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Test Report

Report Number: F140852E1

Applicant:

Trimble Kaiserslautern GmbH

Manufacturer:

Trimble Navigation Limited

Equipment under Test (EUT):

TI RF Module

Laboratory accredited by
Deutsche Akkreditierungsstelle GmbH (DAkkS)
in compliance with DIN EN ISO/IEC 17025
under the Reg. No. D-PL-17186-01-02,
FCC Test site registration number 90877 and
Industry Canada Test site registration IC3469A-1

REFERENCES

[1] **ANSI C63.4-2009** American National Standard for Methods of Measuring of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

[2] **FCC CFR 47 Part 15 (July 2014)** Radio Frequency Devices

[3] **Publication Number 558074 (June 2014)** DTS Meas Guidance v03r02

[4] **RSS-210 Issue 8 (December 2010)** Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment

[5] **RSS-Gen Issue 3 (December 2010)** General Requirements and Bluetooth module Information for the Certification of Radiocommunication Equipment

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		8 September 2014
	Name	Signature	Date
Authorized reviewer:	Bernd STEINER		8 September 2014
	Name	Signature	Date

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1 IDENTIFICATION

1.1 Applicant

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1.2 Manufacturer

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Manufacturer represented during the test by the following person:	None

1.3 Test laboratory

The tests were carried out at: **PHOENIX TESTLAB GmbH**
Königswinkel 10
32825 Blomberg
Germany

accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under the Reg. No. D-PL-17186-01-02, FCC Test site registration number 90877 and Industry Canada Test site registration IC3469A-1.

1.4 EUT (Equipment Under Test)

Test object: *	ZigBee Module
Type: *	TI RF Module
FCC ID: *	**PWR-TK14RF**
IC: *	**4131A-TK14RF**
Serial number: *	97012-00 000033
PCB identifier: *	PCB RF TI
Hardware version: *	Rev. B
Software version: *	-

Channel 11	RX:	2405 MHz	TX:	2405 MHz
Channel 12	RX:	2410 MHz	TX:	2410 MHz
Channel 13	RX:	2415 MHz	TX:	2415 MHz
Channel 14	RX:	2420 MHz	TX:	2420 MHz
Channel 15	RX:	2425 MHz	TX:	2425 MHz
Channel 16	RX:	2430 MHz	TX:	2430 MHz
Channel 17	RX:	2435 MHz	TX:	2435 MHz
Channel 18	RX:	2440 MHz	TX:	2440 MHz
Channel 19	RX:	2445 MHz	TX:	2445 MHz
Channel 20	RX:	2450 MHz	TX:	2450 MHz
Channel 21	RX:	2455 MHz	TX:	2455 MHz
Channel 22	RX:	2460 MHz	TX:	2460 MHz
Channel 23	RX:	2465 MHz	TX:	2465 MHz
Channel 24	RX:	2470 MHz	TX:	2470 MHz
Channel 25	RX:	2475 MHz	TX:	2475 MHz
Channel 26	RX:	2480 MHz	TX:	2480 MHz

Fulfills ZigBee specification: *	802.15.4					
Antenna type: *	PCB Antenna					
Antenna gain: *	None*[1]					
Antenna connector: *	None (internal antenna)					
Power supply - EUT	3.3 V DC					
Power supply Host	U_{nom}=	3 V DC	U_{min}=	1.8 V DC	U_{max}=	3.6 V DC
Type of modulation: *	DSSS (Q-PSK)					
Operating frequency range:*	2405 MHz to 2480 MHz					
Number of channels: *	16					
Temperature range: *	-20 °C to +50 °C					
Lowest / highest internal clock frequency: *	8 MHz / 32 MHz					

* declared by the applicant.
*[1] all measurements were performed as radiated measurements, therefore no antenna gain was determined

Table 1 Antenna specification

Antenna name	**Manufacturer**	**Type**	**Comment**	**Gain** [dBi]
Manufacture specific antenna	Trimble Navigation Limited	PCB antenna	None	-

The following external I/O cables were used:

Identification	Length
DC power cable	2 m *

*: Length during the test if not other specified.

1.5 Dates

Date of receipt of test sample:	14 June 2014
Start of test:	30 June 2014
End of test:	2 July 2014

2 OPERATIONAL STATES

The equipment under test (EUT) is a ZigBee mode module connected on to a carrier board. The ZigBee module has only one internal PCB antenna and no antenna ports.

The tests were carried out with an unmodified sample of the EUT. All tests were performed as radiated tests. Therefore the radiation was am EIRP value and the antenna gain is included in the measurement result.

The carrier board was equipped with a special firmware, which allowed the user to set the module into a test mode. No additional laptop was needed, since the carrier board provided a number of buttons and an LCD display to control the test modes of the module.

During the tests, the test samples were powered with 3 V via the power supply connection of the carrier board from a laboratory power supply.

Since the module only had one modulation and data rate, only the lowest, highest and the middle channel of the supported channels were tested. The table below shows the tested channels and the according frequencies.

Operation mode	Description of the operation mode	ZigBee channel	Modulation
1	Continuous transmitting on 2405 MHz	11	Q-PSK
2	Continuous transmitting on 2440 MHz	18	Q-PSK
3	Continuous transmitting on 2480 MHz	26	Q-PSK

Preliminary tests were performed to find worst-case configuration and position. The radiated emission measurements were carried out in the orthogonal direction that emits the highest spurious emission levels. The figure below shows the setup that produced the worst case emission, in which all of the following test are performed.

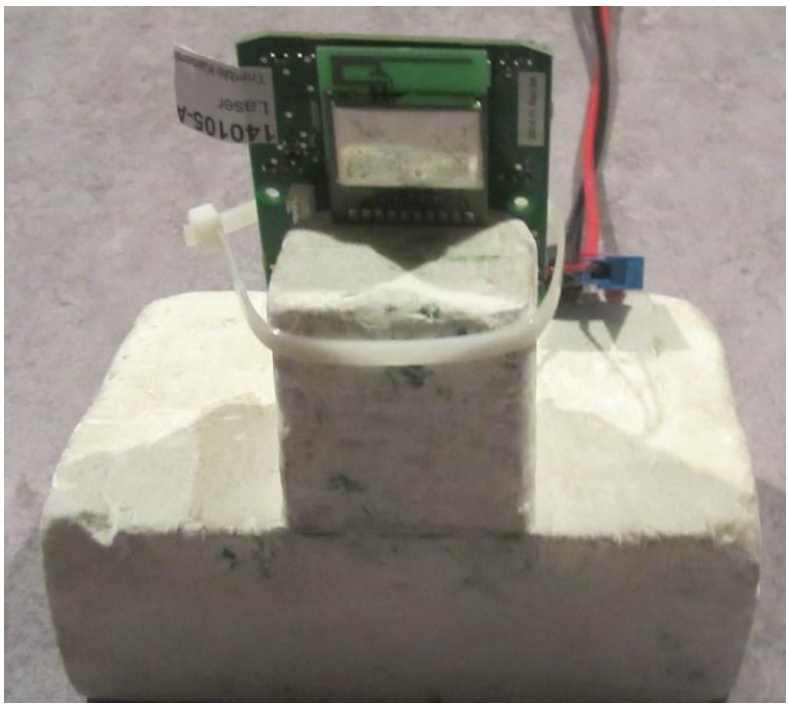


Figure 1 Worst case emission setup

The following test modes were adjusted during the tests:

Test items	Operation mode
Maximum Peak Output Power	1 - 3
DTS Bandwidth	1 - 3
Peak Power Spectral Density	1 - 3
Band Edge Compliance	1, 3
Maximum Unwanted Emissions	1 - 3
Conducted emissions on power supply lines	Normal operation mode

3 ADDITIONAL INFORMATION

None

4 OVERVIEW

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS 210, Issue 8 [4] or RSS-Gen, Issue 3 [5]	Status	Refer page
Maximum Peak Output Power	2400.0 - 2483.5	15.247 (b) (3), (4)	A8.4 (4) [4]	Passed	13 et seq
DTS Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	A8.2 (a) [4]	Passed	15 et seq
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	A8.2 (b) [4]	Passed	17 et seq
Band edge compliance	2400.0 - 2483.5	15.247 (d)	A8.5 [4]	Passed	19 et seq.
Radiated emissions (transmitter)	0.009 – 26,500	15.247 (d) 15.205 (a) 15.209 (a)	A8.5 [4] 7.2.2 [5], 2.5 [4]	Passed	24 et seq.
Conducted emissions on supply line	0.15 - 30	15.207 (a)	7.2.4 [5]	Passed	38 et seq.

5 TEST RESULTS

5.1 Duty cycle

5.1.1 Method of measurement

The measurement was performed as a radiated measurement. Please refer to 5.6.2 for the test setup for the radiated measurements.

Acceptable measurement configurations

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

The method described in chapter 6.0 b)of document [3] 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:

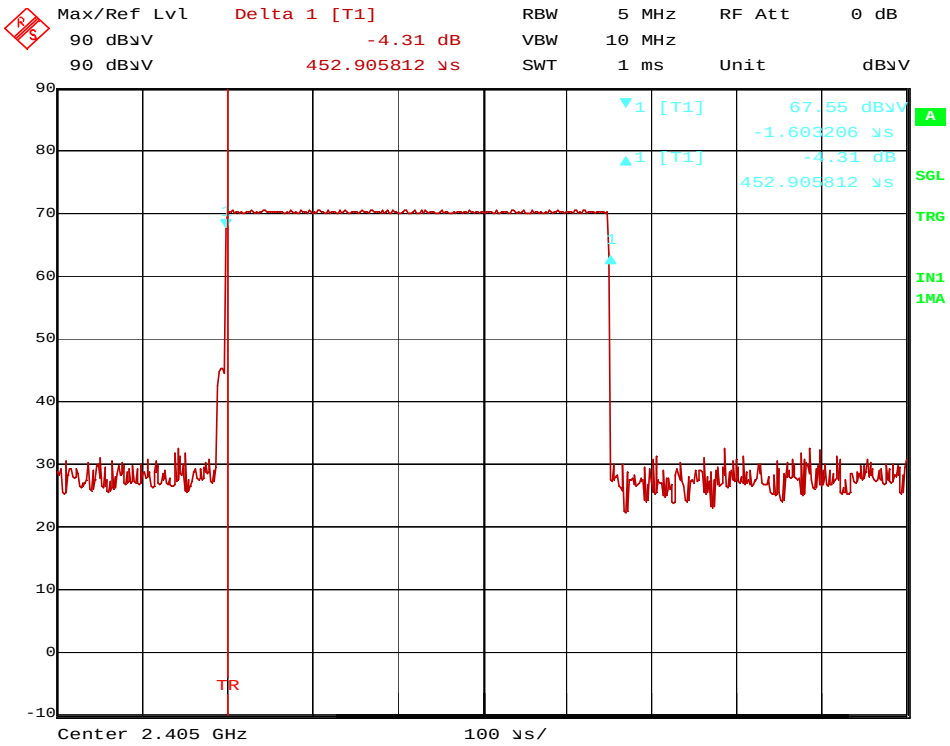
The zero-span mode on a spectrum analyzer or EMI receiver if the response time and spacing between bins on the sweep are sufficient to permit accurate measurements of the on and off times of the transmitted signal.

- 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 %

140852_Low_DutyCycle_M1: Duty cycle measurement 1 on channel 11:

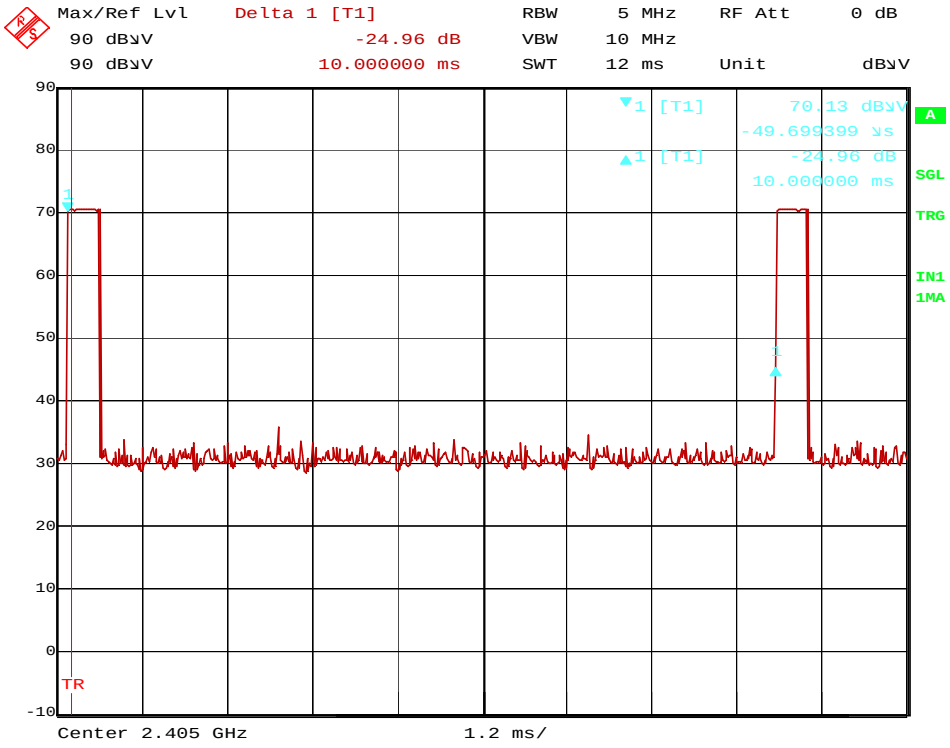


$$T_{TX} = 452.9\mu s \qquad (1)$$

$$\frac{50}{T_{TX}} = \frac{50}{452.9\mu} = 110.4kHz \le RBW \le VBW \qquad (2)$$

Measurement Points 500 → 100 µs = 50 measurement points → Signal has 226 measurement points (and fulfils the requirement of at least 100 Points resolution for the signal)

140852_Low_DutyCycle_M1: Duty cycle measurement 1 on channel 11:



$$T_{TX\_On} = 452.9\mu s \quad (3)$$

$$T_{TX\_Period} = 10ms \quad (4)$$

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.

$$x = \frac{452.9\mu s}{10ms} = 0.04529 = 4.5\% \quad (5)$$

Correction factor: $10 \cdot \log\left(\frac{1}{x}\right) = 10 \cdot \log\left(\frac{1}{0.04529}\right) = 10 \cdot \log\left(\frac{1}{0.04529}\right) = 13.4dB$ (6)

Therefore, for average measurements a correction factor of 13.4 dB is use in all applicable tests.

TEST EQUIPMENT USED FOR THE TEST:

6, 8 - 11, 13, 17, 18, 22

5.2 Maximum peak conducted output power

5.2.1 Method of measurement

The measurement was performed as a radiated measurement. Please refer to 5.6.2 for the test setup for the radiated measurements.

Acceptable measurement configurations

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

The method described in chapter 9.1.1 of document [3] was used to perform the following test.

The procedure refers to conducted measurements, but section 3.0 in [3] also accepts radiated tests to demonstrate compliance.

This procedure shall be used when the measurement instrument has available a resolution bandwidth that is greater than the DTS bandwidth.

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

To convert the radiated measurement results into conducted values the following formula form ANSI C63.10 was used:

$$P = \frac{(Ed)^2}{30G} \qquad (7)$$

Where

P is the power, in W
E is the measured peak field strength, in V/m
d is the distance at which the measurement was made, in m
G is the numeric gain of the radiating element

Because the gain of the radiating element is not known, the EIRP may be calculated from the measured field strength, by using G = 1 in (7).

For reason of simplification, not ERP but EIRP will be compared to the applicable maximum peak conducted output power limits (which is a stricter limit)

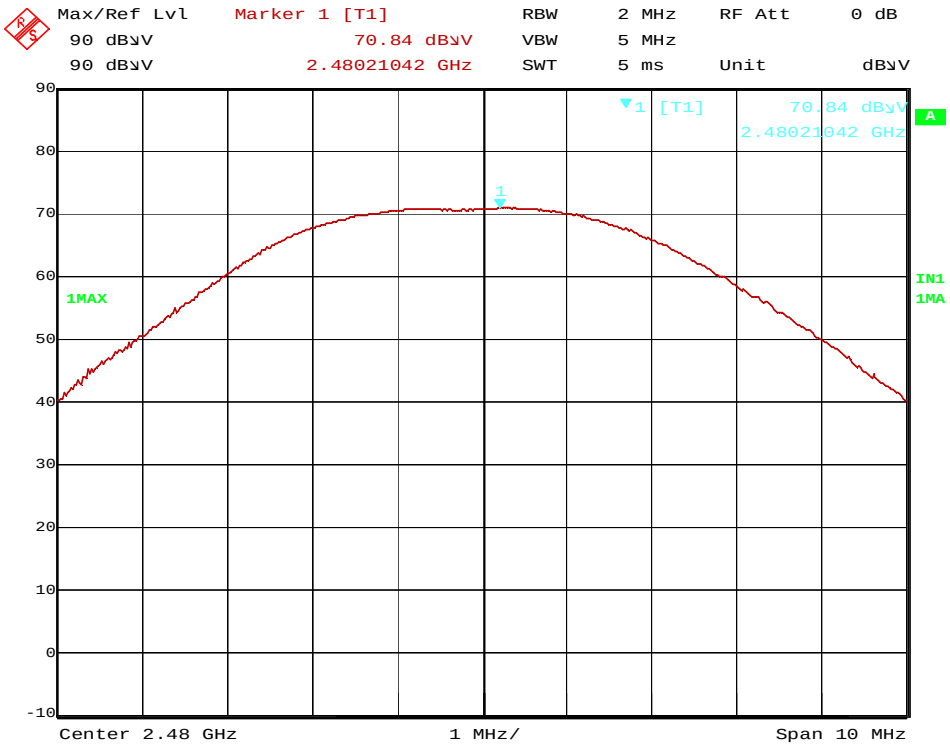
5.2.2 Test results

Ambient temperature	22 °C

Relative humidity	40 %

Only the plot of the worst case emission is submitted below.

140852_Up_Pwr: Maximum Peak Output Power, channel 26:



Channel	Frequency [MHz]	reading [dBµV]	Transducer incl cable loss [dB/m]	Measured field strength [dBµV/m]	Calculated conducted Power [dBm]	Margin [dB]	Peak power limit [dBm]
11	2405	70.5	31.3	101.8	5.3*	14.7	30
18	2440	70.7	31.4	102.1	5.5*	14.5	30
26	2480	70.8	31.4	102.2	5.6*	14.4	30
Measurement uncertainty			+2.2 dB / -3.6 dB				

*With an antenna gain of 0 dB respected

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

6, 8 - 11, 13, 17, 18, 22

5.3 DTS Bandwidth

5.3.1 Method of measurement

The measurement was performed as a radiated measurement. Please refer to 5.6.2 for the test setup for the radiated measurements.

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

The procedure refers to conducted measurements, but section 3.0 in [3] also accepts radiated tests to demonstrate compliance.

The relating measurements were carried out in a conducting manner. Therefore, the antenna connector was directly connected to a spectrum analyser. The measurement procedure refers to part 8.0 of document [3].

- 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.

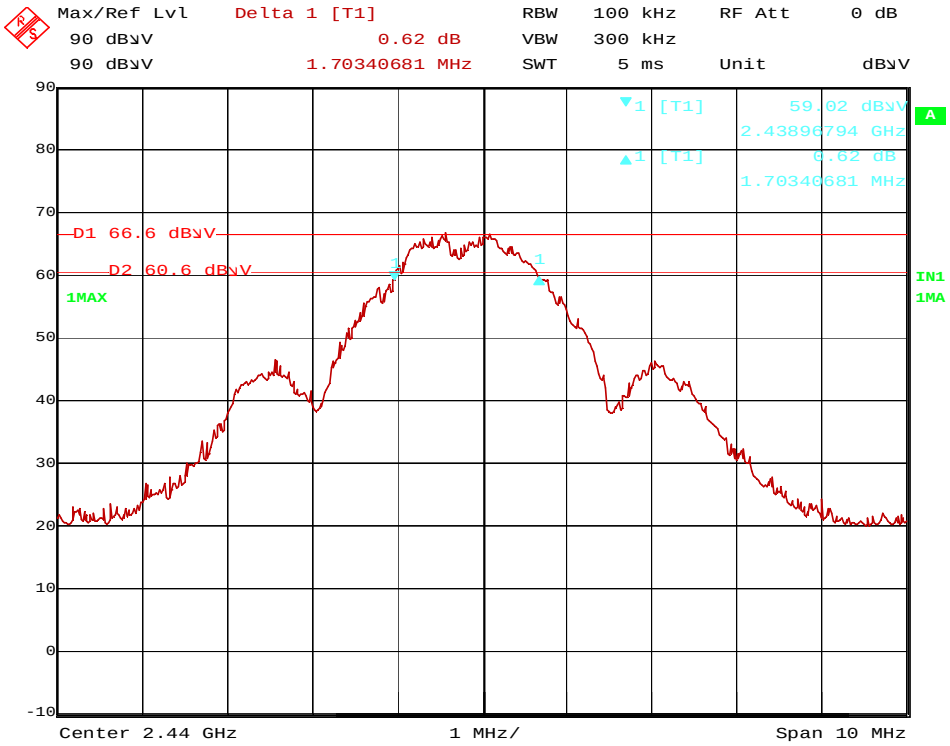
Since this is a relative measurement, the absolute level of the emission does not matter. Therefore no calculation from radiated to conducted values is performed.

5.3.2 Test result

Ambient temperature	22 °C	Relative humidity	40 %

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.

140852_Mid_6dB_BW: DTS Bandwidth, channel 18:



Operation Mode	Center Frequency [MHz]	Minimum 6-dB Bandwidth Limit [MHz]	6 dB Bandwidth [MHz]	Result
1	2412	0.5	1.744	Passed
2	2437	0.5	1.703	Passed
3	2462	0.5	1.744	Passed
Measurement uncertainty		+2.2 dB / -3.6 dB		

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

6, 8 - 11, 13, 17, 18, 22

5.4 Peak Power Spectral Density

5.4.1 Method of measurement

The measurement was performed as a radiated measurement. Please refer to 5.6.2 for the test setup for the radiated measurements.

Acceptable measurement configurations

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

The procedure refers to conducted measurements, but section 3.0 in [3] also accepts radiated tests to demonstrate compliance.

The method described in chapter 10.2 of document [3] was used to perform the following test.

- 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.

To convert the radiated measurement results into conducted values the following formula form ANSI C63.10 was used:

$$P = \frac{(Ed)^2}{30G} \qquad \textbf{(8)}$$

Where

P is the power, in W
E is the measured peak field strength, in V/m
d is the distance at which the measurement was made, in m
G is the numeric gain of the radiating element

Because the gain of the radiating element is not known, the EIRP may be calculated from the measured field strength, by using G = 1 in **(8)**.

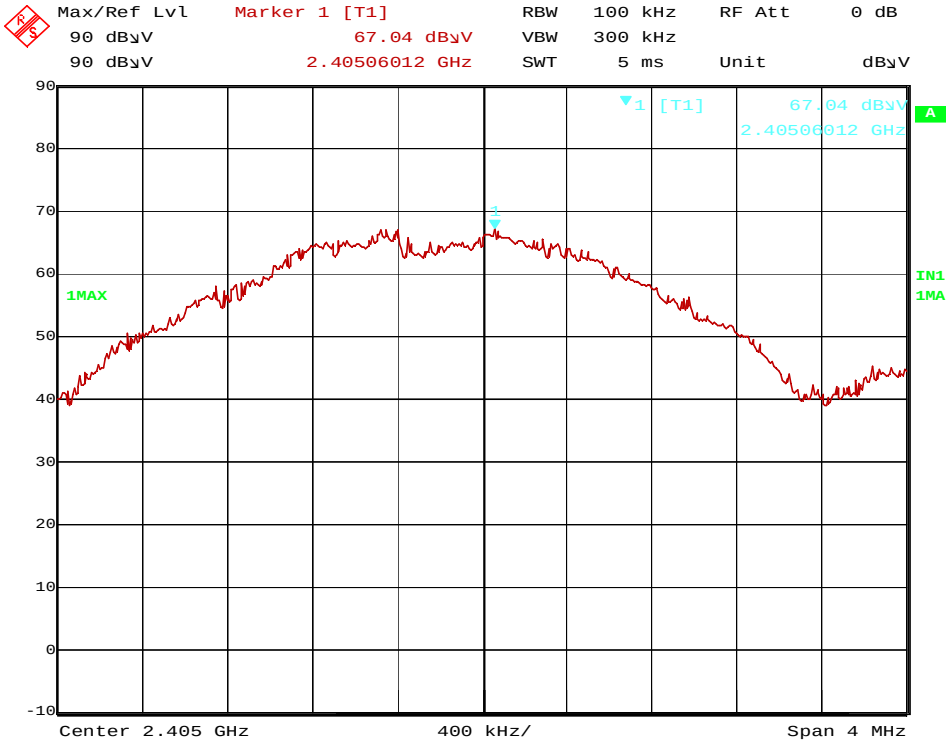
The resulting value is already an EIRP value, therefore the antenna gain will not be considered.

5.4.2 Test result

Ambient temperature	22 °C	Relative humidity	40 %

The following results were measured at the antenna port of the EUT. The plot shows an exemplary measurement result. Since there is no worst case, a result is randomly chosen.

140852_Low_PSD.wmf: Power Spectral Density, channel 11:



Operation Mode	Peak Frequency [MHz]	Power Spectral Density Reading [dBµV/100kHz]	Transducer dB/m	Power Spectral Density Field strength [dBµV/m/100 kHz]	Array Gain [dB]	Power Spectral Density Level [dBm/100kHz]	Power Spectral Density Limit [dBm/3kHz]	Margin [dB]	Result
1	2405.060	67.0	31.3	98.3	0.00	1.8	8	6.2	Passed
2	2439.555	67.0	31.4	98.4	0.00	1.8	8	6.2	Passed
3	2479.515	67.0	31.4	98.4	0.00	1.8	8	6.2	Passed
Measurement uncertainty			+2.2 dB / -3.6 dB						

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:

6, 8 - 11, 13, 17, 18, 22

5.5 Band-edge compliance

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

The relating measurements were carried out in a radiated manner. Radiated tests must conform to the test site requirements and utilize maximization procedures. Please refer to 5.6.2 for the test setup for the radiated measurements.

The measurement procedure refers to part 11.2 and 11.3 of document [3].

Measurement Procedure Reference – Reference Level:

- Set instrument center frequency to DTS channel center frequency.
- Set the span to ≥ 1.5 times the DTS Bandwidth.
- RBW = 100 kHz.
- VBW ≥ 3 x RBW.
- 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 ≥ 3 x RBW.
- 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.

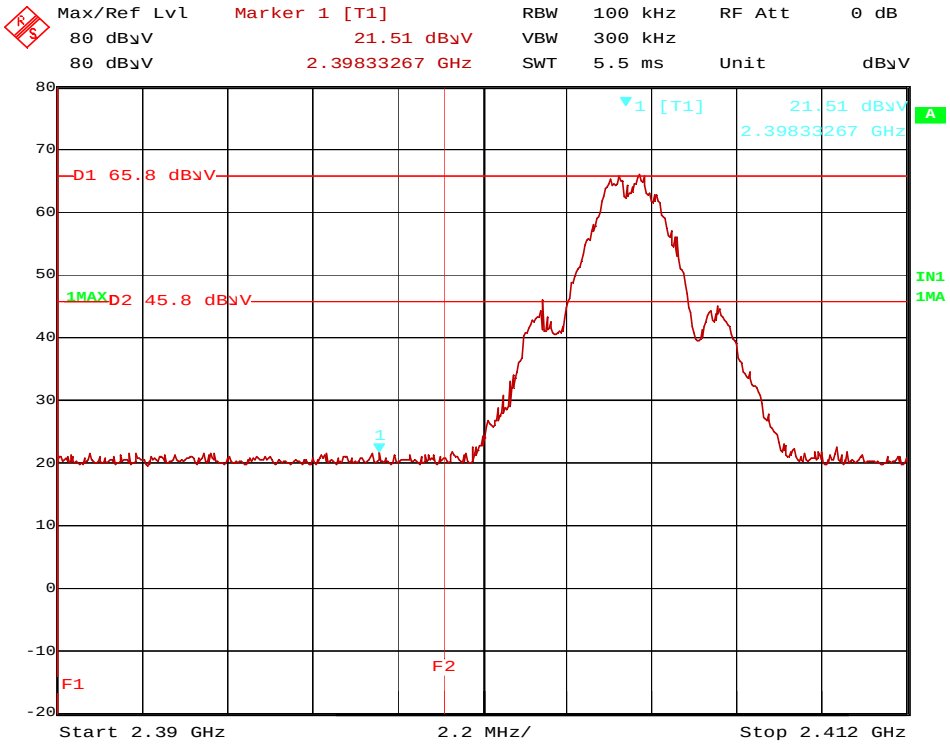
Both, the in-band-emission and the unwanted emission were be encompassed by the span. After trace stabilization, the maximum peak was be determined by a peak detector and the value was marked by an appropriate limit line. The second limit line, which is 20 dB below the first, marks the limit for the 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))

Ambient temperature	22 °C	Relative humidity	40 %

140852_Low_BandEdge.wmf: radiated band-edge compliance, channel 11:



Operation Mode	channel	Frequency [MHz]	Band-Edge	Reference Level [dµV]	Limit [dµV]	Unwanted Emission Frequency MHz	Unwanted Emission Value [dµV]	Margin [dB]
1	1	2405	low	65.8	45.8	2398.333	21.5	24.3
Measurement uncertainty				+2.2 dB / -3.6 dB				

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
6, 8 - 11, 13, 17, 18, 22

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

The relating measurements were carried out in a radiated manner. Please refer to 5.6.2 for the test setup and measurement procedures for the radiated measurements.

The normal measurement procedure for measurement of the peak value in restricted bands was used also at the band edges.

For the measurement of the average power, the integration method described in section 13.3.2 in [3] was used:

If continuous transmission of the EUT (i.e., duty cycle ≥ 98 percent) cannot be achieved and the duty cycle is constant (i.e., duty cycle variations are less ± 2 percent), then the following procedure may be used to measure the average power of unwanted emissions within 2 MHz of the authorized band edge:

1. The EUT shall be configured to operate at the maximum achievable duty cycle.
2. Measure the duty cycle, x, of the transmitter output signal as described in section 6.0.
3. Set instrument center frequency to the frequency of the emission to be measured.
4. Set span to 2 MHz
5. RBW = 100 kHz.
6. VBW ≥ 3 x RBW.
7. Detector = RMS, if span/(# of points in sweep) ≤ (RBW/2). Satisfying this condition may require increasing the number of points in the sweep or reducing the span. If this condition cannot be satisfied, then the detector mode shall be set to peak.
8. Averaging type = power (i.e., RMS).
9. Sweep time = auto.
10. Perform a trace average of at least 100 traces.
11. Compute the power by integrating the spectrum over 1 MHz using the instrument's band power measurement function with band limits set equal to the emission frequency (femission) ± 0.5 MHz. If the spectrum analyzer does not have a band power function, then sum the amplitude levels (in power units) at 100 kHz intervals extending across the 1 MHz spectrum defined by femission ± 0.5 MHz.
12. A correction factor shall be added to the measurement results prior to comparing to the emission limit in order to compute the emission level that would have been measured had the test been performed at 100 percent duty cycle. The correction factor is computed as follows:
    a. correction factor is 10 log(1/x), where x is the duty cycle.

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

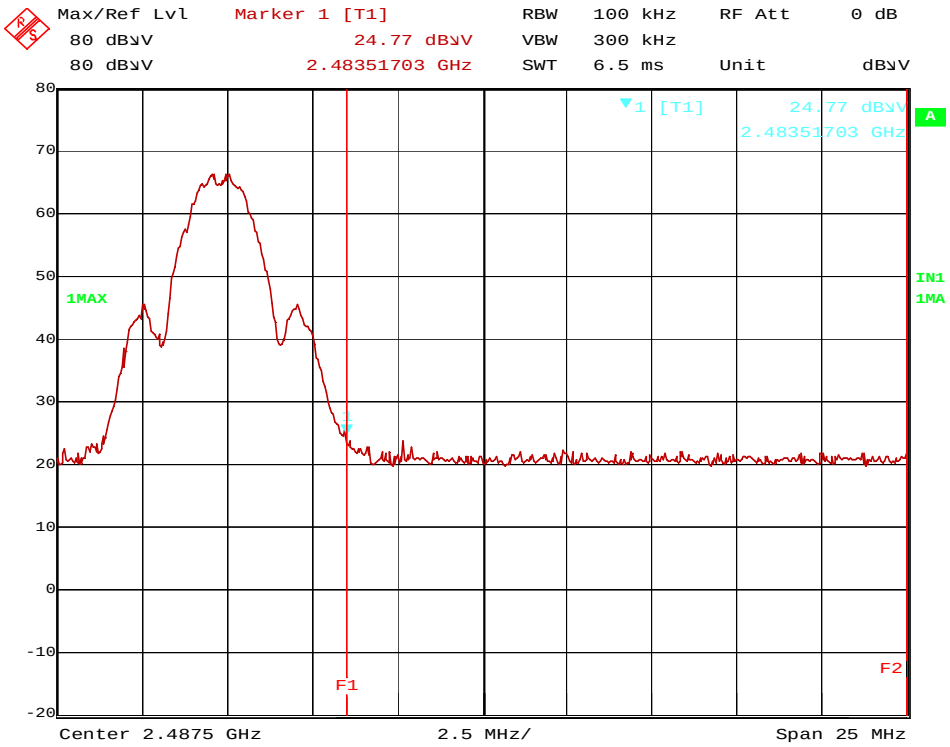
The duty cycle correction factor, as described in 5.1.2, is 13.4 dB.

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

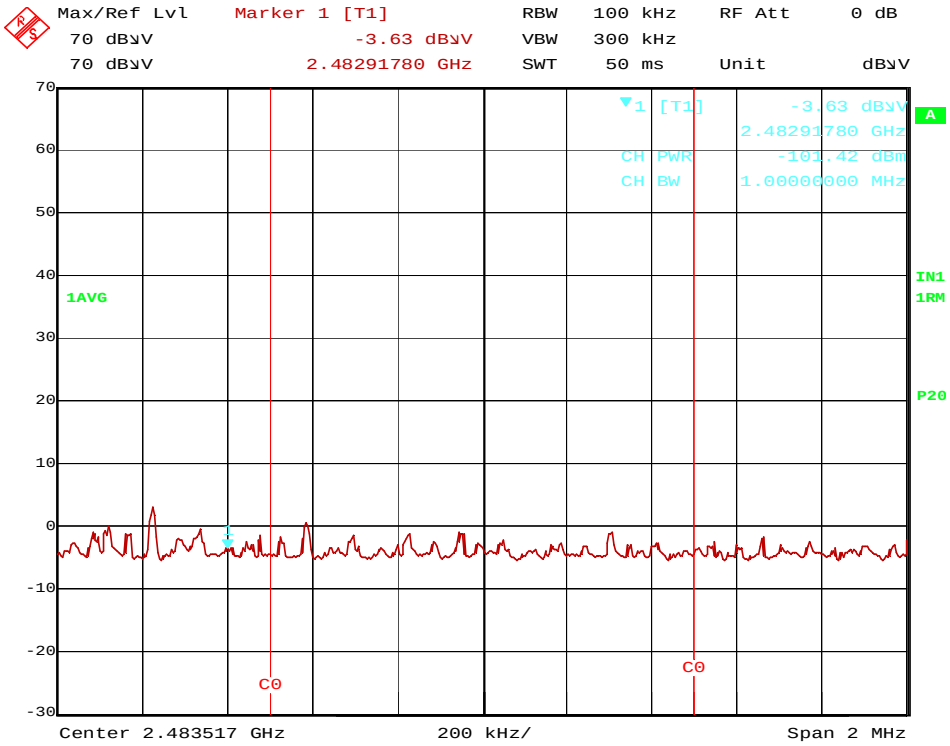
Ambient temperature	22 °C	Relative humidity	40 %

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

140852_Up_BandEdge.wmf: radiated band-edge compliance - Prescan, channel 26:



140852_Up_BandEdgeAvgge.wmf: radiated band-edge compliance – average measuerment, channel 26:



The resulting average value is -101.42dBm @ 50 Ohm = 5.57dBµV

Transmitter operates at the lower 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.	Pos.
2483.517	68.4	74.0	5.6	36.0	28.6	0.0	3.8	150	Hor.	1
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.	Pos.
2483.517	51.4	54.0	2.6	5.6	28.6	0.0	3.8	150	Hor.	2
Measurement uncertainty				+2.2 dB / -3.6 dB						

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
6, 8 - 11, 13, 17, 18, 22

5.6 Maximum unwanted emissions

5.6.1 Method of measurement (radiated emissions)

The radiated emission measurement is subdivided into four stages.

- A preliminary measurement carried out in a fully anechoic chamber with a fixed antenna height in the frequency range 1 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 1 GHz to 110 GHz.
- A final measurement carried out on an outdoor test side without reflecting ground plane and a fixed antenna height in the frequency range 1 MHz 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 final measurement carried out in a fully anechoic chamber with a variable antenna distance and height in the frequency range 1 GHz to 110 GHz.

All measurements will be carried out with the EUT working on the middle of the assigned frequency band.

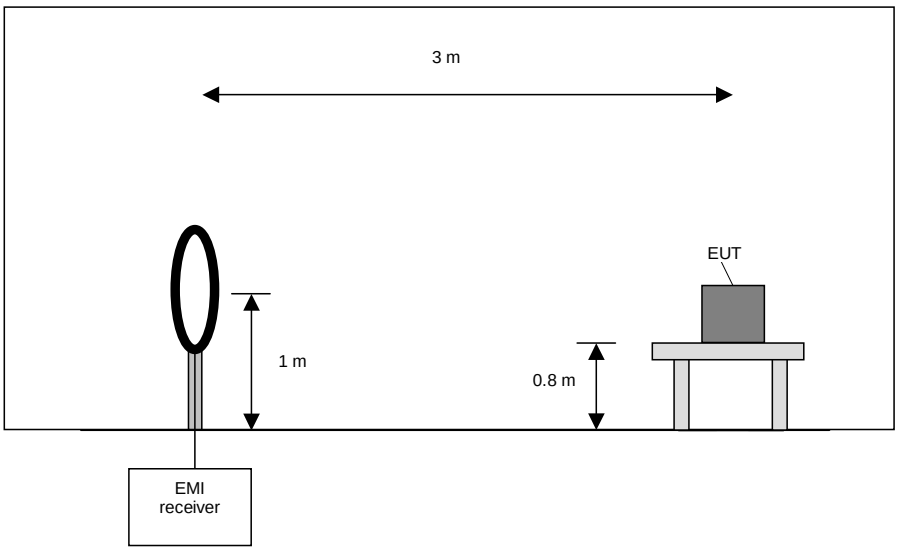
Preliminary measurement (9 kHz to 30 MHz):

In the first stage a preliminary measurement will be performed in a shielded room with a measuring distance of 3 meters. Tabletop devices will set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. 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 ANSI C63.4-2009 [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, 150 kHz to 1 MHz and 1 MHz to 30 MHz.

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) Make a hardcopy of the spectrum.
5) Measure the frequencies of highest detected emission with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
6) Repeat steps 1) to 5) with the other orthogonal axes of the EUT (because of EUT is a module and might be used in a handheld equipment application).
7) Rotate the measuring antenna and repeat steps 1) to 5).

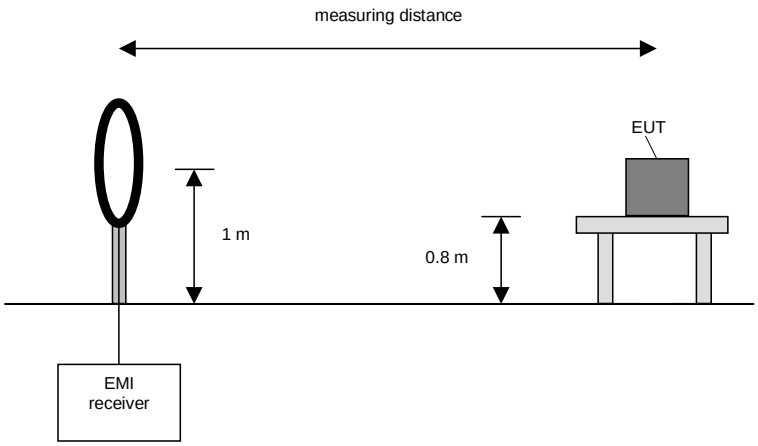
Final measurement (9 kHz to 30 MHz):

In the second stage a final measurement will be performed on an open area test site with no conducting ground plane with 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 during the preliminary measurement detected frequencies 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	10 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 (because of EUT is a module and might be used in a handheld equipment application).

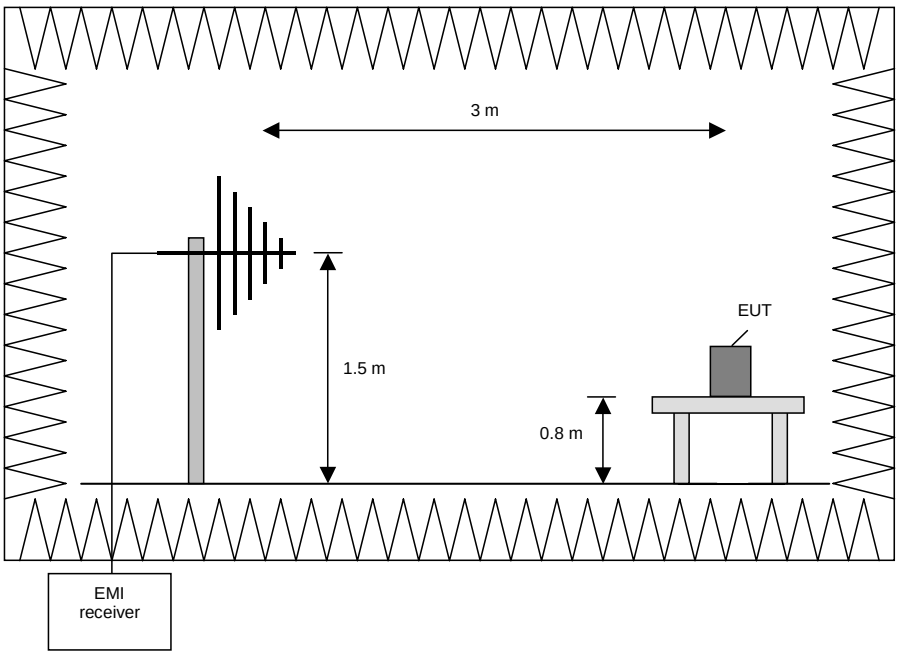
Preliminary measurement (30 MHz to 1 GHz)

In the first stage a preliminary measurement will be performed in a fully anechoic chamber with a measuring distance of 3 meter. Tabletop devices will set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. 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 ANSI C63.4-2009 [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 °.

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

Frequency range	Resolution bandwidth
30 MHz to 1 GHz	100 kHz



Procedure preliminary measurement:

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

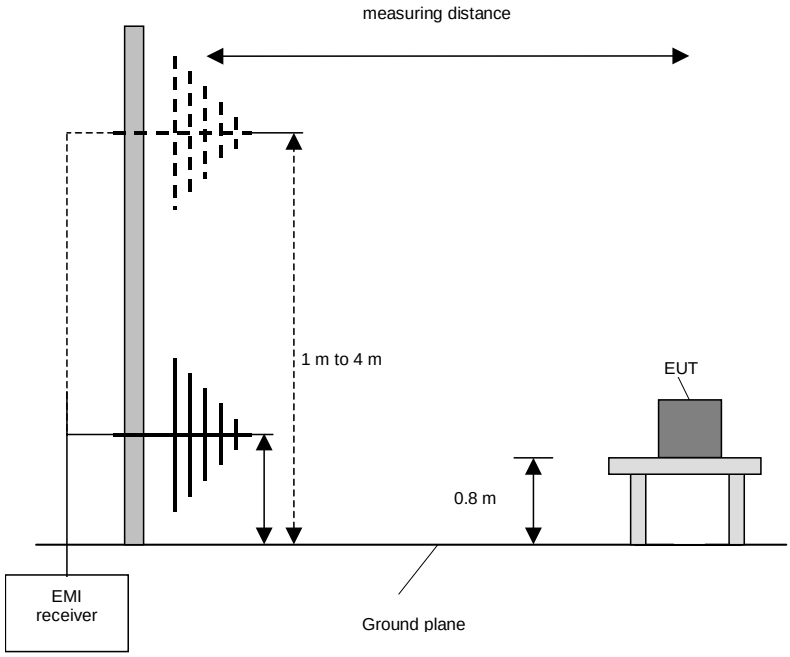
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Manipulate the system cables within the range to produce the maximum level of emission.
3. Rotate the EUT by 360 ° to maximize the detected signals.
4. Make a hardcopy of the spectrum.
5. Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
6. Repeat 1) to 4) with the other orthogonal axes of the EUT (because of EUT is a module and might be used in a handheld equipment application).
7. Repeat 1) to 5) with the vertical polarisation of the measuring antenna.

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 110 GHz)

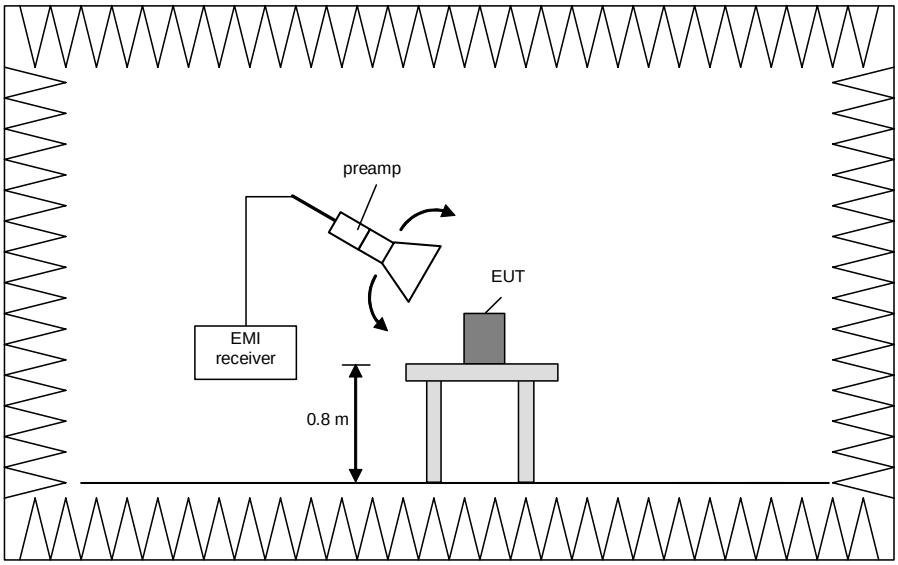
This measurement will be performed in a fully anechoic chamber. Tabletop devices will set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. Floor-standing devices will be placed directly on the turntable/ground plane. The set up of the Equipment under test will be in accordance to ANSI C63.4-2009 [1].

Preliminary measurement (1 GHz to 110 GHz)

The frequency range will be divided into different sub ranges depending on 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, the antenna close to the EUT and while moving the antenna over all sides of the EUT. With the spectrum analyser in CLEAR / WRITE mode the cone of the emission should be found and than the measuring distance will be set to 3 m with the receiving antenna moving in this cone of emission. At this position the final measurement will be carried out.

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 26.5 GHz	100 kHz
26.5 GHz to 40 GHz	100 kHz
40 GHz to 60 GHz	100 kHz
50 GHz to 75 GHz	100 kHz
75 GHz to 110 GHz	100 kHz

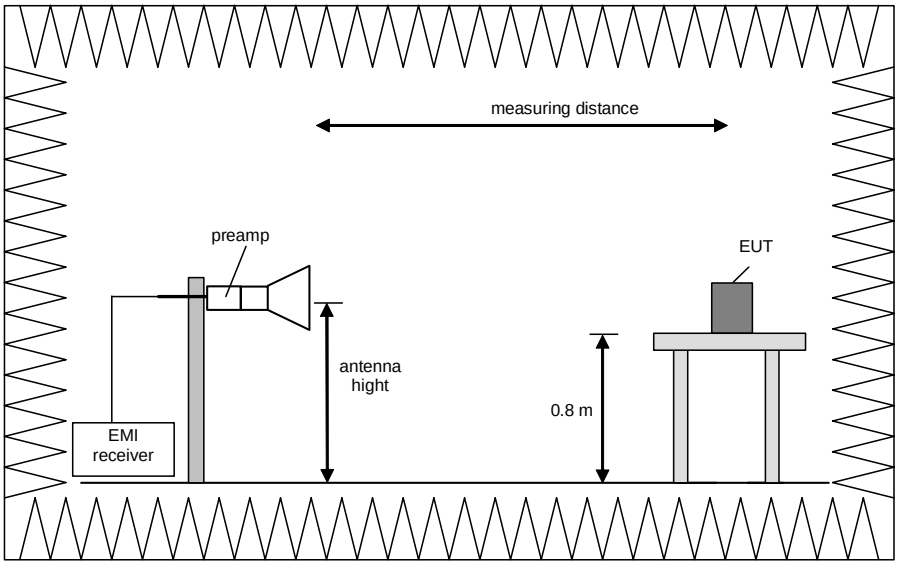


Final measurement (1 GHz to 110 GHz)

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 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 ° in order to have the antenna inside the cone of radiation.

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 26.5 GHz	1 MHz
26.5 GHz to 40 GHz	1 MHz
40 GHz to 60 GHz	1 MHz
50 GHz to 75 GHz	1 MHz
75 GHz to 110 GHz	1 MHz



Procedure of measurement:

The measurements were performed in the frequency range 1 GHz to 4 GHz, 4 GHz to 12 GHz, 12 GHz to 18 GHz, 18 GHz to 26.5 GHz, 26.5 GHz to 40 GHz, 40 GHz to 60 GHz, 60 GHz to 75 GHz and 75 GHz to 110 GHz.
The following procedure will be used:

1) Monitor the frequency range at horizontal polarisation and move the antenna over all sides of the EUT (if necessary move the EUT to another orthogonal axis).
2) Change the antenna polarisation and repeat 1) with vertical polarisation.
3) Make a hardcopy of the spectrum.
4) Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
5) Change the analyser mode to Clear / Write and found the cone of emission.
6) Rotate and move the EUT, so that the measuring distance can be enlarged to 3 m and the antenna will be still inside the cone of emission.
7) Measure the level of the detected frequency with the correct resolution bandwidth, with the antenna polarisation and azimuth and the peak and average detector, which causes the maximum emission.
8) Repeat steps 1) to 7) for the next antenna spot if the EUT is larger than the antenna beamwidth.

Step 1) to 6) are defined as preliminary measurement.

5.6.2 Test results (radiated emissions)

5.6.2.1 Preliminary radiated emission measurement

Ambient temperature	21 °C	Relative humidity	51 %

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 picture in Figure 1.

Test record: All results are shown in the following.

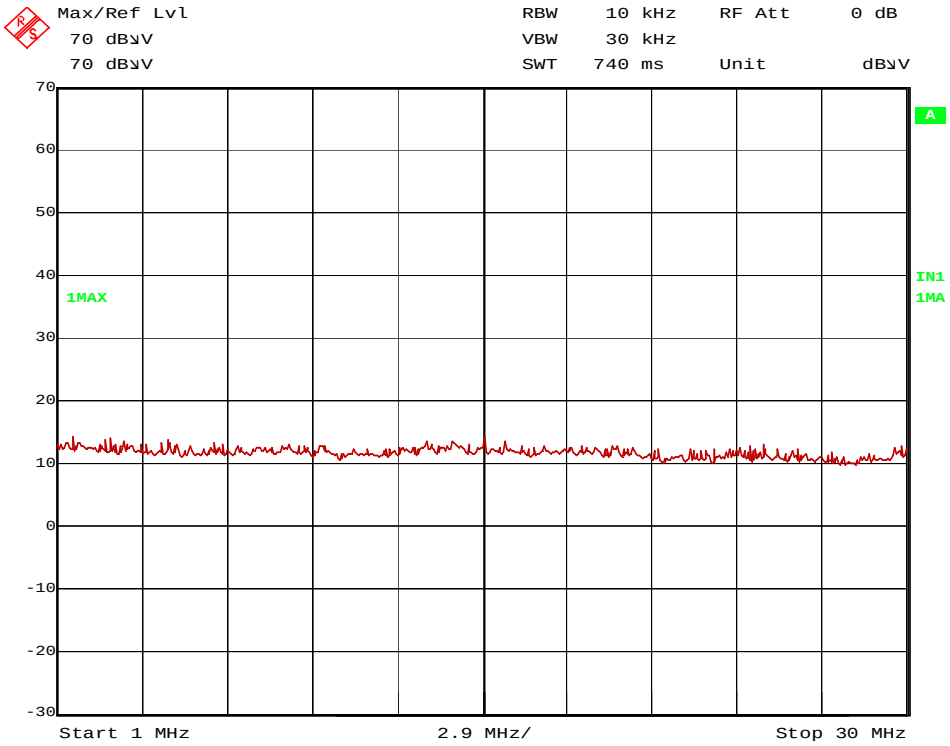
Supply voltage: During all measurements the host of the EUT was powered with 3 V via an AC/DC Adapter.

Remark: Only the plots of the worst case emissions are submitted for every frequency range above 1 GHz in the preliminary results.

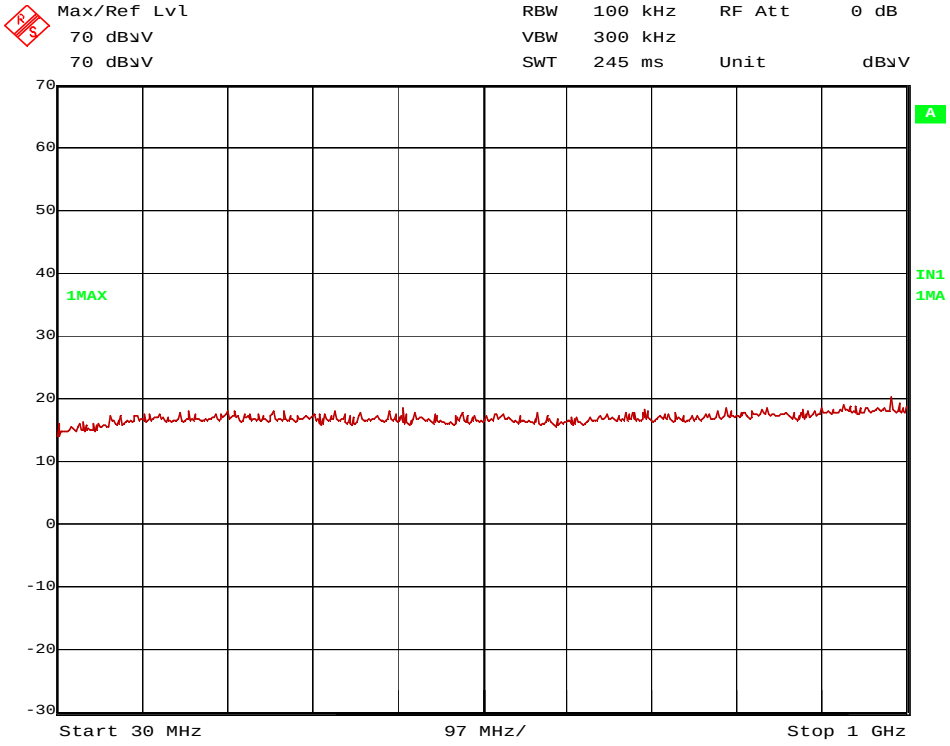
Only the frequencies from 1 MHz and higher are tested, because the lowest clock frequency in the EUT is 8 MHz.

The Emissions below 1 GHz were equal for all transmit frequencies. Therefore only the result of one exemplary test case for each frequency range is submitted below.

140852_Up_1M-30M.wmf: Spurious emissions from 1 MHz to 30 MHz, all modes:

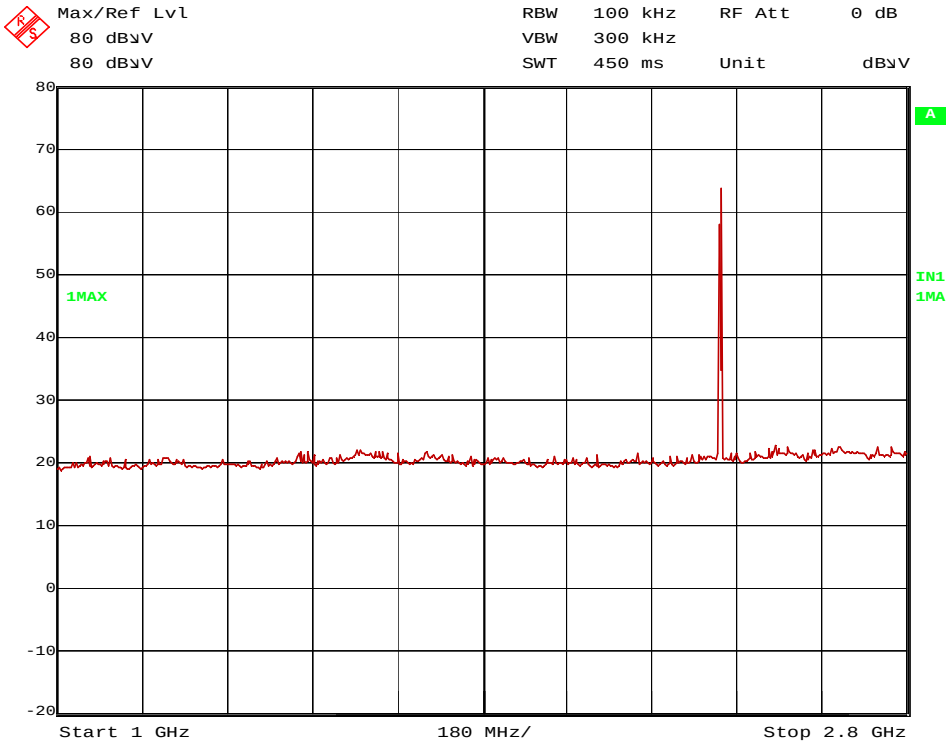


140852_mid_30M-1G.wmf: Spurious emissions from 30 MHz to 1 GHz, all modes:

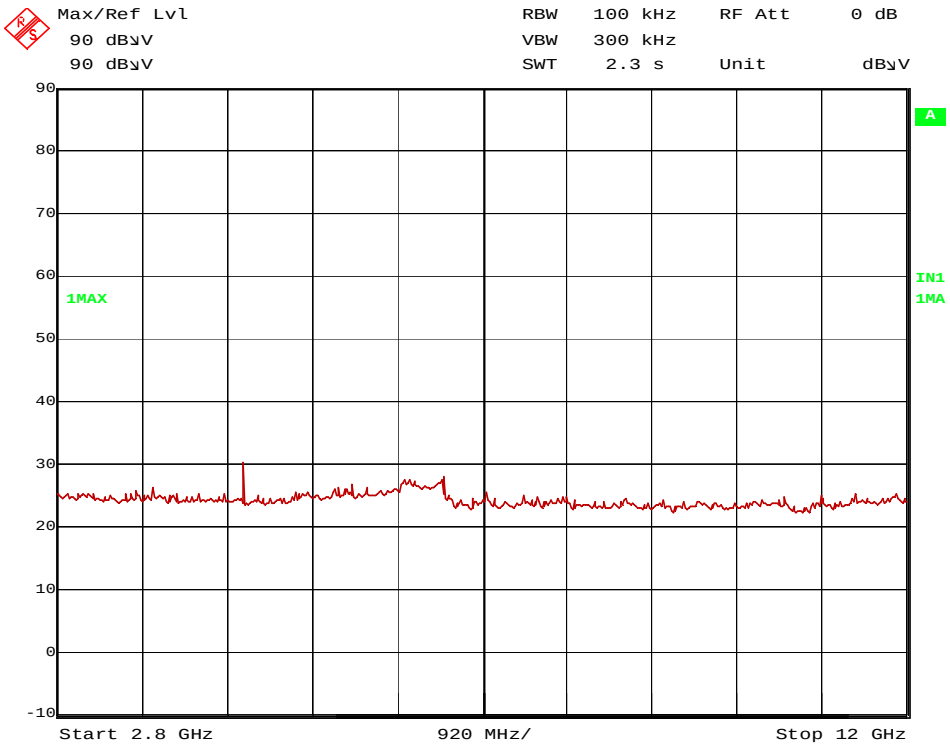


Transmitter operates at the lower end of the assigned frequency band (operation mode 1)

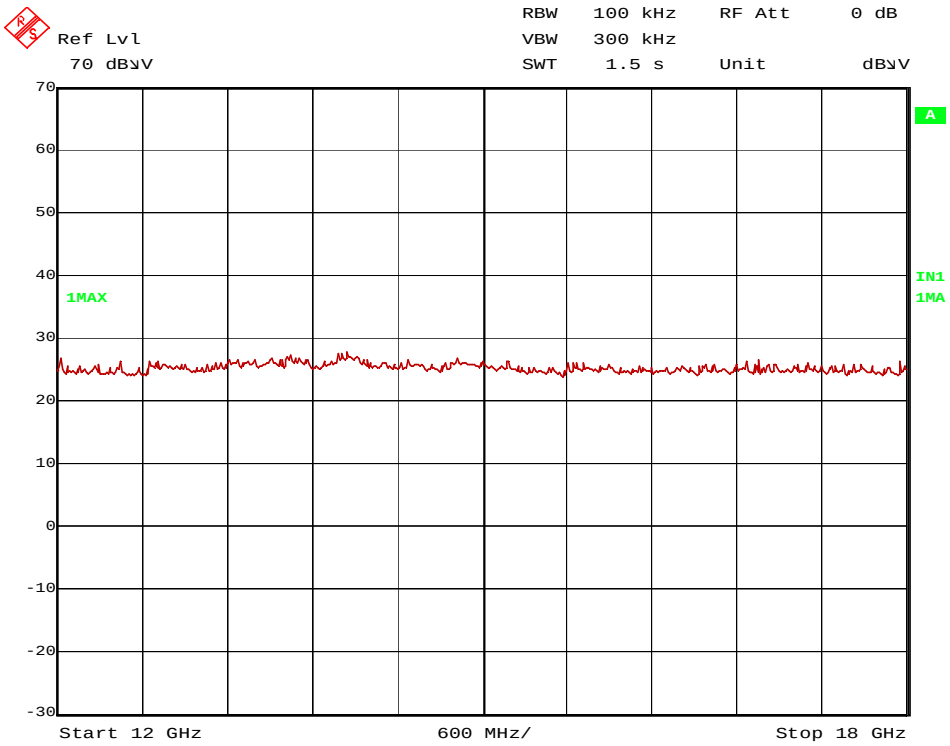
140852_Low_1-2,8G_SpurEmiss.wmf: Spurious emissions from 1 GHz to 2.8 GHz, channel 11:



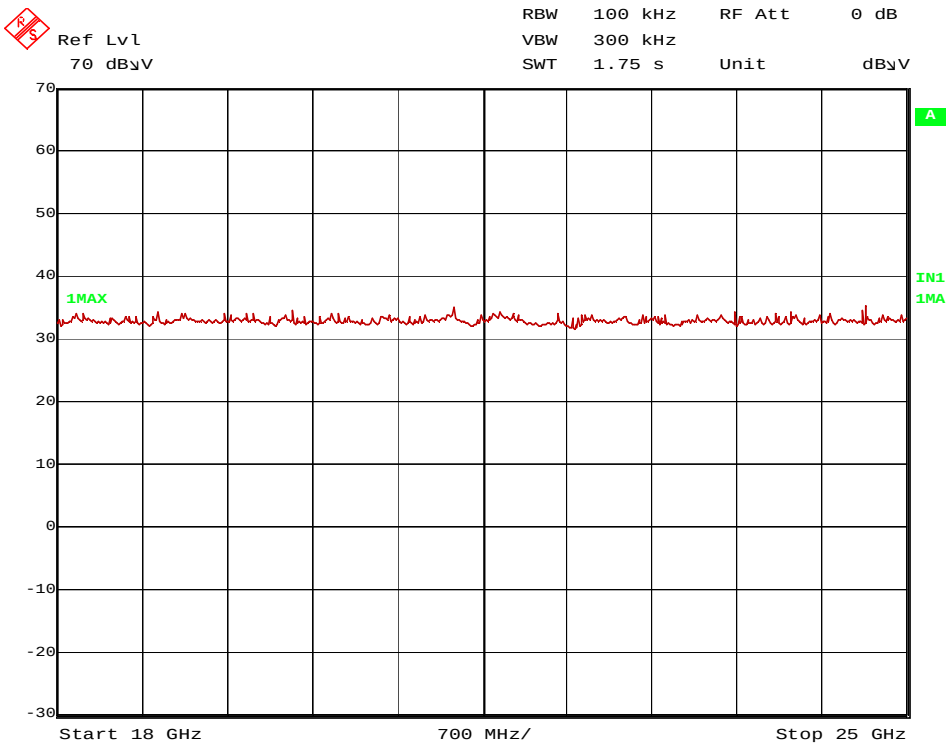
140852_Low_2.8-12G.wmf: Spurious emissions from 2.8 GHz to 12 GHz, channel 11:



140852_low_12-18G.wmf: Spurious emissions from 12 to 18 GHz, channel 11:



140852_low_18-25G.wmf: Spurious emissions from 18 – 25 GHz, channel 11:



The following frequencies were found inside the restricted bands during the preliminary radiated emission test:

- 4810 MHz.

No frequencies were found outside the restricted bands during the preliminary radiated emission test:

These frequencies have to be measured in a final measurement. The results are presented in the following.

TEST EQUIPMENT USED FOR THE TEST:
5, 6, 8 - 25, 29

5.6.2.2 Final radiated emission measurement (1 MHz to 1 GHz)

No emissions could be found in the preliminary measurements, therefore no results for the final measurements were performed.

5.6.2.3 Final radiated emission measurement (1 GHz to 25 GHz)

Ambient temperature	22 °C	Relative humidity	55 %

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 annex A of this test report.

Test record: All results are shown in the following.

Supply voltage: During all measurements the host of the EUT was powered with 2.2 V via an laboratory 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.

The results of the average measurements are corrected by a duty cycle correction factor, in adding 13.4 dB to the reading (in addition to antenna factor preamp and cable loss) as calculated in 5.1.

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.	Pos.
4810.0	46.9	74.00	27.1	34.6	32.6	25.6	5.3	150	Hor.	1
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.	Pos.
4810.0	51.5	54.00	2.5	25.8	32.6	25.6	5.3	150	Hor.	1
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.	Pos.
4880.0	47.1	74.0	26.9	34.6	32.8	25.6	5.3	150	Hor.	2
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.	Pos.
4880.0	50.4	54.0	3.6	24.5	32.8	25.6	5.3	150	Hor.	2
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.	Pos.
4960.0	47.60	74.00	26.40	35.01	32.89	25.60	5.30	150	Hor.	2
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.	Pos.
4960.0	49.8	54.00	4.2	23.8	32.9	25.6	5.3	150	Hor.	2
Measurement uncertainty				+2.2 dB / -3.6 dB						

Test: Passed

TEST EQUIPMENT USED FOR THE TEST:
5, 6, 8 - 15,17-25, 29

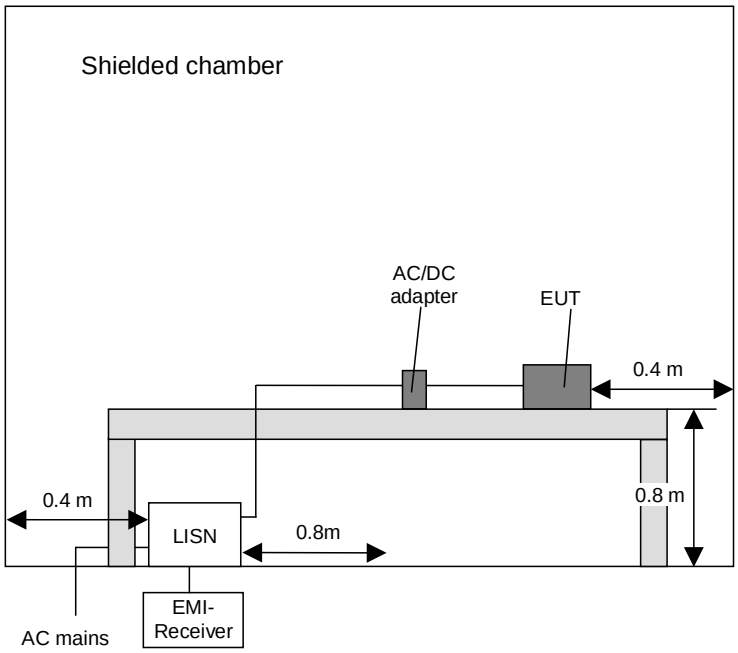
5.7 Conducted emissions on power supply lines (150 kHz to 30 MHz)

5.7.1 Method of measurement

This test will be carried out in a shielded chamber. Tabletop devices will set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm above the ground plane. Floor-standing devices will be placed directly on the ground plane. The setup of the Equipment under test will be in accordance to ANSI C63.4-2009 [1].

The frequency range 150 kHz to 30 MHz will be measured with an EMI Receiver set to MAX Hold mode with peak and average detector and a resolution bandwidth of 9 kHz. A scan will be carried out on the phase (or plus pole in case of DC powered devices) of the AC mains network. If levels detected 10 dB below the appropriable limit. this emission will be measured with the average and quasi-peak detector on all lines.

Frequency range	Resolution bandwidth
150 kHz to 30 MHz	9 kHz



5.7.2 Test results (conducted emissions on power supply lines)

Ambient temperature	22 °C	Relative humidity	72 %

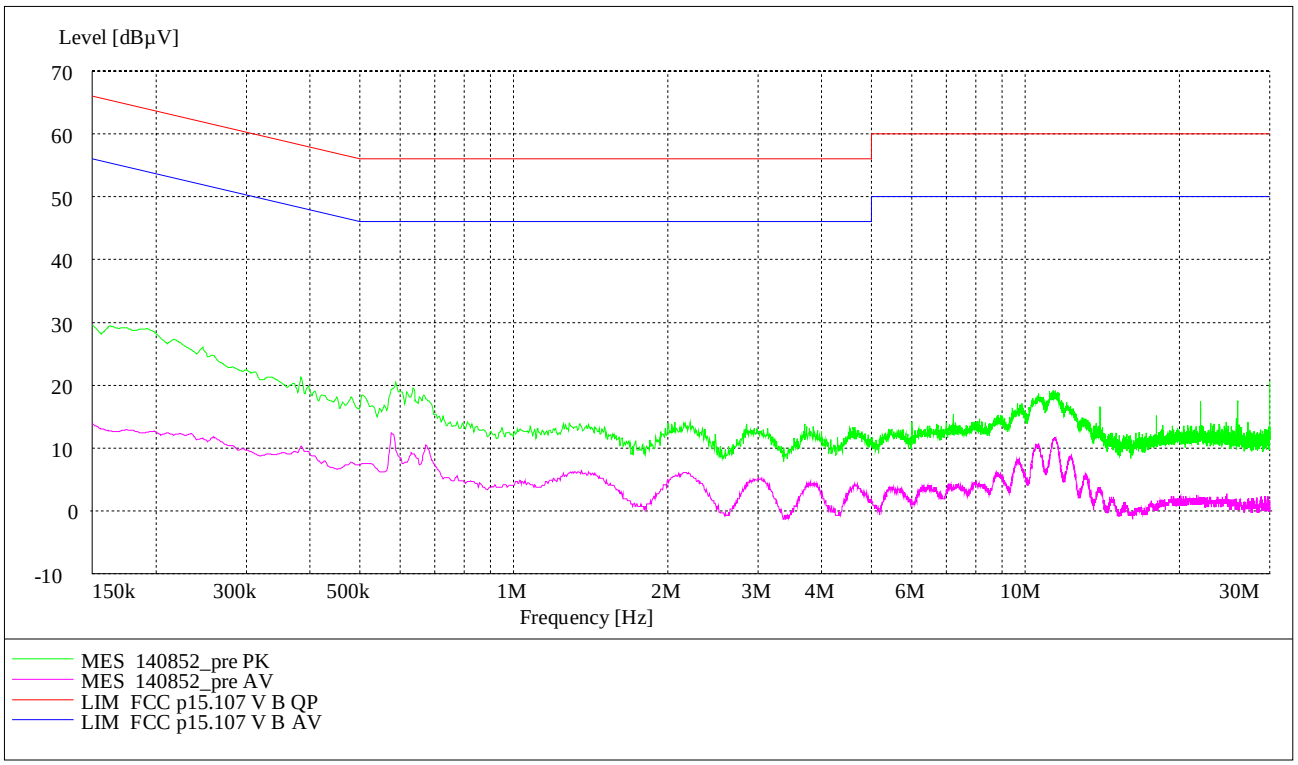
Position of EUT: For this test the EUT was configured to transmit a counter value to an ancillary device. The EUT was set to transmit on channel 1 at 2405 MHz.
The EUT was set-up on a non-conducting table of a height of 0.8 m.

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

Test record: All results are shown in the following.

Supply voltage: Measurement performed with US 120V/60Hz. For the test an AC – to – DC Power Adapter from enercell was used..

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 an x and the average measured points by an +.



Data record name: 140852

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	03/21/2014	03/2016
3	LISN	NSLK8128	Schwarzbeck	8128155	480058	12/20/2013	12/2014
4	High pass filter	HR 0.13-5ENN	FSY Microwave Inc.	DC 0109 SN 002	480340	Weekly verification (system cal.)	
5	EMI Software	ES-K1	Rohde & Schwarz	-	480111	-	-
6	Fully anechoic chamber M20	-	Albatross Projects	B83107-E2439-T232	480303	Weekly verification (system cal.)	
7	Spectrum analyser	FSU	Rohde & Schwarz	200125	480956	07/15/2013	07/2015
8	Measuring receiver	ESI 40	Rohde & Schwarz	100064	480355	02/26/2014	02/2016
9	Controller	MCU	Maturo	MCU/043/971107	480832	-	-
10	Turntable	DS420HE	Deisel	420/620/80	480315	-	-
11	Antenna support	AS615P	Deisel	615/310	480187	-	-
12	Antenna	CBL6112 B	Chase	2688	480328	04/14/2014	04/2017
13	Antenna	3115 A	EMCO	9609-4918	480183	11/09/2011	11/2014
14	Standard Gain Horn 11.9 GHz – 18 GHz	18240-20	Flann Microwave	483	480294	Six month verification (system cal.)	
15	Standard Gain Horn 17.9 GHz – 26.7 GHz	20240-20	Flann Microwave	411	480297	Six month verification (system cal.)	
16	Standard Gain Horn Antenne 26.4 – 40.1 GHz	22240-20	Flann Microwave	469	480229	Six month verification (system cal.)	
17	RF-cable No. 3	Sucoflex 106B	Huber&Suhner	0563/6B / Kabel 3	480670	Weekly verification (system cal.)	
18	RF-cable No. 40	Sucoflex 106B	Huber&Suhner	0708/6B / Kabel 40	481330	Weekly verification (system cal.)	
19	RF-cable No. 36	Sucoflex 106B	Huber&Suhner	500003/6B / Kabel 36-	481680	Weekly verification (system cal.)	
20	RF-cable 1 m	KPS-1533-400-KPS	Insulated Wire	-	480300	Six month verification (system cal.)	
21	RF-cable 2 m	KPS-1533-800-KPS	Insulated Wire		480302	Six month verification (system cal.)	
22	Preamplifier	JS3-00101200-23-5A	Miteq	681851	480337	Six month verification (system cal.)	
23	Preamplifier	JS3-12001800-16-5A	Miteq	571667	480343	Six month verification (system cal.)	
24	Preamplifier	JS3-18002600-20-5A	Miteq	658697	480342	Six month verification (system cal.)	
25	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	02/2014	02/2016
26	Power Meter	NRVD	Rohde & Schwarz	833697/030	480589	07/2013	07/2015
27	Peak Power Sensor	NRV-Z32	Rohde & Schwarz	849745/016	480551	07/2013	07/2015
28	4 GHz High Pass Filter	WHKX4.0/18G-8SS	Wainwright Instruments	1	480587	Weekly verification (system cal.)	

29	Single Control Unit	SCU	Maturo GmbH	SCU/006/971107	480831	Calibration not necessary	
30	High-pass Filter	H26G40G1	Microwave Circuits, Inc.	33471	480593	Six month verification (system cal.)	
31	High-pass Filter	WHK2.8/18G -10SS	Wainwright Instuments GmbH	1	480867	09/19/2013	09/2014

7 REPORT HISTORY

Report Number	Date	Comment
F140852E1	8 September 2014	Document created

8 LIST OF ANNEXES

ANNEX A TEST SET-UP PHOTOS 4 pages

140852_01: Test setup - Radiated emission. Antennas terminated (fully anechoic chamber)
140852_32: Test setup - Radiated emission. Antennas terminated (fully anechoic chamber)
140852_03: Test setup - Radiated emission. Antennas terminated (fully anechoic chamber)
140852_04: Test setup – conducted emissions on power supply lines

ANNEX B EXTERNAL PHOTOGRAPHS 2 pages

140852_05.jpg: Carrier Board + EUT – Top View
140852_06.jpg: Carrier Board + EUT – Bottom View

ANNEX C INTERNAL PHOTOGRAPHS 3 pages

140852_07.JPG: EUT - top view, with shielding
140852_08.JPG: EUT - top view, shielding removed
140852_09.JPG: EUT – bottom view