PHOENIX TESTLAB
Königswinkel 10
32825 Blomberg, Germany
Phone: +49 (0) 52 35 / 95 00-0
Fax: +49 (0) 52 35 / 95 00-10
office@phoenix-testlab.de
www.phoenix-testlab.de

# Test Report

Report Number:

**F190629E3**

Equipment under Test (EUT):

**VU113**
**BTLE Display**

Applicant:

**Endress+Hauser SE+Co. KG**

Manufacturer:

**Endress+Hauser SE+Co. KG**

ilac-MRA
DAkkS 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 (March 2017)**, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

**[4]** **RSS-Gen Issue 5 (March 2019)**, General Requirements for Compliance of Radio Apparatus


## Test Result

The requirements of the tests performed as shown in the overview (clause 0) were fulfilled by the equipment under test.
The complete test results are presented in the following.

| | | | |
|---|---|---|---|
| Test engineer: | Paul NEUFELD<br>Name |  <br>Signature | 13.11.2019<br>Date |
| Authorized reviewer: | Bernd STEINER<br>Name |  <br>Signature | 13.11.2019<br>Date |

**This test report is only valid in its original form.**



This test report is valid in hardcopy form as well as in electronic form.

## Contents

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# 1 Identification

## 1.1 Applicant

| | |
|---|---|
| Name: | Endress+Hauser SE+Co. KG |
| Address: | Hauptstr. 1, 79689 Maulburg |
| Country: | Germany |
| Name for contact purposes: | Mr. Ralph STIB |
| Phone: | +49 7622-28-1943 |
| eMail Address: | ralph.stib@endress.com |
| Applicant represented during the test by the following person: | None |

## 1.2 Manufacturer

| | |
|---|---|
| Name: | Endress+Hauser SE+Co. KG |
| Address: | Hauptstr. 1, 79689 Maulburg |
| Country: | Germany |
| Name for contact purposes: | Mr. Ralph STIB |
| Phone: | +49 7622-28-1943 |
| eMail Address: | ralph.stib@endress.com |
| Applicant represented during the test by the following person: | None |

## 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 ISED# 3469A.

## 1.4 EUT (Equipment Under Test)

| | |
|---|---|
| Test object: * | BTLE Display |
| Type / PMN: * | VU113 |
| FCC ID: * | LCGVU113 |
| IC: * | 2519A-VU113 |
| Serial number: * | VU113_A_05 / VU113_A_03 |
| EUT marking: * | EUT with temporary antenna connector: VU113_A_05<br>EUT with internal antenna: VE113A_A_03 |
| PCB identifier: * | 71374885 a |
| HVIN (Hardware Version Identification Number): * | VU113 |
| FVIN (Firmware Version Identification Number): * | S132 - Ver. 6.1.1 |
| Hardware version: * | VU113_A |
| Software version: * | Nordic DTM Software |

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

Bluetooth Low Energy radio channels:

| | | | | |
|---|---|---|---|---|
| Channel 0 | RX: | 2402 MHz | TX: | 2402 MHz |
| Channel 19 | RX: | 2440 MHz | TX: | 2440 MHz |
| Channel 39 | RX: | 2480 MHz | TX: | 2480 MHz |

## 1.5 Technical Data of Equipment

| | | | | | | |
|---|---|---|---|---|---|---|
| Fulfills specifications: * | Bluetooth 4.2 low energy only | | | | | |
| Antenna type: * | PCB antenna | | | | | |
| Antenna name: * | - | | | | | |
| Antenna gain: * | < 0 dBi | | | | | |
| Antenna connector: * | None | | | | | |
| Supply voltage EUT: * | $U_{nom}$= | 3.2 V DC | $U_{min}$= | 3.1 V DC | $U_{max}$= | 3.4 V DC |
| Type of modulation: * | GFSK (1 Mbps only) | | | | | |
| Operating frequency range:* | Both units: 2402 – 2480 MHz | | | | | |
| Number of channels: * | 40 | | | | | |
| Temperature range: * | -52 °C to +85 °C | | | | | |
| Lowest / highest Internal clock frequency: * | 32 MHz / 2480 MHz | | | | | |

* Declared by the applicant

| Ancillary Equipment | |
|---|---|
| Cables (connected to the EUT): *1 | USB cable with serial to USB converter (~ 1.5m) |
| USB extension: *2 | ~ 1.5 m |
| Power adaptor: *1 | Type self-designed “MU-VU-Splitter D01726” with ~ 1.5 m cable |
| USB adaptor: *1 | Type FTDI TTL-232R-3V3-WE |
| Fibre optic converter: *2 | Opto USB2.0, MK Messtechnik (PM. No. 482617) |
| Laptop PC:*2 | Fujitsu Lifebook S751 (PM No. 201036) |

## 1.6 Dates

| | |
|---|---|
| Date of receipt of test sample: | 19.08.2019 |
| Start of test: | 19.08.2019 |
| End of test: | 23.09.2019 |

# 2 Operational States

The EUT is a display unit with integrated Bluetooth Low Energy capability, which is intended to be implemented in various sensor devices for process automation. This test contains the test results on the EUT without a housing.

A connection to the EUT was established via a Serial to USB converter cable attached to the EUT. The operation modes were set using a software called “nRFgo Studio” by Nordic Semiconductor, which was downloaded using a link provided by the applicant. The test were performed using pseudorandom payload data (PRBS9) and a maximum payload of 37 Bytes.

For the tests in the anechoic chamber, the USB signal was transmitted via an USB to fiber-optics converter.

During the tests the EUT was supplied with 3.2 V DC via a laboratory power supply.

Maximum power Settings for all measurements:

| Modulation | Power setting ch. 0 - 39 |
|---|---|
| GFSK, 1 Mbps | 4 dBm |

| Operation mode | Description of the operation mode | mode | channel | Modulation | Data rate / Mbps |
|---|---|---|---|---|---|
| 1 | Continuous transmitting on 2402 MHz | BLE | 0 | GFSK | 1 Mbps |
| 2 | Continuous transmitting on 2440 MHz | BLE | 19 | GFSK | 1 Mbps |
| 3 | Continuous transmitting on 2480 MHz | BLE | 39 | GFSK | 1 Mbps |

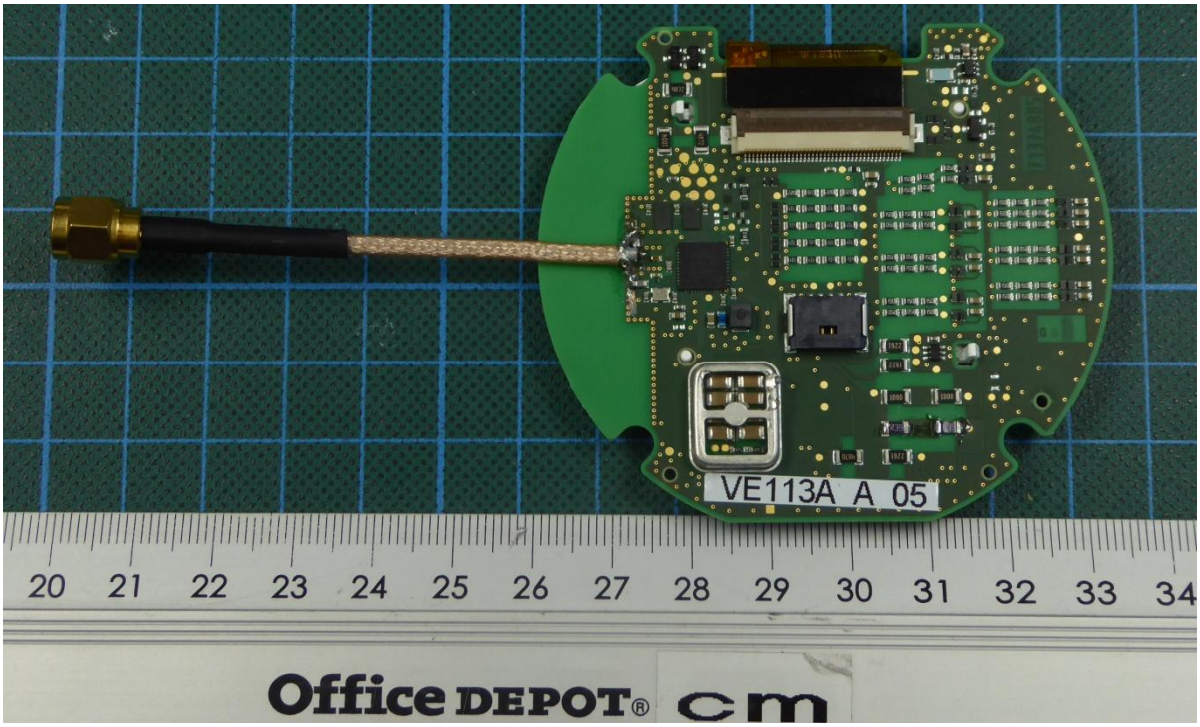
For the conducted emission measurement on the power supply line, the EUT was integrated within aluminium housing and pressure sensor: 1-Chamber Aluminium Housing, non ExD („PMP51B_P2_002“) Aluminium-Cover with plastic inspection glass-Cerabar Sensor - 1 Bar .. 1 Bar - A_MU101A_057 Main Unit with EVO SW 00.00.26, Device Tag: “EVO2”. For the test the EUT was communicating with an ancillary device, which was labelled “USB-BLE Dongle 01” and was provided by the applicant.

# 3 Additional Information

All tests were performed with an unmodified sample.

The in-band and unrestricted band-edge tests were performed using a sample with temporary antenna connector, which was provided by the applicant.

The photograph below shows the EUT with the temporary antenna connector:



# 4 Overview

| Application | Frequency range [MHz] | FCC 47 CFR Part 15 section [2] | RSS-247 [3] or RSS-Gen [4] | Status | Refer page |
|---|---|---|---|---|---|
| Maximum conducted output power | 2400.0 - 2483.5 | 15.247 (b) (3), (4) | 5.4 (d) [3] | Passed | 12 et seq |
| DTS Bandwidth / 99% Bandwidth | 2400.0 - 2483.5 | 15.247 (a) (2) | 5.2 (a) [3] | Passed | 14 et seq |
| Average Power Spectral Density | 2400.0 - 2483.5 | 15.247 (e) | 5.2 (b) [3] | Passed | 17 et seq |
| Band edge compliance | 2400.0 - 2483.5 | 15.247 (d)<br>15.205 (a)<br>15.209 (a) | 5.5 [3] | Passed | 19 et seq. |
| Maximum unwanted emissions | 0.009 – 26,500 | 15.247 (d)<br>15.205 (a)<br>15.209 (a) | 5.5 [3]<br>8.9 [4],<br>8.10 [4] | Passed | 23 et seq. |
| Conducted emissions on supply line | 0.15 - 30 | 15.207 (a) | 8.8 [4] | Passed | 33 et seq. |

# 5 Results

## 5.1 Duty cycle

The EUT was measured conducted on a sample with a temporary antenna connector, which was provided by the applicant.

The method described in chapter 11.6 b) of document [1] was used to perform the following test.

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.

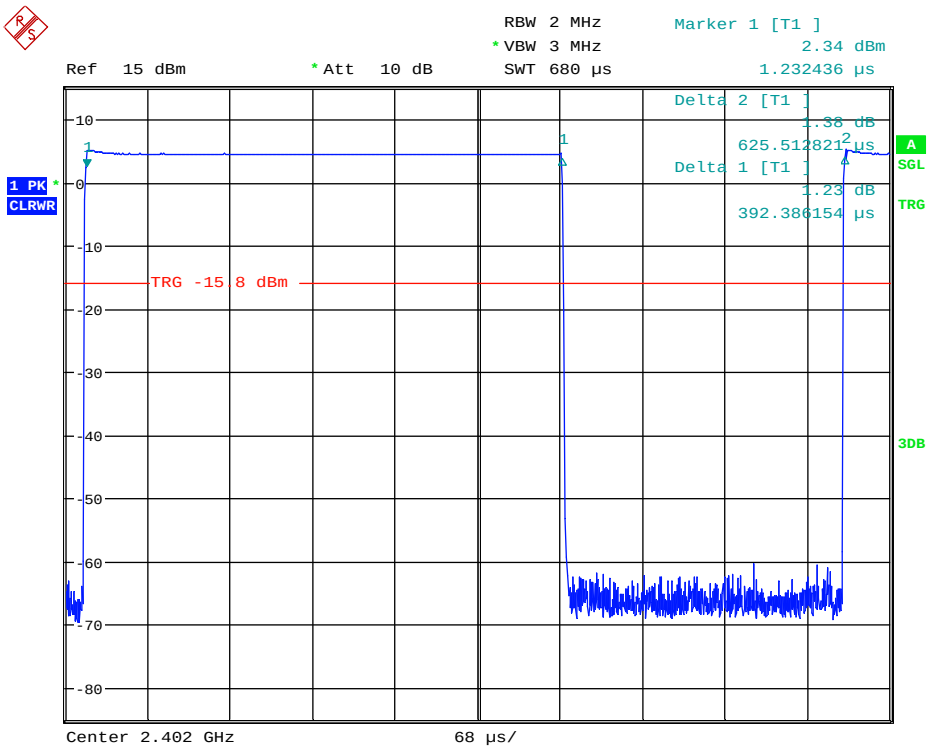
- Set the center frequency of the instrument to the center frequency of the transmission.
- Set RBW ≥ OBW if possible; otherwise, set RBW to the largest available value.
- Set VBW ≥ RBW.
- Set detector = peak or average.
- The zero-span measurement method shall not be used unless both RBW and VBW are > 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 ≤ 16.7 microseconds.)

### 5.1.1 Test results

| Ambient temperature | 22 °C |
|---|---|

| Relative humidity | 40 % |
|---|---|

190629_BTLE_DutyCycle.wmf: Duty cycle measurement on channel 0 (operation mode 1):




$$T_{TX_{On}} = 392.386\,\mu s \qquad T_{Tx_{Cycle}} = 625.513\,\mu s \tag{1}$$

$$\frac{50}{T_{TX\_On}} = \frac{50}{392.386\,\mu s} = 127.426kHz \leq RBW \leq VBW \tag{2}$$

Measurement Points 4001 for 680 µs à 392.386 µs = 2308 measurement points à Signal has 2308 measurement points (and fulfils the requirement of at least 100 Points resolution for the signal)

If power averaging (RMS) mode was used in step f), then the applicable correction factor is 10 log(1/x), where x is the duty cycle.

$$x = \frac{T_{Tx\_On}}{T_{Tx\_Cycle}} = \frac{392.386\mu s}{625.513\mu s} = 0.6273 = 62.73\% \tag{3}$$

$$correction\ factor = 10 \cdot log\left(\frac{1}{x}\right) = 10 \cdot log\left(\frac{1}{0.6273}\right) = 2.03dB \tag{4}$$

Therefore, for average measurements a correction factor of 2.03 dB is used.

TEST EQUIPMENT USED FOR THE TEST:

| 27, 28, 29 |
|---|

## 5.2 Maximum conducted output power

### 5.2.1 Method of measurement

The EUT was measured conducted on a sample with a temporary antenna connector, which was provided by the applicant.

**Acceptable measurement configurations**

Procedure 11.9.2.2.4 in [1] was used for the following test.

Method AVGSA-2 uses trace averaging across ON and OFF times of the EUT transmissions, followed by duty cycle correction. The procedure for this method is as follows:

a) Measure the duty cycle D of the transmitter output signal as described in 11.6.
b) Set span to at least 1.5 times the OBW.
c) Set RBW = 1% to 5% of the OBW, not to exceed 1 MHz.
d) Set VBW ≥ [3 × RBW].
e) Number of points in sweep ≥ [2 × span / RBW]. (This gives bin-to-bin spacing ≤ RBW / 2, so that narrowband signals are not lost between frequency bins.)
f) Sweep time = auto.
g) Detector = RMS (i.e., power averaging), if available. Otherwise, use the sample detector mode.
h) Do not use sweep triggering. Allow the sweep to “free run.”
i) Trace average at least 100 traces in power averaging (rms) mode; however, the number of traces to be averaged shall be increased above 100 as needed such that the average accurately represents the true average over the ON and OFF periods of the transmitter.
j) Compute power by integrating the spectrum across the OBW of the signal using the instrument’s band power measurement function with band limits set equal to the OBW band edges. If the instrument does not have a band power function, then sum the spectrum levels (in power units) at intervals equal to the RBW extending across the entire OBW of the spectrum.
k) Add [10 log (1 / D)], where D is the duty cycle, to the measured power to compute the average power during the actual transmission times (because the measurement represents an average over both the ON and OFF times of the transmission). For example, add [10 log (1/0.25)] = 6 dB if the duty cycle is 25%.

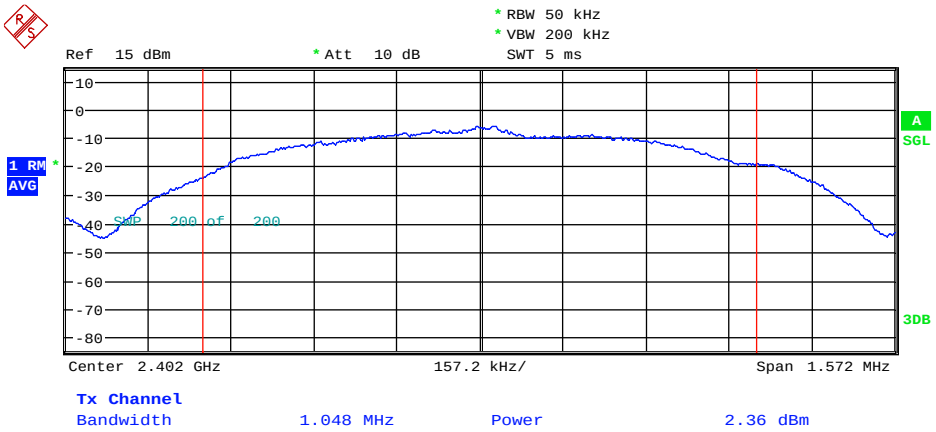
The measurement was performed at the upper and lower end and the middle of the assigned frequency band.

## 5.2.2 Test results

| | | | |
|---|---|---|---|
| Ambient temperature | 22 °C | Relative humidity | 62 % |

The plot below shows the worst case result. All other results are submitted in the table below

190629_AvOutpPwr_BTLE_BT1.wmf: Maximum output power measured on channel 1 (operation mode 1):




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

| Operation mode | | Frequency [MHz] | Reading [dBm] | DC Corr. [dB] | Corr. Reading [dBm] | Margin [dB] | Limit [dBm] |
|---|---|---|---|---|---|---|---|
| 1 | GFSK | 2402 | 2.36 | 2.03 | 4.39 | 25.61 | 30 |
| 2 | GFSK | 2440 | 2.33 | 2.03 | 4.36 | 25.64 | 30 |
| 3 | GFSK | 2480 | 2.15 | 2.03 | 4.18 | 25.82 | 30 |

The maximum antenna gain was declared to be below 0 dBi, as declared by the applicant. Therefore the antenna gain for the calculation above was calculated with 0 dBi as worst case.

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

| |
|---|
| 27, 28, 29 |

## 5.3 DTS Bandwidth / 99% Bandwidth

### 5.3.1 Method of measurement

The EUT was measured conducted on a sample with a temporary antenna connector, which was provided by the applicant.

**Acceptable measurement configurations**

The measurement for the DTS bandwidth procedure refers to part 11.8.1 of document [1].

- Set RBW = 100 kHz.
- Set the video bandwidth (VBW) ≥ 3 x 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:

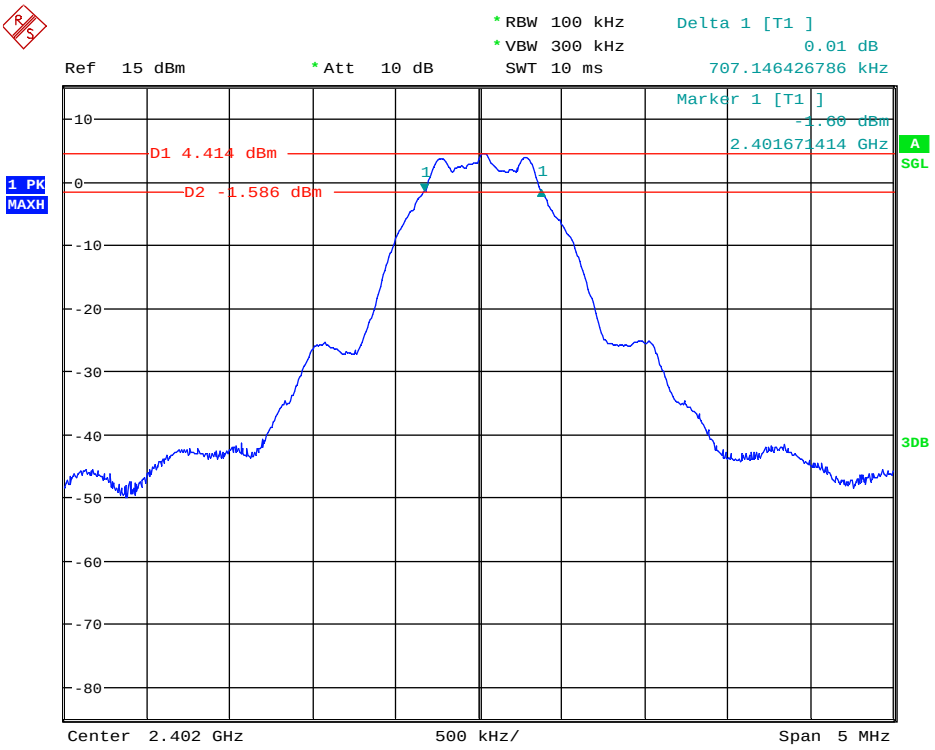
- The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW.
- The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately 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 (OBW/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 labelled. Tabular data maybe reported in addition to the plot(s).

### 5.3.2 Test result

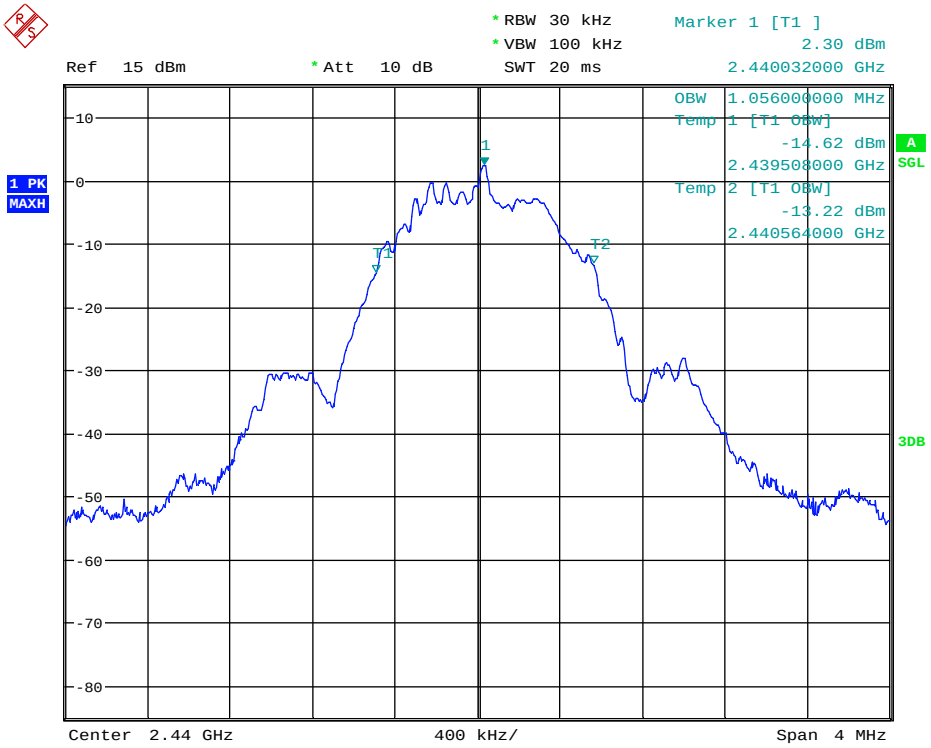
| | | | |
|---|---|---|---|
| Ambient temperature | 22 °C | Relative humidity | 59 % |

The plots show an exemplary measurement result for the worst documented case. The other results are listed in the following tables.

190629_6dB-BW_BTLE_BT1.wmf: 6-dB Bandwidth (operation mode 1):



190629_99%BW_BTLE_BTLE19.wmf: 99% Bandwidth (operation mode 2):




| Operation Mode | | Center Frequency [MHz] | Minimum 6-dB Bandwidth Limit [MHz] | 6 dB Bandwidth [MHz] | 99 % Bandwidth [MHz] | Result |
|---|---|---|---|---|---|---|
| 1 | GFSK | 2402 | 0.5 | 0.707 | 1.0480 | Passed |
| 2 | GFSK | 2440 | 0.5 | 0.720 | 1.0560 | Passed |
| 3 | GFSK | 2480 | 0.5 | 0.727 | 1.0560 | Passed |

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

| |
|---|
| 27, 28, 29 |

## 5.4 Average Power Spectral Density

### 5.4.1 Method of measurement

The EUT was measured conducted on a sample with a temporary antenna connector, which was provided by the applicant.

**Acceptable measurement configurations**

The measurement procedure refers to part 11.10.5 of document [1].

Method AVGPSD-2 uses trace averaging across ON and OFF times of the EUT transmissions, followed by duty cycle correction.

The following procedure is applicable when the EUT cannot be configured to transmit continuously (i.e., D < 98%), when sweep triggering/signal gating cannot be used to measure only when the EUT is transmitting at its maximum power control level, and when the transmission duty cycle is constant (i.e., duty cycle variations are less than ±2%):

- Measure the duty cycle (D) of the transmitter output signal as described in 11.6.
- Set instrument center frequency to DTS channel center frequency.
- Set span to at least 1.5 times the OBW.
- Set RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
- Set VBW ≥ [3 × RBW].
- Detector = power averaging (rms) or sample detector (when rms not available).
- Ensure that the number of measurement points in the sweep ≥ [2 × span / RBW].
- Sweep time = auto couple.
- Do not use sweep triggering; allow sweep to “free run.”
- Employ trace averaging (rms) mode over a minimum of 100 traces.
- Use the peak marker function to determine the maximum amplitude level.
- Add [10 log (1 / D)], where D is the duty cycle measured in step a), to the measured PSD to compute the average PSD during the actual transmission time.
- If measured value exceeds requirement specified by regulatory agency, then reduce RBW (but no less than 3 kHz) and repeat (note that this may require zooming in on the emission of interest and reducing the span to meet the minimum measurement point requirement as the RBW is reduced).

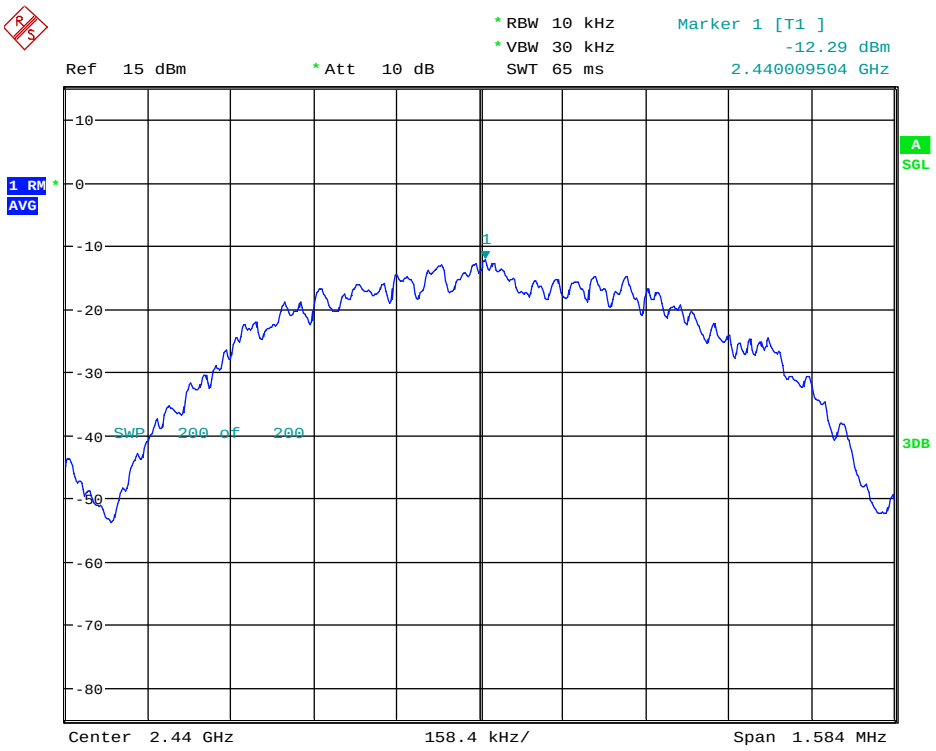
The measurement was performed at the upper and lower end and the middle of the assigned frequency band.

### 5.4.2 Test result

| | | | |
|---|---|---|---|
| Ambient temperature | 22 °C | Relative humidity | 59 % |

The plots show an exemplary measurement result for the worst documented case. The other results are listed in the following tables.

190629_AVPwrSpecDens_BTLE_BTLE19.wmf: Average Power Spectral Density (operation mode 2):




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

| Operation Mode | | Peak Frequency [MHz] | AvPSD Reading [dBm/10 kHz] | Duty Cycle Corr. [dB] | Corr. Reading [dBm /10 kHz] | Margin [dB] | AvPSD Limit [dBm/3kHz] |
|---|---|---|---|---|---|---|---|
| 1 | GFSK | 2402.009 | -12.33 | 2.03 | -10.30 | 18.30 | 8 |
| 2 | GFSK | 2440.010 | -12.29 | 2.03 | -10.26 | 18.26 | 8 |
| 3 | GFSK | 2480.010 | -12.50 | 2.03 | -10.47 | 18.47 | 8 |

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

| |
|---|
| 27, 28, 29 |

## 5.5 Band-edge compliance

### 5.5.1 Method of measurement (band edges next to unrestricted bands (radiated))

The EUT was measured conducted on a sample with a temporary antenna connector, which was provided by the applicant.

**Acceptable measurement configurations**

The measurement procedure refers to part 11.11.2 and 11.11.3 of document [1].

Measurement Procedure Reference – Reference Level:

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

Measurement Procedure – Unwanted Emissions

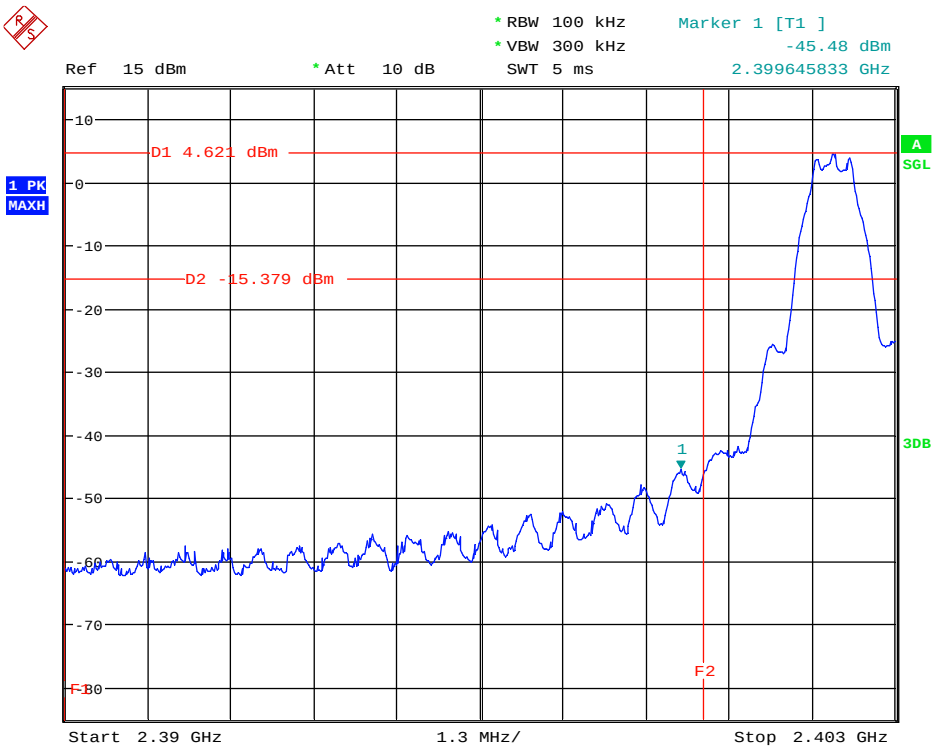
- Set the center frequency and span to encompass the frequency range to be measured.
- RBW = 100 kHz.
- VBW ≥ 300 kHz.
- Detector = Peak.
- Ensure that the number of measurement points ≥ span/RBW.
- Sweep time = auto couple.
- Trace Mode = max hold.
- Allow the trace to stabilise.
- Use the peak marker 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.

The measurement were performed at the lower end of the 2.4 GHz band.

### 5.5.2 Test result (band edges next to unrestricted bands (radiated))

190625_LowBE.wmf: Radiated band-edge compliance at an unrestricted band-edge (operation mode 1):




| Operation Mode | | Tx Frequency [MHz] | Emission Frequency [MHz] | Reference Level [dBm] | Limit [dBm] | Emisson Level [dBm] | Margin [dB] | Result |
|---|---|---|---|---|---|---|---|---|
| 1 | GFSK | 2402 | 2399.646 | 4.6 | -15.4 | -45.3 | 29.9 | Passed |

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

| |
|---|
| 27, 28, 29 |

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

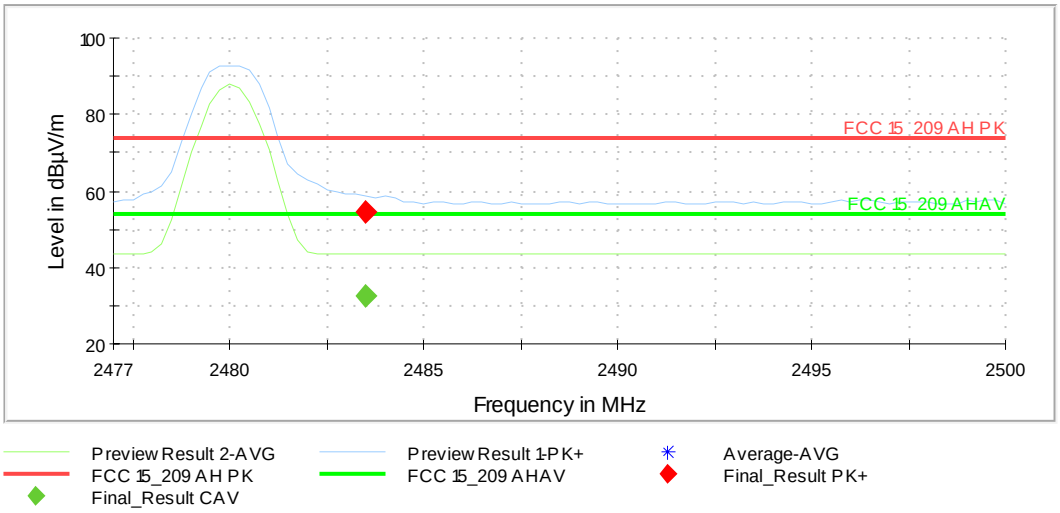
The EUT was measured radiated in the anechoic chamber using the procedures described in 5.6.1.

**Acceptable measurement configurations**

The same measurement configurations as described in 5.6.1. were used for the preview and final measurement.

### 5.5.4 Test result (band edges next to restricted bands (radiated))

190629_highBE: radiated band-edge compliance at an restricted band-edge (operation mode 3):



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

| Frequency [MHz] | MaxPeak [dBµV/m] | Caverage [dBµV/m] | Limit [dBµV/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 2377.500 | --- | 32.74 | 54 | 21.26 | H | 303 | 0 | 33.3 |
| 2377.500 | 43.18 | --- | 74 | 30.82 | H | 303 | 0 | 33.3 |
| 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 [dBµV/m] | Caverage [dBµV/m] | Limit [dBµV/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 2483.500 | --- | 34.35 | 54 | 19.65 | V | 320 | 90 | 33.5 |
| 2483.500 | 54.54 | --- | 74 | 19.46 | V | 320 | 90 | 33.5 |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | |

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

| |
|---|
| 7 – 14, 17, 18, 28, 29 |

## 5.6 Maximum unwanted emissions

### 5.6.1 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 30 MHz to 1 GHz.
- A final measurement carried out on an open area test side 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.

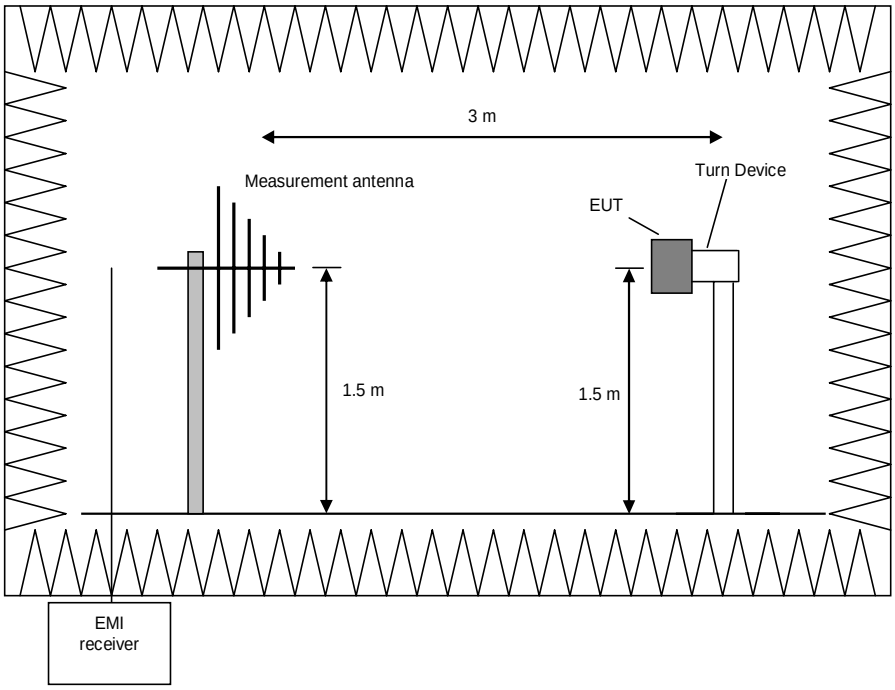
**Preliminary measurement (30 MHz to 1 GHz)**

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 1 GHz | 100 kHz |



Procedure preliminary measurement:

Prescans were performed in the frequency range 30 MHz to 230 MHz and 230 MHz to 1 GHz.
The following procedure will be used:

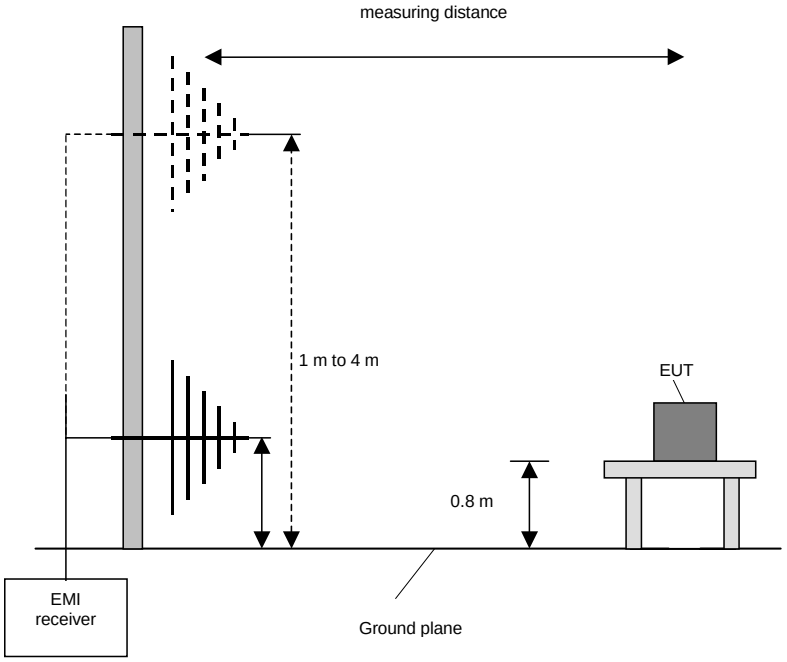
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Manipulate the system cables within the range to produce the maximum level of emission.
3. Rotate the EUT by 360 ° to maximize the detected signals.
4. Repeat 1) to 3) with the vertical polarisation of the measuring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

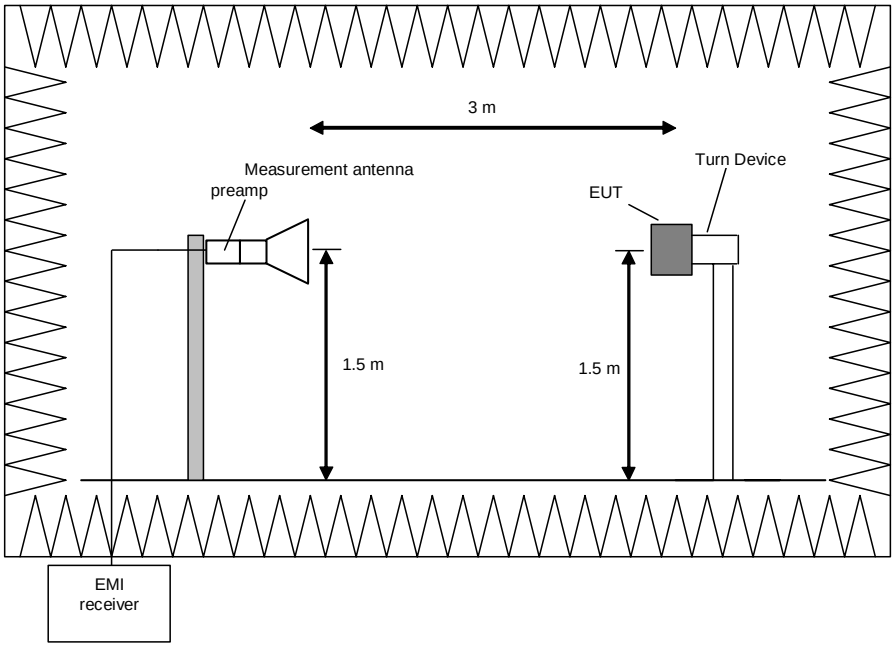
This measurement will be performed in a fully anechoic chamber. Table top devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

**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:

Prescans were performed in the frequency range 1 to 40 GHz.
The following procedure will be used:

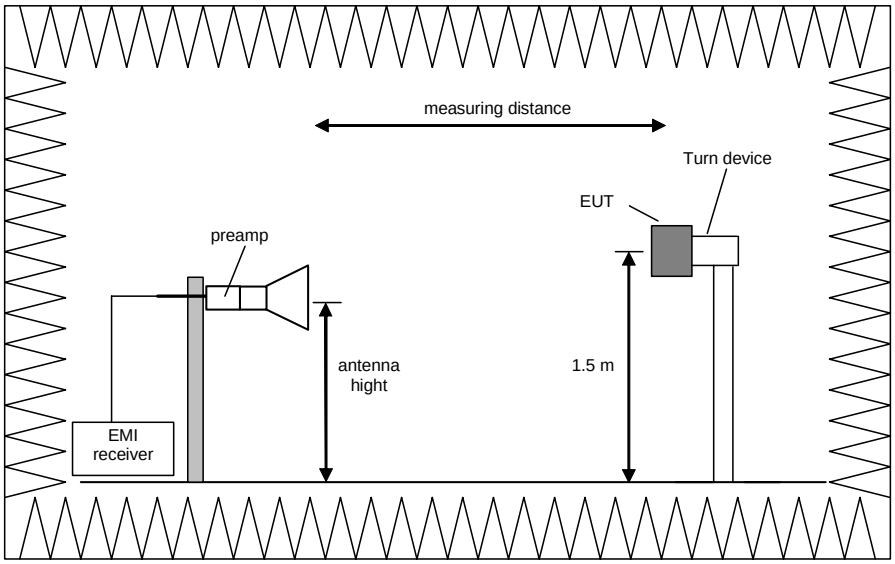
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an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

### 5.6.2 Test results (radiated emissions) – Emissions with internal antenna from 30 MHz – 26.5 GHz

#### 5.6.2.1 Preliminary radiated emission measurement 30 MHz – 26.5 GHz

| | | | |
|---|---|---|---|
| Ambient temperature | 22 °C | Relative humidity | 59 % |

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.

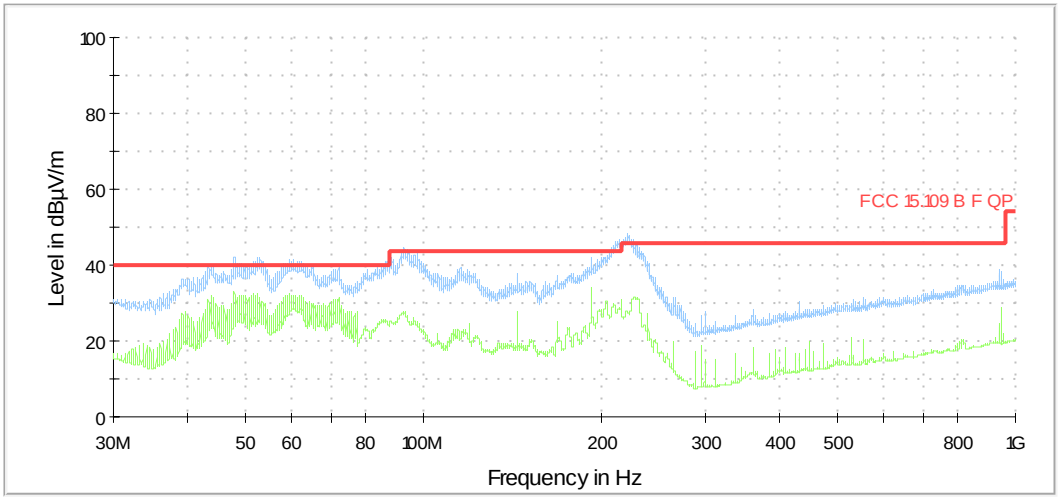
Test record: Only the plot of the worst case emission is submitted below.

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

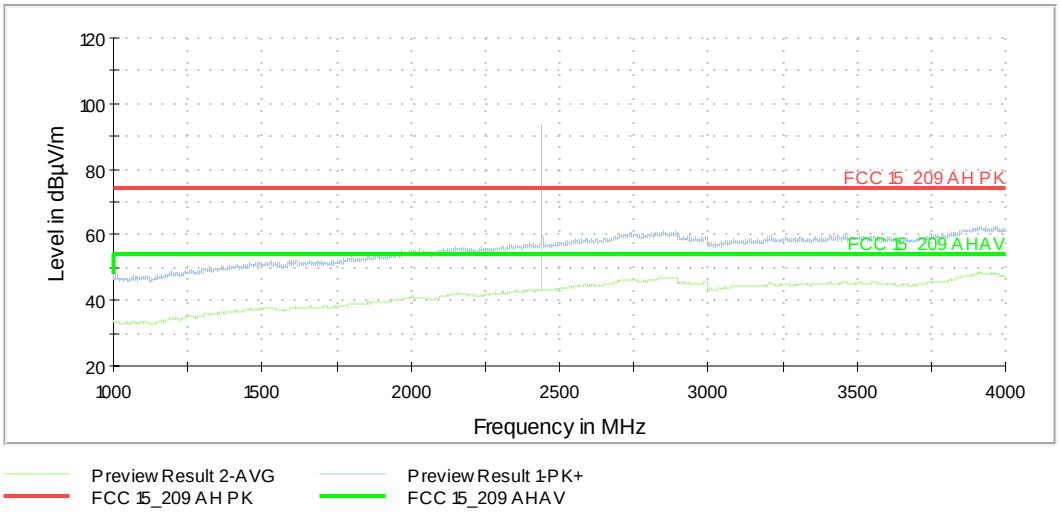
Since the lowest internal frequency is 32 MHz, no tests below 30 MHz were performed.

**Plots of the worst case transmitter spurious emissions**

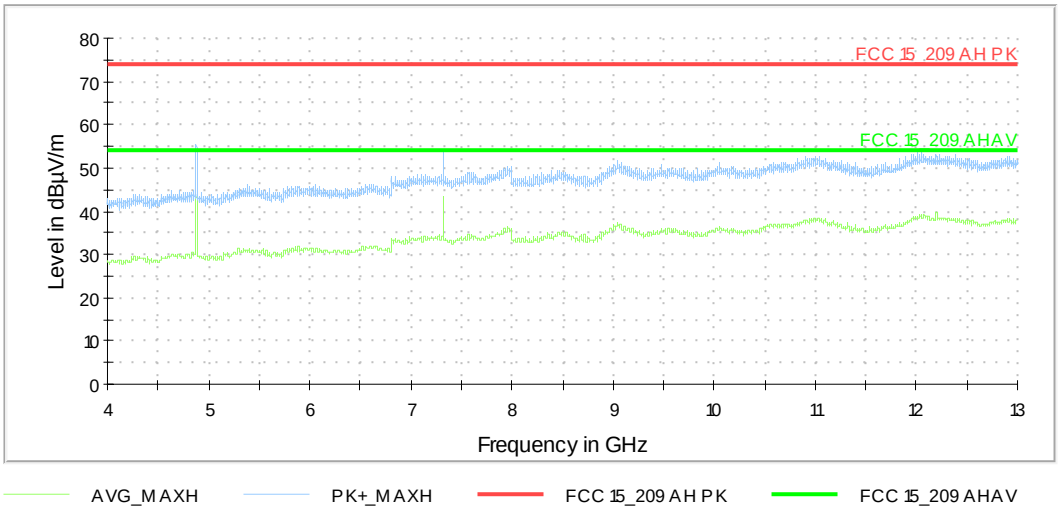
ch19_30M-1G: Spurious emissions from 30 MHz to 1 GHz (operation mode 2):



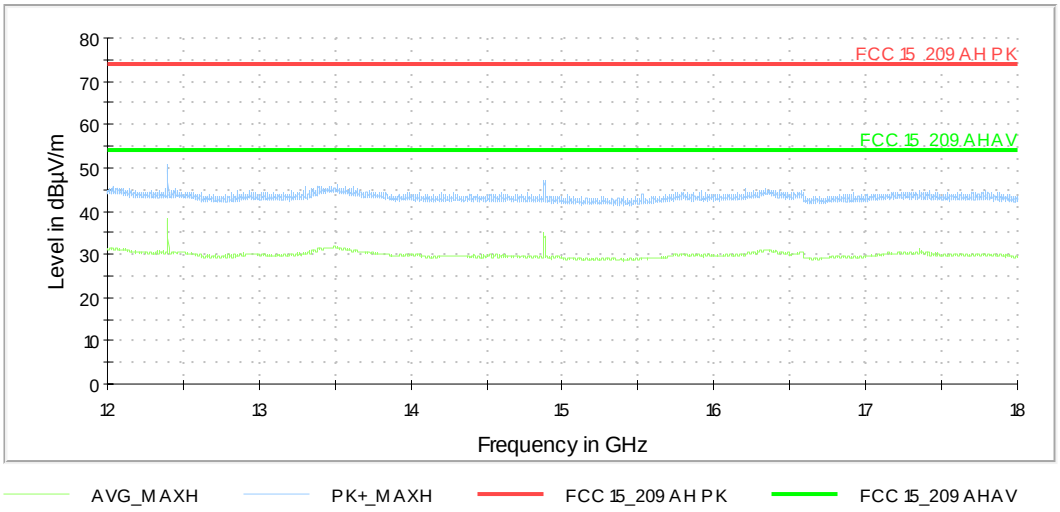
190629_ch19_1-4G: Spurious emissions from 1 GHz to 4 GHz (operation mode 2)



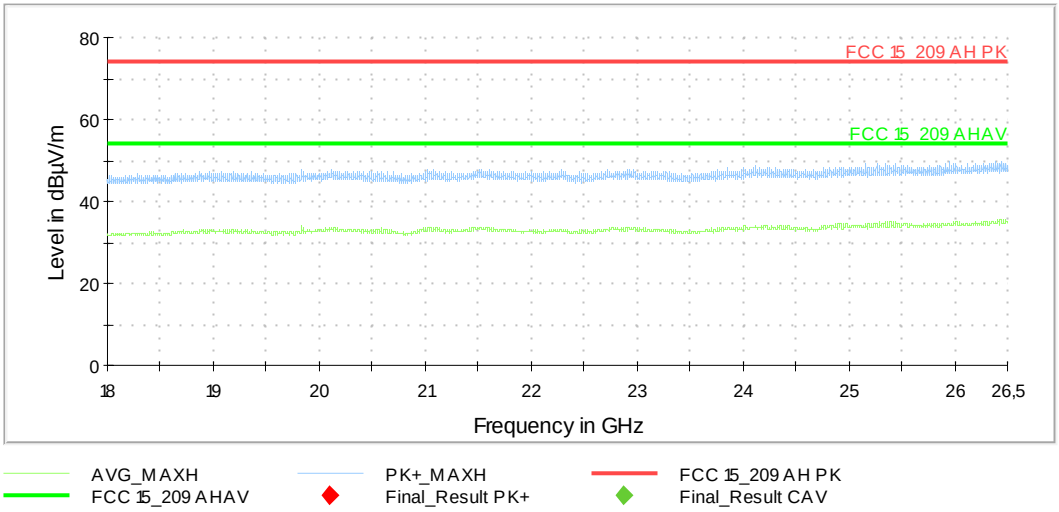

ch19_4-12G: Spurious emissions from 4 GHz to 12 GHz (operation mode 2):



Ch39_18-26,5G: Spurious emissions from 12 GHz to 18 GHz (operation mode 3):




ch39_18-26,5G: Spurious emissions from 18 GHz to 26.5 GHz (operation mode 3):



### 5.6.2.2 Final radiated measurements

**All TX modes (no difference detected when comparing channel / modulation)**

| Frequency [MHz] | QuasiPeak [dBµV/m] | Limit [dBµV/m] | Margin [dB] | Meas. Time [ms] | Bandwidth [kHz] | Height [cm] | Pol | Azimuth [deg] | Corr. [dB] |
|---|---|---|---|---|---|---|---|---|---|
| 48.010000 | 38.35 | 40.00 | 1.65 | 1000.0 | 120.000 | 100.0 | V | 168.0 | 14.8 |
| 52.580000 | 37.68 | 40.00 | 2.32 | 1000.0 | 120.000 | 158.0 | V | 324.0 | 12.5 |
| 53.040000 | 37.08 | 40.00 | 2.92 | 1000.0 | 120.000 | 118.0 | V | 327.0 | 12.3 |
| 59.500000 | 36.03 | 40.00 | 3.97 | 1000.0 | 120.000 | 205.0 | V | 225.0 | 12.1 |
| 61.350000 | 35.80 | 40.00 | 4.20 | 1000.0 | 120.000 | 166.0 | V | 192.0 | 12.4 |
| 92.830000 | 36.87 | 43.50 | 6.63 | 1000.0 | 120.000 | 105.0 | V | 11.0 | 16.6 |
| 93.390000 | 35.94 | 43.50 | 7.56 | 1000.0 | 120.000 | 114.0 | V | 47.0 | 16.6 |
| 144.140000 | 28.91 | 43.50 | 14.59 | 1000.0 | 120.000 | 254.0 | H | 150.0 | 16.0 |
| 192.070000 | 35.29 | 43.50 | 8.21 | 1000.0 | 120.000 | 132.0 | H | 265.0 | 15.3 |
| 211.090000 | 37.10 | 43.50 | 6.40 | 1000.0 | 120.000 | 133.0 | H | 270.0 | 16.0 |
| 213.840000 | 38.91 | 43.50 | 4.59 | 1000.0 | 120.000 | 115.0 | H | 282.0 | 16.3 |
| 221.180000 | 40.43 | 46.00 | 5.57 | 1000.0 | 120.000 | 126.0 | H | 278.0 | 16.7 |
| 221.580000 | 40.67 | 46.00 | 5.33 | 1000.0 | 120.000 | 122.0 | H | 272.0 | 16.8 |
| 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 [dBµV/m] | Caverage [dBµV/m] | Limit [dBµV/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 2402.250 | --- | 88.56 | Fund. | - | H | 87 | 120 | 33.4 |
| 2402.250 | 92.63 | --- | Fund. | - | H | 87 | 120 | 33.4 |
| 4804.000 | --- | 44.14 | 54 | 9.86 | H | 337 | 120 | -2 |
| 4804.000 | 55.98 | --- | 74 | 18.02 | H | 337 | 120 | -2 |
| 7205.250 | --- | 43.92 | 54 | 10.08 | V | 138 | 120 | 4.1 |
| 7205.250 | 53.42 | --- | 74 | 20.58 | V | 138 | 120 | 4.1 |
| 12008.750 | --- | 37.96 | 54 | 16.04 | V | 83 | 120 | 12.1 |
| 12008.750 | 48.28 | --- | 74 | 25.72 | V | 83 | 120 | 12.1 |
| 14413.750 | --- | 36.09 | 54 | 17.91 | V | 154 | 150 | 11.5 |
| 14413.750 | 47.12 | --- | 74 | 26.88 | V | 154 | 150 | 11.5 |
| 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 [dBµV/m] | Caverage [dBµV/m] | Limit [dBµV/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 2440.250 | --- | 89.77 | Fund. | - | H | 98 | 120 | 33.6 |
| 2440.250 | 93.83 | --- | Fund. | - | H | 98 | 120 | 33.6 |
| 4880.000 | --- | 44.74 | 54 | 9.26 | H | 338 | 120 | -1.7 |
| 4880.000 | 55.18 | --- | 74 | 18.82 | H | 338 | 120 | -1.7 |
| 7319.250 | --- | 44.33 | 54 | 9.67 | V | 132 | 120 | 4.8 |
| 7319.250 | 53.72 | --- | 74 | 20.28 | V | 132 | 120 | 4.8 |
| 12201.250 | --- | 37.36 | 54 | 16.64 | V | 87 | 120 | 11.9 |
| 12201.250 | 47.93 | --- | 74 | 26.07 | V | 87 | 120 | 11.9 |
| 14638.750 | --- | 37.82 | 54 | 16.18 | V | 157 | 150 | 11.4 |
| 14638.750 | 47.61 | --- | 74 | 26.39 | V | 157 | 150 | 11.4 |
| 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 [dBµV/m] | Caverage [dBµV/m] | Limit [dBµV/m] | Margin (dB) | Pol | Azimuth (deg) | Elevation (deg) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|
| 2479.750 | --- | 89.46 | Fund. | - | H | 109 | 120 | 33.5 |
| 2479.750 | 93.78 | --- | Fund. | - | H | 109 | 120 | 33.5 |
| 4960.000 | --- | 43.99 | 54 | 10.01 | H | 284 | 90 | -1.8 |
| 4960.000 | 54.05 | --- | 74 | 19.95 | H | 284 | 90 | -1.8 |
| 7439.250 | --- | 44.29 | 54 | 9.71 | V | 138 | 120 | 5.1 |
| 7439.250 | 53.97 | --- | 74 | 20.03 | V | 138 | 120 | 5.1 |
| 7439.250 | --- | 44.29 | 54 | 9.71 | V | 138 | 120 | 5.1 |
| 7439.250 | 53.97 | --- | 74 | 20.03 | V | 138 | 120 | 5.1 |
| 14878.750 | --- | 38.46 | 54 | 15.54 | V | 156 | 150 | 11.2 |
| 14878.750 | 48.08 | --- | 74 | 25.92 | V | 156 | 150 | 11.2 |
| Measurement uncertainty | | | | +2.2 dB / -3.6 dB | | | | |

| TEST EQUIPMENT USED FOR THE TEST: |
|---|
| 7 – 26, 28 - 36 |

## 5.7 Conducted emissions on power supply lines (150 kHz to 30 MHz)

| | | | |
|---|---|---|---|
| Ambient temperature | 20 °C | Relative humidity | 52 % |

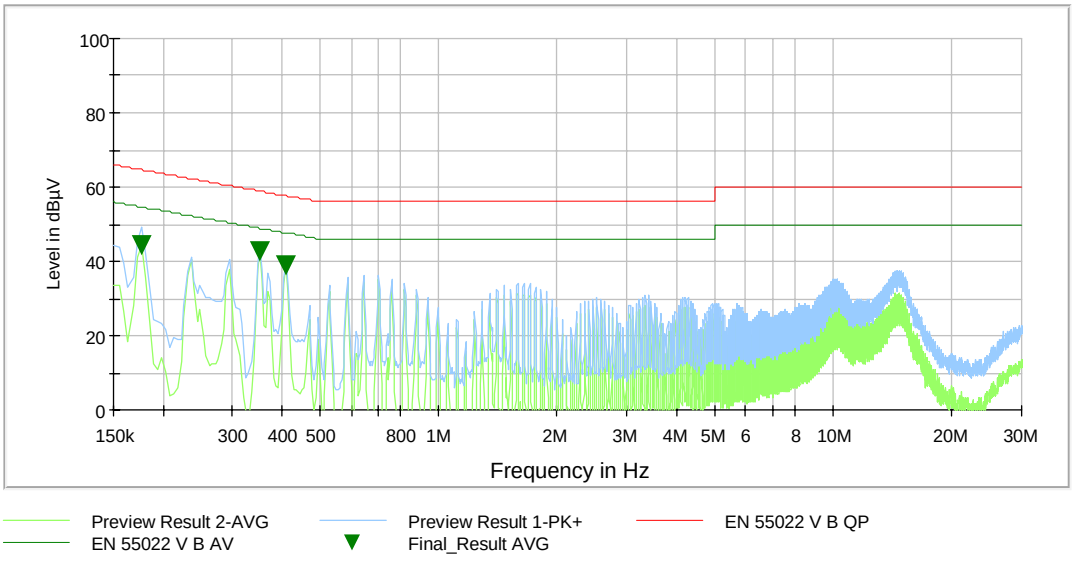
Position of EUT: For this test, the EUT was operated in normal mode. The EUT was inserted in a representative housing (aluminium housing and pressure sensor:1-Chamber Aluminium Housing, non ExD („PMP51B_P2_002“) Aluminium-Cover with plastic inspection glass).

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

Test record: All results are shown in the following.

Supply voltage: Measurement performed with US 120V/60Hz.
For the test an AC/DC Adaptor from Phoenix Contact Model MINI-PS-100-240AC/24DC/2 was used, which had an output voltage of 24.0 V DC.

The curves in the diagram only represent for each frequency point the maximum measured value of all preliminary measurements which were made for each power supply line. The top measured curve represents the peak measurement and the bottom measured curve the average measurement. The quasi-peak measured points are marked by “♦” and the average measured points by “▼”.




| Frequency (MHz) | QuasiPeak (dBµV) | Average (dBµV) | Limit (dBµV) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Line | PE | Transducer (dB) |
|---|---|---|---|---|---|---|---|---|---|
| 0.176 | --- | 44.38 | 54.67 | 10.29 | 5000 | 9 | N | GND | 9.8 |
| 0.352 | --- | 42.92 | 48.92 | 6.01 | 5000 | 9 | N | GND | 9.9 |
| 0.410 | --- | 39.02 | 47.65 | 8.63 | 5000 | 9 | N | FLO | 9.9 |
| Measurement uncertainty | | | | +2.76 dB / -2.76 dB | | | | | |

Test: Passed

| TEST EQUIPMENT USED FOR THE TEST: |
|---|
| 1 – 7, 28, 29 |

# 6 Test equipment and ancillaries used for tests

| No. | Test equipment | Type | Manufacturer | Serial No. | PM. No. | Cal. Date | Cal. Due |
|---|---|---|---|---|---|---|---|
| 1 | Shielded chamber M4 | - | Albatross Projects | B83117-C6439-T262 | 480662 | Calibration not necessary | |
| 2 | EMI Receiver | ESIB 26 | Rohde & Schwarz | 1088.7490 | 481182 | 28.02.2018 | 02.2020 |
| 3 | LISN | NSLK8128 | Schwarzbeck | 8128155 | 480058 | 19.04.2018 | 02.2020 |
| 4 | High pass filter | HR 0.13-5ENN | FSY Microwave | DC 0109 SN 002 | 480340 | Calibration not necessary | |
| 5 | EMI Software | ES-K1 | Rohde & Schwarz | - | 480111 | Calibration not necessary | |
| 6 | Netzteil AC | AC6803A AC Quelle 2000VA | Keysight | JPVJ002509 | 482350 | Calibration not necessary | |
| 7 | EMI Software | EMC32 | Rohde & Schwarz | 100061 | 481022 | Calibration not necessary | |
| 8 | HF-Cable | Sucoflex 104 | Huber+Suhner | 517406 | 482391 | Calibration not necessary | |
| 9 | Fully anechoic chamber M20 | - | Albatross Projects | B83107-E2439-T232 | 480303 | Calibration not necessary | |
| 10 | Signal & Spectrum Analyzer | ESW44 | Rohde & Schwarz | 101635 | 482467 | 29.03.2018 | 03.2020 |
| 11 | Controller | MCU | Maturo | MCU/043/971107 | 480832 | Calibration not necessary | |
| 12 | Turntable | DS420HE | Deisel | 420/620/80 | 480315 | Calibration not necessary | |
| 13 | Antenna support | AS615P | Deisel | 615/310 | 480187 | Calibration not necessary | |
| 14 | Antenna (Log.Per.) | HL050 | Rohde & Schwarz | 100438 | 481170 | 09.10.2017 | 10.2020 |
| 15 | Standard Gain Horn 11.9 GHz – 18 GHz | 18240-20 | Flann Microwave | 483 | 480294 | Calibration not necessary | |
| 16 | Standard Gain Horn 17.9 GHz – 26.7 GHz | 20240-20 | Flann Microwave | 411 | 480297 | Calibration not necessary | |
| 17 | RF-cable No. 3 | Sucoflex 106B | Huber&Suhner | 500234/6B | 482644 | Calibration not necessary | |
| 18 | RF-cable No. 40 | Sucoflex 106B | Huber&Suhner | SF106B/11N/11N/1500MM | 482125 | Calibration not necessary | |
| 19 | Loop antenna | HFH2-Z2 | Rohde & Schwarz | 832609/014 | 480059 | 21.02.2018 | 02.2020 |
| 20 | Antenna (Bilog) | CBL6112B | Schaffner EMV GmbH (-Chase) | 2688 | 480328 | 19.06.2017 | 06.2020 |
| 21 | RF-cable 2 m | KPS-1533-800-KPS | Insulated Wire | - | 480302 | Calibration not necessary | |
| 22 | RF cable 36 | Sucoflex 106B | Suhner | 500003/6B / Kabel 36 | 481680 | Calibration not necessary | |
| 23 | Preamplifier 100 MHz - 16 GHz | AFS6-00101600-23-10P-6-R | Narda MITEQ | 2011215 | 482333 | 10.07.2018 | 07.2020 |
| 24 | Preamplifier | JS3-12001800-16-5A | Miteq | 571667 | 480343 | 10.07.2018 | 07.2020 |
| 25 | Preamplifier | JS3-18002600-20-5A | Miteq | 658697 | 480342 | 10.07.2018 | 07.2020 |
| 26 | 4 GHz High Pass Filter | WHKX4.0/18G-8SS | Wainwright Instruments | 1 | 480587 | Calibration not necessary | |
| 27 | Spectrum Analyser | FSU46 | Rohde & Schwarz | 200125 | 480956 | 27.03.2019 | 03.2020 |
| 28 | Power Supply | TOE8752-32 (DC) | Toellner Electronic Inst. | 31566 | 480010 | Calibration not necessary | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 29 | Multimeter | 971A | Hewlett Packard | JP39009358 | 480721 | 19.02.2019 | 02.2020 |
| 30 | Semi anechoic chamber | M276 | Albatross Projects | C62128-A540-A138-10-0006 | 483227 | Calibration not necessary | |
| 31 | Antenna mast | BAM4.5-P-10kg | maturo | 222/2612.01 | 483225 | Calibration not necessary | |
| 32 | Turntable | | Deisel | 412/316 | 480087 | Calibration not necessary | |
| 33 | Controller | HD100 | Deisel | 100/349 | 480139 | Calibration not necessary | |
| 34 | Software | EMC32 | Rohde & Schwarz | ID: 1300.7010.12-100970-Be | 482972 | Calibration not necessary | |
| 35 | Ultralog Antenna | HL562E | Rohde & Schwarz | - | 482978 | 07.08.2019 | 08.2022 |
| 36 | EMI Testreceiver | ESW | Rohde & Schwarz | 101828 | 482979 | 12.04.2019 | 04.2021 |

# 7 Test site Validation

| Test equipment | PM. No. | Frequency range | Type of validation | According to | Val. Date | Val Due |
|---|---|---|---|---|---|---|
| Semi anechoic chamber M276 | 483227 | 30 – 1000 MHz | NSA | ANSI C63.4-2017 | 19.09.2019 | 18.09.2021 |
| Semi anechoic chamber M276 | 483227 | 1 -18 GHz | SVSWR*1 | CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017 | 19.09.2019 | 18.09.2021 |
| Fully anechoic chamber M20 | 480303 | 30 – 1000 MHz | NSA | ANSI C63.4-2014 | 13.02.2018 | 12.02.2020 |
| Fully anechoic chamber M20 | 480303 | 1 -18 GHz | SVSWR | CISPR 16-1-4 Amd. 1 | 13.07.2018 | 12.07.2020 |
| Shielded chamber M4 | 480088 | 9 kHz – 30 MHz | GND-Plane | ANSI C63.4-2014 | 06.11.2018 | 05.11.2020 |

# 8 Report History

| Report Number | Date | Comment |
|---|---|---|
| F190629E3 | 13.11.2019 | Initial Test Report |
| | | |
| | | |
| | | |

# 9 List of Annexes

| | | |
|---|---|---|
| ANNEX A | TEST SETUP PHOTOS | 7 pages |
| ANNEX B | EXTERNAL PHOTOS | 2 pages |
| ANNEX C | INTERNAL PHOTOS | 4 pages |