# Test Report 23-1-0144002T002_TR1-R01-D1
# 3D Antenna Pattern and OTA Performance of Kick Sensor (HfA), R-HFA GEN2

| | | | |
|---|---|---|---|
| **Number of pages:** | 12 | **Date of Report:** | 29.08.2024 |
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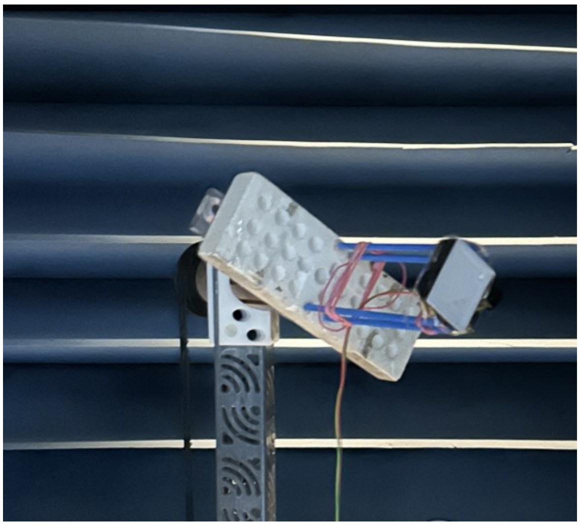
| | |
|---|---|
| **Test Object / Tested Device(s):** | Kick Sensor (HfA), R-HFA GEN2 |



| | |
|---|---|
| **Frequency Range:** | 77 GHz – 79 GHz |
| **Test Specification:** | Final draft ETSI EN 303 883-1 V2.1.1 (2024-06) [1] and Vodafone OTA Test Specification [3] |
| **Test Results:** | TRP = 4.3 dBm / EIRP = 13.9 dBm / Gain = 9.6 dBi |
| **Signatures:** | |

| | |
|---|---|
| Dipl.-Ing. Christian Lorenz | B.Sc. Al-Amin Hossain |
| Test Lab Manager | Test Manager |
| Authorization of test report | Responsible of test report |

# Table of Contents

# 1 General information

## 1.1 Disclaimer and Notes

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## 1.2 Summary of Test Results

The EUT integrates a 77-79 GHz Radar transmitter.

| Test case | TRP [dBm] | EIRP [dBm] | Directivity (Gain) [dBi] |
|---|---|---|---|
| Antenna Gain | 4.3 | 13.9 | 9.6 |

Tab. 1: OTA data summary.

# 2 Administrative Data

## 2.1 Identification of Entity Providing the Service

| | |
|---|---|
| Company address (HQ): | cetecom advanced GmbH / Untertürkheimer Str. 6–10 / 66117 Saarbrücken / Germany |
| Test location: | Lab FAR / cetecom advanced GmbH / Im Teelbruch 116 / 45219 Essen / Germany |
| Internet site: | www.cetecomadvanced.com |
| Accreditation scope: | https://cetecomadvanced.com/en/about-us/accreditations-references/ |

## 2.2 General Limits for Environmental Conditions

| | |
|---|---|
| Temperature: | 22±2 °C |
| Humidity: | 45 ± 15% rH |

## 2.3 Organizational Items

| | |
|---|---|
| Cetecom advanced project number: | 23-1-0144002T002_TR1-R01-D1 |
| Test Date(s): | 26.08.2024-27.08.2024 |
| Test Engineer(s): | B.Sc. Al-Amin Hossain |
| Witness during tests: | None |
| Responsible for test report: | B.Sc. Al-Amin Hossain |
| Date of report: | 29.08.2024 |

## 2.4 Customer Details

| | |
|---|---|
| Customer address: | Brose Fahrzeugteile SE & Co. KG, Bamberg / Berliner Ring 1, 96052 Bamberg, Bavaria, Germany |
| Customer internet site: | www.brose.com |
| Contact person: | Maximilian Lengel <maximilian.lengel@brose.com> |
| Po number: | |

## 2.5 Equipment under Test (EUT)

| EUT No.*) | Sample No. | Product | Model | Type | SN | HW | SW |
|---|---|---|---|---|---|---|---|
| EUT 1 | 23-1-01440S12_C01 | Kick Sensor (HfA) | R-HFA GEN2 | AWRL 1422 | -- | G69634-100 | B013 |

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

## 2.6 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. For further information please see Annex 5: Declaration of applicant of model differences.

If the table above does not show any other line than the headline, no untested variants are available.

## 2.7 Auxiliary Equipment (AE)

| AE No.*) | Sample No. | Auxiliary Equipment | Model | SN | HW | SW |
|---|---|---|---|---|---|---|
| AE 1 | -- | 12 V Power supply | EA-PS2032-050 | 2004420995 | -- | -- |

*) 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

## 2.8 Connected cables (CAB)

| CAB No.*) | Sample No. | Cable Type | Connectors / Details | Length |
|---|---|---|---|---|
| CAB 1 | 23-1-01440S25_C01 | Cable Harness | Banana Connector | Not Applicable |

*) 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

## 2.9 EUT set-ups

| set-up no.*) | Combination of EUT and AE | Description |
|---|---|---|
| 1 | EUT 1 + AE 1 + CAB 1 | Used for TRP, EIRP, Antenna Gain measurements |

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

## 2.10 EUT operation modes

| EUT operating mode no.*) | Operating modes | Additional information |
|---|---|---|
| op. 1 | Normal FMCW mode | |

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

# 3 Measurements

## 3.1 Test Set Up an Method for Gathering Data

3D Antenna Measurements in GHz range are carried out in the in Essen by using an appropriate spectrum analyzer and antennas as shown in the sketch and photo below. The whole test set up and method follows EN 303 883-1 [1] which are same principles as outlined by CTIA [2] and Vodafone [3] for executing TRP measurements. The actual applied test parameters are as below:

- Measurement distance: 1.0 m for frequencies above 15 GHz and 1.5 m for lower frequencies in order to get the necessary signal to noise ratio. (Distance is surface DUT to horn antenna front plane). The position and distance is checked by means of a laser meter.
- Test Signal: DUT is in a test mode and provides a standard FMCW signal at maximum power.
- Polarization: Both, horizontal and vertical, measurement antenna rotated 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.

  Eventually there are four tests per frequency: Full 3D "rough" pattern test for both polarizations and two (both polarizations) "fine" pattern tests around the beam for an more accurate EIRP estimation.
- Angular resolution: 10° x 10° for "rough" pattern test and 3° x 5° for the "fine" pattern test around the beam.
- Spectrum analyzer settings: Test have been carried out with positive peak detector and at 10 MHT RBW in zero span with 240 ms sweep.

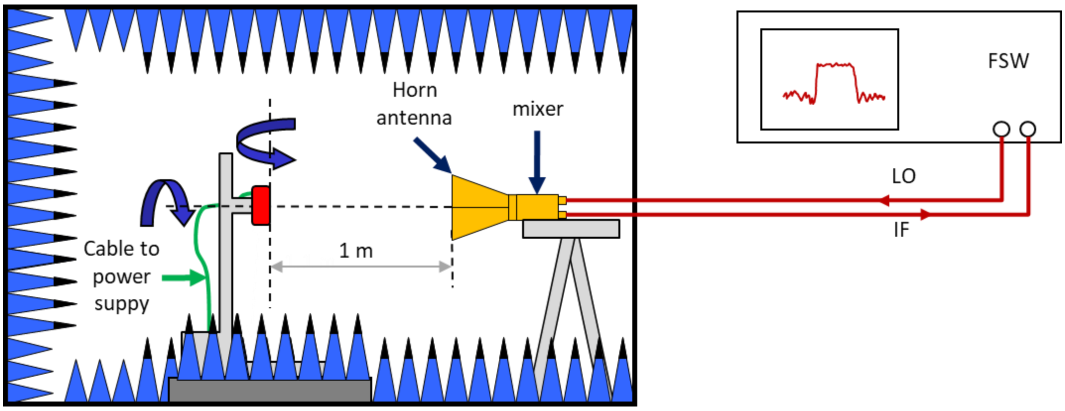


Fig. 1: Set up with dual axis positioning device and horn antennas which might be rotated to cover both polarizations.

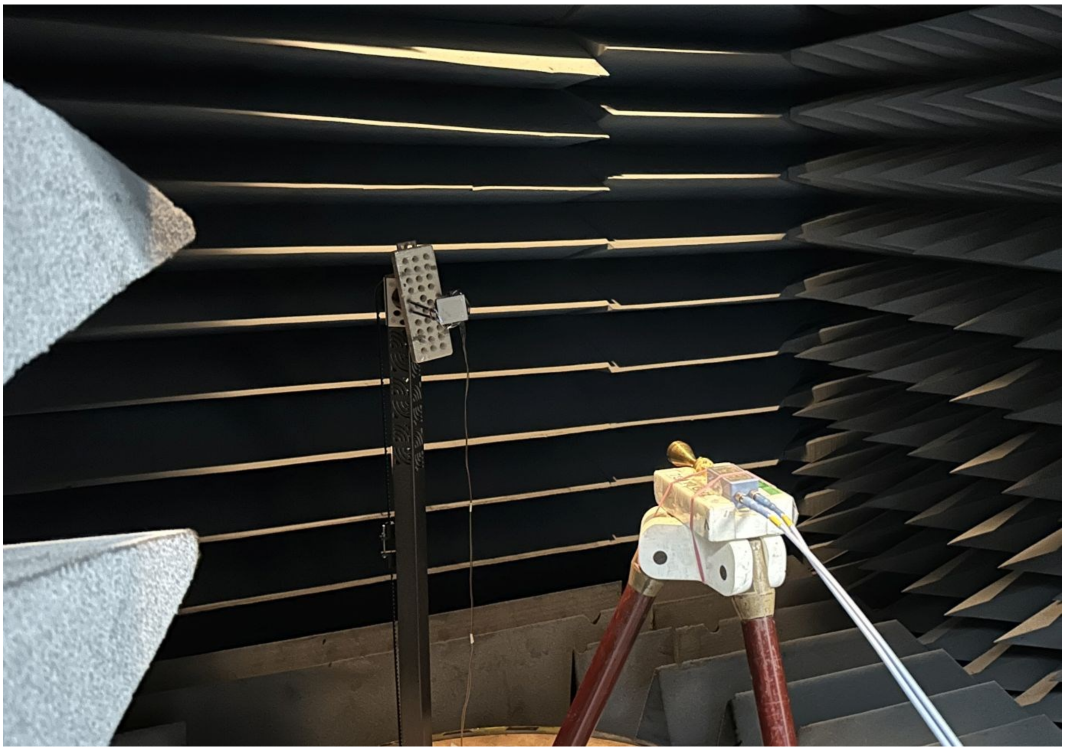

Fig. 2: Radiated setup (1 m distance).

Fig. 3: DUT holder.

## 3.2 Coordinate System

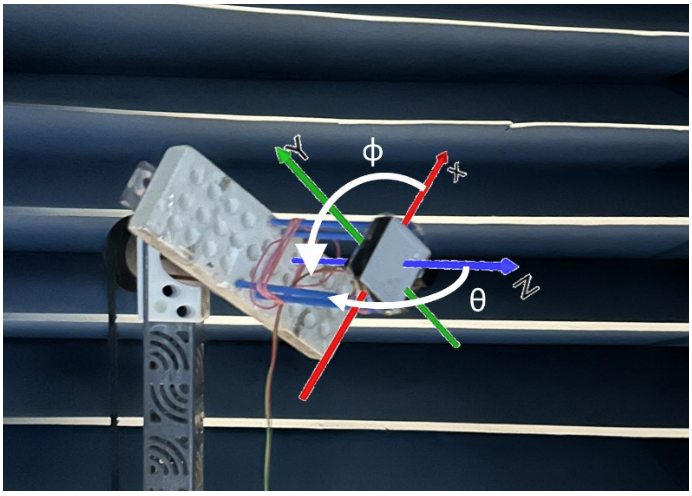


Fig. 4: Polarization and Coordinate system. The classical sphere coordinate system is used.

The coordinate system is as in EN 303 883-1 [1]. The main beam is expected to depict in direction of the z-axis. A rotation around the z-axis is $\varphi$ and $\Theta$ is the polar angle (or 90°- $\Theta$ is the elevation). The measured horizontal polarization is along the longitudes and vertical polarization is along the latitudes of the DUTs antenna pattern.

## 3.3 TRP and Gain Calculation

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 (see [1], [2] and [3]:

$$TRP = \oiint \frac{E_{eff}^2}{Z_0} r^2 \sin\Theta \, d\Theta \, d\Phi \qquad (1)$$

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):

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

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

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

Where $w$ is the area or a "weight" to take into account the none-equidistant test point distribution. According to [3] this can be calculated by means of:

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

Note, a good approximation for small ΔΘ is:

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

which is used in the CTIA test plan [2] and in the EN 303 883-1 (see equation 32 [1]). The used tool wpn_3D.exe does calculate the TRP based on Eq. 3 and using the more accurate approximation as stated in Eq. 4.

The directivity *D* is the difference between the maximum power reading found in the EIRP data, and TRP:

$$D_{[dBi]} = EIRP_{[dBm]} - TRP_{[dBm]} \; . \tag{6}$$

Using the known conducted power data (applied at the antenna feeding port) *P* we have for the antenna efficiency $\eta$:

$$\eta_{[dB]} = TRP_{[dBm]} - P_{[dBm]} \, , \tag{7}$$

and finally for the effective antenna gain (to be used for approval related considerations):

$$G_{[dBi]} = EIRP_{[dBm]} - TRP_{[dBm]} + \eta_{[dB]} \; . \tag{8}$$

For lossless antennas, the gain and directivity are the same.

## 3.4 Data Processing Details

There are text files containing a list of turn table position, tilt device position and a (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: OTA_10.bat, OTA_f.bat (f for “fine”) which do call OTA_g.bat. This scripts creates a result files for the different polarizations (e.g. h.mes and v.mes) containing spectrum marker data readings for all directions (3D). In a next step one file is created by appending both polarization specific files into one file which can serve as an input file for an appropriate post processing (by e.g. using type h.mes > power.mes and V.mes >> Power.mes). For further data processing the software wpn_3D.exe, version 1.35 was used. This tool calculates the TRP value (using –w 7 or –w 3) and shows the maximum EIRP, e.g.:

```
wpn_3D Power.mes –w 3 –p+ 0.7
```

The offset of e.g. 0.7 does take into account distance deviations (from 1 m) or the impact of a desensitation caused by the measurement resolution bandwidth of 10 MHz. The appropriate offset was determined before by separate test with different RWB values.

Examples:

```
>wpn_3D R1 -F 78e9 -p+ 0.7
R1 78.000 GHz Directivity = 8.96 dBi TRP= 4.34 dBm  EIRP= 13.30 dBm

>wpn_3D R5 -F 78e9 -p+ 0.7
R5 78.000 GHz Directivity = 7.62 dBi TRP= 6.30 dBm  EIRP= 13.92 dBm
```

The rough test provides the most accurate value for TRP. Hence in Tab. 2 as TRP value 4.34 dBm. For a more accurate EIRP value the data from the fine test R5 is used: 13.92 dBm.

Note, because the measurement in the fine test does cover only a part of the full sphere the TRP and gain values are meaningless.)

In addition the wpn_3D tool can create 3D VRML files (*.wrl) as shown below. Examples:

```
wpn_3D R1 -C -c3 -p -19 -P 11 -p+ 0.7 -XT2 -XP2 > R1_grob.wrl
```

The results are shown below in chapter 4.2.

# 4 Results

## 4.1 Summary

| File | Frequency | Angular resolution | TRP | EIRP | Directivity (Gain) |
|---|---|---|---|---|---|
| R3 | 77.005 GHz | 10° x 10° | 4.84 dBm | 13.01 dBm | 13.9 dBm (R5) – 4.3 dBm (R1) = 9.6 dBi |
| R1 | 78.000 GHz | 10° x 10° | 4.34 dBm | 13.30 dBm | |
| R4 | 78.970 GHz | 10° x 10° | 2.77 dBm | 11.67 dBm | |
| R5 | 78.000 GHz | 3° x 5° | | 13.92 dBm | |

Tab. 2: Result summary.

## 4.2 Test Result Details: 3D Pattern

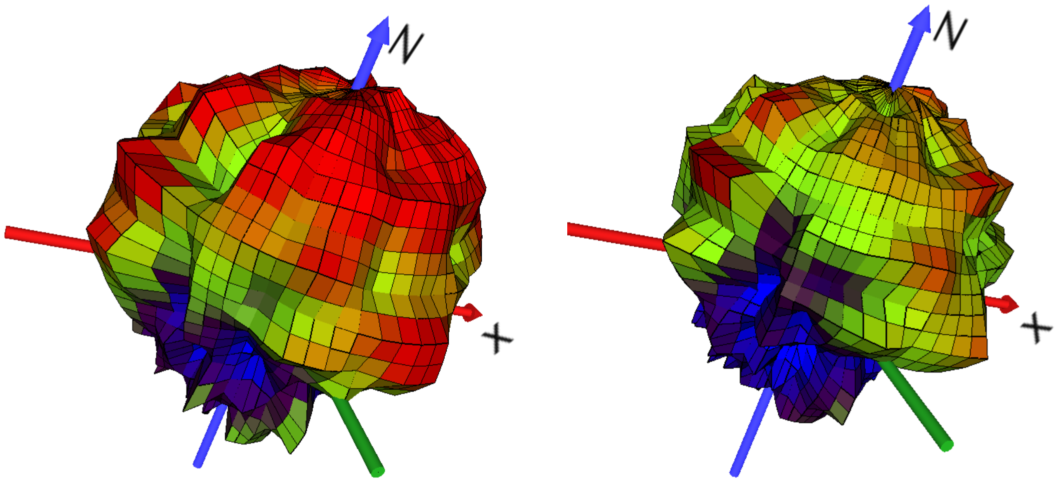

Fig. 5: 3D (rough) pattern at 77 and 79 GHz.

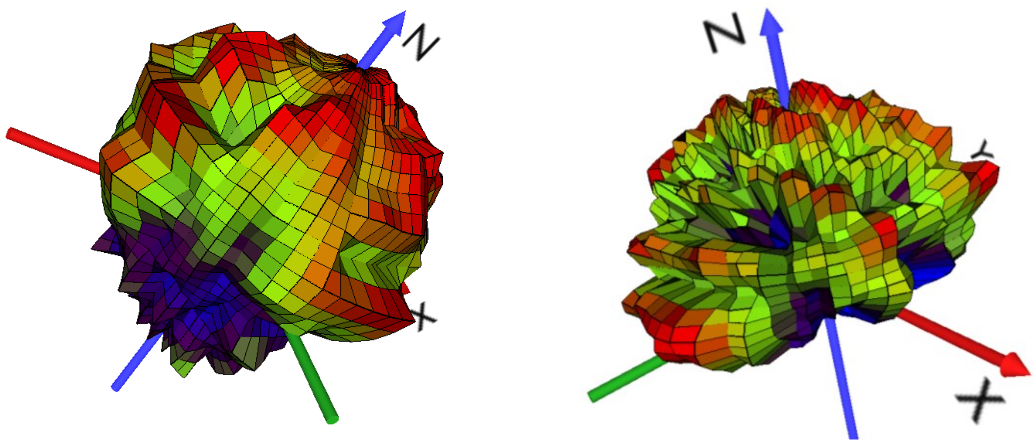

Fig. 6: 3D pattern at 78 GHz. Left rough and right fine resolution.

## 4.3 Test Result Details: 2D Pattern

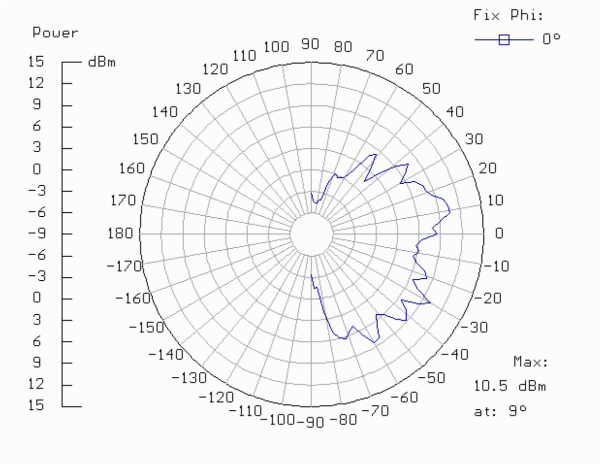


Fig. 7: 2D pattern at 78 GHz for ϕ = 0°.

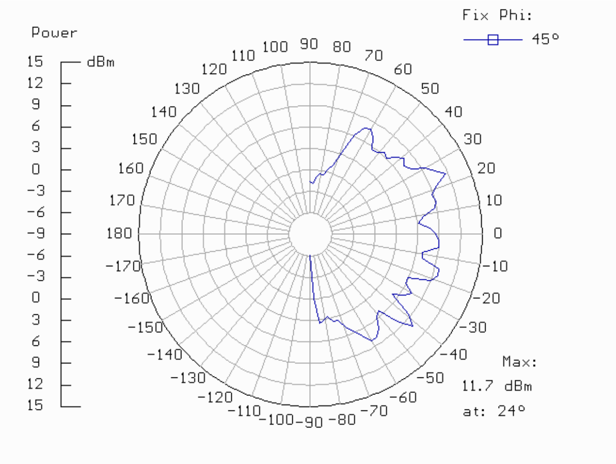


Fig. 8: 2D pattern at 78 GHz for ϕ = 45°.

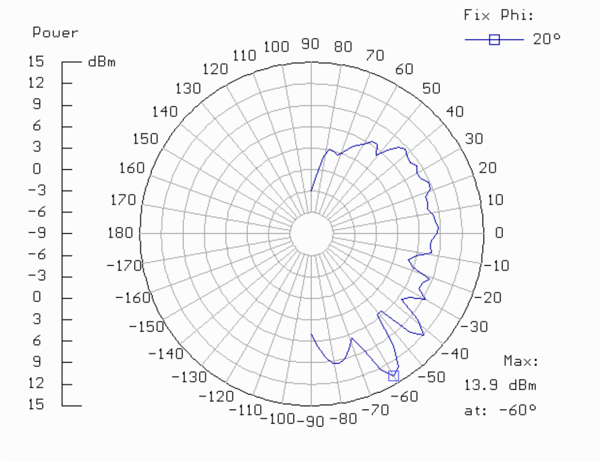


Fig. 9: 2D pattern at 78 GHz for ϕ = 20°.

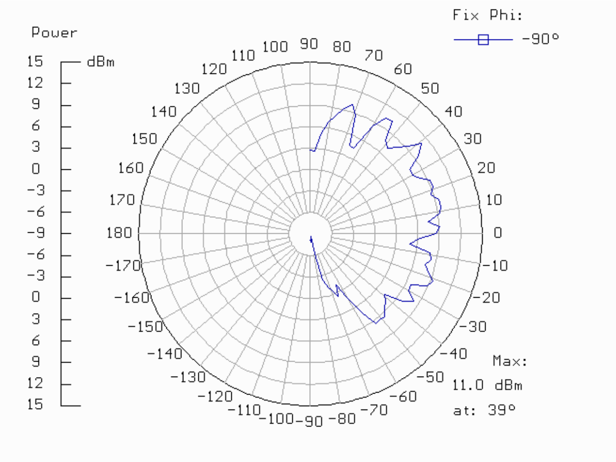


Fig. 10: 2D pattern at 78 GHz for ϕ = 90°.

# 5 Equipment Lists

| ID | Description | Manufacturer | Serial Number | Calibration Due Date |
|---|---|---|---|---|
| 20412 | Fully Anechoic Chamber 2 (FAR2) | ETS-Lindgren | --- | --- |
| 20972 | Spectrum Analyzer FSW50 | Rohde & Schwarz | 101929 | 05.01.2025 |
| 20815 | Horn Antenna FH-PP 110 / 75-110 GHz | RPG-Radiometer Physics | 10014 | 20.10.2024 |
| 20730 | Mixer/ 75-110 GHz | Rohde & Schwarz | 101468 | 02.06.2026 |

# 6 Measurement Uncertainty

The absolute measurement uncertainty for the conducted and radiated test has been calculated and reported in a separate document [5]. For frequencies in the rage of 75-110 GHz the 95% extended absolute uncertainty for radiated power levels (EIRP) is: 4.2 dB.

# 7 References


[1] Final draft ETSI EN 303 883-1: „Short Range Devices (SRD) and Ultra Wide Band (UWB); Part 1: Measurement techniques for transmitter requirements“, V2.1.1, June 2024.

[2] 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.

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

[4] cetecom advanced: “Working Instruction – Compliance RC/EMC CETECOM-WI-COMP-LAB-RCE-20011-Messunsicherheiten_V5.0.1”, Version 5.0.1, October 2022.

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

[6] Rohde&Schwarz: “R&S® FSW Signal and Spectrum Analyzer Specifications”, data sheet, version 03.00, Feb. 2019.


# 8 Versions of Test Report (Change History)

| Version | Applied changes | Date of release |
|---|---|---|
| R01 | Initial release | 29.08.2024 |

**End of Test Report**