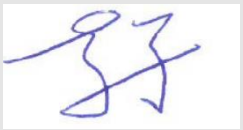
Test Report
1-3179-21-01-13-B
3D OTA Performance
of a 60 GHz Radar Device

Deutsche Akkreditierungsstelle
D-PL-12047-01-01
D-PL-12047-01-03
D-PL-12047-01-04

Number of pages:	16	**Date of Report:**	2023-Jul-14
Testing company:	cetecom advanced GmbH Im Teelbruch 116 45219 Essen Germany Tel. + 49 (0) 20 54 / 95 19-0 Fax: + 49 (0) 20 54 / 95 19-150	**Applicant:**	ifm electronic gmbh, Essen
Product: **Model:**	**Distance Radar, 60 GHz** **R1D102 (TR22)**		
Testing has been carried out in accordance with:	**CTIA: "Test Plan for Wireless Device Over the Air Performance, Method of Measurement for Radiated RF Power and Receiver Performance", and Vodafone: "Vodafone Specification for Terminals on Over the Air RF Performance"**		
Tested Technology:	FMCW Radar, 60GHz		
Test Results:	EIRP 7.2dBm / Gain 20.6dBi		

The current version of Test Report 1-3179_21-01-13-B replaces the test report 1-3179_21-01-13-A dated 2023-Jul-04. The replaced test report is herewith invalid.

Signatures:



Dipl.-Ing. Ninovic Perez	M.Sc. Guangcheng Huang
Test Lab Manager	Technical Consultant
Authorization of test report	Responsible of test report

Table of Contents

1 General information

1.1 Disclaimer and Notes

The test results of this test report relate exclusively to the test item specified in this test report as specified in chapter 2.7. cetecom advanced does not assume responsibility for any conclusions and generalizations drawn from the test results with regard to other specimens or samples of the type of the equipment represented by the test item.
The test report may only be reproduced or published in full. Reproduction or publication of extracts from the report requires the prior written approval of cetecom advanced.
The testing service provided by cetecom advanced has been rendered under the current "General Terms and Conditions for cetecom advanced".
cetecom advanced will not be liable for any loss or damage resulting from false, inaccurate, inappropriate or incomplete product information provided by the customer.
Under no circumstances does the cetecom advanced test report include any endorsement or warranty regarding the functionality, quality or performance of any other product or service provided.
Under no circumstances does the cetecom advanced test report include or imply any product or service warranties from cetecom advanced, including, without limitation, any implied warranties of merchantability, fitness for purpose, or non-infringement, all of which are expressly disclaimed by cetecom advanced.
All rights and remedies regarding vendor’s products and services for which cetecom advanced has prepared this test report shall be provided by the party offering such products or services and not by cetecom advanced.
In no case this test report can be considered as a Letter of Approval.

This test report is electronically signed and valid without handwritten signature. For verification of the electronic signatures, the public keys can be requested at the testing laboratory.

The test report must always be reproduced in full; reproduction of an excerpt only is subject to written approval of the testing laboratory. The documentation of the testing performed on the tested devices is archived for 10 years at cetecom advanced.

1.2 Summary of Test Results

The EUT integrates a Radar transmitter. Other implemented wireless technologies were not considered within this test report.

Test case	TRP [dBm]	EIRP [dBm]	Gain [dBi]
Antenna Gain	-13.41	7.20	20.6

Decision Rule: cetecom advanced GmbH follows ILAC G8:2019 chapter 4.2.1 (Simple Acceptance Rule).

2 Administrative Data

2.1 Identification of the Testing Laboratory

Company name:	cetecom advanced GmbH
Address:	Im Teelbruch 116 45219 Essen - Kettwig Germany
Responsible for testing laboratory:	Dipl.-Ing. Ninovic Perez
Accreditation scope:	**DAkkS Webpage: FCC ISED**
IC Lab company No. / CAB ID:	3462D / DE0005
Test location:	Im Teelbruch 116; 45219 Essen

2.2 General limits for environmental conditions

Temperature:	22±2 °C
Relative. humidity:	45±15% rH

2.3 Test Laboratories sub-contracted

Company name:	--

2.4 Organizational Items

Responsible test manager:	M.Sc. Guangcheng Huang
Receipt of EUT:	2023-Jan-25
Date(s) of test:	2023-Jan-25 to 2023-Jan-26
Version of template:	22.1101

2.5 Applicant's details

Applicant's name:	ifm electronic gmbh
Address:	Friedrichsstraße 1 45128 Essen Germany
Contact Person:	Holger Wenzel
Contact Person's Email:	Holger.Wenzel@ifm.com

2.6 Manufacturer's details

Manufacturer's name:	ifm electronic gmbh
Address:	Friedrichsstraße 1 45128 Essen Germany

2.7 Equipment under Test (EUT)

EUT No.*)	Sample No.	Product	Model	Type	SN	HW	SW
EUT 1	--	Distance Radar, 60 GHz	R1D102 (TR22)	M4285AA	092	AA2209	SW Frontend: V1.007 SW Backend: V1.0.8

*) EUT short description is used to simplify the identification of the EUT in this test report.

2.8 Untested Variant (VAR)

VAR No.*)	Sample No.	Product	Model	Type	SN	HW	SW

*) The listed additional untested model variant(s) (VAR) is/are not object of evaluation of compliance.
If the table above does not show any other line than the headline, no untested variants are available.

2.9 Auxiliary Equipment (AE)

AE No.*)	Sample No.	Auxiliary Equipment	Model	SN	HW	SW
AE 1	--			--	--	--

*) AE short description is used to simplify the identification of the auxiliary equipment in this test report. If the table above does not show any other line than the headline, no AE was used during testing nor was taken into account for evaluation

2.10 Connected cables (CAB)

CAB No.*)	Sample No.	Cable Type	Connectors / Details	Length
CAB 1	--	EVC070 cable socket	--	2m

*) CAB short description is used to simplify the identification of the connected cables in this test report. If the table above does not show any other line than the headline, no cable was used during testing nor was taken into account for evaluation

2.11 Software (SW)

SW No.*)	Sample No.	SW Name	Description	SW Status

*) SW short description is used to simplify the identification of the used software in this test report. If the table above does not show any other line than the headline, no SW was used during testing nor was taken into account for evaluation.

2.12 EUT set-ups

set-up no.*)	Combination of EUT and AE	Description
1	EUT 1 + CAB 1	

*) EUT set-up no. is used to simplify the identification of the EUT set-up in this test report.

2.13 EUT operation modes

EUT operating mode no.*)	Operating modes	Additional information
op. 1	TX-Mode	With help of special test firmware TX-mode was set-up. We refer to applicants information/papers for details about necessary commands.

*) EUT operating mode no. is used to simplify the test report.

For more information regarding operation modes, please check below document,

- Setup and Measurement Instruction_ver00

3 Measurements

3.1 The maximum peak power EIRP / peak EIRP spectral density. The maximum power EIRP/ average EIRP.

Testing method:

Measurements in GHz range are carried out in the OTA1 chamber in Essen by using an appropriate spectrum analyzer, antennas and external mixer as shown in the sketch and photo below. The whole test set up and method follows the principles as outlined by CTIA [1] and Vodafone [2]. The actual applied test parameters are as below:

- Measurement distance: 1 m (surface DUT to Horn antenna front plane). The position and distance is checked by means of a laser meter.
- Polarization: Both, horizontal and vertical, switched manually.
- Test Method: Rotate the device to a selected turn table and tilt device position (angle) and then fetch the spectrum analyzer marker reading after a trace max hold for this position.
- Angular resolution: 10° for “rough” pattern test and 3° for the “fine” pattern test around the beam.

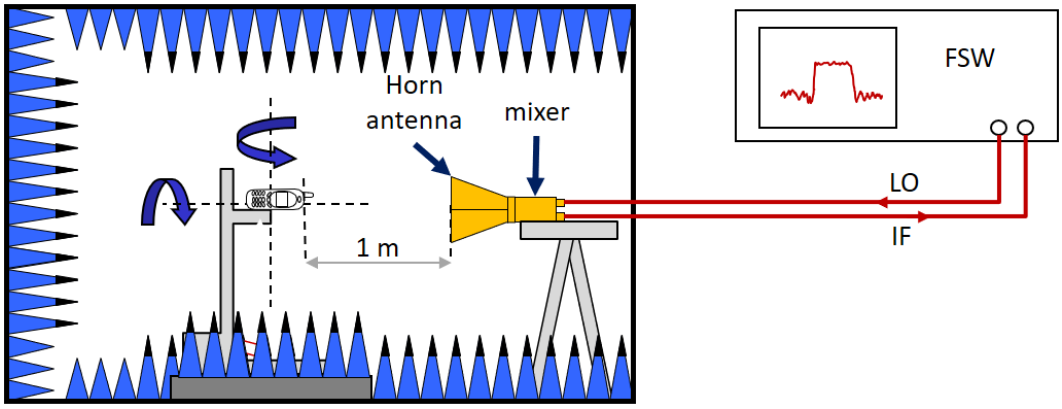


Fig. 1: GHz measurement set up with dual axis positioning device and a horn antenna with down-converter (mixer).

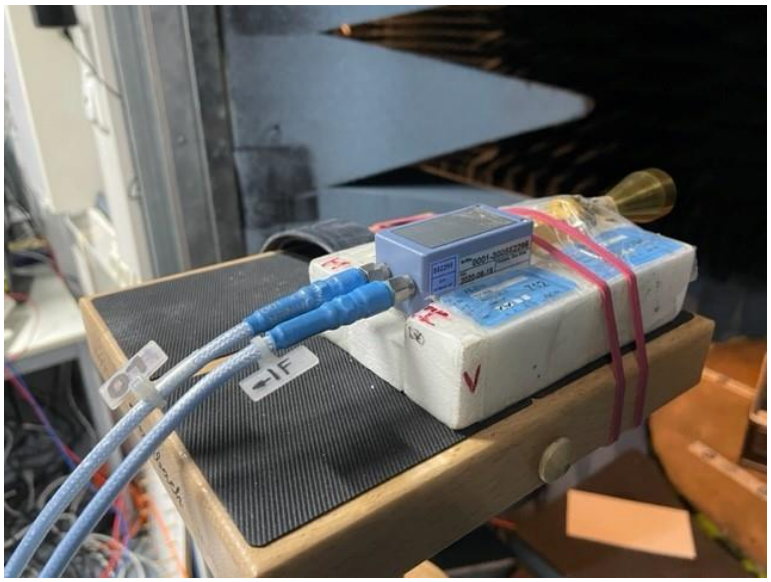


Fig. 2: Antenna and mixer currently used.

3.1.1 Measurement Location

Test site	**120907 - FAC2**

3.1.2 Spectrum-Analyzer Settings

Span	Zero Span
Resolution Bandwidth (RBW)	50 MHz
	Due to FMCW Peak Desensitization factor RBW used more to receive the Carrier Signal
Video Bandwidth (VBW)	5 MHz
Sweep time	≥ 300 ms (continuous sweep)
Detector	Peak detector with max peak search
Sweep mode	Continuous Sweep, MAX-HOLD

3.2 Data Processing Details

There are text files containing a list of turn table position, tilt device position and a (for 1 m calibrated) power value for one polarization. The whole procedure is done twice: for both measurement antenna polarizations. There are Microsoft Windows console scripts (*.BAT files) for automated tests: OTA1E_1.bat, OTAE1_2.bat which do call OTAE1_g.bat. This scripts creates a result file called “erg.tmp”. Hence, at the end copy the “erg.tmp” to e.g. DUT1P6. Expected results are e.g.: DUT1V6 and DUT1H6 for the different polarizations. In a next step one file is created by appending both to one file which can serve as an input file for an appropriate post processing tool. This can be done via (Microsoft Windows console commands):
Full 3D, 10° step size in Azimuth and Elevation,

- `type DUT1H5 > DUT1P5`
- `type DUT1V5 >> DUT1P5`

Fine Resolution around Peak, 1° step size in Azimuth and 15° in Elevation

- `type DUT1H6 > DUT1P6`
- `type DUT1V6 >> DUT1P6`

For further data processing the software wpn_3D.exe version 1.14 was used.

3.3 TRP and Gain Calculation

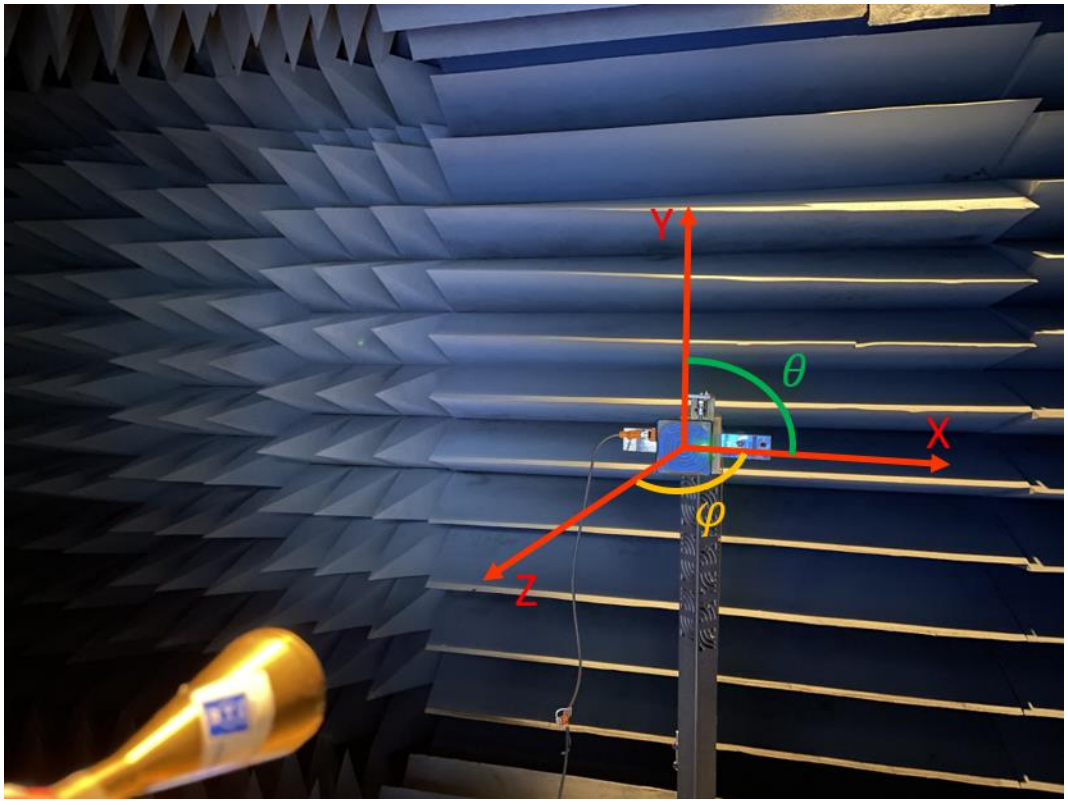


Fig. 3: Polarization and Coordinate system. The measured horizontal polarization was along the longitudes and vertical polarization is along the latitudes of the DUT.

Because the measurement method applying constant angular steps a none-equidistant test point distribution must be taken into account when calculating the total radiated power (TRP). TRP is calculated using power readings in spherical coordinates.

The total radiated power (TRP) at one frequency therefore equals to:

$$TRP = \oint\!\!\oint \frac{E_{eff}^2}{Z_0} r^2 \sin\Theta d\Theta d\Phi \quad (1)$$

Where r is the measurement distance and E_{eff} is the effective, rms field strength measured in certain directions and by taking into account both polarizations and timing (e.g. during a pulse):

$$E_{eff} = \sqrt{E_{vertical}^2 + E_{horiz}^2} \quad (2)$$

In case of discrete, constant angle steps $\Delta\Theta$ and $\Delta\Phi$ the integration becomes a summation in terms of:

$$TRP = \sum_{\Theta,\Phi} \frac{E_{eff}^2(\Theta,\Phi)}{Z_0} w(r,\Theta,\Phi,\Delta\Theta,\Delta\Phi) \quad (3)$$

Where w is the area or a "weight" to take into account the none-equidistant test point distribution. According to [2] this can be calculated by means of:

$$w = r^2 \Delta\Phi \left(\cos\left(\Theta - \frac{\Delta\Theta}{2}\right) - \cos\left(\Theta + \frac{\Delta\Theta}{2}\right) \right) . \quad (4)$$

Note, a good approximation for small $\Delta\Theta$ is:

$$\left(\cos\left(\Theta - \frac{\Delta\Theta}{2}\right) - \cos\left(\Theta + \frac{\Delta\Theta}{2}\right) \right) \approx \Delta\Theta \cdot \sin(\Theta) \quad (5)$$

Which is used in the CTIA test plan [1]. The CETECOM tool wpn_3D.exe does calculate the TRP based on Eq. 3 and Eq. 4.

The gain G is the difference between the maximum power reading found EIRP, and TRP:

$G_{[dBi]} = EIRP_{[dBm]} - TRP_{[dBm]}$ (6)

Conducted Input Power = Antenna Feeding Power = Total Radiated Power (TRP) (7)

Remark: Formula (7) is only valid for an optimal Transmitter, it has been assumed that there is no path loss between RADAR Module to Antenna input.

3.4 Data Post Processing

There exist a tool for calculating the TRP values by applying:

```
wpn_3D -w 7 DUT1P5 and
wpn_3D -w 7 DUT1P6.
```

The result are:

```
* test_05/ DUT1P5
FSW Setting: RBW 50 MHz, VBW 5 MHz, SWT 100 ms
TRP  = -13.41 dBm
TRP2 = -13.41 dBm (only sector)
EIRP =   7.07 dBm at Theta =  -6.0° and Phi = -60.0°
Gain =  20.49 dBi

* test_06/ DUT1P6
FSW Setting: RBW 50 MHz, VBW 5 MHz, SWT 100 ms
TRP  = -11.52 dBm
TRP2 = -16.29 dBm (only sector)
EIRP =   7.20 dBm at Theta =  -6.0ø and Phi = -75.0ø
Gain =  18.72 dBi
```

For the most accurate results the TRP data must be used from the full 3D data test, whereas the maximum EIRP data is more accurate when using the fine angular resolution test results. The appropriate results are shown in Tab. 1.

4 Results

4.1 Test Plan Overview and Summary

Device	Full 3D(Grob) (10°)	TRP [dBm]	EIRP [dBm]	Theta $_{EIRP}$ [°]	Phi $_{EIRP}$ [°]	Fine Resolution Around Peak (1°)	EIRP [dBm]	Theta $_{EIRP}$ [°]	Phi $_{EIRP}$ [°]
R1D102 (TR22)	DUT1P5	-13.41	7.07	-6	-60	DUT1P6	7.20	-6	-75

Tab. 1: Result files covering raw data.

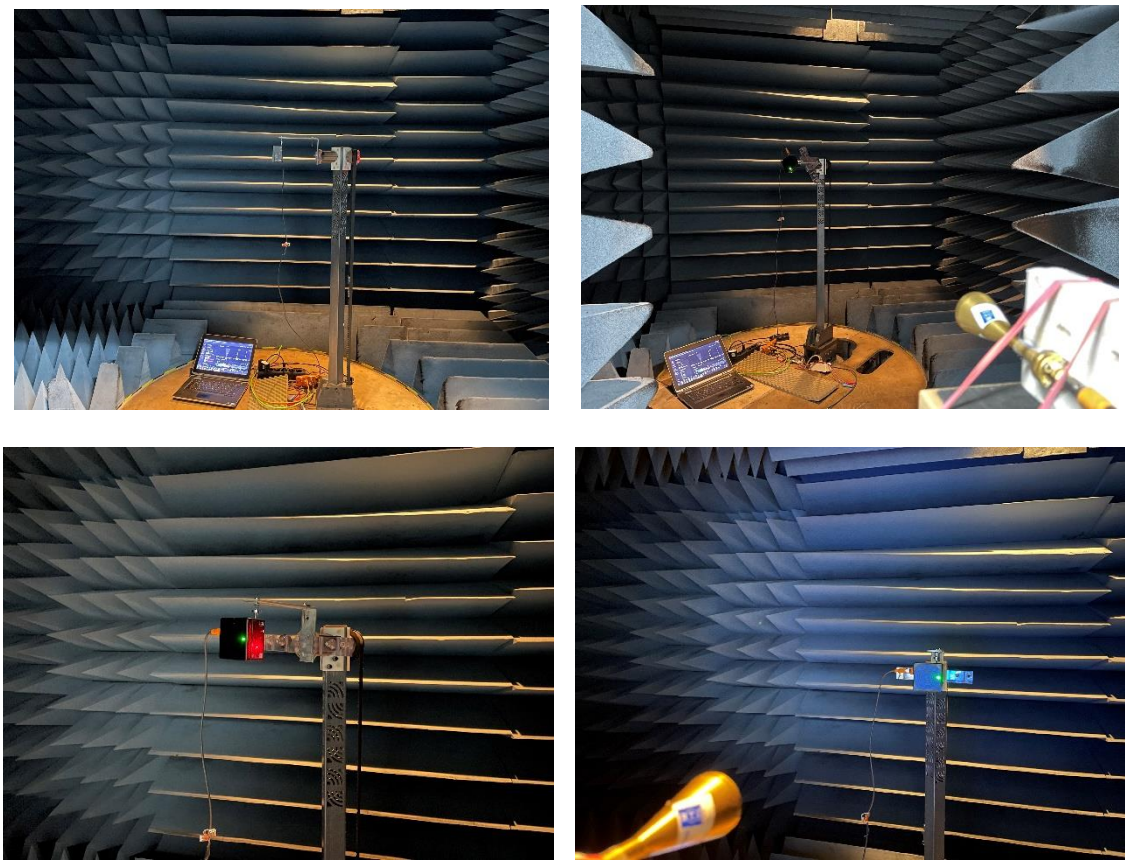


Fig. 4: Photo of the DUT and the chamber.

4.2 3D and 2D Pattern

In order to create a 3D view of the test results there is a tool (wpn_3D.exe), able to create WRL files out of the measured data:

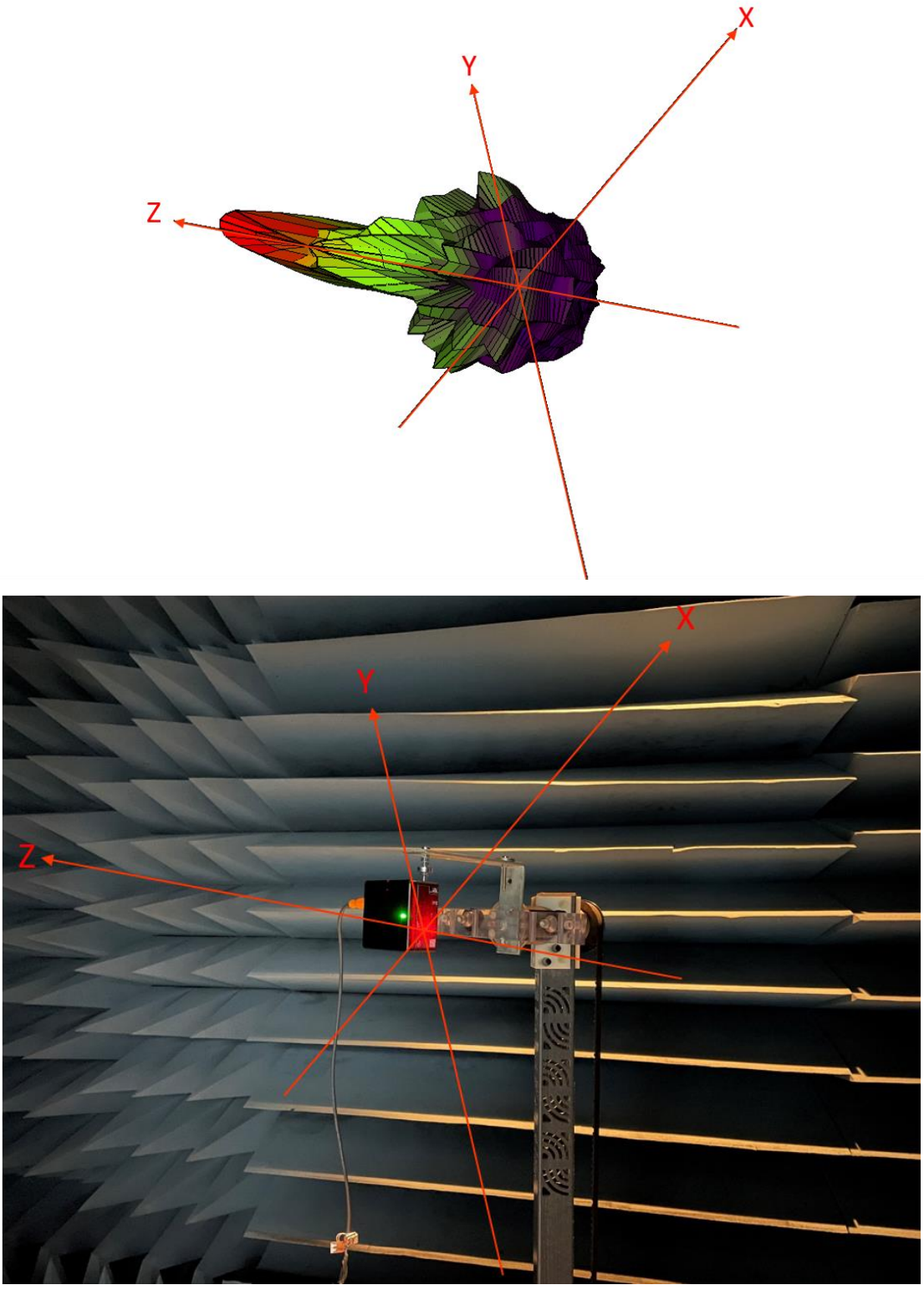


Fig. 5: Full_3D_Fine

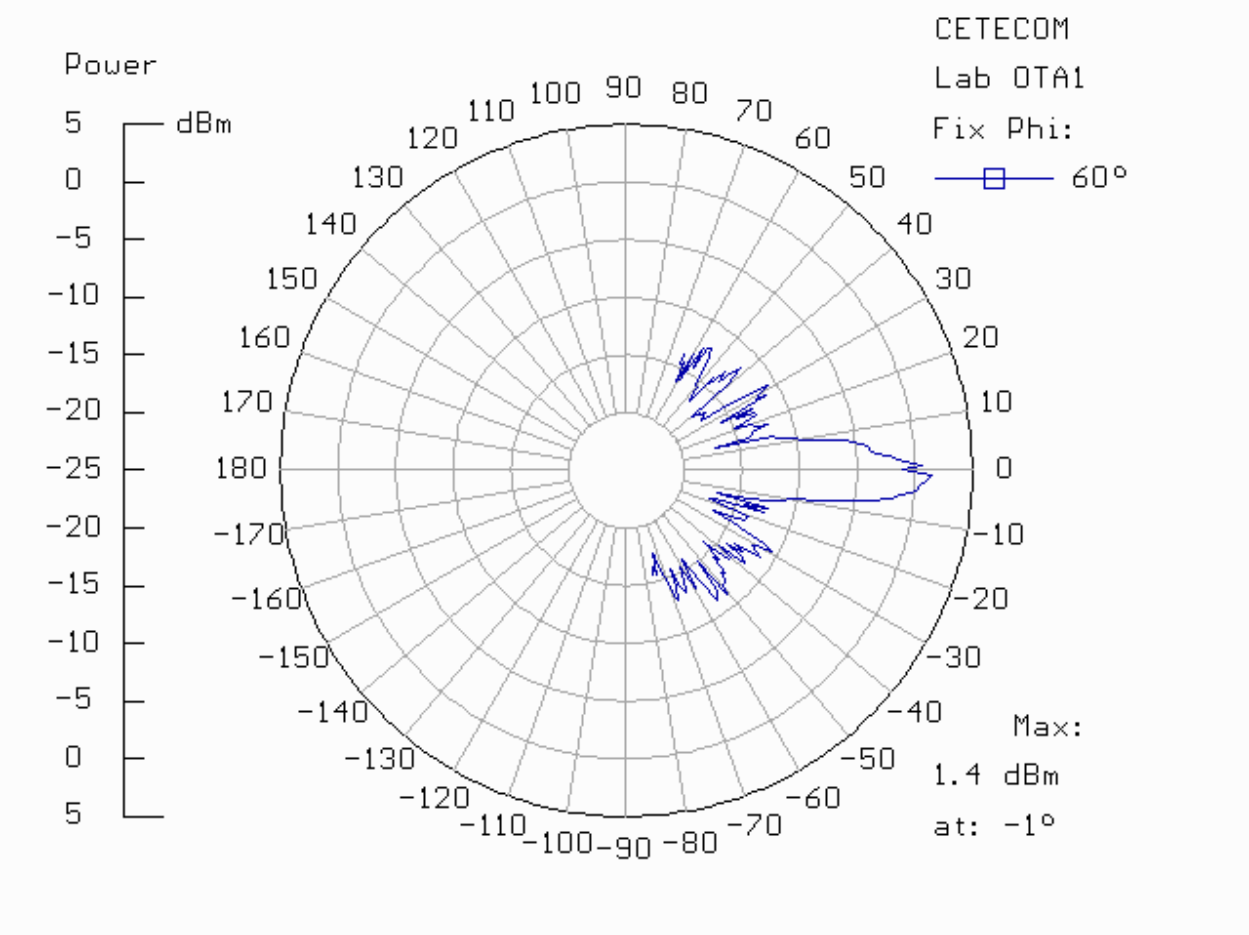


Fig. 6: 2D_Fine_(fix phi).

4.3 Equipment lists

ID	Description	Manufacturer	SerNo	CheckType	Last Check	Interval	Next Check
20412	Fully Anechoic Chamber 2	ETS-Lindgren Gmbh / Taufkirchen	without	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -
20730	FS-Z110	Rohde & Schwarz Messgerätebau GmbH	101468	cal	cal: 2020-Jun-19	cal: 36M	cal: 2023-Jun-19
20732	Signal- and Spectrum Analyzer FSW67	Rohde & Schwarz Messgerätebau GmbH / Memmingen	104023	cal	cal: 2022-Jun-08	cal: 12M	cal: 2023-Jun-08
20814	Pickett-Potter Horn Antenna FH-PP 140	RPG-Radiometer Physics GmbH	10008	cnn	cal: - chk: -	cal: - chk: -	cal: - chk: -

4.3.1 Legend

Note / remarks	Interval of calibration & Verification
12M	12 months
24M	24 months
36M	36 months
10Y	10 Years

Abbreviation Check Type	Description
cnn	Calibration and verification not necessary
cal	Calibration
calchk	Calibration plus intermediate Verification
chk	Verification
cpu	Verification before usage

5 Results from external laboratory

None	-

6 Opinions and interpretations

None	-

7 List of abbreviations

None	-

8 Measurement Uncertainty valid for conducted/radiated measurements

The reported uncertainties are calculated based on the standard uncertainty multiplied with the appropriate coverage factor **k**, such that a confidence level of approximately 95% is achieved. For uncertainty determination, each component used in the concrete measurement set-up was taken in account and it contribution to the overall uncertainty according its statistical distribution calculated.

Measurement type	Frequency range of measurement		Calculated Uncertainty based on confidence level of 95.54%	Remarks
	Start [MHz]	Stop [MHz]		
Magnetic field strength	0.009	30	4.86	Magnetic loop antenna, Pre-amp on
RF-Output power (eirp) Unwanted emissions (eirp) [dB]	30	100	4.57	without Pre-Amp
	30	100	4.91	with PreAmp
	100	1000	4.02	without Pre-Amp
	100	1000	4.26	with PreAmp
	1000	18000	4.36	without Pre-Amp
	1000	18000	5.23	with PreAmp
	18000	33000	4.92	Schwarzbeck BBHA9170 (#20302) Antenna set-up non-waveguide antenna)
	33000	50000	4.17	Set-up for Q-Band (WR-22), non-wave guide antenna
	40000	60000	4.69	Set-up U-Band (WR-19), non-waveguide antenna
	50000	75000	4.06	External Mixer set-up V-Band (WR-15)
	75000	110000	4.17	External Mixer set-up W-Band (WR-6)
	90000	140000	5.49	External Mixer set-up F-Band (WR-8)
	140000	225000	6.22	External Mixer set-up G-Band (WR-5)
	225000	325000	7.04	External Mixer set-up (WR-3)
	325000	500000	8.84	External Mixer set-up (WR-2.2)
Radiated Blocking [dB]	1000	18000	2.85	Typical set-up with microwave generator and antenna, value for 7GHz calculated
	18000	33000	4.66	Typical set-up with microwave generator and antenna
	33000	50000	3.48	WR-22 set-up
	50000	75000	3.73	WR-15 set-up
	75000	110000	4.26	WR-6 set-up
Frequency Error [kHz]	40000	77000	276.19	calculated for 77 GHz (FMCW) carrier
	6000	7000	33.92	calculated for 6.5GHz UWB Ch.5
TS 8997 conducted Parameters	30	6000	1.11	1. Power measurement with Fast-sampling-detector
	30	6000	1.20	2. Power measurement with Spectrum-Analyzer
	30	6000	1.20	3. Power Spectrum-Density measurement
	30	7500	1.20	4. Conducted Spurious emissions:
	0.009	30	2.56	5. Conducted Spurious emissions:
	2.4	2.48	1.95 ppm	6a. Bandwidth / 2-Marker Method for 2.4GHz ISM
	5.18	5.825	7.180 ppm	6b. Bandwidth / 2-Marker Method for 5GHz WLAN
	5.18	5.825	1.099 ppm	7 Frequency (Marker method) for 5GHz WLAN
	30	6000	0.11561µs	8 Medium-Utilization factor / Timing
	30	6000	1.85	9 Blocking-Level of companion device
	30	6000	1.62	9 Blocking Generator level
Conducted emissions	0.009	30	3.57	

9 References

[1] CTIA OTA Test Requirement: “Test Plan for Wireless Device Over the Air Performance, Method of Measurement for Radiated RF Power and Receiver Performance”, Revision 3.9, Nov 2019.

[2] Vodafone: “Vodafone Specification for Terminals on Over the Air RF Performance”, VF_Ant_Req_V2.5, 2011.

[3] CETECOM: “Measurement Uncertainty Calculation for Spurious Emissions and EIRP above 40 GHz”, April 2019.

10 Versions of test reports (change history)

Version	Applied changes	Date of release
--	Initial release	2023-Apr-04
A	Chapter 2.7 SW changed to SW frontend and SW backend	2023-Jul-04
B	Chapter 2.8 corrected, reference to Annex 5 removed	2023-Jul-14

End Of Test Report