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Test Report

Report Number:

F160902E1

Equipment under Test (EUT):

Areus Bluetooth Low Energy Module

Applicant:

Areus Engineering GmbH

Manufacturer:

Areus Engineering GmbH

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 (September 2016)**, Radio Frequency Devices

[3] **RSS-247 (May 2015)**, 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		13.09.2016
	Name	Signature	Date
Authorized reviewer:	Bernd STEINER		13.09.2016
	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

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Applicant represented during the test by the following person:	Partly. Dr. Oliver Stäbler

1.2 Manufacturer

Name:	Areus Engineering GmbH
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eMail Address:	osama.dengler@areus.de
Applicant represented during the test by the following person:	Partly. Dr. Oliver Stäbler

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: *	Bluetooth Low Energy module
Type / PMN: *	Areus Bluetooth Low Energy module
FCC ID: *	2AIO7BLE
IC: *	21720-BLE
Serial number: *	#1
PCB identifier: *	100747
HVIN (Hardware Version Identification Number): *	102122
FVIN (Firmware Version Identification Number): *	2.0.0
Hardware version: *	V2.0
Software version: *	1.0

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 Bluetooth specification: *	4.2 (Bluetooth Low Energy only)					
Antenna type: *	PCB antenna					
Antenna gain: *	Not available					
Antenna connector: *	none					
Power supply - EUT	U_{nom}=	3.3 V DC	U_{min}=	1.8 V DC	U_{max}=	3.6 V DC
Type of modulation: *	GFSK					
Operating frequency range:*	2402 MHz to 2480 MHz					
Number of channels: *	40					
Temperature range: *	-40 °C to +105 °C					
Lowest / highest Internal clock frequency: *	32.768 kHz / 2480 MHz					

* Declared by the applicant

Ancillary devices (supplied by the applicant):

USB – Serial converter	USB RS232 Serial TTL PL2303HX

Ancillary devices (supplied by the test laboratory):

Test Laptop	Fujitsu Siemens S7220

1.6 Dates

Date of receipt of test sample:	09.08.2016
Start of test:	09.08.2016
End of test:	11.08.2016

2 Operational States

The EUT is a Bluetooth Low Energy module targeted for integration into different OEM products.

For the test the EUT was soldered on a 100748 carrier-board. This carrier board was connected to a Laptop PC via a serial interface with the aid of serial to USB converter cable. The EUT was powered by this interface and set into test mode using the “nRFgo Studio” software by “NORDIC SEMICONDUCTOR”.

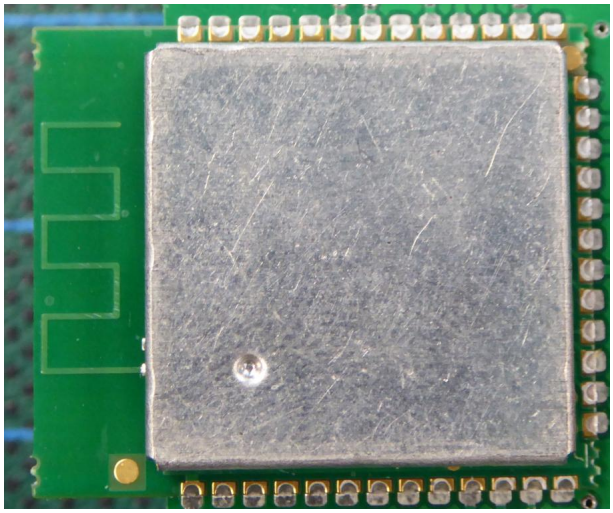
The RF transmit power was set to the maximum possible 4 dBm for all tests by a setting in the firmware.

The following operation modes were identified as worst case condition and used during the tests:

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

3 Additional Information

All tests were performed with unmodified samples.



EUT as marketed

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 (2) [3]	Passed	11 et seq
DTS Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	5.2 (1) [3]	Passed	12 et seq
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	5.2 (2) [3]	Passed	15 et seq
Band edge compliance	2400.0 - 2483.5	15.247 (d)	5.5 [3] 8.9 [4], 8.10 [4]	Passed	17 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	21 et seq.
Conducted emissions on supply line	0.15 - 30	15.207 (a)	8.8 [4]	Passed	35 wet seq.

5 Results

5.1 Duty cycle

5.1.1 Method of measurement

The measurement was performed as described in chapter 5.6.1 of this test report.

The measurement procedures described herein are based on the use of radiated measurements.

The method described in chapter 11.6.0 b) of document [1] was used to perform the following test.

The measurement was only performed on only one frequency, because the timing behaviour was found to be independent of the selected channel.

The following measurement technique was used:

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

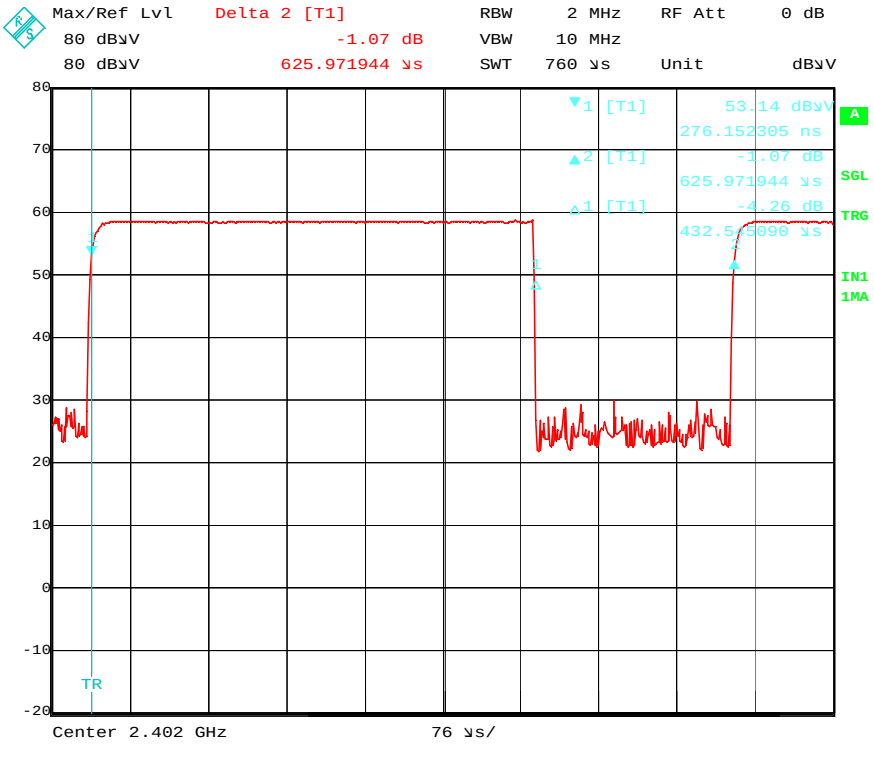
- Set the center frequency of the instrument to the center frequency of the transmission.
- Set RBW ≥ OBW if possible; otherwise, set RBW to the largest available value.
- Set VBW ≥ RBW.
- Set detector = peak or average.
- The zero-span measurement method shall not be used unless both RBW and VBW are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

5.1.2 Test results

Ambient temperature	22 °C	Relative humidity	40 %

The following plot only shows the worst case for the duty cycle correction, the other results are only submitted in the calculations below.

160903_ch0_DutyCycle.wmf: Duty cycle measurement on channel 0 with 1 Mpbs:



$$T_{TX} = 432.6\mu s \quad (1)$$

$$\frac{50}{T_{TX}} = \frac{50}{432.6\mu s} = 115.6kHz \le RBW \le VBW \quad (2)$$

Measurement Points 500 for 760 us → 345.5 us = 411 measurement points → Signal has 345.5 measurement points (and fulfils the requirement of at least 100 Points resolution for the signal)

$$T_{TX\_On} = 432.6\mu s \quad (3)$$

$$T_{TX\_Period} = 626.0\mu s \quad (4)$$

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.

$$x = \frac{432.6\mu s}{626.0\mu s} = 0.691 = 69.1\% \quad (5)$$

Correction factor: $10 \cdot \log\left(\frac{1}{x}\right) = 10 \cdot \log\left(\frac{1}{0.691}\right) = 1.6dB$ (6)

Therefore, for average measurements a correction factor of 1.6 dB is use in all tests.

TEST EQUIPMENT USED FOR THE TEST:

29, 31 – 36, 41, 42

5.2 Maximum conducted output power

5.2.1 Method of measurement

The EUT was measured in a radiated setup within an anechoic chamber. The radiated measurement setup was made according to chapter 5.6.1 of this test report.

Acceptable measurement configurations

Annex G in [1] is used for calculating radiated values to conducted values.

Procedure 11.9.1.2 in [1] was used for the following test.

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

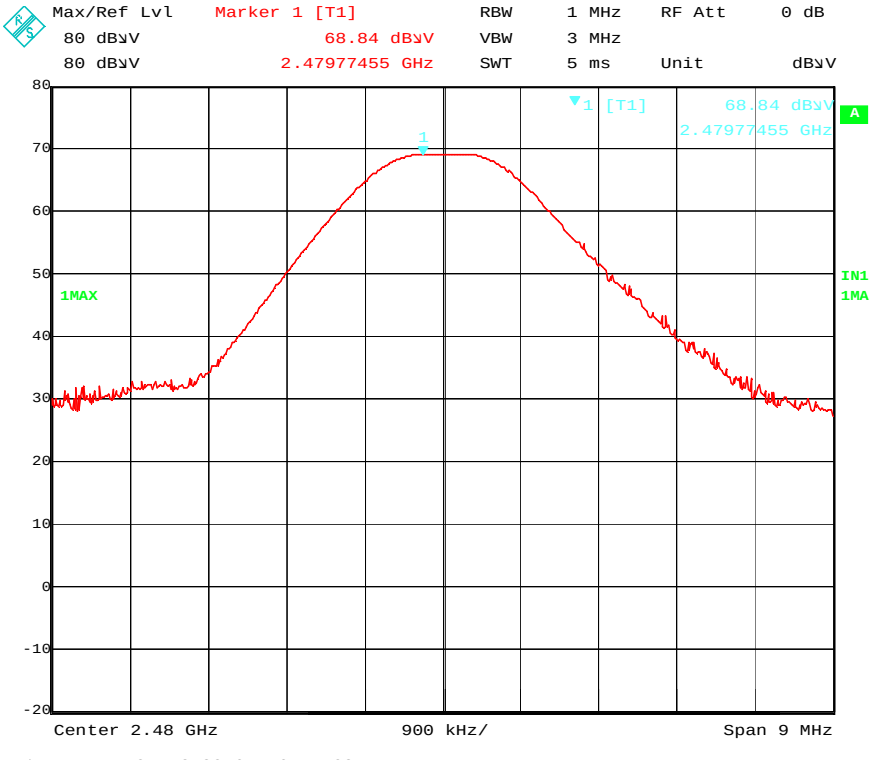
The measurement result in [dBµV/m] was calculated to [dBm] using the formula
in chapter 11.12.2.2 e) in [1].

5.2.2 Test results

Ambient temperature	22 °C	Relative humidity	62 %

The following results were measured in a radiated setup. The plot shows an exemplary measurement result for the worst documented case. The other results are listed in the following table.

160903_ch39_PWR_0°.wmf: Maximum peak output power (operation mode 3):



Operation Mode	Frequency [MHz]	Antenna gain combined [dBi]	Reading [dBµV]	Antenna factor [1/m]	Cable Loss [dB]	Meas. Result [dBµV/m]	Maximum conducted output power [dBm]	Limit [dBm]
1	2402	0	67.0	28.3	3.0	98.3	3.0	30
2	2440	0	67.1	28.4	3.0	98.5	3.0	30
3	2480	0	68.8	28.5	2.9	100.2	4.9	30
Measurement uncertainty				+2.2 dB / -3.6 dB				

Meas. Result [dBµV/m] = Reading [dBµV] + Antenna factor [1/m] + Cable Loss [dB]

Maximum conducted output power [dBm]
= Meas. Result [dBµV/m] - Antenna gain combined [dBi] -95.3 [m] (For measurement distance = 3m)

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

29, 31 – 36, 41, 42

5.3 DTS Bandwidth

5.3.1 Method of measurement

The EUT was measured in a radiated setup within an anechoic chamber. The radiated measurement setup was made according to chapter 5.6.1 of this test report.

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

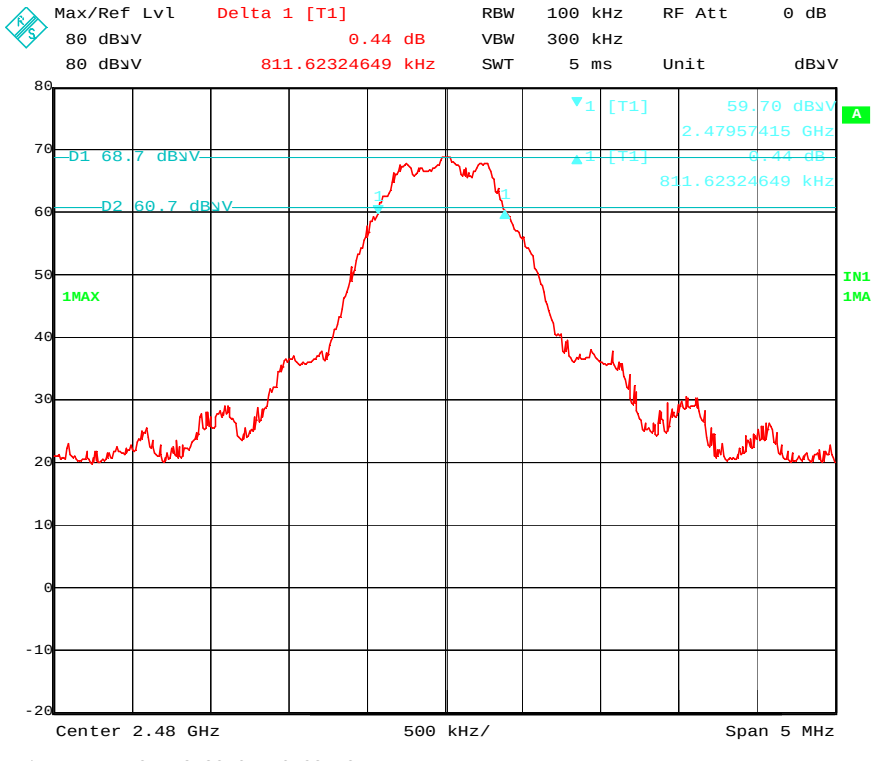
- Set RBW = 100 kHz.
- Set the video bandwidth (VBW) ≥ 3 x RBW.
- Detector = Peak.
- Trace mode = max hold.
- Sweep = auto couple.
- Allow the trace to stabilize.
- Measure the maximum width of the emission that is constrained by the frequencies associated with the two outermost amplitude points (upper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

5.3.2 Test result

Ambient temperature	22 °C	Relative humidity	59 %

The following results were measured at the 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.

160903_ch39_6dB-BW_0°.wmf: 6-dB Bandwidth (operation mode 3):



Operation Mode	Center Frequency [MHz]	Minimum 6-dB Bandwidth Limit [MHz]	6 dB Bandwidth [MHz]	99 % BW [MHz]	Result
1	2402	0.5	0.711	1.233	Passed
2	2440	0.5	0.732	1.152	Passed
3	2480	0.5	0.812	1.062	Passed
Measurement uncertainty		+0.66 dB / -0.72 dB			

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

29, 31 – 36, 41, 42

5.4 Peak Power Spectral Density

5.4.1 Method of measurement

The EUT was measured in a radiated setup within an anechoic chamber. The radiated measurement setup was made according to chapter 5.6.1 of this test report.

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.

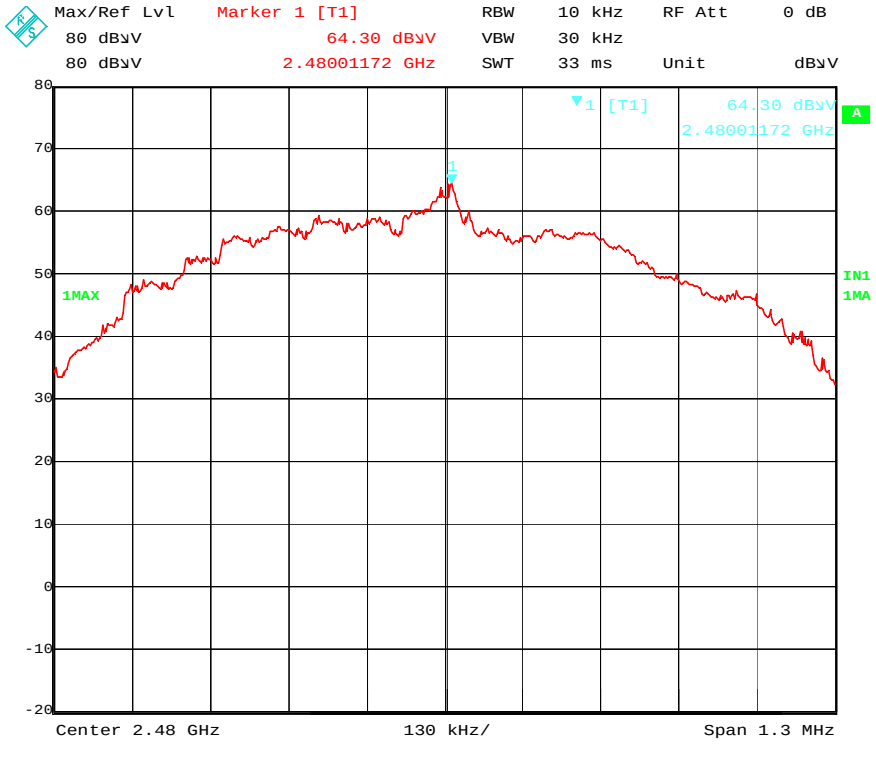
The measurement result in [dBµV/m] was calculated to [dBm] using the formula in chapter 11.12.2.2 e) in [1].

5.4.2 Test result

Ambient temperature	22 °C	Relative humidity	59 %

The following results were measured at the 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.

160903_ch39_PSD_0°.wmf: Power Spectral Density (operation mode 3):



Operation Mode	Peak Frequency [MHz]	Antenna gain combined [dBi]	Reading [dBµV]	Antenna factor [1/m]	Cable Loss [dB]	Meas. Result [dBµV/m]	Maximum conducted output power [dBm]	Power Spectral Density Limit [dBm/3kHz]
1	2402.012	0	61.0	28.3	3.0	92.3	-3.0	8
2	2436.488	0	61.6	28.4	3.0	93.0	-2.3	8
3	2461.487	0	64.3	28.5	2.9	95.7	0.4	8
Measurement uncertainty				+2.2 dB / -3.6 dB				

Meas. Result [dBµV/m] = Reading [dBµV] + Antenna factor [1/m] + Cable Loss [dB]

Maximum conducted output power [dBm]
= Meas. Result [dBµV/m] - Antenna gain combined [dBi] -95.3 [m] (For measurement distance = 3m)

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

29, 31 – 36, 41, 42

5.5 Band-edge compliance

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

The EUT was measured in a radiated setup within an anechoic chamber. The radiated measurement setup was made according to chapter 5.6.1 of this document.

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.

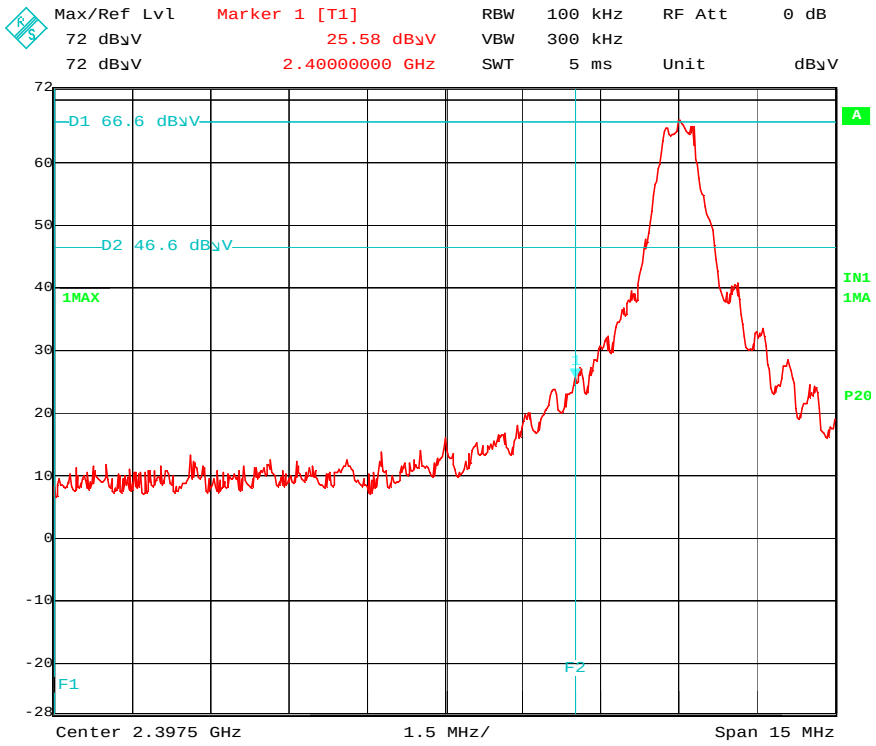
The measurement procedure at the band edges was simplified by performing the measurement in just one plot. Both, the in-band-emission and the unwanted emission were be encompassed by the span. After trace stabilization, the maximum peak was be determined by a peak detector and the value was marked by 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))

The following results were measured radiated . The plot shows an exemplary measurement result for the worst documented case. The other results are listed in the following table.

160903_ch0_BandEdgeUnRestr_0°.wmf: conducted band-edge compliance (operation mode 1):



Operation mode	Emission Frequency [MHz]	Reference Level [dµV]	Limit [dµV]	Emisson Level [dµV]	Margin [dB]	Result
1	2400.000	66.6	46.6	25.6	21.0	Passed

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
29, 31 – 36, 41, 42

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

The EUT was measured in a radiated setup within an anechoic chamber. The radiated measurement setup was made according to chapter 5.6.1 of this test report.

After trace stabilisation the marker shall be set on the signal peak. The frequency line shall be set on the edge of the assigned frequency band. Now set the second marker on the emission at the band-edge, or on the highest modulation product outside of the band, if this level is higher than that at the band-edge. The level of the measured field strength shall be compared to the general limits specified in § 15.205.

The measurement was performed at the lower and the upper end of the 2.4 GHz band.

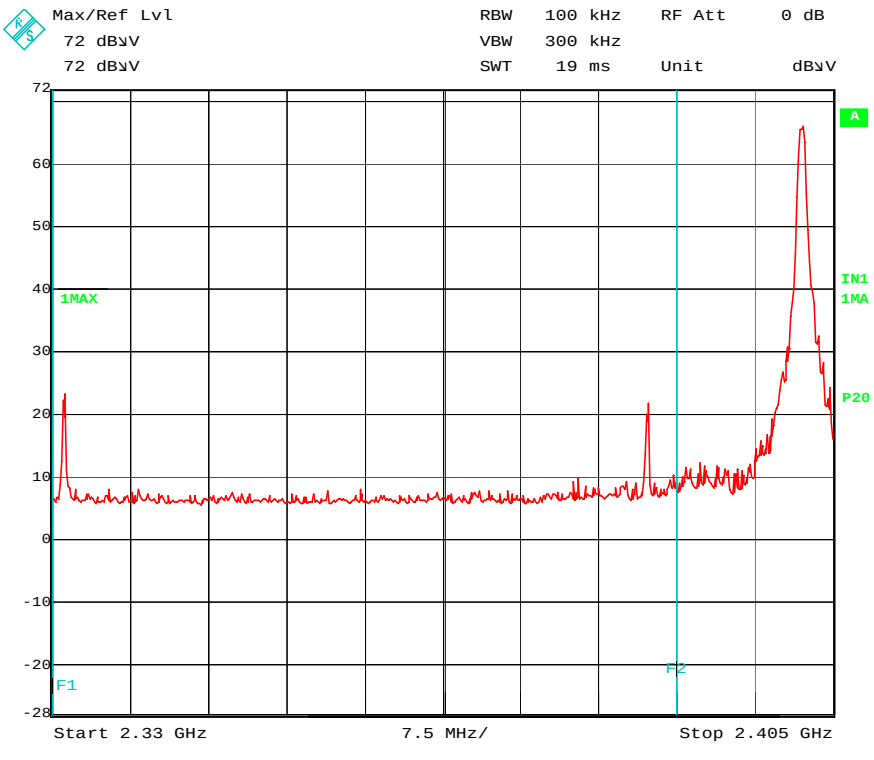
All average results are corrected by a correction factor of 1.6 dB as described in chapter 5.1 of this document.

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

Ambient temperature	22 °C	Relative humidity	59 %

The plot shows an exemplary measurement result for the worst documented case. The other results are listed in the following table.

160903_ch0_BandEdgeRestr_90°.wmf: conducted band-edge compliance (operation mode 1):



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

Result measured with the peak detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2331.2	61.54	74	12.46	29.84	28.1	0	3.6	150	Hor.	90
2387.1	59.94	74	14.06	27.9	28.34	0	3.7	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

Result measured with the average detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2331.2	34.84	54	19.16	3.14	28.1	0	3.6	150	Hor.	90
2387.1	35.44	54	18.56	3.4	28.34	0	3.7	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

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

Result measured with the peak detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2484	56.56	74	17.44	24.21	28.55	0	3.8	150	Hor.	0
Measurement uncertainty				+2.2 dB / -3.6 dB						

Result measured with the average detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2484	37.4	54	16.6	5.05	28.55	0	3.8	150	Hor.	0
Measurement uncertainty				+2.2 dB / -3.6 dB						

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
29, 31 – 36, 41, 42

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.

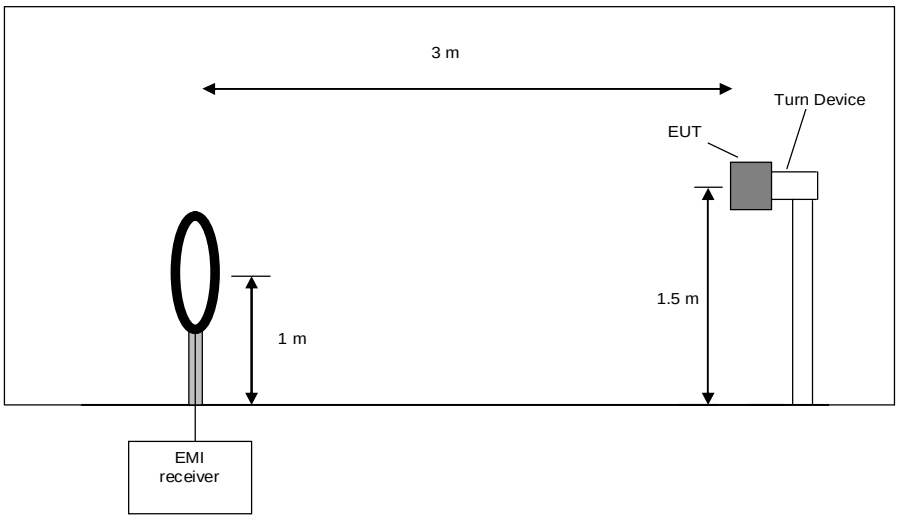
Preliminary measurement (9 kHz to 30 MHz):

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.

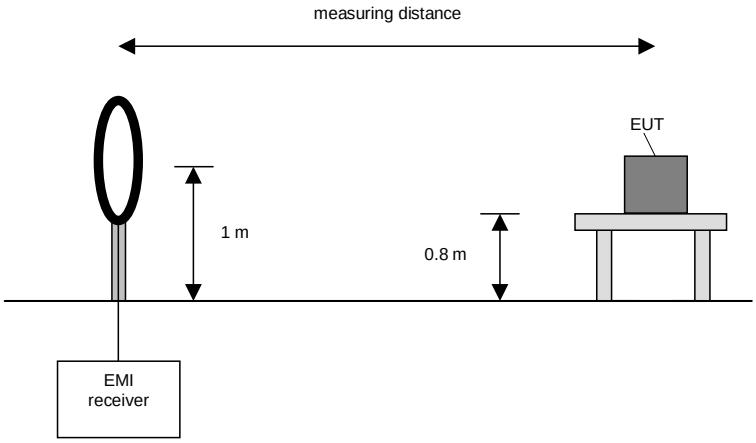
Final measurement (9 kHz to 30 MHz):

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).

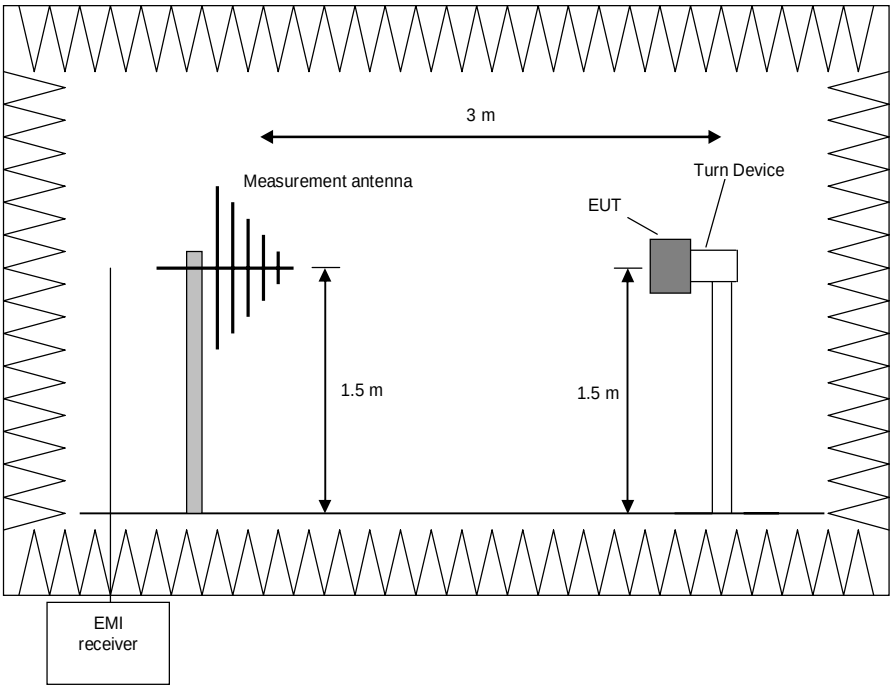
Preliminary measurement (30 MHz to 1 GHz)

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:

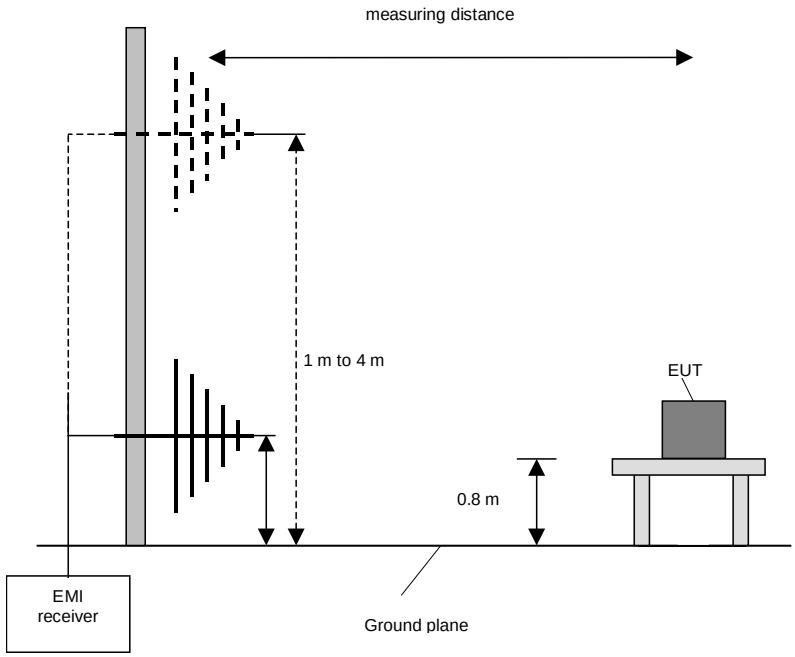
8. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
9. Manipulate the system cables within the range to produce the maximum level of emission.
10. Rotate the EUT by 360 ° to maximize the detected signals.
11. Repeat 1) to 3) with the vertical polarisation of the measuring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

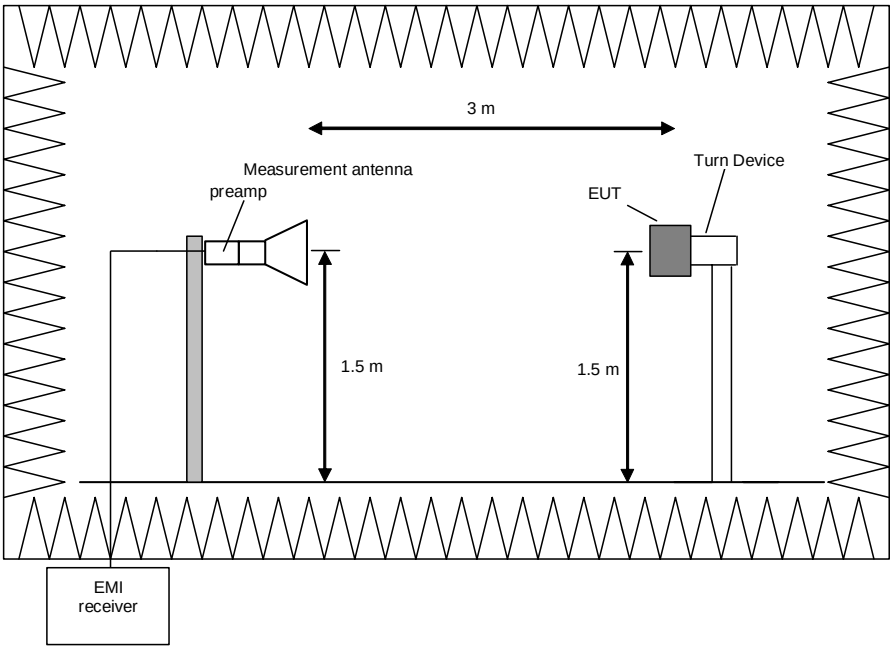
This measurement will be performed in a fully anechoic chamber. Table top devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

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:

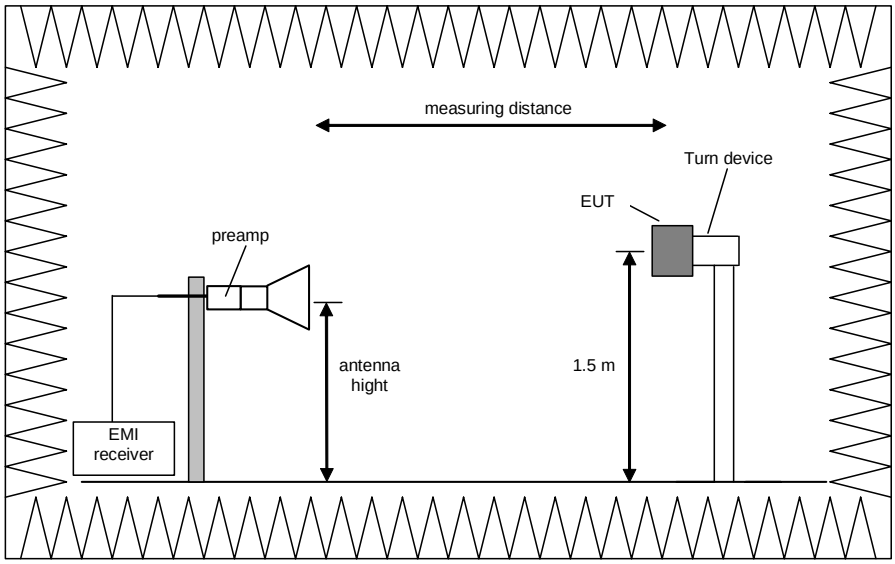
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an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

5.6.2.1 Preliminary radiated emission measurement

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.

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

Test record: The emissions were the same for all channels for frequencies below 1 GHz, therefore only one plot for each frequency range is submitted below.

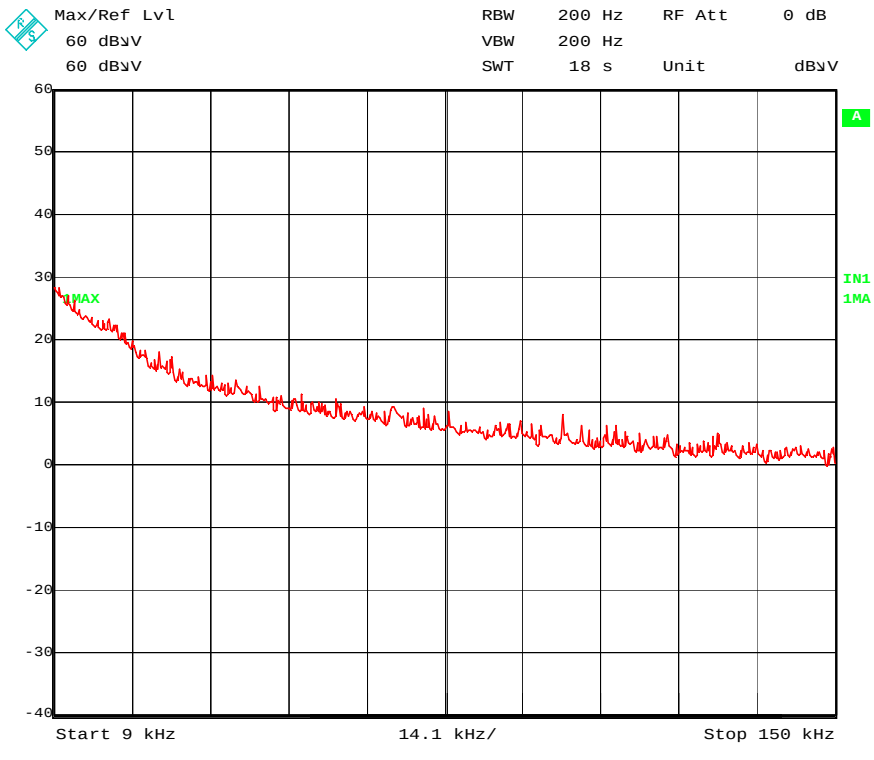
Supply voltage: During all measurements the host of the EUT was powered with 6 V by 4 AAA batteries.

Remark: Since the EUT has only an internal antenna, radiated test encompass emissions both from the antenna and the housing.

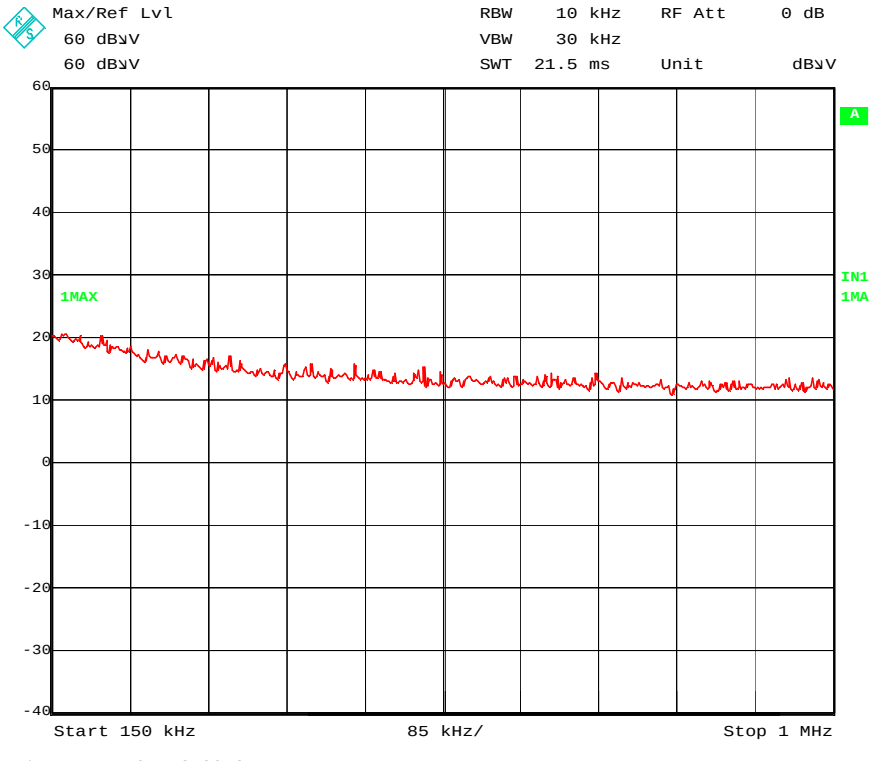
The emissions from 30 MHz – 1 GHz were not caused by the RF part, because the EUT has the same spectrum when the transmission is inactive (as seen by comparing the according plots below). For the test the transmitter was operating in idle mode (neither transmitting nor receiving).

Emissions below 1 GHz

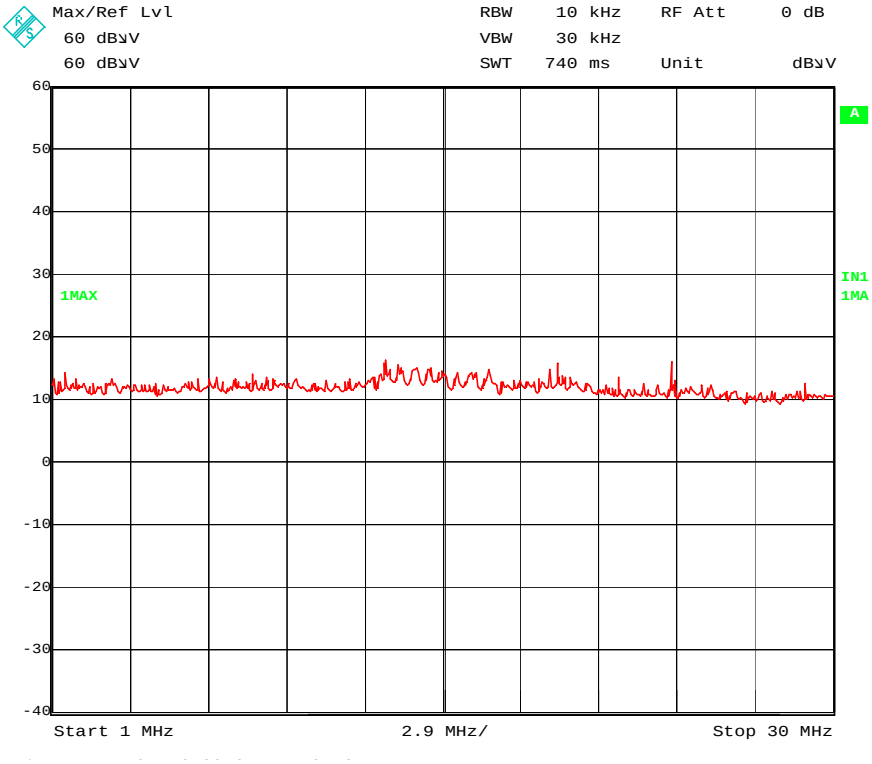
160903_ch0_9-150k_90°.wmf: Spurious emissions from 9 – 150 kHz:



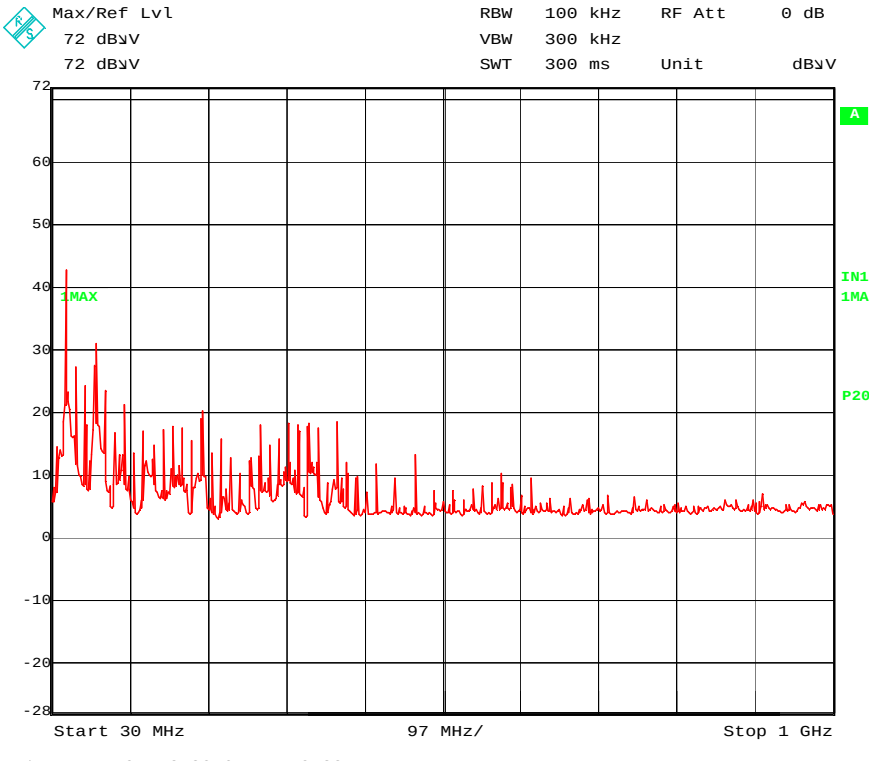
160903_ch0_150k-1M_0°.wmf: Spurious emissions from 150 kHz – 1 MHz:



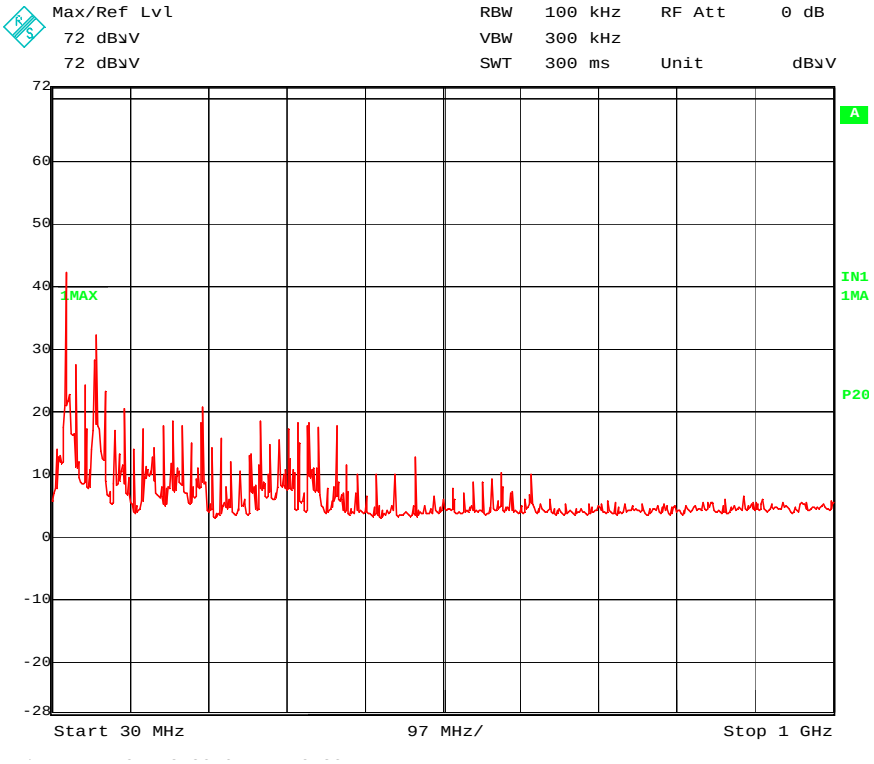
160903_ch19_1-30M_0°.wmf: Spurious emissions from 1 - 30 MHz:



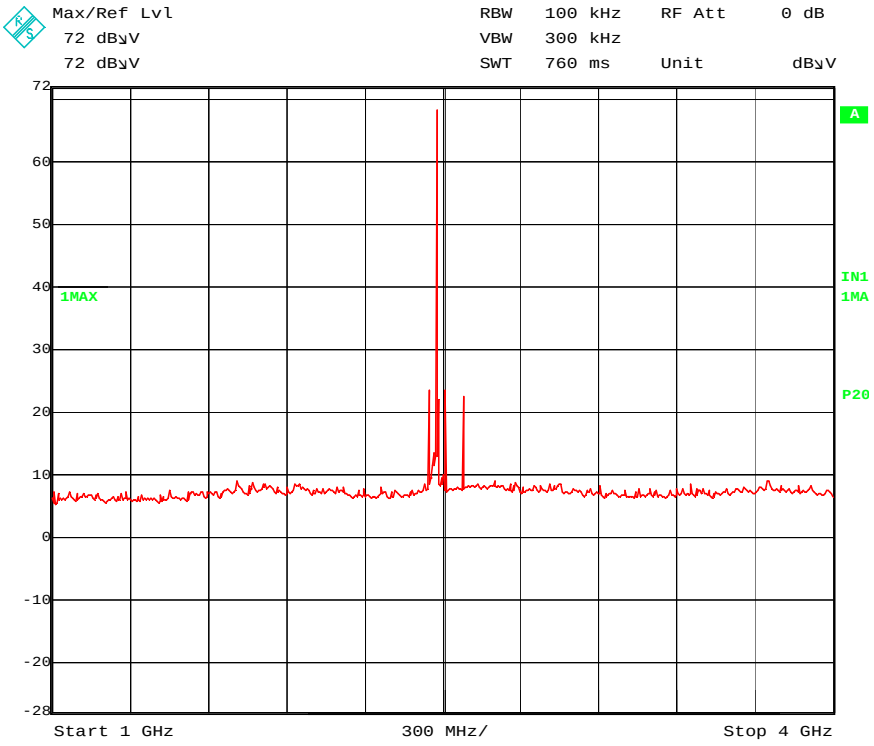
160903_30M-1G_0°_TxOff.wmf: Spurious emissions from –30 MHz - 1 GHz



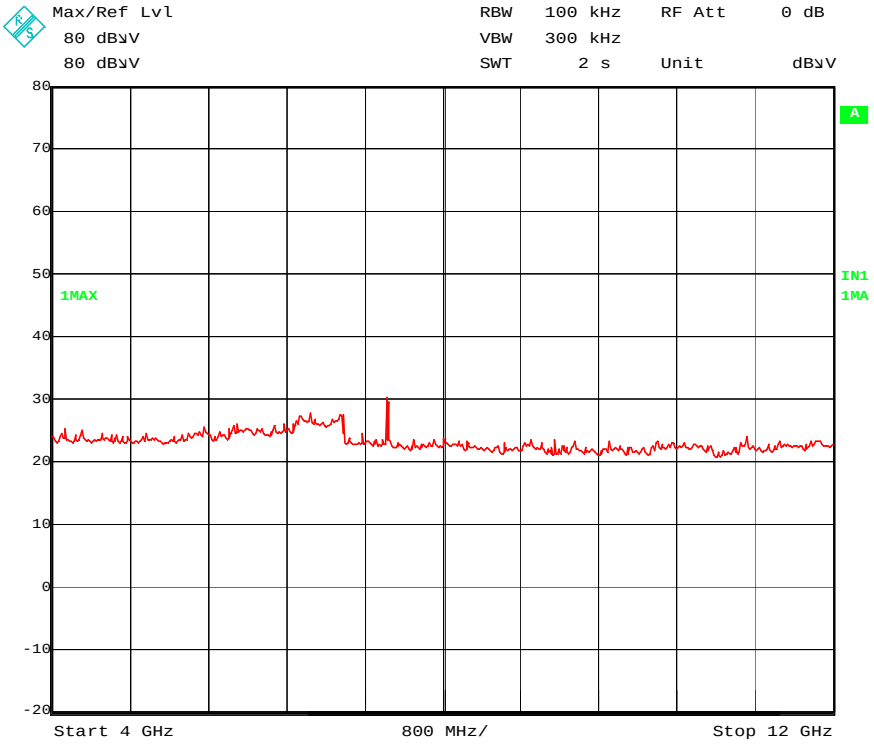
160903_ch19_30M-1G_0°.wmf: Spurious emissions from 30 MHz - 1 GHz:



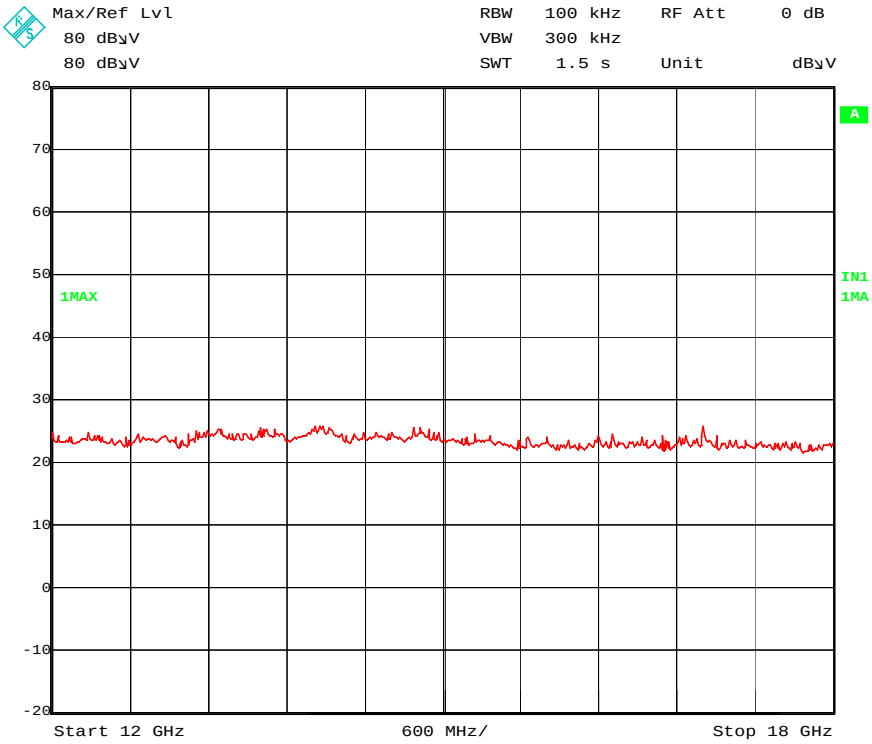
160903_ch39_1-4G_0°.wmf: Spurious emissions from 1 GHz to 4 GHz (operation mode 3):



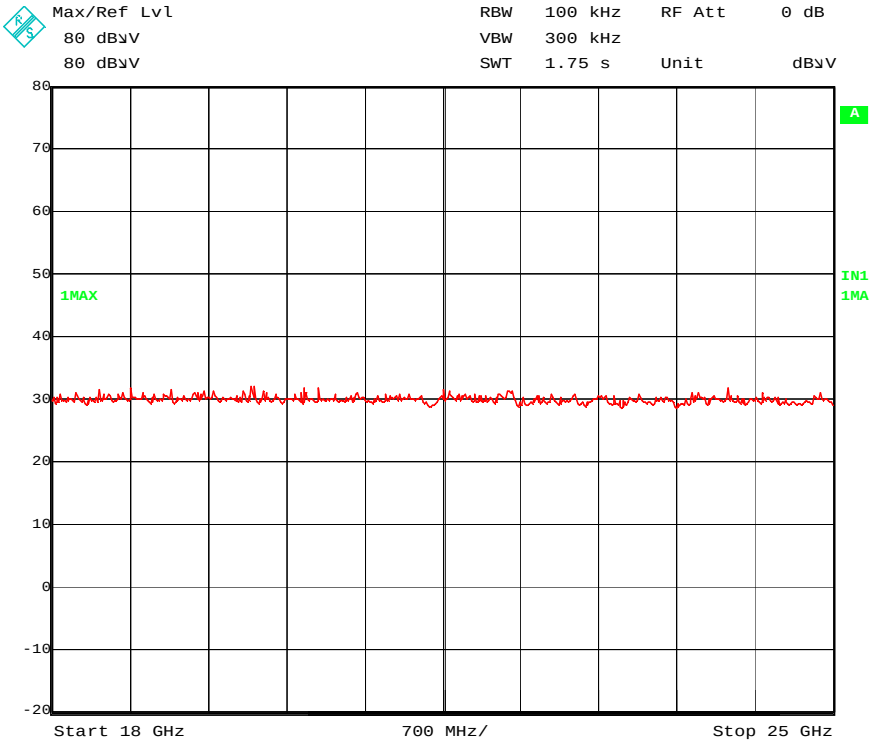
160903_ch39_4-12G_90°.wmf: Spurious emissions from 4 GHz to 12 GHz (operation mode 3):



160903_ch39_12-18G_Hor_0°.wmf: Spurious emissions from 12 GHz to 18 GHz (operation mode 3):



160903_ch39_18-25G_Hor_0°.wmf: Spurious emissions from 18 GHz to 25 GHz (operation mode 3):



5.6.2.2 Final radiated measurements

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

Result measured with the peak detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
7206	53.56	74	20.44	35.82	35.64	24.7	6.8	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

Result measured with the average detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
7206	41.53	54	12.47	23.79	35.64	24.7	6.8	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

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

Result measured with the peak detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2331.2	61.17	74	12.83	29.47	28.1	0	3.6	150	Hor.	30
2387.1	59.42	74	14.58	27.38	28.34	0	3.7	150	Hor.	30
7320	54.05	74	19.95	35.82	36.13	24.7	6.8	150	Hor.	60
Measurement uncertainty				+2.2 dB / -3.6 dB						

Result measured with the average detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2331.2	34.01	54	19.99	2.31	28.1	0	3.6	150	Hor.	30
2387.1	34.64	54	19.36	2.6	28.34	0	3.7	150	Vert.	30
7320	40.59	54	13.41	22.36	36.13	24.7	6.8	150	Hor.	60
Measurement uncertainty				+2.2 dB / -3.6 dB						

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

Result measured with the peak detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2509.9	63.93	74	10.07	31.58	28.55	0	3.8	150	Hor.	120
2579.8	62.04	74	11.96	29.59	28.55	0	3.9	150	Hor.	120
7440	55.75	74	18.25	37.32	36.33	24.7	6.8	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

Result measured with the average detector:

Frequency MHz	Meas. Result dBµV/m	Limit dBµV/m	Margin dB	Readings dBµV	Antenna factor 1/m	Preamp dB	Cable loss dB	Height cm	Pol.	Angle / °
2509.9	36.9	54	17.1	4.55	28.55	0	3.8	150	Hor.	120
2579.8	36.4	54	17.6	3.95	28.55	0	3.9	150	Hor.	120
7440	43.76	54	10.24	25.33	36.33	24.7	6.8	150	Hor.	90
Measurement uncertainty				+2.2 dB / -3.6 dB						

TEST EQUIPMENT USED FOR THE TEST:
29, 31 – 51

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

Ambient temperature	20 °C	Relative humidity	52 %

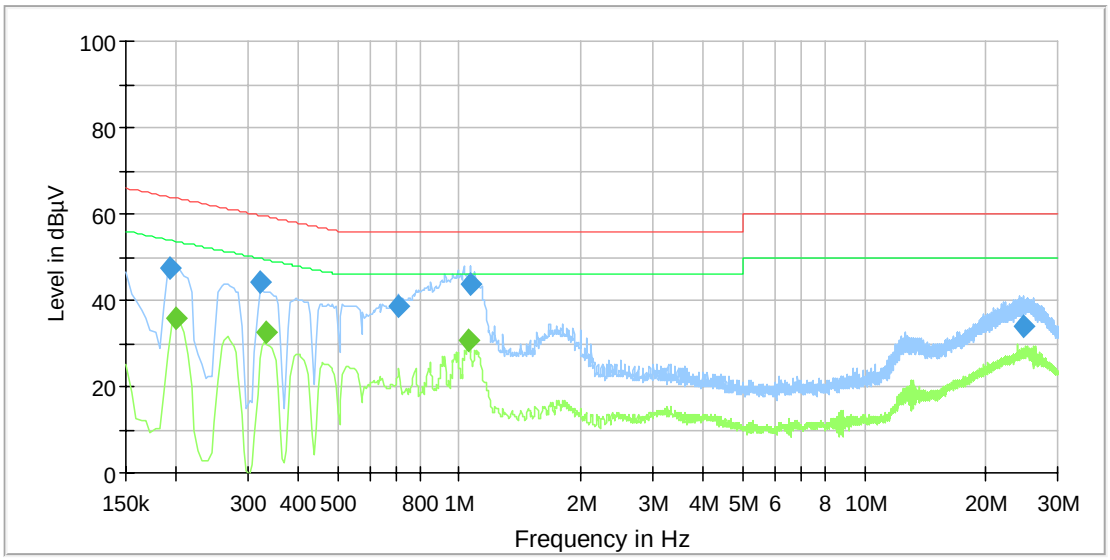
Position of EUT: For the test the EUT was powered by a laptop PC. The EUT was supplied by a USB cable, which also was used for setting up the test mode.
The Laptop which was used was a Fujitsu Siemens model S7220. The Laptop was powered by the AC adapter which was delivered with the laptop.

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.

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 "+".



160903_FCC-AC
24.08.2016

Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	Average (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.193200	47.36	---	63.90	16.54	5000.0	9.000	L1	FLO	9.8
0.198600	---	35.87	53.67	17.80	5000.0	9.000	L1	GND	9.8
0.322800	44.36	---	59.63	15.28	5000.0	9.000	N	GND	9.9
0.331800	---	32.74	49.41	16.67	5000.0	9.000	N	GND	9.9
0.709800	38.80	---	56.00	17.20	5000.0	9.000	N	GND	9.9
1.052700	---	30.85	46.00	15.15	5000.0	9.000	N	GND	9.9
1.064400	43.88	---	56.00	12.12	5000.0	9.000	N	FLO	9.9
24.612000	34.13	---	60.00	25.87	5000.0	9.000	L1	GND	11.0

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
1 – 5

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	Weekly verification (system cal.)	
2	EMI Receiver	ESIB 26	Rohde & Schwarz	1088.7490	481182	15.02.2016	15.02.2018
3	LISN	NSLK8128	Schwarzbeck	8128155	480058	16.02.2016	16.02.2018
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	-	-
29	Fully anechoic chamber M20	-	Albatross Projects	B83107-E2439-T232	480303	Weekly verification (system cal.)	
30	Spectrum analyser	FSU	Rohde & Schwarz	200125	480956	17.02.2016	17.02.2017
31	Measuring receiver	ESI 40	Rohde & Schwarz	100064	480355	16.04.2016	16.04.2017
32	Controller	MCU	Maturo	MCU/043/971107	480832	-	-
33	Turntable	DS420HE	Deisel	420/620/80	480315	-	-
34	Antenna support	AS615P	Deisel	615/310	480187	-	-
36	Antenna	3115 A	EMCO	9609-4918	480183	10.11.2014	10.11.2016
37	Standard Gain Horn 11.9 GHz – 18 GHz	18240-20	Flann Microwave	483	480294	Six month verification (system cal.)	
39	Standard Gain Horn 17.9 GHz – 26.7 GHz	20240-20	Flann Microwave	411	480297	Six month verification (system cal.)	
40	Standard Gain Horn Antenne 26.4 – 40.1 GHz	22240-20	Flann Microwave	469	480299	Six month verification (system cal.)	
41	RF-cable No. 3	Sucoflex 106B	Huber&Suhner	0563/6B / Kabel 3	480670	Weekly verification (system cal.)	
42	RF-cable No. 40	Sucoflex 106B	Huber&Suhner	0708/6B / Kabel 40	481330	Weekly verification (system cal.)	
43	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	29.02.2016	29.02.2018
44	Antenna	CBL6112 B	Chase	2688	480328	14.04.2014	14.04.2017
46	RF-cable 2 m	KPS-1533-800-KPS	Insulated Wire	-	480302	Six month verification (system cal.)	
49	Preamplifier	JS3-00101200-23-5A	Miteq	681851	480337	18.02.2016	18.02.2018
50	Preamplifier	JS3-12001800-16-5A	Miteq	571667	480343	18.02.2016	18.02.2018
51	Preamplifier	JS3-18002600-20-5A	Miteq	658697	480342	17.02.2016	17.02.2018
60	Power Meter	NRVD	Rohde & Schwarz	833697/030	480589	18.02.2016	18.02.2018
61	Peak Power Sensor	NRV-Z32	Rohde & Schwarz	849745/016	480551	18.02.2016	18.02.2018
72	4 GHz High Pass Filter	WHKX4.0/18 G-8SS	Wainwright Instruments	1	480587	Weekly verification (system cal.)	

7 Report History

Report Number	Date	Comment
F160902E1	13.09.2016	Initial Test Report

8 List of Annexes

ANNEX A TEST SETUP PHOTOS 6 pages

160903_01.jpg	Test setup - Radiated emission anechoic chamber
160903_02.jpg	Test setup - Radiated emission anechoic chamber
160903_03.jpg	Test setup - Radiated emission anechoic chamber
160903_04.jpg	Test setup - Radiated emission anechoic chamber
160903_05.jpg	Test setup - Radiated emission anechoic chamber
160903_13.jpg	Test setup – conducted emissions on power supply lines

ANNEX B EXTERNAL PHOTOS 4 pages

160903_20.jpg	EUT on carrier board – top view
160903_21.jpg	Close-up of the EUT on the carrier board – top view
160903_22.jpg	Close-up of the EUT without shielding – top view
160903_23.jpg	Carrier board – bottom view

ANNEX C INTERNAL PHOTOS 2 page

160903_24.jpg	EUT without shielding – top view
160903_25.jpg	EUT without shielding – bottom view