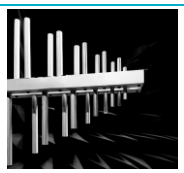
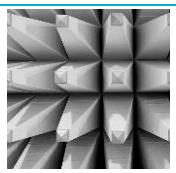

CTC advanced
member of RWTÜV group

Bundesnetzagentur

BNetzA-CAB-02/21-102

# TEST REPORT

**Test report no.: 1-0599/20-04-02**

## Testing laboratory


**CTC advanced GmbH**
Untertuerkheimer Strasse 6 – 10
66117 Saarbruecken / Germany
Phone: + 49 681 5 98 - 0
Fax: + 49 681 5 98 - 9075
Internet: https://www.ctcadvanced.com
e-mail: mail@ctcadvanced.com


**Accredited Testing Laboratory:**
The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2018-03) by the Deutsche Akkreditierungsstelle GmbH (DAkkS)
The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate starting with the registration number: D-PL-12076-01.

## Applicant


**ASTYX GmbH**
Caroline-Herschel-Str. 2
85521 Ottobrunn / GERMANY
Phone: +49 (0) 89 201 804 0
Contact: Serhat Ay & Sigmund Ott
e-mail: serhat.ay@getcruise.com & sigmund.ott@getcruise.com
Phone: +49 173 2127350 & +49 173 2112952


## Manufacturer


**ASTYX GmbH**
Caroline-Herschel-Str. 2
85521 Ottobrunn / GERMANY


## Test standard/s

| | |
|---|---|
| CFR 47 Part 95, Subpart M | The 76-81 GHz Band Radar Service |
| CFR 47 Part 2, Subpart J | Frequency allocations and radio treaty matters; general rules and regulations |

For further applied test standards please refer to section 3 of this test report.

## Test Item

| | |
|---|---|
| **Kind of test item:** | **77GHz Radar for Autonomous Drive Applications** |
| **Model name:** | **HiRes 6455** |
| **FCC ID:** | **2ASKB-HIRES55** |
| Frequency: | 76 – 81 GHz |
| Antenna: | Integrated patch antenna |
| Power supply: | 10 V to 16 V DC |
| Temperature range: | -20°C to +50°C |

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.

## Test report authorized:

Thomas Vogler

cn=Thomas Vogler, o=CTC advanced GmbH, ou=VOG-161125, email=thomas.vogler@ctcadvanced.com, c=DE
2021.05.19 18:45:05 +02'00'

Thomas Vogler
Lab Manager
Radio Communications

## Test performed:

M. Walla

cn=Meheza Walla, o=CTC advanced GmbH, ou=WAL-200806, email=meheza.walla@ctcadvanced.com, c=DE
2021.05.19 14:28:50 +02'00'

Meheza Walla
Lab Manager
Radio Communications

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# 2 General information

## 2.1 Notes and disclaimer

The test results of this test report relate exclusively to the test item specified in this test report. CTC advanced GmbH 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 CTC advanced GmbH.
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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.

## 2.2 Application details

| | |
|---|---|
| Date of receipt of order: | 2021-03-09 |
| Date of receipt of test item: | 2021-03-11 |
| Start of test:* | 2021-03-15 |
| End of test:* | 2021-03-19 |
| Person(s) present during the test: | -/- |

*Date of each measurement, if not shown in the plot, can be requested. Dates are stored in the measurement software.

## 2.3 Test laboratories sub-contracted

None

# 3 Test standard/s, references and accreditations

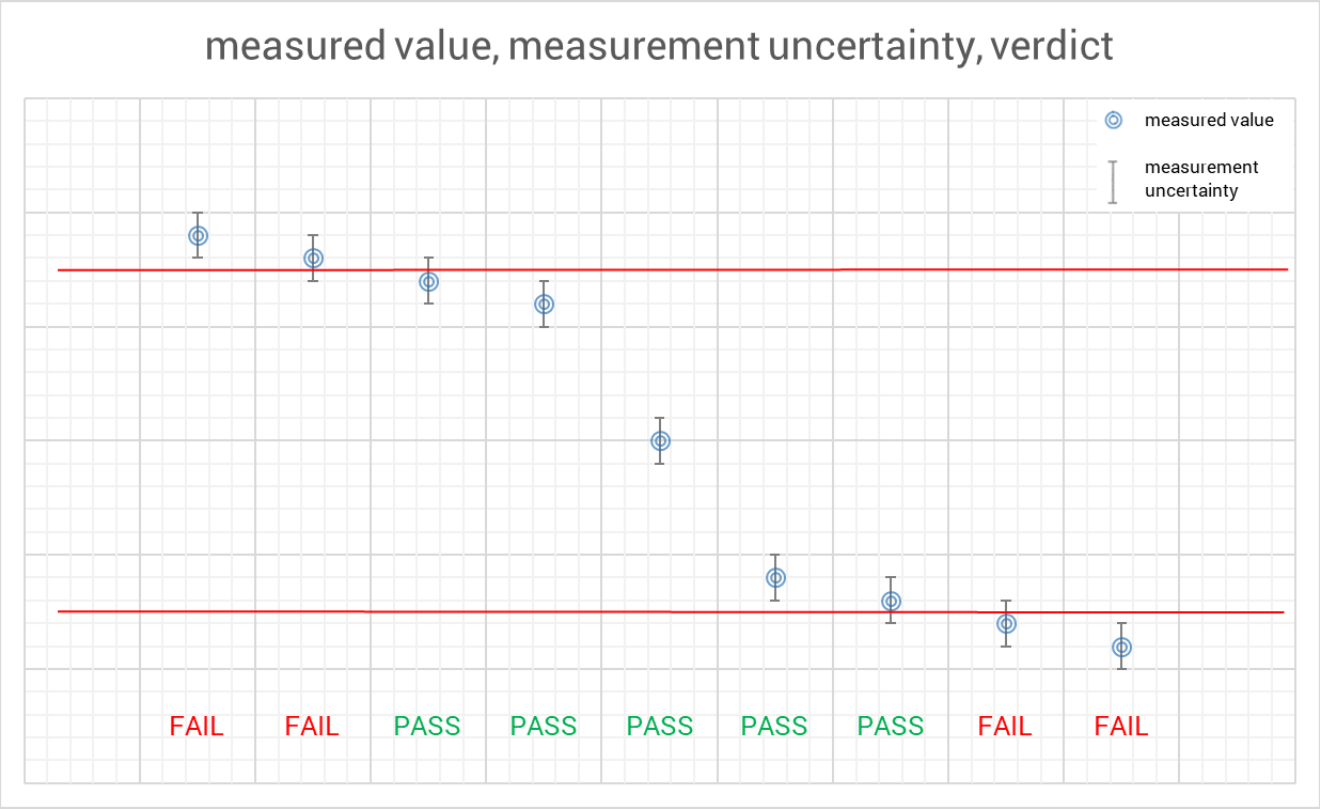
| Test standard | Date | Description |
|---|---|---|
| CFR 47 Part 95, Subpart M | -/- | The 76-81 GHz Band Radar Service |
| CFR 47 Part 2, Subpart J | -/- | Frequency allocations and radio treaty matters; general rules and regulations |

| Guidance | Version | Description |
|---|---|---|
| ANSI C63.4-2014 | -/- | American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz |
| ANSI C63.10-2013 | -/- | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |
| ANSI C63.26-2015 | -/- | American National Standard for Compliance Testing of Transmitters Used in Licensed Radio Services |
| KDB 653005 D01 | v01r01 2019-04 | Equipment Authorization Guidance for 76-81 GHz Radar Devices |

| Accreditation | Description | |
|---|---|---|
| | | |
| D-PL-12076-01-05 | Telecommunication FCC requirements https://www.dakks.de/as/ast/d/D-PL-12076-01-05.pdf | ilac-MRA DAkkS Deutsche Akkreditierungsstelle D-PL-12076-01-05 |

## 4 Reporting statements of conformity – decision rule

Only the measured values related to their corresponding limits will be used to decide whether the equipment under test meets the requirements of the test standards listed in chapter 3.
The measurement uncertainty is mentioned in this test report, see chapter 9, but is not taken into account - neither to the limits nor to the measurement results. Measurement results with a smaller margin to the corresponding limits than the measurement uncertainty have a potential risk of more than 5% that the decision might be wrong."




## 5 Test environment

| | | | |
|---|---|---|---|
| Temperature : | $T_{nom}$<br>$T_{max}$<br>$T_{min}$ | +22 °C during room temperature tests<br>+50 °C during high temperature tests<br>-20 °C during low temperature tests |
| Relative humidity content : | | 47 % |
| Barometric pressure : | | 1019 hpa |
| Power supply : | $V_{nom}$<br>$V_{max}$<br>$V_{min}$ | 12 V DC by external power supply<br>16 V<br>10 V |

# 6 Test item

## 6.1 General description

| | | |
|---|---|---|
| Kind of test item | : | 77GHz Radar for Autonomous Drive Applications |
| Model name | : | HiRes 6455 |
| S/N serial number | : | 1196-M1 |
| Hardware status | : | ST 6455 1100- |
| Software status | : | 13.1.0 with Mode 5_5784, 5_5169, 5_4262 |
| Frequency band | : | 76 – 81 GHz |
| Type of modulation | : | FMCW |
| Number of channels | : | 1 |
| Antenna | : | Integrated patch antenna |
| Power supply | : | 10 V to 16 V DC |
| Temperature range | : | -20°C to +50°C |

## 6.2 Additional information

The content of the following annexes is defined in the QA. It may be that not all of the listed annexes are necessary for this report, thus some values in between may be missing.

Test setup and EUT photos are included in test report: 1-0599/20-04-01_AnnexA
1-0599/20-04-01_AnnexB
1-0599/20-04-01_AnnexD

Tests were performed on 3 modulations, Mode 5_5784, Mode 5_5169 and Mode 5_4262.

Channel power, positive peak power and the OBW were measured on all modulations at $T_{nom}$ / $V_{nom}$.
Tests under extreme test conditions were done according to ANSI 63.10 as worst case mode for given tests:

Frequency Stability:
Mode 5_5784

Spurious emission:
Mode 5_5784

# 7 Description of the test setup

Typically, the calibrations of the test apparatus are commissioned to and performed by an accredited calibration laboratory. The calibration intervals are determined in accordance with the DIN EN ISO/IEC 17025. In addition to the external calibrations, the laboratory executes comparison measurements with other calibrated test systems or effective verifications. Weekly chamber inspections and range calibrations are performed. Where possible, RF generating and signaling equipment as well as measuring receivers and analyzers are connected to an external high-precision 10 MHz reference (GPS-based or rubidium frequency standard).

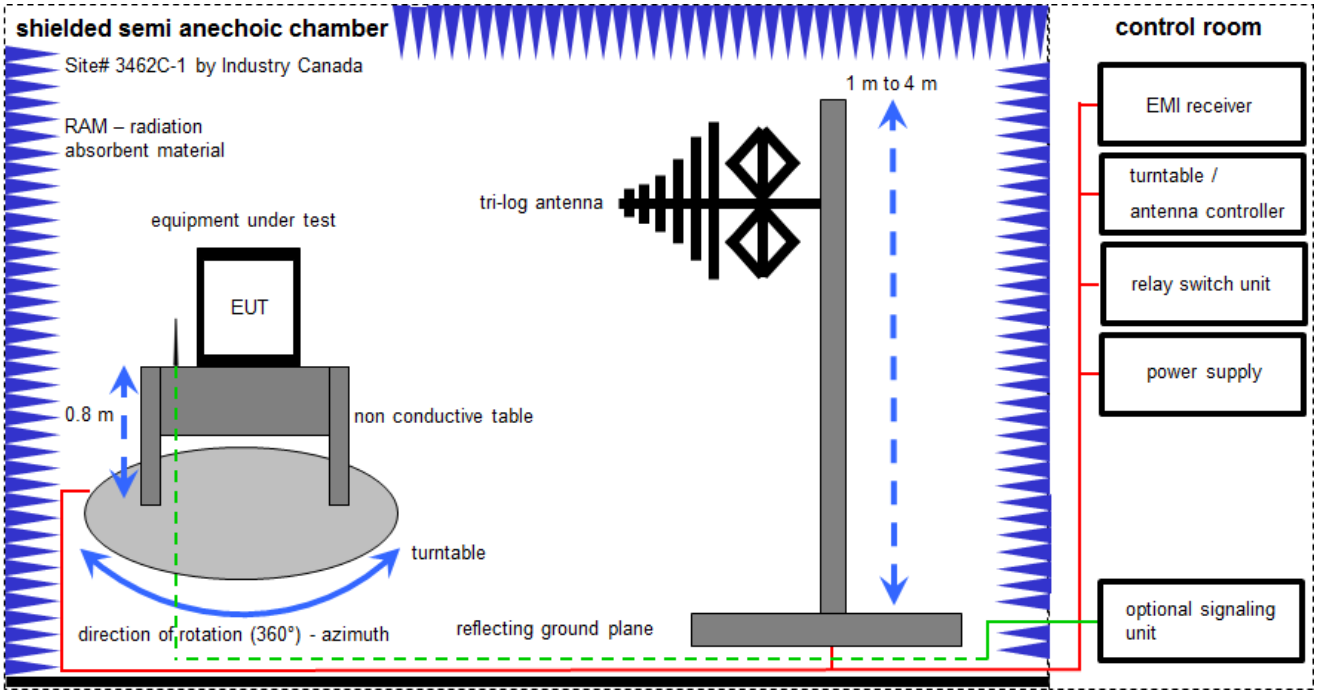
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

**Agenda:** Kind of Calibration

| | | | | |
|---|---|---|---|---|
| k | calibration / calibrated | | EK | limited calibration |
| ne | not required (k, ev, izw, zw not required) | | zw | cyclical maintenance (external cyclical maintenance) |
| ev | periodic self verification | | izw | internal cyclical maintenance |
| Ve | long-term stability recognized | | g | blocked for accredited testing |
| vlkl! | Attention: extended calibration interval | | | |
| NK! | Attention: not calibrated | | *) | next calibration ordered / currently in progress |

## 7.1 Shielded semi anechoic chamber

The radiated measurements are performed in vertical and horizontal plane in the frequency range from 30 MHz to 1 GHz in semi-anechoic chambers. The EUT is positioned on a non-conductive support with a height of 0.80 m above a conductive ground plane that covers the whole chamber. The receiving antennas are conform to specifications ANSI C63. These antennas can be moved over the height range between 1.0 m and 4.0 m in order to search for maximum field strength emitted from EUT. The measurement distances between EUT and receiving antennas are indicated in the test setups for the various frequency ranges. For each measurement, the EUT is rotated in all three axes until the maximum field strength is received. The wanted and unwanted emissions are received by spectrum analyzers where the detector modes and resolution bandwidths over various frequency ranges are set according to requirement ANSI C63.




Measurement distance: tri-log antenna 10 meter

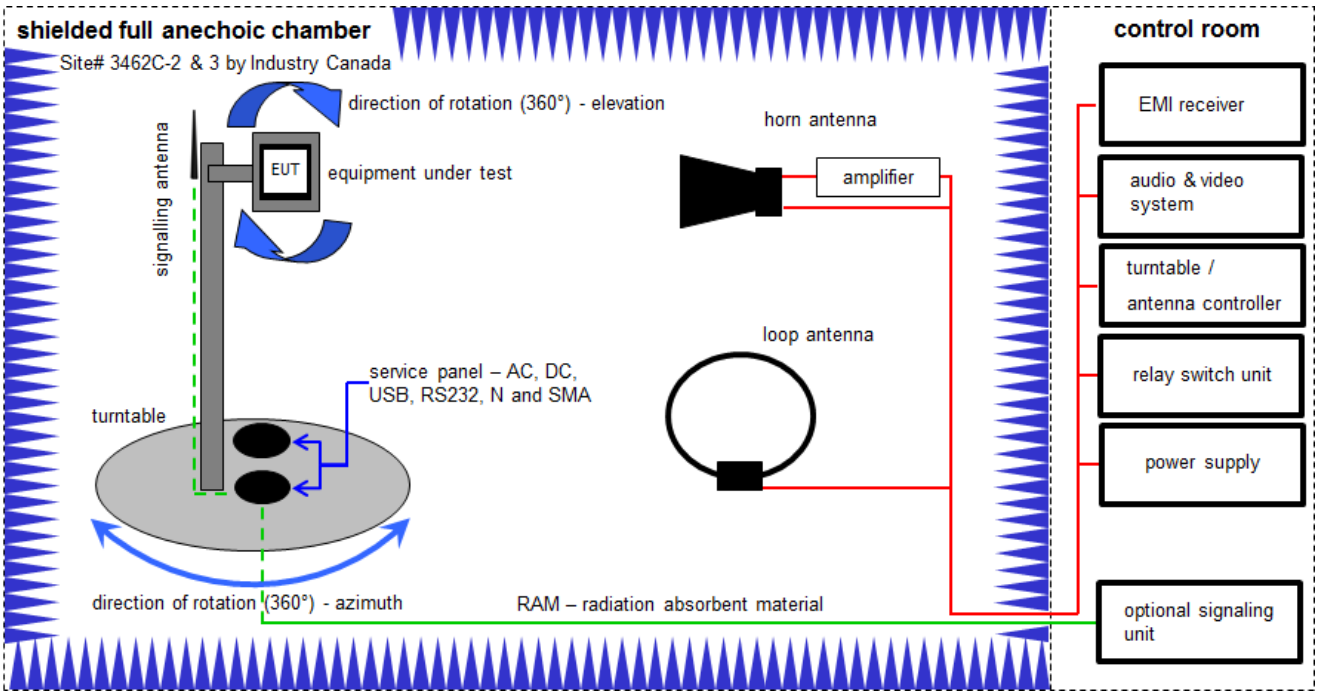
FS = UR + CL + AF
(FS-field strength; UR-voltage at the receiver; CL-loss of the cable; AF-antenna factor)

*Example calculation:*
FS [dBµV/m] = 12.35 [dBµV/m] + 1.90 [dB] + 16.80 [dB/m] = 31.05 [dBµV/m] (35.69 µV/m)

## Equipment table:

| No. | Lab / Item | Equipment | Type | Manufacturer | Serial No. | INV. No. | Kind of Calibration | Last Calibration | Next Calibration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | n. a. | Switch-Unit | 3488A | HP | 2719A14505 | 300000368 | ev | -/- | -/- |
| 2 | n. a. | DC power supply, 60Vdc, 50A, 1200 W | 6032A | HP | 2920A04466 | 300000580 | ne | -/- | -/- |
| 3 | n. a. | Meßkabine 1 | HF-Absorberhalle | MWB AG 300023 | | 300000551 | ne | -/- | -/- |
| 4 | n. a. | EMI Test Receiver | ESCI 3 | R&S | 100083 | 300003312 | k | 09.12.2020 | 08.12.2021 |
| 5 | n. a. | Antenna Tower | Model 2175 | ETS-Lindgren | 64762 | 300003745 | izw | -/- | -/- |
| 6 | n. a. | Positioning Controller | Model 2090 | ETS-Lindgren | 64672 | 300003746 | izw | -/- | -/- |
| 7 | n. a. | Turntable Interface-Box | Model 105637 | ETS-Lindgren | 44583 | 300003747 | izw | -/- | -/- |
| 8 | n. a. | TRILOG Broadband Test-Antenna 30 MHz - 3 GHz | VULB9163 | Schwarzbeck Mess - Elektronik | 295 | 300003787 | vlKl! | 04.09.2019 | 03.09.2021 |
| 9 | n. a. | Switch-Unit | 3488A | HP | 2719A14505 | 300000368 | ev | -/- | -/- |
| 10 | n. a. | EMI Test Receiver | ESR3 | Rohde & Schwarz | 102587 | 300005771 | k | 10.12.2020 | 09.06.2022 |

## 7.2 Shielded fully anechoic chamber




Measurement distance: horn antenna 3 meter; loop antenna 3 meter / 1 meter

FS = UR + CA + AF
(FS-field strength; UR-voltage at the receiver; CA-loss of the signal path; AF-antenna factor)

*Example calculation:*
FS [dBµV/m] = 40.0 [dBµV/m] + (-35.8) [dB] + 32.9 [dB/m] = 37.1 [dBµV/m] (71.61 µV/m)

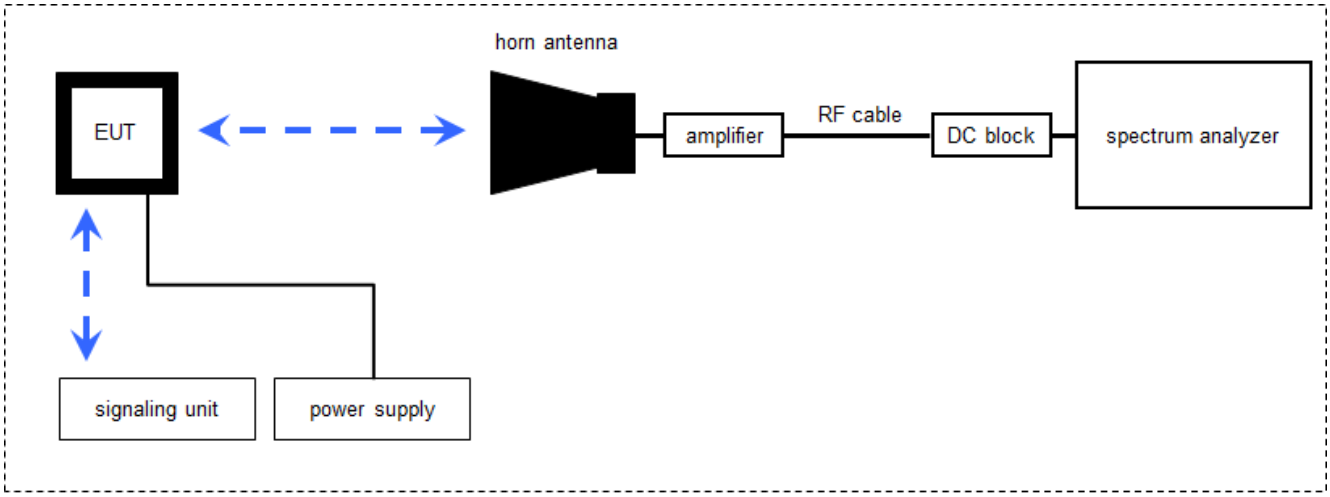
OP = AV + D - G + CA
(OP-radiated output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain+amplifier gain; CA-loss signal path)

*Example calculation:*
OP [dBm] = -39.0 [dBm] + 57.0 [dB] - 12.0 [dBi] + (-36.0) [dB] = -30 [dBm] (1 µW)

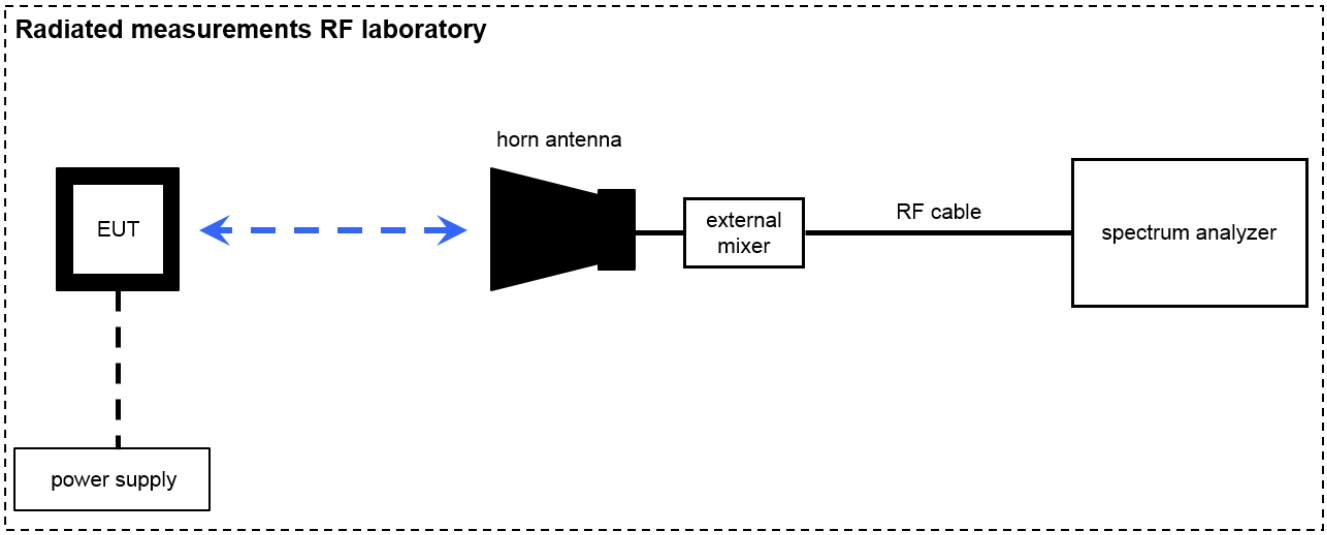
## Equipment table:

| No. | Lab / Item | Equipment | Type | Manufacturer | Serial No. | INV. No. | Kind of Calibration | Last Calibration | Next Calibration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | n. a. | DC power supply, 60Vdc, 50A, 1200 W | 6032A | HP | 2818A03450 | 300001040 | vIKI! | 09.12.2020 | 08.12.2023 |
| 2 | n. a. | Active Loop Antenna 9 kHz to 30 MHz | 6502 | EMCO | 2210 | 300001015 | vIKI! | 13.06.2019 | 12.06.2021 |
| 3 | n. a. | Anechoic chamber | FAC 3/5m | MWB / TDK | 87400/02 | 300000996 | ev | -/- | -/- |
| 4 | n. a. | TRILOG Broadband Test-Antenna 30 MHz - 3 GHz | VULB9163 | Schwarzbeck Mess - Elektronik | 371 | 300003854 | vIKI! | 14.01.2020 | 13.01.2022 |
| 5 | n. a. | Double-Ridged Waveguide Horn Antenna 1-18.0GHz | 3115 | EMCO | 9709-5289 | 300000213 | vIKI! | 14.07.2020 | 13.07.2022 |
| 6 | n. a. | Switch / Control Unit | 3488A | HP | * | 300000199 | ne | -/- | -/- |
| 7 | n. a. | Variable isolating transformer | MPL IEC625 Bus Variable isolating transformer | Erfi | 91350 | 300001155 | ne | -/- | -/- |
| 8 | n. a. | EMI Test Receiver 20Hz- 26,5GHz | ESU26 | R&S | 100037 | 300003555 | k | 11.12.2020 | 10.12.2021 |
| 9 | n. a. | Highpass Filter | WHKX7.0/18G-8SS | Wainwright | 19 | 300003790 | ne | -/- | -/- |
| 10 | n. a. | Broadband Amplifier 0.5-18 GHz | CBLU5184540 | CERNEX | 22049 | 300004481 | ev | -/- | -/- |
| 11 | n. a. | Broadband Amplifier 5-13 GHz | CBLU5135235 | CERNEX | 22010 | 300004491 | ev | -/- | -/- |
| 12 | n. a. | 4U RF Switch Platform | L4491A | Agilent Technologies | MY50000037 | 300004509 | ne | -/- | -/- |
| 13 | n. a. | NEXIO EMV-Software | BAT EMC V3.16.0.49 | EMCO | | 300004682 | ne | -/- | -/- |
| 14 | n. a. | PC | ExOne | F+W | | 300004703 | ne | -/- | -/- |
| 15 | n. a. | RF-Amplifier | AMF-6F06001800-30-10P-R | NARDA-MITEQ Inc | 2011572 | 300005241 | ev | -/- | -/- |

## 7.3 Radiated measurements > 18 GHz




## 7.4 Radiated measurements > 50/85 GHz




OP = AV + D - G
(OP-rad. output power; AV-analyzer value; D-free field attenuation of measurement distance; G-antenna gain)

*Example calculation:*
OP [dBm] = -54.0 [dBm] + 64.0 [dB] - 20.0 [dBi] = -10 [dBm] (100 µW)

Note: conversion loss of mixer is already included in analyzer value.

## Equipment table:

| No. | Lab / Item | Equipment | Type | Manufacturer | Serial No. | INV. No. | Kind of Calibration | Last Calibration | Next Calibration |
|---|---|---|---|---|---|---|---|---|---|
| 1 | n.a. | Horn Antenna 18,0-40,0 GHz | LHAF180 | Microw.Devel | 39180-103-021 | 300001747 | vIKI! | 18.02.2019 | 17.02.2022 |
| 2 | n. a. | Std. Gain Horn Antenna 18.0-26.5 GHz | 638 | Narda | | 300000486 | vIKI! | 21.01.2020 | 20.01.2022 |
| 3 | n. a. | Std. Gain Horn Antenna 26.5-40.0 GHz | V637 | Narda | 82-16 | 300000510 | vIKI! | 23.01.2020 | 22.01.2022 |
| 4 | n.a. | Std. Gain Horn Antenna 33.0-50.1 GHz | 2324-20 | Flann | 57 | 400000683 | ne | -/- | -/- |
| 5 | n. a. | Std. Gain Horn Antenna 49.9-75.8 GHz | 2524-20 | Flann | * | 300001983 | ne | -/- | -/- |
| 6 | n. a. | Std. Gain Horn Antenna 60-90 GHz | COR 60_90 | Thomson CSF | | 300000814 | ev | -/- | -/- |
| 7 | n. a. | Std. Gain Horn Antenna 73.8-112 GHz | 2724-20 | Flann | * | 300001988 | ne | -/- | -/- |
| 8 | n.a. | Std. Gain Horn Antenna 92.3-140 GHz | 2824-20 | Flann | | 300001993 | ne | -/- | -/- |
| 9 | n. a. | Std. Gain Horn Antenna 114-173 GHz | 2924-20 | Flann | * | 300001999 | ne | -/- | -/- |
| 10 | n. a. | Std. Gain Horn Antenna 145-220 GHz | 3024-20 | Flann | * | 300002000 | ne | -/- | -/- |
| 11 | n. a. | Std. Gain Horn Antenna 217-330 GHz | 32240-20 | Flann | 233278 | 300004960 | ne | -/- | -/- |
| 12 | n. a. | Standard Gain Horn 325-500 GHz | 570240-20 1785-2a | Flann | 273569 | 300006097 | ev | 25.05.2020 | 24.05.2022 |
| 13 | n. a. | Broadband LNA 18-50 GHz | CBL18503070PN | CERNEX | 25240 | 300004948 | ev | 09.03.2020 | 08.03.2022 |
| 14 | n. a. | Harmonic Mixer 3-Port, 50-75 GHz | FS-Z75 | Rohde & Schwarz | 101578 | 300005788 | k | 17.06.2020 | 16.06.2021 |
| 15 | n. a. | Harmonic Mixer 3-Port, 60-90 GHz | FS-Z90 | R&S | 101555 | 300004691 | k | 08.07.2020 | 07.07.2021 |
| 16 | n. a. | Harmonic Mixer 3-Port, 75-110 GHz | FS-Z110 | R&S | 101411 | 300004959 | k | 19.06.2020 | 18.06.2021 |
| 17 | n.a. | Harmonic Mixer 3-port, 90-140 GHz | FS-Z140 | Rohde & Schwarz | 101119 | 300005581 | k | 09.07.2020 | 08.07.2021 |
| 18 | n. a. | Harmonic Mixer 3-Port, 110-170 GHz | FS-Z170 | Radiometer Physics GmbH | 100014 | 300004156 | k | 28.05.2020 | 27.05.2021 |
| 19 | n. a. | Harmonic Mixer 3-Port, 140-220 GHz | SAM-220 | Radiometer Physics GmbH | 200001 | 300004157 | k | 14.07.2020 | 13.07.2021 |
| 20 | n. a. | Harmonic Mixer 3-Port, 220-325 GHz | SAM-325 | Radiometer Physics GmbH | 100002 | 300004158 | k | 23.07.2020 | 22.07.2021 |
| 21 | n.a. | Harmonic Mixer 325-500GHz | FS-Z500 | Radiometer Physics GmbH | 101016 | 300006096 | k | 25.05.2020 | 24.05.2021 |
| 22 | n. a. | Spectrum Analyzer 2 Hz - 85 GHz | FSW85 | R&S | 101333 | 300005568 | k | 17.06.2020 | 16.06.2021 |

# 8 Sequence of testing

## 8.1 Sequence of testing radiated spurious 9 kHz to 30 MHz

**Setup**

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, it is placed on a table with 0.8 m height.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

**Premeasurement***

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna height is 1 m.
- At each turntable position the analyzer sweeps with positive-peak detector to find the maximum of all emissions.

**Final measurement**

- Identified emissions during the pre-measurement are maximized by the software by rotating the turntable from 0° to 360°.
- Loop antenna is rotated about its vertical axis for maximum response at each azimuth about the EUT. (For certain applications, the loop antenna plane may also need to be positioned horizontally at the specified distance from the EUT)
- The final measurement is done in the position (turntable and elevation) causing the highest emissions with quasi-peak (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, correction factor, margin to the limit and limit will be recorded. A plot with the graph of the premeasurement and the limit is stored.

*)Note: The sequence will be repeated three times with different EUT orientations.

## 8.2 Sequence of testing radiated spurious 30 MHz to 1 GHz

**Setup**

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a table with 0.8 m height is used, which is placed on the ground plane.
- If the EUT is a floor standing device, it is placed on the ground plane with insulation between both.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 10 m or 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

**Premeasurement**

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height changes from 1 m to 3 m.
- At each turntable position, antenna polarization and height the analyzer sweeps three times in peak to find the maximum of all emissions.

**Final measurement**

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximize the peaks by changing turntable position ± 45° and antenna height between 1 and 4 m.
- The final measurement is done with quasi-peak detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, antenna height, antenna polarization, turntable angle, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

## 8.3 Sequence of testing radiated spurious 1 GHz to 18 GHz

**Setup**

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- If the EUT is a tabletop system, a 2-axis positioner with 1.5 m height is used.
- If the EUT is a floor standing device, it is placed directly on the turn table.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet below the turntable.
- Measurement distance is 3 m (see ANSI C 63.4) – see test details.
- EUT is set into operation.

**Premeasurement**

- The turntable rotates from 0° to 315° using 45° steps.
- The antenna is polarized vertical and horizontal.
- The antenna height is 1.5 m.
- At each turntable position and antenna polarization the analyzer sweeps with positive peak detector to find the maximum of all emissions.

**Final measurement**

- The final measurement is performed for at least six highest peaks according to the requirements of the ANSI C63.4.
- Based on antenna and turntable positions at which the peak values are measured the software maximizes the peaks by rotating the turntable from 0° to 360°. This measurement is repeated for different EUT-table positions (0° to 150° in 30°-steps) and for both antenna polarizations.
- The final measurement is done in the position (turntable, EUT-table and antenna polarization) causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, turntable position, EUT-table position, antenna polarization, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement with marked maximum final results and the limit is stored.

## 8.4 Sequence of testing radiated spurious above 18 GHz

**Setup**

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate (e.g. 0.5 m).
- The EUT is set into operation.

**Premeasurement**

- The test antenna is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.

**Final measurement**

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

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## 8.5 Sequence of testing radiated spurious above 50/85 GHz with external mixers

**Setup**

- The equipment is set up to simulate normal operation mode as described in the user manual or defined by the manufacturer.
- Auxiliary equipment and cables are positioned to simulate normal operation conditions as described in ANSI C 63.4.
- The AC power port of the EUT (if available) is connected to a power outlet.
- The measurement distance is as appropriate for far field (e.g. 0.25 m).
- The EUT is set into operation.

**Premeasurement**

- The test antenna with external mixer is handheld and moved carefully over the EUT to cover the EUT's whole sphere and different polarizations of the antenna.
- Caution is taken to reduce the possible overloading of the external mixer.

**Final measurement**

- The final measurement is performed at the position and antenna orientation causing the highest emissions with Peak and RMS detector (as described in ANSI C 63.4).
- As external mixers may generate false images care is taken to ensure that any emission measured by the spectrum analyzer does indeed originate in the EUT. Signal identification feature of spectrum analyzer is used to eliminate false mixer images (i.e., it is not the fundamental emission or a harmonic falling precisely at the measured frequency).
- Final levels, frequency, measuring time, bandwidth, correction factor, margin to the limit and limit are recorded. A plot with the graph of the premeasurement and the limit is stored.

# 9 Measurement uncertainty

| Test case | Uncertainty |
|---|---|
| Equivalent isotropically radiated power (e.i.r.p.) | Conducted value ± 1 dB<br>Radiated value ± 3 dB |
| Permitted range of operating frequencies | ± 100 kHz |
| Conducted unwanted emissions in the spurious domain (up to 18 GHz) | ± 1 dB |
| Radiated unwanted emissions in the spurious domain (up to 18 GHz) | ± 3 dB |
| Conducted unwanted emissions in the spurious domain (18 to 40 GHz) | ± 4 dB |
| Radiated unwanted emissions in the spurious domain (18 to 40 GHz) | ± 4 dB |
| Conducted unwanted emissions in the spurious domain (40 to 50 GHz) | ± 4.5 dB |
| Radiated unwanted emissions in the spurious domain (40 to 50 GHz) | ± 4.5 dB |
| Conducted unwanted emissions in the spurious domain (above 50 GHz) | ± 5 dB |
| Radiated unwanted emissions in the spurious domain (above 50 GHz) | ± 5 dB |
| DC and low frequency voltages | ± 3 % |
| Temperature | ± 1 °C |
| Humidity | ± 3 % |

# 10 Far field consideration for measurements above 18 GHz

**Far field distance calculation:**

$D_{ff} = 2 \times D^2/\lambda$

with

$D_{ff}$ Far field distance

D Antenna dimension

$\lambda$ wavelength

**Spurious emission measurements:**

| Antenna frequency range in GHz | Highest measured frequency in GHz | D in cm | λ in cm | $D_{ff}$ in cm |
|---|---|---|---|---|
| 18-26 | 26 | 3.4 | 1.15 | 20.04 |
| 26-40 | 40 | 2.2 | 0.75 | 12.91 |
| 40-50 | 50 | 2.77 | 0.60 | 25.58 |
| 50-75 | 75 | 1.85 | 0.40 | 17.11 |
| 75-110 | 110 | 1.24 | 0.27 | 11.28 |
| 90-140 | 140 | 1.02 | 0.22 | 9.72 |
| 110-170 | 170 | 0.85 | 0.18 | 8.19 |
| 140-220 | 220 | 0.68 | 0.14 | 6.78 |
| 220-325 | 325 | 0.43 | 0.09 | 4.01 |
| 325-500 | 500 | 0.26 | 0.06 | 2.22 |

## 11 Summary of measurement results

| | |
|---|---|
| ☒ | **No deviations from the technical specifications were ascertained** |
| ☐ | There were deviations from the technical specifications ascertained |
| ☐ | This test report is only a partial test report.<br>The content and verdict of the performed test cases are listed below. |

| TC Identifier | Description | Verdict | Date | Remark |
|---|---|---|---|---|
| RF-Testing | 47 CFR Part 95 Subpart M | see below | 2021-05-19 | -/- |

| Test specification clause | Test case | Temperature conditions | Power source voltages | C | NC | NA | NP | Results (max.) |
|---|---|---|---|---|---|---|---|---|
| §2.1046<br>§95.3367 (a) / (b) | Radiated power | Nominal | Nominal | ☒ | ☐ | ☐ | ☐ | -/- |
| | | | | | | | | |
| §2.1047 | Modulation characteristics | -/- | -/- | ☒ | ☐ | ☐ | ☐ | -/- |
| | | | | | | | | |
| §2.1049 | Occupied bandwidth (99% bandwidth) | Nominal | Nominal | ☒ | ☐ | ☐ | ☐ | -/- |
| | | | | | | | | |
| §2.1051 | Spurious emissions at antenna terminals | Nominal | Nominal | ☐ | ☐ | ☒ | ☐ | see note |
| | | | | | | | | |
| §2.1053<br>§95.3379 (a)(1)<br>§95.3379 (a)(2)<br>§95.3379 (a)(3) | Field strength of emissions (radiated spurious) | Nominal | Nominal | ☒ | ☐ | ☐ | ☐ | -/- |
| | | | | | | | | |
| §2.1055<br>§95.3379 (b) | Frequency stability | Nominal<br>Extreme | Nominal<br>Extreme | ☒ | ☐ | ☐ | ☐ | -/- |
| | | | | | | | | |

**Note:** C = Compliant; NC = Not compliant; NA = Not applicable; NP = Not performed

**See FCC's Millimeter Wave Test Procedures:**
I. A radiated method of measurements in order to demonstrate compliance with the various regulatory requirements has been chosen in consideration of test equipment availability and the limitations of many external harmonic mixers. A conducted method of measurement could be employed if EUT and mixer waveguides both are accessible and of the same type (WG number) and if waveguide sections and transitions can be found. Another potential problem is that the peak power output of devices operating under Sections 15.253 and 15.255 may exceed the +20 dBm input power limit of many commercially available mixers. For these reasons a radiated method is preferred.

# 12 Measurement results

## 12.1 Radiated power

**Description:**

The fundamental radiated emission limits within the 76-81 GHz band are expressed in terms of Equivalent Isotropically Radiated Power (EIRP) and are as shown below.

**Measurement:**

| Parameters | |
|---|---|
| Detector: | Pos-Peak / RMS |
| Sweep time: | 100s |
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 3 MHz |
| Trace-Mode: | Max Hold / Clear Write |

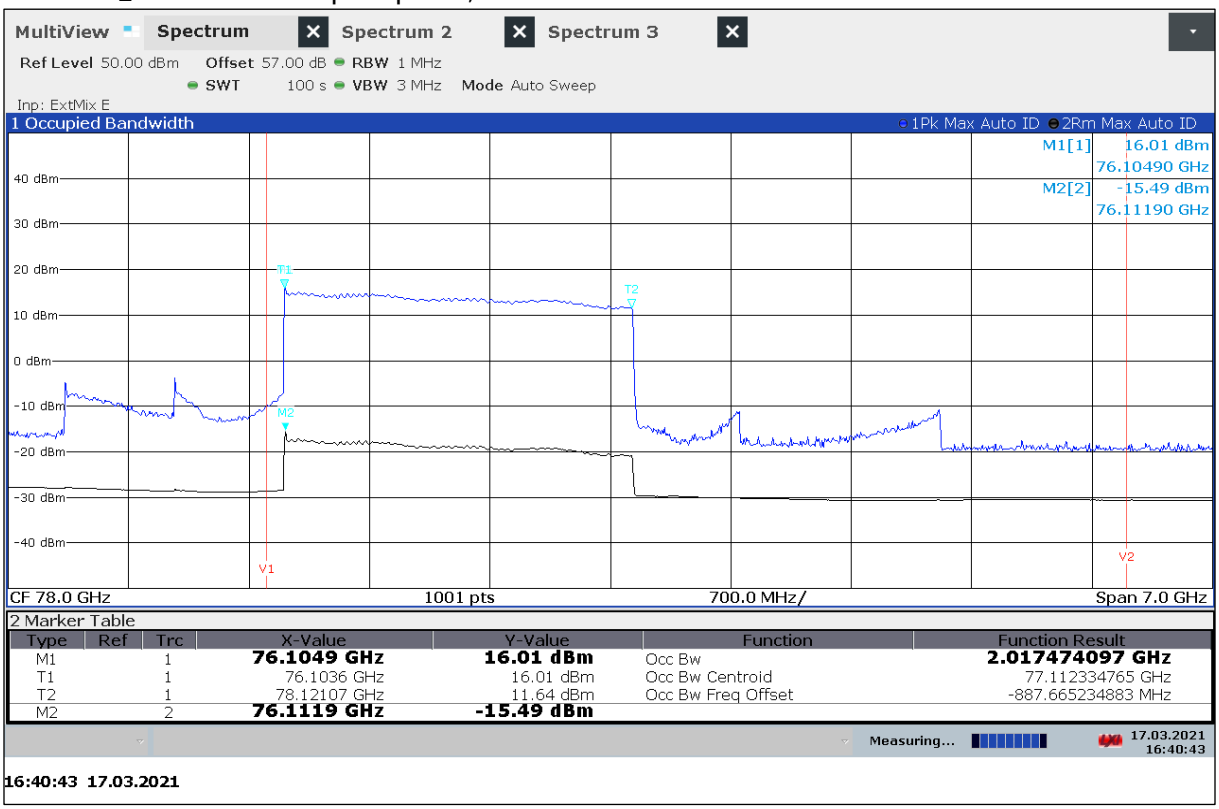
**Limits:** **FCC §95.3367 (a) (b)**

| Frequency | Measurement distance | EIRP |
|---|---|---|
| 76.0 - 81.0 GHz | 3.0 m | 88 µW/cm² → 50 dBm (Average)<br>279 µW/cm² → 55 dBm (PEAK) |

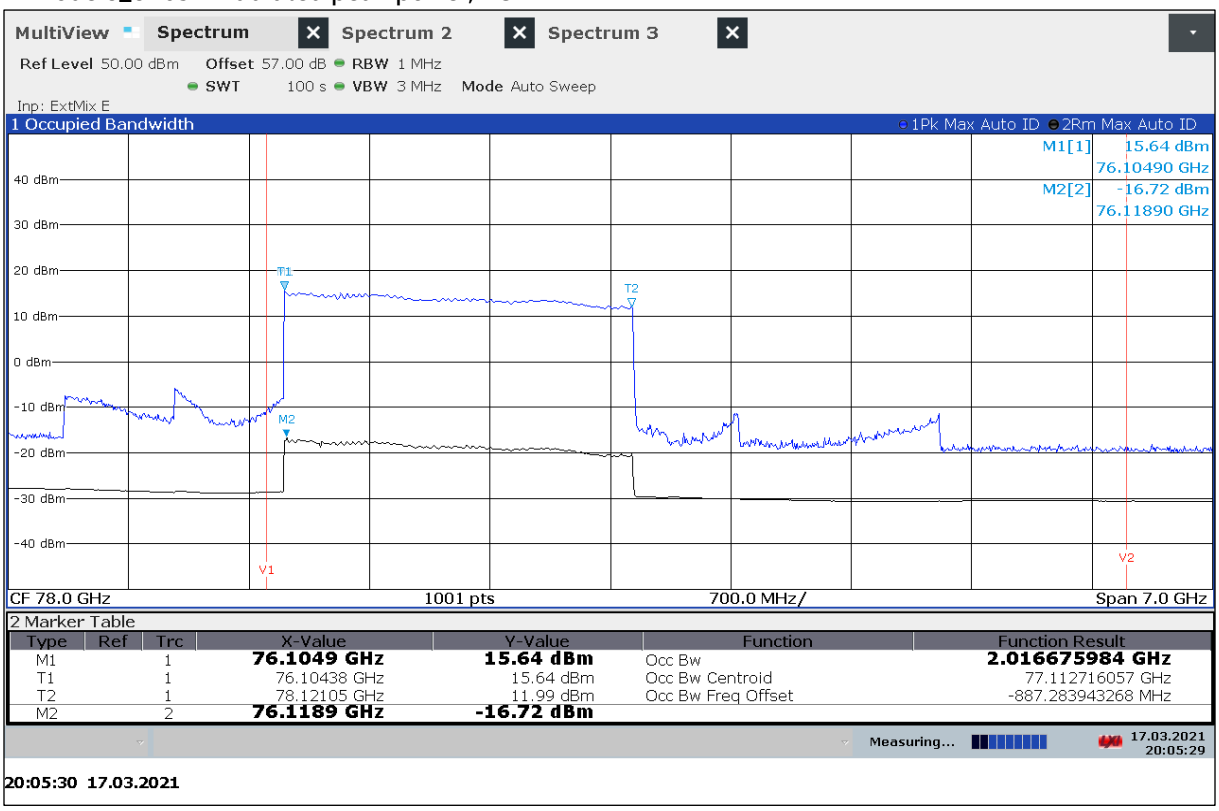
**Measurement results:**

| Mode | Test conditions | Radiated peak power (eirp) [dBm] | Channel power [dBm] | Power spectral density [dBm/MHz] |
|---|---|---|---|---|
| Mode 5_5784 | $T_{nom}$ / $V_{nom}$ | 16.01 | 14.32 | -15.49 |
| Mode 5_5169 | $T_{nom}$ / $V_{nom}$ | 15.64 | 14.29 | -16.72 |
| Mode 5_4262 | $T_{nom}$ / $V_{nom}$ | 15.13 | 14.34 | -16.98 |

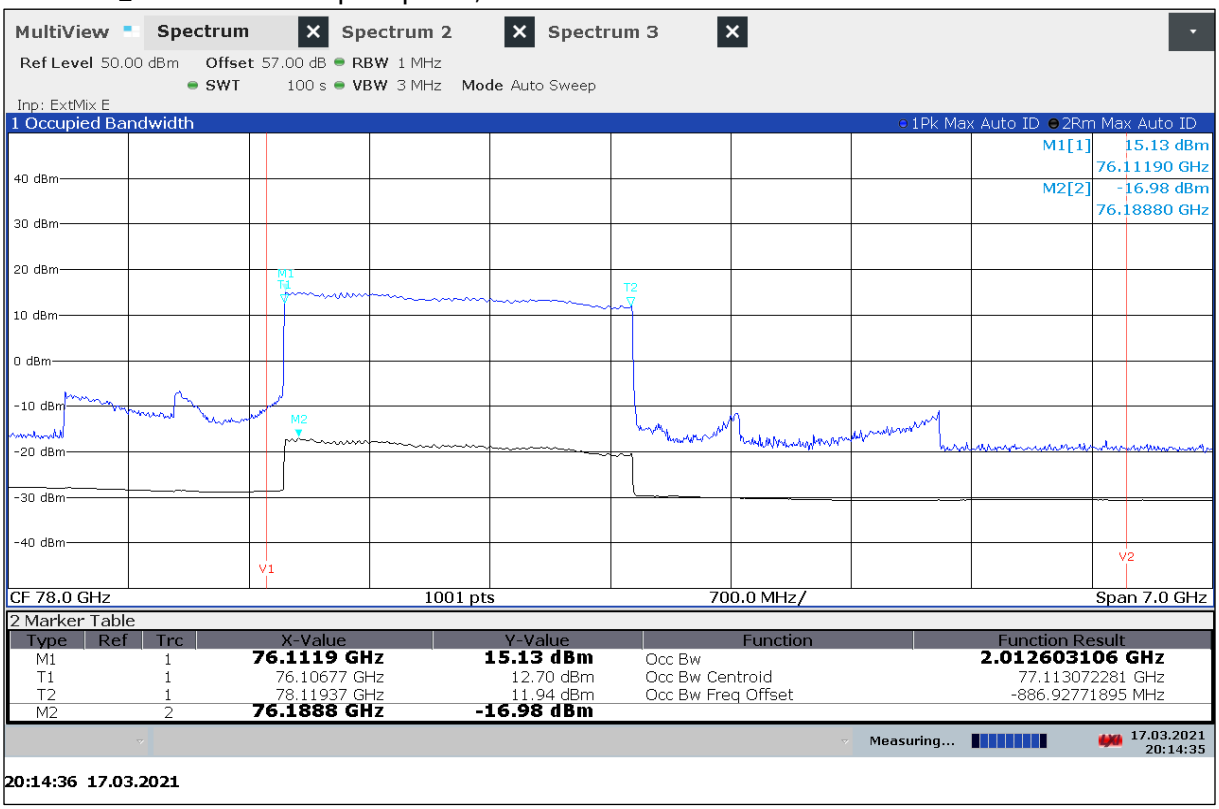
Plot 1: Mode 5_5784– Radiated peak power, PSD



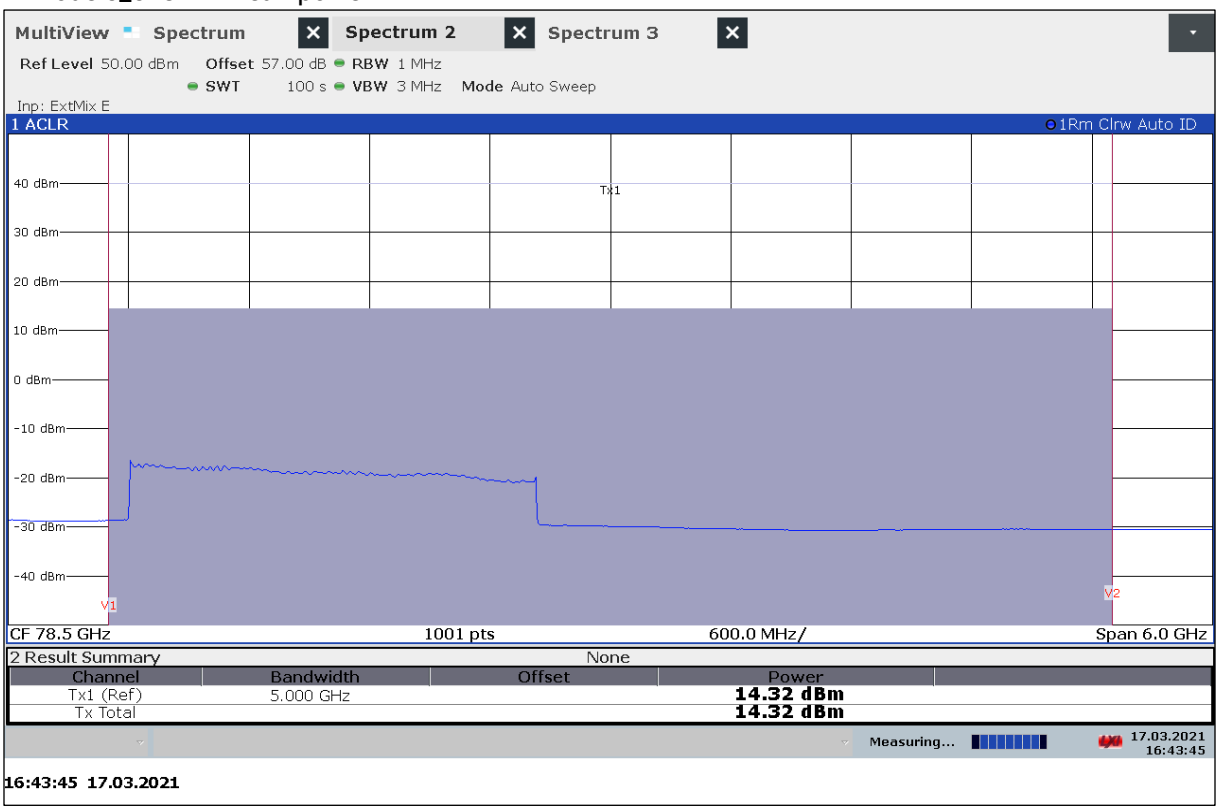

Plot 2: Mode 5_5169– Radiated peak power, PSD



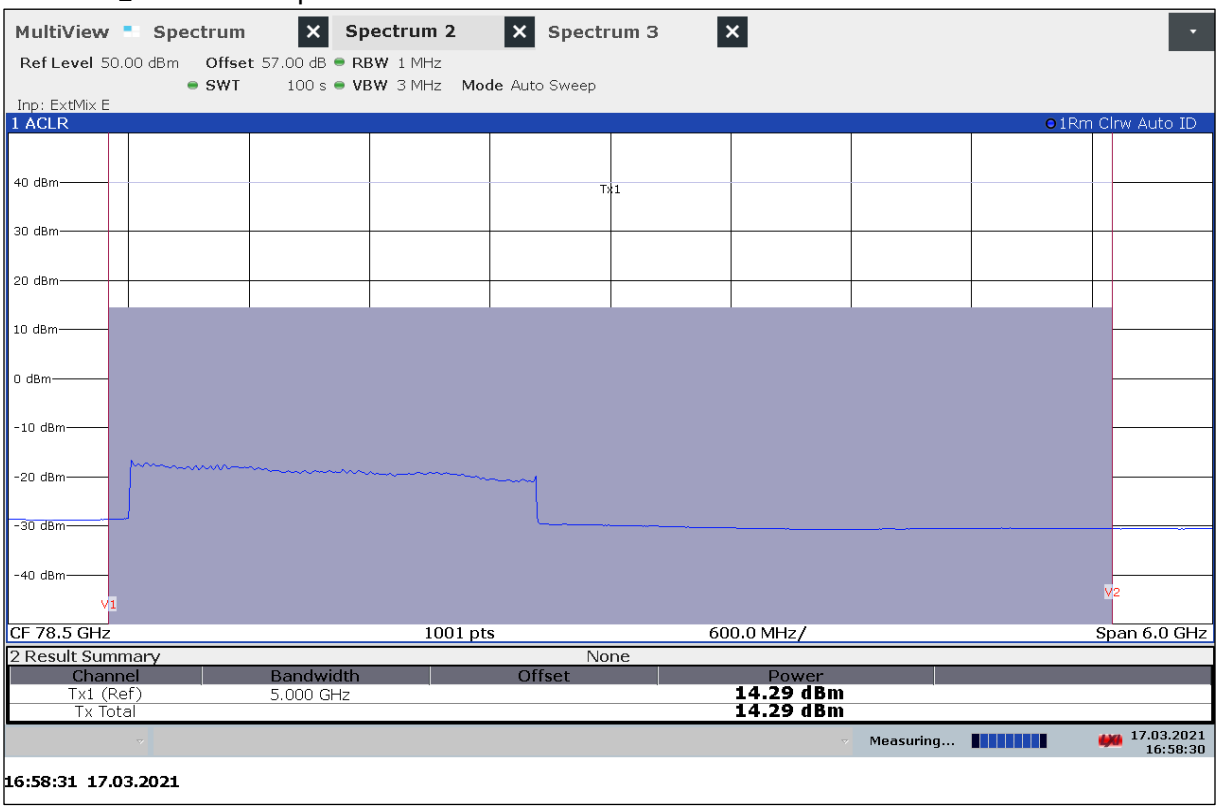
Plot 3: Mode 5_4262 – Radiated peak power, PSD



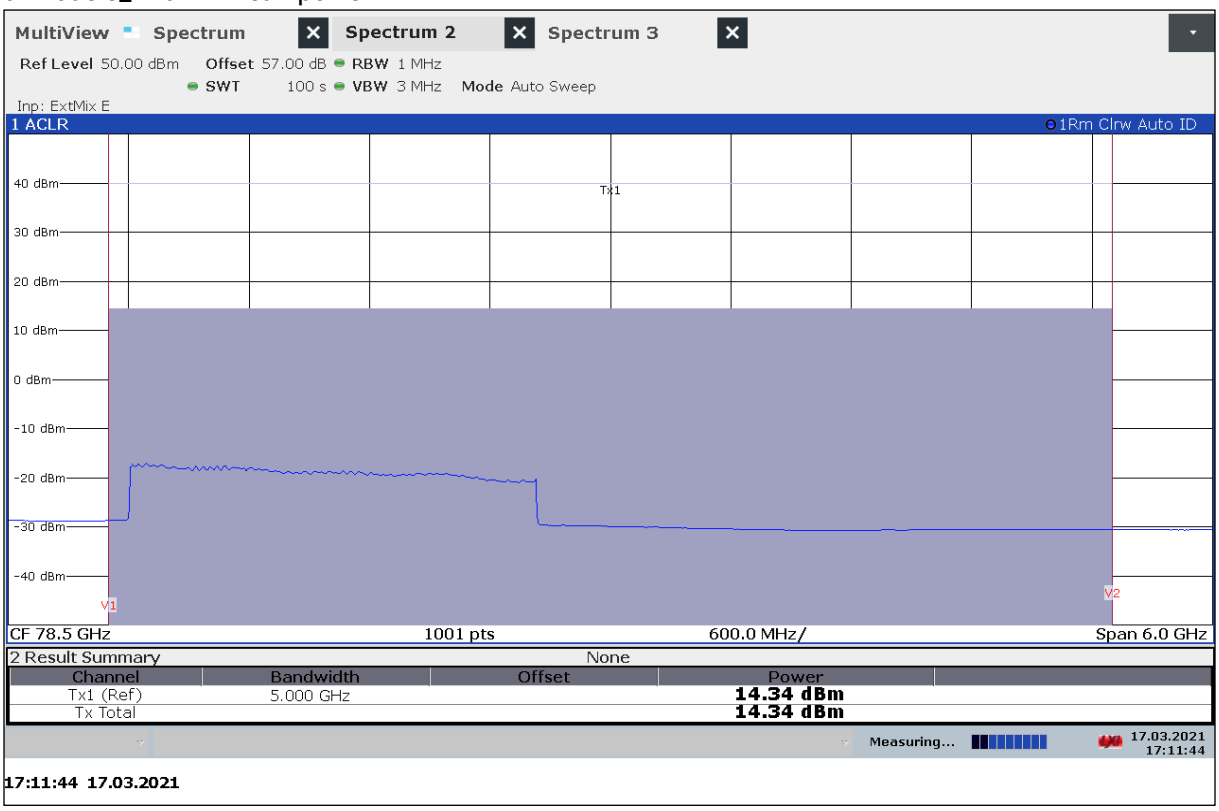

Plot 4: Mode 5_5784 – Mean power



Plot 5: Mode 5_5169 – Mean power




Plot 6: Mode 5_4262 – Mean power



## 12.2 Modulation characteristics

**Description:**

§2.1047 (d) *Other types of equipment.* A curve or equivalent data which shows that the equipment will meet the modulation requirements of the rules under which the equipment is to be licensed.

**Comments from manufacturer on modulation characteristics according to KDB:**

| Parameter | Mode 5_5784 | Mode 5_5169 | Mode 5_4262 |
|---|---|---|---|
| Duty Cycle % | 14.8 | 13.2 | 10.9 |
| Timing RF on (ms) | 14.8 | 13.2 | 10.9 |
| Timing RF off (ms) | 85.2 | 86.8 | 89.1 |
| Power | Constant during RF on | Constant during RF on | Constant during RF on |
| Steepness of Ramps (GHz/s) | 24414.1 | 24414.1 | 24414.1 |
| Calibration | N/A | N/A | N/A |
| Antenna Beam Steering (Tx) | No | No | No |
| Characteristic | Linear FMCW | Linear FMCW | Linear FMCW |
| Sweep Bandwidth (GHz) | 2 | 2 | 2 |
| Sweep Rate (kHz) | 8.6 | 9.7 | 11.7 |
| Sweep Time (us) | 83.3 | 83.3 | 83.3 |

## 12.3 Occupied bandwidth

**Description:**

§2.1049 The occupied bandwidth, that is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers radiated are each equal to 0.5 percent of the total mean power radiated by a given emission.

**Measurement:**

| Parameters | |
|---|---|
| Detector: | Pos-Peak |
| Sweep time: | 100s |
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 3 MHz |
| Trace-Mode: | Max Hold |
| Measurement uncertainty | Span/1000 |

**Limits:** **FCC §95.3379 (b)**

| | | |
|---|---|---|
| Frequency range | f(lowest) > 76.0 GHz | f(highest) < 81.0 GHz |

**Measurement results:**

| Mode | Operating Frequency Range | | |
|---|---|---|---|
| | $f_L$ [GHz] | $f_H$ [GHz] | OBW [GHz] |
| Mode 5_5784 | 76.103 600 | 78.121 070 | 2.017 |
| Mode 5_5169 | 76.104 380 | 78.121 050 | 2.017 |
| Mode 5_4262 | 76.106 770 | 78.119 370 | 2.013 |

**Note:** for corresponding plots refer to chapter 12.1

## 12.4 Band edge compliance

**Description:**

Investigation of the emission limits at the band edge.

**Measurement:**

| Parameters | |
|---|---|
| Detector: | RMS |
| Sweep time: | 10 s |
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 3 MHz |
| Trace-Mode: | Max Hold |

**Limits:** **FCC §95.3379 (a) (2) (i) + (ii) / ANSI C63.10-2013 / 6.10**

| Frequency Range [GHz] | Measurement distance | Power Density |
|---|---|---|
| 40 – 200 | 3.0 m | 600 pW/cm$^2$ → -1.7 dBm |

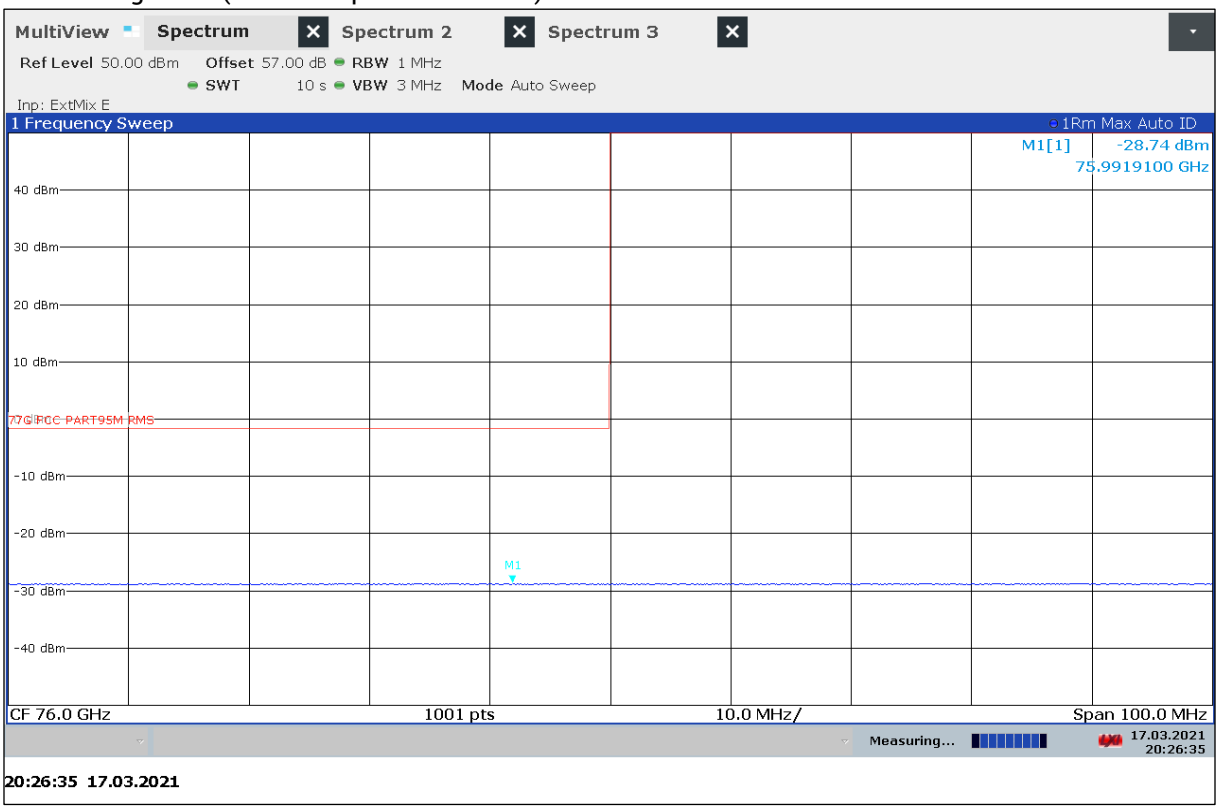
**Limits:** **FCC §95.3379 (b)**

| | | |
|---|---|---|
| Frequency range | f(lowest) > 76.0 GHz | f(highest) < 81.0 GHz |

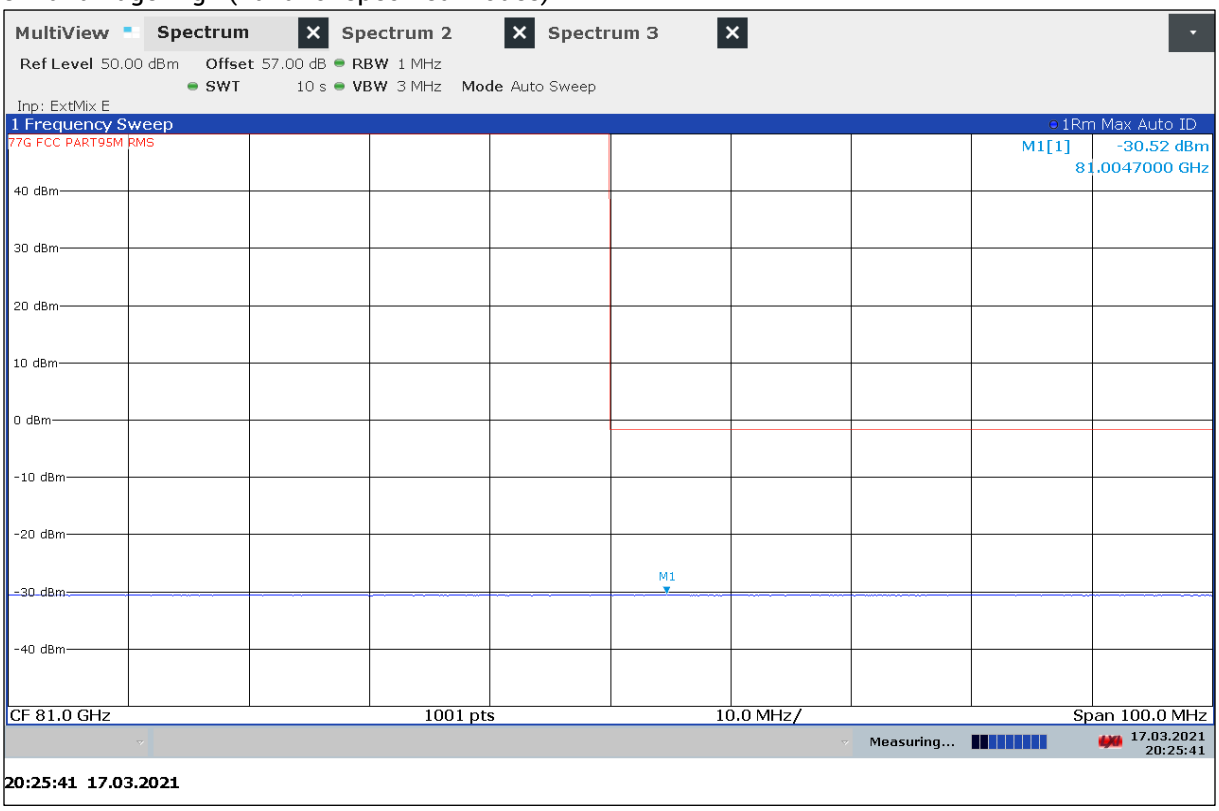
**Measurement results:**

See plots below.

Plot 7: Band Edge Low (Valid for specified Modes)




Plot 8: Band Edge High (Valid for specified Modes)



## 12.5 Field strength of spurious emissions

**Description:**

The power density of any emissions outside the 76-81 GHz band shall consist solely of spurious emissions and shall not exceed the following:

**Limits:** **FCC §95.3379**

| FCC | | |
|---|---|---|
| CFR Part 95.3379 (a) (1) / CFR Part 95.3379 (a) (3) | | |
| Radiated Spurious Emissions | | |
| Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in § 15.209, whichever is the lesser attenuation. | | |
| Frequency [MHz] | Field Strength [dBµV/m] | Measurement distance |
| 0.009 – 0.490 | 2400/F[kHz] | 300 |
| 0.490 – 1.705 | 24000/F[kHz] | 30 |
| 1.705 – 30.0 | 30 | 30 |
| 30  88 | 30.0 | 10 |
| 88 – 216 | 33.5 | 10 |
| 216 – 960 | 36.0 | 10 |
| 960 – 40 000 | 54.0 | 3 |

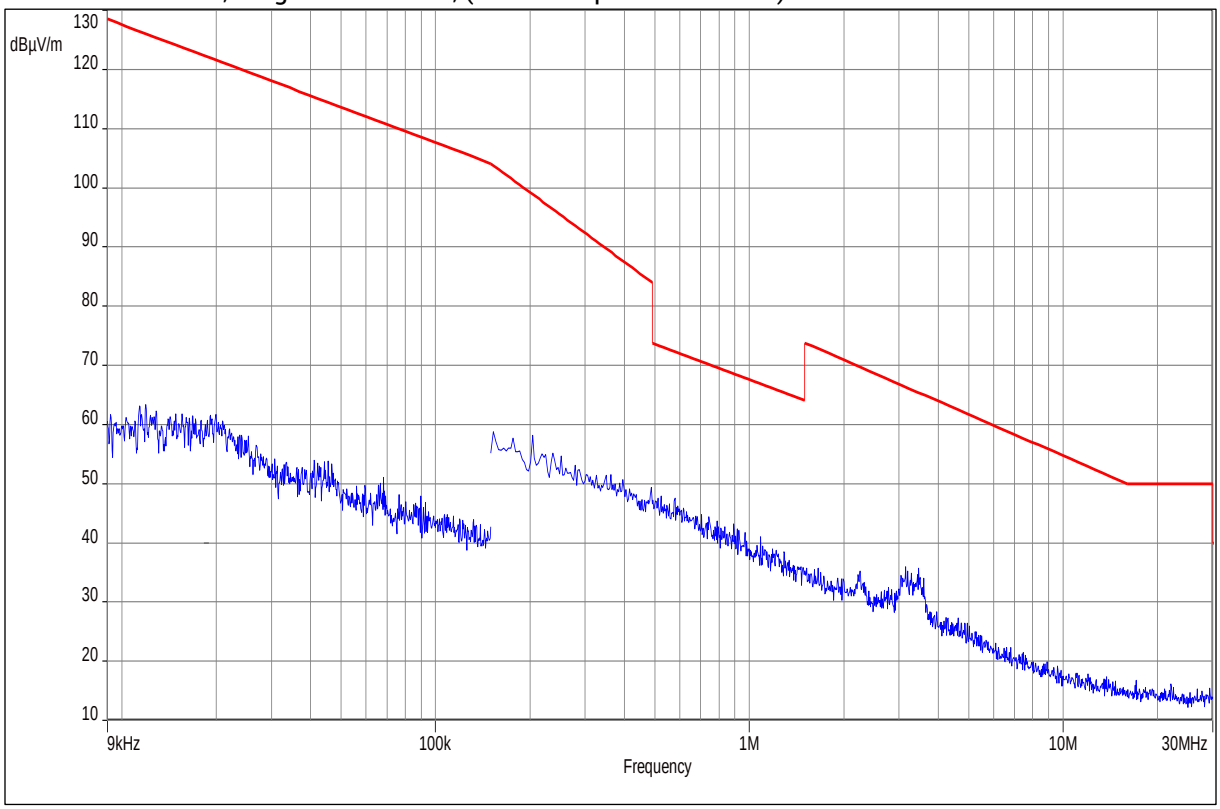
**Limits:** **FCC §95.3379 (a) (2) (i) + (ii)**

| Frequency Range [GHz] | Measurement distance | Power Density |
|---|---|---|
| 40 – 200 | 3.0 m | 600 pW/cm$^2$ → -1.7 dBm |
| 200 – 231 | 3.0 m | 1000 pW/cm$^2$ → +0.5 dBm |

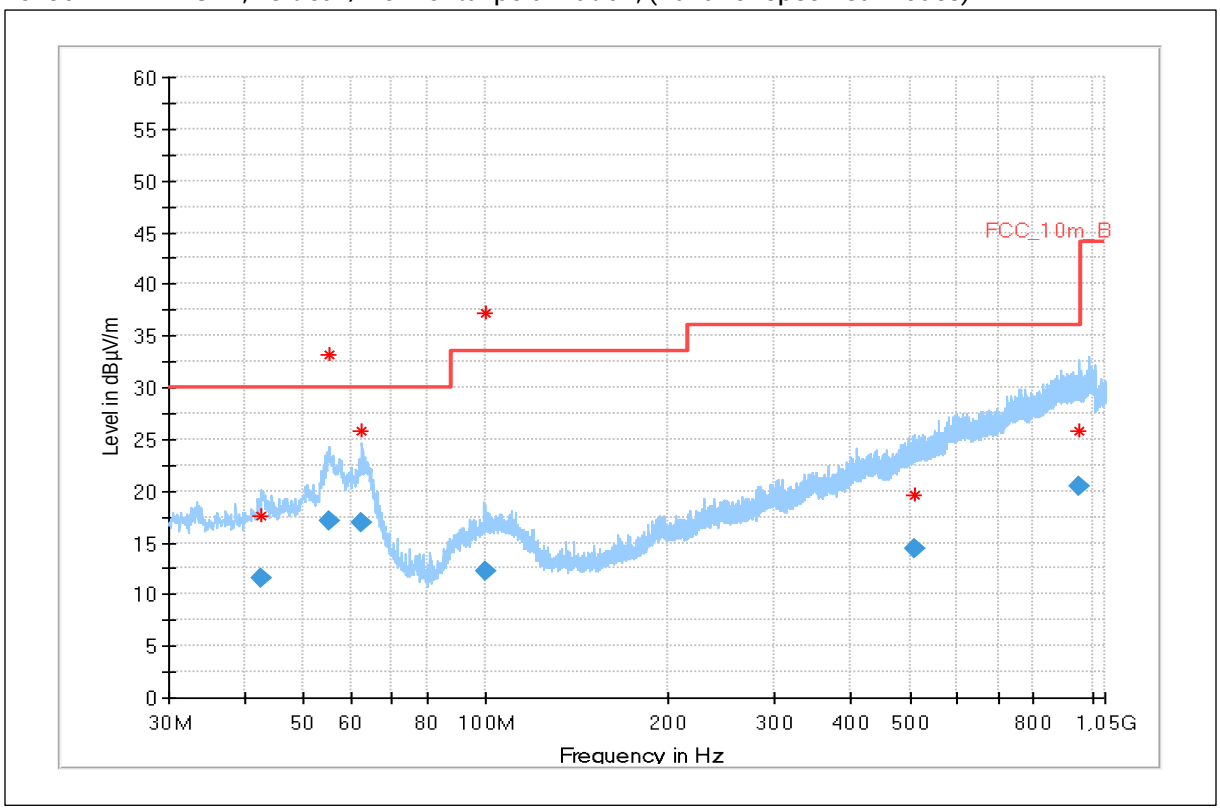
**Measurement results:**

| Frequency | Detector | Bandwidth | Level [dBµV] | Distance [m] | Limit [dBµV] | Margin [dB] |
|---|---|---|---|---|---|---|
| | | | | | | |
| 38.8 GHz | AVG | 1 MHz | 30.76 | 0.5 | 54 | 23.2 |
| | | | | | | |

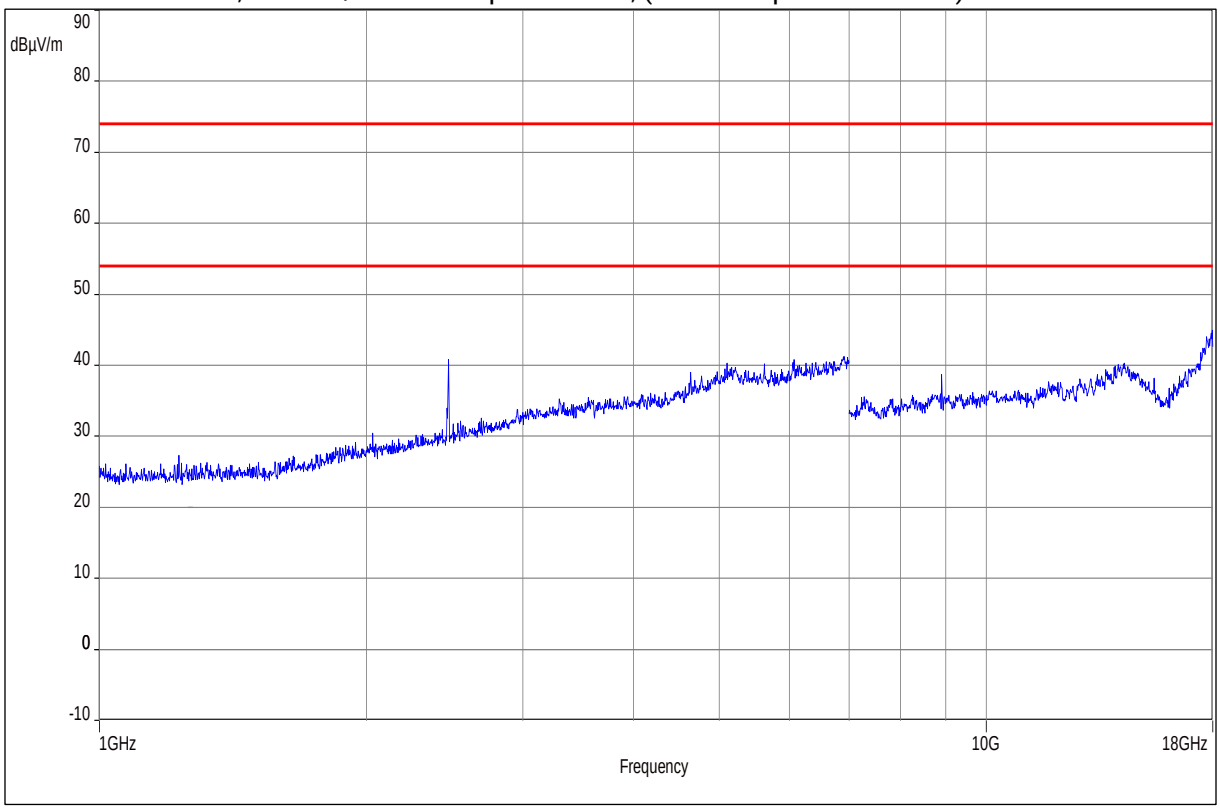
Plot 9: 9 kHz – 30 MHz, Magnetic antenna, (Valid for specified Modes)



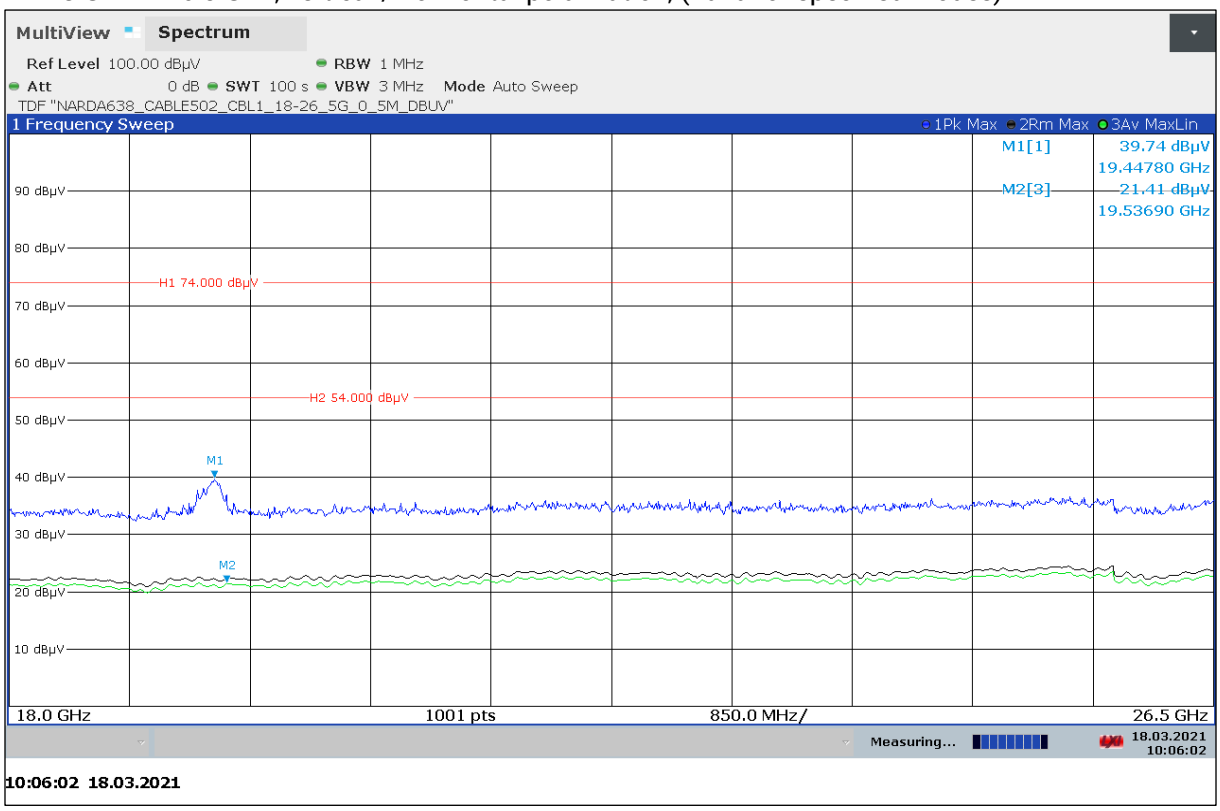

Plot 10: 30 MHz – 1 GHz, vertical / horizontal polarization, (Valid for specified Modes)



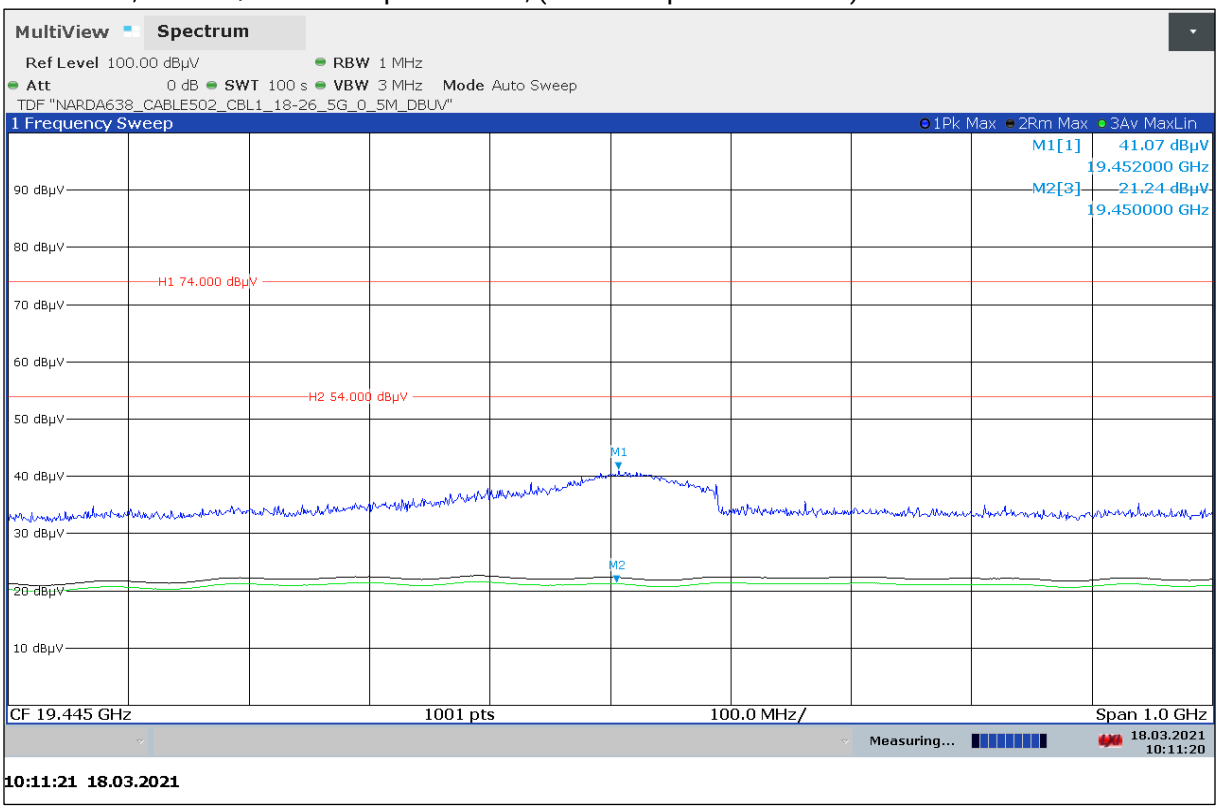
Plot 11: 1 GHz – 18 GHz, vertical / horizontal polarization, (Valid for specified Modes)



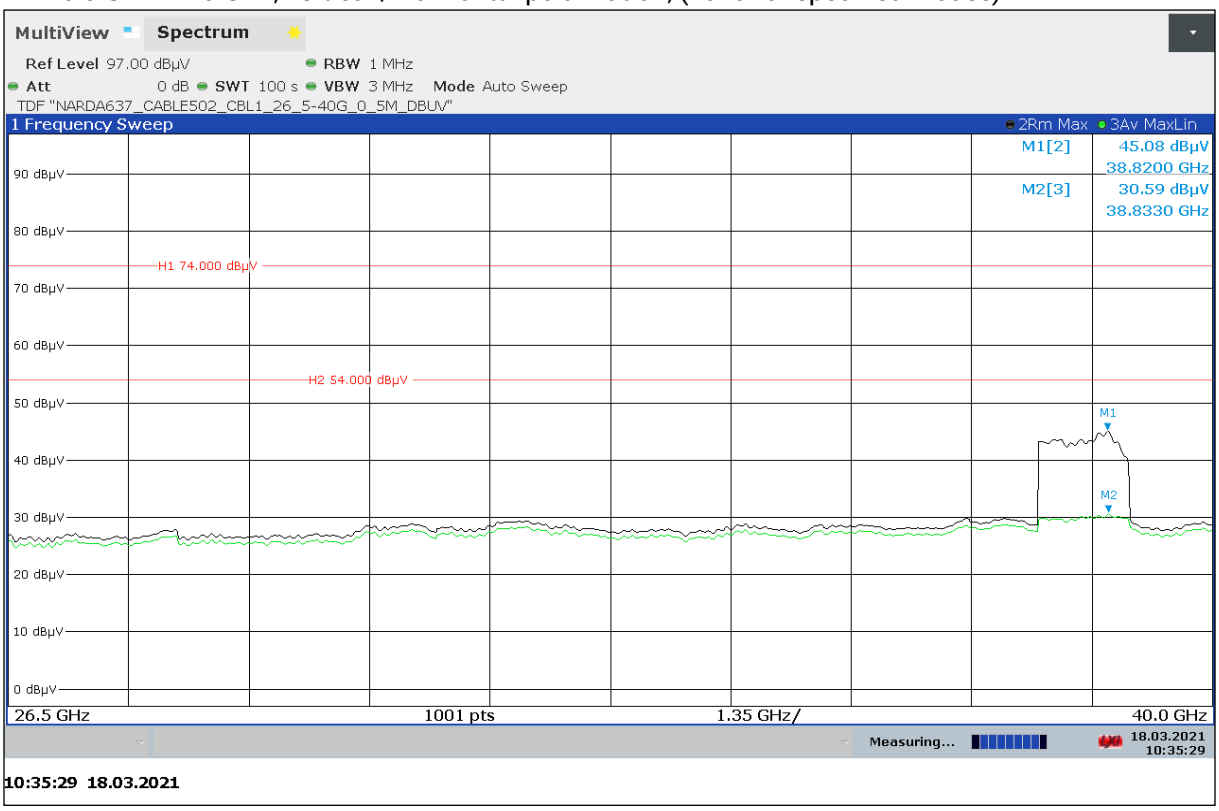

Plot 12: 18 GHz – 26.5 GHz, vertical / horizontal polarization, (Valid for specified Modes)



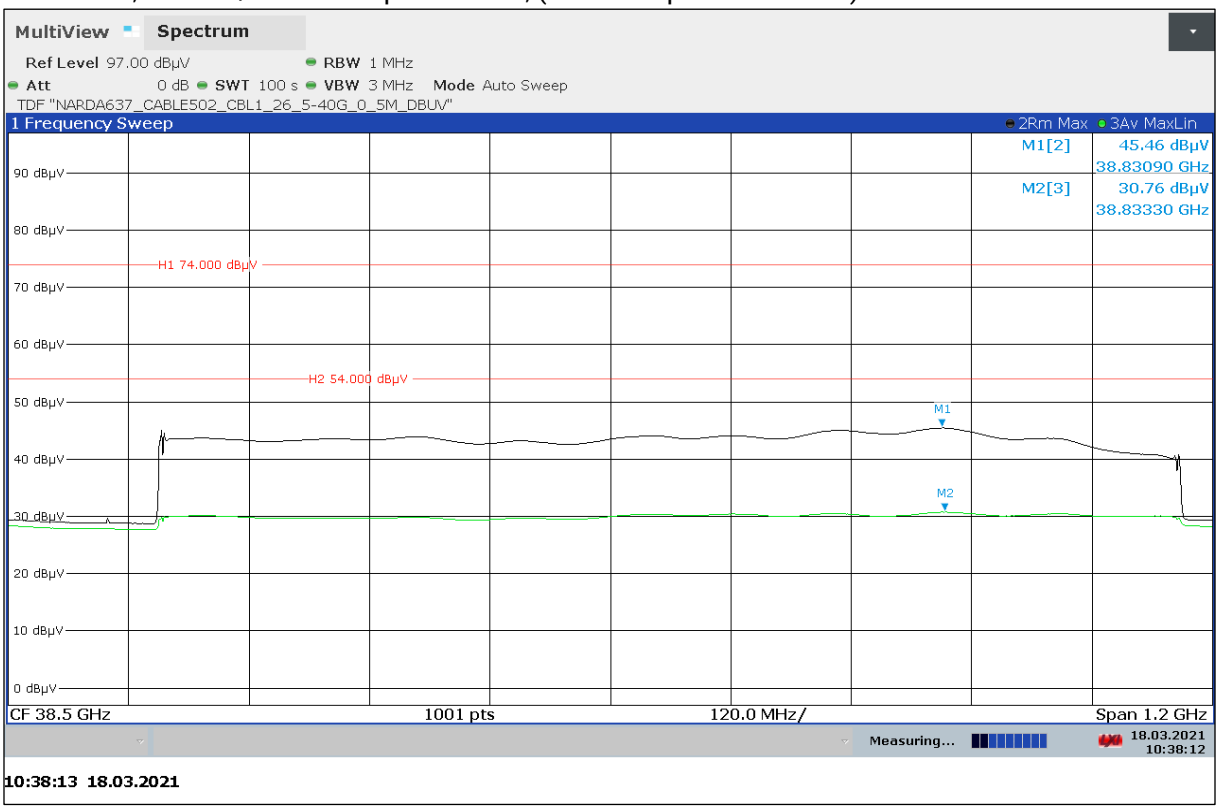
Plot 13: 19 GHz, vertical / horizontal polarization, (Valid for specified Modes)



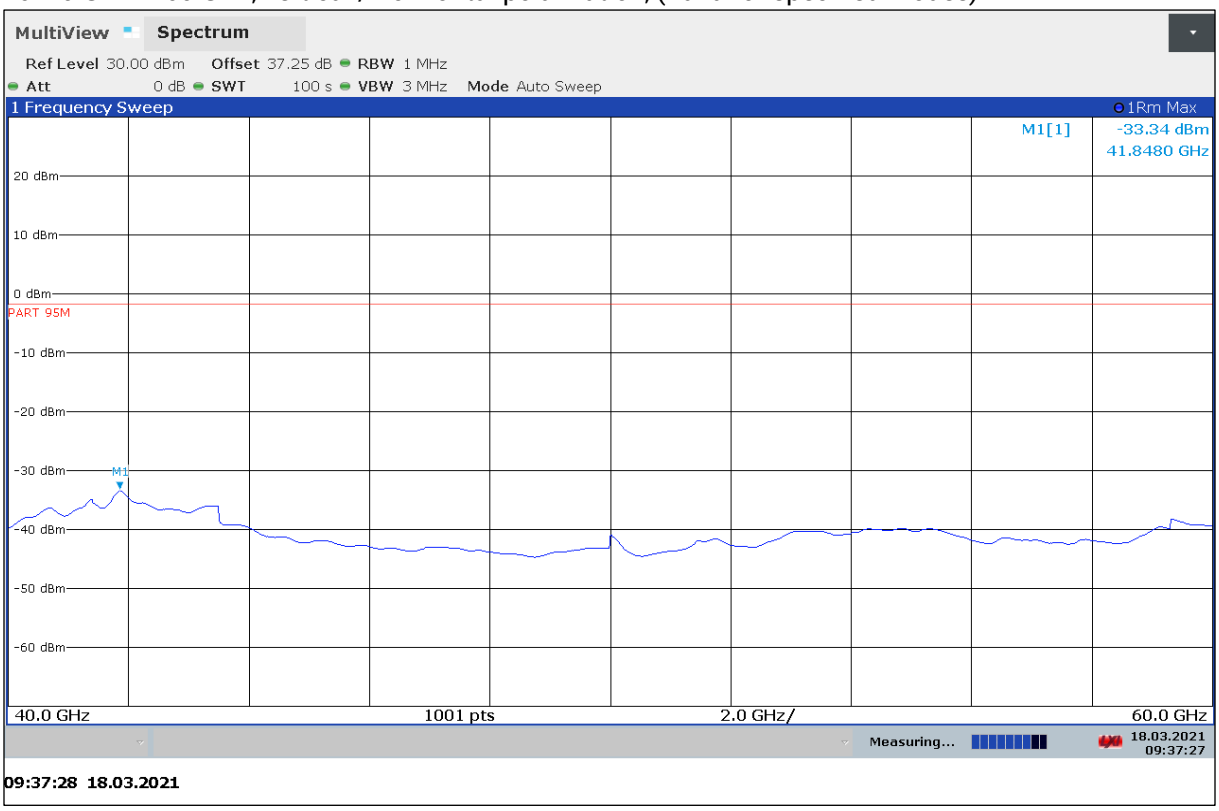

Plot 14: 26.5 GHz – 40 GHz, vertical / horizontal polarization, (Valid for specified Modes)



Plot 15: 38 GHz, vertical / horizontal polarization, (Valid for specified Modes)

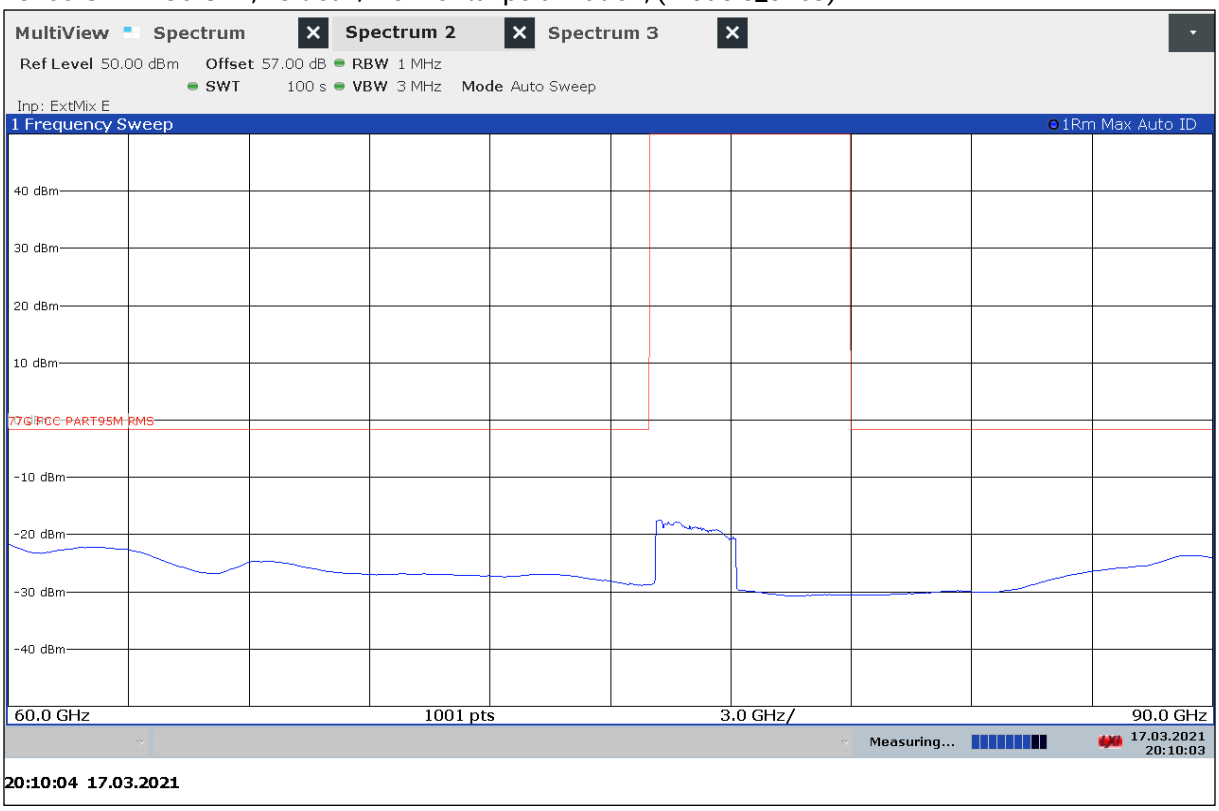



Plot 16: 40 GHz – 60 GHz, vertical / horizontal polarization, (Valid for specified Modes)



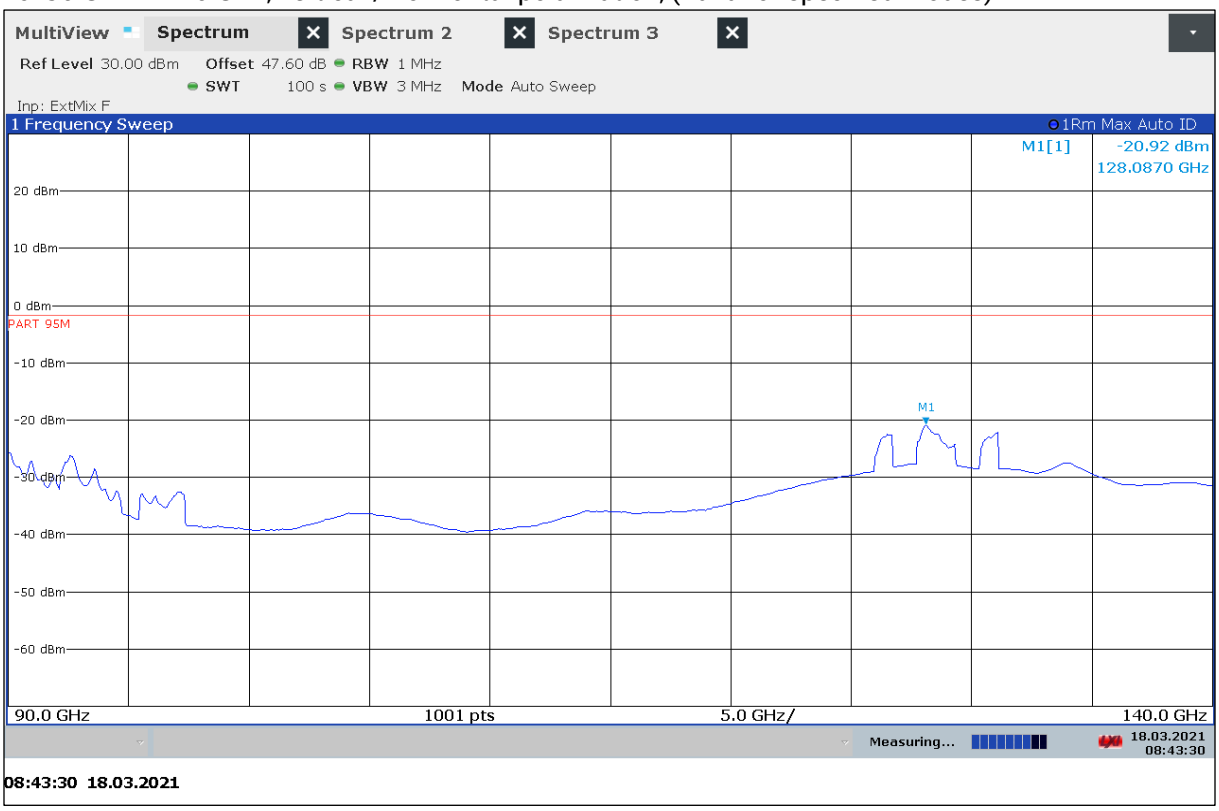
Plot 17: 60 GHz – 90 GHz, vertical / horizontal polarization, (Mode 5_5784)

Plot 18: 60 GHz – 90 GHz, vertical / horizontal polarization, (Mode 5_5169)

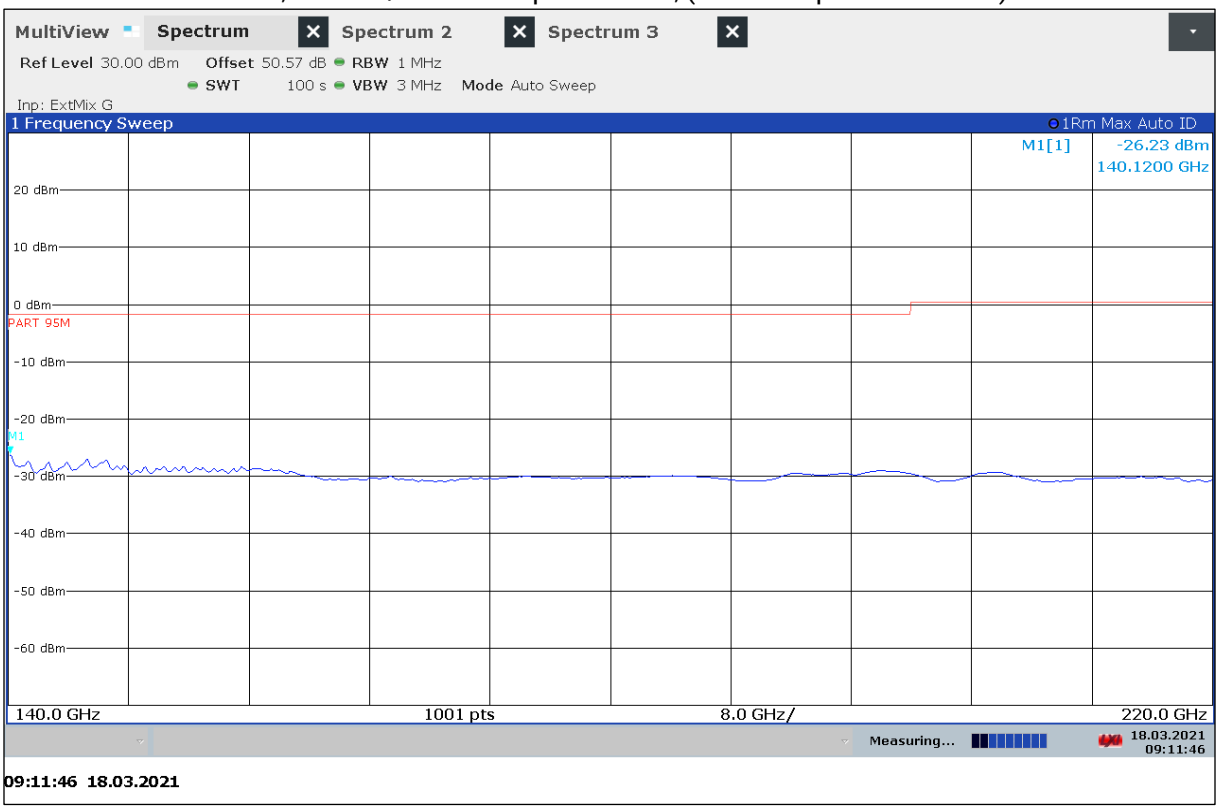


Plot 19: 60 GHz – 90 GHz, vertical / horizontal polarization, (Mode 5_4262)

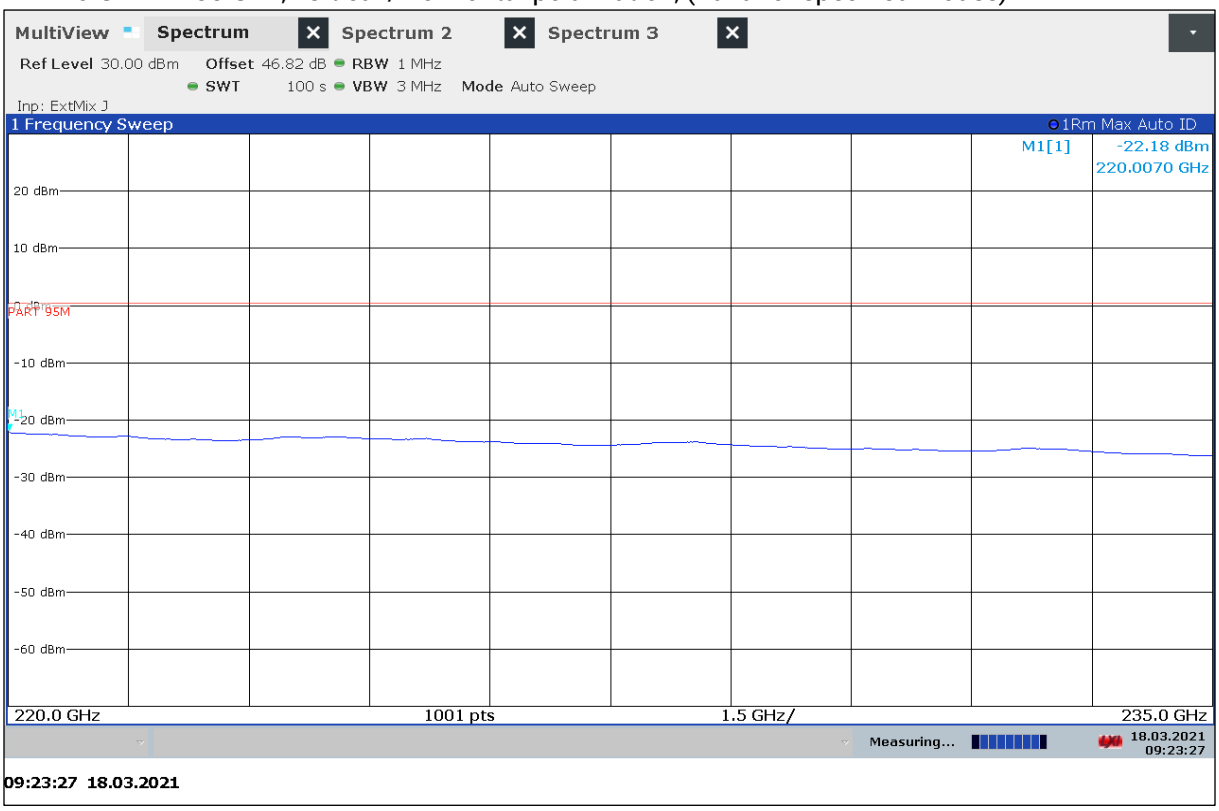
Plot 20: 90 GHz – 140 GHz, vertical / horizontal polarization, (Valid for specified Modes)



Plot 21: 140 GHz – 220 GHz, vertical / horizontal polarization, (Valid for specified Modes)




Plot 22: 220 GHz – 235 GHz, vertical / horizontal polarization, (Valid for specified Modes)



## 12.6 Frequency stability

**Description:**

§95.3379 (b) Fundamental emissions must be contained within the frequency bands specified in this section during all conditions of operation. Equipment is presumed to operate over the temperature range −20 to +50 degrees Celsius with an input voltage variation of 85% to 115% of rated input voltage, unless justification is presented to demonstrate otherwise.

**Limits:** **FCC §95.3379 (b)**

| | | |
|---|---|---|
| Frequency range | f(lowest) > 76.0 GHz | f(highest) < 81.0 GHz |

**Measurement results:**

**Mode 5_5784 (Worst Case)**

**Measurement results:**

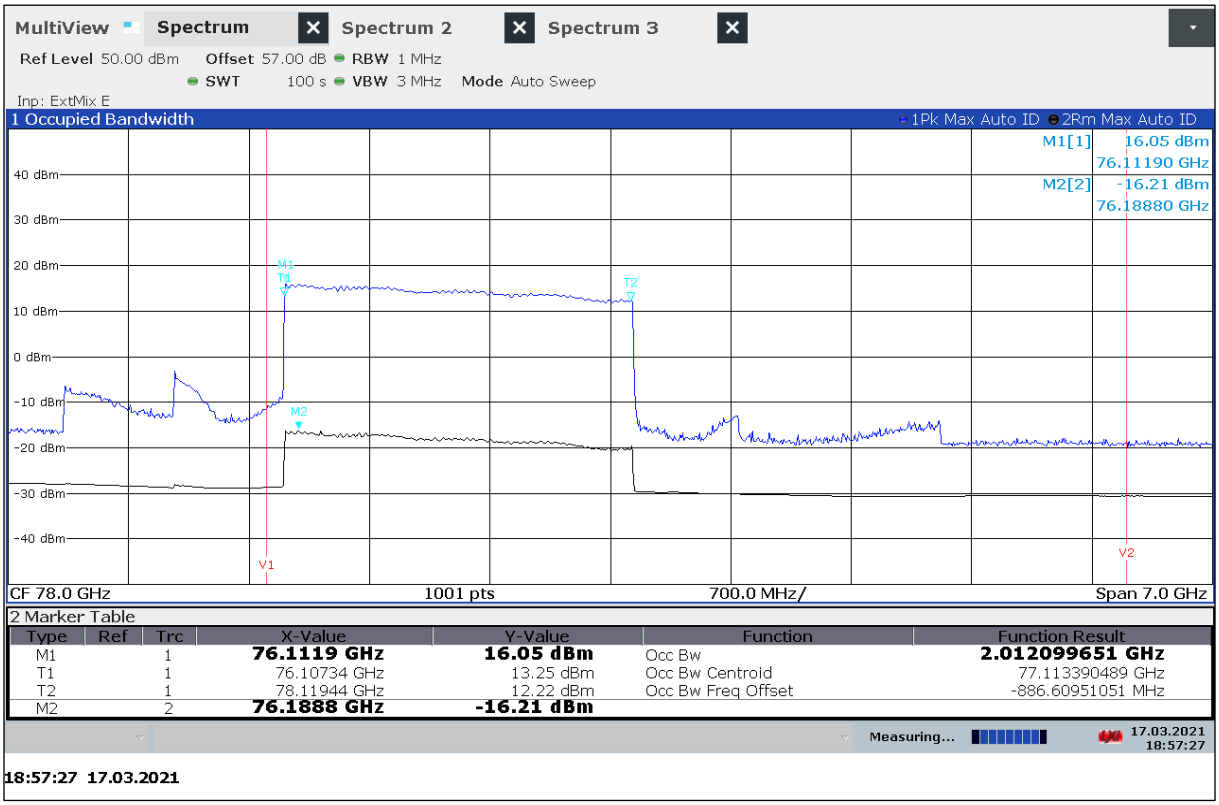
**Temperature variation**

| Mode | Temperature in °C | $f_L$ in GHz | $f_H$ in GHz | Bandwidth [GHz] |
|---|---|---|---|---|
| Mode 5_5784 (Worst case) | -20 °C / $V_{nom}$ | 76.107 340 | 78.119 440 | 2.012 |
| | -10 °C / $V_{nom}$ | 76.106 160 | 78.122 030 | 2.016 |
| | 0 °C / $V_{nom}$ | 76.109 370 | 78.122 500 | 2.013 |
| | 10 °C / $V_{nom}$ | 76.109 020 | 78.120 350 | 2.011 |
| | 20 °C / $V_{min-max}$ | 76.103 630 | 78.119 830 | 2.016 |
| | 30 °C / $V_{nom}$ | 76.102 690 | 78.121 410 | 2.019 |
| | 40 °C / $V_{nom}$ | 76.102 570 | 78.122 200 | 2.020 |
| | 50 °C / $V_{min-max}$ | 76.102 690 | 78.121 730 | 2.019 |

**Voltage variation**

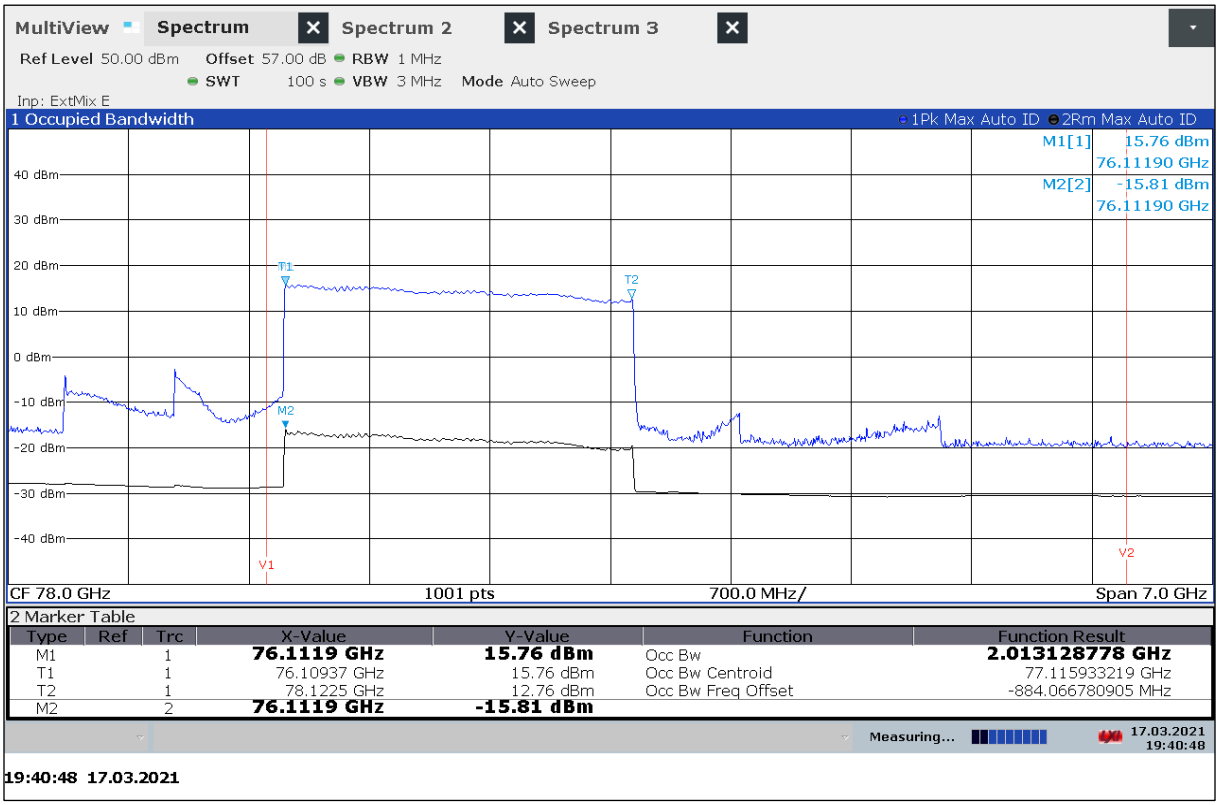
| Voltage variation of rated input voltage | $f_L$ in GHz | $f_H$ in GHz |
|---|---|---|
| < 85 % of U | Voltage variation does not affect the radiated signal | |
| > 115 % of U | | |

Plot 23: OBW, -20 °C / $V_{nom}$



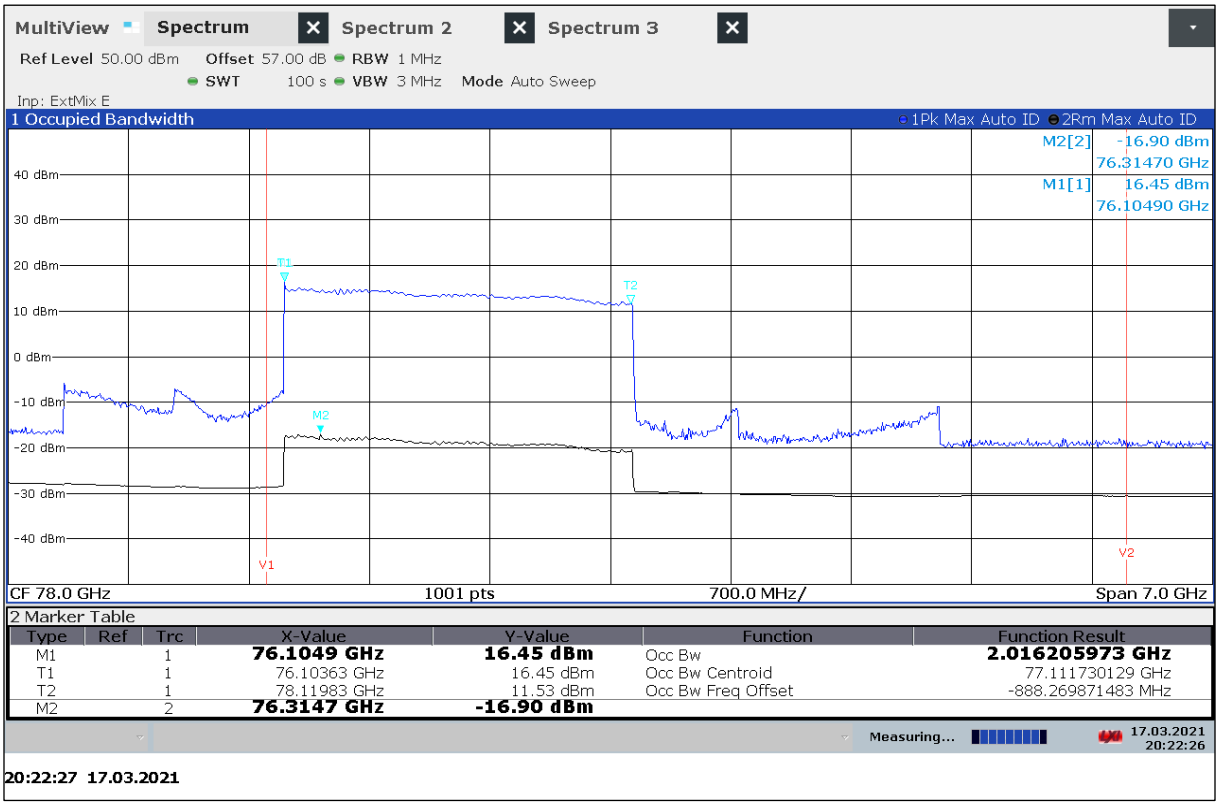

Plot 24: OBW, -10 °C / $V_{nom}$

Plot 25: OBW, 0 °C / $V_{nom}$



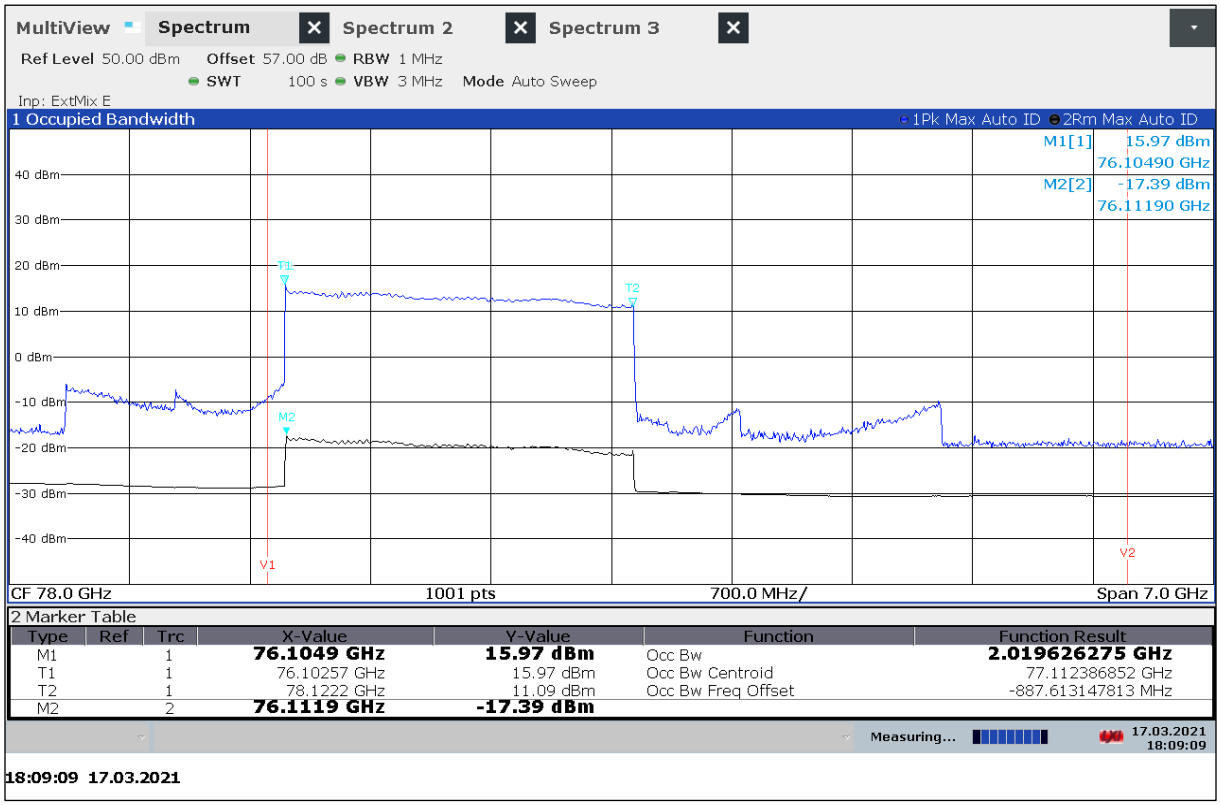

Plot 26: OBW, 10 °C / $V_{nom}$

Plot 27: OBW, 20 °C / $V_{min-max}$




Plot 28: OBW, 30 °C / $V_{nom}$

Plot 29: OBW, 40 °C / $V_{nom}$




Plot 30: OBW, 50 °C / $V_{min\text{-}max}$

# 13 Glossary

| | |
|---|---|
| **EUT** | Equipment under test |
| **DUT** | Device under test |
| **UUT** | Unit under test |
| **GUE** | GNSS User Equipment |
| **ETSI** | European Telecommunications Standards Institute |
| **EN** | European Standard |
| **FCC** | Federal Communications Commission |
| **FCC ID** | Company Identifier at FCC |
| **IC** | Industry Canada |
| **PMN** | Product marketing name |
| **HMN** | Host marketing name |
| **HVIN** | Hardware version identification number |
| **FVIN** | Firmware version identification number |
| **EMC** | Electromagnetic Compatibility |
| **HW** | Hardware |
| **SW** | Software |
| **Inv. No.** | Inventory number |
| **S/N or SN** | Serial number |
| **C** | Compliant |
| **NC** | Not compliant |
| **NA** | Not applicable |
| **NP** | Not performed |
| **PP** | Positive peak |
| **QP** | Quasi peak |
| **AVG** | Average |
| **OC** | Operating channel |
| **OCW** | Operating channel bandwidth |
| **OBW** | Occupied bandwidth |
| **OOB** | Out of band |
| **DFS** | Dynamic frequency selection |
| **CAC** | Channel availability check |
| **OP** | Occupancy period |
| **NOP** | Non occupancy period |
| **DC** | Duty cycle |
| **PER** | Packet error rate |
| **CW** | Clean wave |
| **WLAN** | Wireless local area network |
| **MC** | Modulated carrier |
| **RLAN** | Radio local area network |
| **DSSS** | Dynamic sequence spread spectrum |
| **OFDM** | Orthogonal frequency division multiplexing |
| **FHSS** | Frequency hopping spread spectrum |
| **GNSS** | Global Navigation Satellite System |
| **$C/N_0$** | Carrier to noise-density ratio, expressed in dB-Hz |

## 14 Document history

| Version | Applied changes | Date of release |
|---|---|---|
| -/- | Initial release - DRAFT | 2021-04-15 |
| -/- | Minor changes | 2021-05-19 |

## 15 Accreditation Certificate – D-PL-12076-01-05

| first page | last page |
|---|---|

DAkkS Deutsche Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

**Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV**
Signatory to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition

**Accreditation**

The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory

**CTC advanced GmbH**
**Untertürkheimer Straße 6-10, 66117 Saarbrücken**

is competent under the terms of DIN EN ISO/IEC 17025:2018 to carry out tests in the following fields:

**Telecommunication (FCC Requirements)**

The accreditation certificate shall only apply in connection with the notice of accreditation of 09.06.2020 with the accreditation number D-PL-12076-01. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 05 pages.

Registration number of the certificate: **D-PL-12076-01-05**

Frankfurt am Main, 09.06.2020

by order Dipl.-Ing. (FH) Ralf Egner
Head of Division

*The certificate together with its annex reflects the status at the time of the date of issue. The current status of the scope of accreditation can be found in the database of accredited bodies of Deutsche Akkreditierungsstelle GmbH.*
*https://www.dakks.de/en/content/accredited-bodies-dakks*

See notes overleaf.

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The publication of extracts of the accreditation certificate is subject to the prior written approval by Deutsche Akkreditierungsstelle GmbH (DAkkS). Exempted is the unchanged form of separate disseminations of the cover sheet by the conformity assessment body mentioned overleaf.

No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkkS.

The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 31 July 2009 (Federal Law Gazette I p. 2625) and the Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products (Official Journal of the European Union L 218 of 9 July 2008, p. 30). DAkkS is a signatory to the Multilateral Agreements for Mutual Recognition of the European co-operation for Accreditation (EA), International Accreditation Forum (IAF) and International Laboratory Accreditation Cooperation (ILAC). The signatories to these agreements recognise each other's accreditations.

The up-to-date state of membership can be retrieved from the following websites:
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ILAC: www.ilac.org
IAF: www.iaf.nu

**Note: The current certificate annex is published on the website (link see below) of the Accreditation Body DAkkS or may be received by CTC advanced GmbH on request**

https://www.dakks.de/as/ast/d/D-PL-12076-01-05e.pdf

################################## END OF TEST REPORT ##########################