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Test Report

Report Number:

F181436E1

Equipment under Test (EUT):

JRG LegioTherm valve with controller

Applicant:

Georg Fischer JRG AG

Manufacturer:

Georg Fischer JRG 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**, Radio Frequency Devices

[3] **RSS-247 Issue 2 (February 2017)**, Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

[4] **RSS-Gen Issue 5 (April 2018)**, General Requirements for Compliance of Radio Apparatus

[5] **558074 D01 DTS Meas Guidance v04 (April 2017),** Guidance for performing compliance measurements on transmission systems (DTS) operating under section 15.247

Test Result

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

Tested and written by:	Bernward ROHDE		28.05.2019
	Name	Signature	Date
Reviewed and approved by:	Bernd STEINER		28.05.2019
	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.

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1 Identification

1.1 Applicant

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eMail address:	Antonio.de-agostini@georgfischer.com
Applicant represented during the test by the following person:	-

1.2 Manufacturer

Name:	Georg Fischer JRG AG
Address:	Hauptstrasse 130, 4450 Sissach
Country:	Switzerland
Name for contact purposes:	Mr. Antonio DE AGOSTINI
Phone:	+41 52 6313-026
Fax:	+41 52 63128-96
eMail address:	Antonio.de-agostini@georgfischer.com
Manufacturer represented during the test by the following person:	-

1.3 Test Laboratory

The tests were carried out by:

PHOENIX TESTLAB GmbH
Königswinkel 10
32825 Blomberg
Germany

accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-02, FCC Test Firm Accreditation with the registration number 469623, designation number DE0004 and Industry Canada Test site registration SITE# IC3469A-1.

1.4 EUT (Equipment under Test)

EUT	
Test object: *	Valve control unit
Product description: *	Hycleen Automation System
Model series:*	JRG Legiotherm 2T DN15 (9901.015)
Model name: * Product marketing name:* PMN:*	JRG LegioTherm valve with controller
FCC ID: *	2ASE5-9900
ISED Certification number: * IC: *	24912-9900
Hardware version identification number:* HVIN: *	9900
Host model name:* HMN: *	-
Firmware version identification name:* FVIN: *	Version 542
Serial number: *	V0000192
PCB identifier: *	GFP01.0220-LS-04 L

* Declared by the applicant

Bluetooth Low Energy frequencies				
Channel 00	RX	2402 MHz	TX	2402 MHz
Channel 19	RX	2440 MHz	TX	2440 MHz
Channel 39*	RX	2480 MHz	TX	2480 MHz

Equipment used for testing	
Cables (connected to the EUT):	M12 cable (data and DC power supply)*1
Fiber optic converter:	Opto USB2.0, MK Messtechnik (PM. No. 482617) *2
Programming adaptor:	USB to RS-485 converter*1
Power supply	Meanwell AC/DC switching adaptor (model No. GS25E28)*1
Laptop PC:	Fujitsu Lifebook S751 (PM No. 201036)*2

*1 Provided by the applicant
*2 Provided by the laboratory

1.5 Technical Data of Equipment

Bluetooth Low Energy radio mode						
Fulfils Bluetooth specification: *	Bluetooth® low energy 4.2 (1 Mbps)					
Radio chip	nRF51822					
Antenna type: *	Lambda/4 monopole PCB antenna					
Antenna name: *	-					
Antenna gain: *	3.35 dBi according to data sheet					
Antenna connector: *	None					
Power supply EUT: *	DC					
Supply voltage EUT: *	U_{nom} =	36 V	U_{min} =	28.8 V	U_{max} =	36 V
Supply voltage radio module: *	U_{nom} =	3.3	U_{min} =	1.8 V	U_{max} =	3.6 V
Type of modulation: *	GFSK (1 Mbit/s)					
Operating frequency range: *	2402 – 2480 MHz					
Number of channels: *	40 (2 MHz channel spacing)					
Temperature range: *	+5 °C to +45 °C					
Lowest / highest internal clock frequency: *	32.786 kHz to 2.4835 GHz					

* Declared by the applicant

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

1.6 Dates

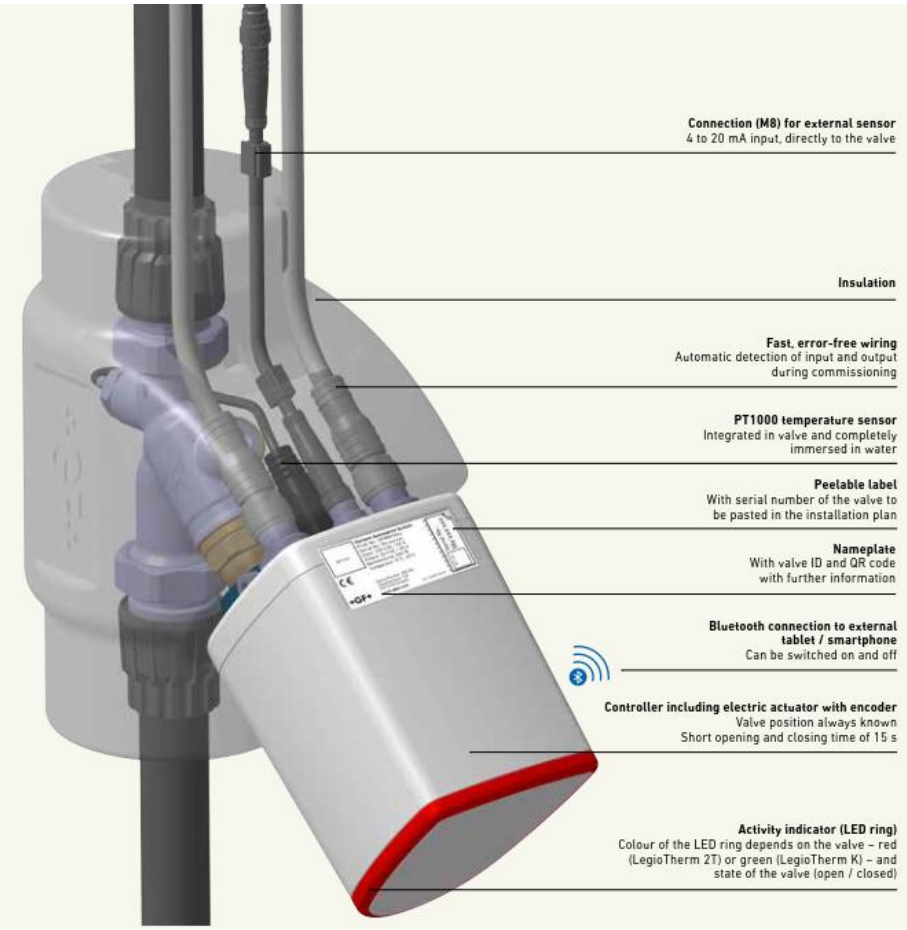
Date of receipt of test sample:	18.10.2018
Start of test:	26.10.2018
End of test:	13.12.2018

2 Operational States

2.1 Description of function of the EUT

The EUT is a valve containing a BLE radio chip for communication purposes.

The EUT and its physical boundaries:



2.2 The following states were defined as the operating conditions

2.2.1 Operation modes/Power settings

Operation mode #	Radio technology	Frequency [MHz]	Channel	Modulation / Mode	Data rate	Power setting
1	BLE	2402	0	GFSK	1 Mbit/s	+4 dBm
2	BLE	2440	19	GFSK	1 Mbit/s	+4 dBm
3	BLE	2480	39	GFSK	1 Mbit/s	+4 dBm

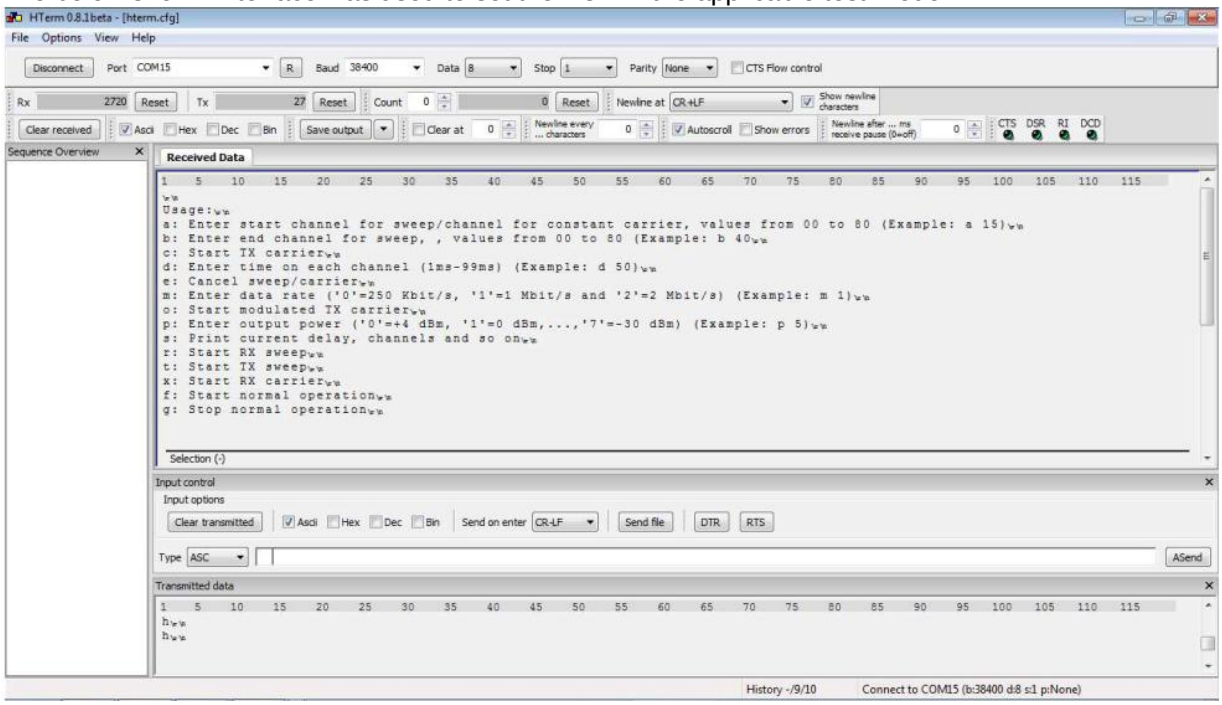
2.2.2 Radio tests

For the radio tests the following settings were used:

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

Baud rate: 38400
Data: 8 bit
Parity: None
Stop: 1 bit
Flow control: None

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



3 Additional Information

The EUT was not labeled with the final label.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-247 [3] or RSS-Gen, Issue 5 [4]	Status	Refer page
Maximum Peak Output Power	2400.0 - 2483.5	15.247 (b) (3), (4)	5.4 (d) [3]	Passed	14 et seq.
DTS Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	5.2 (a) [3]	Passed	15 et seq.
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	5.2 (b) [3]	Passed	20 et seq.
Band edge compliance	2400.0 - 2483.5	15.247 (d) 15.205 (a) 15.209 (a)	5.5 [3] 8.9 [4], 8.10 [4]	Passed	22 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	27 et seq.
Conducted emissions on supply line	0.15 - 30	15.207 (a)	8.8 [4]	Passed	27 et seq.

5 Results

5.1 Duty cycle

5.1.1 Method of measurement

For the duty cycle measurement, the EUT was measured radiated in its worst case position (position of the maximum emission level) in the anechoic chamber using the procedures described in 5.6.1.

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

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

The following measurement technique was used:

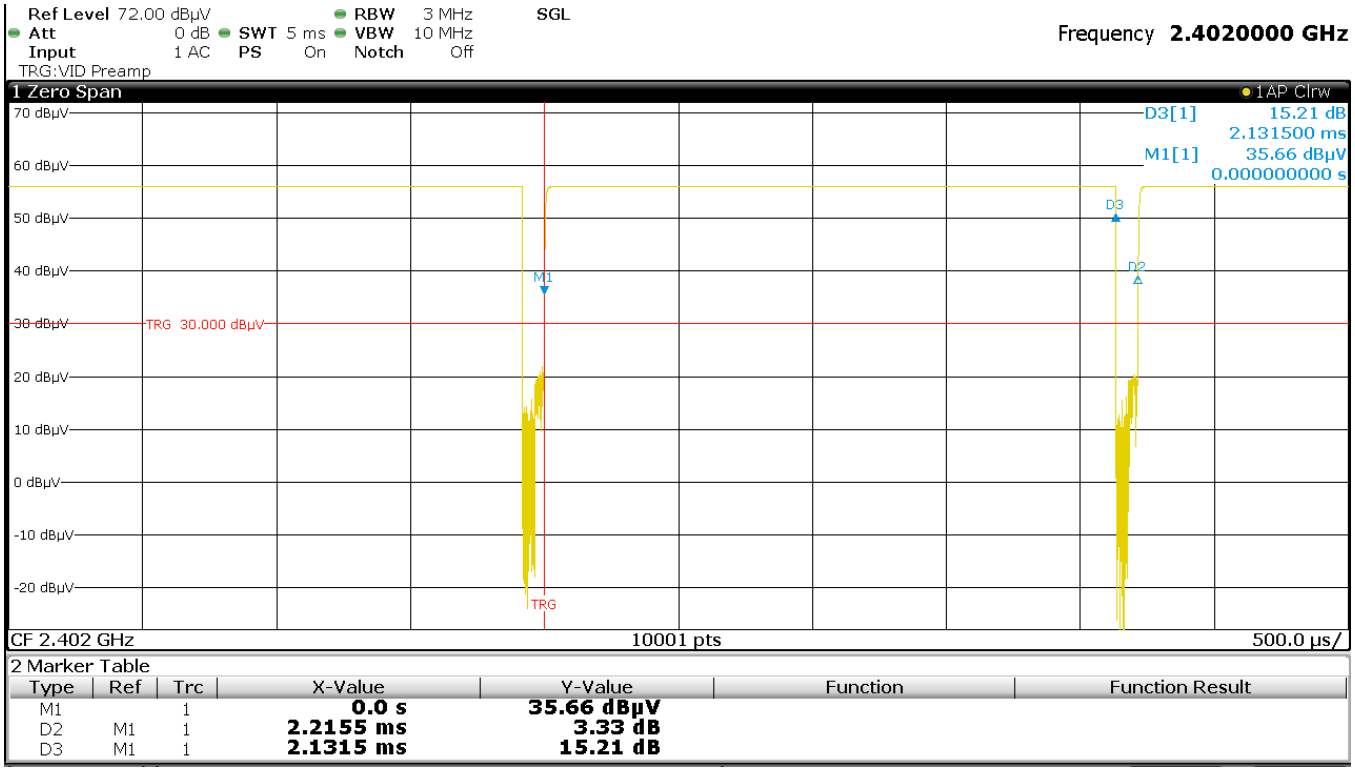
The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between two bins on the sweep are sufficient to permit accurate measurements of the on and off times of the transmitted signal.

- Set the center frequency of the instrument to the center frequency of the transmission.
- Set RBW ≥ 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	52 %

Date	26.10.2018
Tested by	B. ROHDE



Operation mode	TX_on [µs]	TX_ges [µs]	RBW [MHz]	50/T [kHz]	50/T < RBW?
1-3	2132	2216	3	23	Yes

Operation mode	Sweep points	Sweep time [µs]	Meas points	Meas points >100?	Duty cycle %	DCCF [dB]
1-3	10001	5000	4432	Yes	96	0.17

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

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

Therefore, for average measurements a correction factor of 0.17 dB is used for all tests in test mode 1 -3.

Test equipment (please refer to chapter 6 for details)
1 - 9

5.2 DTS Bandwidth / 99% Bandwidth

5.2.1 Method of measurement (conducted)

Not tested, because EUT has an integral antenna, measurement done radiated.

5.2.2 Method of measurement (radiated)

For the DTS bandwidth measurement, the EUT was measured radiated in its worst case position (position of the maximum emission level) in the anechoic chamber using the procedures described in 5.6.1.

DTS bandwidth:

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

a) Set RBW = 100 kHz.
b) Set the VBW ≥ [3 × RBW].
c) Detector = peak.
d) Trace mode = max hold.
e) Sweep = auto couple.
f) Allow the trace to stabilize.
g) 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.

99 % bandwidth / occupied 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:

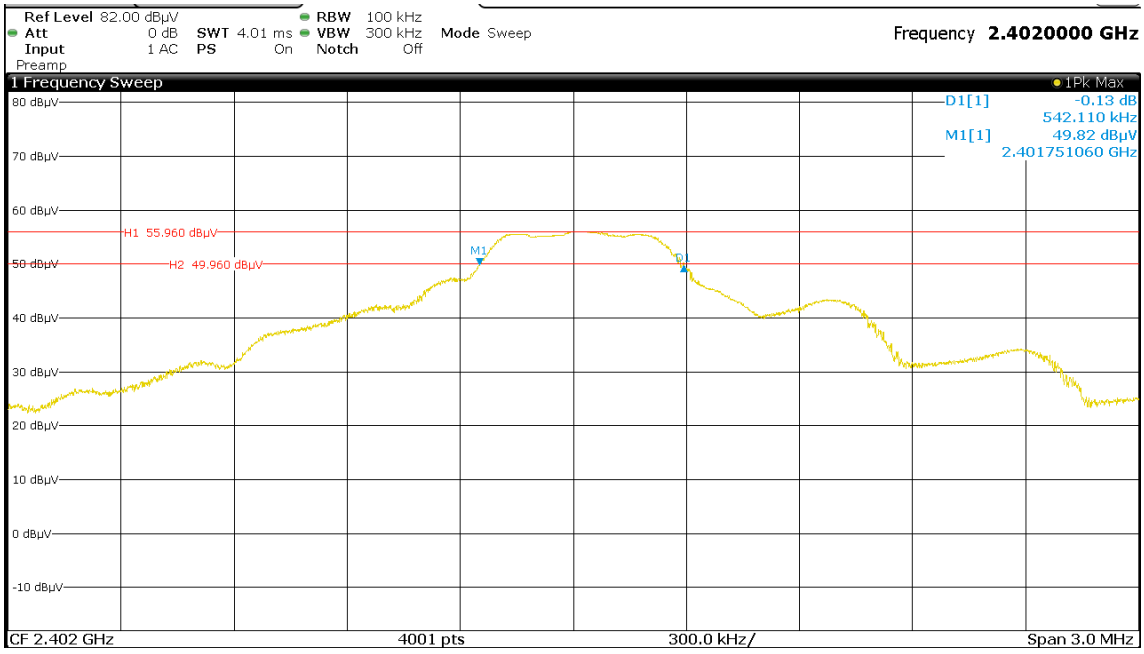
a) The instrument center frequency is set to the nominal EUT channel center frequency. The frequency span for the spectrum analyzer shall be between 1.5 times and 5.0 times the OBW.
b) The nominal IF filter bandwidth (3 dB RBW) shall be in the range of 1% to 5% of the OBW and VBW shall be approximately three times the RBW, unless otherwise specified by the applicable requirement.
c) 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.
d) 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. Since this is only a relative measurement, no measurement level correction was performed.
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.
h) The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

5.2.3 Test results (radiated)

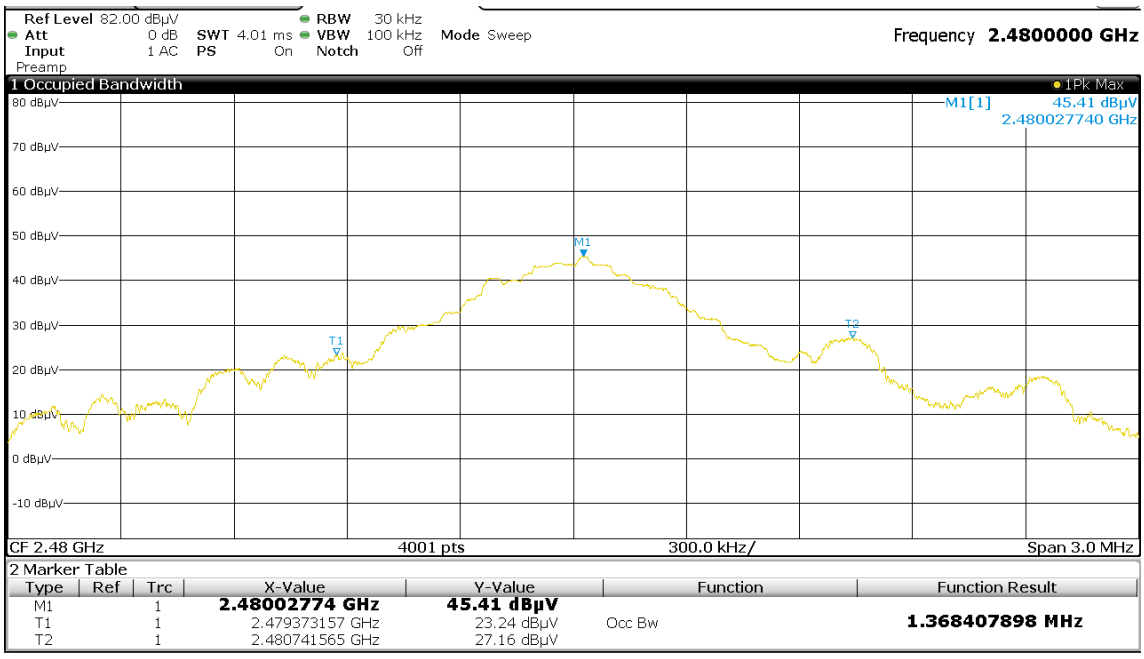
Ambient temperature	22 °C
Relative humidity	40 %

Date	26.10.2018
Tested by	B. ROHDE

DTS-BW; Operation mode 1



OBW; Operation mode 3



OP mode	Data rate	Center Frequency [MHz]	Minimum 6-dB Bandwidth Limit [MHz]	6 dB Bandwidth [MHz]	99 % Bandwidth [MHz]	Result
1	1 Mbit/s	2402	0.5	0.542	1.172	Passed
2	1 Mbit/s	2440	0.5	0.592	1.344	Passed
3	1 Mbit/s	2480	0.5	0.608	1.368	Passed

Test equipment (please refer to chapter 6 for details)
1 - 9

5.3 Maximum conducted (average) output power

5.3.1 Method of measurement (conducted)

Not tested, because EUT has an integral antenna, measurement done radiated.

5.3.2 Method of measurement (radiated)

Tested according to 8.3.2.2 in [5]; method AVGSA-2 as described in 11.9.2.2.4 in [1] was used for the following test.

Tests were carried out in the worst case position (position of the maximum emission level), as determined in 5.6.

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

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

The formula in 11.12.2.2 e) in [1] was used to calculate the EIRP power:

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

$MPOP = EIRP - G$

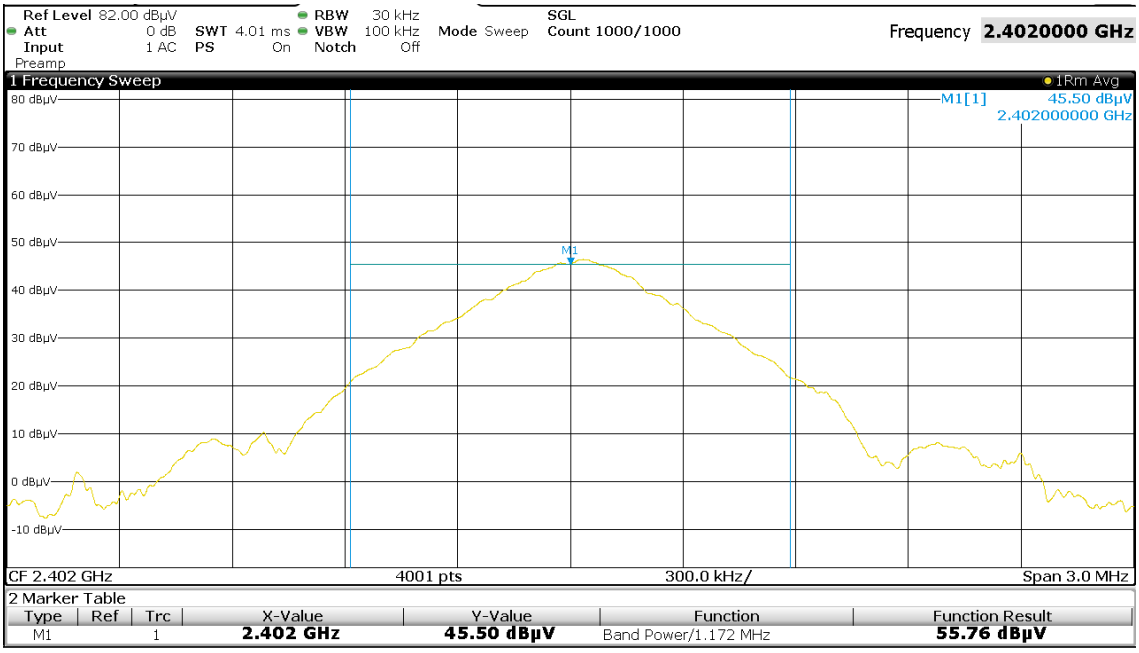
E is the electric field strength in dBµV/m
EIRP is the equivalent isotropically radiated power in dBm
d is the specified measurement distance in m
G is the antenna gain in dBi
MPOP is the maximum peak output power – measured antenna port conducted – in dBm

5.3.3 Test results (radiated)

Ambient temperature	22° C
Relative humidity	40 %

Date	26.10.2018
Tested by	B. ROHDE

Operation mode 1:



Antenna gain of used antenna according to the data sheet: 3.35 dBi

A DCCF of 0.17 dB was used.

Mode	Data rate	Frequency [MHz]	Reading [dBµV]	Corr. Fact. [dB/m]	Field strength @3m [dBµV/m]	EIRP [dBm]	EIRP Incl. DCCF [dBm]	Result [dBm]	Limit [dBm]
1	1 Mbit/s	2402	55.8	33.8	89.6	-5.7	-5.5	-8.9	30.0
2	1 Mbit/s	2440	51.3	34.1	85.4	-9.9	-9.7	-13.1	30.0
3	1 Mbit/s	2480	42.4	34.0	76.4	-18.9	-18.7	-22.1	30.0

Test equipment (please refer to chapter 6 for details)
1 - 9

5.4 Peak Power Spectral Density

5.4.1 Method of measurement (conducted)

Not tested, because EUT has an integral antenna, measurement done radiated.

5.4.2 Method of measurement (radiated)

Tested according to 8.4 in [5]; method AVGPSD-2 as described in 11.10.5 in [1] was used for the following test.

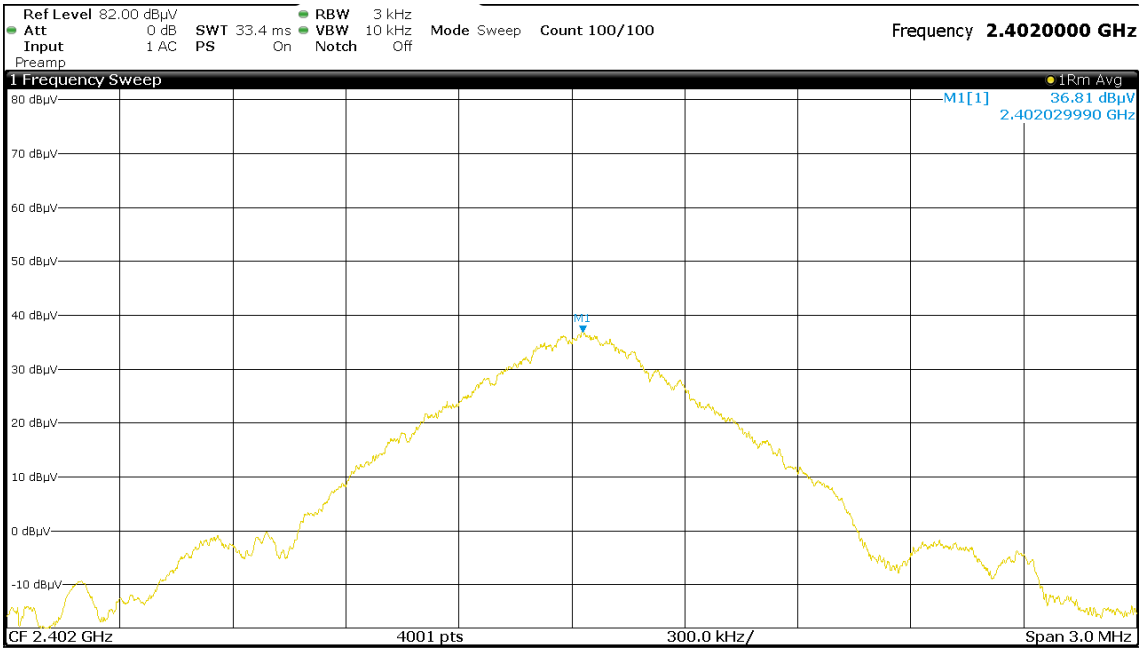
Tests were carried out in the worst case position (position of the maximum emission level), as determined in 5.6.

5.4.3 Test results (radiated)

Ambient temperature	22 °C
Relative humidity	45 %

Date	26.10.2018
Tested by	B. ROHDE

Operation mode 1:



Antenna gain of used antenna according to the data sheet: 3.35 dBi

A DCCF of 0.17 dB was used.

Operation mode	Frequency [MHz]	Reading [dBmV]	Corr. Fact. [dB/m]	Field strength @ 3m [dBmV]	EIRP [dBm / 3 kHz]	EIRP incl DCCF [dBm / 3 kHz]	Power Spectral Density Reading [dBm / 3 kHz]	Limit [dBm]
1	2402.030	36.8	33.8	70.6	-24.6	-24.5	-27.8	8.00
2	2439.972	32.3	34.1	66.4	-28.8	-28.6	-32.0	8.00
3	2480.029	25.2	34.0	59.2	-36.1	-35.9	-39.3	8.00

Test equipment (please refer to chapter 6 for details)
1 - 9

5.5 Band-edge compliance

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

Not tested, because EUT has an integral antenna, measurement done radiated.

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

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

Measurement Procedure Reference – Reference Level:

a) Set instrument center frequency to DTS channel center frequency.
b) Set the span to ≥ 1.5 times the DTS bandwidth.
c) Set the RBW = 100 kHz.
d) Set the VBW ≥ [3 × RBW].
e) Detector = peak.
f) Sweep time = auto couple.
g) Trace mode = max hold.
h) Allow trace to fully stabilize.
i) Use the peak marker function to determine the maximum PSD level.

Measurement Procedure – Unwanted Emissions

a) Set the center frequency and span to encompass frequency range to be measured.
b) Set the RBW = 100 kHz.
c) Set the VBW ≥ [3 × RBW].
d) Detector = peak.
e) Sweep time = auto couple.
f) Trace mode = max hold.
g) Allow trace to fully stabilize.
h) Use the peak marker function to determine the maximum amplitude level.

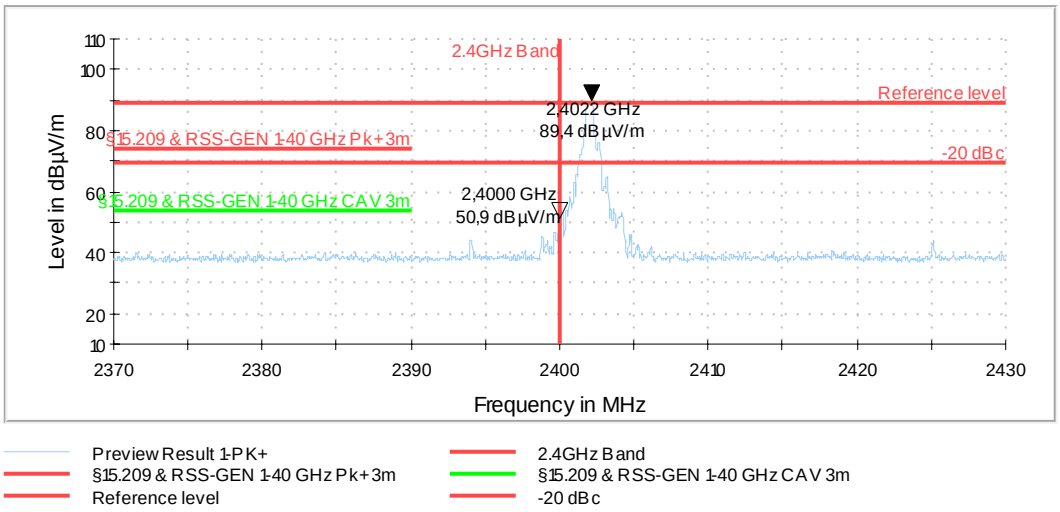
The measurement of the band edges were performed in one single run. Deviating from the above mentioned procedure the maximum emissions were radiated measured as described in 5.6.1 with a start frequency of 2370 MHz and a stop frequency of 2430 MHz. The maximum in band PSD was determined with the peak marker; this level represents the reference level. A limit line was drawn 20 dB below the reference level to show the applicable limit. A second marker was used to determine the highest unwanted emission in the unrestricted band.
This measurement was conducted at the lower end of the used frequency band (operation mode 1).

5.5.3 Test results (radiated)

Ambient temperature	22 °C
Relative humidity	52 %

Date	29.10.2018
Tested by	B. ROHDE

Operation mode 1



Operation Mode	Tx Frequency [MHz]	Emission Frequency [MHz]	Reference Level [dBµV]	Limit [dBm]	Emission Level [dBµV]	Margin [dB]	Result
1	2402	2400.00	89.4	69.4	50.9	38.5	Passed

Test equipment (please refer to chapter 6 for details)
1 - 9

5.5.4 Method of measurement (band edges next to restricted bands (conducted))

Not tested, tested done radiated, EUT has not antenna port.

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

The measurement of the band edges were performed in one single run. Deviating from the above mentioned procedure the maximum emissions were radiated measured as described in 5.6.1 with a start frequency of 2370 respectively 2450 MHz and a stop frequency of 2430 MHz respectively 2500 MHz

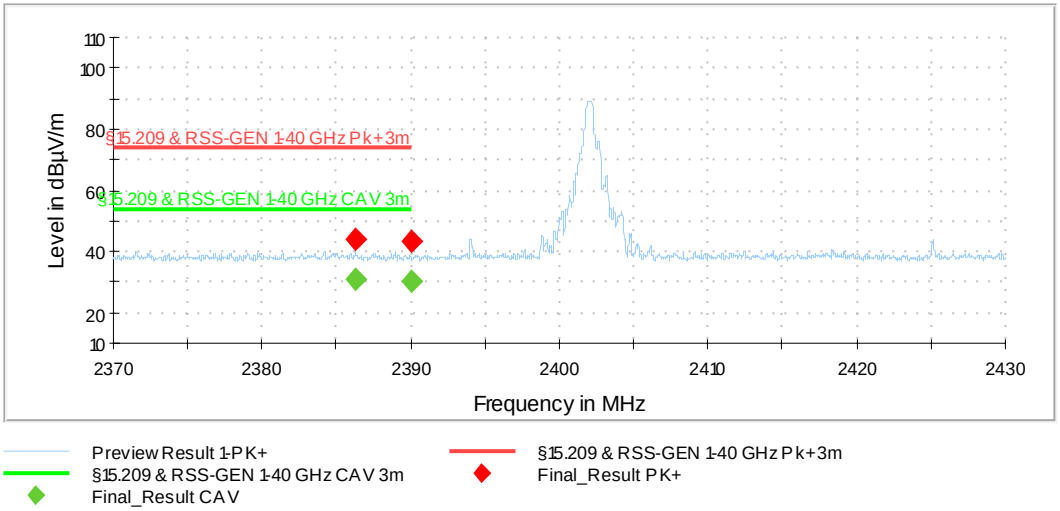
The measurement procedure refers to part 6.10.5 of document [1].

5.5.6 Test results (radiated)

Ambient temperature	22 °C
Relative humidity	52 %

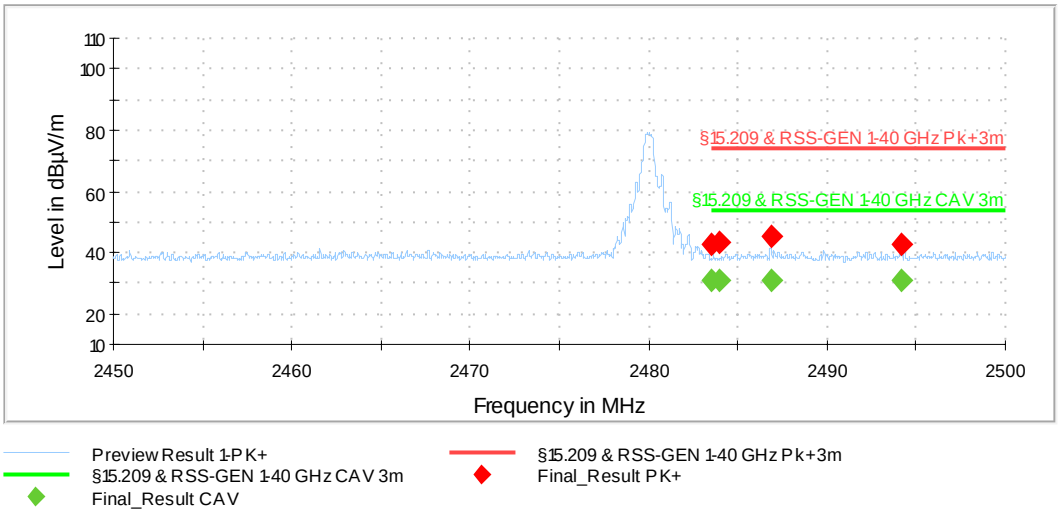
Date	29.10.2018
Tested by	B. ROHDE

Operation mode 1



Lower band edge									
Operation mode 1			Duty cycle correction factor of 0.17 dB was applied for the Average reading						
Frequency	Max Peak	Average	Limit	Margin	Pol	Azimuth	Elevation	Correction	Result
[MHz]	[dBµV/m]	[dBµV/m]	[dBµV/m]	dB		[°]	[°]	[dB]	
2386.260000	44.0	---	74	30.0	H	322	30	33.0	Passed
2386.260000	---	30.8	54	23.2	H	322	30	33.2	Passed
Measurement uncertainty			+2.2 dB / -3.6 dB						

Operation mode 3



Upper band edge									
Operation mode 3			Duty cycle correction factor of 0.17 dB was applied for the Average reading						
Frequency	Max Peak	Average	Limit	Margin	Pol	Azimuth	Elevation	Correction	Result
[MHz]	[dBµV/m]	[dBµV/m]	[dBµV/m]	dB		[°]	[°]	[dB]	
2483.500000	43.0	---	74	31.0	V	146	150	34.0	Passed
2483.500000	---	31.2	54	22.8	V	146	150	34.2	Passed
2484.000000	43.5	---	74	30.5	H	98	90	34.0	Passed
2484.000000	---	31.2	54	22.8	H	98	90	34.2	Passed
2486.875000	45.4	---	74	28.6	V	348	60	34.0	Passed
2486.875000	---	31.3	54	22.7	V	348	60	34.2	Passed
2494.175000	43.0	---	74	31.0	H	262	60	33.0	Passed
2494.175000	---	31.1	54	22.9	H	262	60	33.2	Passed
Measurement uncertainty				+2.2 dB / -3.6 dB					

Test equipment (please refer to chapter 6 for details)
1 - 9

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.

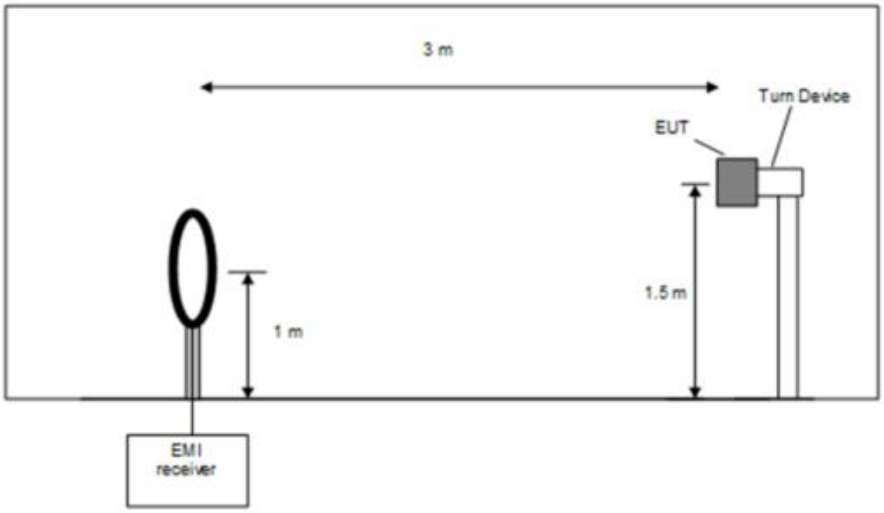
5.6.1.1 Preliminary measurement (9 kHz to 30 MHz)

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 analyzer while the system and its cables will be manipulated to find out the configuration with the maximum emission levels if applicable. The EMI Receiver will be set to MAX Hold mode. The EUT and the measuring antenna will be rotated around their vertical axis to found the maximum emissions.

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

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



Preliminary measurement procedure:

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

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

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

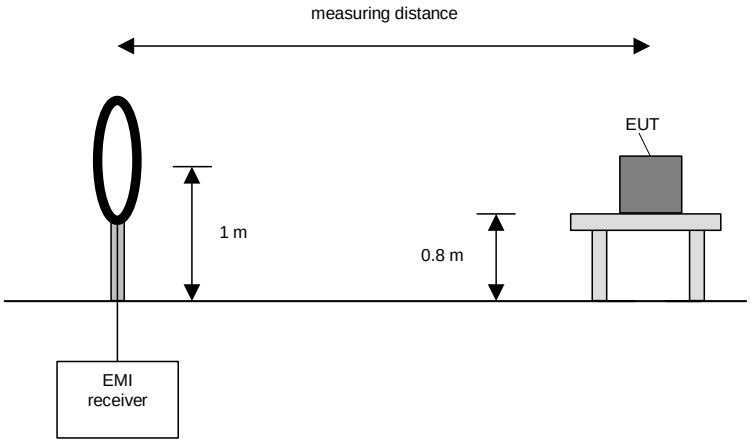
5.6.1.2 Final measurement (9 kHz to 30 MHz):

In the second stage a final measurement will be performed on an open area test site with no conducting ground plane in measuring distances of 3 m, 10 m and 30 m. In the case where larger measuring distances is 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).

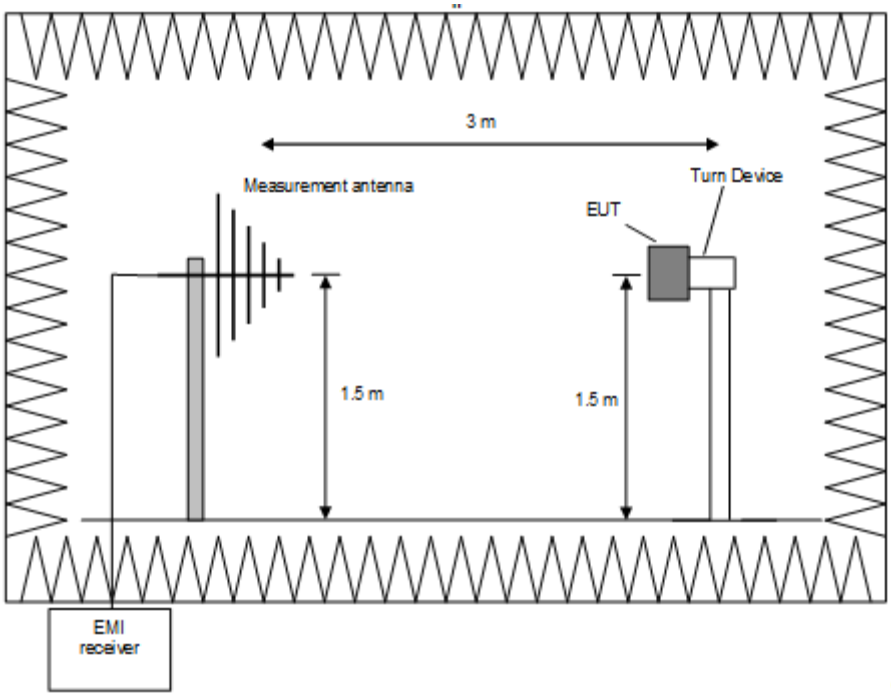
5.6.1.3 Preliminary measurement (30 MHz to 1 GHz)

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 setup 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 polarization of the measuring antenna and while rotating the EUT in its vertical axis in the range of 0 ° to 360 °. This measurement is repeated after raising the EUT in 30° steps according 6.6.5.4 in [1].

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

Frequency range	Resolution bandwidth
30 MHz to 230 MHz	100 kHz
230 MHz to 1 GHz	100 kHz



Procedure preliminary measurement:

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

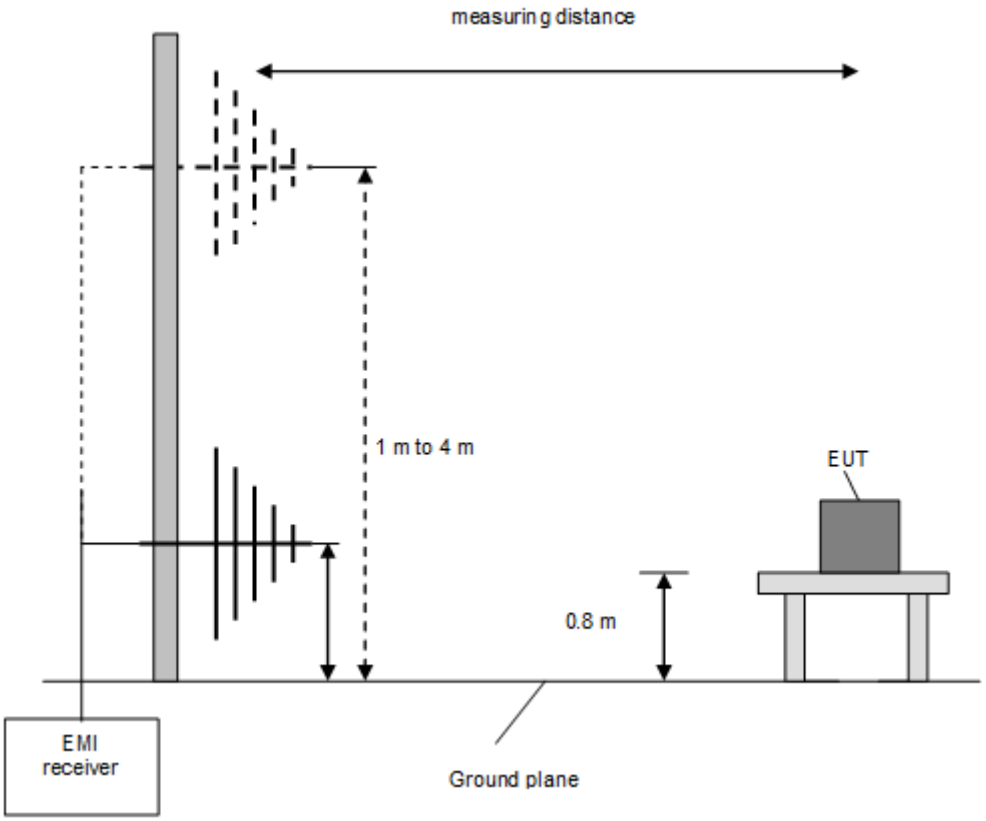
8. Monitor the frequency range at horizontal polarization and a EUT azimuth of 0 °.
9. Manipulate the system cables within the range to produce the maximum level of emission.
10. Rotate the EUT by 360 ° to maximize the detected signals.
11. Repeat 1) to 3) with the vertical polarization of the measuring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

5.6.1.4 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 polarization and raised and lowered in the range from 1 m to 4 m to find the maximum level of emissions.

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

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).

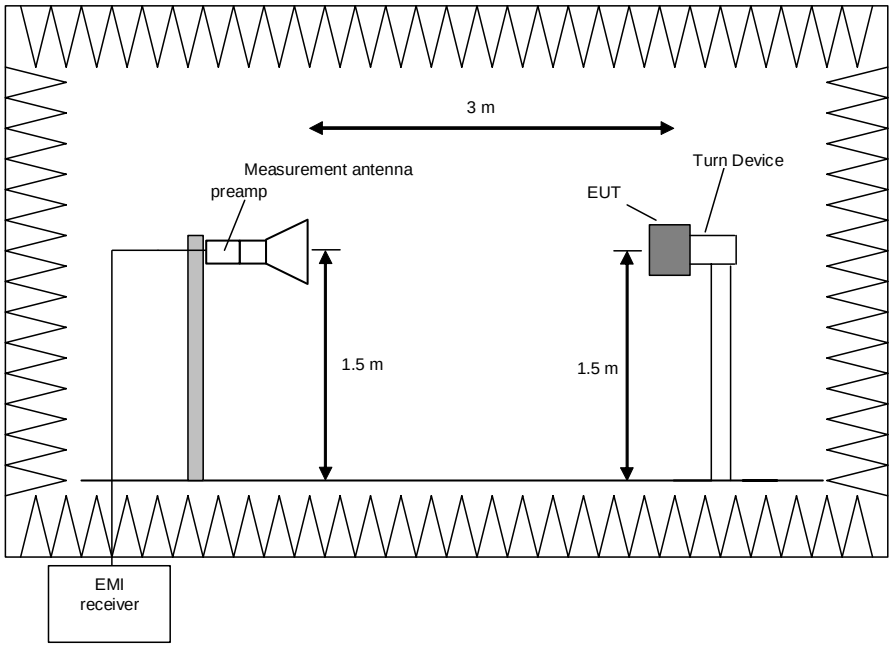
5.6.1.5 Preliminary measurement (1 GHz to 40 GHz)

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].

The frequency range will be divided into different sub ranges depending of the frequency range of the used horn antenna. The spectrum analyzer set to MAX Hold mode and a resolution bandwidth of 100 kHz. The measurement will be performed in horizontal and vertical polarization of the measuring antenna and while rotating the EUT in its vertical axis in the range of 0 ° to 360 °. This measurement is repeated after raising the EUT in 30° steps according 6.6.5.4 in [1].

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

Frequency range	Resolution bandwidth
1 GHz to 4 GHz	100 kHz
4 GHz to 12 GHz	100 kHz
12 GHz to 18 GHz	100 kHz
18 GHz to 25 / 26.5 GHz	100 kHz
26.5 GHz to 40 GHz	100 kHz



Procedure preliminary measurement:

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

1. Monitor the frequency range at horizontal polarization 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 polarization 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 polarization, 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.

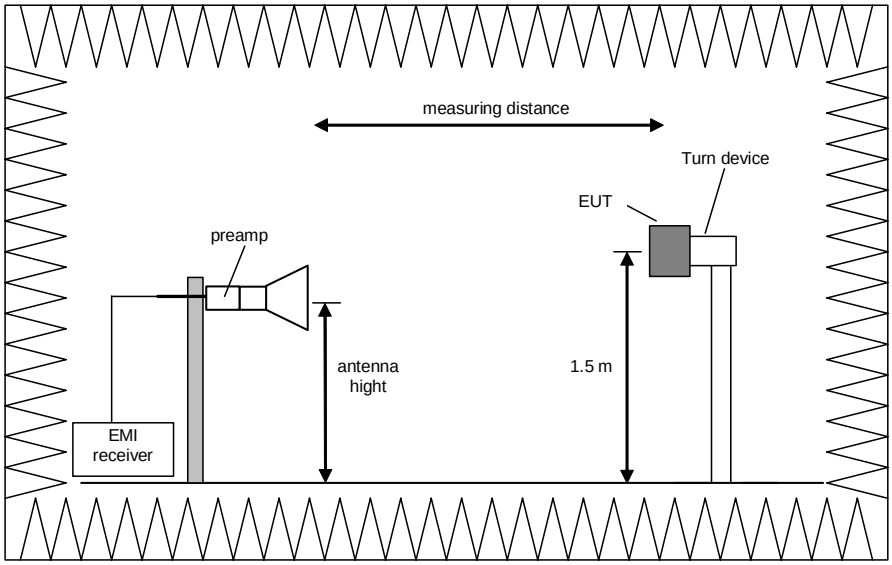
5.6.1.6 Final measurement (1 GHz to 40 GHz)

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].

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 polarization to the orientation with the highest emission for the first frequency identified in the preliminary measurements.
3) Set the spectrum analyzer 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)

5.6.2.1 Preliminary radiated emission measurement (9 kHz to 30 MHz)

Ambient temperature	22 °C	Date	13.12.2018
Relative humidity	45 %	Tested by	B. ROHDE

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 Test setup Photo annex.

Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was powered with 28 V DC via a AC/DC switching adaptor power supply.

No significant emission was found during the preliminary measurement, so no final measurement was carried out, no plot delivered.

Test equipment (please refer to chapter 6 for details)
1 – 8, 11

5.6.2.2 Preliminary radiated emission measurement (30 MHz – 1 GHz)

Ambient temperature	22 °C	Date	29.10.2018
Relative humidity	45 %	Tested by	B. ROHDE

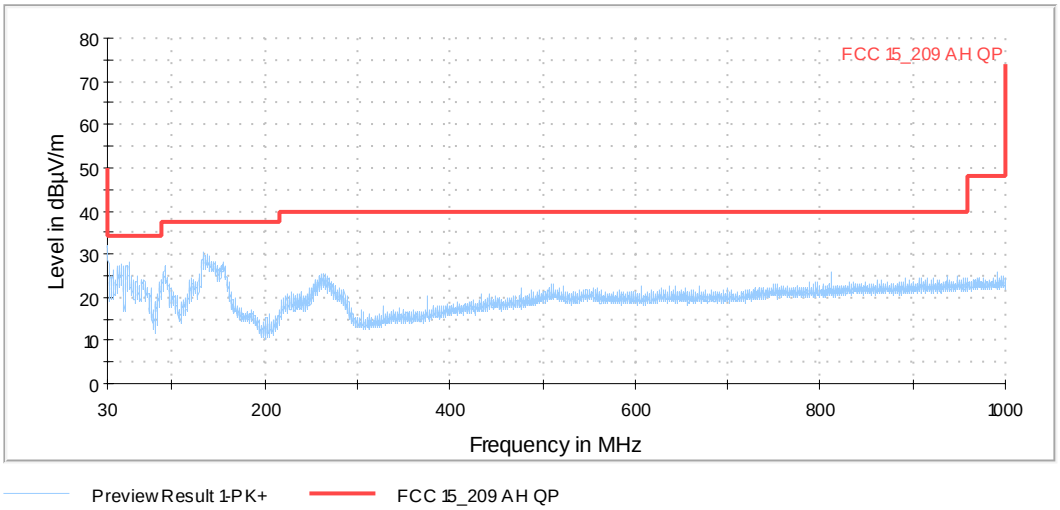
Position of EUT: The EUT was set-up on an EUT turn device of a height of 1.5 m. The distance between EUT and antenna was 3 m.

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

Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was powered with 28 V DC via a AC/DC switching adaptor power supply.

Spurious emissions from 30 MHz – 1 GHz (All operation modes; preliminary plot):



The following frequencies were identified during the preliminary measurement, a final measurement on the OATS will be carried out.

Frequency [MHz]	
30.388000	134.469000
45.762500	155.130000
53.328500	374.932000
92.710500	477.073000
120.016000	---

Test equipment (please refer to chapter 6 for details)
2, 4, 8 - 9, 12 - 16

5.6.2.3 Preliminary radiated emissions measurement (above 1 GHz)

Ambient temperature	22 °C
Relative humidity	45 %

Date	26.10.2018
Tested by	B. ROHDE

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 Test setup Photo annex.

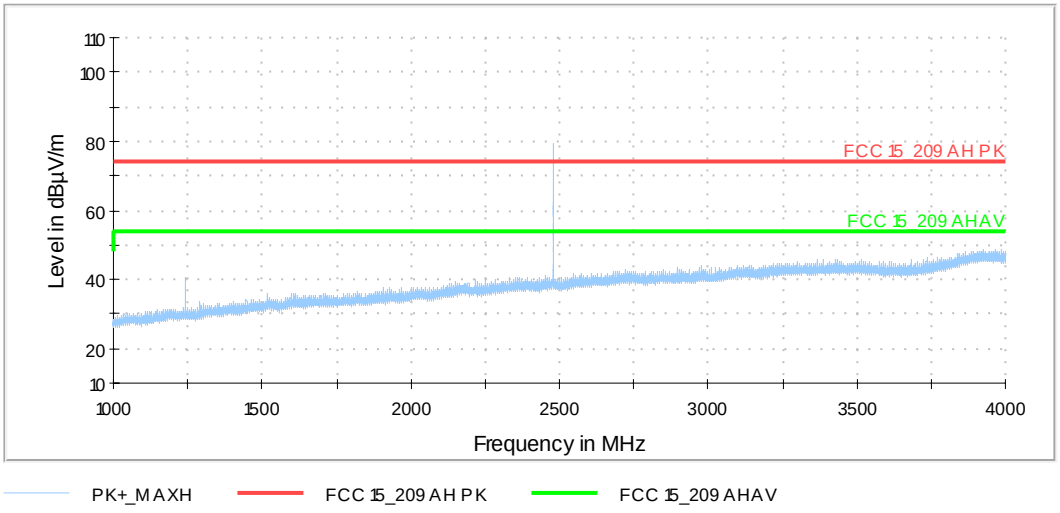
Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was powered with 28 V DC via a AC/DC switching adaptor power supply.

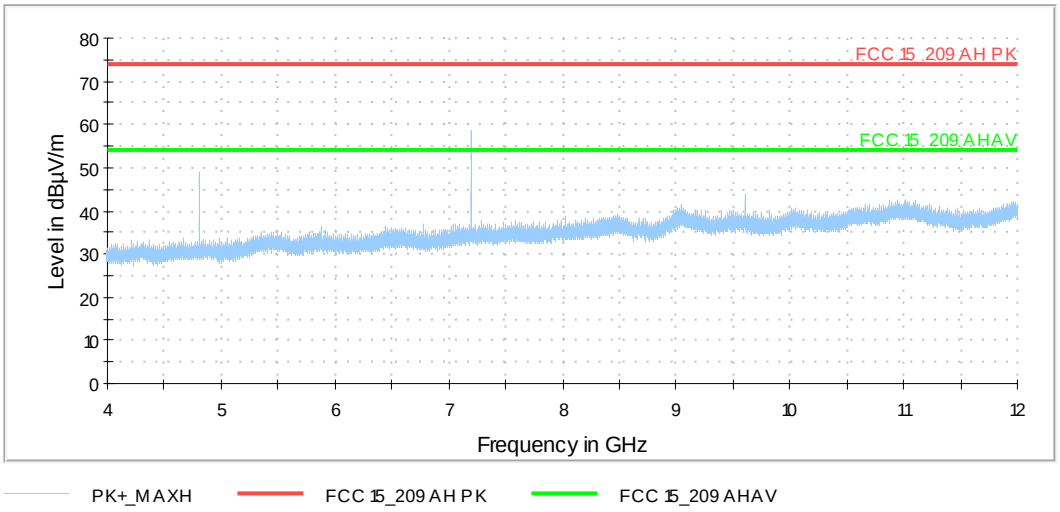
The correction factor is calculated as :
Antenna Factor [dB] + Cable Attenuation [dB] - Amplifier Gain [dB] + DCCF (if applicable) [dB]

The result Peak/Average is the result of Reading [dBµV/m] – Correction factor [dB]

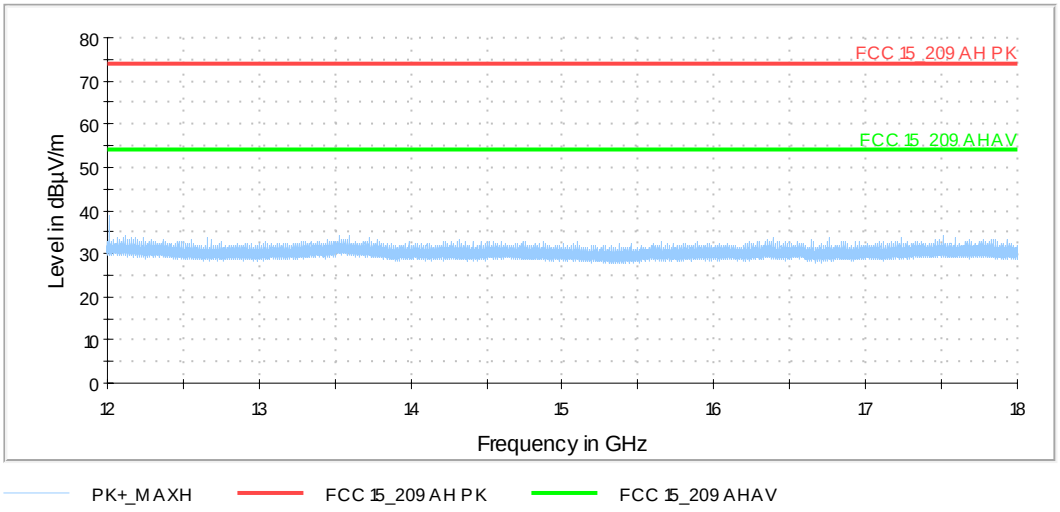
Spurious emissions from 1 – 4 GHz (Operation mode 3; Preliminary plot):



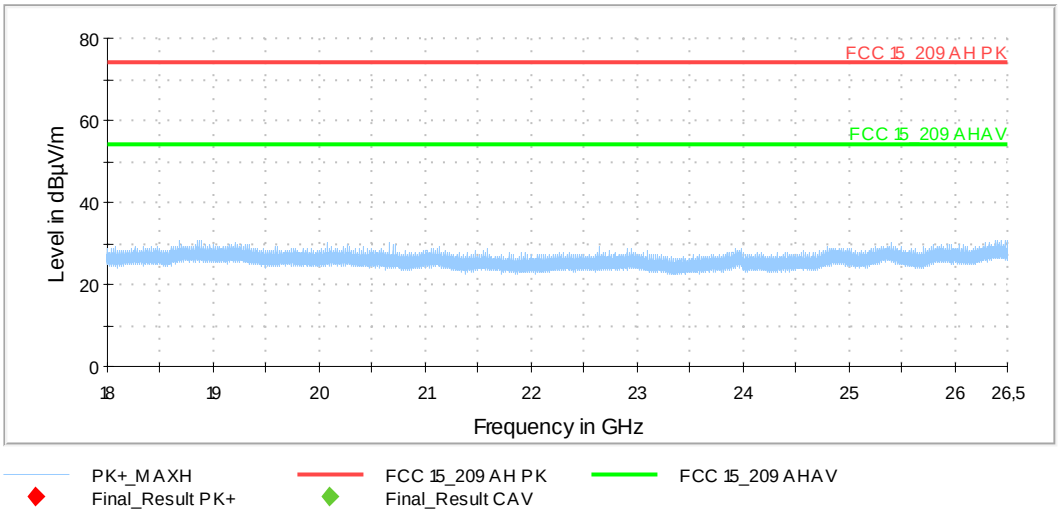
Spurious emissions from 4 - 12 GHz (Operation mode 1; Preliminary and final plot):



Spurious emissions from 12 - 18 GHz (Operation mode 1; Preliminary and final plot):



Spurious emissions from 18 – 26.5 GHz (Operation mode 1; Preliminary plot):



Test equipment (please refer to chapter 6 for details)
1 - 6, 8 - 9, 13, 16, 24 - 30

5.6.2.4 Final radiated emission measurement (9 kHz to 30 MHz)

No final measurement was carried out in the frequency range 9 kHz to 30 MHz.

5.6.2.5 Final radiated emission measurement (30MHz to 1 GHz)

Ambient temperature	22 °C
Relative humidity	45 %

Date	16.11.2018
Tested by	B. ROHDE

Position of EUT: The EUT was set-up on a non-conducting table of a 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 test setup photos.

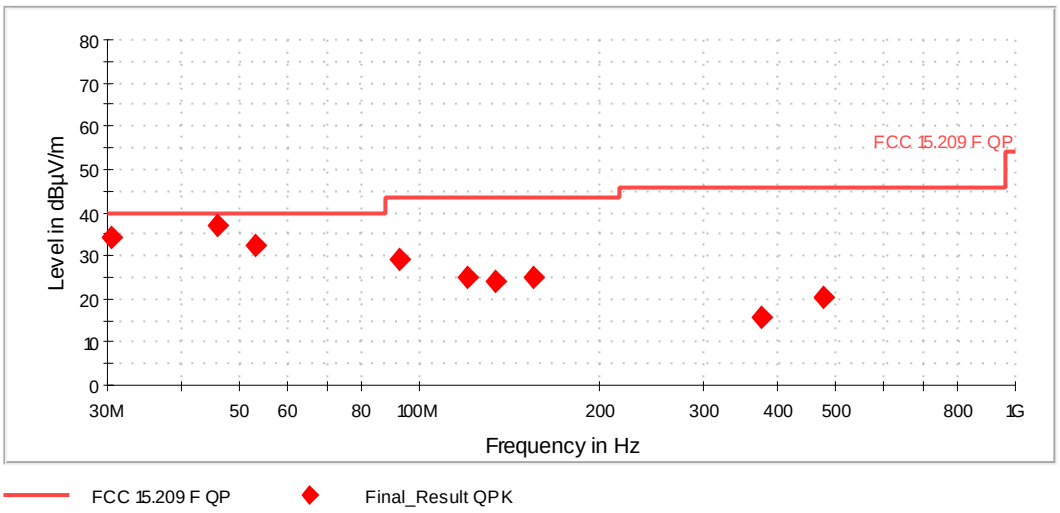
Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was powered with 28 V DC via a AC/DC switching adaptor power supply.

The correction factor is calculated as Antenna Factor [dB] + Cable Attenuation [dB] - Amplifier Gain [dB]

The result Quasipeak is the result of Reading [dBµV/m] – Correction factor [dB]

Spurious emissions from 30 MHz – 1 GHz (Operation mode 2; final plot):



Spurious Emissions (Operation mode 2) 30 MHz - 1 GHz								
Frequency [MHz]	QuasiPeak [dBµV/m]	Limit [dBµV/m]	Margin dB	Pol	Azimuth [°]	Height [cm]	Correction [dB]	Result
30.388000	34.3	40	5.7	V	319	100	27.0	Passed
45.762500	36.9	40	3.1	V	46	100	19.4	Passed
53.328500	32.2	40	7.8	V	1	100	14.8	Passed
92.710500	28.9	43.5	14.6	H	214	360	16.6	Passed
120.016000	25.0	43.5	18.5	V	148	142	18.9	Passed
134.469000	23.8	43.5	19.7	H	93	210	19.1	Passed
155.130000	25.1	43.5	18.4	V	138	100	18.7	Passed
374.932000	15.6	46	30.4	H	126	102	23.6	Passed
477.073000	20.3	46	25.7	H	137	177	26.8	Passed
Measurement uncertainty				+2.2 dB / -3.6 dB				

Test equipment (please refer to chapter 6 for details)
17 - 23

5.6.2.6 Final radiated emission measurement (above 1 GHz)

Ambient temperature	22 °C	Date	26.10.2018
Relative humidity	45 %	Tested by	B. ROHDE

Position of EUT: The EUT was set-up on a 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 test setup photos.

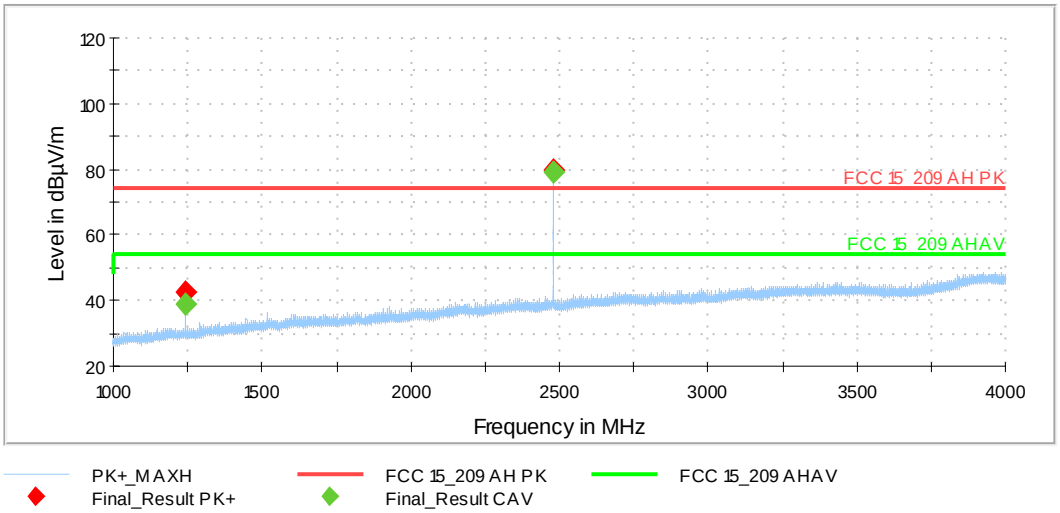
Test record: All results are shown in the following.

Supply voltage: During all measurements the EUT was powered with 28 V DC via a AC/DC switching adaptor power supply.

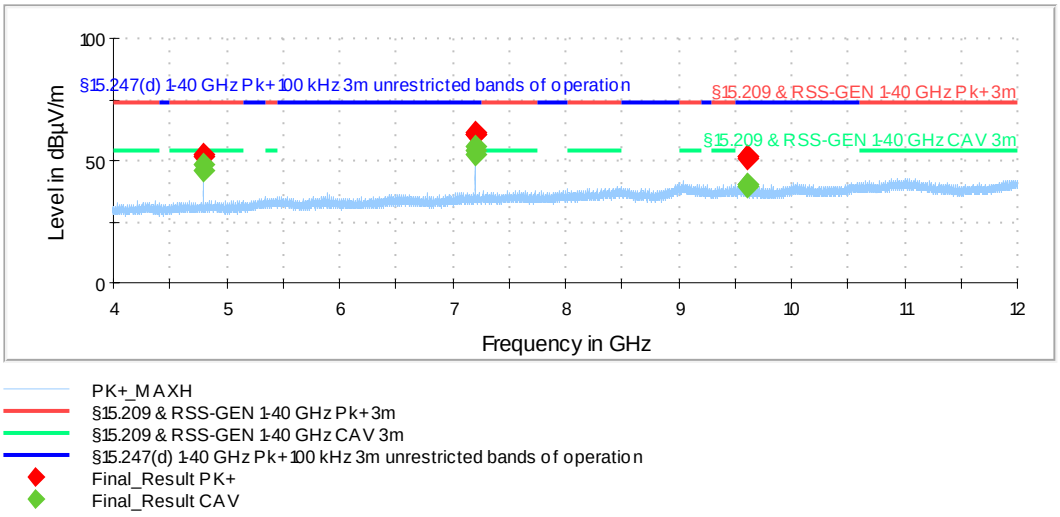
Resolution bandwidth: For all measurements a resolution bandwidth of 1 MHz was used.

Additional information: For simplification all values were compared to the restricted band limits, except in operation mode 1 in the frequency range 4 – 12 GHz.

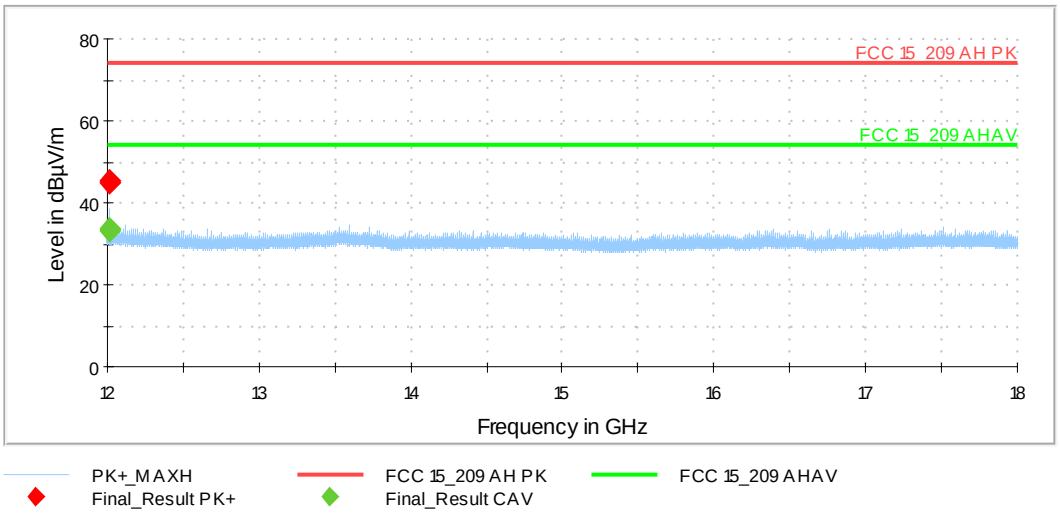
Spurious emissions from 1 – 4 GHz (Operation mode 3; final plot):



Spurious emissions from 4 - 12 GHz (Operation mode 1; final plot):



Spurious emissions from 12 - 18 GHz (Operation mode 1; final plot):



Spurious emissions from 18 – 26.5 GHz (Operation mode 3; final plot):

No final measurement done

Spurious Emissions 1 – 25 GHz (Operation mode 1)										
Frequency	Max Peak	Average	Limit	Margin	Pol	Azimuth	Elevation	Correction	Rest.	Result
[MHz]	[dBµV/m]	[dBµV/m]	[dBµV/m]	dB		[°]	[°]	[dB]	Band?	
1200.950000	40.5	---	74	33.5	V	227	90	26.0	Yes	Passed
1200.950000	---	35.4	54	18.6	V	227	90	26.2	Yes	Passed
2310.200000	53.0	---	74	21.0	V	54	0	33.0	Yes	Passed
2310.200000	---	30.3	54	23.7	V	54	0	33.2	Yes	Passed
4803.688889	52.2	---	74	21.8	V	342	90	-2.0	Yes	Passed
4803.688889	---	46.4	54	7.6	V	342	90	-1.8	Yes	Passed
4804.000000	52.0	---	74	22.0	H	0	150	-2.0	Yes	Passed
4804.000000	---	48.2	54	5.8	H	0	150	-1.8	Yes	Passed
7205.466667	60.3	---	74	13.7	H	161	150	4.0	No	Passed
7205.466667	---	53.0	54	1.0	H	161	150	4.2	No	Passed
7206.044444	60.5	---	74	13.5	V	85	150	4.0	No	Passed*
7206.533333	61.1	---	74	12.9	H	202	30	4.0	No	Passed*
9607.422222	51.4	---	74	22.6	H	156	90	8.0	No	Passed
9607.422222	---	40.4	54	13.6	H	156	90	8.2	No	Passed
9608.000000	50.9	---	74	23.1	V	120	120	8.0	No	Passed
9608.000000	---	39.4	54	14.6	V	120	120	8.2	No	Passed
9608.711111	51.3	---	74	22.7	V	315	120	7.0	No	Passed
9608.711111	---	40.4	54	13.6	V	315	120	7.2	No	Passed
12009.180000	45.4	---	74	28.6	V	0	60	12.0	Yes	Passed
12009.180000	---	33.7	54	20.3	V	0	60	12.2	Yes	Passed
12010.920000	44.8	---	74	29.2	V	62	120	12.0	Yes	Passed
12010.920000	---	33.5	54	20.5	V	62	120	12.2	Yes	Passed
Measurement uncertainty				+2.2 dB / -3.6 dB						

* In the non-restricted band of operation a RBW of 1 MHz instead of 100 kHz was used, in operation mode 1 the reference level is 89.4 dBµV, see 5.5.3; therefore the limit is 20 dB below the reference level, but attenuation below the general limits specified in §15.209(a) is not required.

Spurious Emissions 1 – 25 GHz (Operation mode 2)									
Frequency	Max Peak	Average	Limit	Margin	Pol	Azimuth	Elevation	Correction	Result
[MHz]	[dBµV/m]	[dBµV/m]	[dBµV/m]	dB		[°]	[°]	[dB]	
1219.950000	41.4	---	74	32.6	H	178	0	26.0	Passed
1219.950000	---	36.5	54	17.5	H	178	0	26.2	Passed
4880.000000	50.6	---	74	23.4	H	307	30	-2.0	Passed
4880.000000	---	46.4	54	7.6	H	307	30	-1.8	Passed
7319.466667	56.7	---	74	17.3	V	79	150	5.0	Passed
7319.466667	---	48.8	54	5.2	V	79	150	5.2	Passed
7320.444444	57.1	---	74	16.9	V	81	120	5.0	Passed
7320.444444	---	50.5	54	3.5	V	81	120	5.2	Passed
12199.080000	43.4	---	74	30.6	V	345	120	12.0	Passed
12199.080000	---	31.8	54	22.2	V	345	120	12.2	Passed
12200.820000	43.7	---	74	30.3	H	266	0	12.0	Passed
12200.820000	---	32.1	54	21.9	H	266	0	12.2	Passed
14640.840000	42.8	---	74	31.2	V	348	120	11.0	Passed
14640.840000	---	31.0	54	23.0	V	348	120	11.2	Passed
Measurement uncertainty				+2.2 dB / -3.6 dB					

Spurious Emissions 1 – 25 GHz (Operation mode 3)									
Frequency	Max Peak	Average	Limit	Margin	Pol	Azimuth	Elevation	Correction	Result
[MHz]	[dBµV/m]	[dBµV/m]	[dBµV/m]	dB		[°]	[°]	[dB]	
1239.950000	---	38.9	54	15.1	H	183	0	26.2	Passed
1239.950000	42.6	---	74	31.4	H	183	0	26.0	Passed
4959.955556	48.6	---	74	25.4	H	304	60	-2.0	Passed
4959.955556	---	43.6	54	10.4	H	304	60	-1.8	Passed
7440.488889	55.0	---	74	19.0	V	111	150	5.0	Passed
7440.488889	---	47.4	54	6.6	V	111	150	5.2	Passed
1239.950000	---	38.9	54	15.1	H	183	0	26.2	Passed
1239.950000	42.6	---	74	31.4	H	183	0	26.0	Passed
4959.955556	48.6	---	74	25.4	H	304	60	-2.0	Passed
4959.955556	---	43.6	54	10.4	H	304	60	-1.8	Passed
7440.488889	55.0	---	74	19.0	V	111	150	5.0	Passed
7440.488889	---	47.4	54	6.6	V	111	150	5.2	Passed
Measurement uncertainty				+2.2 dB / -3.6 dB					

Test equipment (please refer to chapter 6 for details)
1 - 6, 8 - 9, 13, 16, 24 - 30

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

Ambient temperature	22 °C
Relative humidity	45 %

Date	10.12.2018
Tested by	B. ROHDE

Position of EUT: Tabletop equipment, see photos in annex A of this test report

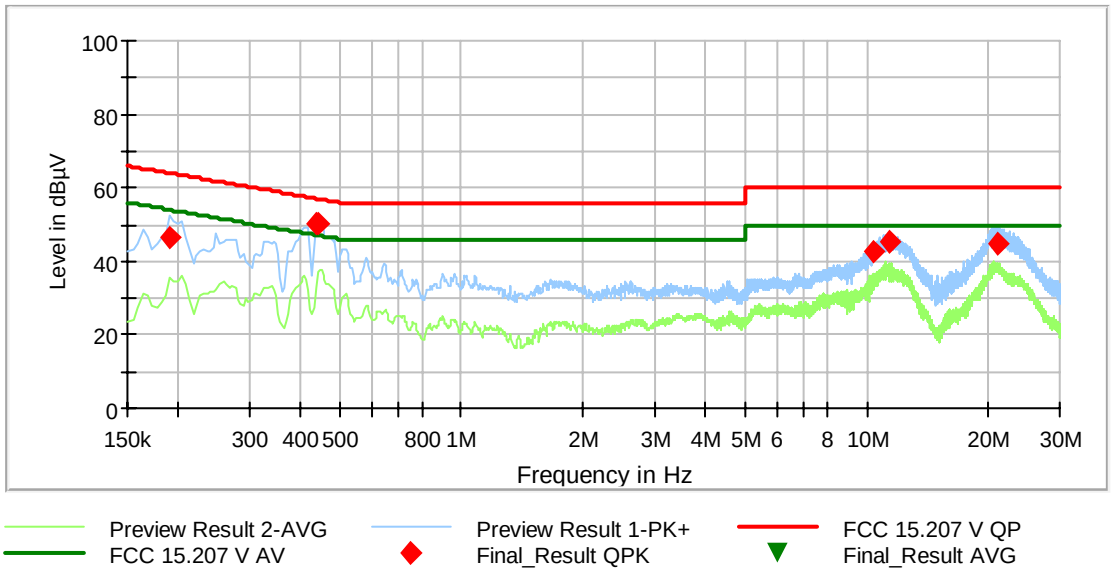
Cable guide: For detail information of test set-up and the cable guide refer to the photos in annex A of this test report.

Test record: All results are shown in the following.

Supply voltage: For the test the EUT was connected to RS485 converter box, the box itself was connected via USB to an ancillary laptop and on the other hand with a AC/DC power supply as delivered by the applicant. The power supply was plugged in the LISN and was powered with 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 " ▼

Conducted emissions on power supply (all operation modes):



Frequency [MHz]	QuasiPeak [dBµV]	Average [dBµV]	Limit [dBµV]	Margin [dB]	Meas. Time [ms]	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.190500	46.48	---	64.01	17.54	5000.0	9.000	L1	GND	9.8
0.439800	50.13	---	57.07	6.94	5000.0	9.000	L1	GND	9.9
0.440700	50.19	---	57.05	6.86	5000.0	9.000	L1	GND	9.9
10.375800	42.85	---	60.00	17.15	5000.0	9.000	L1	FLO	10.6
11.375700	45.39	---	60.00	14.61	5000.0	9.000	L1	GND	10.7
21.087600	45.05	---	60.00	14.95	5000.0	9.000	L1	FLO	10.9

Test: Passed

Test equipment (please refer to chapter 6 for details)
21; 31 – 34

6 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	13.02.2018	02.2019
2	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
3	RF-cable No.3	Sucoflex 106B	Suhner	0563/6B / Kabel 3	480670	Calibration not necessary	
4	Multiple Control Unit	MCU	Maturo GmbH	MCU/043/971107	480832	Calibration not necessary	
5	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	09.10.2017	10.2020
6	RF-Cable No. 40	Sucoflex 106B	Suhner	0708/6B / Kabel 40	481330	Calibration not necessary	
7	HF-Cable	Sucoflex 104	Huber+Suhner	517406	482391	Calibration not necessary	
8	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	22.06.2017	06.2019
9	Antenna mast	AS615P	Deisel	615/310	480187	Calibration not necessary	
10	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
11	loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	19.12.2017	12.2018 *
12	Antenna (Bilog)	CBL6112B	Schaffner EMV GmbH (-Chase)	2688	480328	19.06.2017	06.2020
13	Software	WMS32	Rohde & Schwarz		481800	Calibration not necessary	
14	RF-cable No.36	Sucoflex 106B	Suhner	0587/6B / Kabel 36	480865	Calibration not necessary	
15	HF-Cable	Sucoflex 104	Huber+Suhner	517402	482392	Calibration not necessary	
16	Positioners	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
17	Open area test site M6	OATS M6	Phoenix Contact	-	480085	Calibration not necessary	
18	Antenna mast	MA240-0	Inn-Co GmbH	MA240-0/030/6600603	480086	Calibration not necessary	
19	Turntable	DS412	Deisel	412/316	480087	Calibration not necessary	
20	Controller	HD100	Deisel	100/349	480139	Calibration not necessary	
21	Software	EMC32	Rohde & Schwarz	100061	481022	Calibration not necessary	
22	Antenna (Bilog)	CBL6111D	Schaffner Elektrotest GmbH / Teseq GmbH	25761	480894	19.10.2017	10.2020
23	Measuring receiver	ESR7	Rohde & Schwarz	101939	482558	19.09.2017	09.2019
24	standard gain horn antenna	18240-20	Flann Microwave	483	480294	Calibration not necessary	
25	standard gain horn antenna	20240-20	Flann Microwave	411	480297	Calibration not necessary	
26	Microwave cable 2m	Insulated Wire Inc.	Insulated Wire	KPS-1533-800-KPS	480302	Calibration not necessary	
27	Preamplifier 100 MHz - 13 GHz	JS3-00101200-23-5A	MITEQ Hauppauge N.Y.	681851	480337	10.07.2018	07.2020
28	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ Hauppauge N.Y.	658697	480342	10.07.2018	07.2020

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
29	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ Hauppauge N.Y.	571667	480343	10.07.2018	07.2020
30	High pass Filter	WHKX4.0/18G-8SS	Wainwright Instruments GmbH	1	480587	Calibration not necessary	
31	LISN	NSLK8128	Schwarzbeck	8128161	480138	13.03.2018	02.2020
32	Shielded chamber M4	B83117-S1-X158	Siemens	190075	480088	Calibration not necessary	
33	EMI Receiver / Spectrum Analyzer	ESIB 26	Rohde & Schwarz	100292	481182	28.02.2018	02.2020
34	Transient Filter Limiter	CFL 9206A	Teseq GmbH	38268	481982	14.03.2018	03.2020
35	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	19.12.2017	12.2020

* The test was conducted while the antennas calibration was still valid

7 Report History

Report Number	Date	Comment
F181436E1	28.05.2019	Initial Test Report

8 List of Annexes

Annex A	Test Setup Photos	8 pages
Annex B	External Photos	5 pages
Annex C	Internal Photos	6 pages