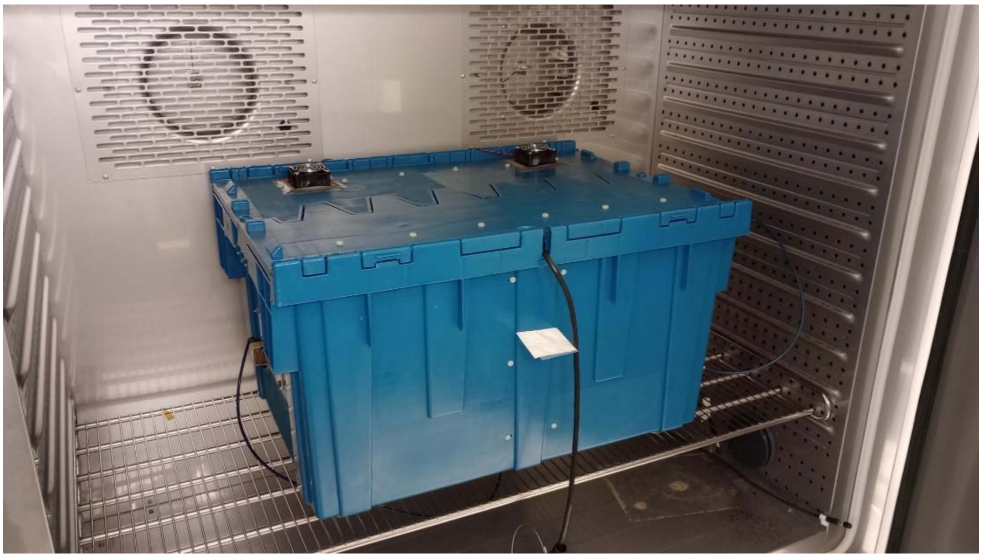


Figure B.42: Absorbing box within temperature chamber

B.4.2 Guidance to justify the performance of the absorbing box

B.4.2.1 General

For the justification of the absorbing box it is sufficient to assess it under normal conditions. Three suggested methods are provided below, although in practical application, the effect of the box and antenna on the EUT (clause B.4.2.3) is sufficient as the goal of measurements with this fixture is to characterize the behaviour of the EUT within the absorber lined box as compared to expected behaviour in a free-space environment. Additionally, should measurements of the change in EUT power over the environmental profile be necessary, characterization transmission through the box over the environmental profile should be performed.

B.4.2.2 Absorbing Box and used measurement antenna

To check/justify the absorbing box the following test setup could be used. For the test a set-up with a network analyser could be used, see figure B.43.

NOTE: The network analyser needs to be run a full 12-term calibration including the cables up to the antennas (see manual of the network analyser).

Justification 1: To justify the impact of the absorbing material to the measurement path in the box the EUT would need to be replaced by a known antenna and the S-parameter of the system could be measured and compared with a comparable free space set-up (identical antennas in free space at same distance) within a tested environment (e.g. full anechoic chamber, see figure B.44).

Assessment: Compare S21_box with S21_free space (or Friis equation derived link budget, see [i.1]) and the difference over the EUT OFR be ≤ 6 dB.

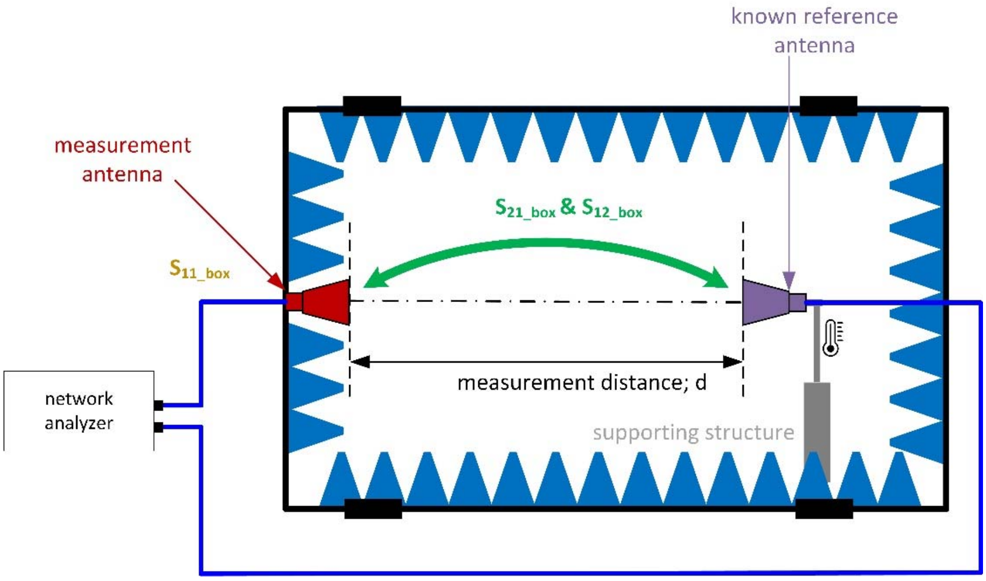


Figure B.43: Test set-up to justify absorbing box

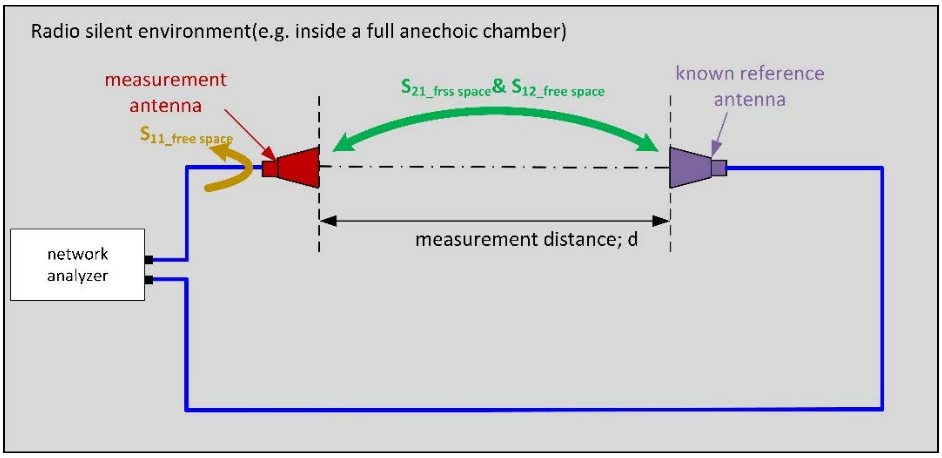


Figure B.44: Test set-up to get reference information to justify absorbing box

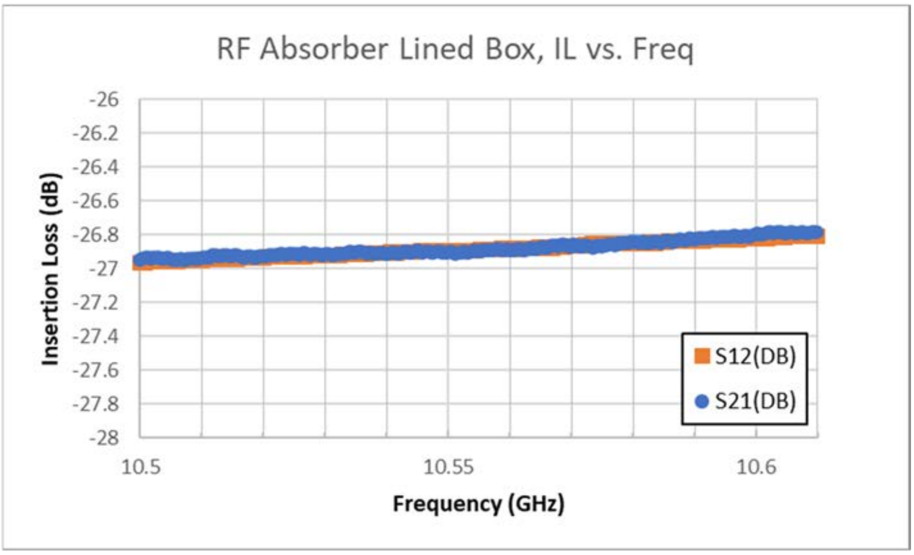


Figure B.45: Insertion loss through box measured at room temperature

For this box, the expected path loss for the pair of nominally 10 dBi antennas is -27,8 dB, which compares well with the measured values shown in the figure above (between -27 dB and -26,8 dB), further supporting the value of this absorbing box as an appropriate RF measurement environment.

Justification 2: To check if the box has an impact on the measurement antenna the S11 impedance (or return loss), see figure B.46 could be compared between mounted case and the free space case) see figures B.43 and B.44. Given that the RCS return of the EUT and reference antenna may differ, this technique may not be applicable.

Assessment: Compare the measured S11_box with the specified information of the datasheet of the measurement antenna (if available). In no case the Return Loss (or VSWR) exceed the value on the datasheet.

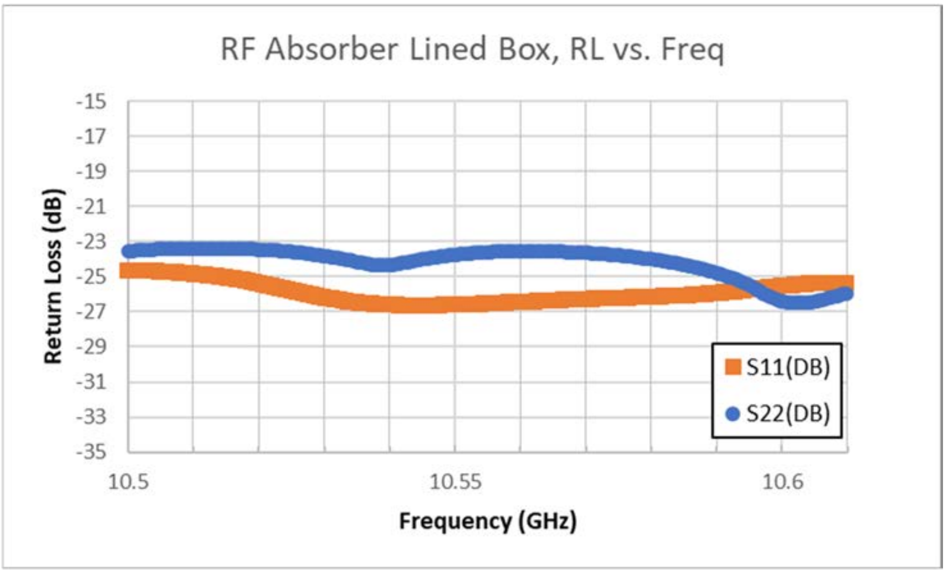


Figure B.46: Return loss in of Port 1 and Port 2 antennas within absorbing box at room temperature

In this case, the specification sheets for these antennas show worst case return losses of -17 dB in the frequency range of interest, indicating that this may be an appropriate setup.

B.4.2.3 Impact absorbing box on EUT emission

Justification of the impact of the absorbing on the EUT emission:

Justification: The impact from the absorbing box on the EUT emission could be assessed by comparing the EUT emission measured in a free space test set-up (still available based an absolute (calibrated emission measurement) with the EUT emission measurement (if mounted inside the box).

NOTE: In order to minimize the possibility of interactions with the absorber and optimize dynamic range of the measurement, the EUT in the box should be oriented such that the main beam of the EUT and measurement antenna are pointed at one another in a co-polarized configuration, however it may be that another direction than the max emission may need to be considered e.g. based on the distance and mounting possibilities inside the absorbing box.

Figure B.47 shows such comparison between a EUT within the absorbing box (see figure B.40) and two measurements outside the box. This overlayed data shows that the shape of the spectrum is not changed by placing it inside the box.

Figure B.48 shows the EUT radiation inside the absorbing box and outside (free space). The comparison shows that the impact (frequency shift in the emission is smaller than the specified Resolution Bandwidth (RBW) of power measurement. (25 kHz shift versus 150 kHz RBW).

In this case the impact on the EUT emission in the assessed direction could be seen as acceptable.

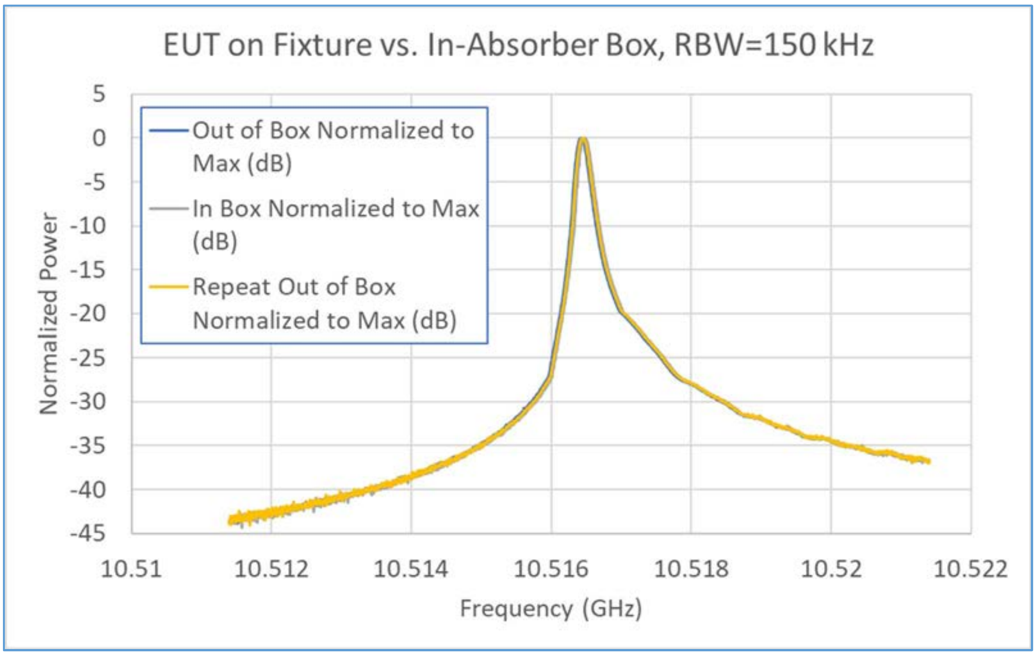


Figure B.47: Overlay of spectra, same EUT inside and outside Absorber Lined Box

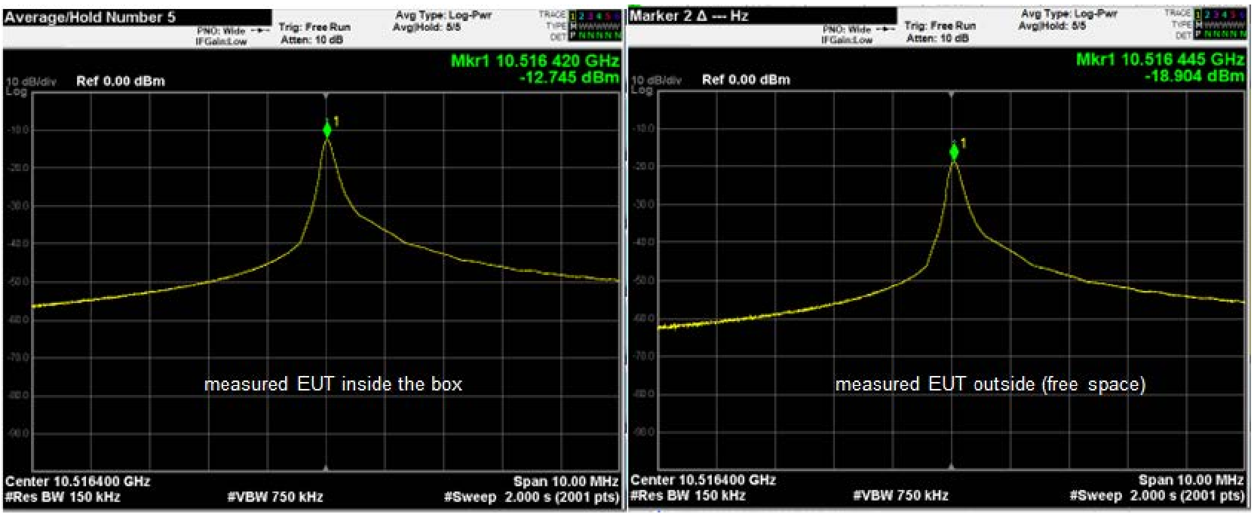


Figure B.48: Uncorrected/raw spectra of EUT inside and outside Absorber Lined Box to confirm frequency stability

B.4.2.4 Scalar link budget measurement within box over temperature profile

Practical estimate of power transmission of absorbing box based on link budget estimate.

Justification: To estimate the effect temperature induced changes in features of the test setup have on the measurement of the power (such as cabling, adapters, horn antennas, etc.) a signal generator is hooked to Port 1 in figure B.43, while a spectrum analyser is hooked to Port 2 and the power received is measured at multiple temperatures. Comparison of the change in raw measured power can be used either as an indication of uncertainty or used as contributions to the EUT power measurement.

Figures B.49 and B.50 show the power measured at the port of a spectrum analyser hooked to Port 2 when a signal generator hooked to Port 1 has a generator power of 10 dBm.

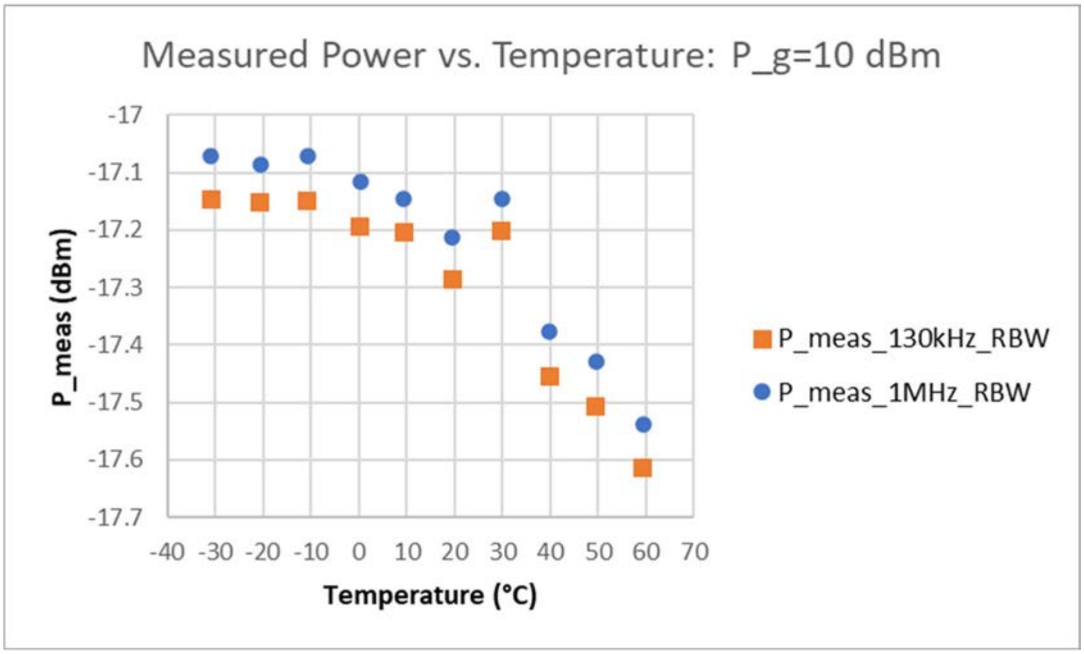


Figure B.49: Measured power through absorber lined box as function of temperature

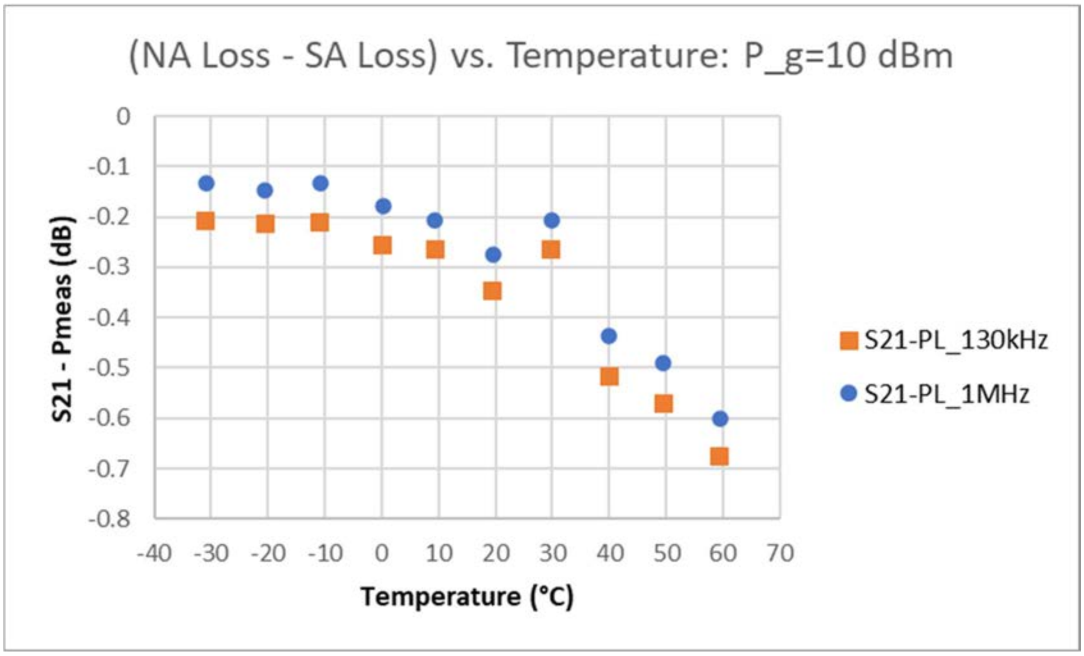


Figure B.50: Difference between room temperature measured S21 through absorber lined box and measured power in Figure B.47

B.4.3 Measurement of an EUT inside an absorbing box

As an example of the effectiveness of this test setup, an intrusion detection radar operating at 10,516 GHz was used as the EUT. The absorbing box is still shown in figures B.40 to B.42:

- In the Figures "Spectra @ Temp", "Frequency vs. Temp", and "Power vs. Temp", data are provided for an example EUT. This data was normalized by to the mean EIRP of the same EUT measured in an anechoic chamber and the sample was measured at multiple temperatures between -30 °C and 60 °C. For the purpose of this example, a threshold line was drawn at -41,3 dBm in terms of this normalized power as a fiducial power envelope measurement.

- Figure B.51: shows an overlay of spectra at multiple temperatures, widening of the spectrum below -35 dBm is a known feature of this EUT's emission.
- Figure B.52: shows spectral width (as measured at -41,3 dBm) and "center frequency" as function of temperature showing that the center frequency of the EUT is consistent across the temperature range.
- Figure B.53: shows changes in EUT power over temperature again, normalized to mean EIRP measured at room temperature in a test fixture calibrated by substitution. The change in power of the EUT over the temperature range (+0,4 dB) is comparable to the change in power measured with a with a signal generator and spectrum analyser (-0,5 dB over the same temperature range).

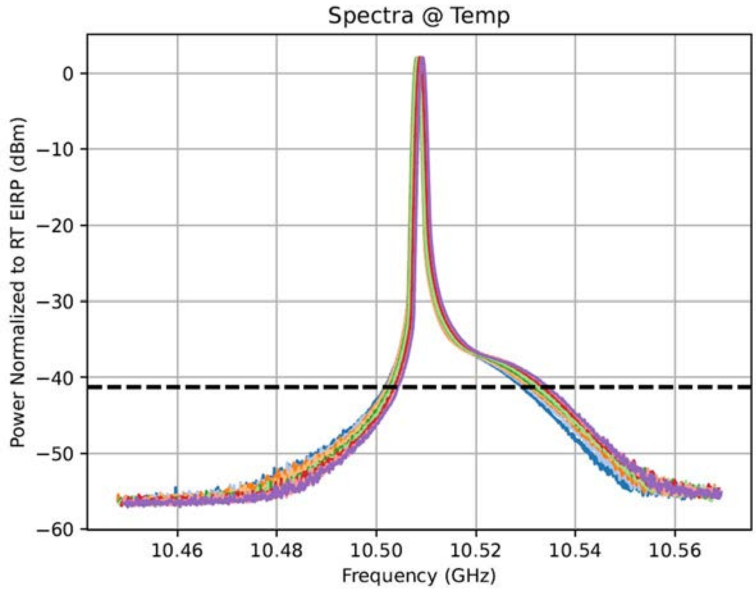


Figure B.51: Overlay of spectra for EUT at multiple temperatures

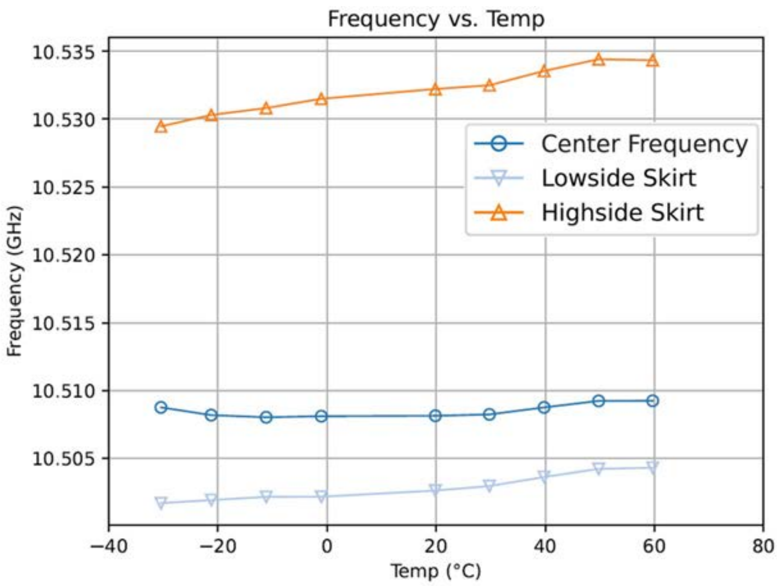


Figure B.52: Frequency of EUT vs. Temperature and selected measures of spectral width (low and high side threshold crossing frequencies at -41,3 dBm

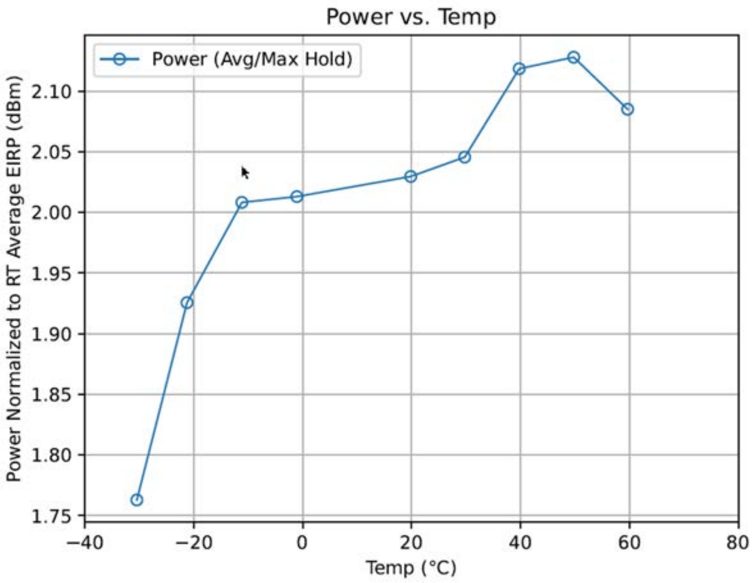


Figure B.53: Power of EUT versus temperature

B.5 Measurement based on a UWB tracking tag

B.5.1 Introduction

A state of the art UWB tag, operating in the range 6 - 8,5 GHz was used to assess if the radiated test set-ups are usable.

B.5.2 Used EUT and measurement antennas

The EUT was a battery driven UWB tag with a more a spherical radiation.

As measuring antenna a Double Ridged waveguide Horn (DRH) from ETS Lindgren was used:

- Model No: 3115
- Nominal Gain: 11 dBi @ 8 GHz
- Aperture: a x b = 244 mm x 159 mm
- Farfield distance: rff = 80 cm

RF Absorbers from Emerson Cumming type "WAVASORP® VHP-4 VC".

B.5.3 Test set-up and measurements

The basis for the assessment a calibrated radiated measurement within a full anechoic chamber based on ETSI EN 302 065-2 [i.10] was used.

For the TX-behaviour assessment under the environmental profile a test set-up as described in clause 5.2.2 was chosen. The measuring antenna was placed outside the temperature chamber to overcome that the thermal effects will have an impact on the test set-up. The temperature chamber itself is built of metal which also causes shielding effects from inside to outside. To get a proper signal from EUT to the measuring antenna the door of temperature chamber was replaced by a radio transparent and thermal isolating plate which keeps the volume of the chamber as it is. The EUT was placed inside the temperature chamber with its antenna pointing to the measuring antenna through the radio transparent plate.

Two options were assessed:

- Option 1: A trial if it is possible to measure through the glass of the temperature chamber door, see figure B.54.
- Option 2: The temperature chamber door was replaced by a plate (material: Jackodur®), see figure B.55.

NOTE: Jackodur® is not a specified "plastic" for radio measurements, details see: jackodur-evo-300-standard (jackon-insulation.de).

There was a need for an offset of the spectrum analysers amplitude to normalize the measured signal to the same maximum level at the same frequency as inside the fully anechoic chamber.

For the first testing no additional attenuation (absorbers) were placed inside the climate chamber.

Figure B.54: Setup with measurement through window of temperature chamber (Source: PHOENIX TESTLAB GmbH)

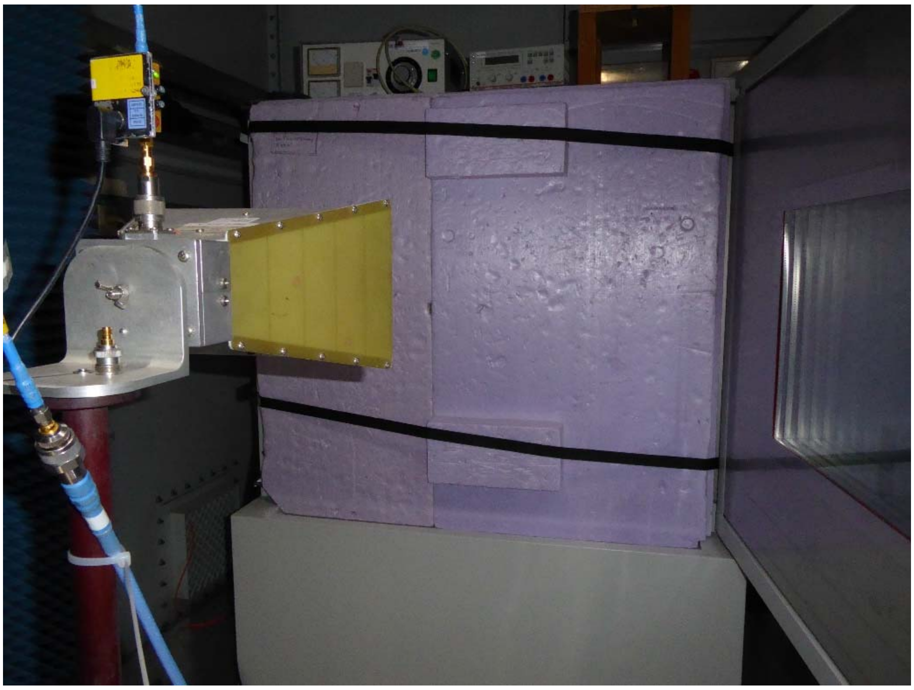


Figure B.55: Setup with radio transparent plate (Source: PHOENIX TESTLAB GmbH)

B.5.4 Measurement Results and assessment

The basis for the assessment the calibrated radiated measurement based on ETSI EN 302 065-2 [i.10] was used, see figure B.56.

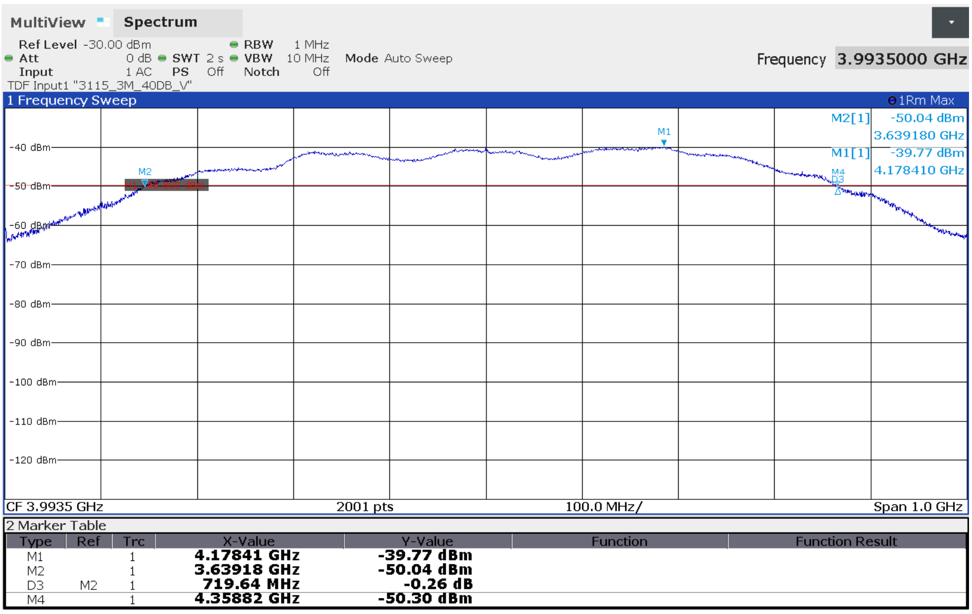


Figure B.56: Result of the measurement in the anechoic chamber (Source: PHOENIX TESTLAB GmbH)

In addition, a conducted measurement was done, see figure B.57.

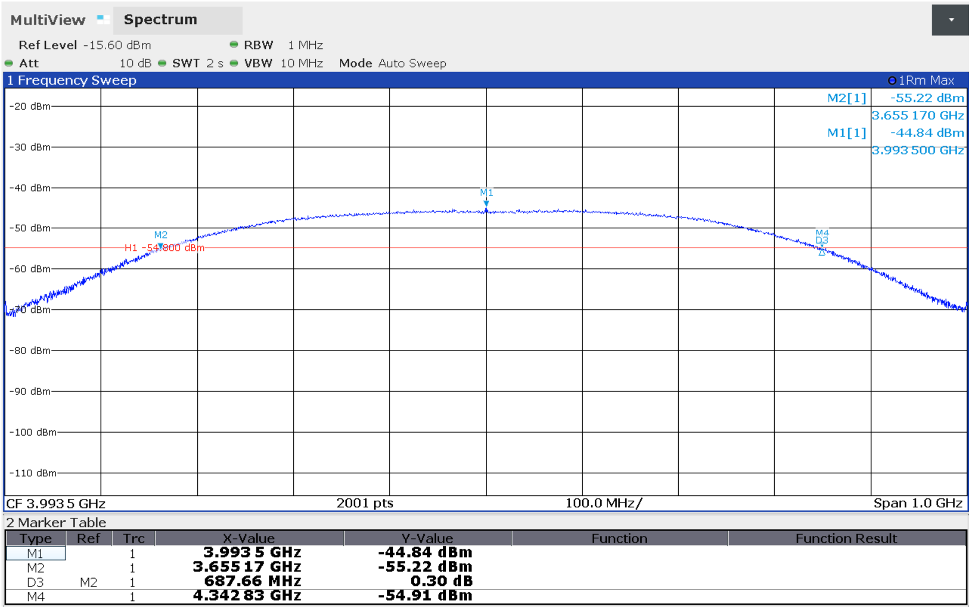


Figure B.57: Result of the measurement at the antenna port (Source: PHOENIX TESTLAB GmbH)

NOTE: The conducted measurement is shown as reference, the intention of the assessment was to check the usability of the radiated assessment test set-up.

The measurement results for the emission assessment based on the test-set-up as in clause 5.2.2 is shown in:

- Figure B.58 with an open temperature chamber door, nothing in front at 20 °C (no absorbing material inside).
- Figure B.59 with closed door, measured through the glass of the temperature chamber door, at 20 °C (no absorbing material inside).
- Figure B.60 with the door replaced by radio transparent plate (with Jackodur® and no absorbing material inside).

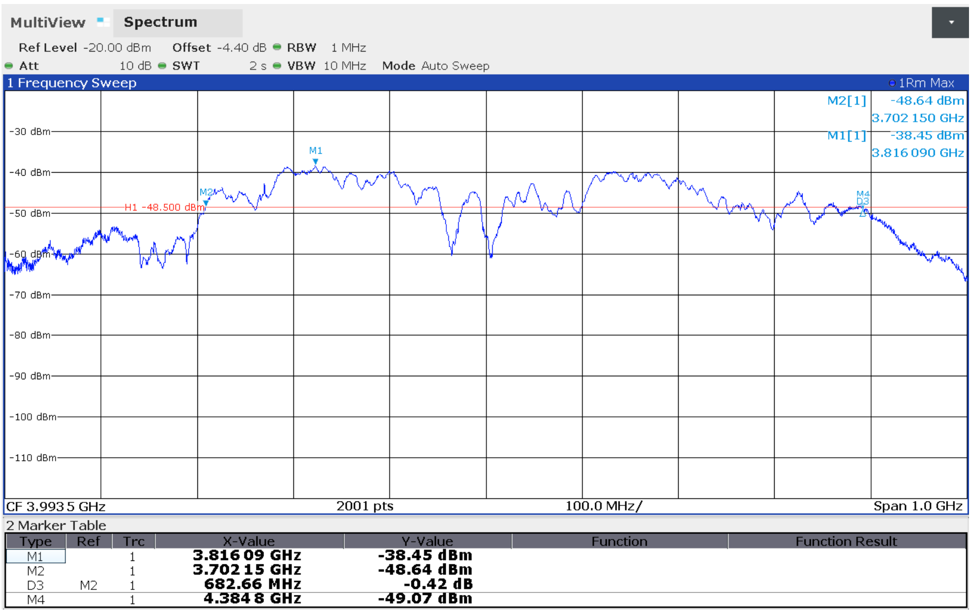


Figure B.58: Result of the measurement with the open door (Source: PHOENIX TESTLAB GmbH)

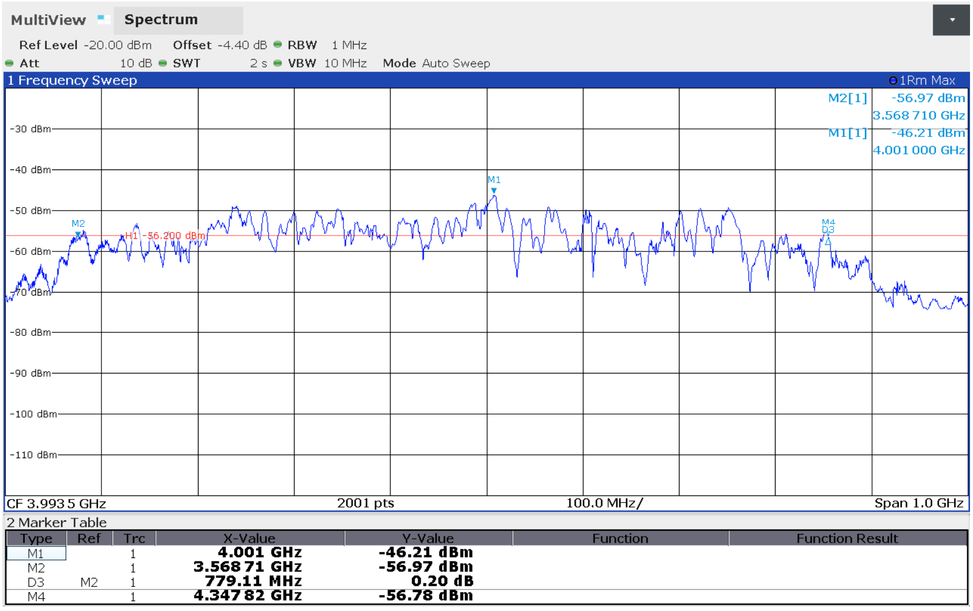


Figure B.59: Result of the measurement with closed door (through the door window) (Source: PHOENIX TESTLAB GmbH)

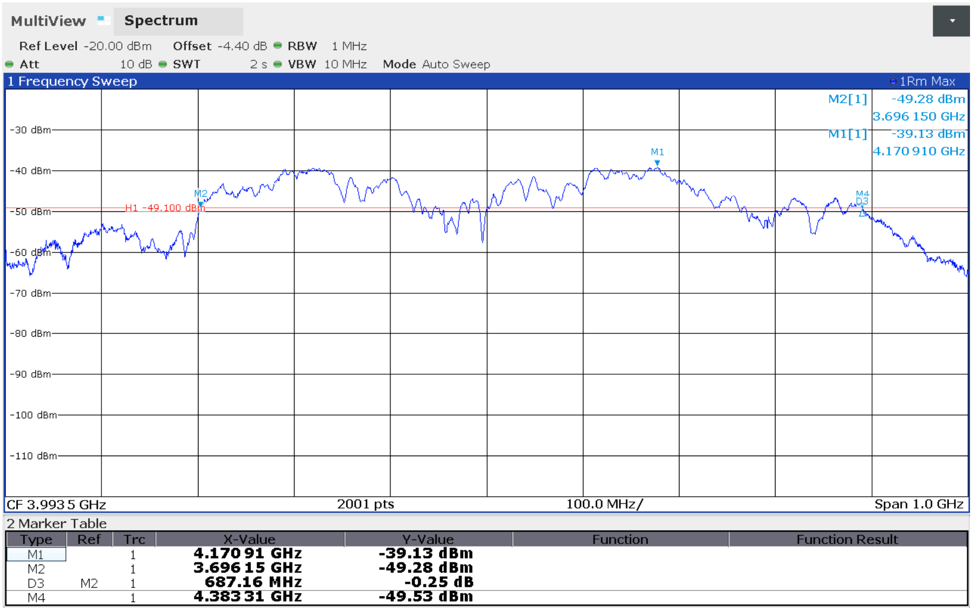


Figure B.60: Result of the measurement with radio transparent plate (Source: PHOENIX TESTLAB GmbH)

Figure B.61 shows an test set-up with absorbing material inside the temperature chamber (band the EUT).

NOTE: For the testing the radio transparent plate was used as door replacement.

Figure B.62 shows the measurement result of a radiated measurement at 20 °C.

Figure B.61: Setup-photo with door opened and one absorber behind the EUT (Source: PHOENIX TESTLAB GmbH)

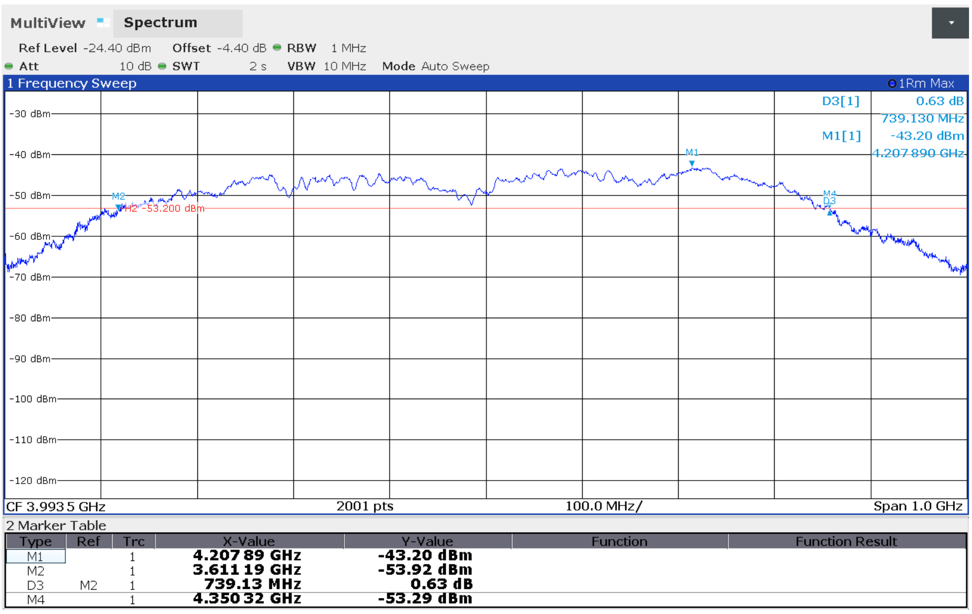


Figure B.62: Measurement with pyramidic absorber behind the EUT in the temperature chamber (Source: PHOENIX TESTLAB GmbH)

B.5.5 Summary and Conclusion

Temperature chambers have due its metal construction a significant shielding effectiveness which may be critical especially for devices with low output power. The shielding effectiveness of thermal insulation glass windows may vary over the temperature profile which has an impact in the level of the measured signal from the EUT.

To overcome both negative effects the door of the temperature chamber can be replaced by a radio transparent plate which minimizes the shielding effect.

Comparing the signal shape of the EUT in the temperature chamber with the measured signal in the anechoic chamber it could be noticed that certain additional notches could be seen in the measured spectrum.

In a second step the walls of the temperature chamber were covered with absorbing material. With the use of absorbing material in the temperature chamber reflection of the walls could be reduced. So, the notches in the spectrum could be minimized. Especially for wideband devices e.g. UWB devices, it is necessary to used absorbing material in the temperature chambers to reflections from the walls and ceilings.

The impact of the use of absorbing material in the temperature chamber and the radio transparent plate should be respected in the calibration of the temperature chamber according IEC 60068-3-5 [i.2].

Annex C (informative): Change history

Date	Version	Information about changes
10.01.2023	0.0.1	First initial draft
23.01.2023	0.0.2	Draft content based on discussions during rapporteurs meeting#2; 19th of January 2023
06.03.2023	0.0.3	New draft based on discussions during TG UWB#63 + change TR to TS (as adopted during TC ERM#79)
23.03.2023	0.0.4	Outcome Rapporteur Meeting#3
30.03.2023	0.0.5	Update clause 6
26.04.2023	0.0.6	Editorial updates and new draft for meeting@27th of April
28.04.2023	0.0.7	Outcome discussion meeting@ 27th of April
24.05.2023	0.0.8	Outcome/Summary discussion after meeting @23rd of May
02.06.2023	0.0.9	Clean up and new editorials as input for TG UWB#64
15.06.2023	0.0.10	Outcome TGUWB#64
11.07.2023	0.0.11	Revision clause 6 based on decision TGUWB#64
17.07.2023	0.0.12	Revised clauses (as discussed during TG UWB#64)
24.07.2023	0.0.13	Outcome rapporteur meeting 19th July
28.07.2023	0.0.14	Editorials based on action agreed during rapporteur meeting 19th of July
07.09.2023	0.0.15	Outcome TG UWB#65
21.09.2023	0.0.16	Editorial updated file by rapporteur
11.10.2023	0.0.17	Outcome TG UWB drafting meeting
09.11.2023	0.1.0	Outcome TG UWB#66; stable draft
09.11.2023	0.1.1	Final editorial corrections
January 2024	1.1.1	First published version

History

Document history		
V1.1.1	January 2024	Publication