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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

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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.

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

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2.2 Informative references

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[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.

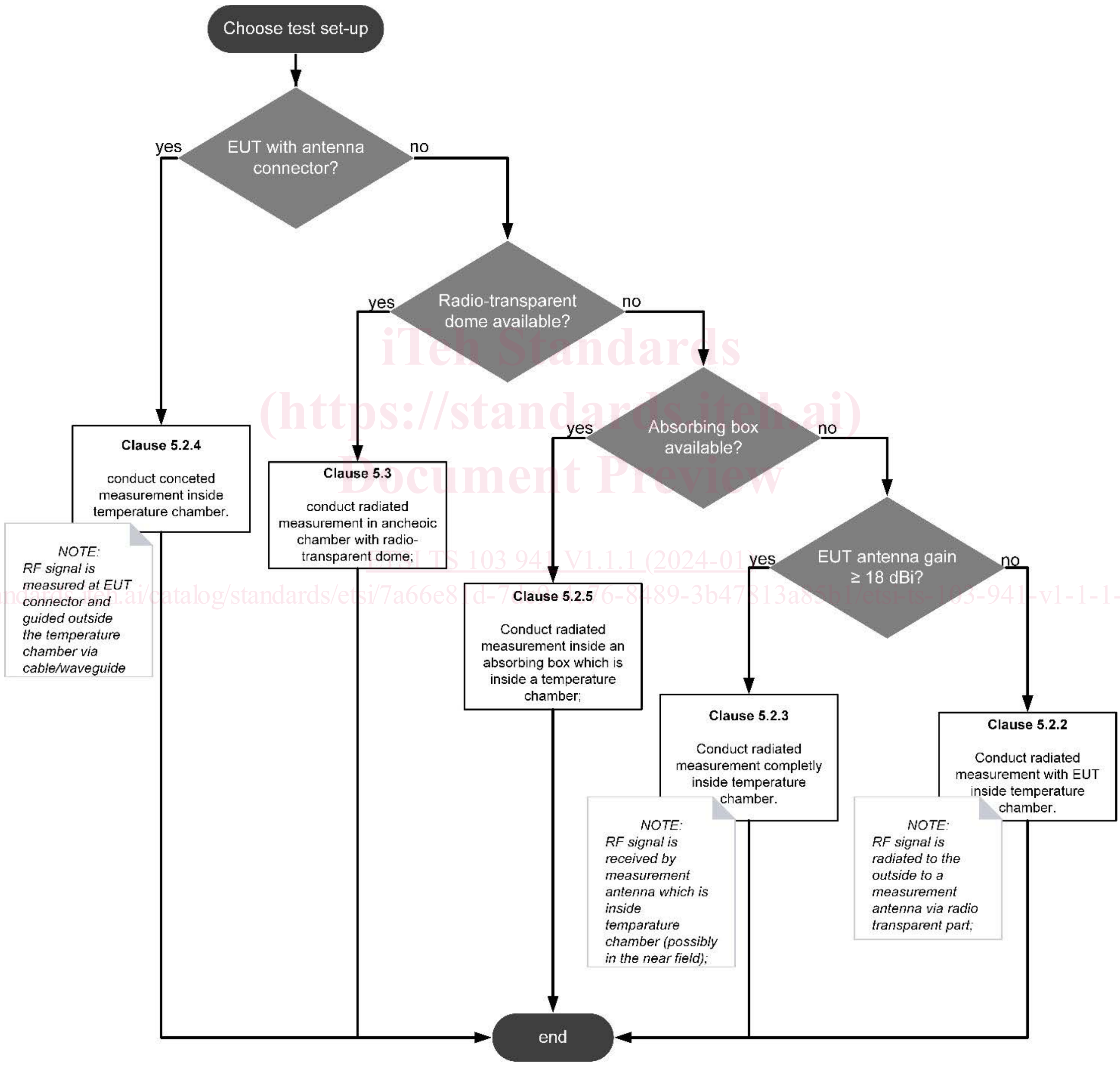

Figure 1: Guidance to choose the right measurement set-up in clause 5

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.

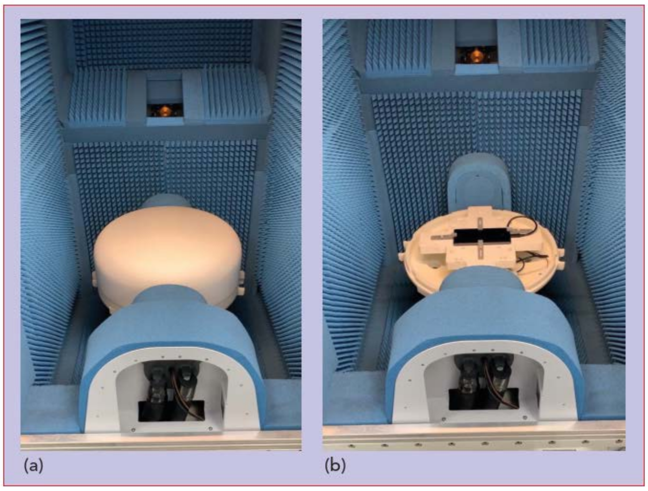

Figure 3: Inside of the OTA test system with 35 l Rohacell and thermal enclosure closed (a) and open showing a EUT (b) (source: ROHDE & SCHWARZ GmbH & Co.KG)

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.

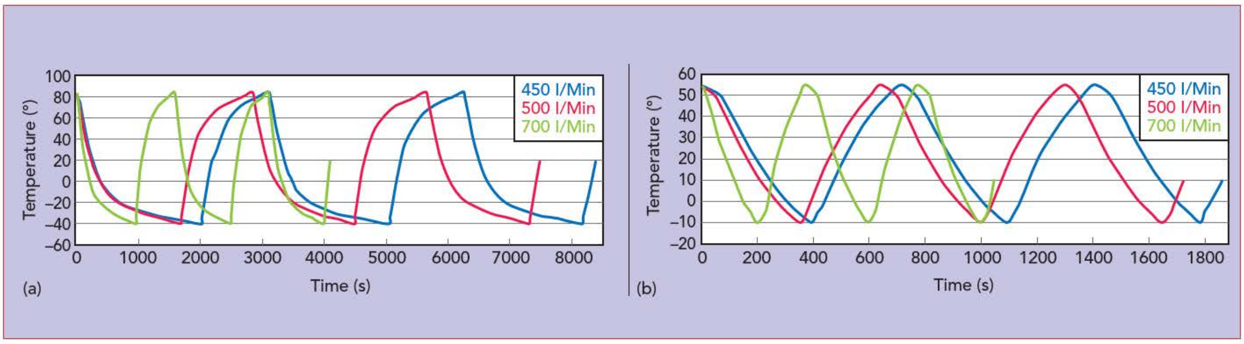

Figure 4: DUT temperature cycling times in 50 l enclosure at 450, 500 and 700 l/min air flow rates: -40 °C to +85 °C (a) and 3GPP (source: ROHDE & SCHWARZ GmbH & Co.KG)

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.