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:

F170014E2

Equipment under Test (EUT):

Flowmeter with Bluetooth Low Energy
PICOMAG

Applicant:

Endress+Hauser Flowtec AG

Manufacturer:

Endress+Hauser Flowtec AG

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 (June 2017)**, 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 4 (November 2014)**, General Requirements for Compliance of Radio Apparatus

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.

Test engineer:	Paul NEUFELD		11.09.2017
	Name	Signature	Date
Authorized reviewer:	Bernd STEINER		11.09.2017
	Name	Signature	Date

This test report is only valid in its original form.

The test results herein refer only to the tested sample. PHOENIX TESTLAB GmbH is not responsible for any generalisations or conclusions drawn from these test results concerning further samples. Any modification of the tested samples is prohibited and leads to the invalidity of this test report. Each page necessarily contains the PHOENIX TESTLAB Logo and the TEST REPORT NUMBER.

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

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1 Identification

1.1 Applicant

Name:	Endress+Hauser Flowtec AG
Address:	Kägenstrasse 7 4153 Reinach
Country:	Switzerland
Name for contact purposes:	Christian Matt
Phone:	+41 61 715 6624
Fax:	+41 61 715 3165
eMail Address:	christian.matt@flowtec.endress.com
Applicant represented during the test by the following person:	none

1.2 Manufacturer

Name:	Endress+Hauser Flowtec AG
Address:	Kägenstrasse 7 4153 Reinach
Country:	Switzerland
Name for contact purposes:	Christian Matt
Phone:	+41 61 715 6624
Fax:	+41 61 715 3165
eMail Address:	christian.matt@flowtec.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-17186-01-02, 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)

Test object: *	**Flowmeter with Bluetooth Low Energy**
Type / PMN: *	**Picomag**
FCC ID: *	2AIMC-DMA
IC-Number: *	21529-DMA
Serial number: *	Engineering sample
PCB identifier: *	341961
HVIN (Hardware Version Identification Number): *	Picomag
FVIN (Firmware Version Identification Number): *	V1.00.00
Hardware version: *	V1.00.00
Software version: *	V1.00.00

Bluetooth Low Energy:

Channel 00	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 4.0 Low Energy					
Antenna type: *	PCB antenna					
Antenna gain: *	< 0dBi					
Antenna connector: *	none					
Power supply - EUT	U_{nom}=	24.0 V DC	U_{min}=	18.0 V DC	U_{max}=	30.0 V DC
Power supply – radio chip	U_{nom}=	3.3 V DC	U_{min}=	1.7 V DC	U_{max}=	3.6 V DC
Type of modulation: *	GFSK					
Operating frequency range:*	2402 – 2480 MHz					
Number of channels: *	40					
Temperature range: *	-10 °C to 60 °C (ambient), -10 °C to 70 °C (fluid)					
Lowest / highest Internal clock frequency: *	32 MHz / 2.48 GHz					

* Declared by the applicant

Ancillary devices:

Test Laptop	Fujitsu LIFEBOOK E751 (provided by the laboratory)

The following external I/O cables were used:

Identification	Connector		Length
	EUT	Ancillary	
DC Power Supply Cable:*	M12x1 (Conec)	Laboratory power supply	3 m *
Serial interface for test mode settings:*	Serial interface soldered to main PCB	TTL-232R-3V3 to USB connector in test laptop	1 m *

*: Length during the test if no other specified.

1.6 Dates

Date of receipt of test sample:	19.04.2017
Start of test:	21.04.2017
End of test:	23.05.2017

2 Operational States

The EUT is an electromagnetic Flowmeter with Bluetooth Low Energy capability. The normal use case is a BTLE connection to a mobile device like a smartphone.

The test modes were set via a modified EUT and an RS-232 to USB connector provided by the applicant. The test modes were set by using a laptop with a test software called “nrfgostudio_win-32_1.21.2_installer.msi”.

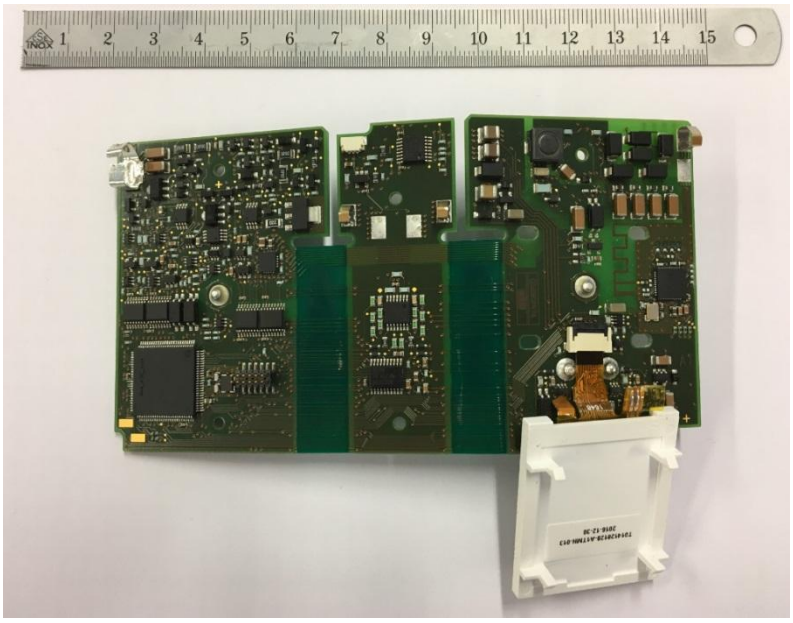
Maximum power Settings for all measurements:

Modulation	Power setting ch. 0 - 39
GFSK	0.0

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

3 Additional Information

The EUT which was used for the radio tests, was modified in the following way:



- black wire: ground
- yellow wire: Rx of serial interface
- red wire: Tx of serial interface

4 Overview

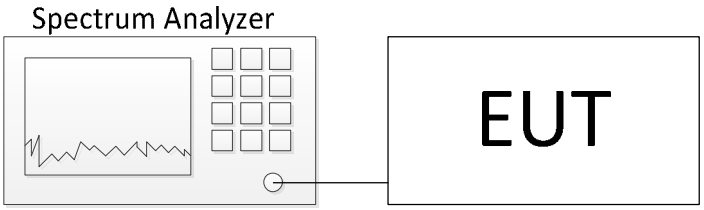
Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-247 [3] or RSS-Gen, Issue 4 [4]	Status	Refer page
Maximum Peak Output Power	2400.0 - 2483.5	15.247 (b) (3), (4)	5.4 (d) [3]	Passed	12 et seq
DTS Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	5.2 (a) [3]	Passed	16 et seq
Peak Power Spectral 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)	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	24 et seq.
Conducted emissions on supply line	0.15 - 30	15.207 (a)	8.8 [4]	Passed	37 et seq.

5 Results

5.1 Duty cycle

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

Test Setup:



The method described in chapter 11.6.0 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.

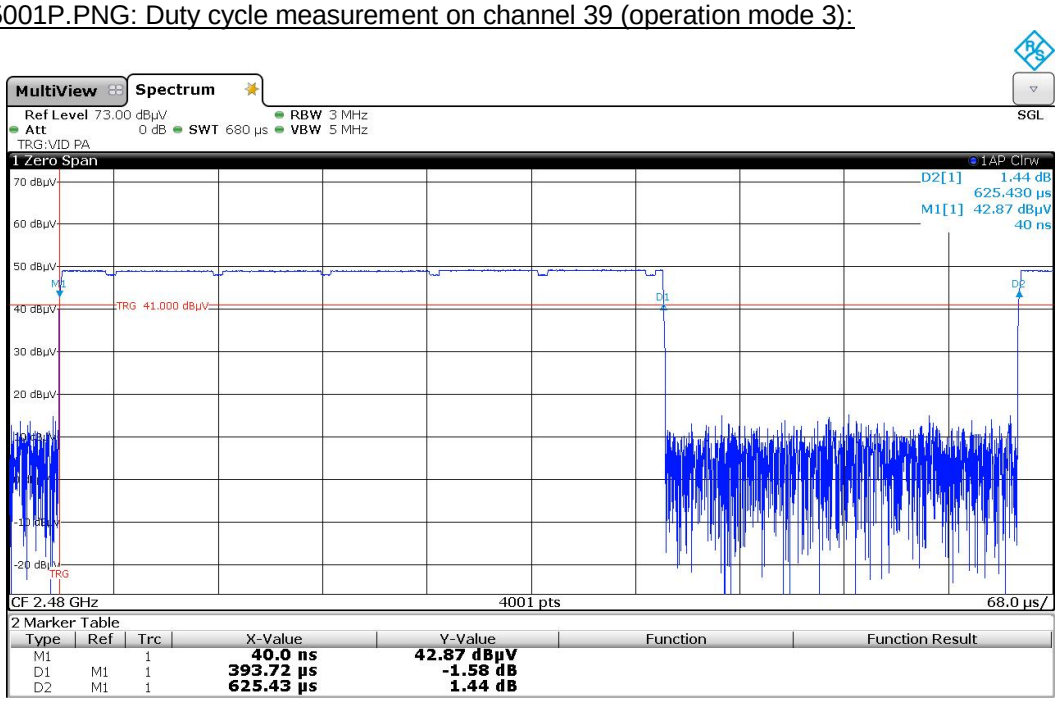
- Set the center frequency of the instrument to the center frequency of the transmission.
- Set RBW ≥ OBW if possible; otherwise, set RBW to the largest available value.
- Set VBW ≥ RBW.
- Set detector = peak or average.
- The zero-span measurement method shall not be used unless both RBW and VBW are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

Since Bluetooth Low Energy only has one modulation, only one duty cycle plot is submitted below.

DutyCycle 5001P.PNG: Duty cycle measurement on channel 39 (operation mode 3):



$$T_{TX\_On} = 393.72\,\mu s \quad , \; T_{TX\_Period} = 625.43\,\mu s \qquad (1)$$

$$\frac{50}{T_{TX\_On}} = \frac{50}{393.72\,\mu s} = 126.994\,kHz \le RBW \le VBW \qquad (2)$$

Measurement Points 4001 for 680 µs à 393.72 µs = 2316 measurement points à Signal has 2316 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.

$$x = \frac{393.72\,\mu s}{625.43\,\mu s} = 0.6295 = 62.95\% \qquad (3)$$

Correction factor: $10 \times \log\left(\frac{1}{x}\right) = 10 \times \log\left(\frac{1}{0.6295}\right) = 2.01\,dB$ (4)

Therefore, for average measurements a correction factor of 2.01 dB is used for all tests.

TEST EQUIPMENT USED FOR THE TEST:

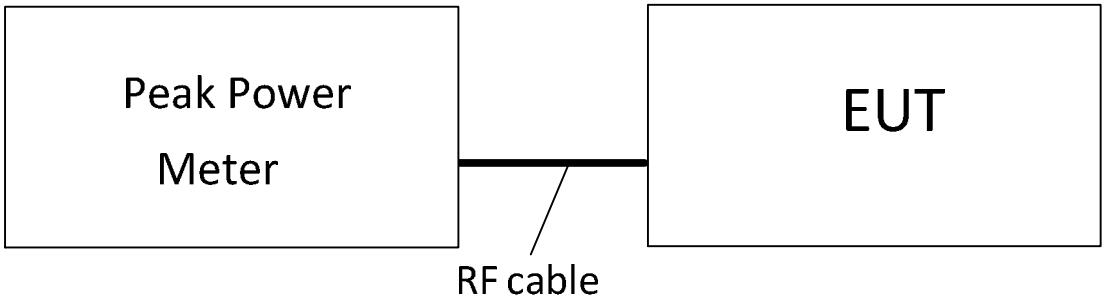
8 – 14, 17, 18

5.2 Maximum peak conducted output power

Since the antenna gain was unknown, two different approaches for the determination of the maximum peak output power were taken. First the power was measured conducted on a sample with temporary antenna connector. Next the EUT was measured radiated with the internal antenna. With this approach it can be shown, that the EUT has an antenna gain less than 6 dBi.

5.2.1 Method of measurement 1

The EUT was measured conducted at the temporary antenna ports with the aid of a peak power meter. The temporary antenna connector was implemented by the manufacturer.



5.2.2 Method of measurement 2

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

Acceptable measurement configurations 1

Procedure 11.9.1.3 in [1] was used for the following test.

The maximum peak conducted output power may be measured using a broadband peak RF power meter. The power meter shall have a video bandwidth that is greater than or equal to the DTS bandwidth and shall use a fast-responding diode detector.

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

Acceptable measurement configurations 2

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:

a) Set the RBW ≥ DTS bandwidth.
b) Set VBW ≥ [3 × RBW].
c) Set span ≥ [3 × RBW].
d) Sweep time = auto couple.
e) Detector = peak.
f) Trace mode = max hold.
g) Allow trace to fully stabilize.
h) 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.

The measured Electric field strength was corrected with the following correction factor:

Antenna Factor [dB] + Cable Attenuation [dB] - Amplifier Gain[dB] = correction factor [dB]

The formula in 11.22.2.2 e) in [1] was used to calculate the EIRP power:

$E = EIRP - 20\log(d) + 104.8$
$EIRP = E - 95.3$

$MPOP = EIRP - G$

E is the electric field strength in dBµV/m
EIRP is the equivalent isotropically radiated power in dBm
d is the specified measurement distance in m
G is the antenna gain in dBi
MPOP is the maximum peak output power – measured antenna port conducted – in dBm

5.2.3 Test results

Ambient temperature	22 °C	Relative humidity	62 %

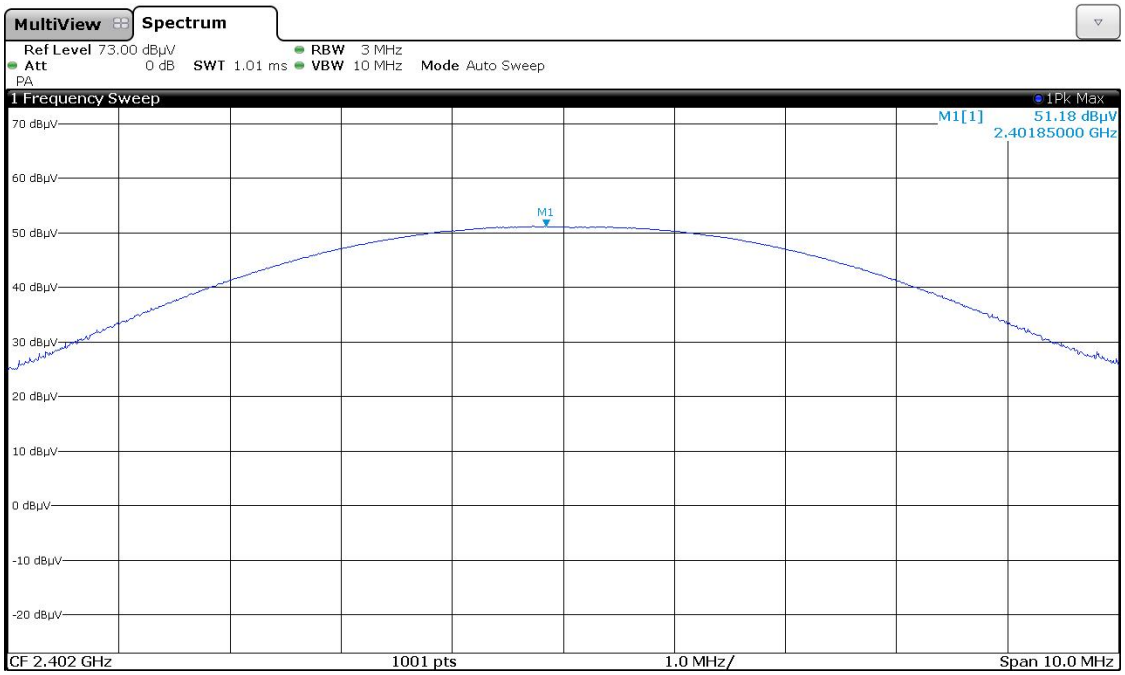
Result 1: conducted measurement on the sample with temporary antenna connector

Operation mode	Frequency [MHz]	Maximum peak output power conducted [dBm]	Limit [dBm]
1	2402	-3.7	30
2	2440	-3.3	30
3	2480	-2.9	30

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

Result 2: radiated measurement on sampel with integral antenna

MPOP_ch0.PNG: Maximum peak output power measured on channe 0 (operation mode 1):



Operation mode	Frequency [MHz]	Reading [dBµV]	Corr. Fact. [dB]	Corr. Reading [dBµV]	EIRP [dBm]	Limit [dBm]
1	2402	51.2	33.5	84.7	-10.6	30
2	2440	49.2	33.7	82.9	-12.4	30
3	2480	49.4	33.6	83	-12.3	30

When comparing the results of the conducted measurements at the antenna port and the radiated measurements, it can be seen that the antenna has a gain less than 6dBi. Therefore no power limit correction has to be performed.

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

8 – 14, 17, 18, 28, 29

5.3 DTS Bandwidth / 99% Bandwidth

5.3.1 Method of measurement

For the DTS bandwidth measurement, the EUT was measured radiated in the anechoic chamber using the procedures described in 5.6.1.

For the 99 % Bandwidth the EUT was measured with the aid of a loop antenna.

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 16abelled. Tabular data maybe reported in addition to the plot(s).

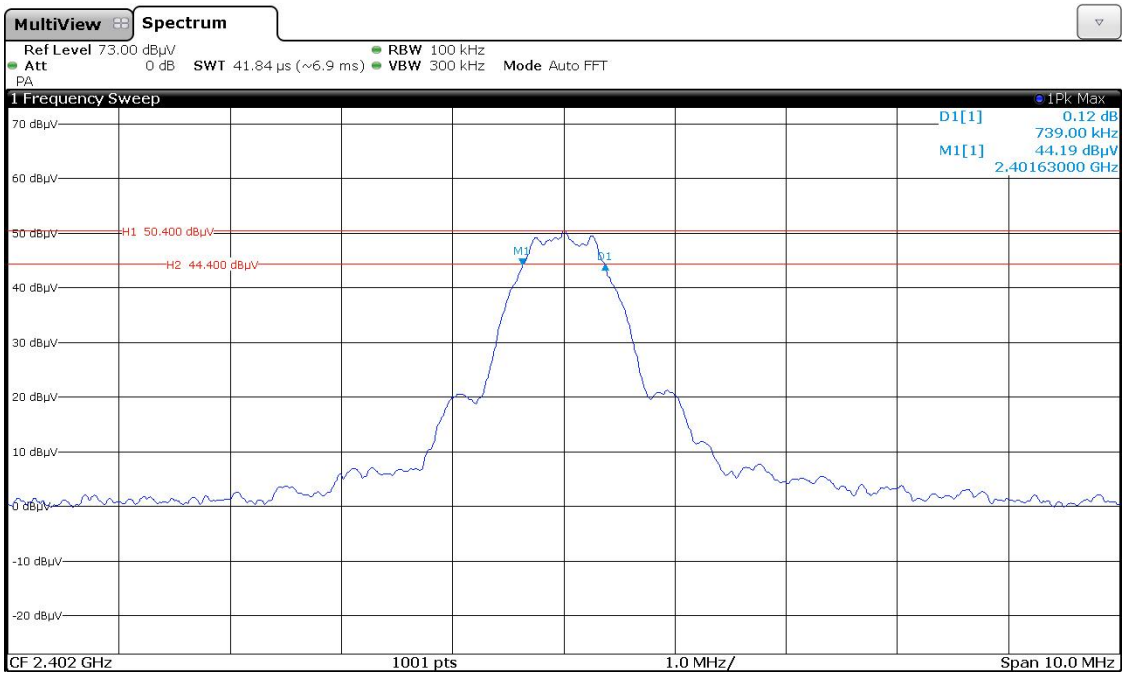
Since this is only a relative measurement, no measurement level correction was performed.

5.3.2 Test result

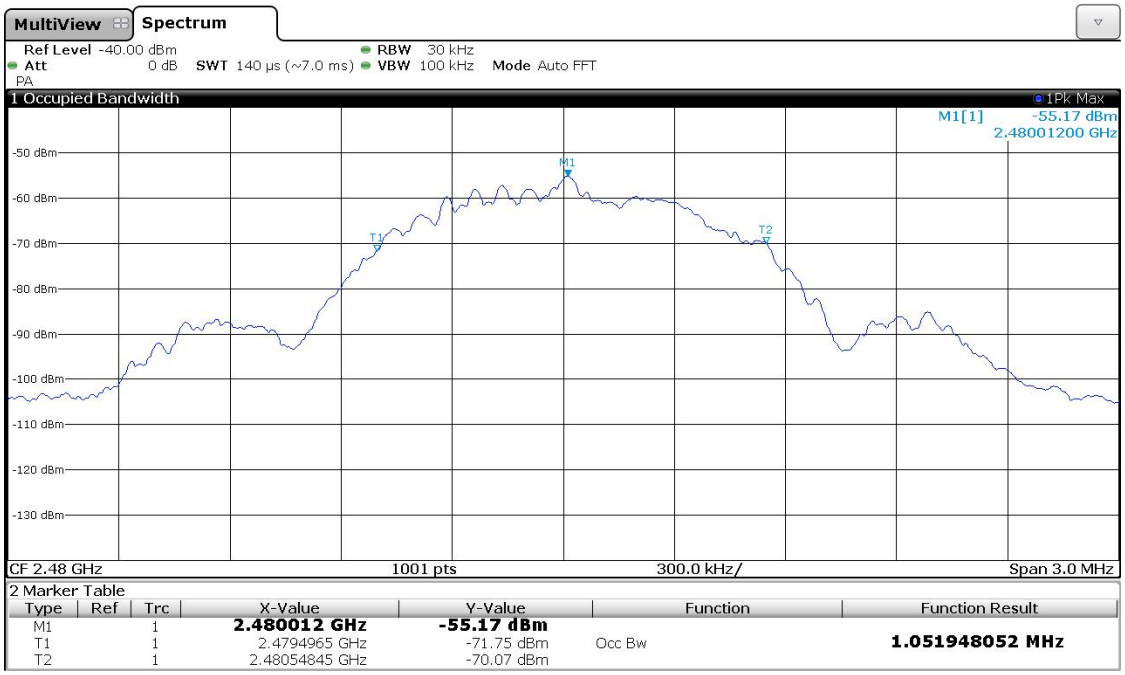
Ambient temperature	22 °C		Relative humidity	59 %

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

DTS_BW_ch0.wmf: 6-dB Bandwidth (operation mode 1):



99%_BW_ch39.png: 99% Bandwidth (operation mode 3):



Operation Mode	Center Frequency [MHz]	Minimum 6-dB Bandwidth Limit [MHz]	6 dB Bandwidth [MHz]	99 % Bandwidth [MHz]	Result
1	2402	0.5	0.739	1.040	Passed
2	2440	0.5	0.739	1.046	Passed
3	2480	0.5	0.739	1.052	Passed

Test: Passed

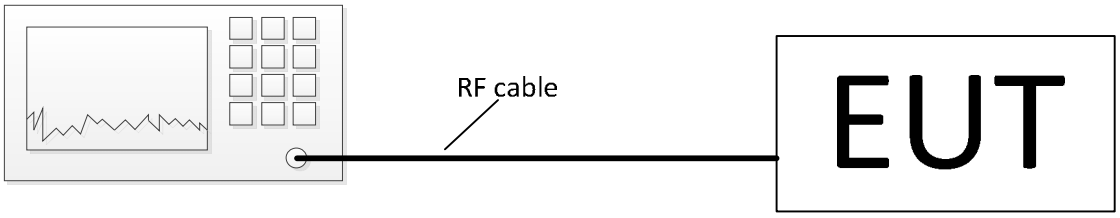
TEST EQUIPMENT USED FOR THE TEST:

8 – 14, 17, 18, 27

5.4 Peak Power Spectral Density

5.4.1 Method of measurement

The EUT was tested with a spectrum analyzer connected to the temporary antenna port.



The measurement procedure refers to part 10.10.2 of document [1].

- Set analyser center frequency to DTS channel center frequency
- Set the span to 1.5 times the DTS bandwidth.
- Set the RBW to: 3 kHz ≤ RBW ≤ 100 kHz.
- Set the VBW ≥ 3 x 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 limit, reduce RBW (not less than 3 kHz) and repeat.

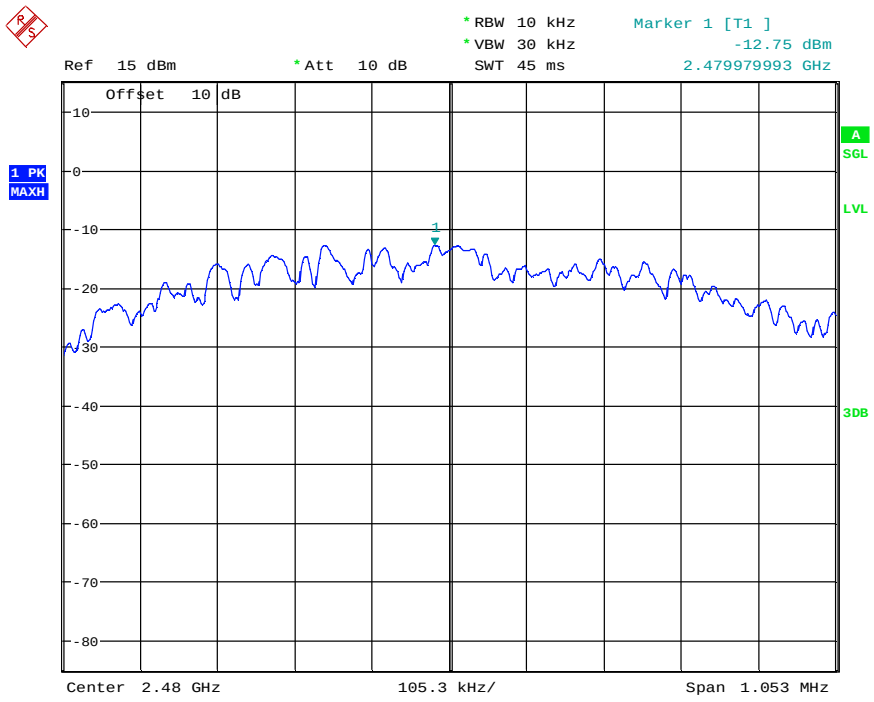
The measurement result in [dBµV/m] was calculated to [dBm] using the formula
in chapter 11.12.2.2 e) in [1].

5.4.2 Test result

Ambient temperature	22 °C	Relative humidity	59 %

The following results were measured at the temporary antenna port of the EUT. The plot shows an exemplary measurement result for the worst documented case. The other results are listed in the following table.

170014_PwrSpecDens_BTLE_BTLE39.wmf: Power Spectral Density (operation mode 3):



Operation Mode	Peak Frequency [MHz]	Power Spectral Density Limit [dBm/3kHz]	Power Spectral Density Reading [dBm / 10 kHz]	Result
1	2401.984	8	-13.4	Passed
2	2439.984	8	-12.9	Passed
3	2479.98	8	-12.8	Passed
Measurement uncertainty			+0.66 dB / -0.72 dB	

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

30

5.5 Band-edge compliance

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

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

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

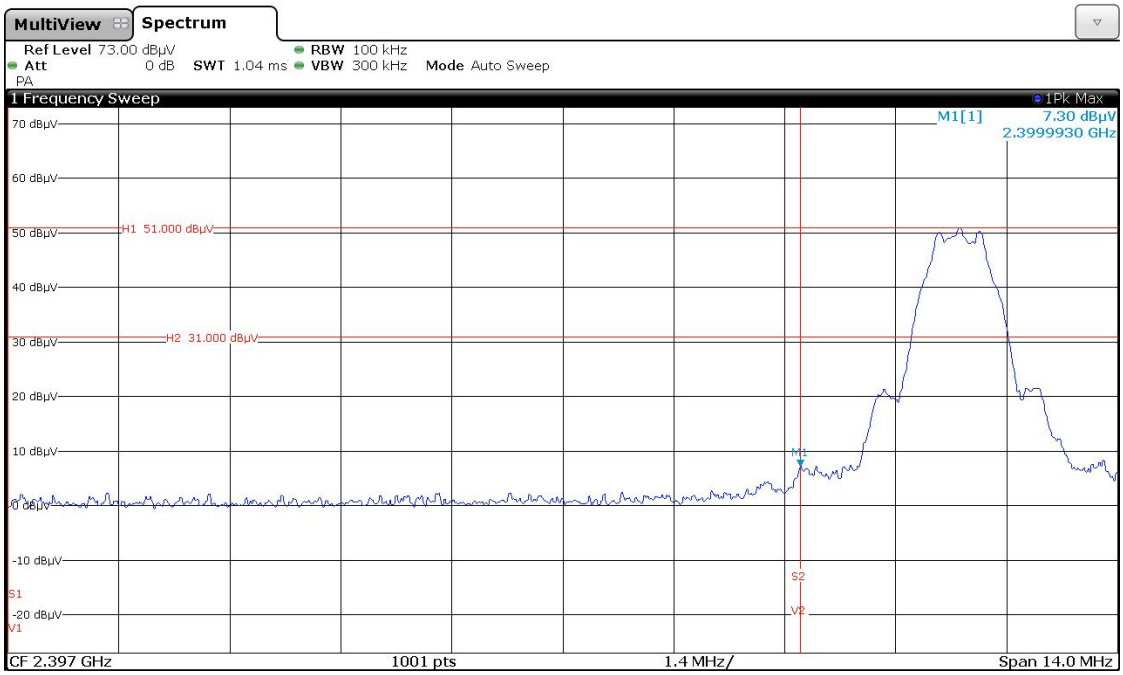
- Set the center frequency and span to encompass the frequency range to be measured.
- RBW = 100 kHz.
- VBW ≥ 300 kHz.
- Detector = Peak.
- Ensure that the number of measurement points ≥ span/RBW.
- Sweep time = auto couple.
- Trace Mode = max hold.
- Allow the trace to stabilise.
- Use the peak marker 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 measurements were performed at the lower end of the 2.4 GHz band.

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

LowerBandEdge_ch0.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	2402	2399.993	51.0	31.0	7.3	23.7	Passed

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

8 – 14, 17, 18

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

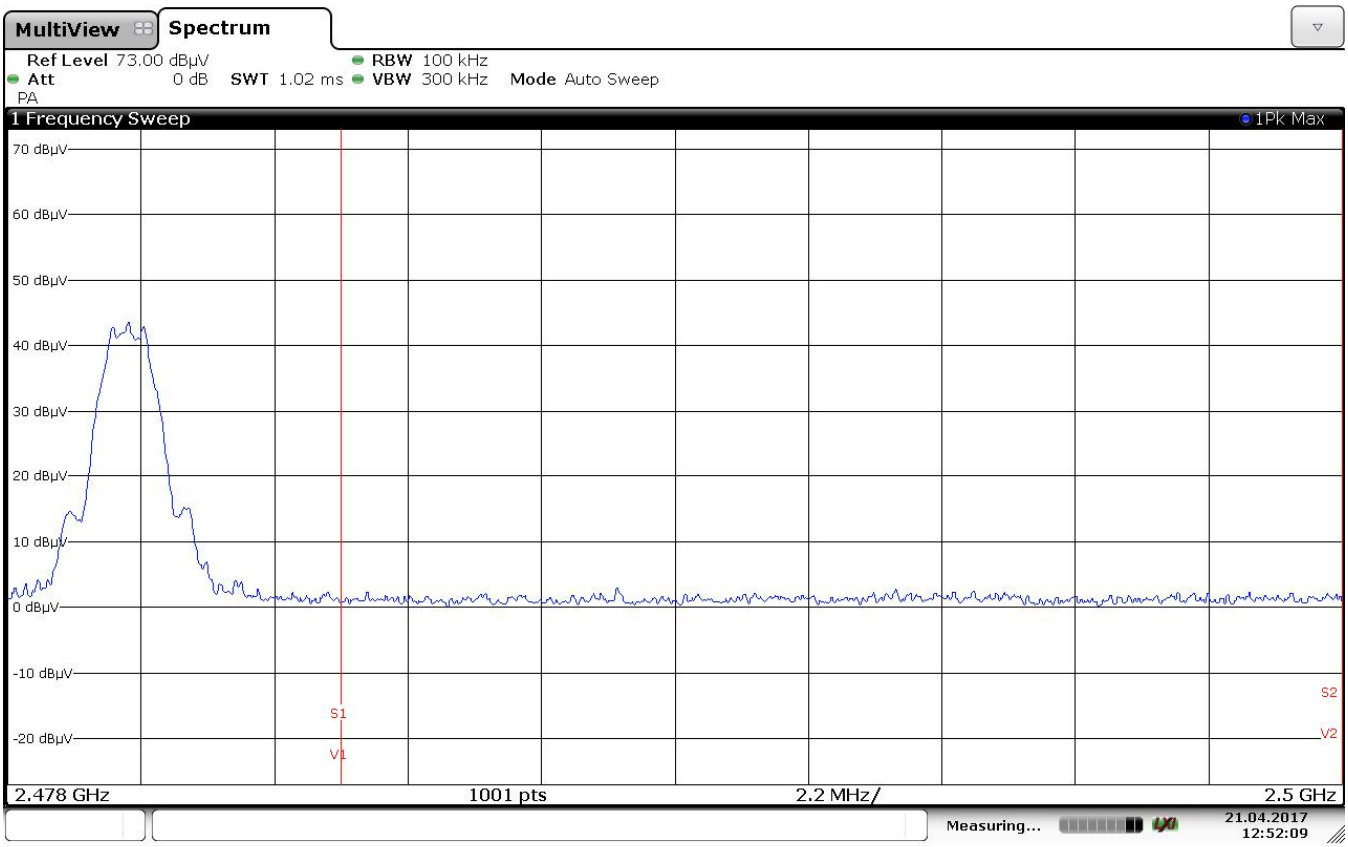
The EUT was measured radiated in the anechoic chamber using the procedures described in 5.6.1.

Acceptable measurement configurations

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

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

UpperBandEdge_ch39.wmf: radiated band-edge compliance at an restricted band-edge (operation mode 3):



Date: 21.APR.2017 12:52:09

No emissions were found during the preliminary measurement, therefore no final measurement was performed.

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

8 – 14, 17, 18

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 9 kHz to 1 GHz.
- A final measurement carried out on an outdoor test side without reflecting ground plane and a fixed antenna height in the frequency range 9 kHz to 30 MHz.
- 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.

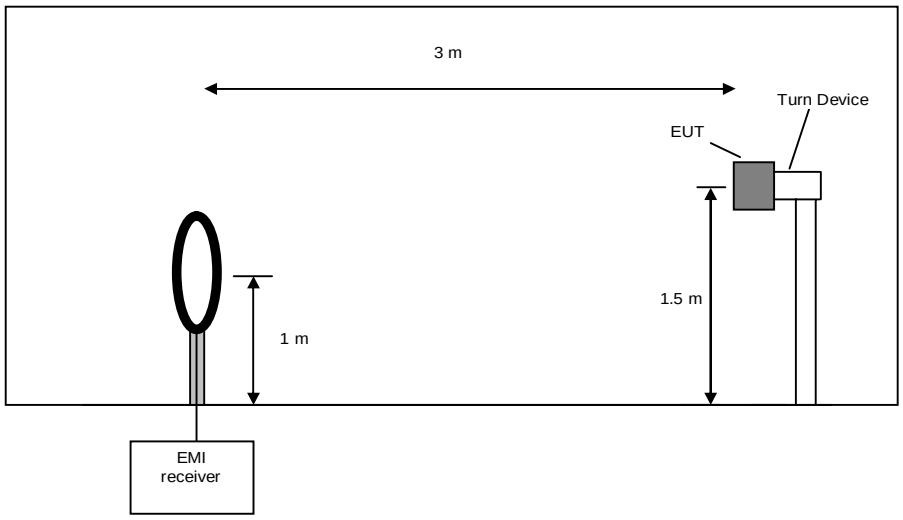
Preliminary measurement (9 kHz to 30 MHz):

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 procedure:

Prescans were performed in the frequency range 9 kHz to 150 kHz and 150 kHz to 30 MHz.

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.

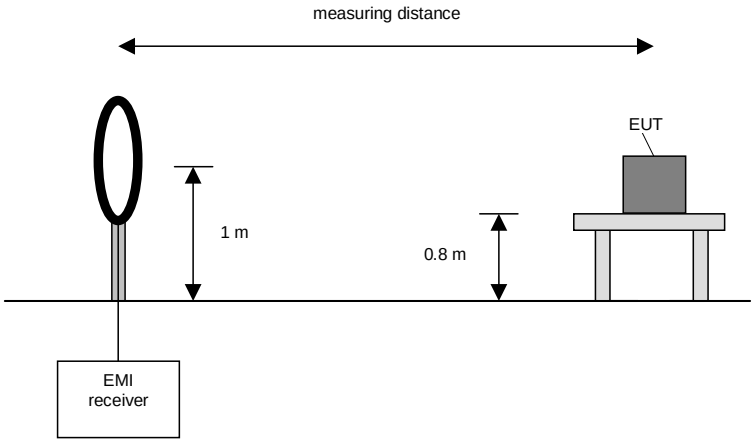
Final measurement (9 kHz to 30 MHz):

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

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

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

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



Final measurement procedure:

The following procedure will be used:

1) Monitor the frequency range with the measuring antenna at vertical orientation parallel to the EUT at an azimuth of 0 °.
2) Rotate the EUT by 360 ° to maximize the detected signals and note the azimuth and orientation.
3) Rotate the measuring antenna to find the maximum and note the value.
4) Rotate the measuring antenna and repeat steps 1) to 3) until the maximum value is found.
5) Repeat steps 1) to 4) with the other orthogonal axes of the EUT (if the EUT is a module and might be used in a handheld equipment application).

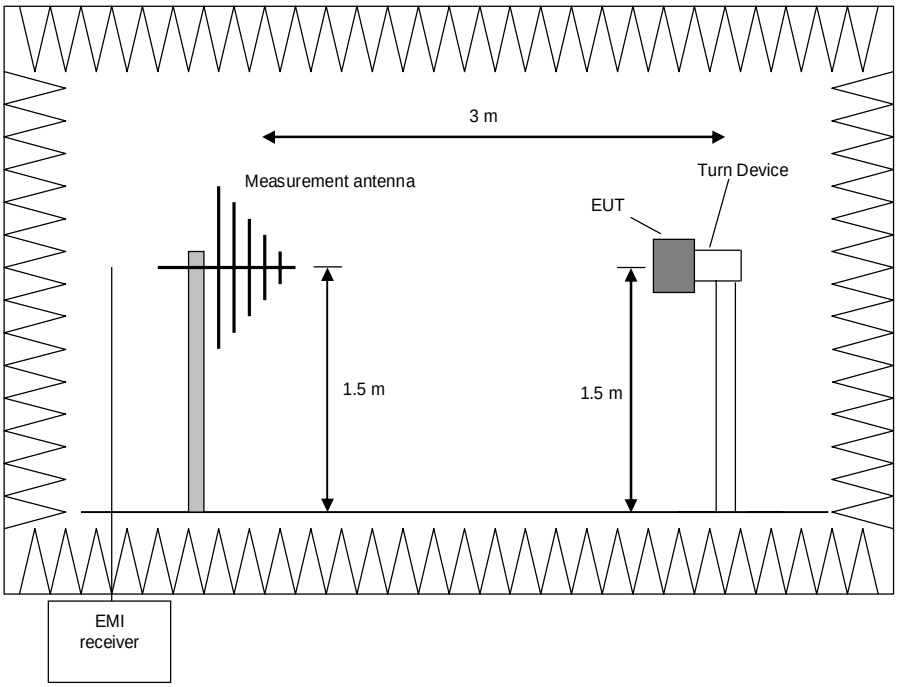
Preliminary measurement (30 MHz to 1 GHz)

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:

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

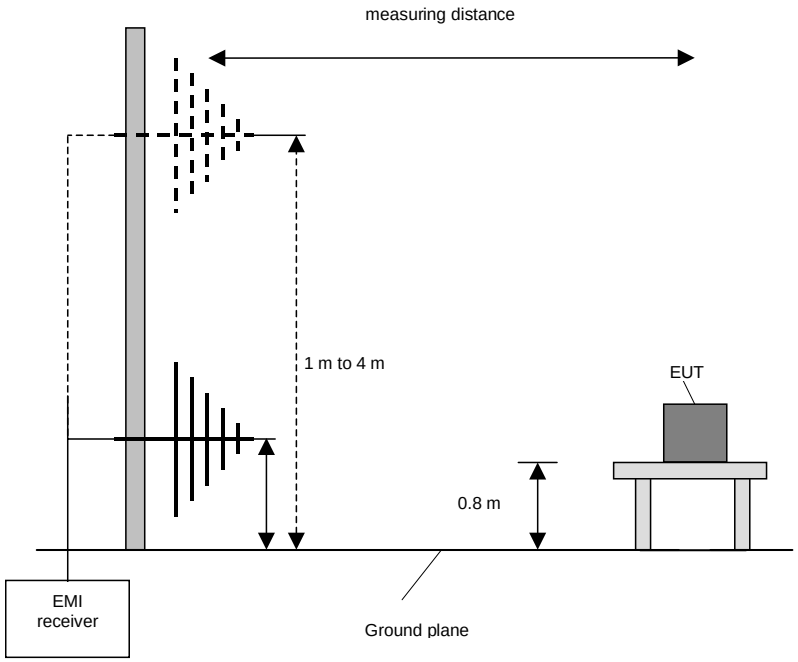
8. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
9. Manipulate the system cables within the range to produce the maximum level of emission.
10. Rotate the EUT by 360 ° to maximize the detected signals.
11. Repeat 1) to 3) with the vertical polarisation of the measuring antenna.
12. Make a hardcopy of the spectrum.
13. Repeat 1) to 5) with the EUT raised by an angle of 0° (45°, 90°) according to 6.6.5.4 in [1].
14. 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)

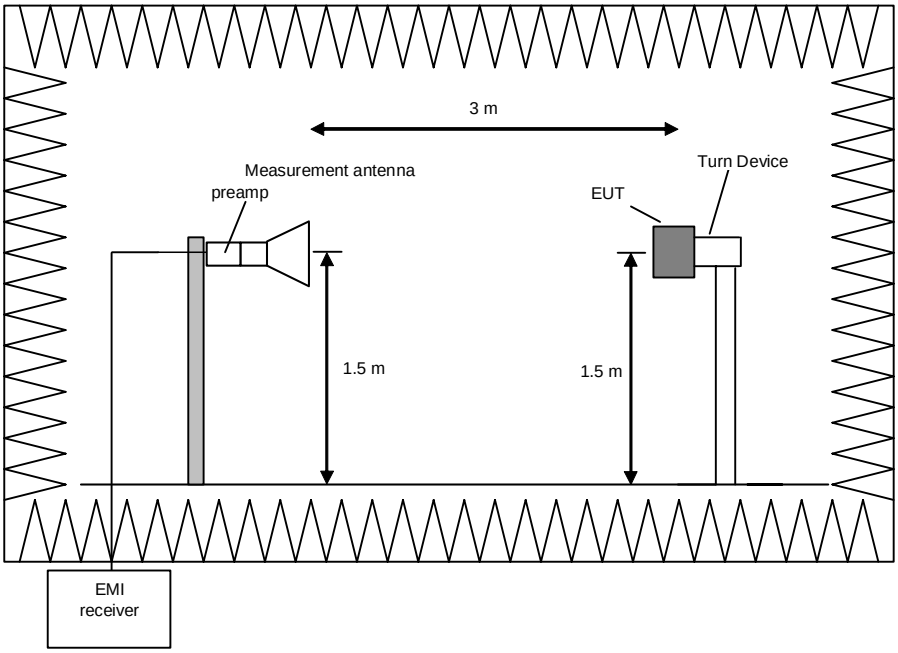
This measurement will be performed in a fully anechoic chamber. Table top devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

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:

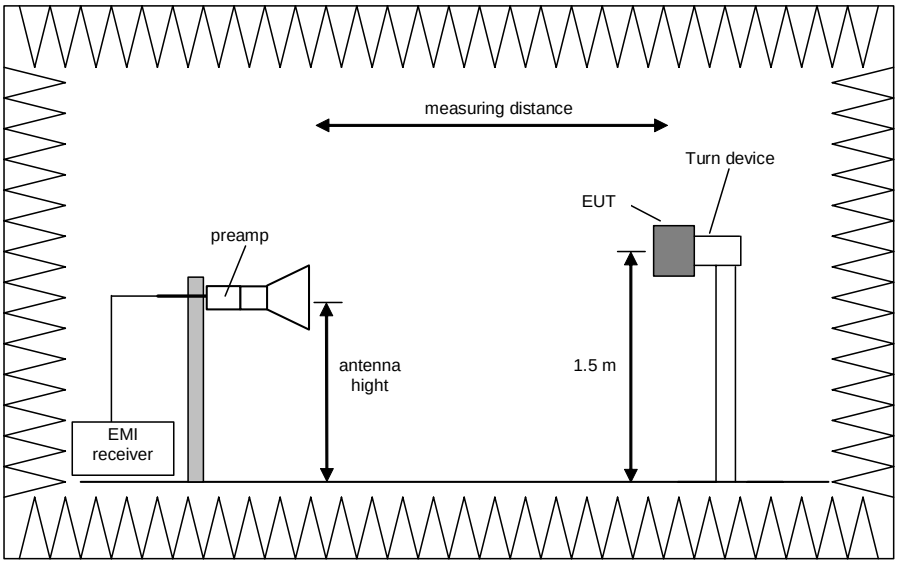
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an 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 9 kHz – 25 GHz

5.6.2.1 Preliminary radiated emission measurement 9kHz – 25 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.

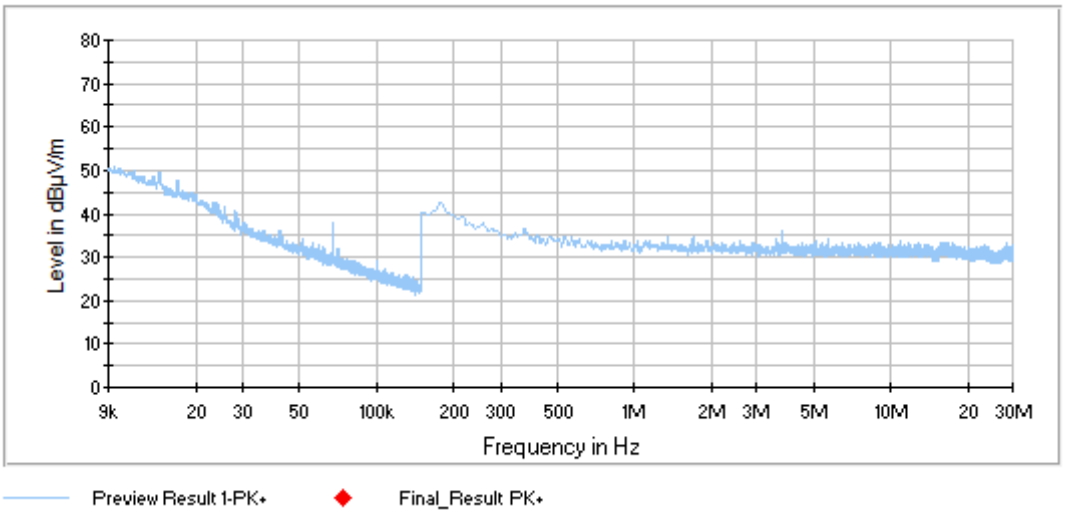
Supply voltage: During all measurements the host of the EUT was powered with 24 V via an AC/DC Laboratory power supply.

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

No significant emissions were found in the frequency range from 9 kHz to 30 MHz, therefore no results are submitted below.

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

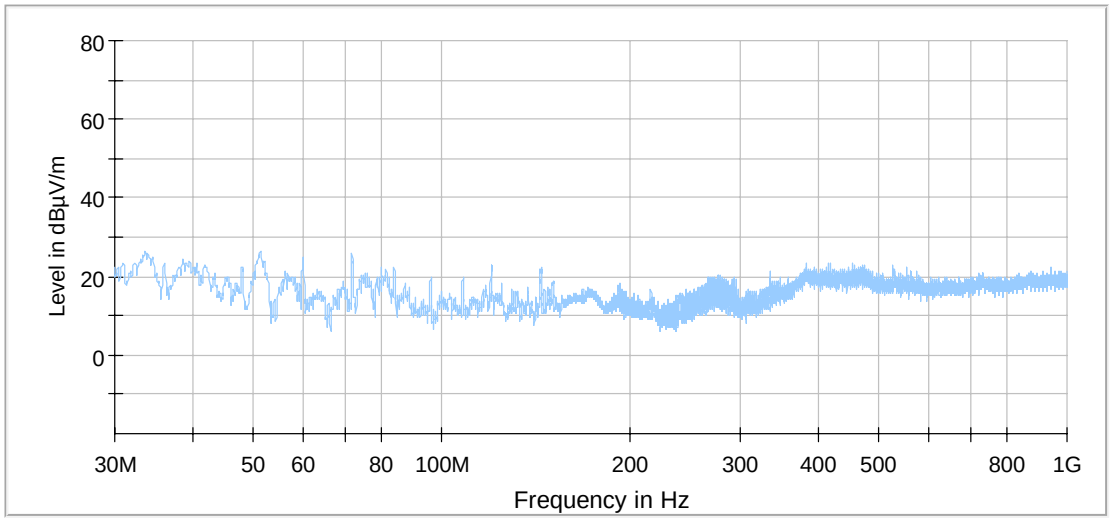
170014 30MHz-1GHz ch39 TX: Spurious emissions from 9 kHz to 30 MHz (operation mode 3):



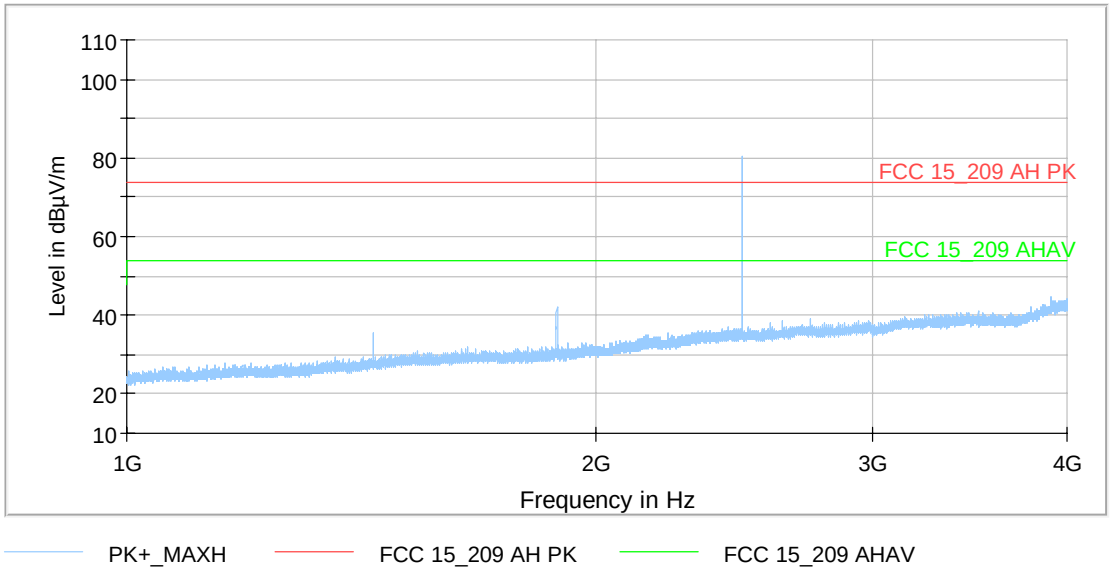
Remark: the peak at 68 kHz was causes by the measurement system and not by the equipment under test

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

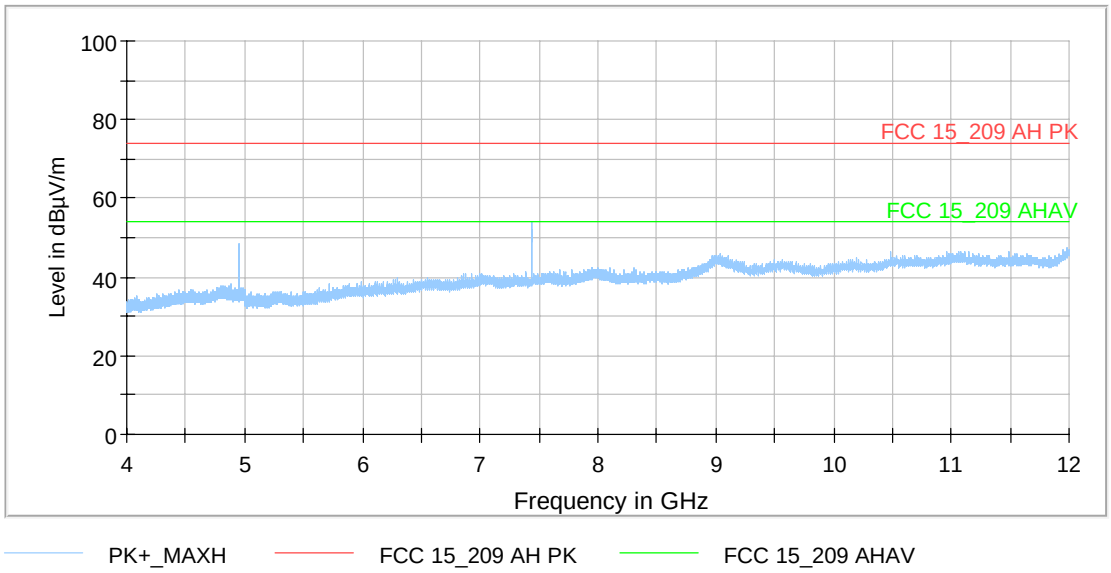
170014 30MHz-1GHz ch39 TX: Spurious emissions from 30 MHz to 1 GHz (operation mode 3):



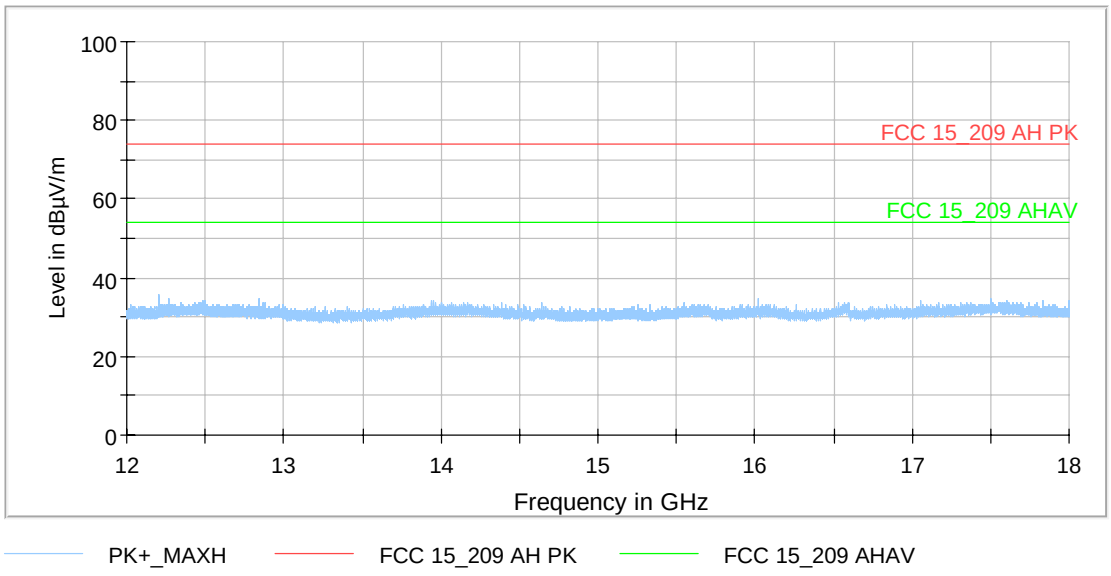
170014 1-4GHz ch39 TX: Spurious emissions from 1 GHz to 4 GHz (operation mode 3):



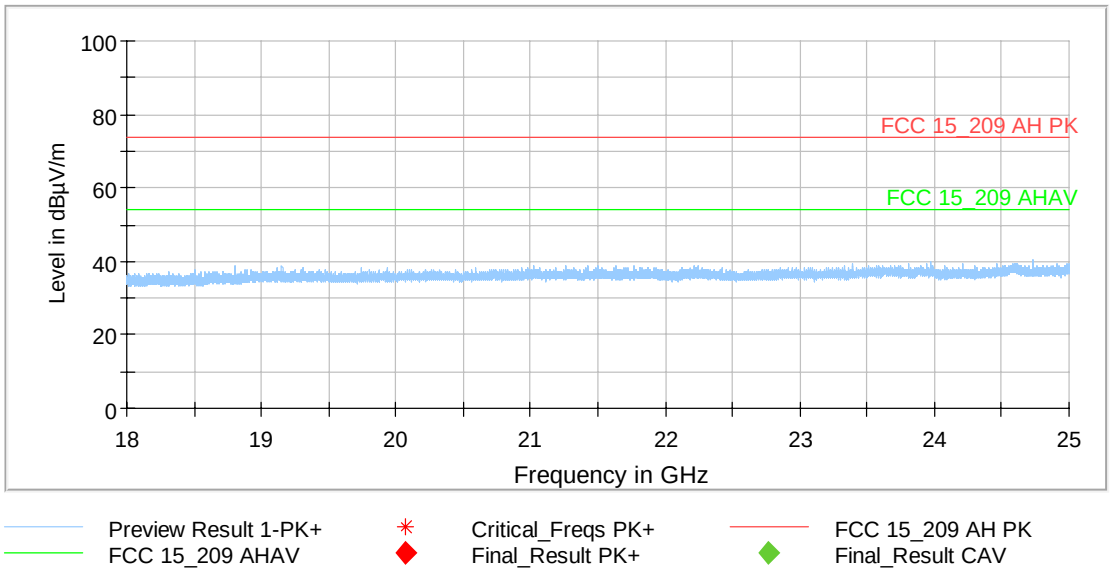
170014 4-12GHz ch39 TX: Spurious emissions from 4 GHz to 12 GHz (operation mode 3):



170014 12-18GHz ch19: Spurious emissions from 12 GHz to 18 GHz (operation mode 2):



170014 18-25GHz ch19: Spurious emissions from 18 GHz to 25 GHz (operation mode 2):



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]
33.556667	23.69	40.00	16.31	1000.0	120.000	132.0	V	355.0	25.0
39.107222	25.41	40.00	14.59	1000.0	120.000	104.0	V	48.0	22.4
47.998889	28.80	40.00	11.20	1000.0	120.000	104.0	V	236.0	17.6
51.286111	23.78	40.00	16.22	1000.0	120.000	100.0	V	18.0	15.7
59.908333	19.70	40.00	20.30	1000.0	120.000	241.0	V	259.0	12.3
72.033333	20.52	40.00	19.48	1000.0	120.000	164.0	V	4.0	14.5
Measurement uncertainty					+2.2 dB / -3.6 dB				

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

Frequency [MHz]	MaxPeak [dBµV/m]	Caverage [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB)
1437.400000	---	40.33	54.00	13.67	V	359.0	120.0	27.6
1437.400000	52.78	---	74.00	21.22	V	359.0	120.0	27.6
1883.500000	---	41.84	54.00	12.16	V	29.0	0.0	30.6
1883.500000	54.84	---	74.00	19.16	V	29.0	0.0	30.6
2402.000000	---	78.95	Fund.	Fund.	H	170.0	90.0	33.5
2402.000000	84.60	---	Fund.	Fund.	H	170.0	90.0	33.5
4803.440000	---	44.70	54.00	9.30	V	148.0	59.0	16.7
4803.440000	54.33	---	74.00	19.67	V	148.0	59.0	16.7
4804.480000	---	44.59	54.00	9.41	V	156.0	59.0	16.7
4804.480000	54.23	---	74.00	19.77	V	156.0	59.0	16.7
7206.000000	---	49.19	54.00	4.81	V	151.0	0.0	21.5
7206.000000	58.22	---	74.00	15.78	V	151.0	0.0	21.5
12010.020000	---	30.26	54.00	23.74	H	166.0	120.0	12.1
12010.020000	44.98	---	74.00	29.02	H	166.0	120.0	12.1
16593.180000	---	29.82	54.00	24.18	V	248.0	60.0	10.5
16593.180000	43.06	---	74.00	30.94	V	248.0	60.0	10.5
Measurement uncertainty				+2.2 dB / -3.6 dB				

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

Frequency [MHz]	MaxPeak [dBµV/m]	Caverage [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB)
1437.400000	---	39.45	54.00	14.55	V	0.0	0.0	27.6
1437.400000	53.26	---	74.00	20.74	V	0.0	0.0	27.6
2440.000000	---	77.22	Fund.	Fund.	H	236.0	90.0	33.7
2440.000000	82.69	---	Fund.	Fund.	H	236.0	90.0	33.7
4880.000000	---	47.29	54.00	6.71	V	264.0	0.0	16.8
4880.000000	54.73	---	74.00	19.27	V	264.0	0.0	16.8
7320.000000	---	46.92	54.00	7.08	H	302.0	119.0	22.1
7320.000000	56.63	---	74.00	17.37	H	302.0	119.0	22.1
12198.660000	---	30.56	54.00	23.44	V	207.0	30.0	11.9
12198.660000	43.91	---	74.00	30.09	V	207.0	30.0	11.9
12201.180000	---	30.90	54.00	23.10	H	214.0	60.0	11.9
12201.180000	43.91	---	74.00	30.09	H	214.0	60.0	11.9
Measurement uncertainty				+2.2 dB / -3.6 dB				

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

Frequency [MHz]	MaxPeak [dBµV/m]	Caverage [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB)
1437.400000	---	39.56	54.00	14.44	V	0.0	90.0	27.6
1437.400000	52.46	---	74.00	21.54	V	0.0	90.0	27.6
1885.300000	---	41.86	54.00	12.14	V	3.0	0.0	30.6
1885.300000	54.80	---	74.00	19.20	V	3.0	0.0	30.6
2480.000000	---	78.20	Fund.	Fund.	H	233.0	90.0	33.6
2480.000000	83.67	---	Fund.	Fund.	H	233.0	90.0	33.6
4959.920000	---	46.63	54.00	7.37	V	88.0	150.0	16.7
4959.920000	53.94	---	74.00	20.06	V	88.0	150.0	16.7
7439.920000	---	49.88	54.00	4.12	V	150.0	0.0	22.2
7439.920000	59.25	---	74.00	14.75	V	150.0	0.0	22.2
12399.960000	---	30.52	54.00	23.48	H	164.0	120.0	12.1
12399.960000	44.62	---	74.00	29.38	H	164.0	120.0	12.1
Measurement uncertainty				+2.2 dB / -3.6 dB				

TEST EQUIPMENT USED FOR THE TEST:
7 – 26

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

Ambient temperature	20 °C	Relative humidity	52 %

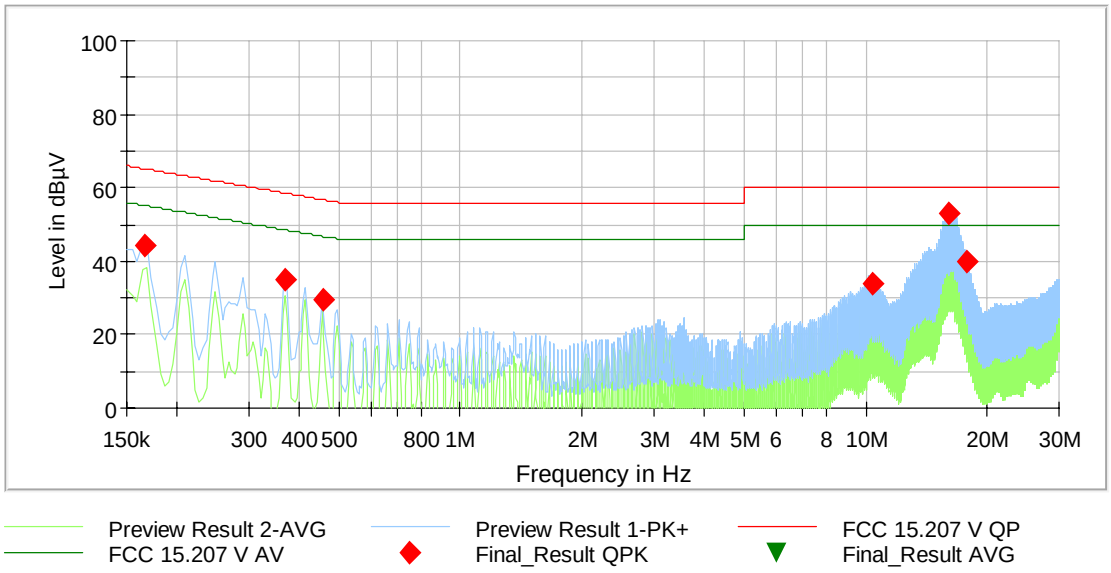
Position of EUT: For this test, the EUT was set to transmit in hopping test mode.

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 a power supply type "MINI-PS-100-240AC/24DC/1.3" by Phoenix Contact was used.
The power supply provided 24 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 "▼".



Data record name: 170014 PowerLineConducted.rtf

Frequency [MHz]	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Meas. Time [ms]	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.165300	44.42	---	65.19	20.77	5000.0	9.000	N	FLO	9.8
0.370500	35.03	---	58.49	23.46	5000.0	9.000	L1	FLO	9.9
0.456000	29.50	---	56.77	27.27	5000.0	9.000	N	FLO	9.9
10.347000	33.86	---	60.00	26.14	5000.0	9.000	L1	GND	10.6
16.062900	52.96	---	60.00	7.04	5000.0	9.000	L1	FLO	10.8
17.675700	40.03	---	60.00	19.97	5000.0	9.000	L1	GND	10.9

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
1 – 6

6 Test equipment and ancillaries used for tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal. Due
1	Shielded chamber M47	-	Albatross Projects	B83117-C6439-T262	480662		
2	EMI Receiver	ESIB 26	Rohde & Schwarz	1088.7490	481182	15.02.2016	2.2018
3	LISN	NSLK8128	Schwarzbeck	8128155	480058	16.02.2016	2.2018
4	High pass filter	HR 0.13-5ENN	FSY Microwave Inc.	DC 0109 SN 002	480340	Weekly verification (system cal.)	
5	EMI Software	ES-K1	Rohde & Schwarz	-	480111	-	
6	Netzteil AC	AC6803A AC Quelle 2000VA	Keysight	JPVJ002509	482350	Calibration not necessary	
7	EMI Software	EMC32	Rohde & Schwarz	100061	481022	-	-
8	HF-Cable	Sucoflex 104	Huber+Suhner	517406	482391	Annual verification (system cal.)	
9	Fully anechoic chamber M20	-	Albatross Projects	B83107-E2439-T232	480303	Weekly verification (system cal.)	
10	Signal & Spectrum Analyzer	FSW43	Rohde & Schwarz	100586	481720	24.02.2016	01.02.2018
11	Controller	MCU	Maturo	MCU/043/971107	480832	-	-
12	Turntable	DS420HE	Deisel	420/620/80	480315	-	-
13	Antenna support	AS615P	Deisel	615/310	480187	-	-
14	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	27.08.2014	01.08.2017
15	Standard Gain Horn 11.9 GHz – 18 GHz	18240-20	Flann Microwave	483	480294	Six month verification (system cal.)	
16	Standard Gain Horn 17.9 GHz – 26.7 GHz	20240-20	Flann Microwave	411	480297	Six month verification (system cal.)	
17	RF-cable No. 3	Sucoflex 106B	Huber&Suhner	0563/6B / Kabel 3	480670	Weekly verification (system cal.)	
18	RF-cable No. 40	Sucoflex 106B	Huber&Suhner	0708/6B / Kabel 40	481330	Weekly verification (system cal.)	
19	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	29.02.2016	29.02.2018
20	Antenna (Bilog)	CBL6112B	Schaffner EMV GmbH (-Chase)	2688	480328	19.06.2017	01.06.2020
21	RF-cable 2 m	KPS-1533-800-KPS	Insulated Wire	-	480302	Six month verification (system cal.)	
22	Kabel 36	Sucoflex 106B	Suhner	500003/6B / Kabel 36	481680	Weekly verification (system cal.)	
23	Preamplifier	JS3-00101200-23-5A	Miteq	681851	480337	18.02.2016	18.02.2018
24	Preamplifier	JS3-12001800-16-5A	Miteq	571667	480343	18.02.2016	18.02.2018
25	Preamplifier	JS3-18002600-20-5A	Miteq	658697	480342	17.02.2016	17.02.2018
26	4 GHz High Pass Filter	WHKX4.0/18 G-8SS	Wainwright Instruments	1	480587	Weekly verification (system cal.)	
27	Loop antenna	-	Phoenix Testlab GmbH	-	410085	Calibration not necessary	
28	Power Meter	NRVD	Rohde & Schwarz	833697/030	480589	18.02.2016	18.02.2018

29	Peak Power Sensor	NRV-Z32	Rohde & Schwarz	849745/016	480551	18.02.2016	18.02.2018
30	Spectrum Analyser	FSU46	Rohde & Schwarz	200125	480956	07.03.2017	01.03.2018

7 Report History

Report Number	Date	Comment
F170014E2	11.09.2017	Initial Test Report

8 List of Annexes

ANNEX A TEST SETUP PHOTOS 9 pages

170014_35.jpg	Test setup – radiated test in anechoic chamber
170014_39.jpg	Test setup – radiated test in anechoic chamber
170014_36.jpg	Test setup – radiated test in anechoic chamber
170014_37.jpg	Test setup – radiated test on open area test site
170014_38.jpg	Test setup – radiated test in anechoic chamber
170014_40.jpg	Test setup – radiated test in anechoic chamber
170014_41.jpg	Test setup – radiated test in anechoic chamber
170014_42.jpg	Test setup – conducted emissions on power supply lines
170014_44.jpg	Test setup – conducted measurements at antennaport

ANNEX B EXTERNAL PHOTOS 6 pages

170014_45.jpg	EUT – 3D view 1
170014_46.jpg	EUT – 3D view 2
170014_47.jpg	EUT – connector view
170014_49.jpg	EUT – side view
170014_19.jpg	TTL-232R-3V3 cable
170014_20.jpg	Power supply cable

ANNEX C INTERNAL PHOTOS 2 pages

170014_30.jpg	EUT internal view – exploded view*
170014_31.jpg	Main PCB – top view*
170014_32.jpg	Main PCB display folded away – top view*
170014_33.jpg	Main PCB – bottom view*
170014_34.jpg	Main PCB –RF part close-up*

*Photograph provided by the applicant