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Test Report

Report Number:

F190261E5

Equipment under Test (EUT):

CargoTrac-ExR-M1

Applicant:

Savvy Telematic Systems AG

Manufacturer:

Savvy Telematic Systems AG



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] **RSS-247 Issue 2 (February 2017)**, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
- [4] **RSS-Gen Issue 5 (April 2018)**, General Requirements for Compliance of Radio Apparatus
- [5] **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 by | Paul NEUFELD Name |  Signature | 18.07.2019 Date |
| Written by | Bernward ROHDE Name |  Signature | 18.07.2019 Date |
| Reviewed and approved by: | Bernd STEINER Name |  Signature | 18.07.2019 Date |

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1 Identification

1.1 Applicant

| | |
|--|---------------------------------|
| Name: | Savvy Telematic Systems AG |
| Address: | Grabenstr. 9, 8200 Schaffhausen |
| Country: | Switzerland |
| Name for contact purposes: | Mr. André SCHÄR |
| Phone: | +41-52-63346-00 |
| eMail Address: | info@savvy-telematics.com |
| Applicant represented during the test by the following person: | - |

1.2 Manufacturer

| | |
|--|---------------------------------|
| Name: | Savvy Telematic Systems AG |
| Address: | Grabenstr. 9, 8200 Schaffhausen |
| Country: | Switzerland |
| Name for contact purposes: | Mr. André SCHÄR |
| Phone: | +41-52-63346-00 |
| eMail Address: | info@savvy-telematics.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-17186-01-02 and D-PL-17186-01-05, FCC Test Firm Accreditation with the registration number 469623, designation number DE0004 and Industry Canada Test site registration SITE# IC3469A-1.

1.4 EUT (Equipment under Test)

| EUT | |
|---------------------------------------|-----------------------------|
| Test object: * | Autonomous Telematic Device |
| PMN / Model name: * | CargoTrac-(Ex)R-M1 |
| FCC ID: * | 2ATWF-CTEXRM1 |
| ISED Certification number: * IC: * | 25039-CTEXRM1 |
| HVIN: * | 1077 |
| HMN: * | N/A |
| FVIN: * | v1.1.2-201905131349 |
| Serial number: * | 1077-000030 |
| PCB identifier: * | CargoTrac-(Ex)R-M1 V1.0 |
| Hardware version: * | V1.1 |
| Software version: * | Build 2019-04-09 12:05:49 |

* Declared by the applicant

| IEEE 802.15.4 (2.4GHz) frequencies | | | | |
|------------------------------------|----|----------|----|----------|
| Channel 11 | RX | 2405 MHz | TX | 2405 MHz |
| Channel 19 | RX | 2440 MHz | TX | 2440 MHz |
| Channel 25 | RX | 2475 MHz | TX | 2475 MHz |

| Equipment used for testing | |
|---|--|
| Control-Terminal ^{*1} | CTEXRM1 in Control-Terminal Mode Setting and USB Interface 014c5997190000f0 |
| Antennas for control purposes ^{*2} | EMCO 3115 used outside the FAR RAD-ISM-2400-ANT-PAN-8-0, Phoenix Contact; used inside the FAR |
| Laptop PC: ^{*2} | Fujitsu Lifebook S751 (PM No. 201036) |

^{*1} Provided by the applicant

^{*2} Provided by the laboratory

1.5 Technical Data of Equipment

| IEEE 802.15.4 radio mode | | | | | | |
|--|---|-------|--------------------|--------|--------------------|--------|
| Fulfils radio specification: * | IEEE 802.15.4 | | | | | |
| Radio chip: | ATmega128RFA1 | | | | | |
| Antenna type: * | Flex antenna | | | | | |
| Antenna name: * | FXP.74 Black Diamond 2.4 GHz Antenna Taoglas | | | | | |
| Antenna gain: * | Max +4 dBi | | | | | |
| Antenna connector: * | ufl. / (second antenna path disabled by software) | | | | | |
| Power supply EUT: * | DC (by internal batteries) | | | | | |
| Supply voltage EUT: * | U _{nom} = | 7.2 V | U _{min} = | 6.0 V | U _{max} = | 7.4 V |
| Supply voltage radio module: * | U _{nom} = | 3.3 | U _{min} = | 3.23 V | U _{max} = | 3.39 V |
| Type of modulation: * | O-QPSK (250 kbit/s) | | | | | |
| Operating frequency range: * | 2405 – 2475 MHz | | | | | |
| Number of channels: * | 15 (5 MHz channel spacing) | | | | | |
| Temperature range: * | -40 °C to +85 °C | | | | | |
| Lowest / highest internal clock frequency: * | 32.768 kHz to 2475 MHz | | | | | |

* Declared by the applicant

1.6 Dates

| | |
|---------------------------------|------------|
| Date of receipt of test sample: | 25.02.2019 |
| Start of test: | 08.05.2019 |
| End of test: | 20.05.2019 |

2 Operational States

The EUT is the radio part of an autonomous telematics system.
The EUT has a built-in GSM/LTE and a IEEE 802.15.4 transceiver. This test report covers only the IEEE 802.15.4 specific test cases.

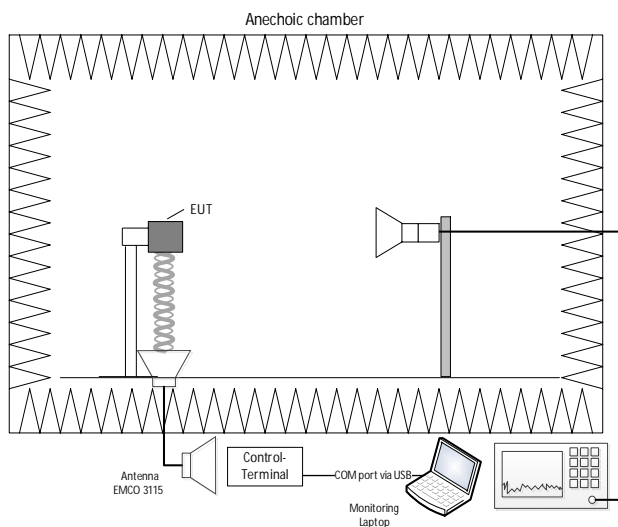
GSM/LTE module
FCC ID: XPYUBX18ZO01
IC: 8595A-UBX18ZO01

The EUT:



2.1 The following states were defined as the operating conditions

The DUT was supplied via internal batteries; no cables were connected to the EUT.
The setup was as following:



A connection to the EUT was established via the control-terminal.

2.1.1 Radio tests

The control terminal is a second “CargoTrac-(Ex)R-M1” that was communicating via IEEE 802.15.4 radio link with the EUT. The connection with the control terminal could be established by following settings:

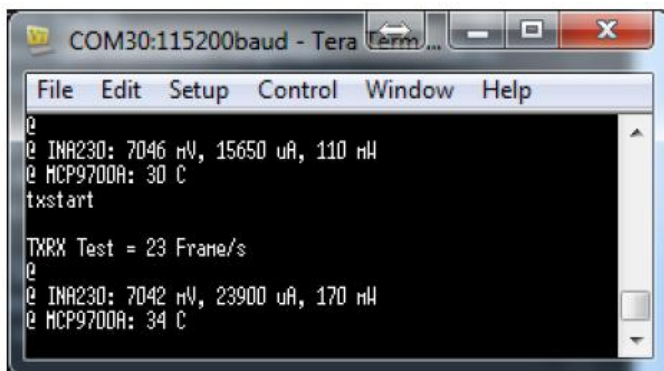
For the radio tests the following settings were used:

A connection to the control terminal was established via USB cable.

The USB connection was converted to a serial connection on the EUT. The following COM port settings were used with “tera term”.

Baud rate: 115200
Data: 8 bit
Parity: None
Stop: 1 bit
Flow control: None

The below shown interface was used to set the EUT in the applicable test-mode.



All relevant RF parameter were set using the control-terminal as described above. The parameters were set according to the documentation as provided by the applicant (EMV_Prüfanleitung_SAVVY_CargoTrac-ExR-M1_V1.3 by A. Schaer 22.05.2019)

2.1.2 Operation Modes

| Operation Mode | Channel | Frequency [MHz] | Data rate | Power setting [dBm] |
|----------------|---------|-----------------|------------|---------------------|
| 1 | 11 | 2405 | 250 kbit/s | -6.5 |
| 2 | 18 | 2440 | 250 kbit/s | -6.5 |
| 3 | 25* | 2475 | 250 kbit/s | -6.5 |

* Remark: As declared by the applicant channel 26 is disabled by software and therefore this will not be used by the device

3 Additional Information

For simplification a plot of one mode each was added here. All other results are listed in the tables for each testcase.

The tested EUT was not labeled with the final label.

4 Overview

| Application | Frequency range [MHz] | FCC 47 CFR Part 15 section [2] | RSS-247 [3] or RSS-Gen, Issue 5 [4] | Status | Refer page |
|--|-----------------------|--|-------------------------------------|------------------------------|------------|
| DTS Bandwidth | 2400.0 - 2483.5 | 15.247 (a) (2) | 5.2 (a) [3] | Passed | 14 et seq. |
| Maximum conducted peak output power | 2400.0 - 2483.5 | 15.247 (b) (3), (4) | 5.4 (d) [3] | Passed ^{*1} | 13 et seq. |
| Maximum conducted (average) output power | 2400.0 - 2483.5 | 15.247 (b) (3), (4) | 5.4 (d) [3] | Passed ^{*1} | 13 et seq. |
| Peak Power Spectral Density | 2400.0 - 2483.5 | 15.247 (e) | 5.2 (b) [3] | Passed | 19 et seq. |
| Average Power Spectral Density | 2400.0 - 2483.5 | 15.247 (e) | 5.2 (b) [3] | Passed | 19 et seq. |
| Band edge compliance | 2400.0 - 2483.5 | 15.247 (d) 15.205 (a) 15.209 (a) | 5.5 [3] 8.9 [4], 8.10 [4] | Passed | 21 et seq. |
| Radiated emissions (transmitter) | 0.009 – 26,500 | 15.247 (d) 15.205 (a) 15.209 (a) | 5.5 [3] 8.9 [4], 8.10 [4] | Passed | 25 et seq. |
| Conducted emissions on supply line | 0.15 - 30 | 15.207 (a) | 8.8 [4] | Not applicable ^{*2} | --- |

^{*1} Antenna gain does not exceed 6 dBi, no power reduction necessary

^{*2} EUT is battery supplied only, without any possibility of charging

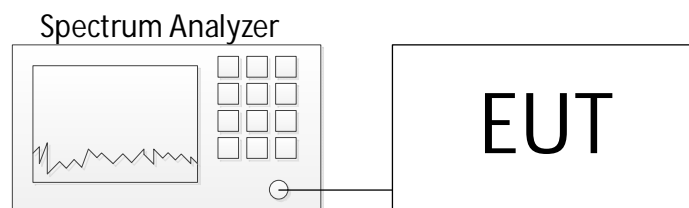
5 Results

5.1 Duty cycle

5.1.1 Method of measurement (conducted)

The measurement was performed as an antenna port conducted measurement, as shown below.

Test Setup:



The method described in chapter 11. b) of document [1] or 6 b) of document [5] was used to perform the following test.

Only the worst case plot for each mode was submitted below.

The following measurement technique was used:

The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between two bins on the sweep are sufficient to permit accurate measurements of the on and off times of the transmitted signal.

- Set the center frequency of the instrument to the center frequency of the transmission.
- Set $RBW \geq OBW$ if possible; otherwise, set RBW to the largest available value.
- Set $VBW \geq RBW$.
- Set detector = peak or average.
- The zero-span measurement method shall not be used unless both RBW and VBW are $> 50/T$ and the number of sweep points across duration T exceeds 100. (For example, if VBW and/or RBW are limited to 3 MHz, then the zero-span method of measuring duty cycle shall not be used if $T \leq 16.7$ microseconds.)

6.1.1 Test results (conducted)

| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 32 % |

| | |
|-----------|------------|
| Date | 08.05.2019 |
| Tested by | P. NEUFELD |

| Operation mode | TX_on [µs] | TX_ges [µs] | RBW [MHz] | 50/T [kHz] | 50/T < RBW? |
|----------------|------------|-------------|-----------|------------|-------------|
| 1 | 1313 | 18306 | 3 | 38 | Yes |

| Operation mode | Sweep points | Sweep time [µs] | Meas points | Meas points >100? | Duty cycle % | DCCF [dB] |
|----------------|--------------|-----------------|-------------|-------------------|--------------|-----------|
| 1 | 10001 | 22000 | 8322 | Yes | 7 | 11.44 |

The DCCF (duty cycle correction factor) is calculated by:

$$DCCF = 10 * \log_{10} \left(\frac{1}{Duty\ cycle} \right)$$

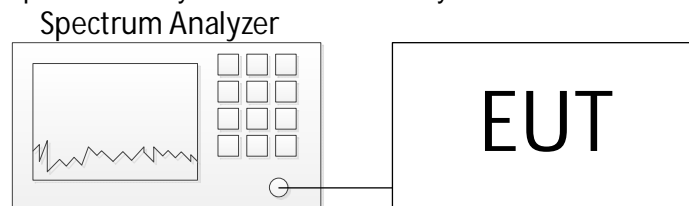
The duty cycle is smaller than 98%, therefore, for average measurements a correction factor of 11.44 dB is used.

| |
|--|
| Test equipment (please refer to chapter 6 for details) |
| 1 |

6.2 DTS Bandwidth / 99% Bandwidth

6.2.1 Method of measurement (conducted)

The EUT was tested with a spectrum analyzer connected directly to the EUT.



DTS bandwidth:

The measurement procedure refers to part 11.8.1 of document [1].

- Set RBW = 100 kHz.
- Set the video bandwidth (VBW) $\geq 3 \times$ RBW.
- Detector = Peak.
- Trace mode = max hold.
- Sweep = auto couple.
- Allow the trace to stabilize.
- Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper and lower frequencies) that are attenuated by 6 dB relative to the maximum level measured in the fundamental emission.

The following procedure was used for measuring the 99 % bandwidth:

The occupied bandwidth is the frequency bandwidth such that, below its lower and above its upper frequency limits, the mean powers are each equal to 0.5% of the total mean power of the given emission. The following procedure shall be used for measuring 99% power bandwidth:

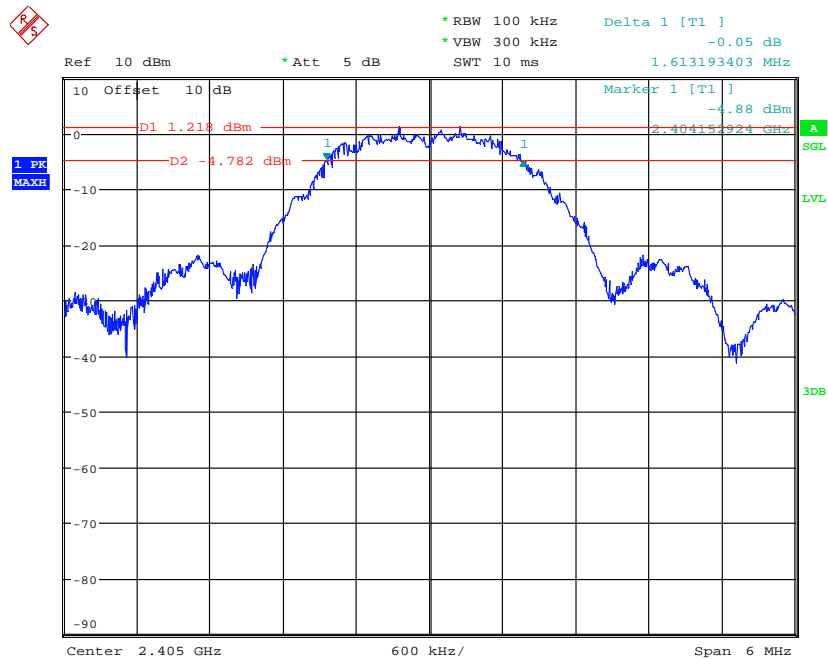
- The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW.
- The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times the RBW, unless otherwise specified by the applicable requirement.
- Set the reference level of the instrument as required, keeping the signal from exceeding the maximum input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than $[10 \log (\text{OBW}/\text{RBW})]$ below the reference level. Specific guidance is given in 4.1.5.2.
- Step a) through step c) might require iteration to adjust within the specified range.
- e) Video averaging is not permitted. Where practical, a sample detection and single sweep mode shall be used. Otherwise, peak detection and max hold mode (until the trace stabilizes) shall be used.
- f) Use the 99% power bandwidth function of the instrument (if available) and report the measured bandwidth.
- g) If the instrument does not have a 99% power bandwidth function, then the trace data points are recovered and directly summed in linear power terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached; that frequency is recorded as the lower frequency. The process is repeated until 99.5% of the total is reached; that frequency is recorded as the upper frequency. The 99% power bandwidth is the difference between these two frequencies.
- The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data maybe reported in addition to the plot(s).

6.2.2 Test results (conducted)

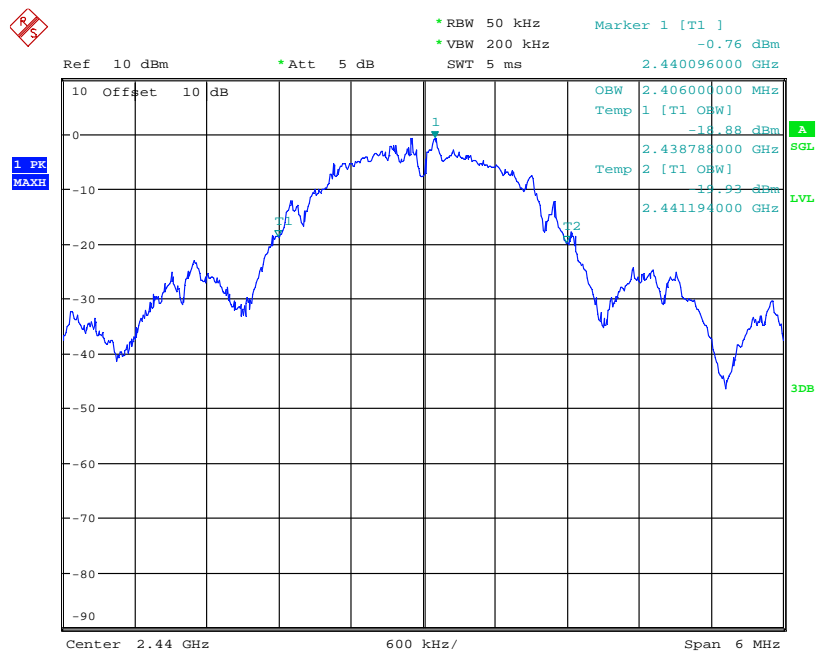
| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 32 % |

| | |
|-----------|------------|
| Date | 08.05.2019 |
| Tested by | P. NEUFELD |

DTS bandwidth (Operation mode 1):



99% bandwidth (Operation mode 2):



| OP mode | Data rate | Center Frequency [MHz] | Minimum 6 dB Bandwidth Limit [MHz] | 6 dB Bandwidth [MHz] | 99 % Bandwidth [MHz] | Result |
|---------|------------|---------------------------|--|-------------------------|----------------------------|--------|
| 1 | 250 kbit/s | 2405 | 0.5 | 1.613 | 2.388 | Passed |
| 2 | 250 kbit/s | 2440 | 0.5 | 1.625 | 2.406 | Passed |
| 3 | 250 kbit/s | 2475 | 0.5 | 1.649 | 2.275 | Passed |

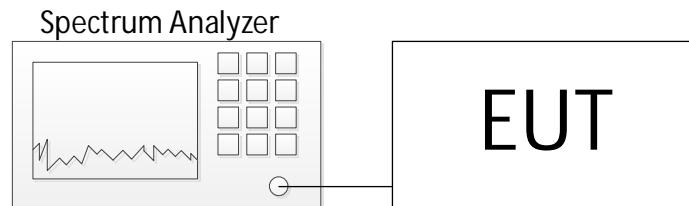
Test equipment (please refer to chapter 6 for details)

1

6.3 Maximum peak conducted output power

6.3.1 Method of measurement (conducted)

The EUT was measured conducted at the antenna ports with the aid of a spectrum analyzer.



Acceptable measurement configurations

Procedure 11.9.1.1 in [1] was used for the following test.

The following procedure shall be used when an instrument with a resolution bandwidth that is greater than the DTS bandwidth is available to perform the measurement:

- Set the $RBW \geq DTS$ bandwidth.
- Set $VBW \geq [3 \times RBW]$.
- Set $span \geq [3 \times RBW]$.
- Sweep time = auto couple.
- Detector = peak.
- Trace mode = max hold.
- Allow trace to fully stabilize.
- Use peak marker function to determine the peak amplitude level.

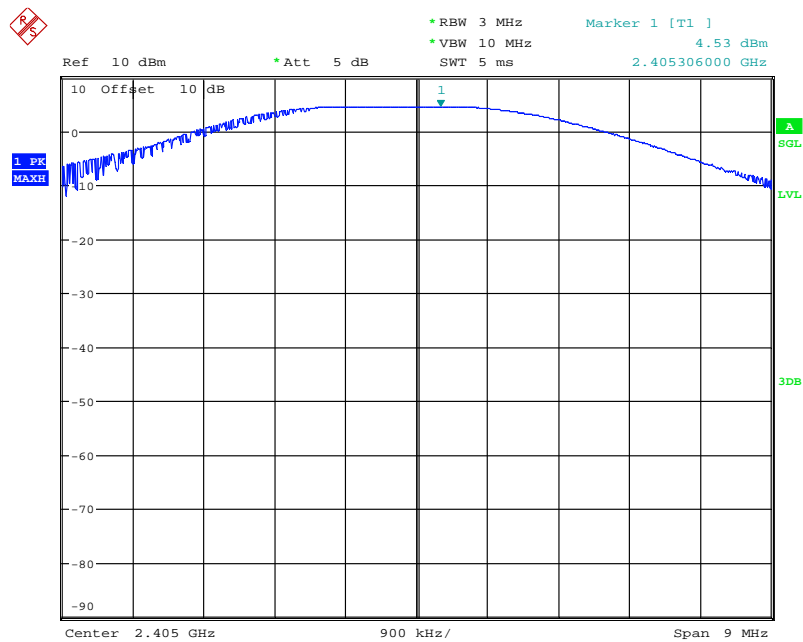
The measurement was performed at the upper and lower end and the middle of the assigned frequency band.

6.3.2 Test results (conducted)

| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 32 % |

| | |
|-----------|------------|
| Date | 08.05.2019 |
| Tested by | P. NEUFELD |

Maximum peak output power (Operation mode 1):



| Operation mode | Data rate | Frequency [MHz] | Result [dBm] | Limit [dBm] |
|----------------|------------|-----------------|--------------|-------------|
| 1 | 250 kbit/s | 2405 | 4.5 | 30 |
| 2 | 250 kbit/s | 2440 | 4.4 | 30 |
| 3 | 250 kbit/s | 2475 | 4.3 | 30 |

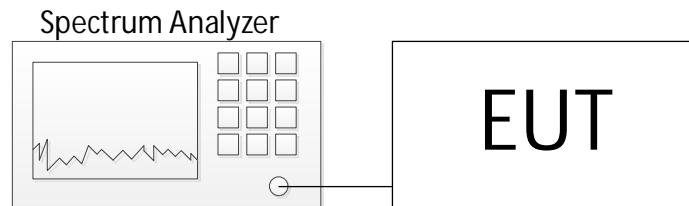
The antenna gain is below 6 dBi, therefore no conducted output limit reduction is necessary.

| |
|--|
| Test equipment (please refer to chapter 6 for details) |
| 1 |

6.4 Peak Power Spectral Density

6.4.1 Method of measurement (conducted)

The EUT was tested with a spectrum analyzer connected directly to the EUT.



The measurement procedure refers to part 11.10.2 of document [1].

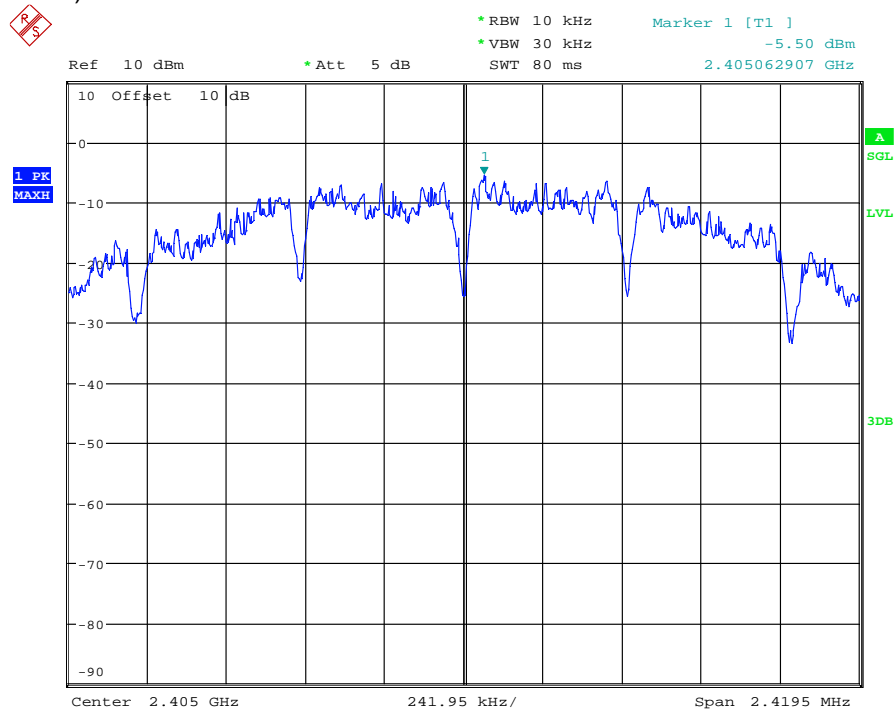
- Set analyzer center frequency to DTS channel center frequency.
- Set the span to 1.5 times the DTS bandwidth.
- Set the RBW to $3 \text{ kHz} \leq \text{RBW} \leq 100 \text{ kHz}$.
- Set the VBW $\geq [3 \times \text{RBW}]$.
- Detector = peak.
- Sweep time = auto couple.
- Trace mode = max hold.
- Allow trace to fully stabilize.
- Use the peak marker function to determine the maximum amplitude level within the RBW.
- If measured value exceeds requirement, then reduce RBW (but no less than 3 kHz) and repeat.

6.4.2 Test results (conducted)

| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 32 % |

| | |
|-----------|------------|
| Date | 08.05.2019 |
| Tested by | P. NEUFELD |

PSD (Operation mode 1):



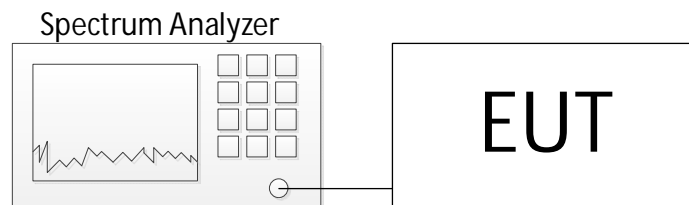
| OP mode | Data rate | Peak Frequency [MHz] | Result [dBm / 10 kHz] | PSD Limit [dBm / 3 kHz] | Result |
|---------|------------|----------------------|-----------------------|-------------------------|--------|
| 1 | 250 kbit/s | 2405.063 | -5.5 | 8 | Passed |
| 2 | 250 kbit/s | 2440.063 | -5.8 | 8 | Passed |
| 3 | 250 kbit/s | 2475.062 | -6.3 | 8 | Passed |

| |
|--|
| Test equipment (please refer to chapter 6 for details) |
| 1 |

6.5 Band-edge compliance

6.5.1 Method of measurement (band edges next to unrestricted bands (conducted))

The EUT was tested with a spectrum analyzer connected directly to the EUT.



The relating measurements were carried out in a conducting manner. Therefore, the antenna connector was directly connected to a spectrum analyzer. The measurement procedure refers to part 11.11.2 and 11.11.3 of document [1].

Measurement Procedure Reference – Reference Level:

- Set the span to ≥ 1.5 times the DTS Bandwidth.
- RBW = 100 kHz.
- VBW ≥ 300 kHz.
- Detector = Peak.
- Sweep time = auto couple.
- Trace mode = max hold.
- Allow trace to fully stabilize.
- Use the peak marker function to determine the maximum amplitude level.

Measurement Procedure – Unwanted Emissions

- Set the center frequency and span to encompass the frequency range to be measured.
- RBW = 100 kHz.
- VBW ≥ 300 kHz.
- Detector = Peak.
- Ensure that the number of measurement points $\geq \text{span}/\text{RBW}$.
- Sweep time = auto couple.
- Trace Mode = max hold.
- Allow the trace to stabilize.
- Use the peak marker function to determine the maximum amplitude level.

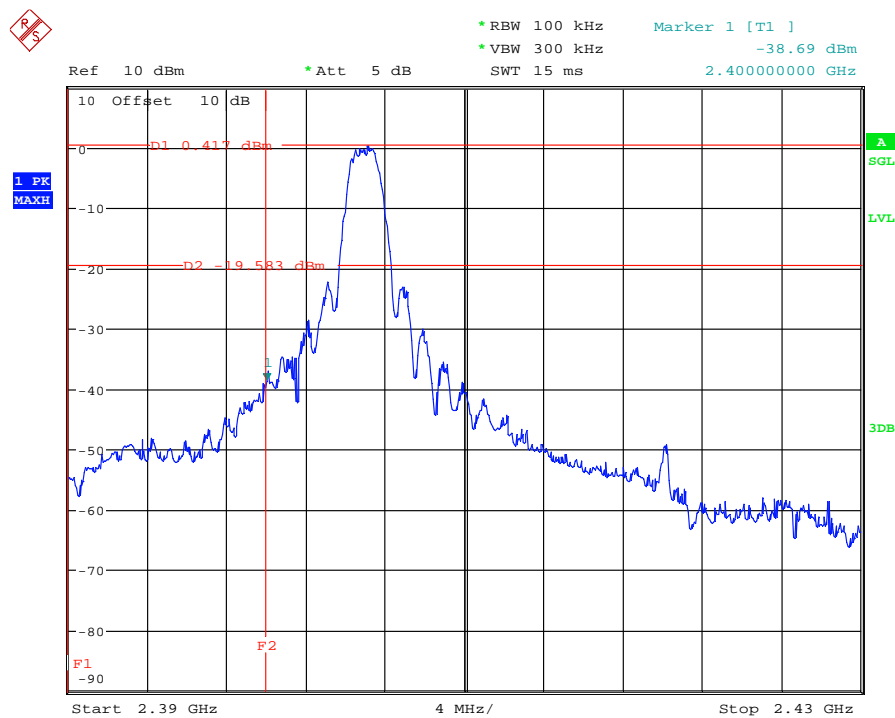
The measurement procedure at the band edges was simplified by performing the measurement in just one plot. Both, the in-band-emission and the unwanted emission were be encompassed by the span. After trace stabilization, the maximum peak was be determined by a peak detector and the value was marked by an appropriate limit line. The second limit line, which is 20 dB below the first, marks the limit for the emissions in the unrestricted band. A maximum-peak-detector marks the highest emission in the unrestricted band next to the band edge.

6.5.2 Test results (conducted)

| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 32 % |

| | |
|-----------|------------|
| Date | 08.05.2019 |
| Tested by | P. NEUFELD |

Unrestricted band edge (Operation mode 1):



| Operation mode | Data rate | Frequency [MHz] | Reference Level [dBm] | Limit [dBm] | Emission Level [dBm] | Margin [dB] | Result |
|----------------|------------|-----------------|-----------------------|-------------|----------------------|-------------|--------|
| 1 | 250 kbit/s | 2400.000 | 0.4 | -19.6 | -38.5 | 18.9 | Passed |

Test equipment (please refer to chapter 6 for details)

1

6.5.3 Method of measurement (band edges next to restricted bands (radiated))

Acceptable measurement configurations

The same measurement configuration as described in 6.6.1 was used for the preview and final measurement of the peak values.

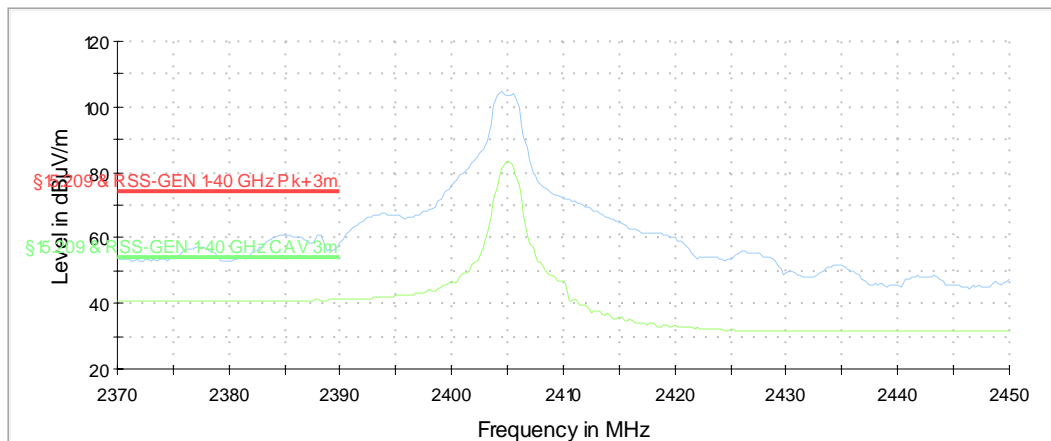
The average value was determined by using method 11.12.2.5.3 of document [1]

6.5.4 Test results (radiated)

| | |
|---------------------|-------|
| Ambient temperature | 22 °C |
| Relative humidity | 40 % |

| | |
|-----------|------------|
| Date | 17.05.2019 |
| Tested by | P. NEUFELD |

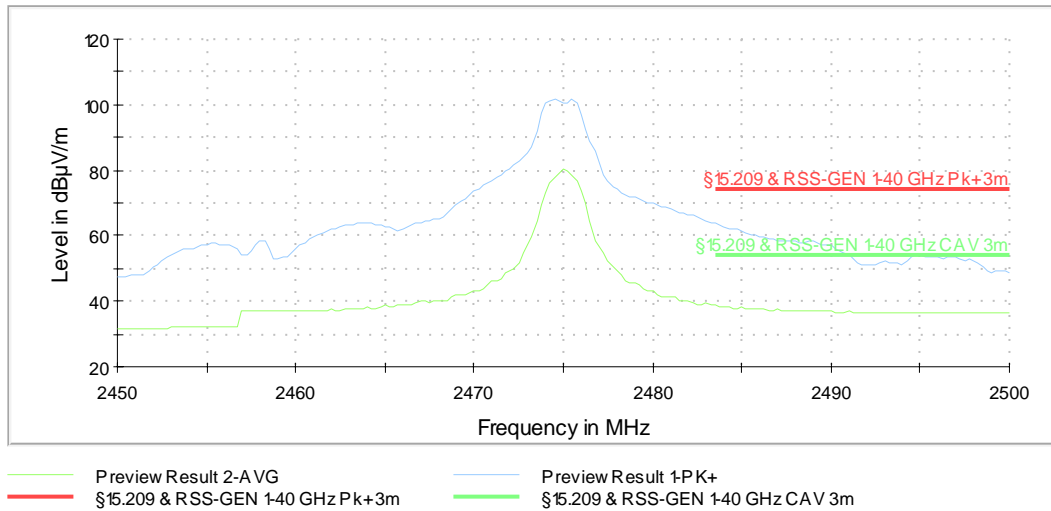
Restricted band edge (Operation mode 1):



— Preview Result 2-AVG
— §15.209 & RSS-GEN 1-40 GHz Pk+3m
— Preview Result 1-PK+
— §15.209 & RSS-GEN 1-40 GHz CAV 3m

| Lower band edge | | | | | | | | | |
|-------------------------|----------|----------|--|-------------------|-----|---------|-----------|------------|--------|
| Operation mode 1 | | | Duty cycle correction factor was not applied for the Average reading due to measurement method | | | | | | |
| Frequency | Max Peak | Average | Limit | Margin | Pol | Azimuth | Elevation | Correction | Result |
| [MHz] | [dBµV/m] | [dBµV/m] | [dBµV/m] | dB | | [°] | [°] | [dB] | |
| 2390.000 | 58.7 | - | 74.0 | 15.3 | V | 253 | 120 | 33.0 | Passed |
| 2390.000 | - | 46.7 | 54.0 | 7.3 | V | 253 | 120 | 33.0 | Passed |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | | |

Restricted band edge (Operation mode 3):



| Upper band edge | | | | | | | | | |
|-------------------------|-------------------|------------------|--|-------------------|-----|-------------|---------------|-----------------|--------|
| Operation mode 3 | | | Duty cycle correction factor was not applied for the Average reading due to measurement method | | | | | | |
| Frequency [MHz] | Max Peak [dBµV/m] | Average [dBµV/m] | Limit [dBµV/m] | Margin [dB] | Pol | Azimuth [°] | Elevation [°] | Correction [dB] | Result |
| 2484.000 | 63.6 | --- | 74.0 | 10.4 | V | 191 | 60 | 33.6 | Passed |
| 2484.000 | --- | 45.5 | 54.0 | 8.5 | V | 191 | 60 | 33.6 | Passed |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | | |

Test equipment (please refer to chapter 6 for details)

2 - 11

6.6 Maximum unwanted emissions

6.6.1 Method of measurement (radiated emissions)

The radiated emission measurement is subdivided into five stages.

- A preliminary measurement carried out in a fully anechoic chamber with a fixed antenna height in the frequency range 9 kHz to 1 GHz.
- A preliminary measurement carried out in a fully anechoic chamber with a fixed antenna height in the frequency range 30 MHz to 1 GHz.
- A final measurement carried out on an open area test site with reflecting ground plane and various antenna height in the frequency range 30 MHz to 1 GHz.
- A preliminary measurement carried out in a fully anechoic chamber with a variable antenna distance and height in the frequency range above 1 GHz.
- A final measurement carried out in a fully anechoic chamber with a fixed antenna height in the frequency range above 1 GHz.

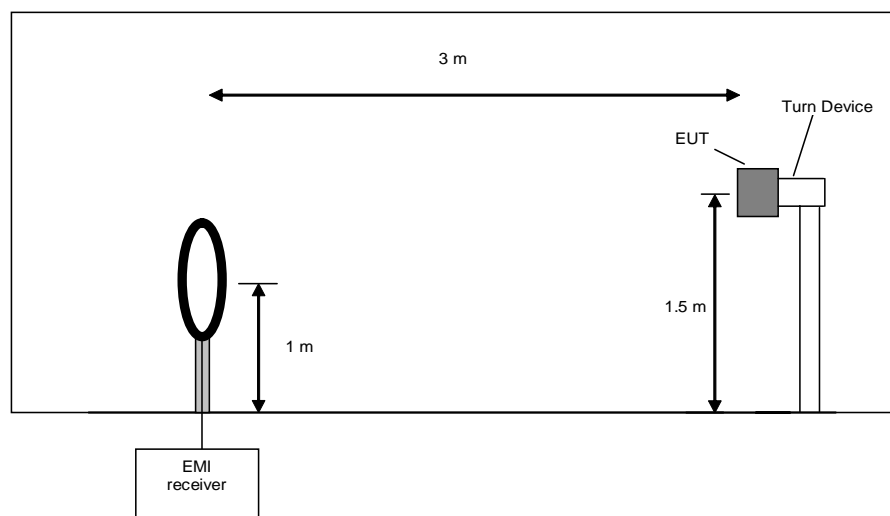
Preliminary measurement (9 kHz to 30 MHz):

In the first stage a preliminary measurement will be performed in a shielded room with a measuring distance of 3 meters. Table top devices will set up on a non-conducting turn device on the height of 1.5m. 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 analyser 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 found the maximum emissions.

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

| Frequency range | Resolution bandwidth |
|-------------------|----------------------|
| 9 kHz to 150 kHz | 200 Hz |
| 150 kHz to 30 MHz | 10 kHz |



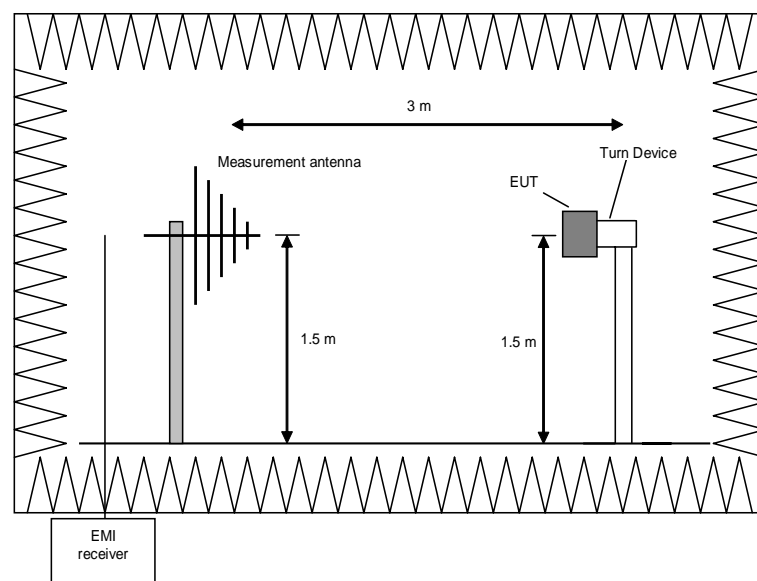
Preliminary measurement (30 MHz to 1 GHz)

In the first stage a preliminary measurement will be performed in a fully anechoic chamber with a measuring distance of 3 meter. Table top devices will set up on a non-conducting turn device on the height of 1.5m. 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 30 MHz to 1 GHz will be measured with an EMI Receiver set to MAX Hold mode and a resolution bandwidth of 100 kHz. 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 |
|-------------------|----------------------|
| 30 MHz to 230 MHz | 100 kHz |
| 230 MHz to 1 GHz | 100 kHz |



Procedure preliminary measurement:

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:

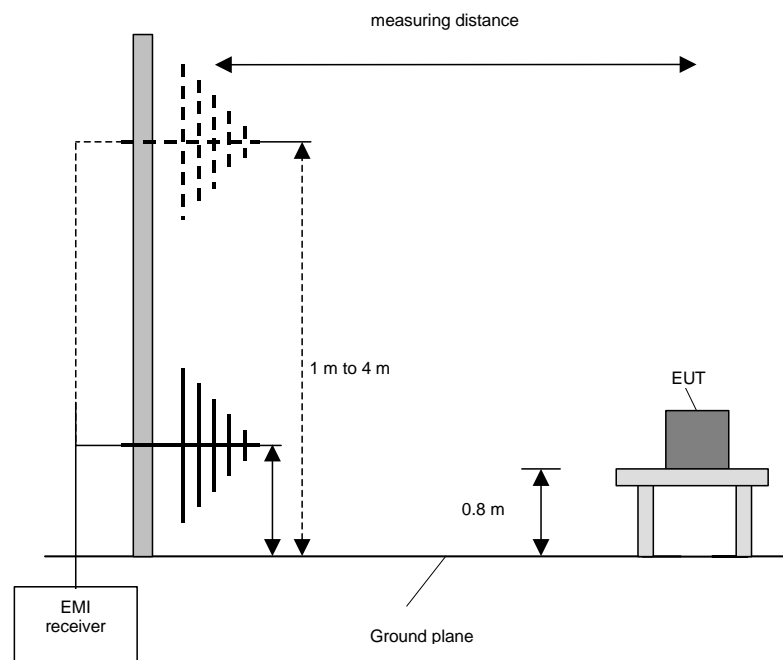
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Manipulate the system cables within the range to produce the maximum level of emission.
3. Rotate the EUT by 360 ° to maximize the detected signals.
4. Repeat 1) to 3) with the vertical polarisation of the measuring 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 (30 MHz to 1 GHz)

A final measurement on an open area test site will be performed on selected frequencies found in the preliminary measurement. During this test the EUT will be rotated in the range of 0 ° to 360 °, the measuring antenna will be set to horizontal and vertical polarisation 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:

| Frequency range | Resolution bandwidth |
|-----------------|----------------------|
| 30 MHz to 1 GHz | 120 kHz |



Procedure final measurement:

The following procedure will be used:

- 1) Measure on the selected frequencies at an antenna height of 1 m and a EUT azimuth of 23 °.
- 2) Move the antenna from 1 m to 4 m and note the maximum value at each frequency.
- 3) Rotate the EUT by 45 ° and repeat 2) until an azimuth of 337 ° is reached.
- 4) Repeat 1) to 3) for the other orthogonal antenna polarization.
- 5) Move the antenna and the turntable to the position where the maximum value is detected.
- 6) Measure while moving the antenna slowly +/- 1 m.
- 7) Set the antenna to the position where the maximum value is found.
- 8) Measure while moving the turntable +/- 45 °.
- 9) Set the turntable to the azimuth where the maximum value is found.
- 10) Measure with Final detector (QP and AV) and note the value.
- 11) Repeat 5) to 10) for each frequency.
- 12) Repeat 1) to 11) for each orthogonal axes of the EUT (because of EUT is a module and might be used in a handheld equipment application).

Preliminary and final measurement (1 GHz to 40 GHz)

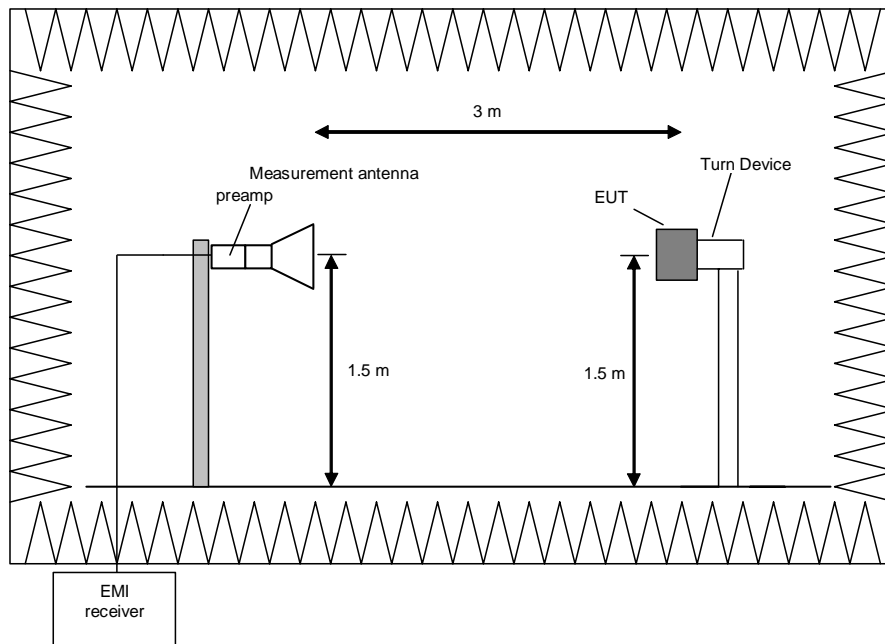
This measurement will be performed in a fully anechoic chamber. Table top devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

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 100 kHz. 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 | 100 kHz |
| 4 GHz to 12 GHz | 100 kHz |
| 12 GHz to 18 GHz | 100 kHz |
| 18 GHz to 25 / 26.5 GHz | 100 kHz |
| 26.5 GHz to 40 GHz | 100 kHz |



Procedure preliminary measurement:

Pre scans were performed in the frequency range 1 to 40 GHz.

The following procedure will be used:

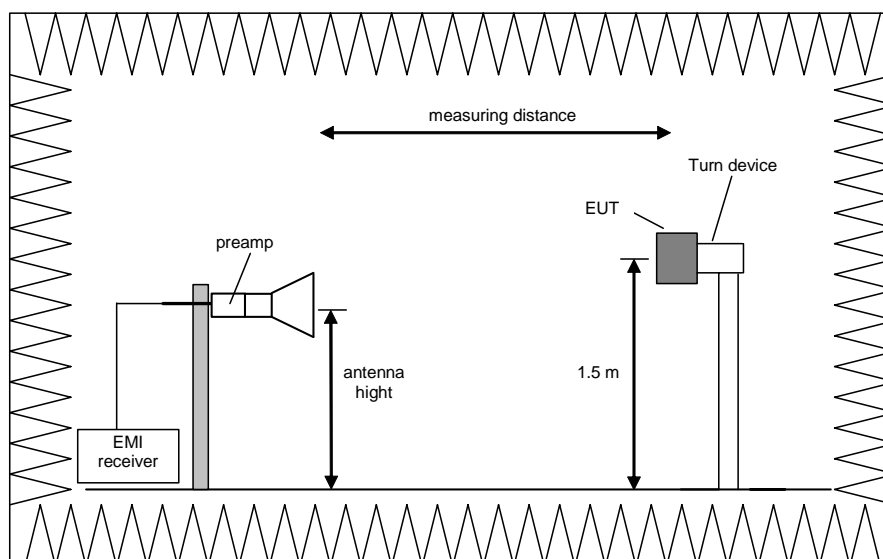
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an 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.

6.6.2 Test results (radiated emissions) – Emissions from 30 MHz – 26.5 GHz

6.6.2.1 Preliminary radiated emission measurement 30 MHz – 26.5 GHz

| | | | |
|---------------------|-------|-----------|------------|
| Ambient temperature | 22 °C | Date | 20.05.2019 |
| Relative humidity | 59 % | Tested by | P. NEUFELD |

Position of EUT: The EUT was set-up on an EUT turn device of a height of 1.5 m. The distance between EUT and antenna was 3 m.

For the final test on the open area test site the EUT was placed on a table with the height of 0.8 m. 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.

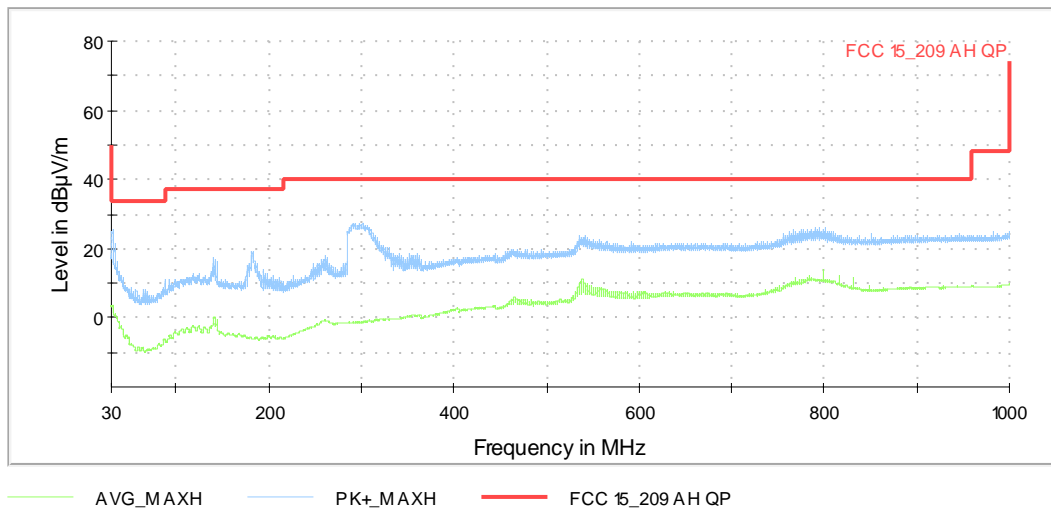
Test record: Only the plot of the worst case emission is submitted below.

Remark: Since there were no differences in the spectrum for $f < 1$ GHz, only one representative plot is submitted below.

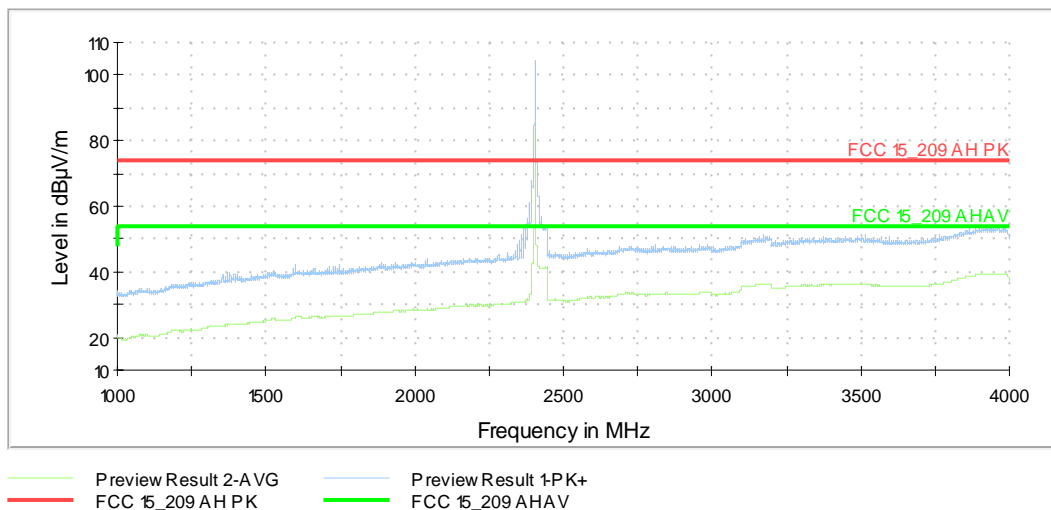
No Emissions greater than 30 dB to the limit was found below 30 MHz during the preliminary test, therefore no final test was performed.

Plots of the worst case transmitter spurious emissions

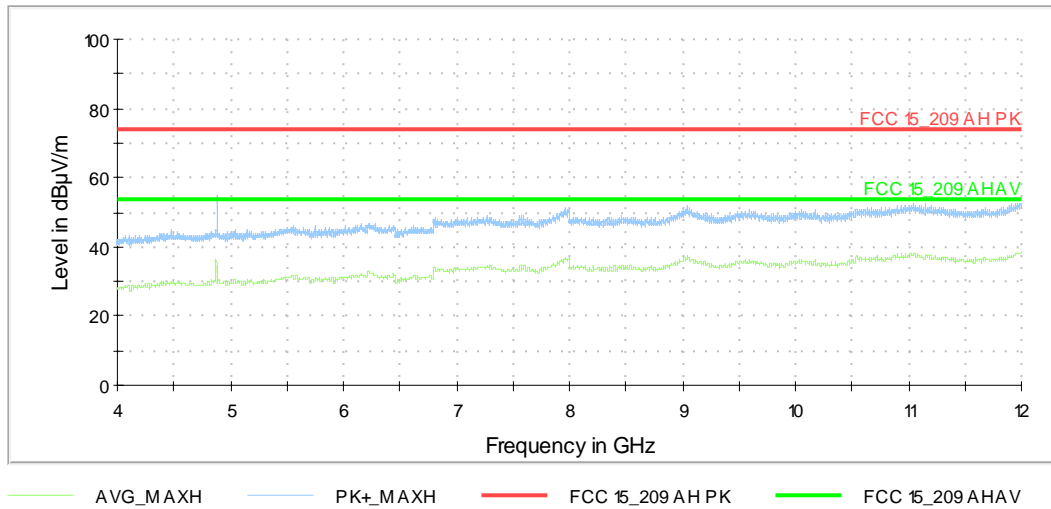
190261_Ch11_30M-1G_AH: Spurious emissions from 30 MHz to 1 GHz (operation mode 1):
Preliminary plot



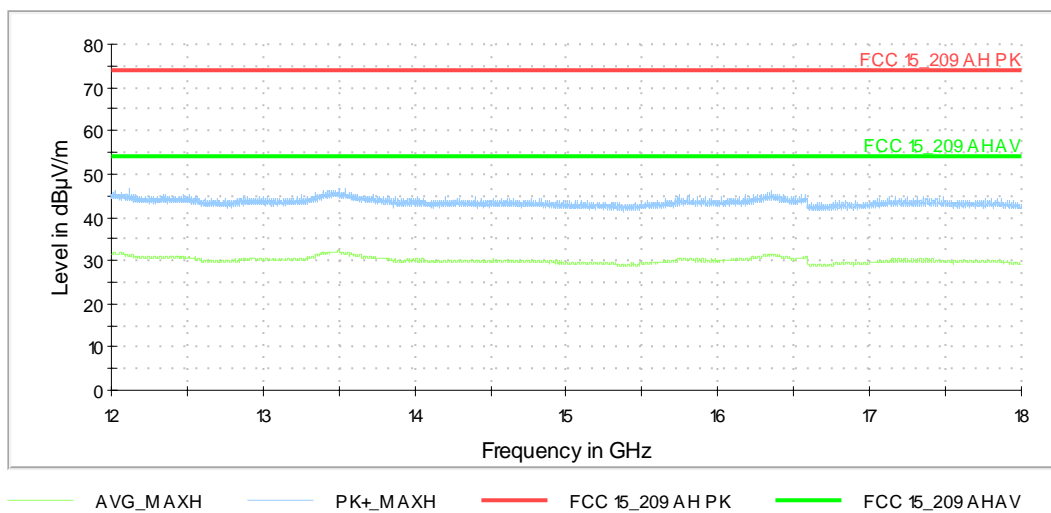
190261_Ch11_1-4G: Spurious emissions from 1 GHz to 4 GHz (operation mode 1)
Preliminary plot – no final measurement conducted



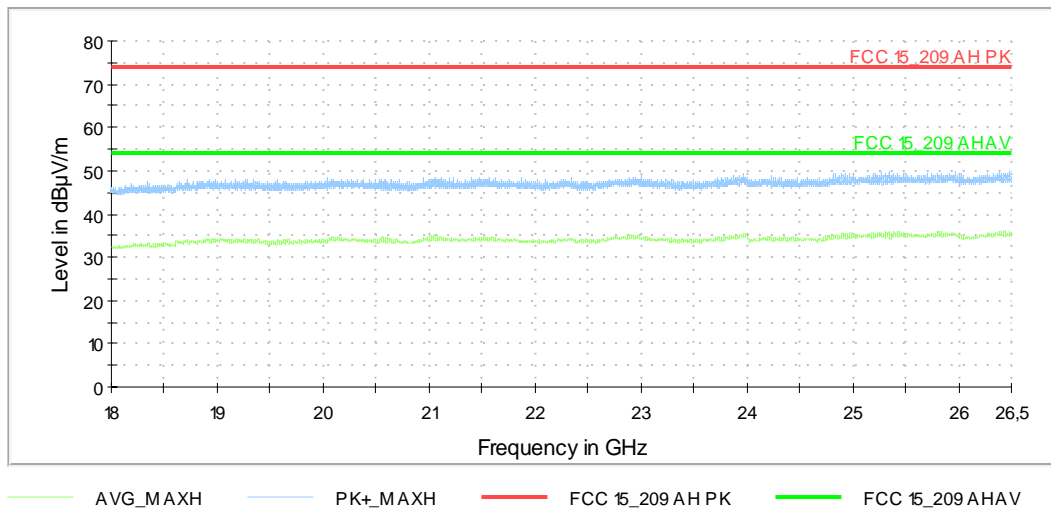
190261_Ch18_4-12G: Spurious emissions from 4 GHz to 12 GHz (operation mode 2):
Preliminary plot



190261_Ch11_12-18G: Spurious emissions from 12 GHz to 18 GHz (operation mode 1):
Preliminary plot - no final measurement conducted



190261_Ch11_18-26,5G: Spurious emissions from 18 GHz to 26.5 GHz (operation mode 3):
Preliminary plot - no final measurement conducted



6.6.2.2 Final radiated measurements

All TX modes (no difference detected when comparing channel)

| Frequency [MHz] | QuasiPeak [dBµV/m] | Limit [dBµV/m] | Margin [dB] | Meas. Time [ms] | Bandwidth [kHz] | Height [cm] | Pol | Azimuth [deg] | Corr. [dB] |
|-------------------------|--------------------|----------------|-------------|-----------------|-------------------|-------------|-----|---------------|------------|
| 31.025 | 29.7 | 40.0 | 10.3 | 1000 | 120 | 118 | V | 277 | 26.7 |
| 31.050 | 29.0 | 40.0 | 11.0 | 1000 | 120 | 124 | V | 238 | 26.7 |
| 104.625 | 21.2 | 43.5 | 22.3 | 1000 | 120 | 302 | H | 227 | 17.3 |
| 123.175 | 17.3 | 43.5 | 26.2 | 1000 | 120 | 104 | V | 181 | 19.0 |
| 141.000 | 17.3 | 43.5 | 26.2 | 1000 | 120 | 107 | V | 76 | 18.9 |
| 540.450 | 26.6 | 46.0 | 19.4 | 1000 | 120 | 290 | V | 311 | 28.1 |
| 541.225 | 26.5 | 46.0 | 19.5 | 1000 | 120 | 400 | V | 91 | 28.2 |
| 801.050 | 35.9 | 46.0 | 10.1 | 1000 | 120 | 400 | H | 214 | 32.1 |
| Measurement uncertainty | | | | | +2.2 dB / -3.6 dB | | | | |

Transmitter operates at the lower end of the assigned frequency band (operation mode 1, GFSK)

| Frequency [MHz] | MaxPeak [dB μ V/m] | Average [dB μ V/m] | Limit [dB μ V/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|-------------------------|------------------------|------------------------|----------------------|-------------------|-----|---------------|-----------------|------------|
| 4810.000000 | --- | 48.0 | 54 | 6.0 | V | 295 | 60 | -2.0 |
| 4810.000000 | 53.3 | --- | 74 | 20.7 | V | 295 | 60 | -2.0 |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | |

Transmitter operates at the middle of the assigned frequency band (operation mode 2, GFSK)

| Frequency [MHz] | MaxPeak [dB μ V/m] | Average [dB μ V/m] | Limit [dB μ V/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|-------------------------|------------------------|------------------------|----------------------|-------------------|-----|---------------|-----------------|------------|
| 4880.000000 | 54.9 | --- | 74 | 19.1 | V | 271 | 60 | -2.0 |
| 4880.000000 | --- | 51.1 | 54 | 2.9 | V | 271 | 60 | -2.0 |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | |

Transmitter operates at the upper end of the assigned frequency band (operation mode 3, GFSK)

| Frequency [MHz] | MaxPeak [dB μ V/m] | Average [dB μ V/m] | Limit [dB μ V/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|-------------------------|------------------------|------------------------|----------------------|-------------------|-----|---------------|-----------------|------------|
| 4951.000000 | 54.0 | --- | 74 | 20.0 | V | 311 | 60 | -2.0 |
| 4951.000000 | --- | 45.5 | 54 | 8.5 | V | 311 | 60 | -2.0 |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | |

Test equipment (please refer to chapter 6 for details)

| | | | |
|---------------------------|--------------------------|---|-----------------------------------|
| Preliminary measurements: | 9 kHz – 30 MHz: 30, | 30 MHz – 1000 MHz: 2 - 4, 6, 9 - 10, 12 – 15; | 1 – 26.5 GHz: 2 - 10, 13, 16 - 22 |
| Final measurements: | 30 – 1000 MHz: 23 – 29 ; | 1 – 26.5 GHz: 2 - 10, 13, 16 - 22 | |

7 Test Equipment used for Tests

| No. | Test equipment | Type | Manufacturer | Serial No. | PM. No. | Cal. Date | Cal Due |
|-----|----------------------------------|---------------------|-----------------------------|---------------------|---------|---------------------------|---------|
| 1 | Spectrum Analyser | FSU46 | Rohde & Schwarz | 200125 | 480956 | 31.10.2018 | 10.2019 |
| 2 | Antenna mast | AS615P | Deisel | 615/310 | 480187 | Calibration not necessary | |
| 3 | Fully anechoic chamber M20 | B83117-E2439-T232 | Albatross Projects | 103 | 480303 | Calibration not necessary | |
| 4 | Turntable | DS420 HE | Deisel | 420/620/00 | 480315 | Calibration not necessary | |
| 5 | RF-cable No.3 | Sucoflex 106B | Suhner | 0563/6B / Kabel 3 | 480670 | Calibration not necessary | |
| 6 | Multiple Control Unit | MCU | Maturo GmbH | MCU/043/971107 | 480832 | Calibration not necessary | |
| 7 | Antenna (Log.Per.) | HL050 | Rohde & Schwarz | 100438 | 481170 | 09.10.2017 | 10.2020 |
| 8 | RF-Cable No. 40 | Sucoflex 106B | Suhner | 0708/6B / Kabel 40 | 481330 | Calibration not necessary | |
| 9 | Positioners | TDF 1.5- 10Kg | Maturo | 15920215 | 482034 | Calibration not necessary | |
| 10 | EMI Receiver / Spectrum Analyser | ESW44 | Rohde & Schwarz | 101635 | 482467 | 29.03.2018 | 03.2020 |
| 11 | HF-Cable | Sucoflex 104 | Huber+Suhner | 517408 | 482391 | Calibration not necessary | |
| 12 | Antenna (Bilog) | CBL6112B | Schaffner EMV GmbH (-Chase) | 2688 | 480328 | 19.06.2017 | 06.2020 |
| 13 | Software | WMS32 | Rohde & Schwarz | | 481800 | Calibration not necessary | |
| 14 | RF-cable No.36 | Sucoflex 106B | Suhner | 0587/6B / Kabel 36 | 480865 | Calibration not necessary | |
| 15 | HF-Cable | Sucoflex 104 | Huber+Suhner | 517402 | 482392 | Calibration not necessary | |
| 16 | standard gain horn antenna | 18240-20 | Flann Microwave | 483 | 480294 | Calibration not necessary | |
| 17 | standard gain horn antenna | 20240-20 | Flann Microwave | 411 | 480297 | Calibration not necessary | |
| 18 | Microwave cable 2m | Insulated Wire Inc. | Insulated Wire | KPS-1533-800-KPS | 480302 | Calibration not necessary | |
| 19 | Preamplifier 100 MHz - 13 GHz | JS3-00101200-23-5A | MITEQ Hauppauge N.Y. | 681851 | 480337 | 10.07.2018 | 07.2020 |
| 20 | Preamplifier 18 GHz - 26 GHz | JS4-18002600-20-5A | MITEQ Hauppauge N.Y. | 658697 | 480342 | 10.07.2018 | 07.2020 |
| 21 | Preamplifier 12 GHz - 18 GHz | JS3-12001800-16-5A | MITEQ Hauppauge N.Y. | 571667 | 480343 | 10.07.2018 | 07.2020 |
| 22 | High pass Filter | WHKX4.0/18G-8SS | Wainwright Instruments GmbH | 1 | 480587 | Calibration not necessary | |
| 23 | Open area test site M6 | Freifeld M6 | Phoenix Contact | - | 480085 | Calibration not necessary | |
| 24 | Antenna mast | MA240-0 | Inn-Co GmbH | MA240-0/030/6600603 | 480086 | Calibration not necessary | |
| 25 | Turntable | DS412 | Deisel | 412/316 | 480087 | Calibration not necessary | |
| 26 | Controller | HD100 | Deisel | 100/349 | 480139 | Calibration not necessary | |
| 27 | Software | EMC32 | Rohde & Schwarz | 100061 | 481022 | Calibration not necessary | |

| No. | Test equipment | Type | Manufacturer | Serial No. | PM. No. | Cal. Date | Cal Due |
|-----|----------------------------------|----------------|--|----------------|---------|---------------------------|---------|
| 28 | Antenna (Bilog) | CBL6111D | Schaffner Elektrottest GmbH / Teseq GmbH | 25761 | 480894 | 19.10.2017 | 10.2020 |
| 29 | Measuring receiver | ESR7 | Rohde & Schwarz | 101939 | 482558 | 19.09.2017 | 09.2019 |
| 30 | Loop antenna | HFH2-Z2 | Rohde & Schwarz | 832609/014 | 480059 | 21.02.2018 | 02.2020 |
| 31 | Fully anechoic chamber M5 | B83117-S1-X156 | Siemens | B83117-S1-X156 | 480073 | Calibration not necessary | |
| 32 | EMI Receiver / Spectrum Analyser | ESR7 | Rohde & Schwarz | 101939 | 482558 | 19.09.2017 | 09.2019 |
| 33 | Multiple Control Unit | MCU | Maturo | 040/971107 | 480924 | Calibration not necessary | |

8 Report History

| Report Number | Date | Comment |
|---------------|------------|---------------------|
| F190261E5 | 18.07.2019 | Initial Test Report |
| | | |
| | | |
| | | |

9 List of Annexes

| | | |
|---------|-------------------|----------|
| Annex A | Test Setup Photos | 8 pages |
| Annex B | External Photos | 4 pages |
| Annex C | Internal Photos | 11 pages |