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Bundesnetzagentur

BNetzA-CAB-02/21-102

## TEST REPORT

Test report no.: 1-5906/18-02-02-B



**DAkkS**  
Deutsche  
Akkreditierungsstelle  
D-PL-12076-01-03

### Testing laboratory

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#### Accredited Testing Laboratory:

The testing laboratory (area of testing) is accredited according to DIN EN ISO/IEC 17025 (2005) by the Deutsche Akkreditierungsstelle GmbH (DAkkS). The accreditation is valid for the scope of testing procedures as stated in the accreditation certificate with the registration number: D-PL-12076-01-03

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### Manufacturer

**RFbeam Microwave GmbH**  
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### Test standard/s

CFR 47 Part 95, The 76-81 GHz Band Radar Service  
Subpart M

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

### Test Item

**Kind of test item:** Automotive Radar  
**Model name:** WDR77-VES  
**FCC ID:** 2ASYV-WDR77-VES  
**Frequency:** 76.0 GHz – 77 GHz  
**Antenna:** Integrated patch antenna  
**Power supply:** 9.5 V to 14.5 V DC by external power supply  
**Temperature range:** -40°C to +85°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:

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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.

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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.

**This test report replaces the test report with the number 1-5906/18-02-02-A and dated 2019-08-07**

### 2.2 Application details

|                                    |                   |
|------------------------------------|-------------------|
| Date of receipt of order:          | 2019-01-14        |
| Date of receipt of test item:      | 2019-01-21        |
| Start of test:                     | 2019-01-21        |
| End of test:                       | 2019-03-28        |
| Person(s) present during the test: | Mr. Léon Audergon |

### 2.3 Test laboratories sub-contracted

None

### 3 Test standard/s and references

| Test standard                | Date    | Description                      |
|------------------------------|---------|----------------------------------|
| CFR 47 Part 95,<br>Subpart M | 2018-12 | The 76-81 GHz Band Radar Service |

| 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  |
| KDB 653005 D01   | V01     | Equipment Authorization Guidance for 76-81 GHz Radar Devices  |

### 4 Test environment

|                           |   |                  |                                      |
|---------------------------|---|------------------|--------------------------------------|
| Temperature               | : | $T_{\text{nom}}$ | +22 °C during room temperature tests |
|                           |   | $T_{\text{max}}$ | +85 °C during high temperature tests |
|                           |   | $T_{\text{min}}$ | -40 °C during low temperature tests  |
| Relative humidity content | : |                  | 55 %                                 |
| Barometric pressure       | : |                  | 1021 hpa                             |
| Power supply              | : | $V_{\text{nom}}$ | 12.0 V DC by external power supply   |
|                           |   | $V_{\text{max}}$ | 14.5 V                               |
|                           |   | $V_{\text{min}}$ | 9.5 V                                |

## 5 Test item

### 5.1 General description

|                     |   |   |
|---------------------|---|---|
| Kind of test item   | : | Automotive Radar                            |
| Type identification | : | WDR77-VES                                   |
| S/N serial number   | : | L1808n00001                                 |
| Hardware status     | : | C0  |
| Software status     | : | V1.09                                       |
| Firmware status     | : | 99  |
| Frequency band      | : | 76.0 GHz – 77 GHz                           |
| Type of modulation  | : | FMCW  |
| Number of modes     | : | 1   |
| Antenna             | : | Integrated patch antenna                    |
| Power supply        | : | 9.5 V to 14.5 V DC by external power supply |
| Temperature range   | : | -40°C to +85°C                              |

### 5.2 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: 1-5906/18-01-01\_AnnexA  
1-5906/18-01-01\_AnnexB  
1-5906/18-01-01\_AnnexD

## 6 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).

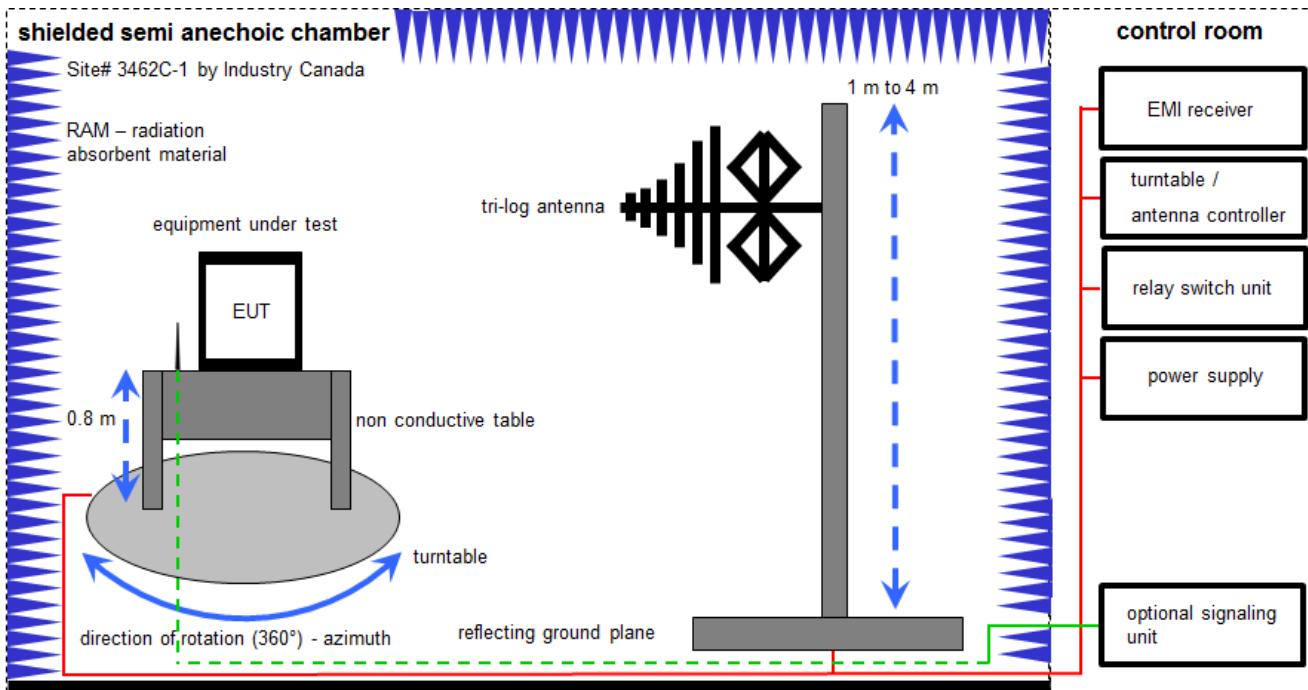
In order to simplify the identification of the equipment used at some special tests, some items of test equipment and ancillaries can be provided with an identifier or number in the equipment list below (Lab/Item).

### 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     |

## 6.1 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)

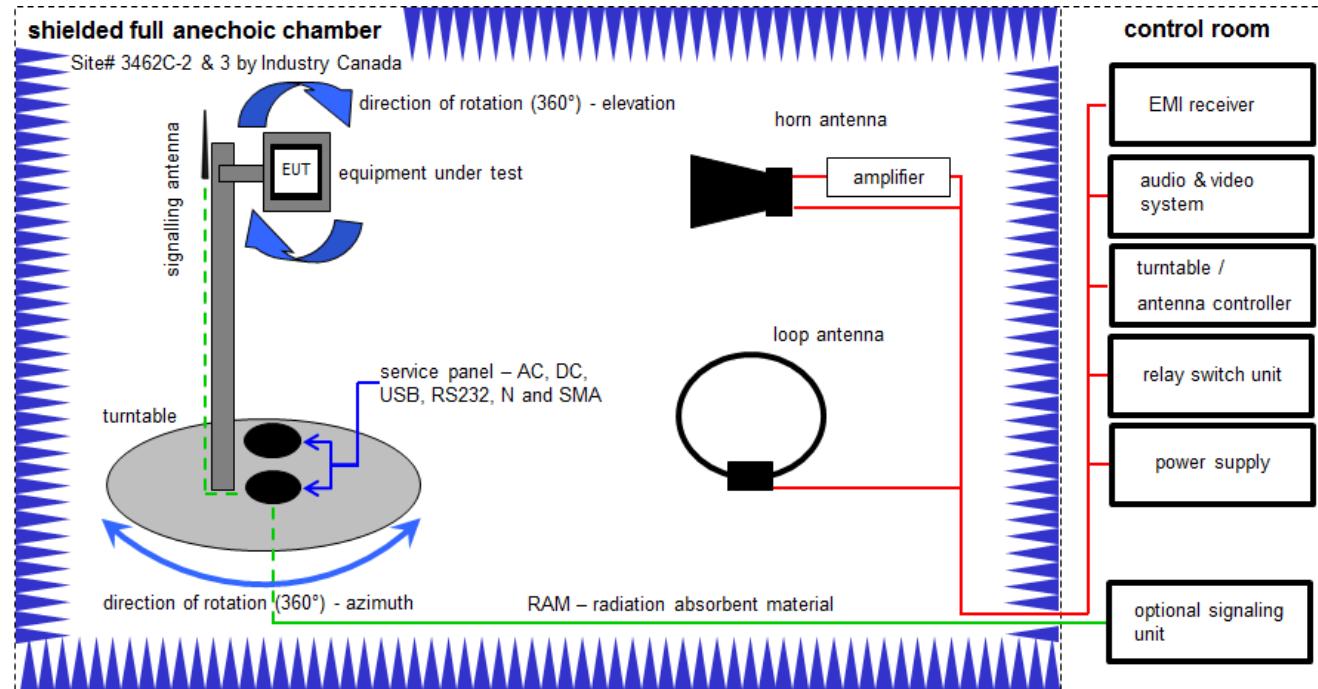
Example calculation:

$$FS [dB\mu V/m] = 12.35 [dB\mu V/m] + 1.90 [dB] + 16.80 [dB/m] = 31.05 [dB\mu V/m] (35.69 \mu V/m)$$

**Equipment table:**

| No. | Lab / Item | Equipment   | Type             | Manufacturer                  | Serial No.      | INV. No.  | Kind of Calibration | Last Calibration | Next Calibration |
|-----|------------|---|------------------|-------------------------------|-----------------|-----------|---------------------|------------------|------------------|
| 1   | 45         | Switch-Unit                                       | 3488A            | HP                            | 2719A14505      | 300000368 | ev                  | -/-              | -/-              |
| 2   | 50         | DC power supply,<br>60Vdc, 50A, 1200 W            | 6032A            | HP                            | 2920A04466      | 300000580 | ne                  | -/-              | -/-              |
| 3   | 93         | Meßkabine 1                                       | HF-Absorberhalle | MWB AG 300023                 |                 | 300000551 | ne                  | -/-              | -/-              |
| 4   | n. a.      | EMI Test Receiver                                 | ESCI 3           | R&S                           | 100083          | 300003312 | k                   | 12.12.2018       | 11.12.2019       |
| 5   | n. a.      | Analyzer-Reference-System (Harmonics and Flicker) | ARS 16/1         | SPS                           | A3509 07/0 0205 | 300003314 | vlKI!               | 15.01.2018       | 14.01.2020       |
| 6   | n. a.      | Antenna Tower                                     | Model 2175       | ETS-Lindgren                  | 64762           | 300003745 | izw                 | -/-              | -/-              |
| 7   | n. a.      | Positioning Controller                            | Model 2090       | ETS-Lindgren                  | 64672           | 300003746 | izw                 | -/-              | -/-              |
| 8   | n. a.      | Turntable Interface-Box                           | Model 105637     | ETS-Lindgren                  | 44583           | 300003747 | izw                 | -/-              | -/-              |
| 9   | n. a.      | TRILOG Broadband Test-Antenna 30 MHz - 3 GHz      | VULB9163         | Schwarzbeck Mess - Elektronik | 371             | 300003854 | vlKI!               | 24.11.2017       | 23.11.2020       |
| 10  | n. a.      | Spectrum-Analyzer                                 | FSU26            | R&S                           | 200809          | 300003874 | k                   | 17.12.2018       | 16.12.2019       |

## 6.2 Shielded fully anechoic chamber



$$FS = UR + CA + AF$$

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

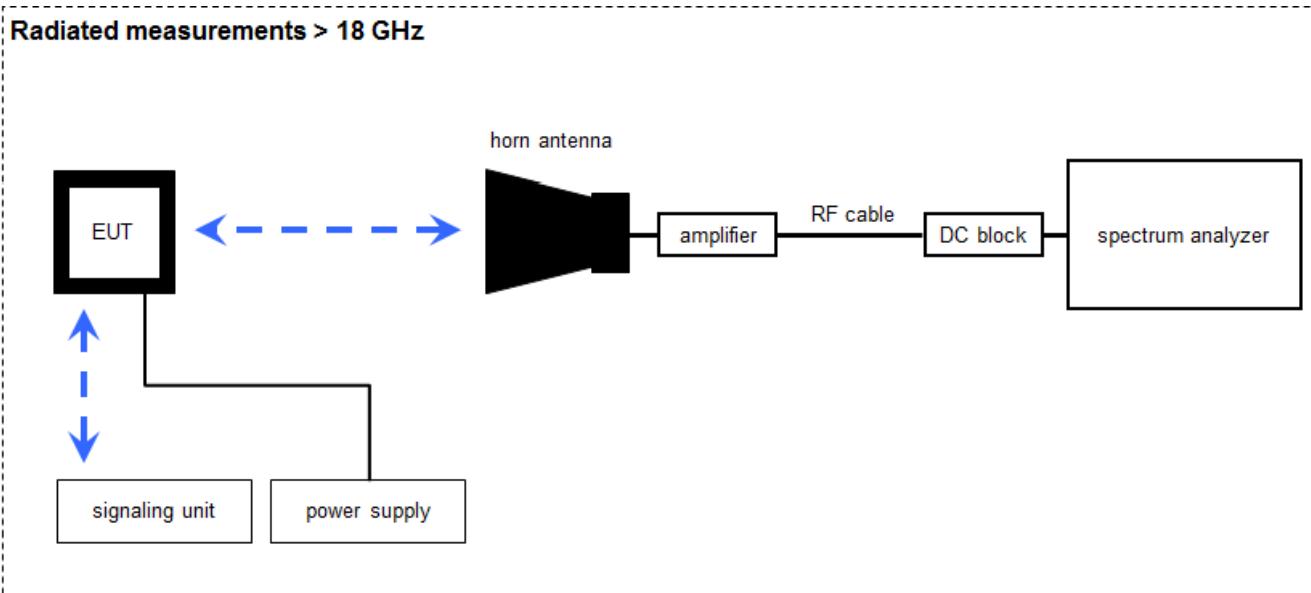
Example calculation:

$$FS [\text{dB}\mu\text{V/m}] = 40.0 [\text{dB}\mu\text{V/m}] + (-35.8) [\text{dB}] + 32.9 [\text{dB}/\text{m}] = 37.1 [\text{dB}\mu\text{V/m}] (71.61 \mu\text{V/m})$$

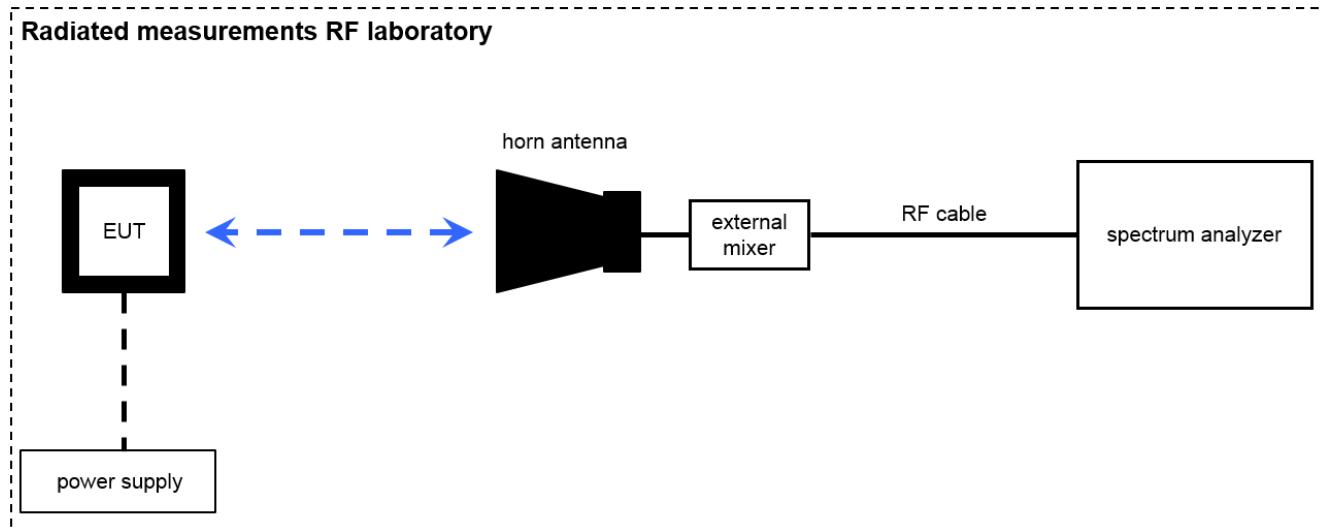
Equipment table:

| 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 | vlKI!               | 12.12.2017       | 11.12.2020       |
| 2   | n. a.      | Active Loop Antenna 9 kHz to 30 MHz            | 6502  | EMCO                 | 2210       | 300001015 | vlKI!               | 07.07.2017       | 06.07.2019       |
| 3   | n. a.      | Anechoic chamber                               | FAC 3/5m                                      | MWB / TDK            | 87400/02   | 300000996 | ev                  | -/-              | -/-              |
| 4   | 19         | Double-Ridged Waveguide Horn Antenna 1-18.0GHz | 3115  | EMCO                 | 9107-3697  | 300001605 | vlKI!               | 14.02.2017       | 13.02.2019       |
| 5   | n. a.      | Switch / Control Unit                          | 3488A   | HP                   | *          | 300000199 | ne                  | -/-              | -/-              |
| 6   | 9          | Variable isolating transformer                 | MPL IEC625 Bus Variable isolating transformer | Erfi                 | 91350      | 300001155 | ne                  | -/-              | -/-              |
| 7   | n. a.      | EMI Test Receiver 20Hz- 26.5GHz                | ESU26   | R&S                  | 100037     | 300003555 | k                   | 14.09.2018       | 13.12.2019       |
| 8   | n. a.      | Highpass Filter                                | WHKX7.0/18G-8SS                               | Wainwright           | 19         | 300003790 | ne                  | -/-              | -/-              |
| 9   | n. a.      | Broadband Amplifier 0.5-18 GHz                 | CBLU5184540                                   | CERNEX               | 22049      | 300004481 | ev                  | -/-              | -/-              |
| 10  | n. a.      | Broadband Amplifier 5-13 GHz                   | CBLU5135235                                   | CERNEX               | 22010      | 300004491 | ev                  | -/-              | -/-              |
| 11  | n. a.      | 4U RF Switch Platform                          | L4491A  | Agilent Technologies | MY50000037 | 300004509 | ne                  | -/-              | -/-              |
| 12  | n. a.      | NEXIO EMV-Software                             | BAT EMC V3.16.0.49                            | EMCO                 |            | 300004682 | ne                  | -/-              | -/-              |
| 13  | n. a.      | PC   | ExOne   | F+W                  |            | 300004703 | ne                  | -/-              | -/-              |
| 14  | n. a.      | RF-Amplifier                                   | AMF-6F06001800-30-10P-R                       | NARDA-MITEQ Inc      | 2011572    | 300005241 | ev                  | -/-              | -/-              |

### 6.3 Radiated measurements > 18 GHz



### 6.4 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:

$$OP [dBm] = -54.0 [dBm] + 64.0 [dB] - 20.0 [dBi] = -10 [dBm] (100 \mu W)$$

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   | CR 79      | Std. Gain Horn Antenna 26.5-40.0 GHz | V637          | Narda                   | 7911       | 300001751 | ne                  | -/-              | -/-              |
| 2   | A023       | Std. Gain Horn Antenna 39.3-59.7 GHz | 2424-20       | Flann                   | 75         | 300001979 | ne                  | -/-              | -/-              |
| 3   | A025       | Std. Gain Horn Antenna 49.9-75.8 GHz | 2524-20       | Flann                   | *          | 300001983 | ne                  | -/-              | -/-              |
| 4   | A027       | Std. Gain Horn Antenna 73.8-112 GHz  | 2724-20       | Flann                   | *          | 300001988 | ne                  | -/-              | -/-              |
| 5   | A032       | Std. Gain Horn Antenna 114-173 GHz   | 2924-20       | Flann                   | *          | 300001999 | ne                  | -/-              | -/-              |
| 6   | A033       | Std. Gain Horn Antenna 145-220 GHz   | 3024-20       | Flann                   | *          | 300002000 | ne                  | -/-              | -/-              |
| 7   | A027       | Std. Gain Horn Antenna 18.0-26.5 GHz | 638           | Narda                   |            | 300000486 | vIKI!               | 13.12.2017       | 12.12.2019       |
| 8   | n. a.      | Harmonic Mixer 3-Port, 110-170 GHz   | SAM-170       | Radiometer Physics GmbH | 100014     | 300004156 | k                   | 15.03.2018       | 14.03.2019       |
| 9   | n. a.      | Harmonic Mixer 3-Port, 140-220 GHz   | SAM-220       | Radiometer Physics GmbH | 200001     | 300004157 | k                   | 08.08.2018       | 07.08.2019       |
| 10  | n. a.      | Harmonic Mixer 3-Port, 220-325 GHz   | SAM-325       | Radiometer Physics GmbH | 100002     | 300004158 | k                   | 02.08.2018       | 01.08.2019       |
| 11  | n. a.      | Std. Gain Horn Antenna 33.0-50.1 GHz | 2324-20       | Flann                   | 57         | 400000683 | ne                  | -/-              | -/-              |
| 12  | n. a.      | Std. Gain Horn Antenna 60-90 GHz     | COR 60_90     | Thomson CSF             |            | 300000814 | ev                  | -/-              | -/-              |
| 13  | n. a.      | Broadband LNA 18-50 GHz              | CBL18503070PN | CERNEX                  | 25240      | 300004948 | ev                  | -/-              | -/-              |
| 14  | n. a.      | Std. Gain Horn Antenna 217-330 GHz   | 32240-20      | Flann                   | 233278     | 300004960 | ne                  | -/-              | -/-              |
| 15  | n. a.      | Harmonic Mixer 3-Port, 75-110 GHz    | FS-Z110       | R&S                     | 101411     | 300004959 | k                   | 23.07.2018       | 22.07.2019       |
| 16  | n. a.      | Spectrum Analyzer                    | FSW85         | Rohde & Schwarz         | 101333     | 300005568 | k                   | 29.06.2018       | 28.06.2019       |
| 17  | n. a.      | Temperature Test Chamber             | T-40/50       | CTS GmbH                | 064023     | 300003540 | ev                  | 07.05.2018       | 06.05.2020       |

## 7 Sequence of testing

### 7.1 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.

## 7.2 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.

### Premereasurement

- 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  $\pm 45^\circ$  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.

## 7.3 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.

### Premereasurement

- 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.

## 7.4 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.

## 7.5 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.

## 8 Measurement uncertainty

| Test case   | Uncertainty   |
|---|---|
| Equivalent isotropically radiated power (e.i.r.p.)                  | Conducted value $\pm 1$ dB<br>Radiated value $\pm 3$ dB |
| Permitted range of operating frequencies                            | $\pm 100$ kHz   |
| Conducted unwanted emissions in the spurious domain (up to 40 GHz)  | $\pm 1$ dB  |
| Radiated unwanted emissions in the spurious domain (up to 40 GHz)   | $\pm 3$ dB  |
| Conducted unwanted emissions in the spurious domain (40 to 50 GHz)  | $\pm 4$ dB  |
| Radiated unwanted emissions in the spurious domain (40 to 50 GHz)   | $\pm 4$ dB  |
| Conducted unwanted emissions in the spurious domain (50 to 300 GHz) | $\pm 5$ dB  |
| Radiated unwanted emissions in the spurious domain (50 to 300 GHz)  | $\pm 5$ dB  |
| DC and low frequency voltages                                       | $\pm 3$ %   |
| Temperature   | $\pm 1$ °C  |
| Humidity  | $\pm 3$ %   |

## 9 Summary of measurement results

|                                     |  |
|-------------------------------------|--|
| <input checked="" type="checkbox"/> | <b>No deviations from the technical specifications were ascertained</b>  |
| <input type="checkbox"/>            | There were deviations from the technical specifications ascertained  |
| <input type="checkbox"/>            | 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 | 2019-08-14 | -/-    |

| 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               | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |                |
| §2.1047  | Modulation characteristics                      | -/-                    | -/-                   | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |                |
| §2.1049  | Occupied bandwidth (99% bandwidth)              | Nominal                | Nominal               | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |                |
| §2.1051  | Spurious emissions at antenna terminals         | Nominal                | Nominal               | <input type="checkbox"/>            | <input type="checkbox"/> | <input type="checkbox"/> | <input checked="" type="checkbox"/> | 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               | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |                |
| §2.1055<br>§95.3379 (b)  | Frequency stability                             | Nominal and Extreme    | Nominal and Extreme   | <input checked="" type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/>            |                |

**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.

## 10 Measurement results

### 10.1 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:             | RMS / Pos-Peak |
| Sweep time:           | 240 s          |
| Resolution bandwidth: | 1 MHz          |
| Video bandwidth:      | 3 MHz          |
| Trace-Mode:           | Max Hold       |
| Measurement distance: | 1.0 m          |

#### Limits:

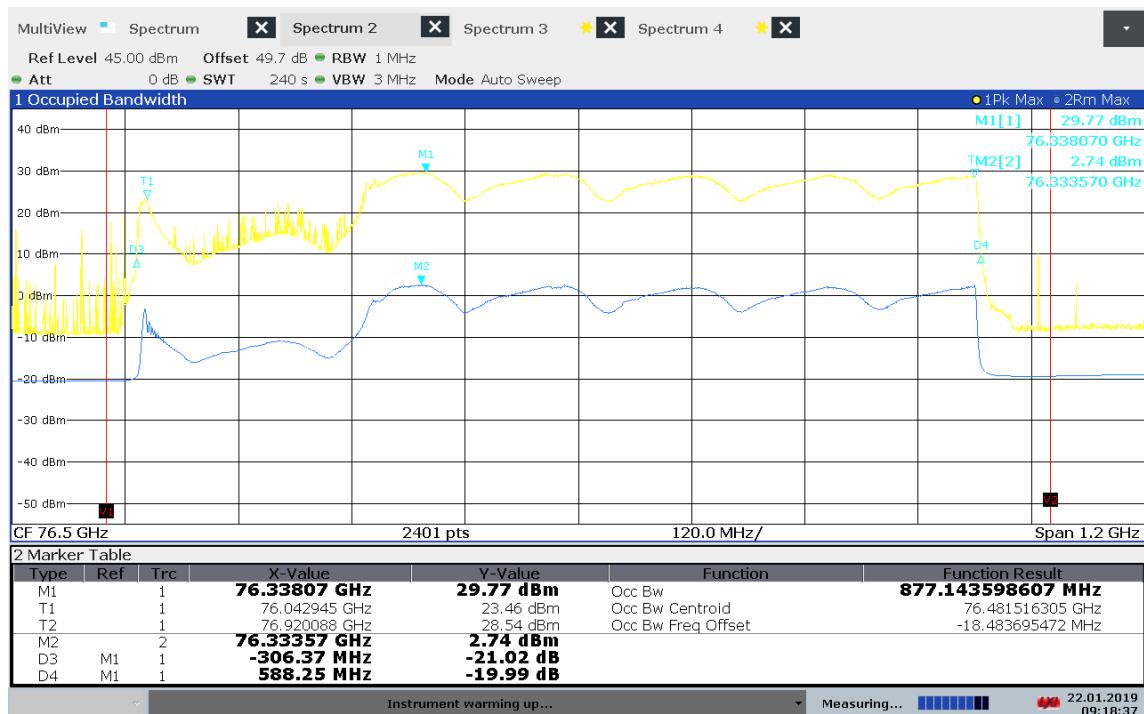
FCC §95.3367 (a) (b)

| Frequency       | Measurement distance | Power Density → EIRP   |
|-----------------|----------------------|--|
| 76.0 - 81.0 GHz | 3.0 m                | 88 $\mu$ W/cm <sup>2</sup> → 50 dBm (Average)<br>279 $\mu$ W/cm <sup>2</sup> → 55 dBm (PEAK) |

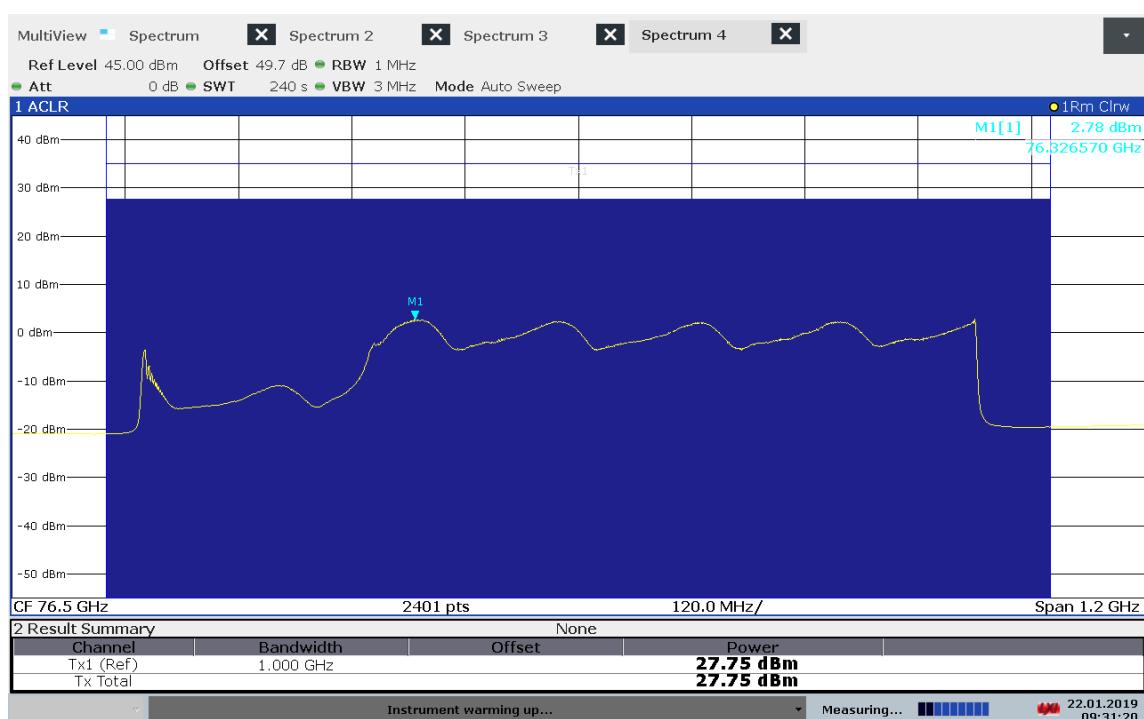
#### Measurement results:

| Mode                  | Test conditions                     | Radiated peak power (eirp)<br>[dBm] | Radiated mean power<br>(eirp) / Channel power<br>[dBm] |
|-----------------------|-------------------------------------|-------------------------------------|--|
| Normal operation mode | T <sub>nom</sub> / V <sub>nom</sub> | 29.8                                | 27.8   |

## Plot 1: Radiated peak power



## Plot 2: Radiated mean power



## 10.2 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:

|                           |                                   |
|---------------------------|-----------------------------------|
| <b>Duty Cycle</b>         | 100 %, Carrier never switched off |
| <b>Timing</b>             | 50 ms Frame repetition            |
| <b>Power</b>              | 30 dBm EIRP                       |
| <b>Steepness of Ramps</b> | 8.25 MHz/µs                       |
| <b>Calibration</b>        | None                              |

|                        |           |
|------------------------|-----------|
| <b>Modulation Type</b> | FMCW      |
| <b>Characteristic</b>  | 76-77 GHz |
| <b>Scantype 1</b>      |           |
| <b>Sweep Bandwidth</b> | 660 MHz   |
| <b>Sweep rate</b>      | 176.5 µs  |
| <b>Sweep time</b>      | 80 µs     |

## 10.3 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:             | 240 s     |
| Resolution bandwidth:   | 1 MHz     |
| Video bandwidth:        | 3 MHz     |
| Trace-Mode:             | Max Hold  |
| Measurement distance:   | 1.0 m     |
| Measurement uncertainty | Span/1000 |

### Limits:

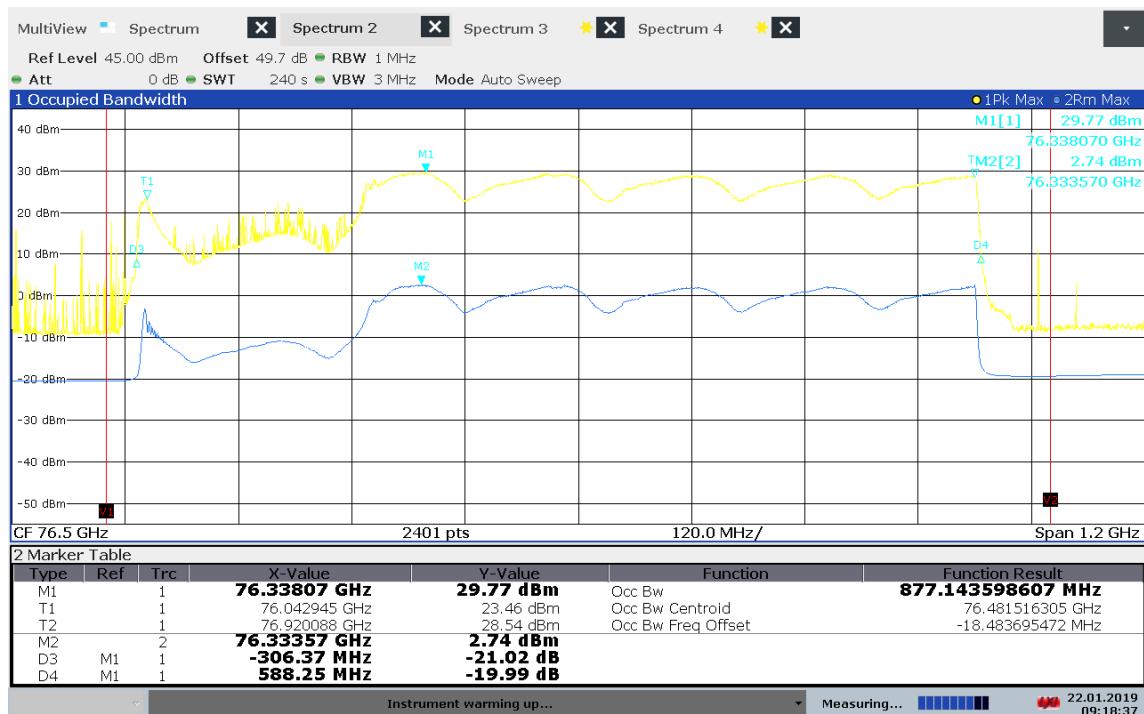
FCC §95.3379 (b)

|                 |                                       |  |
|-----------------|---------------------------------------|--|
| Frequency range | $f(\text{lowest}) > 76.0 \text{ GHz}$ | $f(\text{highest}) < 81.0 \text{ GHz}$ |
|-----------------|---------------------------------------|--|

### Measurement results:

| Mode                  | Test conditions                   | Operating Frequency Range |             | Bandwidth [MHz] |
|-----------------------|-----------------------------------|---------------------------|-------------|-----------------|
|                       |                                   | $f_L$ [GHz]               | $f_H$ [GHz] |                 |
| Normal operating mode | $T_{\text{nom}} / V_{\text{nom}}$ | 76.043                    | 76.920      | 877.1           |

## Plot 3: OBW and 20dB-bandwidth



## 10.4 Band edge compliance

### Description:

Investigation of the emission limits at the band edge.

### Measurement:

| Parameters            |                |
|-----------------------|----------------|
| Detector:             | RMS / Pos-Peak |
| Sweep time:           | 100 s / 240 s  |
| Resolution bandwidth: | 1 MHz          |
| Video bandwidth:      | 3 MHz          |
| Trace-Mode:           | Max Hold       |
| Measurement distance: | 1.0 m          |

### 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 <sup>2</sup> → -1.7 dBm |

### Limits:

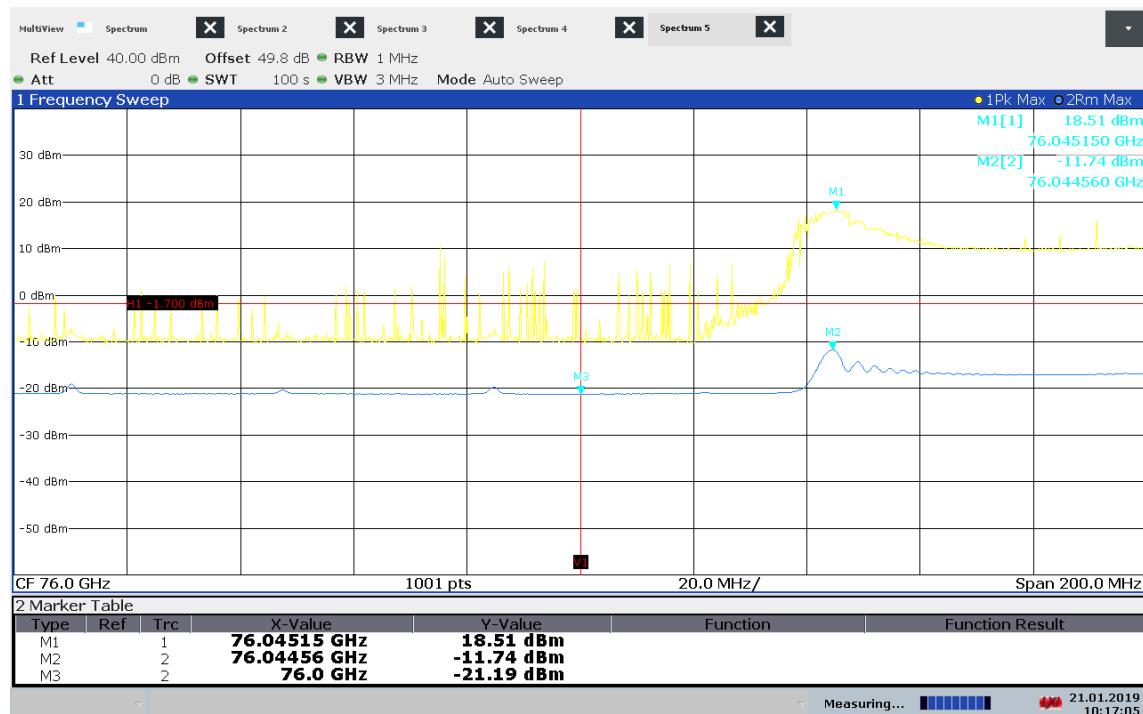
**FCC §95.3379 (b)**

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

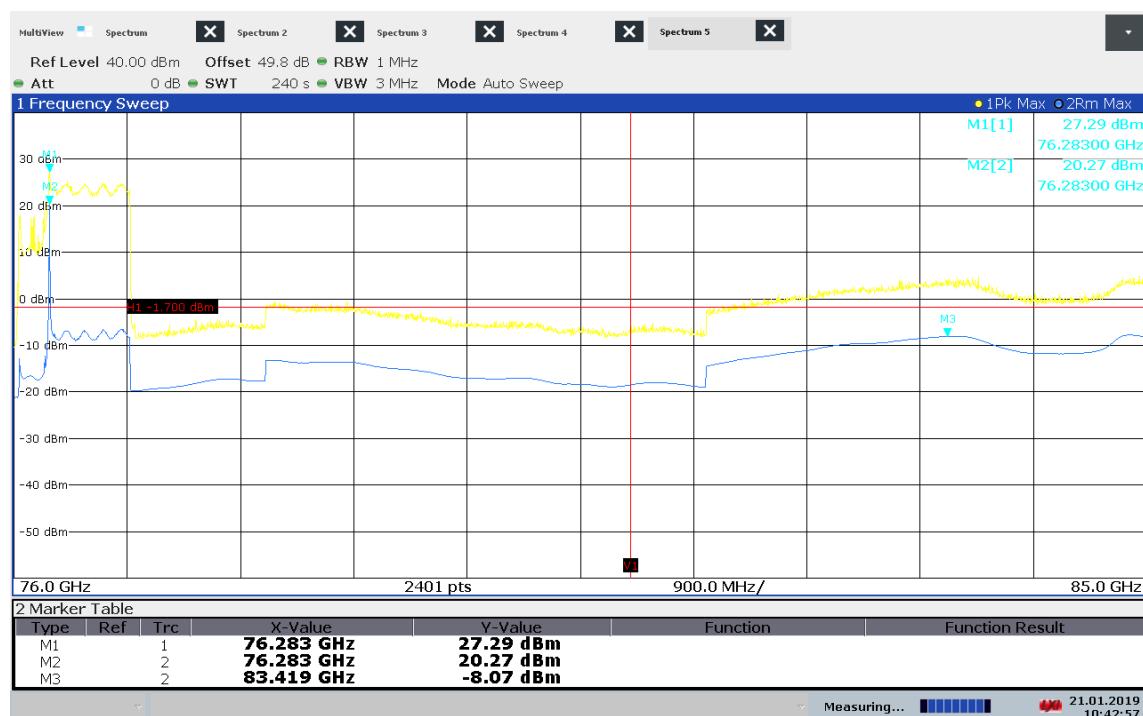
### Measurement results:

See plots below.

## Plot 4: Lower BEC



## Plot 5: Upper BEC



## 10.5 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:

### Measurement:

| Parameters            |                             |
|-----------------------|-----------------------------|
| Detector:             | Pos-Peak / RMS / Quasi-Peak |
| Sweep time:           | Auto                        |
| Resolution bandwidth: | 1 MHz                       |
| Video bandwidth:      | 3 MHz                       |
| Trace-Mode:           | Max Hold                    |
| Measurement distance: | Auto                        |

### 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 [dB $\mu$ V/m] | Measurement distance |
| 0.009 – 0.490  | 2400/F[kHz]                   | 300                  |
| 0.490 – 1.705  | 24000/F[kHz]                  | 30                   |
| 1.705 – 30.0   | 30.0                          | 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)

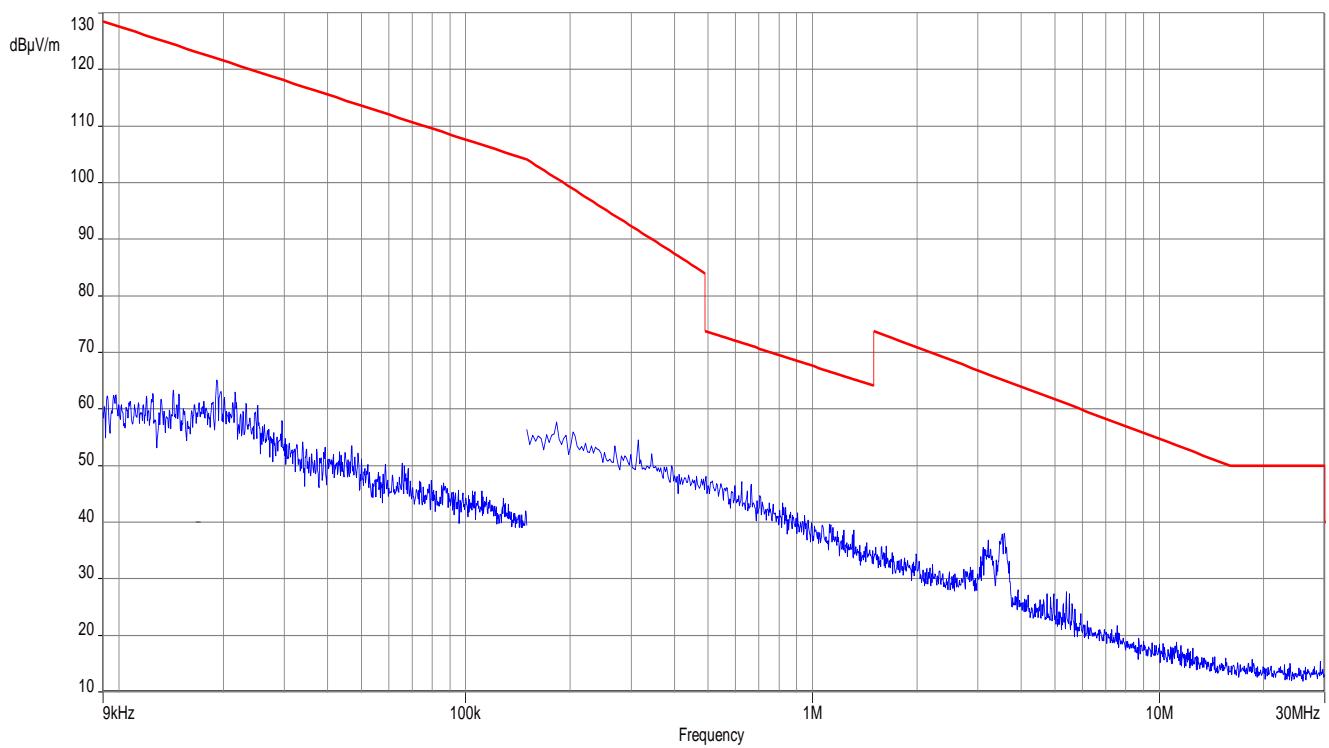
| Frequency Range [GHz] | Measurement distance | Power Density                      |
|-----------------------|----------------------|------------------------------------|
| 40 – 200              | 3.0 m                | 600 pW/cm <sup>2</sup> → -1.7 dBm  |
| 200 – 231             | 3.0 m           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

**Measurement results:**

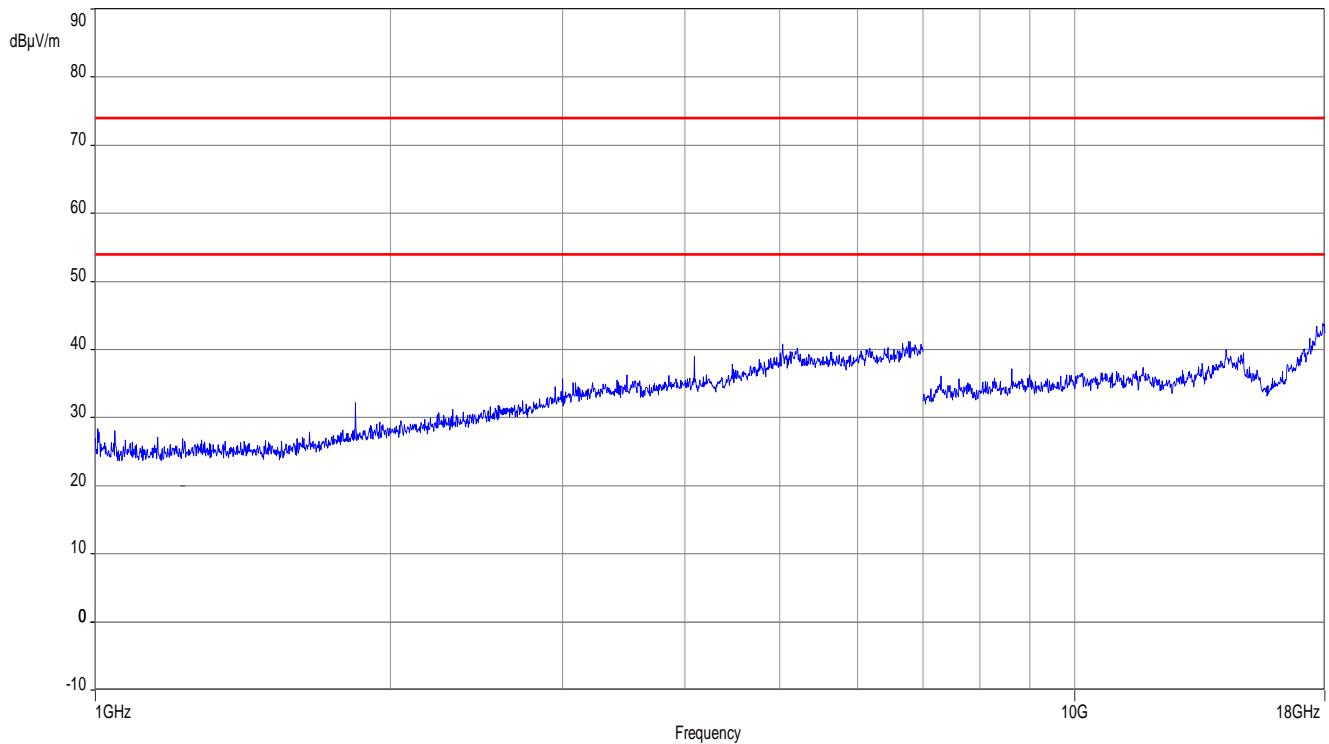
| F [GHz] | Detector | Level           | Limit           | Margin [dB] |
|---------|----------|-----------------|-----------------|-------------|
| 25.774  | Peak     | 42.9 dB $\mu$ V | 74.0 dB $\mu$ V | 31.1        |
| 25.791  | RMS      | 30.3 dB $\mu$ V | 54.0 dB $\mu$ V | 23.7        |
| 38.137  | Peak     | 67.3 dB $\mu$ V | 74.0 dB $\mu$ V | 6.7         |
| 38.165  | RMS      | 42.8 dB $\mu$ V | 54.0 dB $\mu$ V | 11.2        |
| 41.893  | RMS      | -53.2 dBm       | -1.7 dBm        | 51.5        |
| 59.635  | RMS      | -43.2 dBm       | -1.7 dBm        | 41.5        |
| 74.301  | RMS      | -25.6 dBm       | -1.7 dBm        | 23.9        |
| 83.419  | RMS      | -8.1 dBm        | -1.7 dBm        | 6.4         |
| 100.347 | RMS      | -45.7 dBm       | -1.7 dBm        | 44.0        |
| 127.158 | RMS      | -36.5 dBm       | -1.7 dBm        | 34.8        |
| 140.040 | RMS      | -36.6 dBm       | -1.7 dBm        | 34.9        |
| 152.781 | RMS      | -38.7 dBm       | -1.7 dBm        | 37.0        |
| 220.346 | RMS      | -39.3 dBm       | -1.7 dBm        | 37.6        |

For emissions between 30 MHz and 1 GHz, please refer to plot 8.

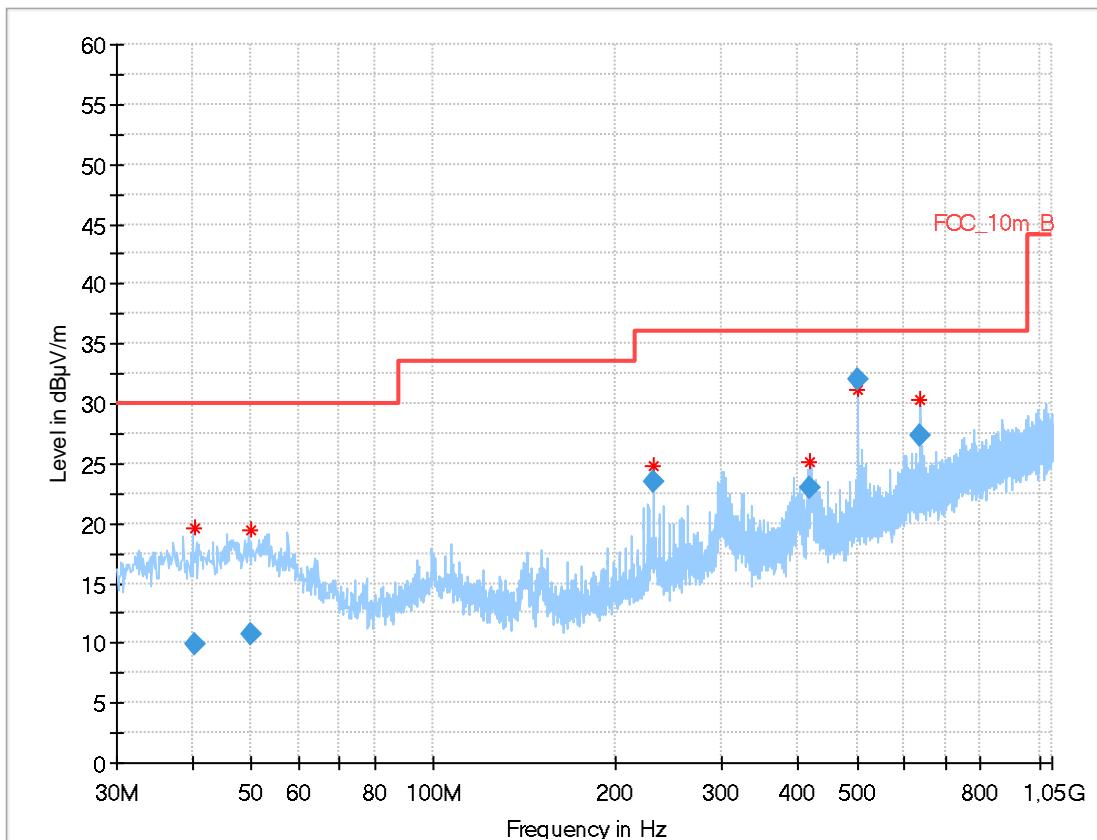
Plot 6: 9 kHz – 30 MHz



Plot 7: 1 GHz – 18 GHz



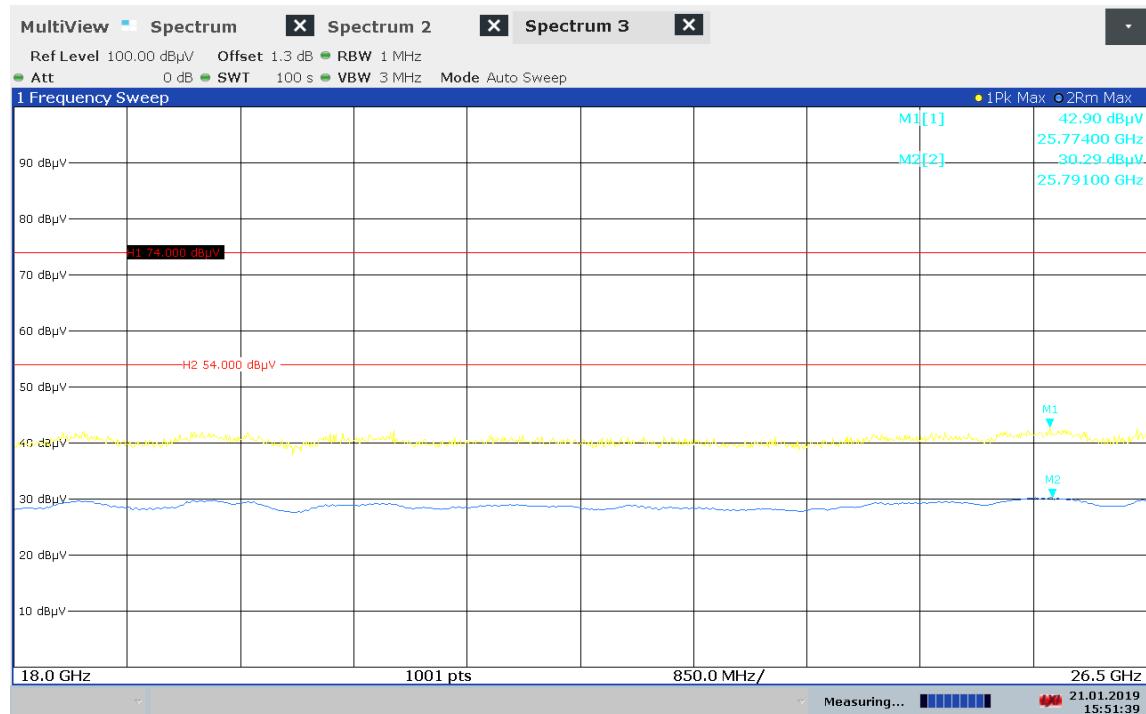
Plot 8: 30 MHz – 1 GHz



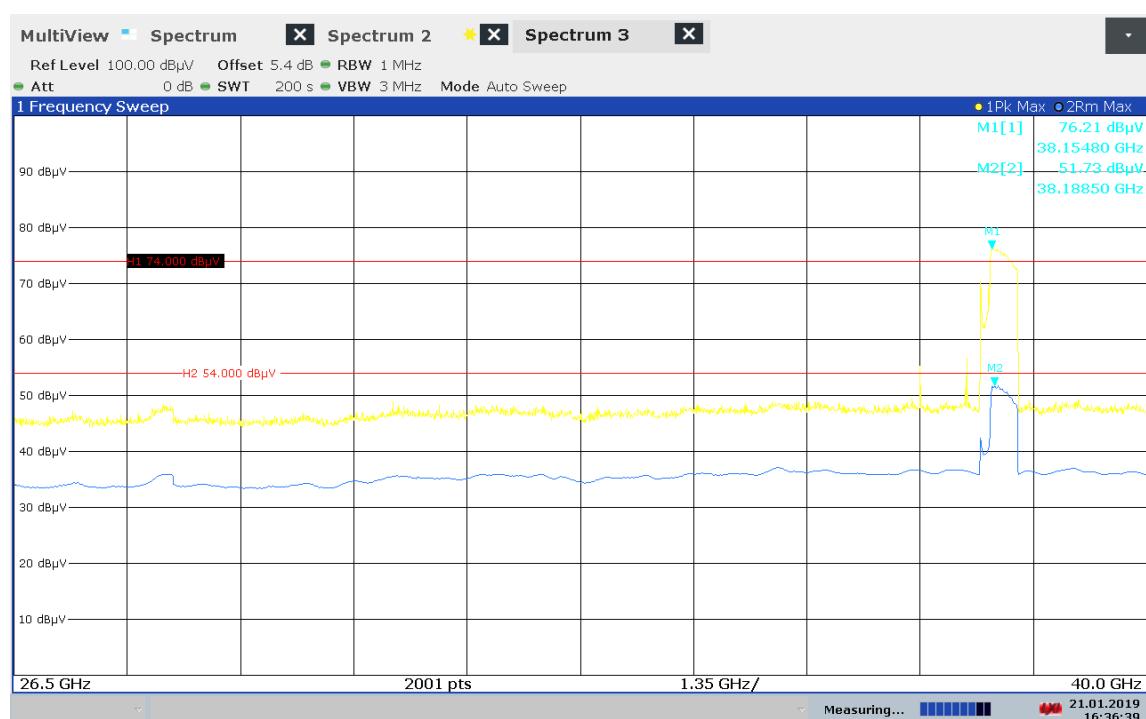
## Final\_Result

| Frequency (MHz) | QuasiPeak (dB $\mu$ V/m) | Limit (dB $\mu$ V/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Corr. (dB/m) |
|-----------------|--------------------------|----------------------|-------------|-----------------|-----------------|-------------|-----|---------------|--------------|
| 40.297          | 9.90                     | 30.0                 | 20.10       | 1000            | 120             | 172.0       | V   | 90.0          | 14           |
| 50.071          | 10.68                    | 30.0                 | 19.32       | 1000            | 120             | 200.0       | V   | 20.0          | 15           |
| 231.215         | 23.43                    | 36.0                 | 12.57       | 1000            | 120             | 400.0       | H   | 225.0         | 13           |
| 418.227         | 22.93                    | 36.0                 | 13.07       | 1000            | 120             | 100.0       | V   | 1.0           | 17           |
| 499.998         | 32.07                    | 36.0                 | 3.93        | 1000            | 120             | 100.0       | V   | 25.0          | 18           |
| 636.731         | 27.35                    | 36.0                 | 8.65        | 1000            | 120             | 271.0       | V   | 252.0         | 21           |

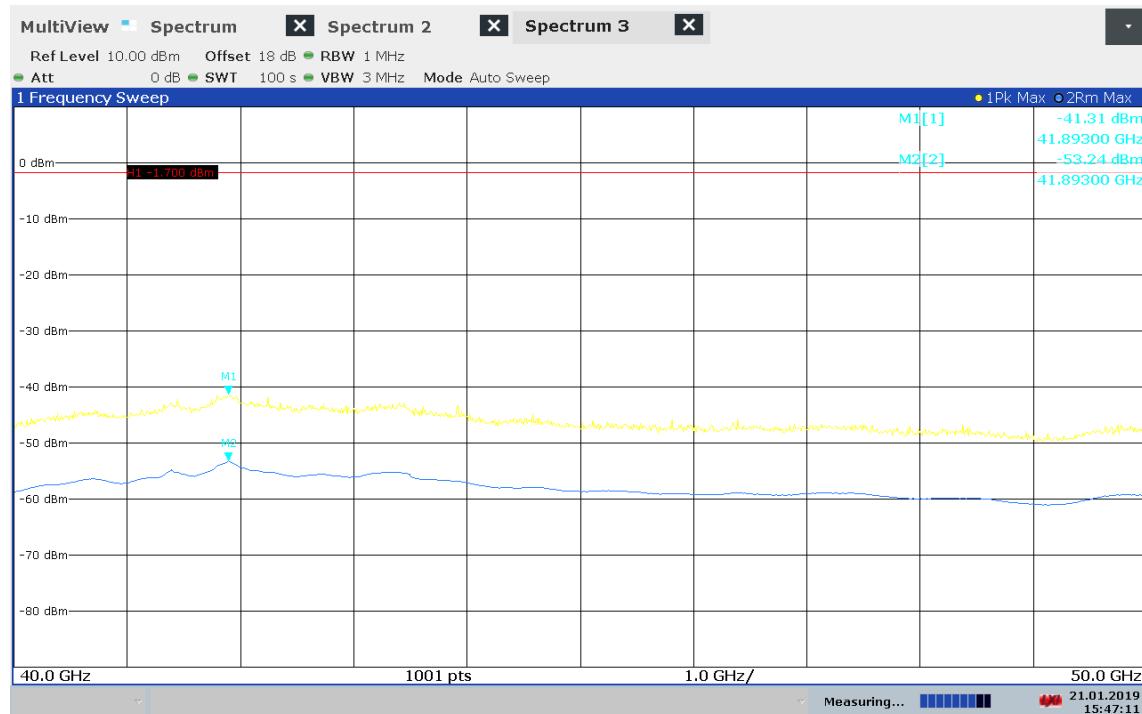
## Plot 9: 18 GHz – 26.5 GHz



## Plot 10: 26.5 GHz – 40 GHz

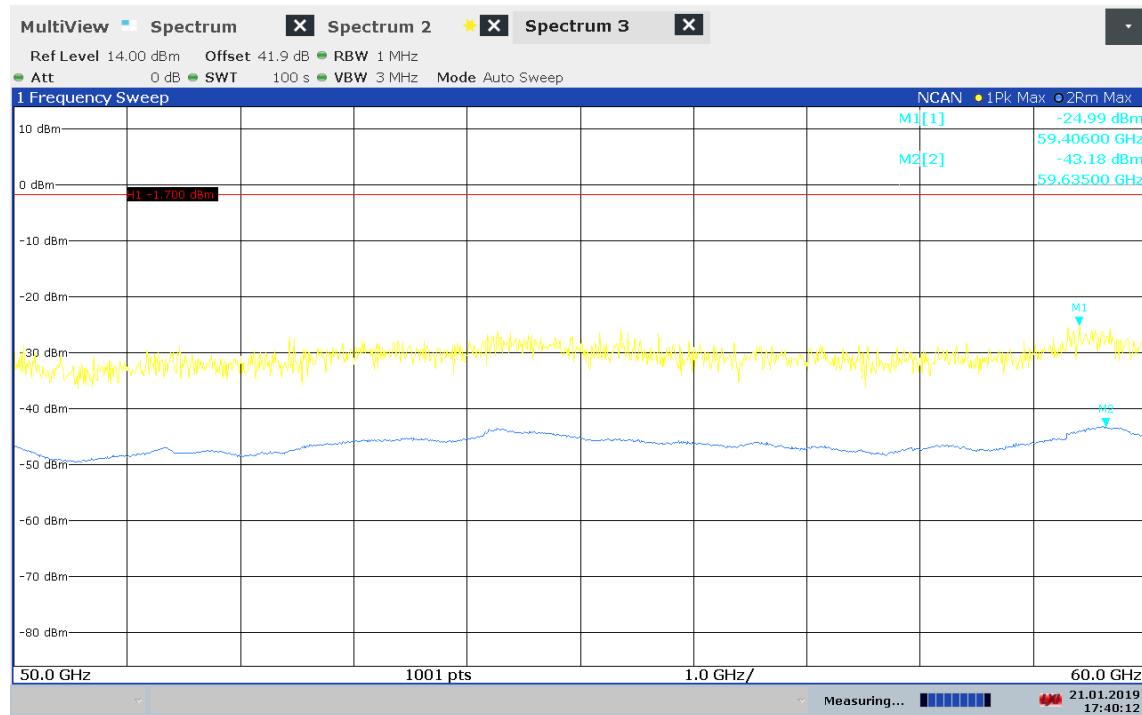


Plot 11: 40 GHz – 50 GHz



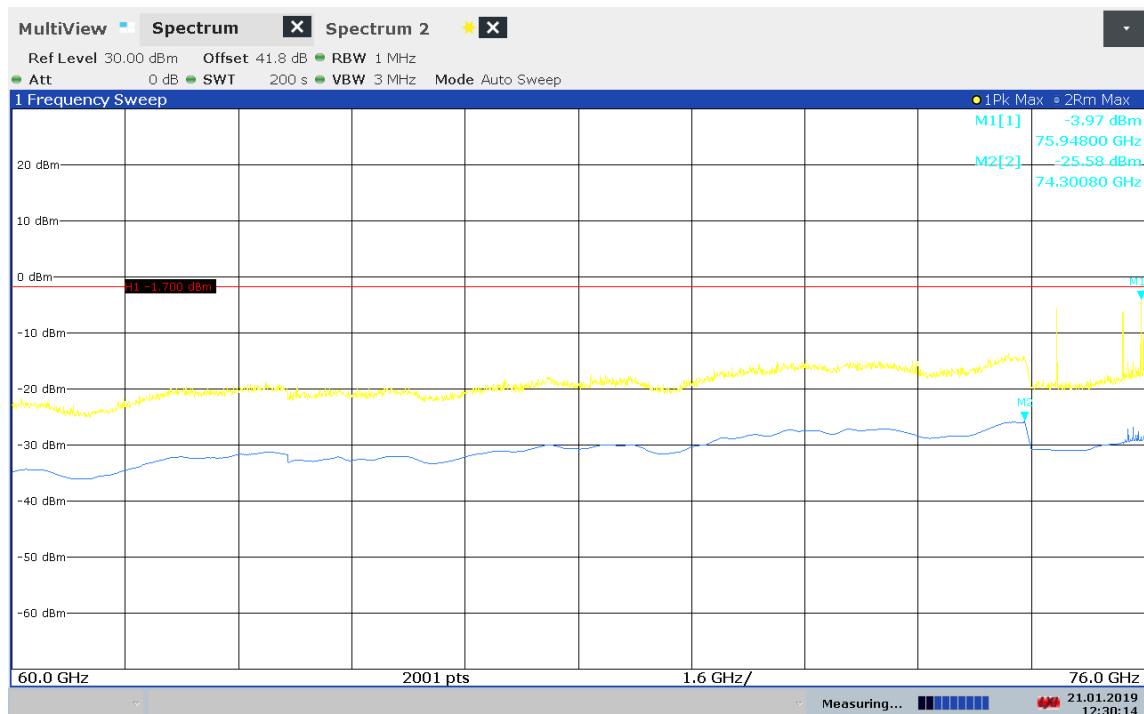
15:47:11 21.01.2019

Plot 12: 50 GHz – 60 GHz

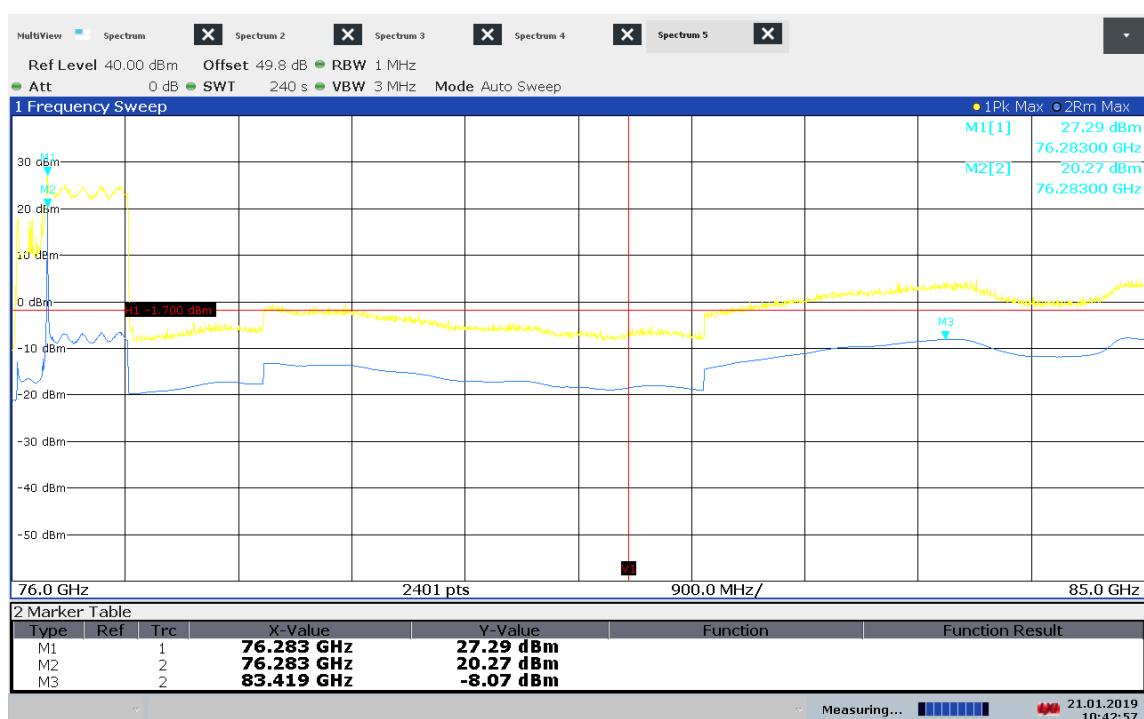


17:40:13 21.01.2019

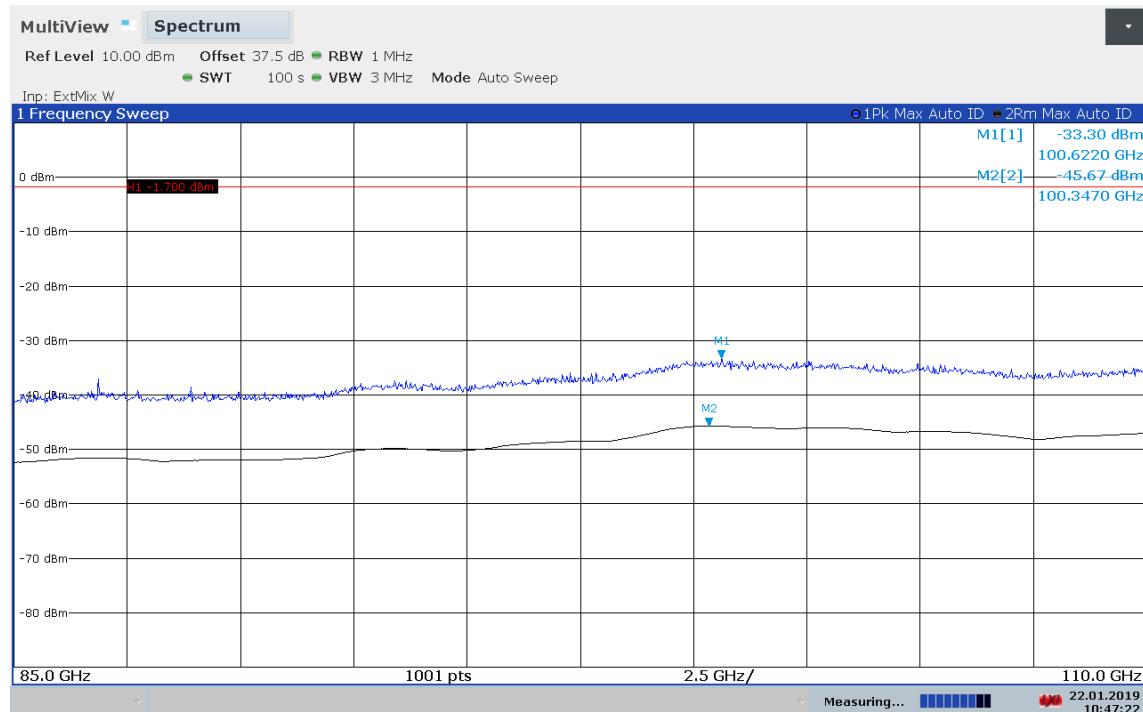
Plot 13: 60 GHz – 76 GHz



Plot 14: 76 GHz – 85 GHz

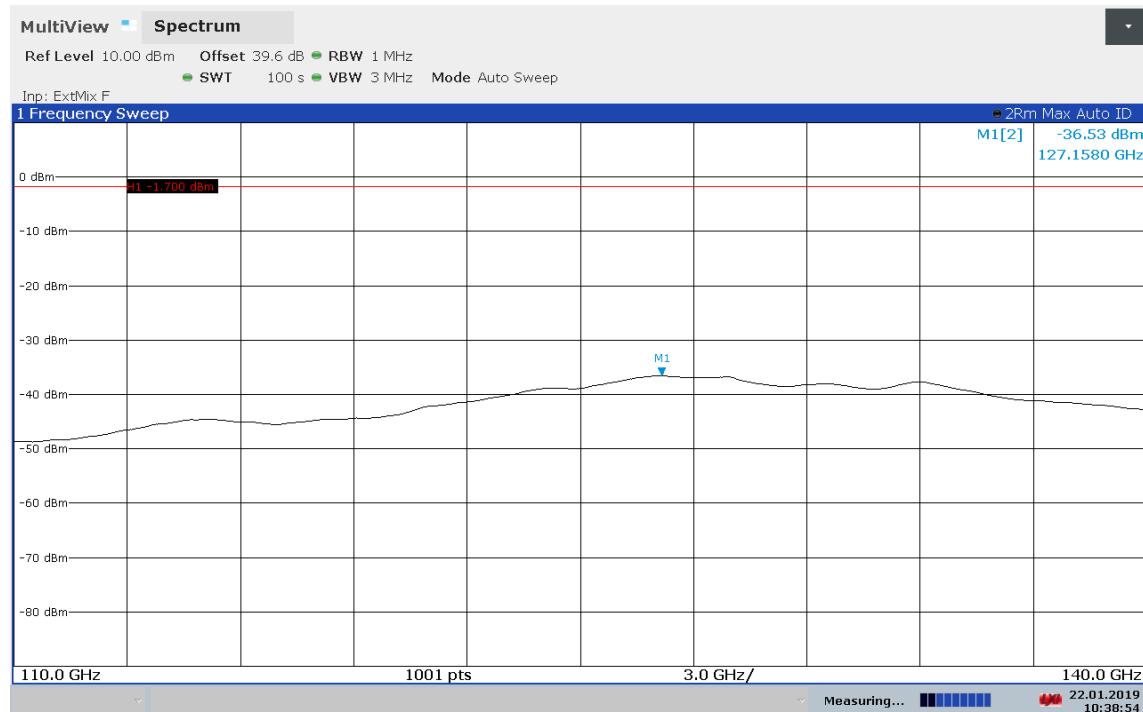


## Plot 15: 85 GHz – 110 GHz



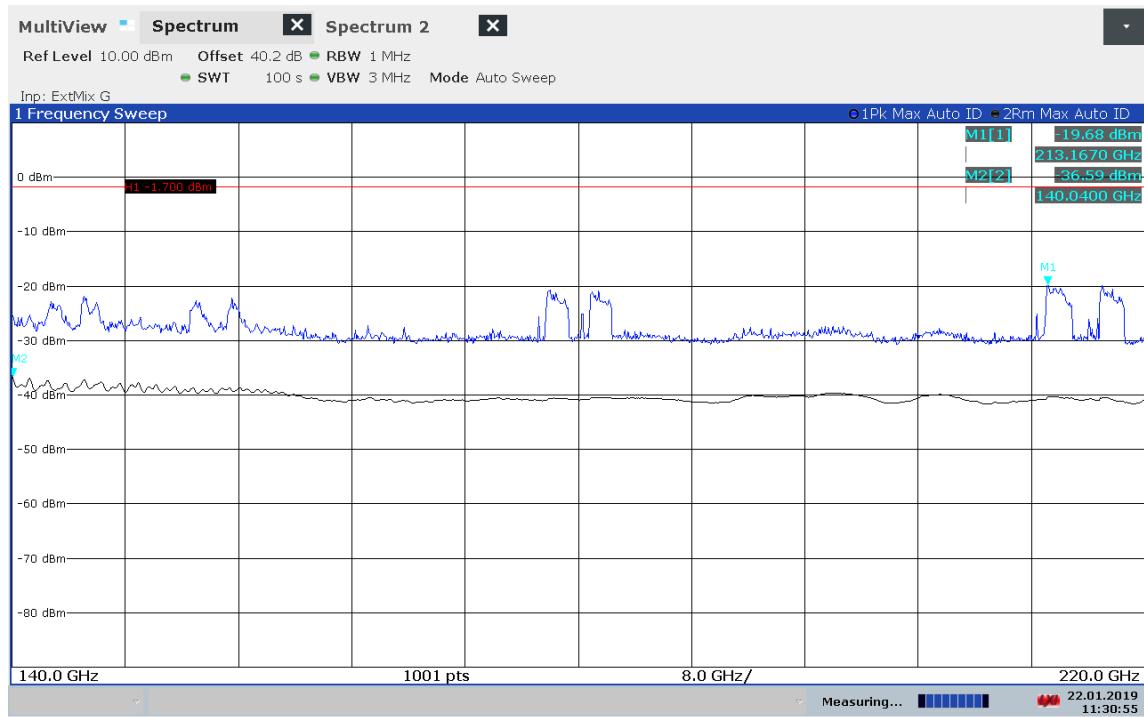
10:47:22 22.01.2019

## Plot 16: 110 GHz – 140 GHz



10:38:54 22.01.2019

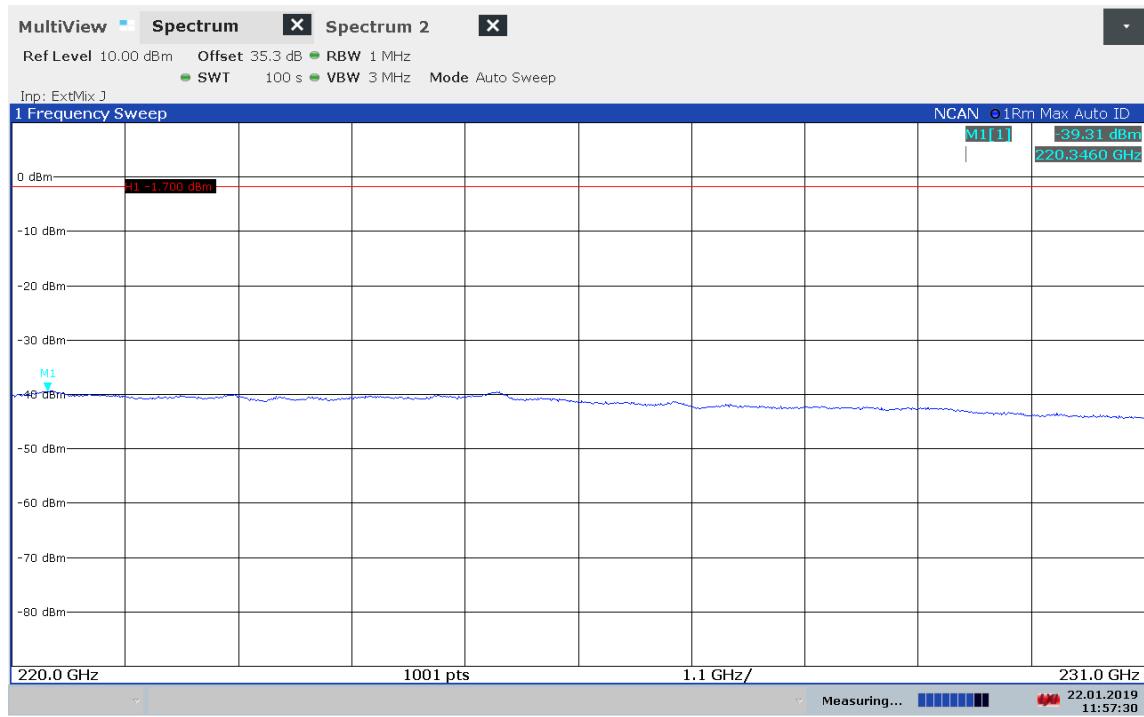
Plot 17: 140 GHz – 220 GHz



11:30:55 22.01.2019

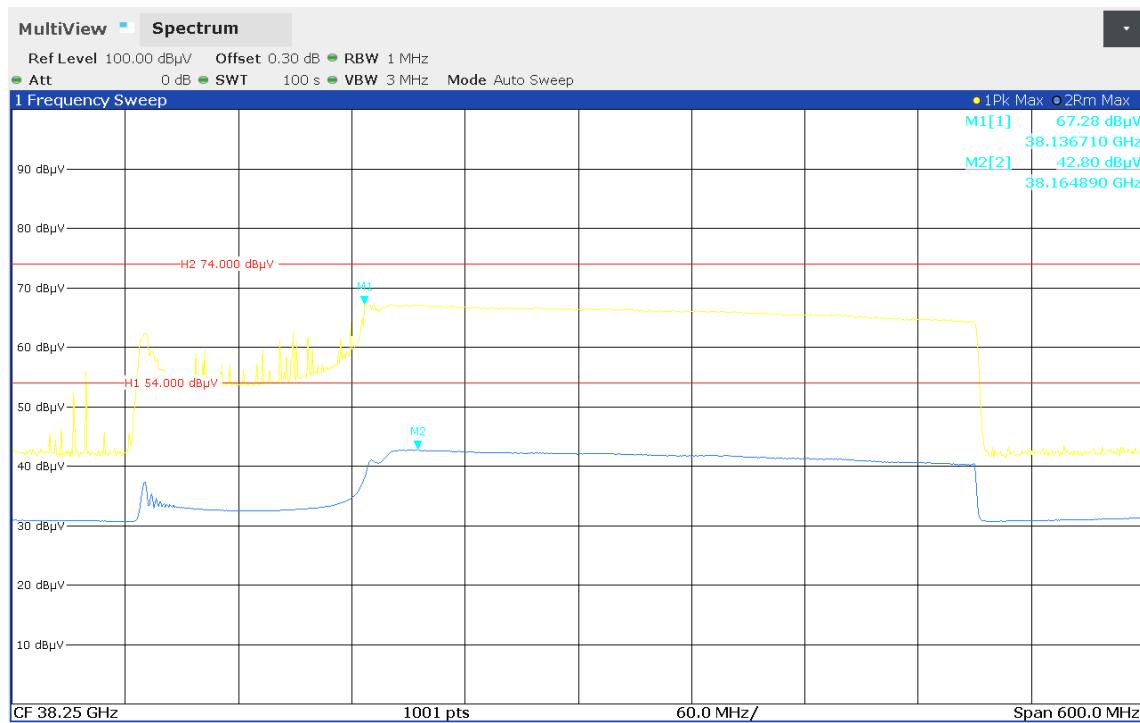
**Note: Plot shows mixing products generated by the harmonic mixer**

Plot 18: 220 GHz – 231 GHz

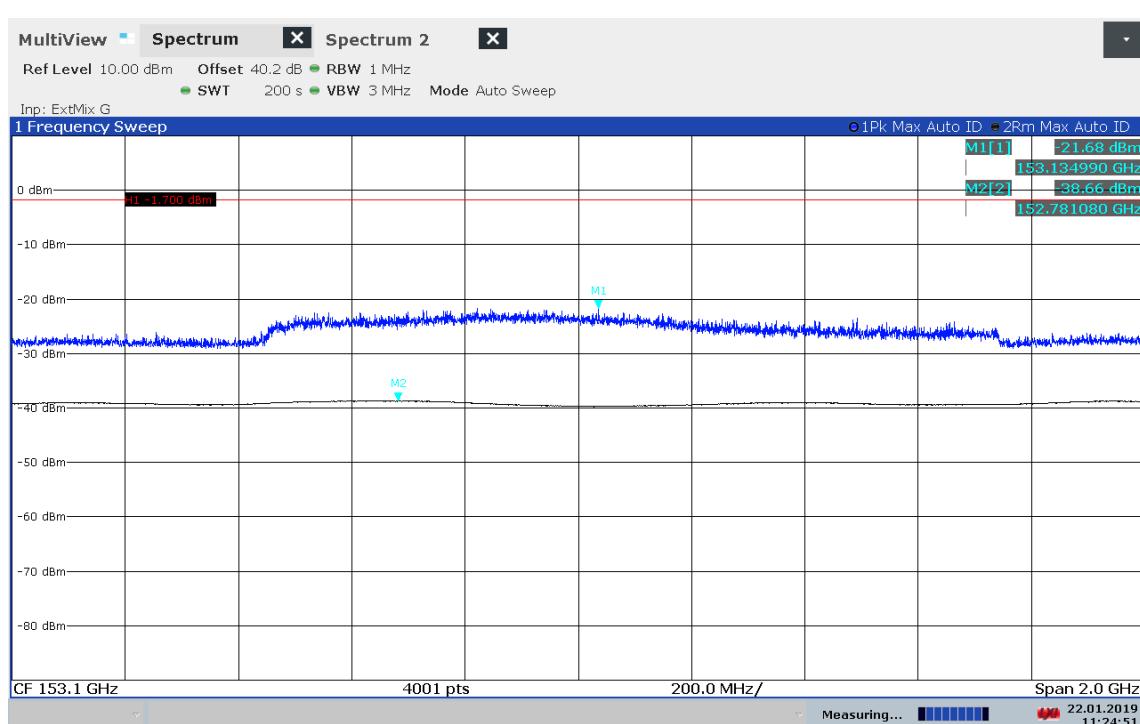


11:57:30 22.01.2019

Plot 19: Final measurement 38.25 GHz



Plot 20: Final measurement 153.1 GHz



## 10.6 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) / §2.1055

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

### Measurement results:

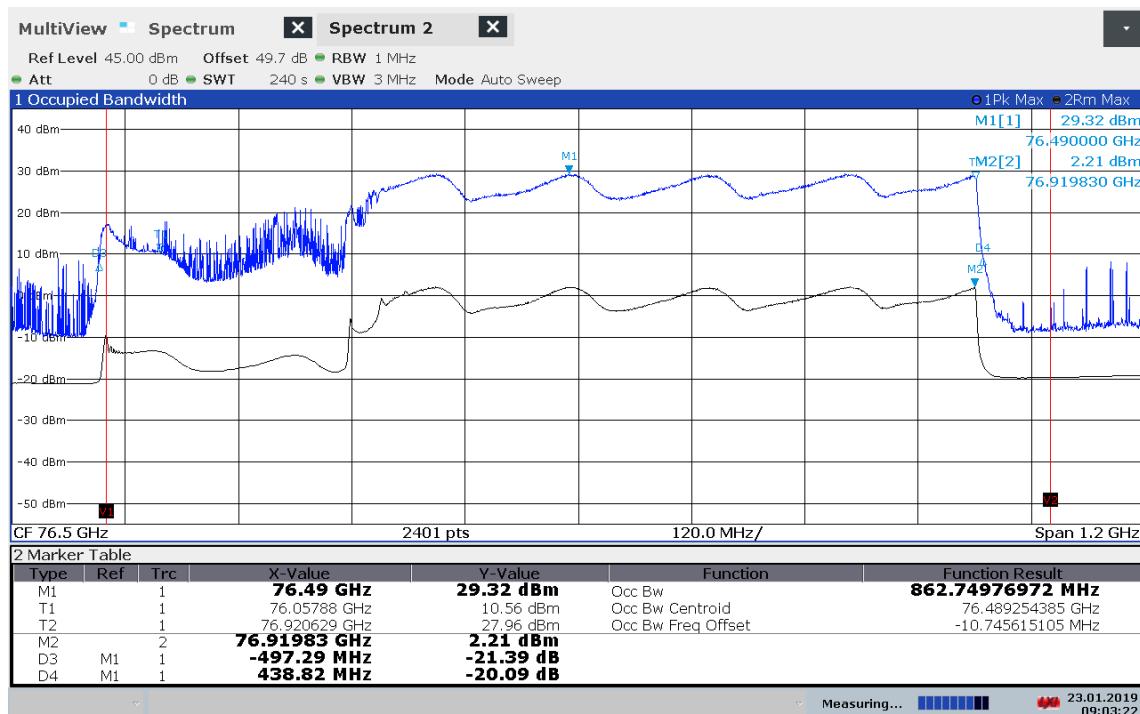
#### Temperature variation

| Mode                  | Temperature in °C | f <sub>L</sub> in GHz | f <sub>H</sub> in GHz |
|-----------------------|-------------------|-----------------------|-----------------------|
| Normal operation mode | -40               | 76.058                | 76.921                |
|                       | -30               | 76.044                | 76.921                |
|                       | -20               | 76.035                | 76.921                |
|                       | -10               | 76.035                | 76.921                |
|                       | 0                 | 76.038                | 76.920                |
|                       | 10                | 76.042                | 76.919                |
|                       | 20                | 76.045                | 76.919                |
|                       | 30                | 76.047                | 76.918                |
|                       | 40                | 76.046                | 76.918                |
|                       | 50                | 76.043                | 76.919                |
|                       | 85                | 76.046                | 76.923                |

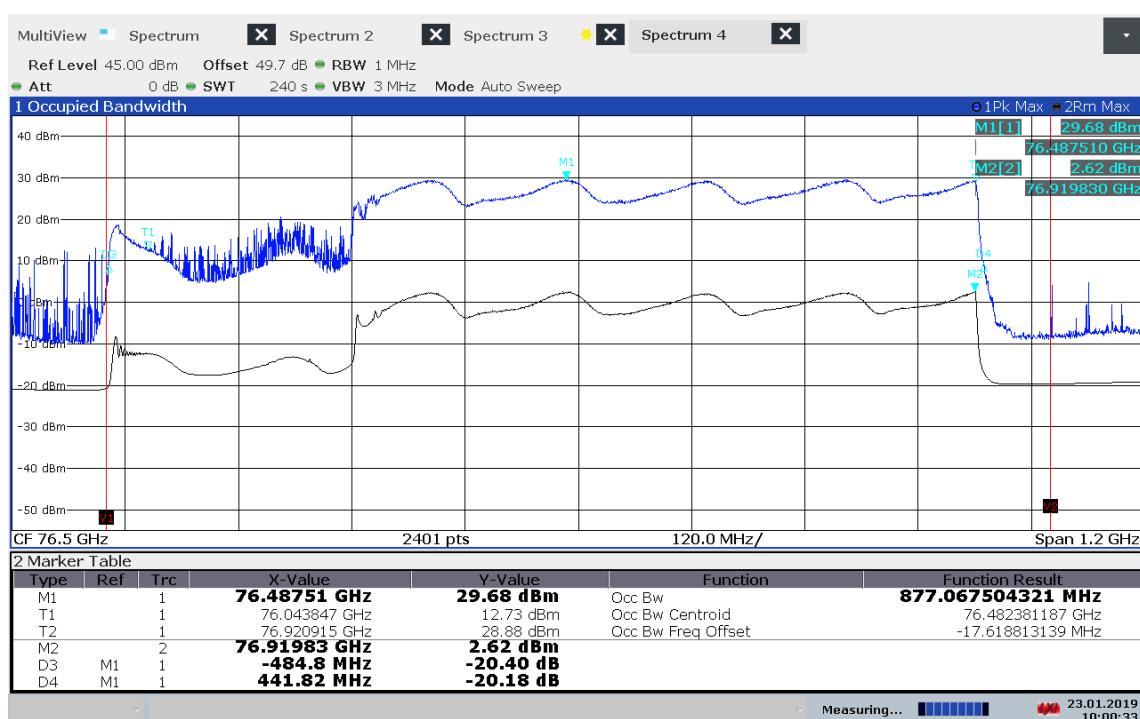
#### Voltage variation

| Voltage variation of rated input voltage | f <sub>L</sub> in GHz   | f <sub>H</sub> in GHz |
|--|---|-----------------------|
| < 85 % of U                              |   |                       |
| > 115 % of U                             | Voltage variation does not affect the radiated signal (see plot 27) |                       |

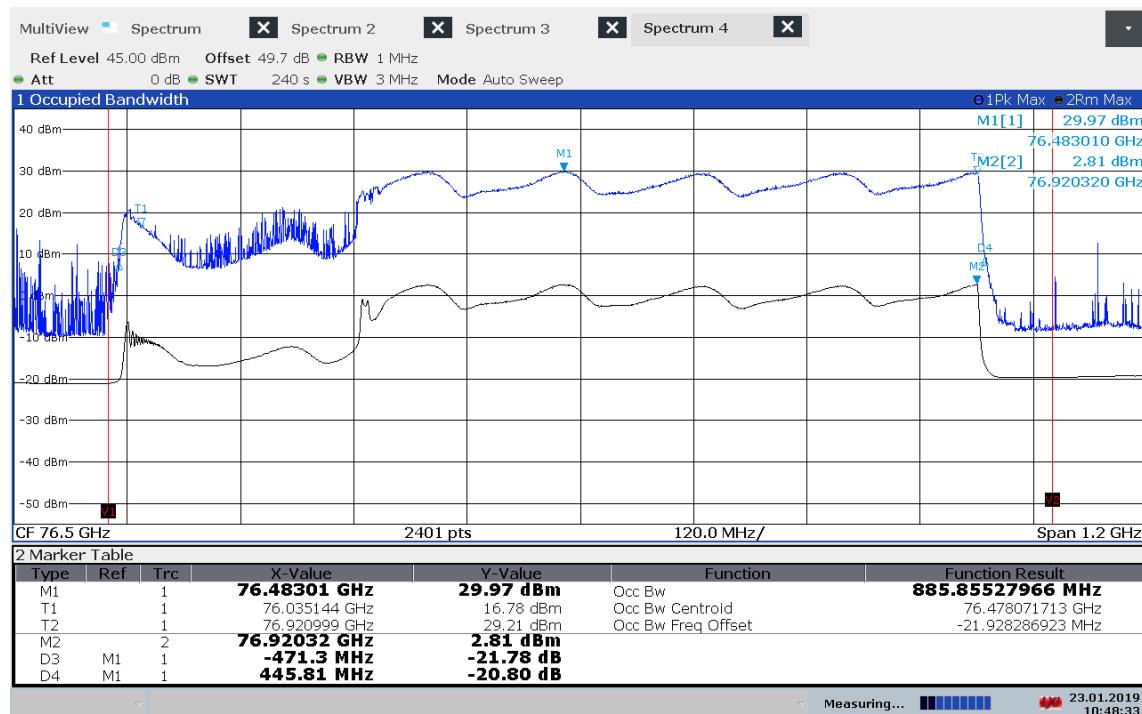
Plot 21: OBW -40 °C



Plot 22: OBW -30 °C

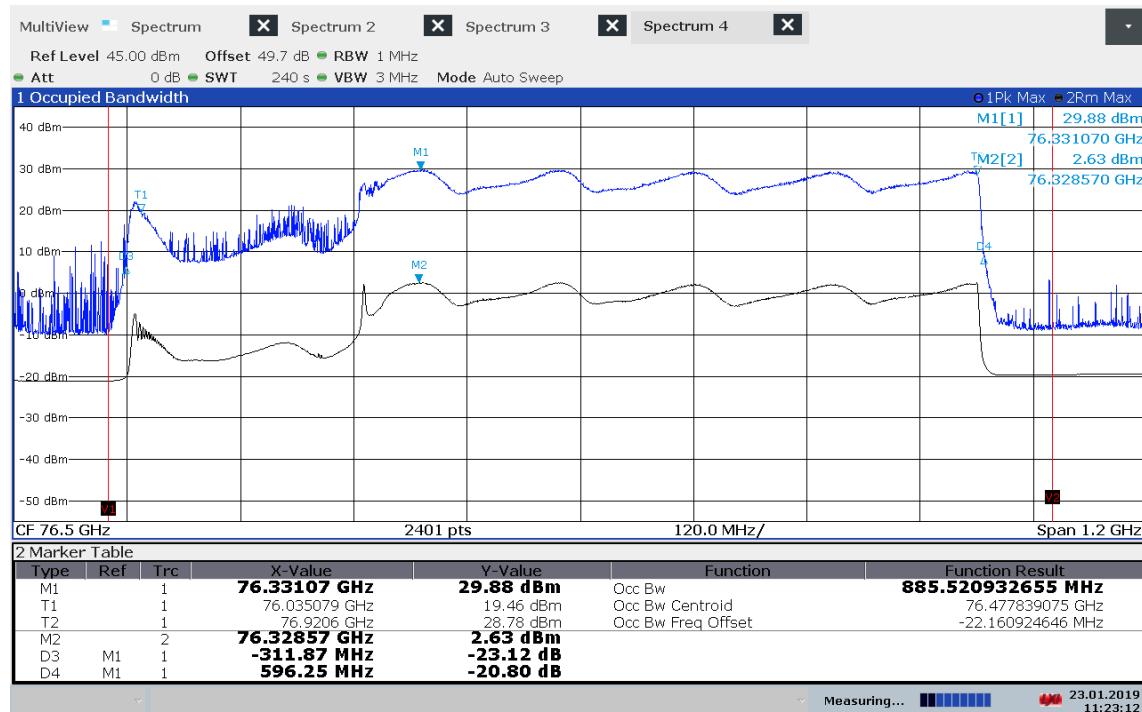


## Plot 23: OBW -20 °C



10:48:33 23.01.2019

## Plot 24: OBW -10 °C



11:23:13 23.01.2019

## Plot 25: OBW 0 °C



## Plot 26: OBW 10 °C



12:37:11 23.01.2019

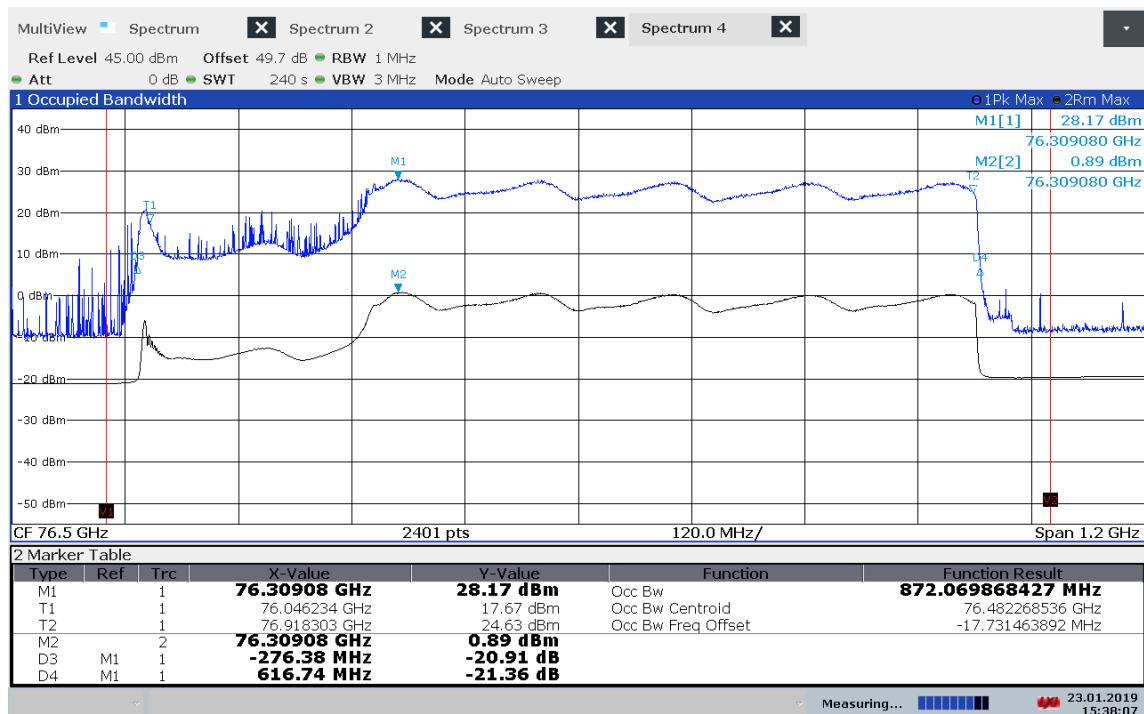
## Plot 27: OBW 20 °C



## Plot 28: OBW 30 °C



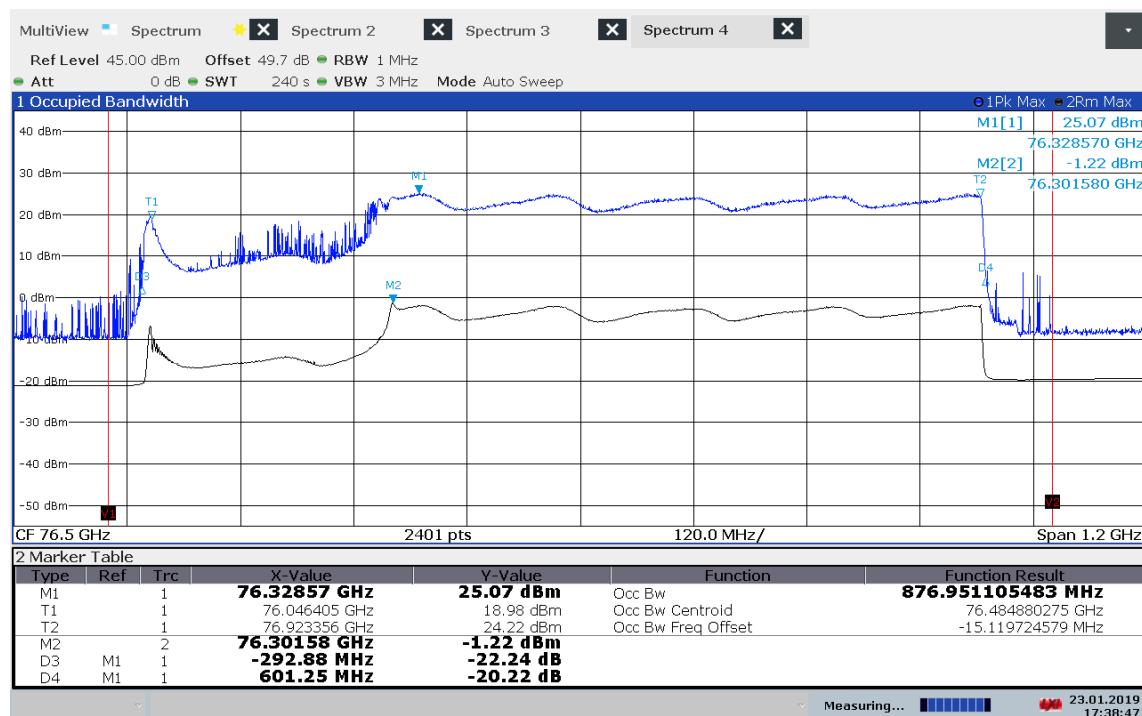
## Plot 29: OBW 40 °C



## Plot 30: OBW 50 °C



## Plot 31: OBW 85 °C



17:38:47 23.01.2019

## 11 Observations

No observations except those reported with the single test cases have been made.

## 12 Glossary

|                        |  |
|------------------------|--|
| <b>EUT</b>             | Equipment under test                               |
| <b>DUT</b>             | Device under test                                  |
| <b>UUT</b>             | Unit under test                                    |
| <b>GUE</b>             | GNSS User Equipment                                |
| <b>FCC</b>             | Federal Communications Commission                  |
| <b>FCC ID</b>          | Company Identifier at FCC                          |
| <b>IC</b>              | Industry Canada                                    |
| <b>PMN</b>             | Product marketing name                             |
| <b>HMN</b>             | Host marketing name                                |
| <b>HVIN</b>            | Hardware version identification number             |
| <b>FVIN</b>            | Firmware version identification number             |
| <b>EMC</b>             | Electromagnetic Compatibility                      |
| <b>HW</b>              | Hardware   |
| <b>SW</b>              | Software   |
| <b>Inv. No.</b>        | Inventory number                                   |
| <b>S/N or SN</b>       | Serial number                                      |
| <b>C</b>               | Compliant  |
| <b>NC</b>              | Not compliant                                      |
| <b>NA</b>              | Not applicable                                     |
| <b>NP</b>              | Not performed                                      |
| <b>PP</b>              | Positive peak                                      |
| <b>QP</b>              | Quasi peak   |
| <b>AVG</b>             | Average  |
| <b>OC</b>              | Operating channel                                  |
| <b>OCW</b>             | Operating channel bandwidth                        |
| <b>OBW</b>             | Occupied bandwidth                                 |
| <b>OOB</b>             | Out of band  |
| <b>DFS</b>             | Dynamic frequency selection                        |
| <b>CAC</b>             | Channel availability check                         |
| <b>OP</b>              | Occupancy period                                   |
| <b>NOP</b>             | Non occupancy period                               |
| <b>DC</b>              | Duty cycle   |
| <b>PER</b>             | Packet error rate                                  |
| <b>CW</b>              | Clean wave   |
| <b>MC</b>              | Modulated carrier                                  |
| <b>DSSS</b>            | Dynamic sequence spread spectrum                   |
| <b>OFDM</b>            | Orthogonal frequency division multiplexing         |
| <b>FHSS</b>            | Frequency hopping spread spectrum                  |
| <b>GNSS</b>            | Global Navigation Satellite System                 |
| <b>C/N<sub>0</sub></b> | Carrier to noise-density ratio, expressed in dB-Hz |

## 13 Document history

| Version | Applied changes  | Date of release |
|---------|--|-----------------|
| -/-     | Initial release - DRAFT  | 2019-03-28      |
| -/-     | Editorial changes  | 2019-05-06      |
| -A      | Editorial changes / type identification name   | 2019-08-07      |
| -B      | Editorial changes based on TCB´s remarks / Replace 20 dB bandwidth with 99 % bandwidth | 2019-08-14      |

## 14 Accreditation Certificate

| first page   | last page  |
|--|--|
| <br><b>Deutsche Akkreditierungsstelle GmbH</b><br><br><b>Entrusted according to Section 8 subsection 1 AkkStelleG in connection with Section 1 subsection 1 AkkStelleGBV</b><br>Signature to the Multilateral Agreements of EA, ILAC and IAF for Mutual Recognition<br><br><b>Accreditation</b><br><br><br>The Deutsche Akkreditierungsstelle GmbH attests that the testing laboratory<br><br><b>CTC advanced GmbH</b><br>Untertürkheimer Straße 6-10, 66117 Saarbrücken<br><br>is competent under the terms of DIN EN ISO/IEC 17025:2005 to carry out tests in the following fields:<br><br><b>Telecommunication</b><br><br><br>The accreditation certificate shall only apply in connection with the notice of accreditation of 02.06.2017 with the accreditation number D-PL-12076-01 and is valid until 21.04.2021. It comprises the cover sheet, the reverse side of the cover sheet and the following annex with a total of 43 pages.<br><br>Registration number of the certificate: D-PL-12076-01-03<br><br><br><br>Frankfurt, 02.06.2017<br>Dipl.-Ing. (FH) Rolf Bömer<br>Head of Division<br><br>See notes overleaf. | <b>Deutsche Akkreditierungsstelle GmbH</b><br><br>Office Berlin<br>Spittelmarkt 10<br>10117 Berlin<br><br>Office Frankfurt am Main<br>Europa-Allee 52<br>60327 Frankfurt am Main<br><br>Office Braunschweig<br>Bundesallee 100<br>38116 Braunschweig<br><br>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.<br><br>No impression shall be made that the accreditation also extends to fields beyond the scope of accreditation attested by DAkkS.<br><br>The accreditation was granted pursuant to the Act on the Accreditation Body (AkkStelleG) of 24 July 2009 (Federal Law Gazette I No. 26/2009) 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 accreditation.<br><br>The up-to-date state of membership can be retrieved from the following websites:<br>EA: <a href="http://www.european-accreditation.org">www.european-accreditation.org</a><br>ILAC: <a href="http://www.ilac.org">www.ilac.org</a><br>IAF: <a href="http://www.iaf.nu">www.iaf.nu</a> |

**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-12076-01-03.pdf>

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