

# Test Report

Report Number:

**F191168E3**

Equipment under Test (EUT):

**Track&Trace - Marker**

Applicant:

**TRUMPF Werkzeugmaschinen GmbH + Co. KG**

Manufacturer:

**TRUMPF Werkzeugmaschinen GmbH + Co. KG**



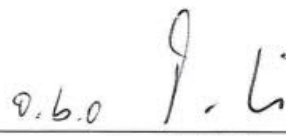
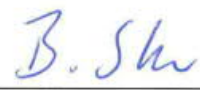
Deutsche  
Akkreditierungsstelle  
D-PL-17186-01-01  
D-PL-17186-01-02  
D-PL-17186-01-03

## References

- [1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- [2] **FCC CFR 47 Part 15**, Radio Frequency Devices
- [3] **558074 D01 15.247 Meas Guidance v05r02 (April 2019)**, GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES

## Test Result

The requirements of the tests performed as shown in the overview (clause 4) were fulfilled by the equipment under test. The complete test results are presented in the following.

|                           |                                       |                                                                                                                  |                                   |
|---------------------------|---------------------------------------|------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Tested and written by:    | Bernward ROHDE<br><small>Name</small> | <br><small>Signature</small> | 07.09.2020<br><small>Date</small> |
| Reviewed and approved by: | Bernd STEINER<br><small>Name</small>  | <br><small>Signature</small> | 07.09.2020<br><small>Date</small> |

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# 1 Identification

## 1.1 Applicant

|                                                                |                                        |
|----------------------------------------------------------------|----------------------------------------|
| Name:                                                          | TRUMPF Werkzeugmaschinen GmbH + Co. KG |
| Address:                                                       | Johann-Maus-Str. 2, 71254 Ditzingen    |
| Country:                                                       | Germany                                |
| Name for contact purposes:                                     | Mr. Guido Schönhardt                   |
| Phone:                                                         | 07156-303-36117                        |
| Fax:                                                           |                                        |
| eMail Address:                                                 | Guido.schoenhardt@trumpf.com           |
| Applicant represented during the test by the following person: | -                                      |

## 1.2 Manufacturer

|                                                                |                                        |
|----------------------------------------------------------------|----------------------------------------|
| Name:                                                          | TRUMPF Werkzeugmaschinen GmbH + Co. KG |
| Address:                                                       | Johann-Maus-Str. 2, 71254 Ditzingen    |
| Country:                                                       | Germany                                |
| Name for contact purposes:                                     | Mr. Guido Schönhardt                   |
| Phone:                                                         | 07156-303-36117                        |
| Fax:                                                           |                                        |
| eMail Address:                                                 | Guido.schoenhardt@trumpf.com           |
| Applicant represented during the test by the following person: | -                                      |

## 1.3 Test Laboratory

The tests were carried out by: **PHOENIX TESTLAB GmbH**  
**Königswinkel 10**  
**32825 Blomberg**  
**Germany**

Accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-05 and D-PL-17186-01-06, FCC Test Firm Accreditation designation number DE0004, FCC Test Firm Registration Number 469623, CAB Identifier DE0003 and ISCED# 3469A.

#### 1.4 EUT (Equipment under Test)

| EUT                 |                                              |
|---------------------|----------------------------------------------|
| Test object: *      | Marker for indoor localization               |
| PMN / Model name: * | Track&Trace - Marker                         |
| FCC ID: *           | 2AVYV-2564360-01                             |
| Serial number: *    | Antenna A: 204579407<br>Antenna B: 204579409 |
| PCB identifier: *   | 1901154A001032B8                             |
| Hardware version: * | Rev D                                        |
| Software version: * | 2.17.9                                       |

\* Declared by the applicant

Note: Phoenix Testlab GmbH does not take samples. The samples used for the tests are provided exclusively by the applicant.

## 1.5 Technical Data of Equipment

| General technical data of EUT                |                                              |                     |                    |                     |                    |                     |
|----------------------------------------------|----------------------------------------------|---------------------|--------------------|---------------------|--------------------|---------------------|
| Power supply EUT: *                          | DC (by internal battery)                     |                     |                    |                     |                    |                     |
| Supply voltage EUT: *                        | U <sub>nom</sub> =                           | 3.7 V <sub>DC</sub> | U <sub>min</sub> = | 3.0 V <sub>DC</sub> | U <sub>max</sub> = | 4.2 V <sub>DC</sub> |
| Temperature range: *                         | -10 °C to +39 °C                             |                     |                    |                     |                    |                     |
| Lowest / highest internal clock frequency: * | 32.768 kHz / 2480 MHz (in IEEE802.15.4 mode) |                     |                    |                     |                    |                     |

| Identification                  | Connector |           | Length |
|---------------------------------|-----------|-----------|--------|
|                                 | EUT       | Ancillary |        |
| No lines connectable to the EUT |           |           |        |

| IEEE 802.15.4 radio mode       |                 |                            |
|--------------------------------|-----------------|----------------------------|
| Fulfils radio specification: * | IEEE 802.15.4   |                            |
| Radio chip: *                  | Atmega256RFR2   |                            |
| Antenna type: *                | Chip-Ceramic    |                            |
| Antenna name: *                | RFANT3216120A5T |                            |
| Antenna gain: *                | 2 dBi (Typical) |                            |
| Antenna connector: *           | MM8030-2610RJ3  |                            |
| Conducted output power: *      | IEEE 802.15.4   | 2.9 dBm (Peak)             |
|                                |                 | 2.8 dBm (Average)          |
| Type of modulation: *          | IEEE 802.15.4   | O-QPSK (250 kbit/s)        |
| Operating frequency range: *   | IEEE 802.15.4   | 2405 – 2480 MHz            |
| Number of channels: *          | IEEE 802.15.4   | 16 (5 MHz channel spacing) |

| IEEE 802.15.4 frequencies |    |          |    |          |
|---------------------------|----|----------|----|----------|
| Channel 11                | RX | 2405 MHz | TX | 2405 MHz |
| Channel 12                | RX | 2410 MHz | TX | 2410 MHz |
| Channel 13                | RX | 2415 MHz | TX | 2415 MHz |
| Channel 14                | RX | 2420 MHz | TX | 2420 MHz |
| Channel 15                | RX | 2425 MHz | TX | 2425 MHz |
| Channel 16                | RX | 2430 MHz | TX | 2430 MHz |
| Channel 17                | RX | 2435 MHz | TX | 2435 MHz |
| Channel 18                | RX | 2440 MHz | TX | 2440 MHz |
| Channel 19                | RX | 2445 MHz | TX | 2445 MHz |
| Channel 20                | RX | 2450 MHz | TX | 2450 MHz |
| Channel 21                | RX | 2455 MHz | TX | 2455 MHz |
| Channel 22                | RX | 2460 MHz | TX | 2460 MHz |
| Channel 23                | RX | 2465 MHz | TX | 2465 MHz |
| Channel 24                | RX | 2470 MHz | TX | 2470 MHz |
| Channel 25                | RX | 2475 MHz | TX | 2475 MHz |
| Channel 26                | RX | 2480 MHz | TX | 2480 MHz |

### 1.5.1 Ancillary Equipment / Equipment used for testing

| Equipment used for testing |
|----------------------------|
| -                          |

### 1.6 Dates

|                                 |            |
|---------------------------------|------------|
| Date of receipt of test sample: | 07.05.2020 |
| Start of test:                  | 14.07.2020 |
| End of test:                    | 09.10.2020 |

## **2 Operational States**

### **2.1 Description of function of the EUT**

The EUT is intended to be used as transceiver for locating of machine tools inside a factory building. It will be mounted onto machines. Therefore, it is defined as mobile indoor equipment.

All radiated tests were carried out with an unmodified test sample powered by an internal battery.

### **2.2 The following states were defined as the operating conditions**

The applicant delivered one sample. The test modes were set with the aid of a magnet, for channel 26 different power settings could be set.

#### **2.2.1 Radio test**

The EUT is equipped with two antennas (further referred as “antenna A” and “antenna B”) for IEEE 802.15.4 communication. The EUT can switch between both antennas (only one antenna used at a time). Therefore, the measurements were done twice, for each antenna configuration separately, except for the duty cycle measurement.

### 2.2.2 Operation modes

Antenna A:

| Operation mode # | Radio technology | Frequency [MHz] | Channel / Band | Modulation / Mode | Data rate  | TX / RX | Power setting |
|------------------|------------------|-----------------|----------------|-------------------|------------|---------|---------------|
| 1                | IEEE 802.15.4    | 2405            | 11             | O-QPSK            | 250 kbit/s | TX      | 3.5 dBm       |
| 2                | IEEE 802.15.4    | 2440            | 18             | O-QPSK            | 250 kbit/s | TX      | 3.5 dBm       |
| 3                | IEEE 802.15.4    | 2480            | 26             | O-QPSK            | 250 kbit/s | TX      | -3.5 dBm      |

Antenna B:

| Operation mode # | Radio technology | Frequency [MHz] | Channel / Band | Modulation / Mode | Data rate  | TX / RX | Power setting |
|------------------|------------------|-----------------|----------------|-------------------|------------|---------|---------------|
| 4                | IEEE 802.15.4    | 2405            | 11             | O-QPSK            | 250 kbit/s | TX      | 3.5 dBm       |
| 5                | IEEE 802.15.4    | 2440            | 18             | O-QPSK            | 250 kbit/s | TX      | 3.5 dBm       |
| 6                | IEEE 802.15.4    | 2480            | 26             | O-QPSK            | 250 kbit/s | TX      | -3.5 dBm      |

## 3 Additional Information

The EUT also contains a BLE and a UWB transceiver. The results of these technologies are documented in the test reports F191168E3 and F191161E4. The emissions of the digital part of the EUT are documented in the test report F191168E1. Object of this test report is the BLE part of the EUT only.

The tested sample was not labeled as required by the FCC.

The tests were done with an unmodified sample.

## 4 Overview

| Application                         | Frequency range [MHz] | FCC 47 CFR Part 15 section [2]   | Status                   | Refer page |
|-------------------------------------|-----------------------|----------------------------------|--------------------------|------------|
| Maximum peak conducted output power | 2400.0 - 2483.5       | 15.247 (b) (3), (4)              | Passed                   | 12         |
| Maximum conducted output power      | 2400.0 - 2483.5       | 15.247 (b) (3), (4)              | Passed                   | 12         |
| DTS Bandwidth / 99% Bandwidth       | 2400.0 - 2483.5       | 15.247 (a) (2)                   | Passed                   | 15         |
| Peak Power Spectral Density         | 2400.0 - 2483.5       | 15.247 (e)                       | Passed                   | 18         |
| Average Power Spectral Density      | 2400.0 - 2483.5       | 15.247 (e)                       | Passed                   | 18         |
| Band edge compliance                | 2400.0 - 2483.5       | 15.247 (d) 15.205 (a) 15.209 (a) | Passed                   | 21         |
| Maximum unwanted emissions          | 0.009 – 26,500*       | 15.247 (d) 15.205 (a) 15.209 (a) | Passed*                  | 26         |
| Conducted emissions on supply line  | 0.15 - 30             | 15.207 (a)                       | Not tested* <sup>2</sup> | -          |
| Antenna Requirement                 | -                     | 15.203 15.247 (b)                | Passed* <sup>1</sup>     | -          |

\*<sup>1</sup> Fixed PCB Antenna, gain below 6 dBi, no power reduction necessary.

\*<sup>2</sup> EUT is battery powered, no connection to the AC mains network.

## 5 Results

### 5.1 Duty cycle

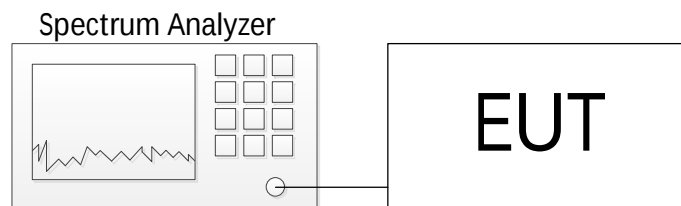
The duty cycle of the IEEE 802.15.4 part of the EUT was set to 100 %, therefore no duty cycle correction factor (DCCF) needs to be calculated.

### 5.1 Maximum conducted output power

#### 5.1.1 Method of measurement (conducted)

The measurements were done conducted at the antenna connectors of both antennas.

##### Test Setup:



##### Acceptable measurement configurations

See 8.3 of document [3] for details.

For the **Maximum *peak* conducted output power** the Procedure **11.9.1.1** in [1] was used.

For the **Maximum conducted *average* output power** the Procedure **11.9.2.2.4** in [1] was used.

Only one representative plot for each measurement configuration is provided.

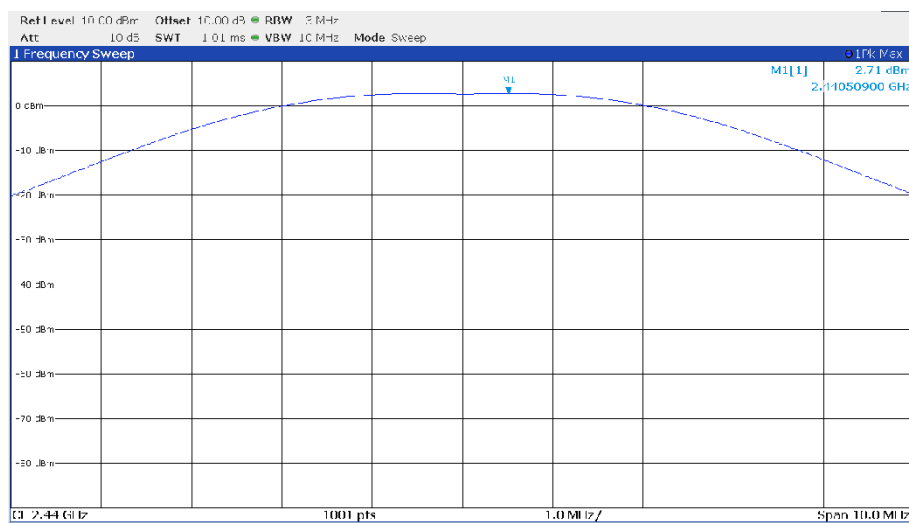
### 5.1.2 Test results

|                     |       |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity   | 53 %  |

|           |            |
|-----------|------------|
| Date      | 08.10.2020 |
| Tested by | B. ROHDE   |

Maximum *peak* conducted output power:

Antenna B Ch 18:



Antenna A / J1:

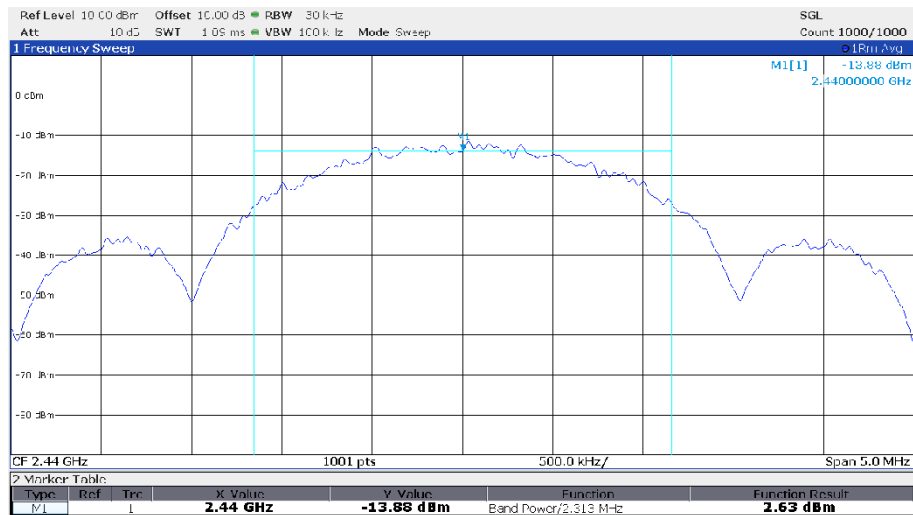
| Operation mode | Reading [dBm] | Corr. Fact. [Cable] [dB] | Result [dBm] | Limit [dBm] |
|----------------|---------------|--------------------------|--------------|-------------|
| 1              | 1.75          | 0.2                      | 1.95         | 30          |
| 2              | 1.74          | 0.2                      | 1.94         | 30          |
| 3              | -5.45         | 0.2                      | -5.25        | 30          |

Antenna B / J2:

| Operation mode | Reading [dBm] | Corr. Fact. [Cable] [dB] | Result [dBm] | Limit [dBm] |
|----------------|---------------|--------------------------|--------------|-------------|
| 4              | 2.66          | 0.2                      | 2.86         | 30          |
| 5              | 2.71          | 0.2                      | 2.91         | 30          |
| 6              | -4.58         | 0.2                      | -4.38        | 30          |

**Maximum average conducted output power:**

**Antenna B Ch 18:**



**Antenna A / J1:**

| Operation mode | Reading [dBm] | Corr. Fact. [Cable] [dB] | DCCF [dB] | Result [dBm] | Limit [dBm] |
|----------------|---------------|--------------------------|-----------|--------------|-------------|
| 1              | 1.66          | 0.2                      | 0.0       | 1.86         | 30          |
| 2              | 1.63          | 0.2                      | 0.0       | 1.83         | 30          |
| 3              | -5.55         | 0.2                      | 0.0       | -5.35        | 30          |

**Antenna B / J2:**

| Operation mode | Reading [dBm] | Corr. Fact. [dB] | DCCF [dB] | Result [dBm] | Limit [dBm] |
|----------------|---------------|------------------|-----------|--------------|-------------|
| 4              | 2.59          | 0.2              | 0.0       | 2.79         | 30          |
| 5              | 2.63          | 0.2              | 0.0       | 2.83         | 30          |
| 6              | -4.65         | 0.2              | 0.0       | -4.45        | 30          |

Test equipment (please refer to chapter 6 for details)

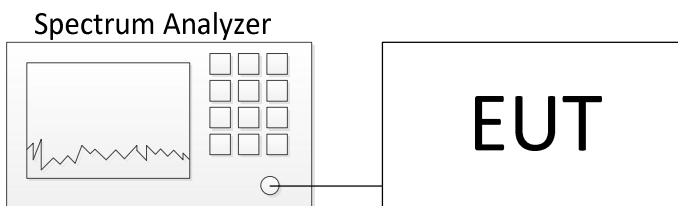
1

## 5.1 DTS Bandwidth / 99% Bandwidth

### 5.1.1 Method of measurement (conducted)

The measurements were done conducted at the antenna connectors of both antennas.

#### Test Setup:



#### Acceptable measurement configurations

See chapter 8.2 of document [3]

For the **DTS bandwidth** the Procedure **11.8.1** in [1] was used.

For the **Occupied bandwidth – 99% Bandwidth** the Procedure **6.9.3** in [1] was used.

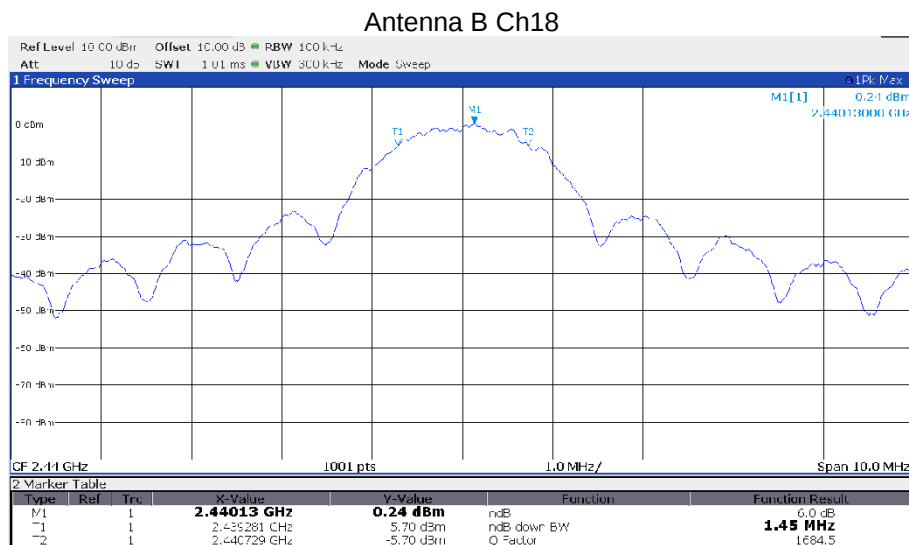
Only one representative plot for each measurement configuration is provided.

### 5.1.2 Test results

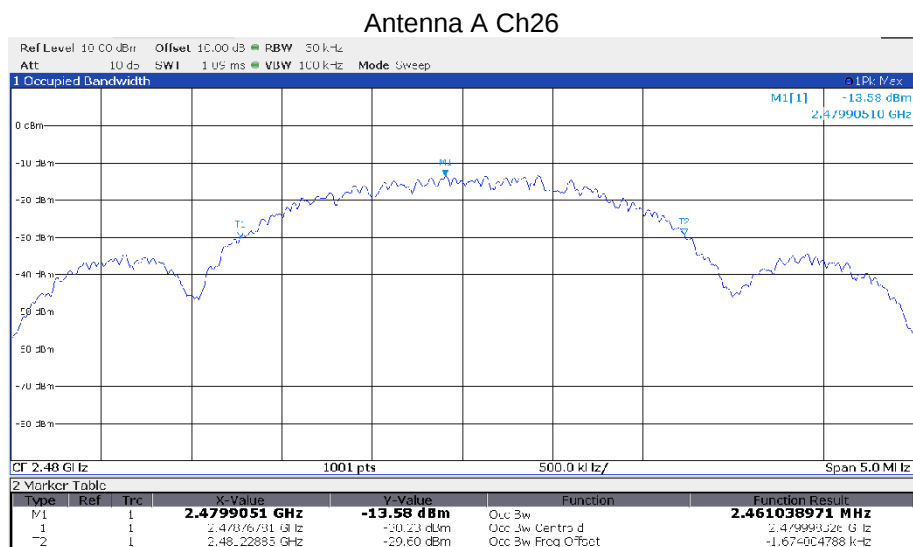
|                     |       |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity   | 53 %  |

|           |            |
|-----------|------------|
| Date      | 08.10.2020 |
| Tested by | B. ROHDE   |

Representative plot DTS bandwidth:



Representative plot 99 % bandwidth



Antenna A:

| OP mode | Data rate  | Center Frequency<br>[MHz] | Minimum 6-dB Bandwidth<br>Limit<br>[MHz] | 6 dB Bandwidth<br>[MHz] | 99 %<br>Bandwidth<br>[MHz] | Result |
|---------|------------|---------------------------|------------------------------------------|-------------------------|----------------------------|--------|
| 1       | 250 kbit/s | 2405                      | 0.5                                      | 1.45                    | 2.394                      | Passed |
| 2       | 250 kbit/s | 2440                      | 0.5                                      | 1.58                    | 2.406                      | Passed |
| 3       | 250 kbit/s | 2475                      | 0.5                                      | 1.81                    | 2.461                      | Passed |

Antenna B:

| OP mode | Data rate  | Center Frequency<br>[MHz] | Minimum 6-dB Bandwidth<br>Limit<br>[MHz] | 6 dB Bandwidth<br>[MHz] | 99 %<br>Bandwidth<br>[MHz] | Result |
|---------|------------|---------------------------|------------------------------------------|-------------------------|----------------------------|--------|
| 4       | 250 kbit/s | 2405                      | 0.5                                      | 1.52                    | 2.287                      | Passed |
| 5       | 250 kbit/s | 2440                      | 0.5                                      | 1.45                    | 2.313                      | Passed |
| 6       | 250 kbit/s | 2475                      | 0.5                                      | 1.54                    | 2.376                      | Passed |

Test equipment (please refer to chapter 6 for details)

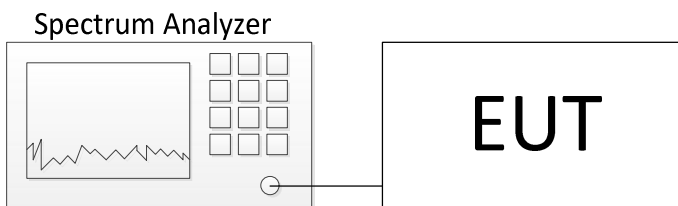
1

## 5.2 Power spectral density

### 5.2.1 Method of measurement (conducted)

The measurements were done conducted at the antenna connectors of both antennas.

#### Test Setup:



#### Acceptable measurement configurations

See chapter 8.4 of document [3]

For the **Maximum *peak* power spectral density level in the fundamental emission** the Procedure **11.10.2** in [1] was used.

For the **Maximum *average* power spectral density level in the fundamental emission** the Procedure **11.10.5** in [1] was used.

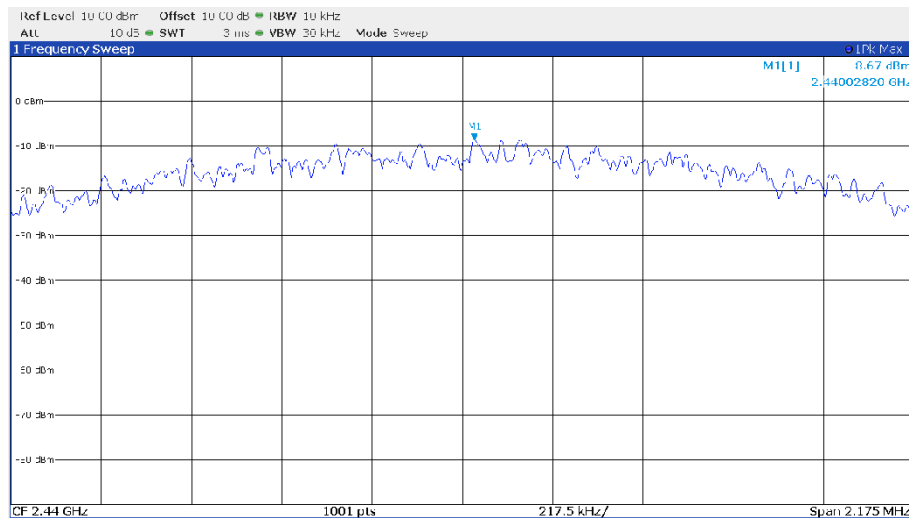
Only one representative plot for each measurement configuration is provided.

## 5.2.2 Test results

|                     |       |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity   | 53 %  |

|           |            |
|-----------|------------|
| Date      | 08.10.2020 |
| Tested by | B. ROHDE   |

Maximum *peak* power spectral density level in the fundamental emission:



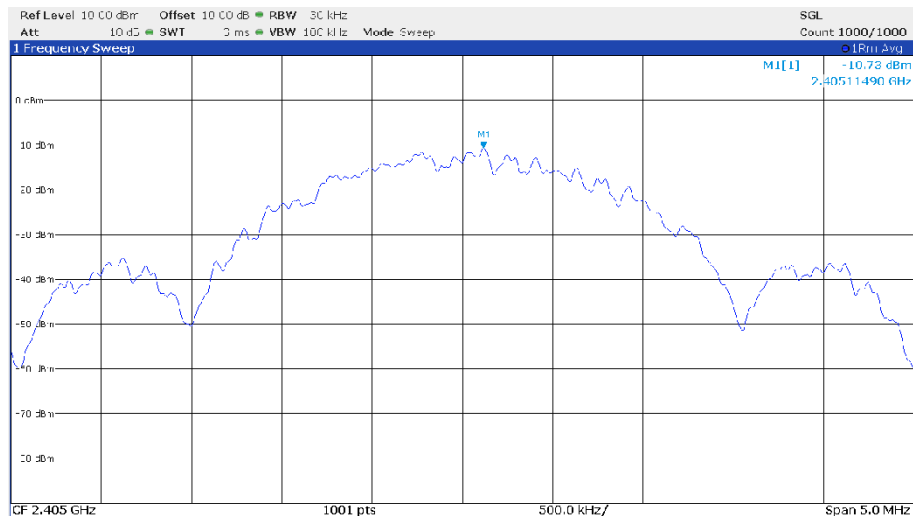
Antenna A:

| OP mode | Peak Frequency [MHz] | Peak PSD Reading [dBm / 10 kHz] | Corr. Fact. [Cable] [dB] | Peak PSD Result [dBm / 10 kHz] | PSD Limit [dBm / 3 kHz] | Result |
|---------|----------------------|---------------------------------|--------------------------|--------------------------------|-------------------------|--------|
| 1       | 2404.764             | -9.76                           | 0.2                      | -9.56                          | 8                       | Passed |
| 2       | 2440.204             | -10.06                          | 0.2                      | -9.86                          | 8                       | Passed |
| 3       | 2479.908             | -18.29                          | 0.2                      | -18.09                         | 8                       | Passed |

Antenna B:

| OP mode | Peak Frequency [MHz] | Peak PSD Reading [dBm / 10 kHz] | Corr. Fact. [Cable] [dB] | Peak PSD Result [dBm / 10 kHz] | PSD Limit [dBm / 3 kHz] | Result |
|---------|----------------------|---------------------------------|--------------------------|--------------------------------|-------------------------|--------|
| 1       | 2405.109             | -8.81                           | 0.2                      | -8.61                          | 8                       | Passed |
| 2       | 2440.028             | -8.67                           | 0.2                      | -8.47                          | 8                       | Passed |
| 3       | 2480.152             | -15.62                          | 0.2                      | -15.42                         | 8                       | Passed |

**Maximum average power spectral density level in the fundamental emission:**



Antenna A:

| OP mode | Peak Frequency [MHz] | PSD Reading [dBm / 30 kHz] | Corr. Fact. [Cable] [dB] | DCCF [dB] | Result incl. DCCF [dBm / 30 kHz] | PSD Limit [dBm / 3 kHz] | Result |
|---------|----------------------|----------------------------|--------------------------|-----------|----------------------------------|-------------------------|--------|
| 1       | 2405.110             | -11.91                     | 0.2                      | 0.0       | -11.71                           | 8                       | Passed |
| 2       | 2440.105             | -13.62                     | 0.2                      | 0.0       | -13.42                           | 8                       | Passed |
| 3       | 2480.135             | -20.16                     | 0.2                      | 0.0       | -19.96                           | 8                       | Passed |

Antenna B:

| OP mode | Peak Frequency [MHz] | PSD Reading [dBm / 30 kHz] | Corr. Fact. [Cable] [dB] | DCCF [dB] | Result incl. DCCF [dBm / 30 kHz] | PSD Limit [dBm / 3 kHz] | Result |
|---------|----------------------|----------------------------|--------------------------|-----------|----------------------------------|-------------------------|--------|
| 1       | 2405.115             | -10.73                     | 0.2                      | 0.0       | -10.53                           | 8                       | Passed |
| 2       | 2440.010             | -11.45                     | 0.2                      | 0.0       | -11.25                           | 8                       | Passed |
| 3       | 2480.155             | -17.91                     | 0.2                      | 0.0       | -17.71                           | 8                       | Passed |

Test equipment (please refer to chapter 6 for details)

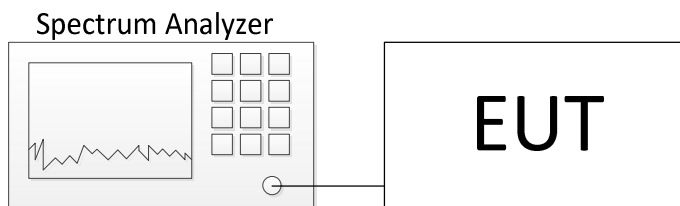
1

## 5.3 Band edge

### 5.3.1 Method of measurement (conducted)

The measurements were done conducted at the antenna connectors of both antennas.

#### Test Setup:



#### Acceptable measurement configurations

See chapter 8.7 of document [3].

For the **Band-edge testing (unrestricted bands)** the Procedure **6.10.4** in [1] was used, see remarks of #59, table A2 of document [1].

For the **Band-edge testing (restricted bands)** the tests were done radiated.

Only one representative plot is provided.

### 5.3.2 Method of measurement (radiated)

The EUT was measured radiated in an anechoic chamber. For test setup and measurement configuration see 5.4.1

For the **Band-edge testing (restricted bands)** the 15.209 limits apply.

Only one representative plot is provided.

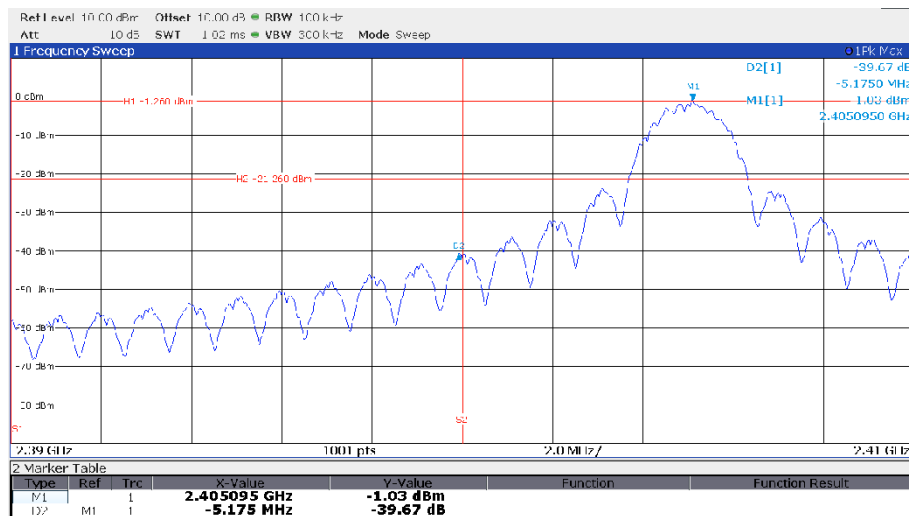
### 5.3.3 Test results

#### 5.3.3.1 Band-edge testing (unrestricted bands; conducted):

|                     |       |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity   | 53 %  |

|           |            |
|-----------|------------|
| Date      | 08.10.2020 |
| Tested by | B. ROHDE   |

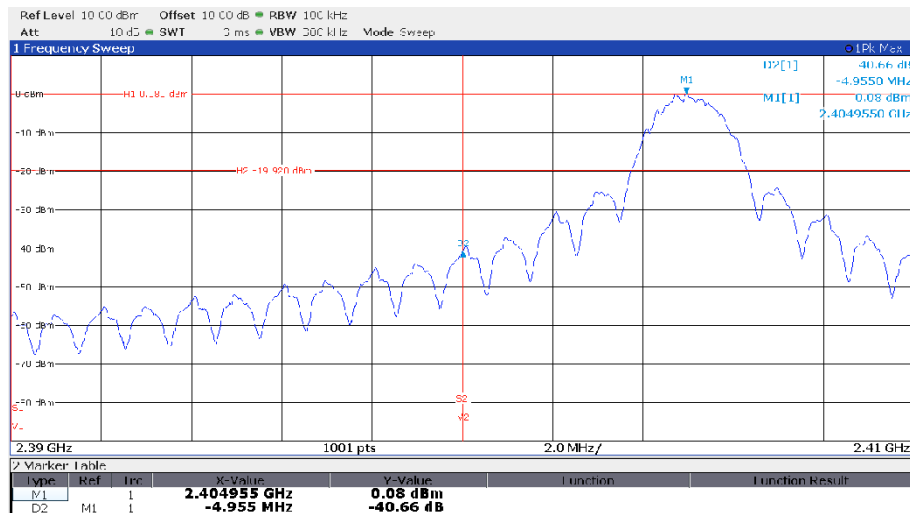
#### Antenna A



#### Antenna A:

| Operation mode | Data rate  | Frequency [MHz] | Reference Level [dBm] | Limit [dBm] | Margin [dB] | Result |
|----------------|------------|-----------------|-----------------------|-------------|-------------|--------|
| 1              | 250 kbit/s | 2405            | -1.03                 | -21.3       | 19.7        | Passed |

Antenna B:



Antenna B:

| Operation mode | Data rate  | Frequency [MHz] | Reference Level [dBm] | Limit [dBm] | Margin [dB] | Result |
|----------------|------------|-----------------|-----------------------|-------------|-------------|--------|
| 4              | 250 kbit/s | 2405            | 0.1                   | -19.9       | 20.7        | Passed |

Test equipment (please refer to chapter 6 for details)

1

### 5.3.3.2 Band-edge testing (restricted bands; radiated):

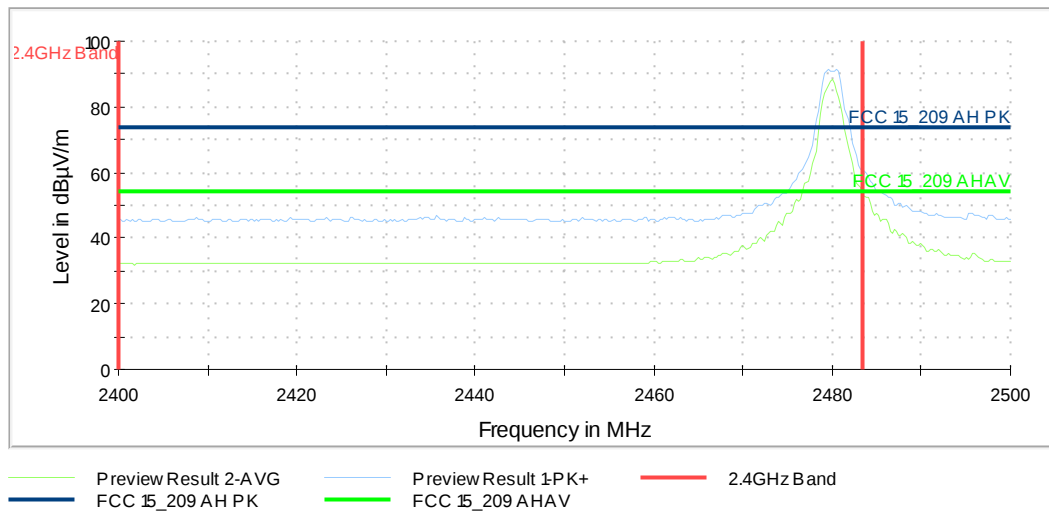
|                     |       |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity   | 43 %  |

|           |            |
|-----------|------------|
| Date      | 09.10.2020 |
| Tested by | B. ROHDE   |

Operation mode 1:  
No significant emission found; no final measurement conducted

Operation mode 3:

Antenna A:

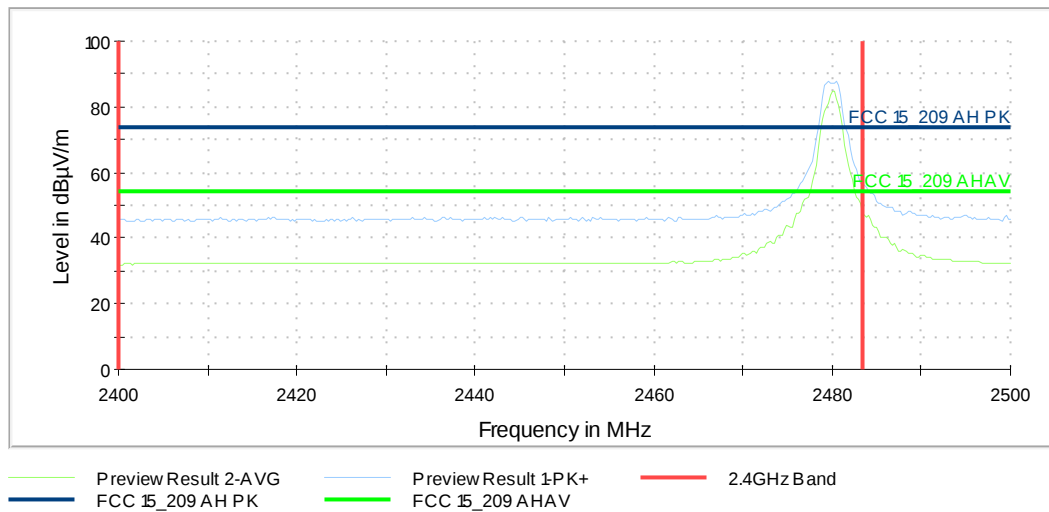


| Frequency<br>[MHz]      | Result<br>(Pk)<br>[dBµV/m] | Result<br>(Av)<br>[dBµV/m] | Limit<br>[dBµV/m] | Margin<br>[dB] | Readings<br>[dBµV] | Correction<br>[dB] | Elevation<br>[deg] | Azimuth<br>[deg] | Pol. | Result |
|-------------------------|----------------------------|----------------------------|-------------------|----------------|--------------------|--------------------|--------------------|------------------|------|--------|
| 2383.500000             | 61.30                      | ---                        | 74                | 12.70          | 26.70              | 34.6               | 0                  | 148              | H    | Passed |
| 2384.000000             | ---                        | 53.5                       | 54                | 0.50           | 17.90              | 34.6               | 0                  | 148              | H    | Passed |
| Measurement uncertainty |                            |                            |                   |                | ±5.5 dB            |                    |                    |                  |      |        |

Operation mode 4:  
No significant emission found; no final measurement conducted

Operation mode 6:

Antenna B:



| Frequency<br>[MHz]      | Result<br>(Pk)<br>[dBµV/m] | Result<br>(Av)<br>[dBµV/m] | Limit<br>[dBµV/m] | Margin<br>[dB] | Readings<br>[dBµV] | Correction<br>[dB] | Elevation<br>[deg] | Azimuth<br>[deg] | Pol. | Result |
|-------------------------|----------------------------|----------------------------|-------------------|----------------|--------------------|--------------------|--------------------|------------------|------|--------|
| 2383.500000             | 58.83                      | ---                        | 74                | 15.17          | 24.23              | 34.6               | 0                  | 40               | H    | Passed |
| 2383.500000             | ---                        | 50.16                      | 54                | 3.84           | 15.56              | 34.6               | 0                  | 40               | H    | Passed |
| Measurement uncertainty |                            |                            |                   |                | ±5.5 dB            |                    |                    |                  |      |        |

Test equipment (please refer to chapter 6 for details)

2 - 9

## 5.4 Maximum unwanted emissions Maximum unwanted emissions

### 5.4.1 Method of measurement (radiated)

The radiated emission measurement is subdivided into six stages.

- A preliminary measurement carried out in a fully anechoic chamber with a fixed antenna height in the frequency range 9 kHz to 30 MHz.
- A final measurement carried out on an outdoor test site without reflecting ground plane and a fixed antenna height in the frequency range 9 kHz to 30 MHz.
- A preliminary and final measurement carried out in a semi anechoic chamber with a varying antenna height in the frequency range 30 MHz to 1 GHz.
- A preliminary and final measurement carried out in a semi anechoic chamber with ground absorbers with a varying antenna height in the frequency range above 1 GHz.

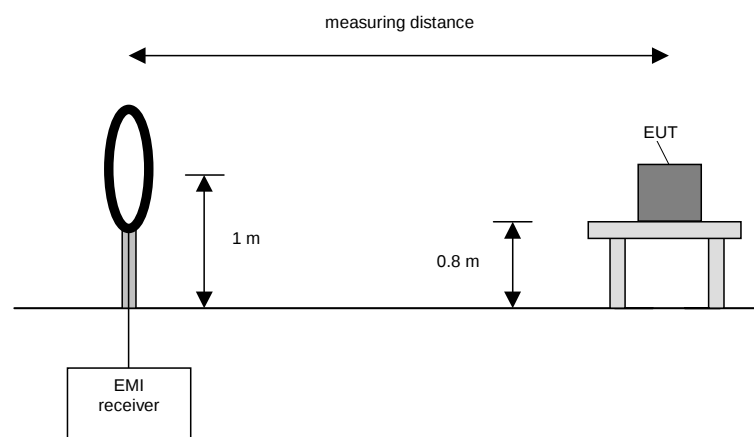
#### Preliminary measurement (9 kHz to 30 MHz):

In the first stage a preliminary measurement will be performed in a shielded room with a measuring distance of 3 meters. Tabletop devices will be set up on a non-conducting turn device on the height of 0.8 m. Floor-standing devices will be placed directly on the turntable/ground plane. The set-up of the Equipment under test will be in accordance to [1].

The frequency range 9 kHz to 30 MHz will be monitored with a spectrum analyzer while the system and its cables will be manipulated to find out the configuration with the maximum emission levels if applicable. The EMI Receiver will be set to MAX Hold mode. The EUT and the measuring antenna will be rotated around their vertical axis to find the maximum emissions.

The resolution bandwidth of the spectrum analyzer will be set to the following values:

| Frequency range   | Resolution bandwidth |
|-------------------|----------------------|
| 9 kHz to 150 kHz  | 200 Hz               |
| 150 kHz to 30 MHz | 9 kHz                |



#### Preliminary measurement procedure:

Pre-scans were performed in the frequency range 9 kHz to 150 kHz and 150 kHz to 30 MHz.

Pre-scans were performed in the frequency range 30 MHz to 230 MHz and 230 MHz to 1 GHz.

The following procedure will be used:

1. Monitor the frequency range at horizontal polarization and a EUT azimuth of 0 °.
2. Manipulate the system cables within the range to produce the maximum level of emission.
3. Rotate the EUT by 360 ° to maximize the detected signals.
4. Repeat 1) to 3) with the vertical polarization of the measuring antenna.
5. Make a hardcopy of the spectrum.
6. Repeat 1) to 5) with the EUT raised by an angle of 0° (45°, 90°) according to 6.6.5.4 in [1].
7. Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.

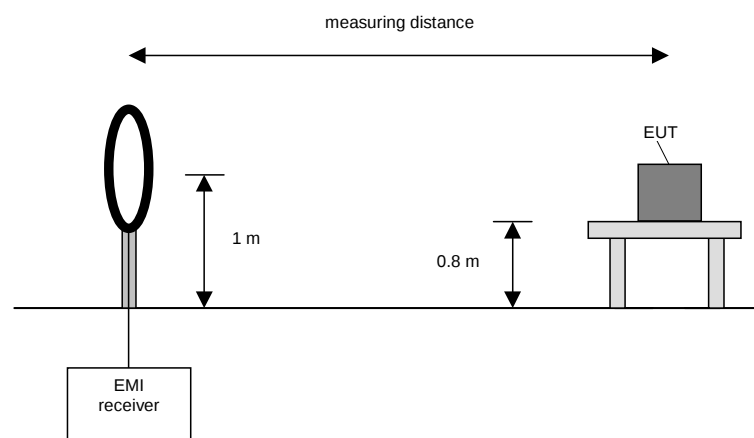
#### Final measurement (9 kHz to 30 MHz):

In the second stage a final measurement will be performed on an open area test site with no conducting ground plane in a measuring distances of 3 m, 10 m and 30 m. In the case where larger measuring distances are required the results will be extrapolated based on the values measured on the closer distances according to Section 15.31 (f) (2) [2]. The final measurement will be performed with a EMI Receiver set to Quasi Peak detector except for the frequency bands 9 kHz to 90 kHz and 110 kHz to 490 kHz where an average detector will be used according Section 15.209 (d) [2].

On the frequencies, which were detected during the preliminary measurements, the final measurement will be performed while rotating the EUT and the measuring antenna in the range of 0 ° to 360 ° around their vertical axis until the maximum value is found.

The resolution bandwidth of the EMI Receiver will be set to the following values:

| Frequency range   | Resolution bandwidth |
|-------------------|----------------------|
| 9 kHz to 150 kHz  | 200 Hz               |
| 150 kHz to 30 MHz | 9 kHz                |

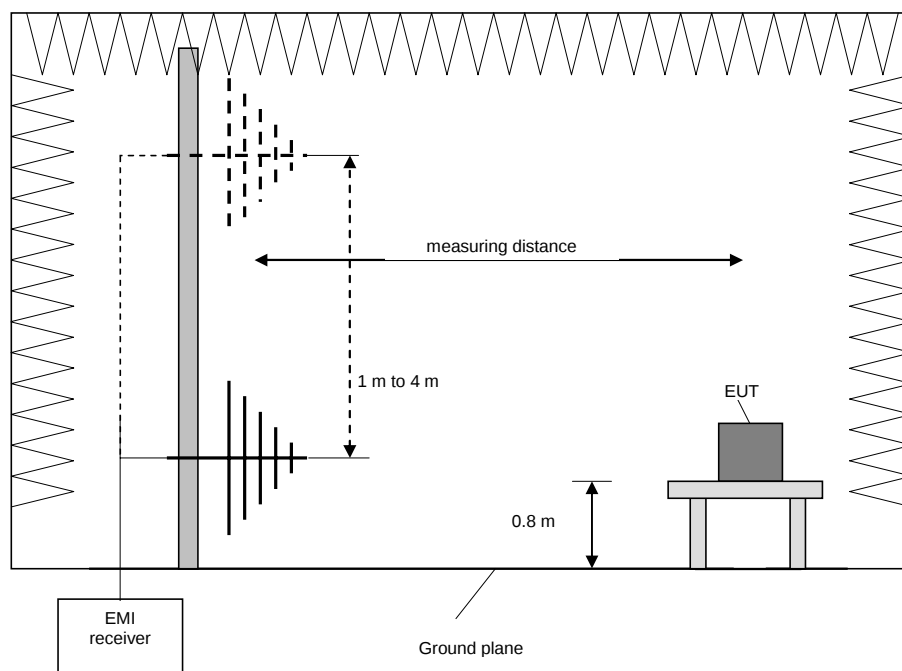


### Preliminary and final measurement (30 MHz to 1 GHz)

The preliminary and final measurements were conducted in a semi-anechoic chamber with a metal ground plane. During the test the EUT will be rotated in the range of 0 ° to 360 °, the measuring antenna will be set to horizontal and vertical polarization and raised and lowered in the range from 1 m to 4 m to find the maximum level of emissions.

The resolution bandwidth of the EMI Receiver will be set to the following values:

| Test                    | Frequency range | Resolution bandwidth | Step size | Measurement time |
|-------------------------|-----------------|----------------------|-----------|------------------|
| Preliminary measurement | 30 MHz to 1 GHz | 120 kHz              | 40 kHz    | 100 ms           |
| Frequency peak search   | 3 x RBW         | 120 kHz              | 10 kHz    | 1000 ms          |
| Final measurement       | 30 MHz to 1 GHz | 120 kHz              | -         | 5 x 1000 ms      |



Procedure preliminary measurement:

The following procedure is used:

1. Set the measurement antenna to 1 m height.
2. Monitor the frequency range at vertical polarization and a EUT azimuth of 0 °.
3. Rotate the EUT by 360° to maximize the detected signals.
4. Repeat 1) to 2) with the vertical polarization of the measuring antenna.
5. Increase the height of the antenna for 0.5 m and repeat steps 2 – 4 until the final height of 4 m is reached.
6. The highest values for each frequency will be saved by the software, including the antenna height, measurement antenna polarization and turntable azimuth for the highest value.

Procedure final measurement:

The following procedure is used:

1. Select the highest frequency peaks to the limit for the final measurement.
2. The software will determine the exact peak frequencies by doing a partial scan with reduced step size with +/- 3 times the RBW of the pre-scan of the selected peaks.
3. If the EUT is portable or ceiling mounted, find the worst case EUT orientation (x,y,z) for the final test.
4. The worst measurement antenna height is found by the measurement software by varying the measurement antenna height by +/- 0.5 m from the worst-case value obtained in the preliminary measurement, and to monitor the emission level.
5. The worst azimuth turntable position is found by varying the turntable azimuth by +/- 30° from the worst-case value obtained in the preliminary measurement, and to monitor the emission level.
6. The final measurement is performed at the worst-case antenna height and the worst-case turntable azimuth.
7. Steps 2 – 6 will be repeated for each frequency peak selected in step 1.

### **Preliminary and final measurement (1 GHz to 40 GHz)**

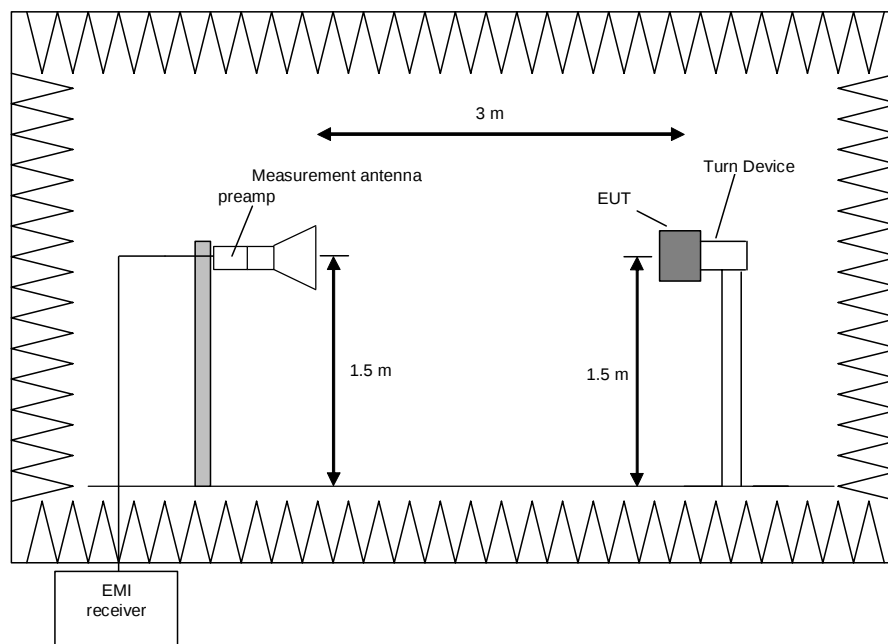
This measurement will be performed in a fully anechoic chamber. Table top devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

### **Preliminary measurement (1 GHz to 40 GHz)**

The frequency range will be divided into different sub ranges depending of the frequency range of the used horn antenna. The spectrum analyser set to MAX Hold mode and a resolution bandwidth of 1 MHz. The measurement will be performed in horizontal and vertical polarisation of the measuring antenna and while rotating the EUT in its vertical axis in the range of 0 ° to 360 °. This measurement is repeated after raising the EUT in 30° steps according 6.6.5.4 in [1].

The resolution bandwidth of the EMI Receiver will be set to the following values:

| Frequency range         | Resolution bandwidth |
|-------------------------|----------------------|
| 1 GHz to 4 GHz          | 1 MHz                |
| 4 GHz to 12 GHz         | 1 MHz                |
| 12 GHz to 18 GHz        | 1 MHz                |
| 18 GHz to 25 / 26.5 GHz | 1 MHz                |
| 26.5 GHz to 40 GHz      | 1 MHz                |



#### Procedure preliminary measurement:

Prescans were performed in the frequency range 1 to 40 GHz.

The following procedure will be used:

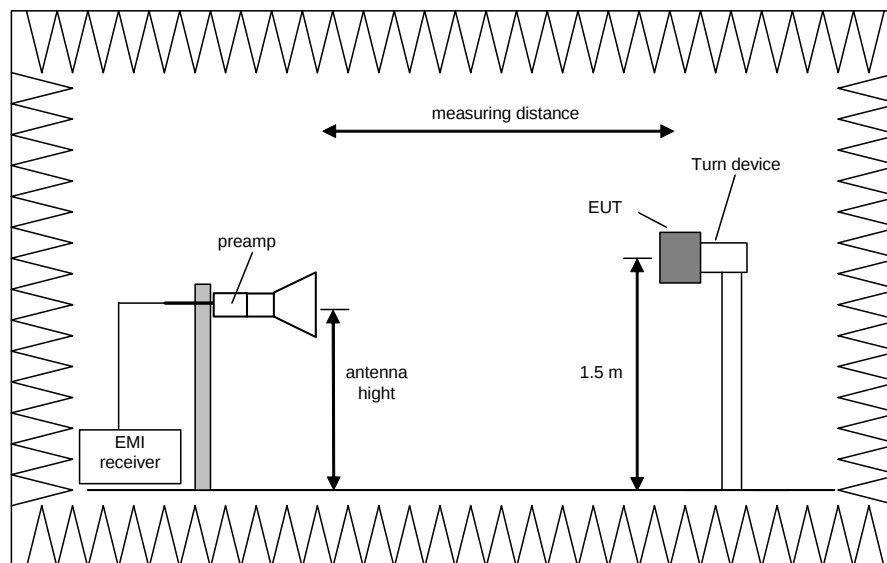
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an angle of 30° (60°, 90°, 120° and 150°) according to 6.6.5.4 in [1].
6. Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
7. The measurement antenna polarisation, with the according EUT position (Turntable and Turn device) which produces the highest emission for each frequency will be used for the final measurement. The six closest values to the applicable limit will be used for the final measurement.

#### Final measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending of the frequency range of the used horn antenna. The EMI Receiver set to peak and average mode and a resolution bandwidth of 1 MHz. The measurement will be performed by rotating the turntable through 0 to 360° in the worst-case EUT orientation which was obtained during the preliminary measurements.

The resolution bandwidth of the EMI Receiver will be set to the following values:

| Frequency range         | Resolution bandwidth |
|-------------------------|----------------------|
| 1 GHz to 4 GHz          | 1 MHz                |
| 4 GHz to 12 GHz         | 1 MHz                |
| 12 GHz to 18 GHz        | 1 MHz                |
| 18 GHz to 25 / 26.5 GHz | 1 MHz                |
| 26.5 GHz to 40 GHz      | 1 MHz                |



Procedure of measurement:

The measurements were performed in the frequency ranges 1 GHz to 4 GHz, 4 GHz to 12 GHz, 12 GHz to 18 GHz, 18 GHz to 25 /26.5 GHz and 26.5 GHz to 40 GHz.

The following procedure will be used:

- 1) Set the turntable and the turn device to obtain the worst-case emission for the first frequency identified in the preliminary measurements.
- 2) Set the measurement antenna polarisation to the orientation with the highest emission for the first frequency identified in the preliminary measurements.
- 3) Set the spectrum analyser to EMI mode with peak and average detector activated.
- 4) Rotate the turntable from 0° to 360° to find the TT Pos. that produces the highest emissions.
- 5) Note the highest displayed peak and average values
- 6) Repeat the steps 1) to 5) for each frequency detected during the preliminary measurements.

## 5.4.2 Test results (radiated)

### 5.4.2.1 Test results (9 kHz – 30 MHz)

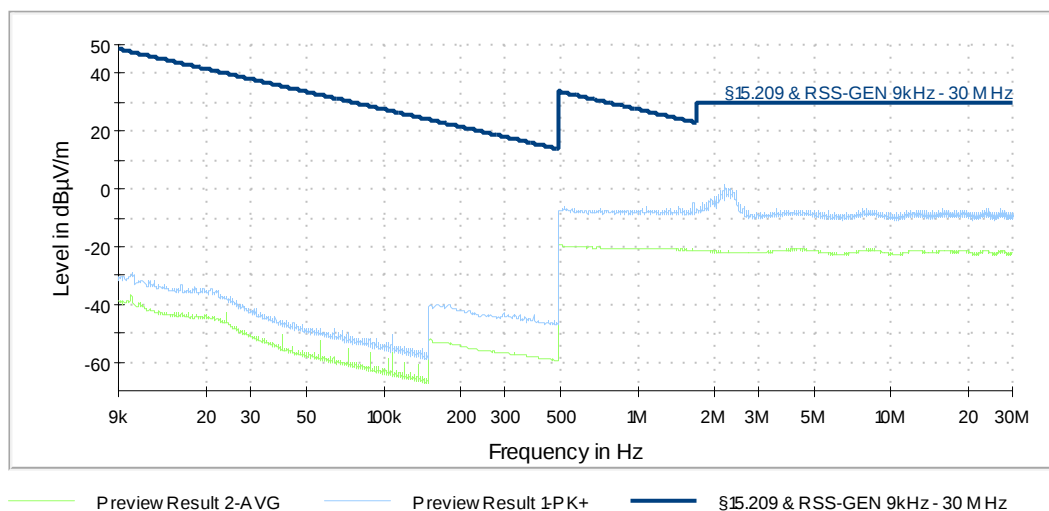
|                     |       |
|---------------------|-------|
| Ambient temperature | 23 °C |
| Relative humidity   | 62 %  |

|           |            |
|-----------|------------|
| Date      | 29.09.2020 |
| Tested by | B. ROHDE   |

- Position of EUT:** For tests for f between 9 kHz and 30 MHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.
- Cable guide:** For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.
- Test record:** The measurement value was already corrected by 40 dB/decade as described in §15.31 (f) (2) regarding to the measurement distance as requested in §15.209
- Remark:** As pretests have shown, no significant difference between modes 1 – 6 could be monitored in the spectrum from 30 MHz to 1 GHz, therefore only one representative final emissions measurement in this frequency range was conducted

#### 5.4.2.1.1 Plots

9k-30M: Spurious emissions from 9 kHz to 30 MHz (Operation mode 5)



**Remark:** In the shown plot a distance correction factor was added to the measurement results to account for the different measuring distances according to standard (9 kHz to 490 kHz @ 300 m; 490 kHz to 30 MHz @ 30 m).

#### 5.4.2.1.2 Result table

All emissions are more the 20 dB from the limit, so no final measurement was conducted.

|                                                        |
|--------------------------------------------------------|
| Test equipment (please refer to chapter 6 for details) |
| 2 - 8, 10                                              |

#### 5.4.2.2 Test results (30 MHz – 1 GHz)

|                     |       |
|---------------------|-------|
| Ambient temperature | 23 °C |
| Relative humidity   | 45 %  |

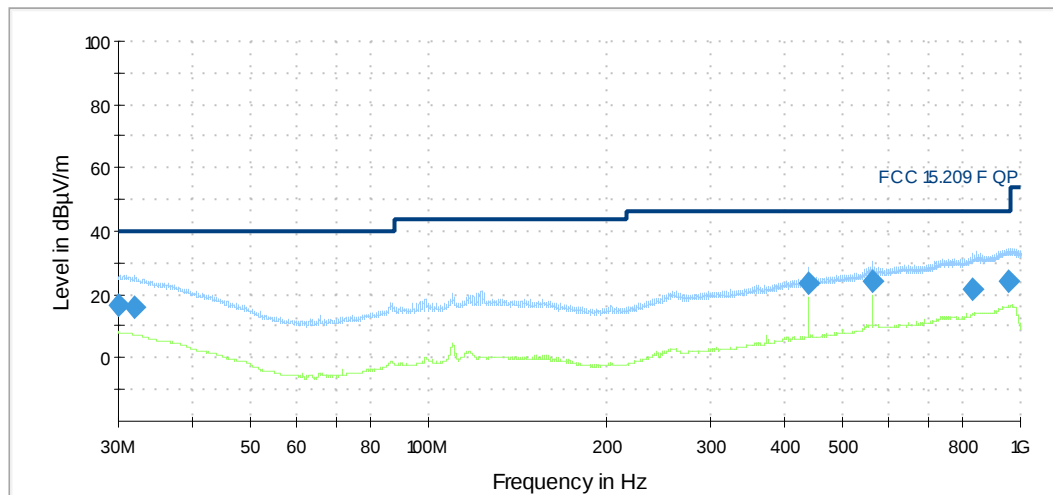
|           |            |
|-----------|------------|
| Date      | 14.07.2020 |
| Tested by | B. ROHDE   |

- Position of EUT: The EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.
- Cable guide: For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.
- Test record: Only the worst-case plot is submitted below.  
As pretests have shown, antenna A is the worst-case, final tests were only conducted on antenna A
- Remark: As pretests have shown, no significant difference between modes 1 – 6 could be monitored in the spectrum from 30 MHz to 1 GHz, therefore only one representative final emissions measurement in this frequency range was conducted

##### 5.4.2.2.1 Plots

###### Antenna B

Spurious emissions from 30 MHz to 1 GHz (operation mode 5):



#### 5.4.2.2.2 Result table

Result table (operation mode 5): ANT B CH18

| Frequency<br>[MHz]              | Result<br>[dBμV/m] | Limit<br>[dBμV/m] | Margin<br>[dB] | Readings<br>[dBμV] | Correction<br>[dB/m] | Height<br>[cm] | Azimuth<br>[deg] | Pol. | Result |
|---------------------------------|--------------------|-------------------|----------------|--------------------|----------------------|----------------|------------------|------|--------|
| 30.015000                       | 16.66              | 40.00             | 23.34          | -10.7              | 27.4                 | 100            | 335              | V    | Passed |
| 31.885000                       | 16.11              | 40.00             | 23.89          | -10.4              | 26.6                 | 278            | 267              | H    | Passed |
| 437.505000                      | 23.66              | 46.00             | 22.34          | -1.1               | 24.8                 | 299            | 307              | V    | Passed |
| 562.510000                      | 24.24              | 46.00             | 21.76          | -4.2               | 28.5                 | 245            | 81               | H    | Passed |
| 832.605000                      | 21.99              | 46.00             | 24.01          | -9.8               | 31.8                 | 400            | 86               | H    | Passed |
| 953.795000                      | 24.51              | 46.00             | 21.49          | -9.6               | 34.1                 | 234            | 141              | V    | Passed |
| Measurement uncertainty ±5.5 dB |                    |                   |                | ±5.5 dB            |                      |                |                  |      |        |

Test equipment (please refer to chapter 6 for details)

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### 5.4.2.3 Test results (above 1 GHz)

|                     |           |
|---------------------|-----------|
| Ambient temperature | 22-23 °C  |
| Relative humidity   | 43 - 56 % |

|           |                          |
|-----------|--------------------------|
| Date      | 14.07.2020 to 09.10.2020 |
| Tested by | B. ROHDE; Y KHALEK       |

Position of EUT: For tests for f between 1 GHz and the 10<sup>th</sup> harmonic, the EUT was set-up on a table with a height of 150 cm. The distance between EUT and antenna was 3 m.

Cable guide: For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.

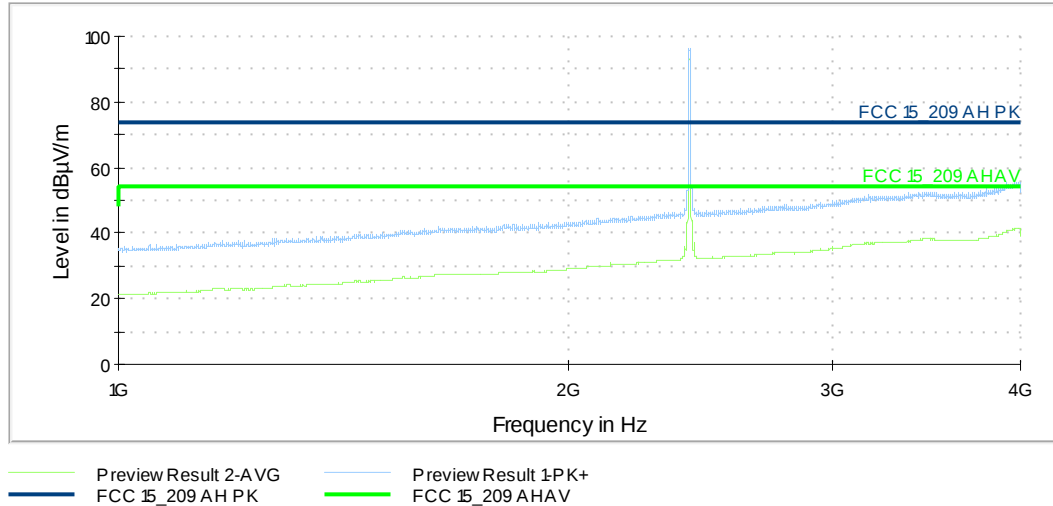
Test record: As pretests have shown, Antenna A is the worst case (radiated), final measurements were conducted only for antenna A

Remark: only the worst-case plots were reported below

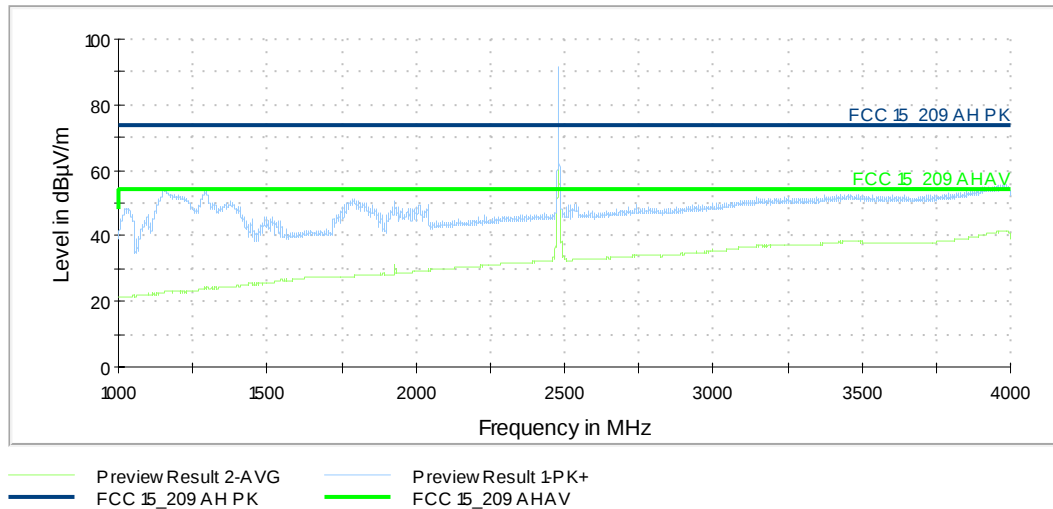
#### 5.4.2.3.1 Plots

##### Antenna A:

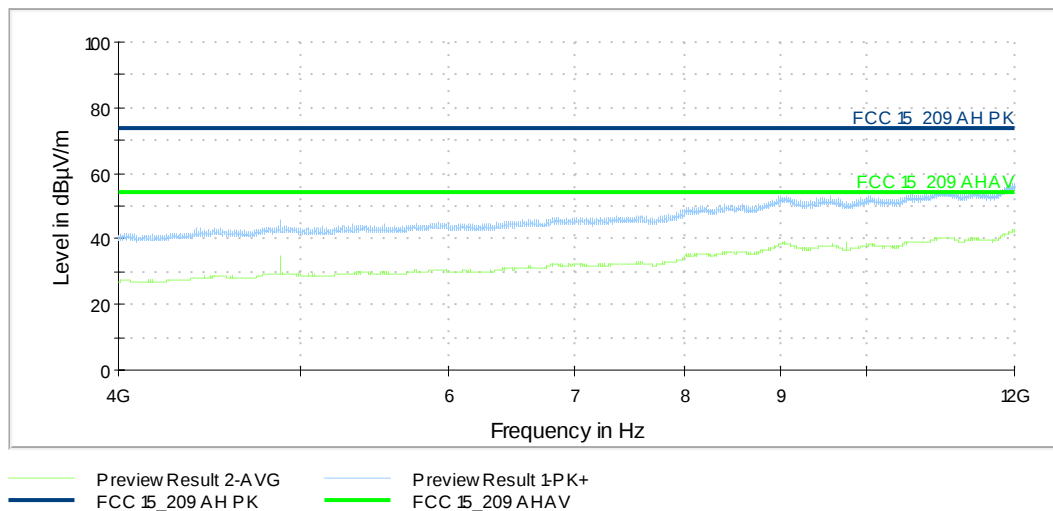
Spurious emissions from 1 GHz to 4 GHz (operation mode 1):  
(highest emissions level in band)



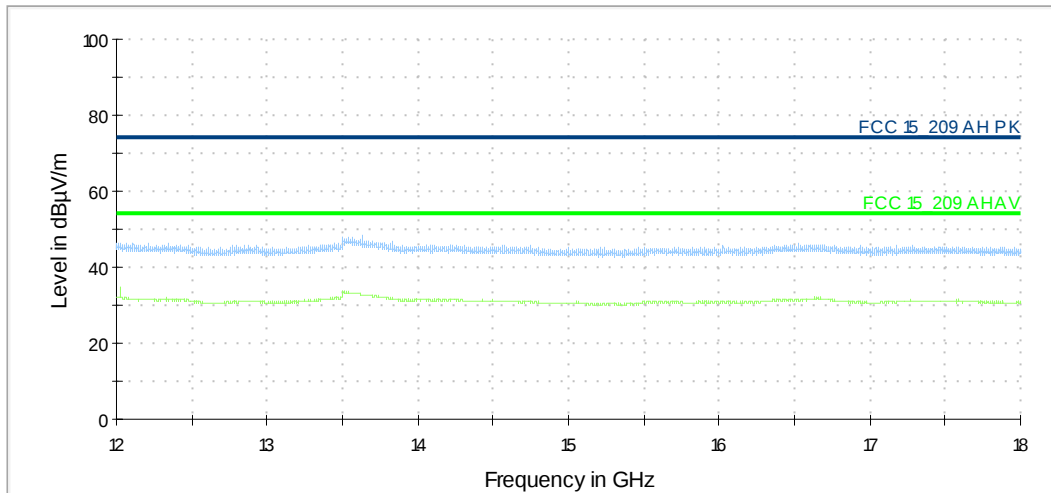
Spurious emissions from 1 GHz to 4 GHz (operation mode 1):  
(highest emissions @ the band edges and out of band)



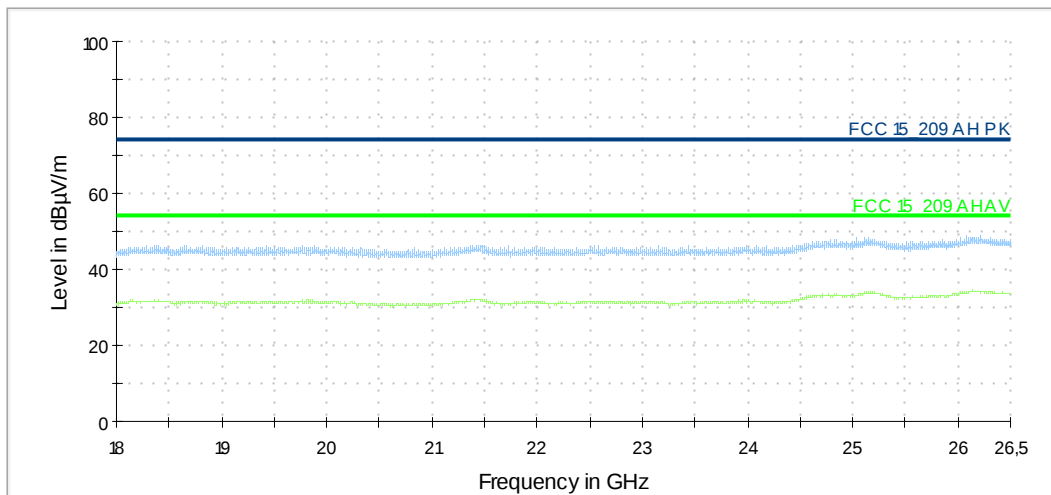
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



Spurious emissions from 12 GHz to 18 GHz (operation mode 1):



Spurious emissions from 18 GHz to 26.5 GHz (operation mode 1):



#### 5.4.2.3.2 Result table

Result table antenna A operation mode 1:

| Frequency<br>[MHz]                                                                                        | MaxPeak<br>[dBμV/m] | Average<br>[dBμV/m] | Limit<br>[dBμV/m] | Margin<br>(dB) | Height<br>(deg) | Pol | Azimuth<br>(deg) | Corr.<br>(dB) |
|-----------------------------------------------------------------------------------------------------------|---------------------|---------------------|-------------------|----------------|-----------------|-----|------------------|---------------|
| All emissions, except the fundamental are more than 20 dB below the limit, no final measurement conducted |                     |                     |                   |                |                 |     |                  |               |
| Measurement uncertainty                                                                                   |                     |                     |                   | +/- 4.79 dB    |                 |     |                  |               |

Result table antenna A operation mode 2:

| Frequency<br>[MHz]                                                                                        | MaxPeak<br>[dBμV/m] | Average<br>[dBμV/m] | Limit<br>[dBμV/m] | Margin<br>(dB) | Height<br>(deg) | Pol | Azimuth<br>(deg) | Corr.<br>(dB) |
|-----------------------------------------------------------------------------------------------------------|---------------------|---------------------|-------------------|----------------|-----------------|-----|------------------|---------------|
| All emissions, except the fundamental are more than 20 dB below the limit, no final measurement conducted |                     |                     |                   |                |                 |     |                  |               |
| Measurement uncertainty                                                                                   |                     |                     |                   | +/- 4.79 dB    |                 |     |                  |               |

Result table antenna A operation mode 3:

| Frequency<br>[MHz]                                                                                        | MaxPeak<br>[dBμV/m] | Average<br>[dBμV/m] | Limit<br>[dBμV/m] | Margin<br>(dB) | Height<br>(deg) | Pol | Azimuth<br>(deg) | Corr.<br>(dB) |
|-----------------------------------------------------------------------------------------------------------|---------------------|---------------------|-------------------|----------------|-----------------|-----|------------------|---------------|
| All emissions, except the fundamental are more than 20 dB below the limit, no final measurement conducted |                     |                     |                   |                |                 |     |                  |               |
| Measurement uncertainty                                                                                   |                     |                     |                   | +/- 4.79 dB    |                 |     |                  |               |

Test equipment (please refer to chapter 6 for details)

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## 6 Test Equipment used for Tests

| No. | Test equipment                           | Type                   | Manufacturer                             | Serial No.               | PM. No. | Cal. Date                 | Cal Due |
|-----|------------------------------------------|------------------------|------------------------------------------|--------------------------|---------|---------------------------|---------|
| 1   | Signal & Spectrum Analyzer               | FSW43                  | Rohde & Schwarz                          | 100586 & 100926          | 481720  | 04.03.2020                | 03.2022 |
| 2   | RF Switch Matrix                         | OSP220                 | Rohde & Schwarz                          |                          | 482976  | Calibration not necessary |         |
| 3   | Turntable                                | TT3.0-3t               | Maturo                                   | 825/2612/.01             | 483224  | Calibration not necessary |         |
| 4   | Antenna support                          | BAM 4.5-P-10kg         | Maturo                                   | 222/2612.01              | 483225  | Calibration not necessary |         |
| 5   | Controller                               | NCD                    | Maturo                                   | 474/2612.01              | 483226  | Calibration not necessary |         |
| 6   | Semi Anechoic Chamber M276               | SAC5-2                 | Albatross Projects                       | C62128-A540-A138-10-0006 | 483227  | Calibration not necessary |         |
| 7   | Measuring software EMC32 M276            | EMC32                  | Rohde & Schwarz                          | 100970                   | 482972  | Calibration not necessary |         |
| 8   | EMI Testreceiver                         | ESW44                  | Rohde & Schwarz                          | 101828                   | 482979  | 14.11.2019                | 11.2021 |
| 9   | Log Per Antenna                          | HL050                  | Rohde & Schwarz                          | 4062.4063.02-100908      | 482977  | 13.08.2019                | 08.2022 |
| 10  | loop antenna                             | HFH2-Z2                | Rohde & Schwarz                          | 100417                   | 481912  | 05.02.2020                | 02.2021 |
| 11  | Antenna (Bilog)                          | CBL6111D               | Schaffner Elektrottest GmbH / Teseq GmbH | 25761                    | 480894  | 19.10.2017                | 10.2020 |
| 12  | Low Noise Amplifier 100 MHz - 18 GHz     | LNA-30-00101800-25-10P | Narda-Miteq                              | 2110917                  | 482967  | 18.02.2020                | 02.2022 |
| 13  | Low Noise Amplifier 12 GHz - 18 GHz      | LNA-30-12001800-13-10P | Narda-Miteq                              | 2089798                  | 482968  | 17.02.2020                | 02.2022 |
| 14  | Standard Gain Horn 20 dB, 12 GHz-18 GHz  | 18240-20               | Flann                                    | 267220                   | 483025  | Calibration not necessary |         |
| 15  | Low Noise Amplifier 18 GHz - 26.5 GHz    | LNA-30-18002650-20-10P | Narda-Miteq                              | 2110911                  | 482969  | 17.02.2020                | 02.2022 |
| 16  | Standard Gain Horn 20 dB, 18 GHz -26 GHz | 20240-20               | Flann                                    | 266399                   | 483026  | Calibration not necessary |         |

## 7 Test site Validation

| Test equipment                | PM. No. | Frequency range | Type of validation | According to                                      | Val. Date  | Val Due    |
|-------------------------------|---------|-----------------|--------------------|---------------------------------------------------|------------|------------|
| Semi anechoic chamber<br>M276 | 483227  | 30 – 1000 MHz   | NSA                | ANSI C63.4-2017                                   | 19.09.2019 | 18.09.2021 |
| Semi anechoic chamber<br>M276 | 483227  | 1 -18 GHz       | SVSWR              | CISPR 16-1-4 +<br>Cor1:2010 + A1:2012<br>+A2:2017 | 19.09.2019 | 18.09.2021 |

## 8 Report History

| Report Number | Date       | Comment             |
|---------------|------------|---------------------|
| F191168E3     | 07.09.2020 | Initial Test Report |
| -             | -          | -                   |
| -             | -          | -                   |

## 9 List of Annexes

Annex A      Test Setup Photos

8 pages