



RF - TEST REPORT

- FCC Part 15.247, RSS-247 -

Type / Model Name : c-med° alpha

Product Description : Medical wearable for continuous vital signs measurement

Applicant : Cosinuss GmbH
Address : Kistlerhofstraße 60
81379 München, GERMANY

Manufacturer : Cosinuss GmbH
Address : Kistlerhofstraße 60
81379 München, GERMANY

Test Result according to the standards listed in clause 1 test standards:

POSITIVE

Test Report No. :	T47140-01-00LH	19. July 2021
		Date of issue



Deutsche
Akkreditierungsstelle
D-PL-12030-01-01
D-PL-12030-01-02

Contents

<u>1 TEST STANDARDS</u>	3
<u>2 EQUIPMENT UNDER TEST</u>	4
2.1 Information provided by the Client	4
2.2 Sampling	4
2.3 General remarks	4
2.4 Photo documentation of the EUT – Detailed photos see ATTACHMENT A	4
2.5 Equipment type	4
2.6 Short description of the equipment under test (EUT)	4
2.7 Variants of the EUT	4
2.8 Operation frequency and channel plan	5
2.9 Transmit operating modes	5
2.10 Antennas	5
2.11 Power supply system utilised	5
2.12 Peripheral devices and interface cables	6
2.13 Determination of worst case conditions for final measurement	6
<u>3 TEST RESULT SUMMARY</u>	7
3.1 Final assessment	7
<u>4 TEST ENVIRONMENT</u>	8
4.1 Address of the test laboratory	8
4.2 Environmental conditions	8
4.3 Statement of the measurement uncertainty	8
4.1 Conformity Decision Rule	8
4.2 Measurement protocol for FCC and ISED	9
<u>5 TEST CONDITIONS AND RESULTS</u>	12
5.1 EBW and OBW	12
5.2 Maximum peak conducted output power	19
5.3 Power spectral density	22
5.4 Radiated emissions in restricted bands	26
5.5 Spurious emissions radiated	37
5.6 Antenna application	42
<u>6 USED TEST EQUIPMENT AND ACCESSORIES</u>	45

ATTACHMENT A AS SEPARATE SUPPLEMENT

1 TEST STANDARDS

The tests were performed according to following standards:

FCC Rules and Regulations Part 15, Subpart A - General (September 2020)

Part 15, Subpart A, Section 15.31	Measurement standards
Part 15, Subpart A, Section 15.33	Frequency range of radiated measurements
Part 15, Subpart A, Section 15.35	Measurement detector functions and bandwidths
FCC Rules and Regulations Part 15, Subpart C - Intentional Radiators (September 2020)	
Part 15, Subpart C, Section 15.203	Antenna requirement
Part 15, Subpart C, Section 15.204 modifications	External radio frequency power amplifiers and antenna
Part 15, Subpart C, Section 15.205	Restricted bands of operation
Part 15, Subpart C, Section 15.207	Conducted limits
Part 15, Subpart C, Section 15.209	Radiated emission limits, general requirements
Part 15, Subpart C, Section 15.247	Operation within the bands 902 - 928 MHz, 2400 - 2483.5 MHz and 5725 - 5850 MHz
ANSI C63.10: 2013	Testing Unlicensed Wireless Devices
ETSI TR 100 028 V1.3.1: 2001-03,	Electromagnetic Compatibility and Radio Spectrum Matters (ERM); Uncertainties in the Measurement of Mobile Radio Equipment Characteristics—Part 1 and Part 2

2 EQUIPMENT UNDER TEST

2.1 Information provided by the Client

Please note, we do not take any responsibility for information provided by the client or his representative which may have an influence on the validity of the test results.

2.2 Sampling

The customer is responsible for the choice of sample. Sample configuration, start-up and operation is carried out by the customer or according his/her instructions.

2.3 General remarks

2.4 Photo documentation of the EUT – Detailed photos see ATTACHMENT A

2.5 Equipment type

Bluetooth 5.0 Low Energy transceiver, portable equipment

2.6 Short description of the equipment under test (EUT)

The EUT is a Bluetooth 5.0 Low Energy wireless device for continuous vital signs measurements. A single PCB antenna is used within the system. The EUT has only one integrated antenna, no temporary connector and no external antenna can be connected.

Radiated and conducted test samples are specially prepared to be connected to a PC and set into test modes by a set of commands in a terminal program.

Number of tested samples:	1 conducted	1 radiated
Type:	MS01	MS01
Serial number:	PCB ID 6001501A.002009	PCB ID 6001501A.002019
Firmware version:	special testing firmware	special testing firmware

EUT configuration:

(The CDF filled by the applicant can be viewed at the test laboratory.)

2.7 Variants of the EUT

There are no variants.

2.8 Operation frequency and channel plan

The operating frequency is 2400 MHz to 2483.5 MHz.

Channel plan BT-Standard 802.15.1:

Channel	Frequency	Channel	Frequency
37	2402	18	2442
0	2404	19	2444
1	2406	20	2446
2	2408	21	2448
3	2410	22	2450
4	2412	23	2452
5	2414	24	2454
6	2416	25	2456
7	2418	26	2458
8	2420	27	2460
9	2422	28	2462
10	2424	29	2464
38	2426	30	2466
11	2428	31	2468
12	2430	32	2470
13	2432	33	2472
14	2434	34	2474
15	2436	35	2476
16	2438	36	2478
17	2440	39	2480

Note: the marked frequencies are determined for final testing.

2.9 Transmit operating modes

The EUT uses GFSK modulation and may provide following data rates:

- 1000 kbps
- 2000 kbps

(kbps = *kilobits per second*)

2.10 Antennas

The following antennas shall be used with the EUT:

The EUT has only an integrated PCB antenna, no temporary connector and no external antenna to be connected.

2.11 Power supply system utilised

Power supply voltage, V_{nom} : 3.7 V_{DC} Battery

2.12 Peripheral devices and interface cables

The following peripheral devices and interface cables are connected during the measurements:

- Device1 Model : Raspberry Pi 3B+
- WLAN Router Model : FRITZ!Box 4020
- Laptop Model : MS-16GD
- UART-USB Converter Model : DLP-USB232R
- USB Mini Cable Model : -
- 2x Ethernetcable Model : -
- USB Micro Cable Model : -

2.13 Determination of worst case conditions for final measurement

Measurements are made in all three orthogonal axes and the settings of the EUT are changed to locate at which position and at what setting of the EUT produce the maximum of the emissions. For the further measurement the EUT is set in X position.

The tests are carried out in the following frequency band:

2400 MHz – 2483.5 MHz

Preliminary tests are performed to find the worst case mode from all possible combinations between available modulations and data rates. The maximum output power depends on used data rate. The output power is set by firmware from 0 dBm to 4 dBm (P0 to P4) in 1 dB steps.

For the final test the following channels and test modes are selected:

Wireless system	Available channel	Tested channels	Power setting	Modulation	Modulation type	Data rate
802.15.1 BLE V5.0	0-39	37, 17, 39	P4	DSSS	GFSK	1.0 Mbps

- TX continuous mode
- RX continuous mode

2.13.1 Test jig

No special test jig was used for testing.

2.13.2 Test software

The test software for the EUT provides the special test mode RX and the TX continuous mode, modulated. The output power is set by firmware and can not be changed by the user. The EUT was set with test modulation to transmit data during the tests with a maximum duty cycle from an internal packet generator.

3 TEST RESULT SUMMARY

Operating in the 2400 MHz – 2483.5 MHz:

FCC Rule Part	RSS Rule Part	Description	Result
15.207(a)	RSS-Gen, 8.8	AC power line conducted emissions	not applicable*
15.247(a)(2)	RSS-247, 6.2.4(1)	-6 dB EBW	passed
15.247(b)(3)	RSS-247, 6.2.4(1)	Maximum peak conducted output power	passed
15.247(b)(4)	-	Defacto limit	passed
15.247(d)	RSS-247, 6.2.4(2)	Out-of-band emission, radiated	passed
15.247(d)	RSS-Gen, 8.9	Emissions in restricted bands	passed
15.247(e)	RSS-247, 6.2.4(1)	PSD	passed
15.203	RSS-Gen, 6.6	Antenna requirement	passed
-	RSS-Gen, 6.11	Transmitter frequency stability	passed
-	RSS-Gen, 6.6	99 % Bandwidth	passed

The mentioned new RSS Rule Parts in the above table are related to:

RSS-Gen, Issue 5 + Amendment 1, March 2019

RSS-247, Issue 2, February 2017

* The EUT is battery powered, therefore AC power line conducted emissions is not applicable.

3.1 Final assessment

The equipment under test fulfills the requirements cited in clause 1 test standards.

Date of receipt of test sample : acc. to storage records

Testing commenced on : 08 March 2021

Testing concluded on : 16 March 2021

Checked by:

Tested by:

Klaus Gegenfurtner
Teamleader Radio

Lukas Scheuermann
Radio Team

4 TEST ENVIRONMENT

4.1 Address of the test laboratory

CSA Group Bayern GmbH
Ohmstrasse 1-4
94342 STRASSKIRCHEN
GERMANY

4.2 Environmental conditions

During the measurement the environmental conditions were within the listed ranges:

Temperature: 15 - 35 °C

Humidity: 30 - 60 %

Atmospheric pressure: 86 - 106 kPa

4.3 Statement of the measurement uncertainty

The data and results referenced in this document are true and accurate. It is noted that the expanded measurement uncertainty corresponds to the measurement results from the standard measurement uncertainty multiplied by the coverage factor $k = 2$. The true value is located in the corresponding interval with a probability of 95 %. The measurement uncertainty was calculated for all measurements listed in this test report acc. to CISPR 16-4-2 / 2011 + A1 / 2014 „Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements“ and is documented in the quality system acc. to DIN EN ISO/IEC 17025. For all measurements shown in this report, the measurement uncertainty of the test laboratory, CSA Group Bayern GmbH, is below the measurement uncertainty as defined by CISPR. Therefore, no special measures must be taken into consideration with regard to the limits according to CISPR. Furthermore, component and process variability of devices similar to that tested may result in additional deviation. The manufacturer has the sole responsibility of continued compliance of the device.

Measurement Type	Range	Confidence Level (%)	Calculated Uncertainty
AC Conducted Spurious Emissions	0.15 MHz to 30 MHz	95%	± 3.29 dB
20 dB Bandwidth	Center frequency of EUT	95%	$\pm 2.5 \times 10^{-7}$
99% Occupied Bandwidth	Center frequency of EUT	95%	$\pm 2.5 \times 10^{-7}$
Radiated Spurious Emissions	9 kHz to 30 MHz	95%	± 3.53 dB
Radiated Spurious Emissions	30 MHz to 1000 MHz	95%	± 3.71 dB
Radiated Spurious Emissions	1000 MHz to 10000 MHz	95%	± 2.34 dB
Peak conducted output power	902 MHz to 928 MHz	95%	± 0.35 dB
Conducted Spurious Emissions	9 kHz to 10000 MHz	95%	± 2.15 dB

4.1 Conformity Decision Rule

The conformity decision rule is based on the ILAC G8 published at the time of reporting.

4.2 Measurement protocol for FCC and ISED

4.2.1 General information

CSA Group Bayern GmbH is recognized as wireless testing laboratory under the CAB identifier:

FCC: DE 0011
ISED: DE0009

4.2.2 General Standard information

The test methods used comply with ANSI C63.10 - "Testing Unlicensed Wireless Devices".

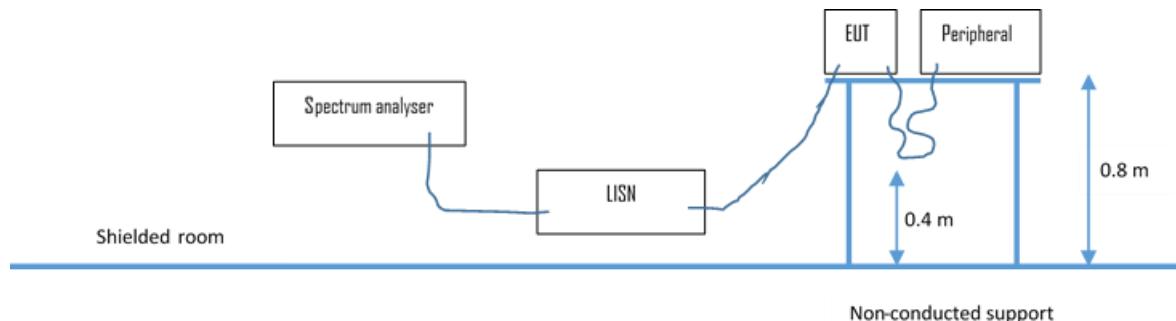
4.2.2.1 Justification

The equipment under test (EUT) is configured in a typical user arrangement in accordance with the manufacturer's instructions.

4.2.3 Details of test procedures

4.2.3.1 Conducted emission

Test setup according ANSI C63.10



The final level, expressed in $\text{dB}\mu\text{V}$, is arrived at by taking the reading directly from the Spectrum analyser. This level is compared to the limit.

To convert between $\text{dB}\mu\text{V}$ and μV , the following conversions apply:

$$\text{dB}\mu\text{V} = 20(\log \mu\text{V})$$

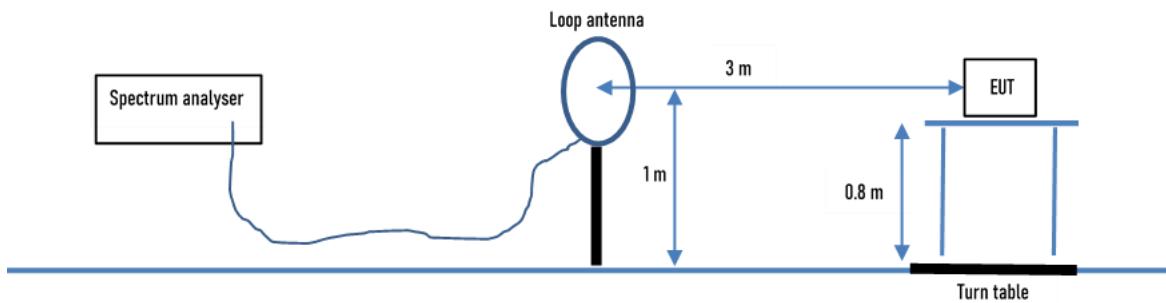
$$\mu\text{V} = \text{Inverse log}(\text{dB}\mu\text{V}/20)$$

Conducted emissions on the 50 Hz and/or 60 Hz power interface of the EUT are measured in the frequency range of 150 kHz to 30 MHz. The measurements are performed using a receiver, which has CISPR characteristic bandwidth and quasi-peak detection and a Line Impedance Stabilization Network (LISN) with $50 \Omega / 50 \mu\text{H}$ (CISPR 16) characteristics. The receiver is protected by means of an impedance matched pulse limiter connected directly to the RF input. Table top equipment is placed on a non-conducting table 80 centimetres above the floor and is positioned 40 centimetres from the vertical ground plane (wall) of the screen room. If the minimum limit margin appears to be less than 20 dB with a peak mode measurement, the emission is re-measured using a tuned receiver with quasi-peak and average detection and recorded on the data sheets.

4.2.3.2 Radiated emission

4.2.3.2.1 OATS1 test site (9 kHz - 30 MHz):

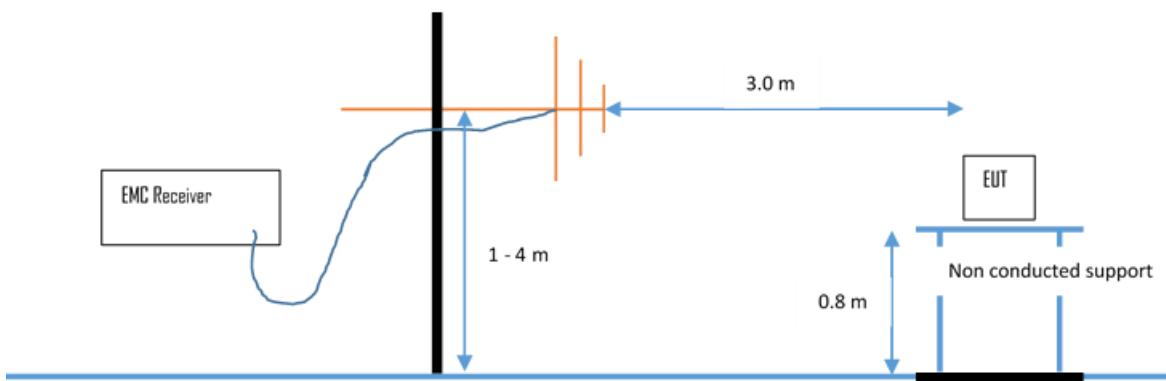
Test setup according ANSI C63.10



Emissions from the EUT are measured in the frequency range of 9 MHz to 30 MHz using a tuned receiver and a calibrated loop antenna. Table top equipment is placed on a 1.0 X 1.5 m non-conducting table 80 centimetres above the ground plane. Cables to simulators/testers (if used in this test) are routed through the center of the table and to a screened room located outside the test area. The antenna is positioned 3, 10 or 30 metres horizontally from the EUT and is repeated vertically. To locate maximum emissions from the test sample the antenna is varied along the site axis and the EUT is rotated 360 degrees.

4.2.3.2.2 OATS1 test site (30 MHz - 1 GHz):

Test setup according ANSI C63.10.



Spurious emissions from the EUT are measured in the frequency range of 30 MHz to 1000 MHz using a tuned receiver and appropriate broadband linearly polarised antennas. Measurements between 30 MHz and 1000 MHz are made with 120 kHz/6 dB bandwidth and quasi-peak detection. Table top equipment is placed on a 1.0 X 1.5 m non-conducting table 80 centimetres above the ground plane. Floor standing equipment is placed directly on the turntable/ground plane. Cables to simulators/testers (if used in this test) are routed through the center of the table and to a screened room located outside the test area. To locate maximum emissions from the test sample the antenna is varied in height from 1 to 4 metres and the EUT is rotated 360 degrees. The final level in dB μ V/m is calculated by taking the reading from the EMI receiver (Level dB μ V) and adding the correction factors and cable loss factor (dB). The FCC limit is subtracted from this result in order to provide the limit margin listed in the measurement protocol.

The resolution bandwidth setting:

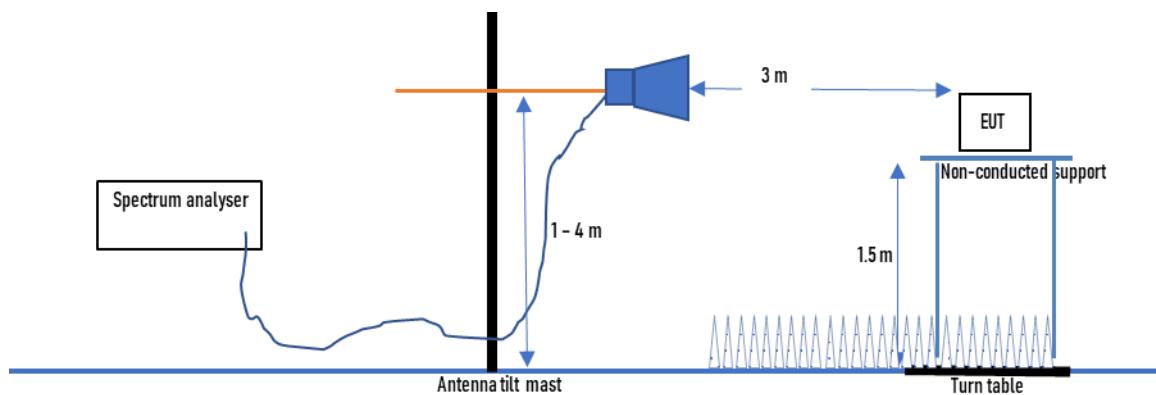
30 MHz – 1000 MHz: RBW: 120 kHz

Example:

Frequency (MHz)	Level (dB μ V)	+	Factor (dB)	=	Level (dB μ V/m)	-	Limit (dB μ V/m)	=	Delta (dB)
719.0	75.0	+	32.6	=	107.6	-	110.0	=	-2.4

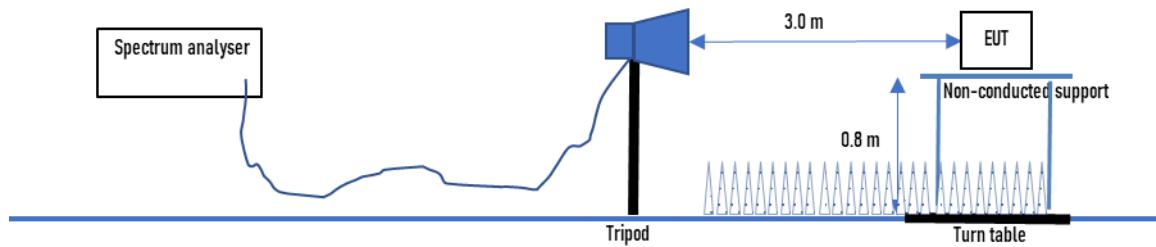
4.2.3.2.3 Anechoic chamber 1 (1000 MHz – 18000 MHz)

Test setup according ANSI C63.10.



Radiated emissions from the EUT are measured in the frequency range 1 GHz up to 18 GHz as specified in 47 CFR Part 15, Subpart A, Section 15.33, using a spectrum analyser and appropriate linearly polarized antennas. Table top equipment is placed on a non-conducting table, 1.5 metre above the ground plane. The turntable is fully covered with the appropriate absorber (Type VHP-12). Any controlling device is positioned such that it does not significantly influence the measurement results. Interconnecting cables that hang closer than 40 cm to the ground plane are folded back and forth in the centre, forming a bundle 30 cm to 40 cm long. Measurements are made in in three orientations of the EUT and the horizontal and vertical polarization planes of measurement antenna in a fully anechoic room. The measurement antenna is adjusted and the EUT orientated to permit the measurement of the maximum emission from the EUT. The conditions determined as worst-case will then be used for the final measurements.

4.2.3.2.4 Anechoic chamber 1 (18 GHz – 40 GHz)



Emissions from the EUT are measured in the frequency range 18 GHz up to 40 GHz as specified in 47 CFR Part 15, Subpart A, Section 15.33, using a spectrum analyser and appropriate linearly polarized antennas. Table top equipment is placed on a non-conducting table, 0.8 metre above the ground plane. The turntable is fully covered with the appropriate absorber (Type VHP-12). Any controlling device is positioned such that it does not significantly influence the measurement results. Interconnecting cables that hang closer than 40 cm to the ground plane are folded back and forth in the centre, forming a bundle 30 cm to 40 cm long. Measurements are made in in three orientations of the EUT and the horizontal and vertical polarization planes of measurement antenna in a fully anechoic room. The measurement antenna is adjusted and the EUT orientated to permit the measurement of the maximum emission from the EUT. The conditions determined as worst-case will then be used for the final measurements. Where appropriate, the test distance may be reduced in order to detect emissions under better uncertainty. The limit are adopted.

5 TEST CONDITIONS AND RESULTS

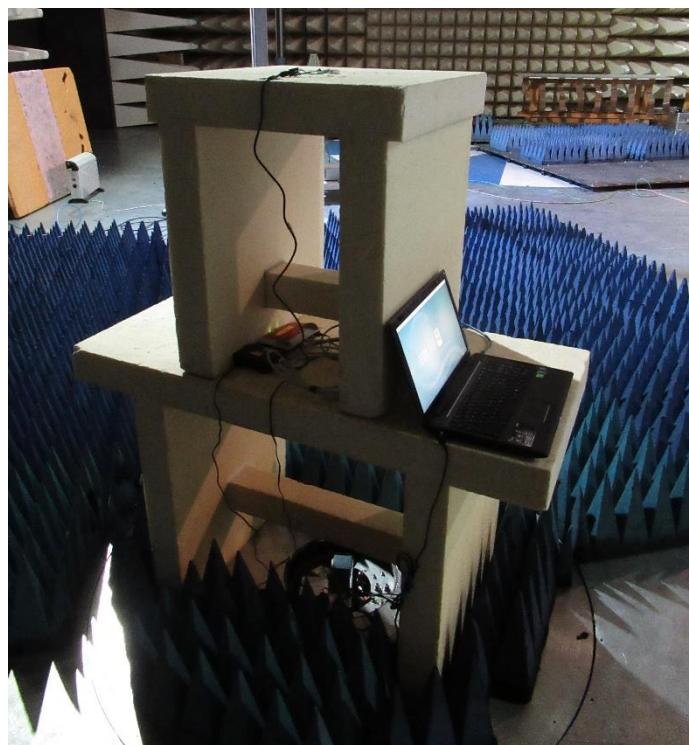
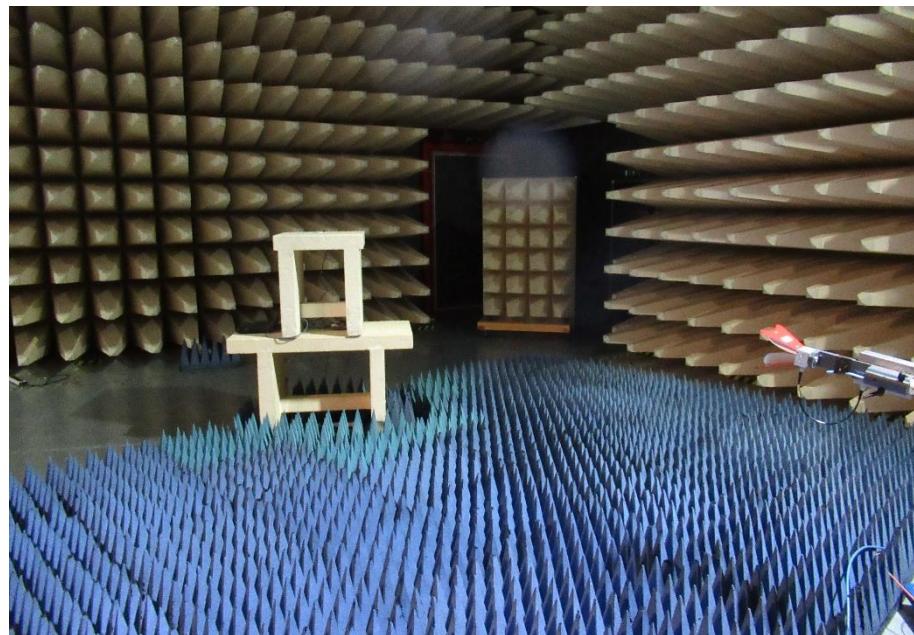
5.1 EBW and OBW

For test instruments and accessories used see section 6 Part **MB**.

5.1.1 Description of the test location

Test location: Anechoic chamber 1

5.1.2 Photo documentation of the test set-up



5.1.3 Applicable standard

According to FCC Part 15, Section 15.247(a)(2):

Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 – 2483.5 MHz and 5725 – 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

5.1.4 Description of Measurement

The bandwidth was measured at an amplitude level reduced from the reference level of a modulated channel by a ratio of -6 dB. The reference level is the level of the highest signal amplitude observed at the transmitter at either the fundamental frequency or the first order modulation products in all typical modes of operation, including the unmodulated carrier, even if atypical. An alternative is to use the bandwidth measurement of the analyser.

Spectrum analyser settings for EBW:

RBW: 100 kHz, VBW: 300 kHz, Detector: Max peak, Span: \geq 2 EBW;

Spectrum analyser settings for OBW:

RBW: 1-5% OBW, VBW: 3 RBW, Detector: Max peak, Span: \geq 2 OBW;

5.1.5 Test result

Standard 802.15.1

EBW, 1 Mbps			
Channel	Channel frequency (MHz)	6 dB bandwidth (kHz)	Minimum limit (kHz)
37	2402	679.3	500
17	2440	679.3	500
39	2480	683.3	500

EBW, 2 Mbps			
Channel	Channel frequency (MHz)	6 dB bandwidth (kHz)	Minimum limit (kHz)
37	2402	1162.8	500
17	2440	1158.8	500
39	2480	1146.9	500

OBW99, 1 Mbps		
Channel	Channel frequency (MHz)	99 % bandwidth (kHz)
37	2402	1046.1
17	2440	1062.9
39	2480	1067.3

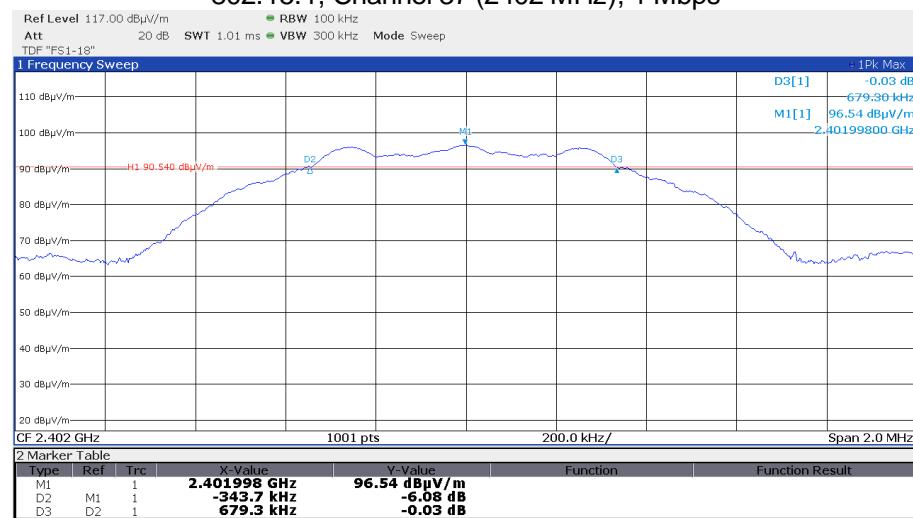
OBW99, 2 Mbps		
Channel	Channel frequency (MHz)	99 % bandwidth (kHz)
37	2402	2072.1
17	2440	2071.5
39	2480	2077.0

The requirements are **FULFILLED**.

Remarks: For detailed test result please see the following test protocols

5.1.6 Test protocols EBW

802.15.1, Channel 37 (2402 MHz), 1 Mbps



802.15.1, Channel 17 (2440 MHz), 1 Mbps



802.15.1, Channel 39 (2480 MHz), 1 Mbps



802.15.1, Channel 37 (2402 MHz), 2 Mbps



802.15.1, Channel 17 (2440 MHz), 2 Mbps



802.15.1, Channel 39 (2480 MHz), 2 Mbps



5.1.7 Test protocols OBW99

802.15.1, Channel 37 (2402 MHz), 1 Mbps



802.15.1, Channel 17 (2440 MHz), 1 Mbps



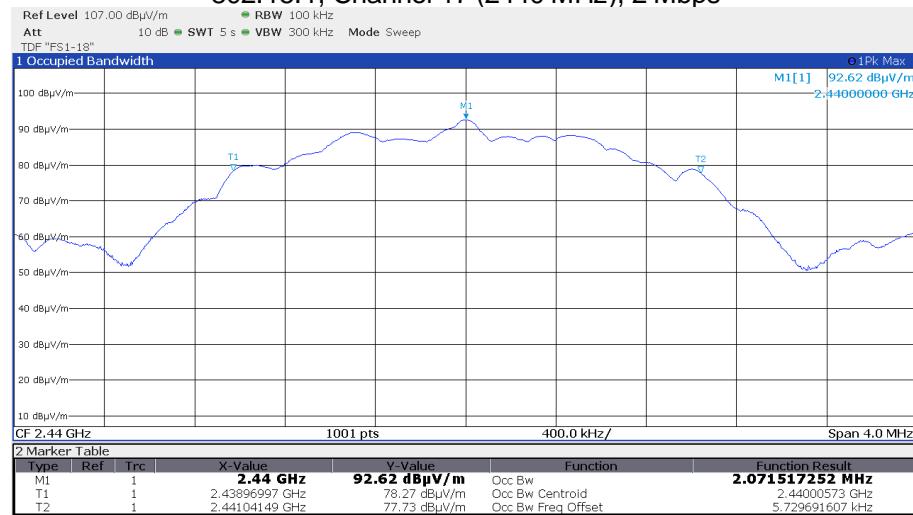
802.15.1, Channel 39 (2480 MHz), 1 Mbps



802.15.1, Channel 37 (2402 MHz), 2 Mbps



802.15.1, Channel 17 (2440 MHz), 2 Mbps



802.15.1, Channel 39 (2480 MHz), 2 Mbps



5.2 Maximum peak conducted output power

For test instruments and accessories used see section 6 Part **CPC 3**.

5.2.1 Description of the test location

Test location: Shielded Room S4

5.2.2 Photo documentation of the test set-up



5.2.3 Applicable standard

According to FCC Part 15, Section 15.247(b)(3):

For systems using digital modulation in the 2400-2483.5 MHz and 5725 – 5850 MHz bands, the maximum peak output power of the transmitter shall not exceed 1 Watt. The limit is based on transmitting antennas of directional gain that do not exceed 6 dBi.

5.2.4 Description of Measurement

The maximum peak conducted output power is measured using a spectrum analyser following the procedure set out in ANSI C64.10, item 11.9.1.1. The EUT is set in TX continuous mode while measuring.

$$E = EIRP - (20 \cdot \log_{10} 3) + 104.8$$

5.2.5 Test result

802.15.1, 1 Mbps, TX	Test results conducted				
	Fieldstrength E (dB μ V/m)	P (dBm)	P (W)	Limit (dBm)	Margin (dB)
Lowest frequency: CH37, 2402 MHz					
T_{nom}	V_{nom}	99.5	4.2	0.0026	30
Middle frequency: CH17, 2440 MHz					
T_{nom}	V_{nom}	99.4	4.2	0.0026	30
Highest frequency: CH39, 2480 MHz					
T_{nom}	V_{nom}	99.1	3.9	0.0024	30
					-26.1

802.15.1, 2 Mbps, TX	Test results conducted				
	Fieldstrength E (dB μ V/m)	P (dBm)	P (W)	Limit (dBm)	Margin (dB)
Lowest frequency: CH37, 2402 MHz					
T_{nom}	V_{nom}	99.3	4.1	0.0026	30
Middle frequency: CH17, 2440 MHz					
T_{nom}	V_{nom}	99.4	4.2	0.0026	30
Highest frequency: CH39, 2480 MHz					
T_{nom}	V_{nom}	99.1	3.9	0.0024	30
					-26.1

Peak Power Limit according to FCC Part 15, Section 15.247(b)(3):

Frequency (MHz)	Peak Power Limit	
	(dBm)	(Watt)
902-928	30	1.0
2400-2483.5	30	1.0
5725-5850	30	1.0

802.15.1, 1 Mbps, TX		Test results radiated				
		Fieldstrength E (dB μ V/m)	EIRP (dBm)	P (W)	EIRP Limit (dBm)	Margin (dB)
Lowest frequency: CH37, 2402 MHz						
T_{nom}	V_{nom}	93.1	-2.1	0.0006	36	-38.1
Middle frequency: CH17, 2440 MHz						
T_{nom}	V_{nom}	95.8	0.6	0.0011	36	-35.4
Highest frequency: CH39, 2480 MHz						
T_{nom}	V_{nom}	95.7	0.4	0.0011	36	-35.6

802.15.1, 2 Mbps, TX		Test results radiated				
		Fieldstrength E (dB μ V/m)	EIRP (dBm)	P (W)	EIRP Limit (dBm)	Margin (dB)
Lowest frequency: CH37, 2402 MHz						
T_{nom}	V_{nom}	95.7	0.4	0.0011	36	-35.6
Middle frequency: CH17, 2440 MHz						
T_{nom}	V_{nom}	95.9	0.7	0.0012	36	-35.3
Highest frequency: CH39, 2480 MHz						
T_{nom}	V_{nom}	95.6	0.3	0.0011	36	-35.7

Peak Power Limit according to FCC Part 15, Section 15.247(b)(4):

Frequency (MHz)	Peak Power Limit	
	(dBm)	(Watt)
902-928	36	4.0
2400-2483.5	36	4.0
5725-5850	36	4.0

The requirements are **FULFILLED**.

Remarks: N/A

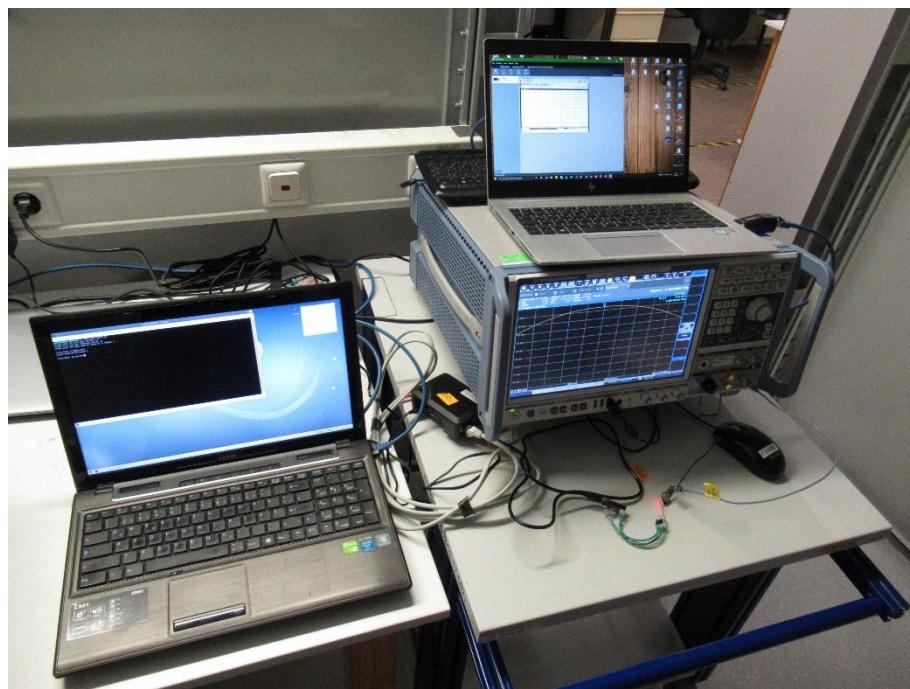
5.3 Power spectral density

For test instruments and accessories used see section 6 Part **CPC 3**.

5.3.1 Description of the test location

Test location: Shielded Room S4

5.3.2 Photo documentation of the test set-up



5.3.3 Applicable standard

According to FCC Part 15, Section 15.247(e):

For digitally modulated systems, the power spectral density radiated from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the radiated output power shall be used to determine the power spectral density.

5.3.4 Description of Measurement

The measurement is performed using the procedure set out in ANSI C64.10, item 11.10.21. The power measurement was done as peak power measurement. Therefore, the PKPSD is measured. The max peak was located and with the spectrum analyser and a marker set to peak.

Spectrum analyser settings:

RBW: 3 kHz, VBW: 10 kHz, Detector: Peak, Sweep time: Auto

5.3.5 Test result

802.15.1, 1 Mbps, TX		Test results conducted		
		PD [Pmax] (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Lowest frequency: CH37, 2402 MHz				
T_{nom}	V_{nom}	-39.9	8.0	-47.9
Middle frequency: CH17, 2440 MHz				
T_{nom}	V_{nom}	-38.6	8.0	-46.6
Highest frequency: CH39, 2480 MHz				
T_{nom}	V_{nom}	-37.8	8.0	-45.8

802.15.1, 2 Mbps, TX		Test results conducted		
		PD [Pmax] (dBm/3kHz)	Limit (dBm/3kHz)	Margin (dB)
Lowest frequency: CH37, 2402 MHz				
T_{nom}	V_{nom}	-41.6	8.0	-49.6
Middle frequency: CH17, 2440 MHz				
T_{nom}	V_{nom}	-39.9	8.0	-47.9
Highest frequency: CH39, 2480 MHz				
T_{nom}	V_{nom}	-38.7	8.0	-46.7

Power spectral density limit according to FCC Part 15, Section 15.247(e):

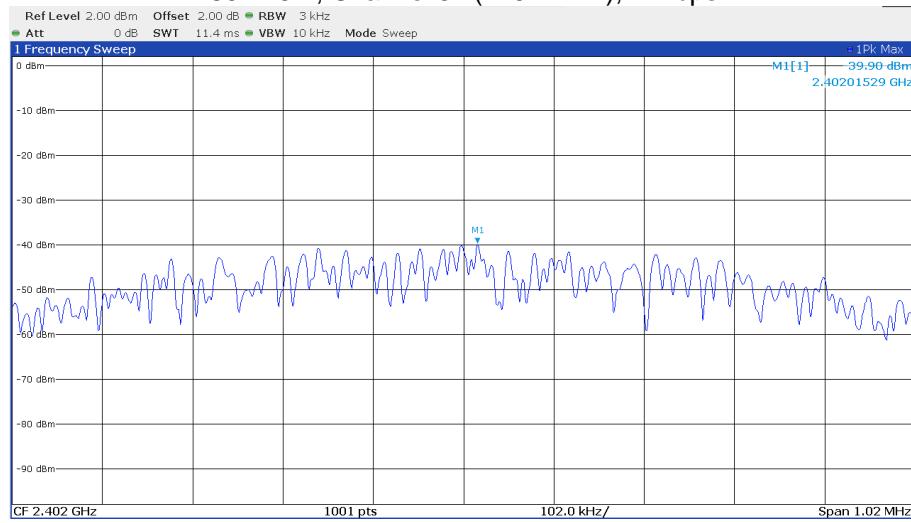
Frequency (MHz)	Power spectral density limit (EIRP)	
	(dBm/3 kHz)	
2400 - 2483.5		8

The requirements are **FULFILLED**.

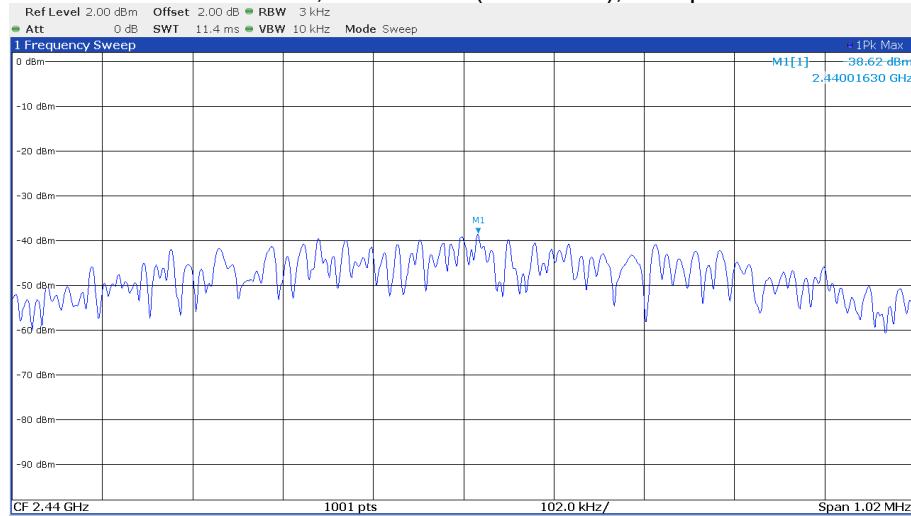
Remarks: For detailed test result please see the following test protocols

5.3.6 Test protocols

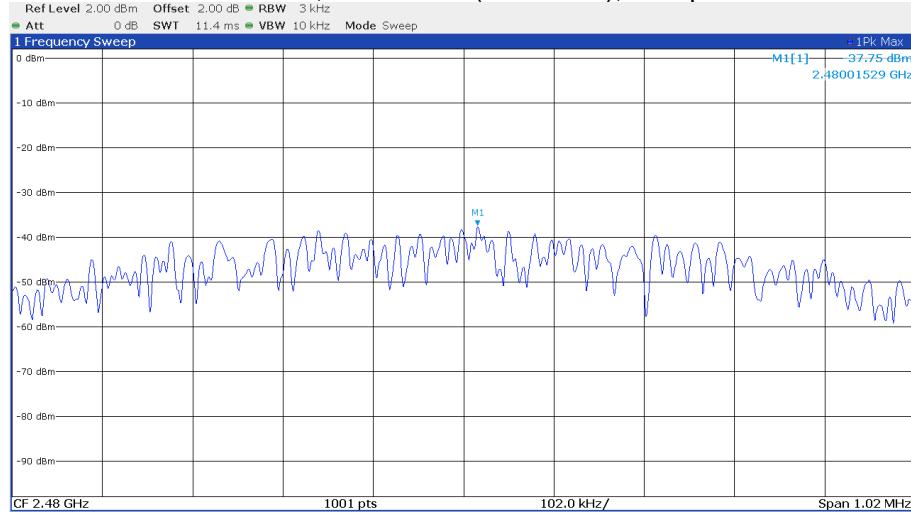
802.15.1, Channel 37 (2402 MHz), 1 Mbps



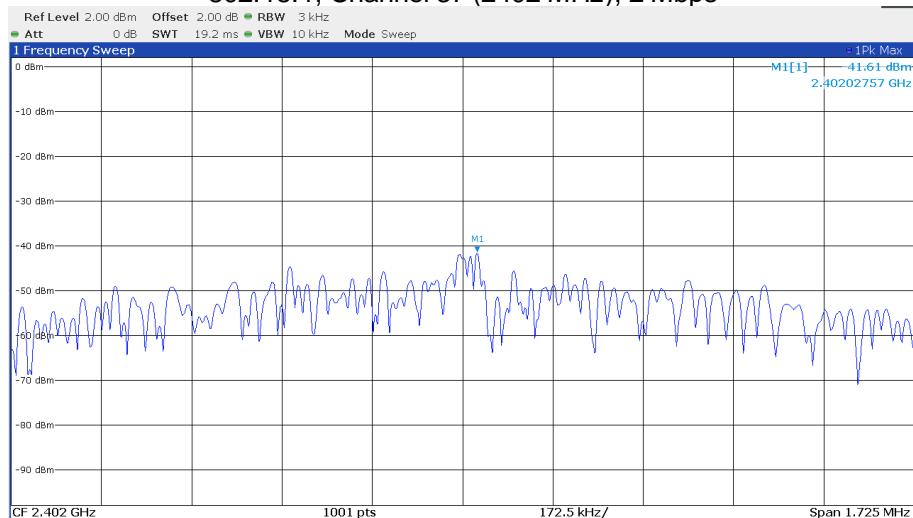
802.15.1, Channel 17 (2440 MHz), 1 Mbps



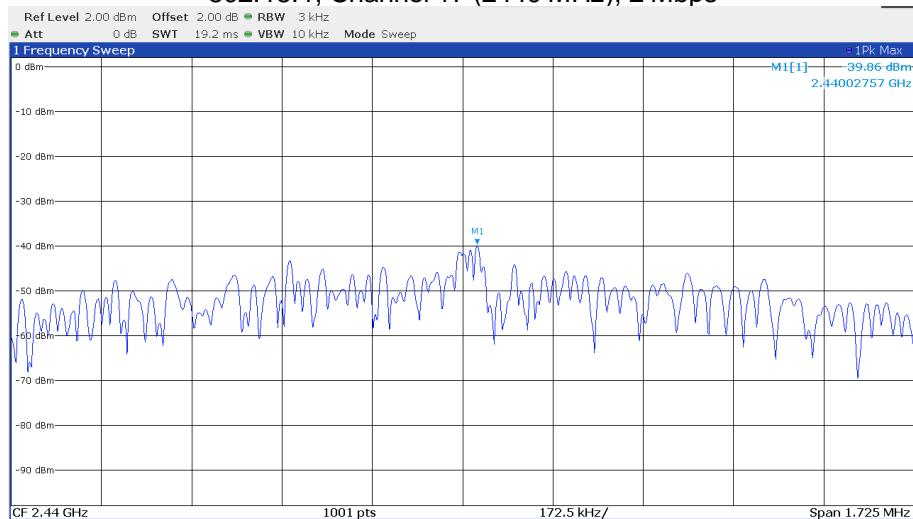
802.15.1, Channel 39 (2480 MHz), 1 Mbps



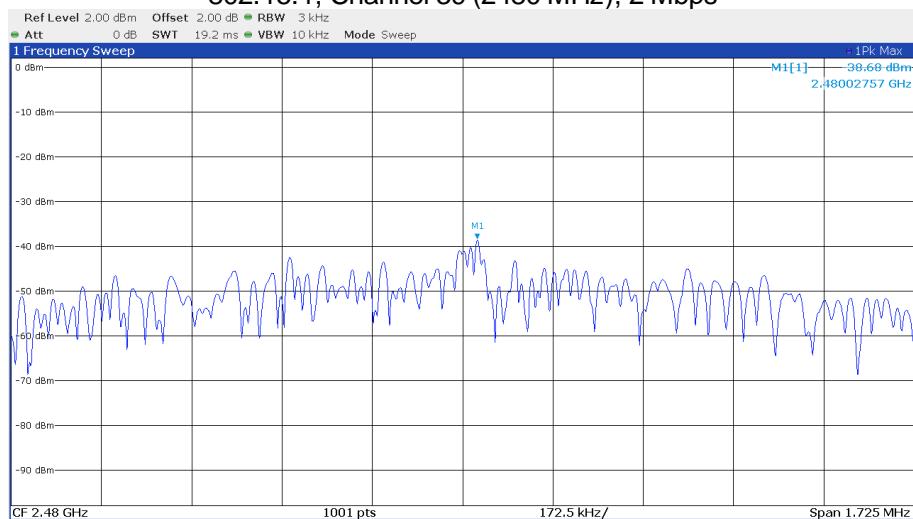
802.15.1, Channel 37 (2402 MHz), 2 Mbps



802.15.1, Channel 17 (2440 MHz), 2 Mbps



802.15.1, Channel 39 (2480 MHz), 2 Mbps



5.4 Radiated emissions in restricted bands

For test instruments and accessories used see section 6 Part **SER 2, SER 3**.

5.4.1 Description of the test location

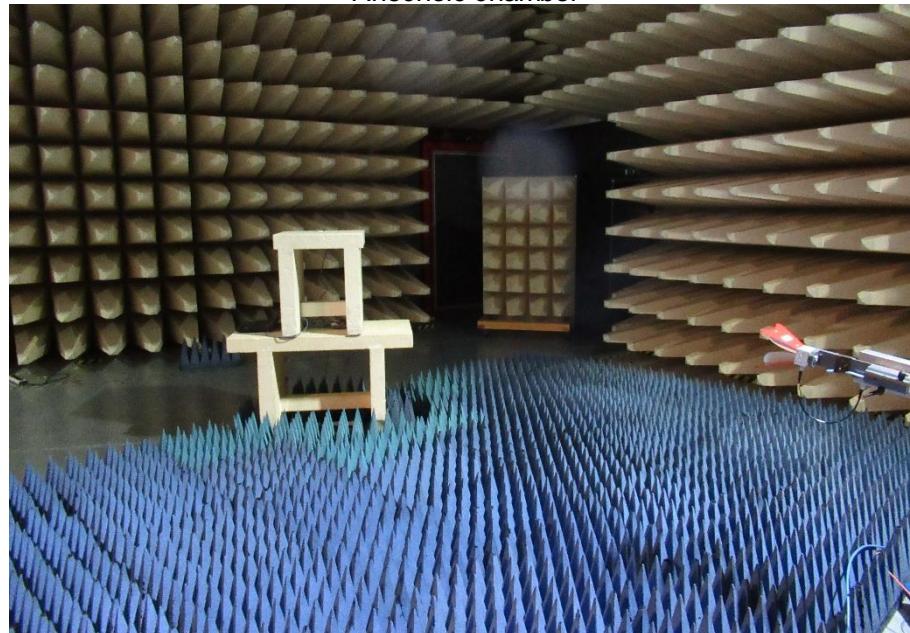
Test location: OATS 1
Test location: Anechoic chamber 1
Test distance: 3 m

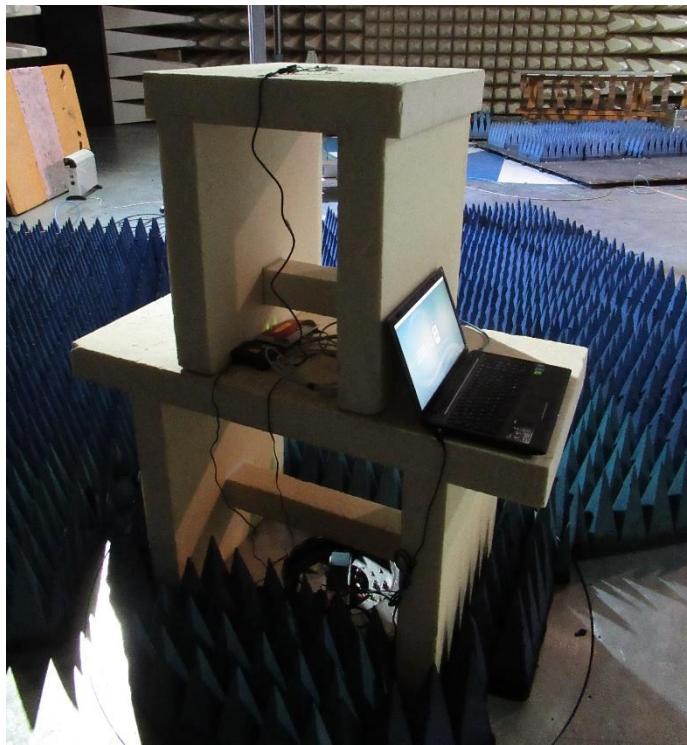
5.4.2 Photo documentation of the test set-up

Open area test site



Anechoic chamber





According to FCC Part 15, Section 15.205(a):

In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limit specified in Section 15.209(a).

5.4.3 Description of Measurement

The restricted bands are measured radiated. The span of the spectrum analyser is set wide enough to capture the restricted band and measure the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products which fall outside of the authorized band of operation. The restricted bands are measured falling emissions into it and the nearest restricted band are checked for emissions also the restricted band for the harmonics of the carrier.

Test receiver settings for SER2:

RBW: 120 MHz, Detector: Quasi peak, Mes. Time: 1 s,

Spectrum analyser settings for SER3:

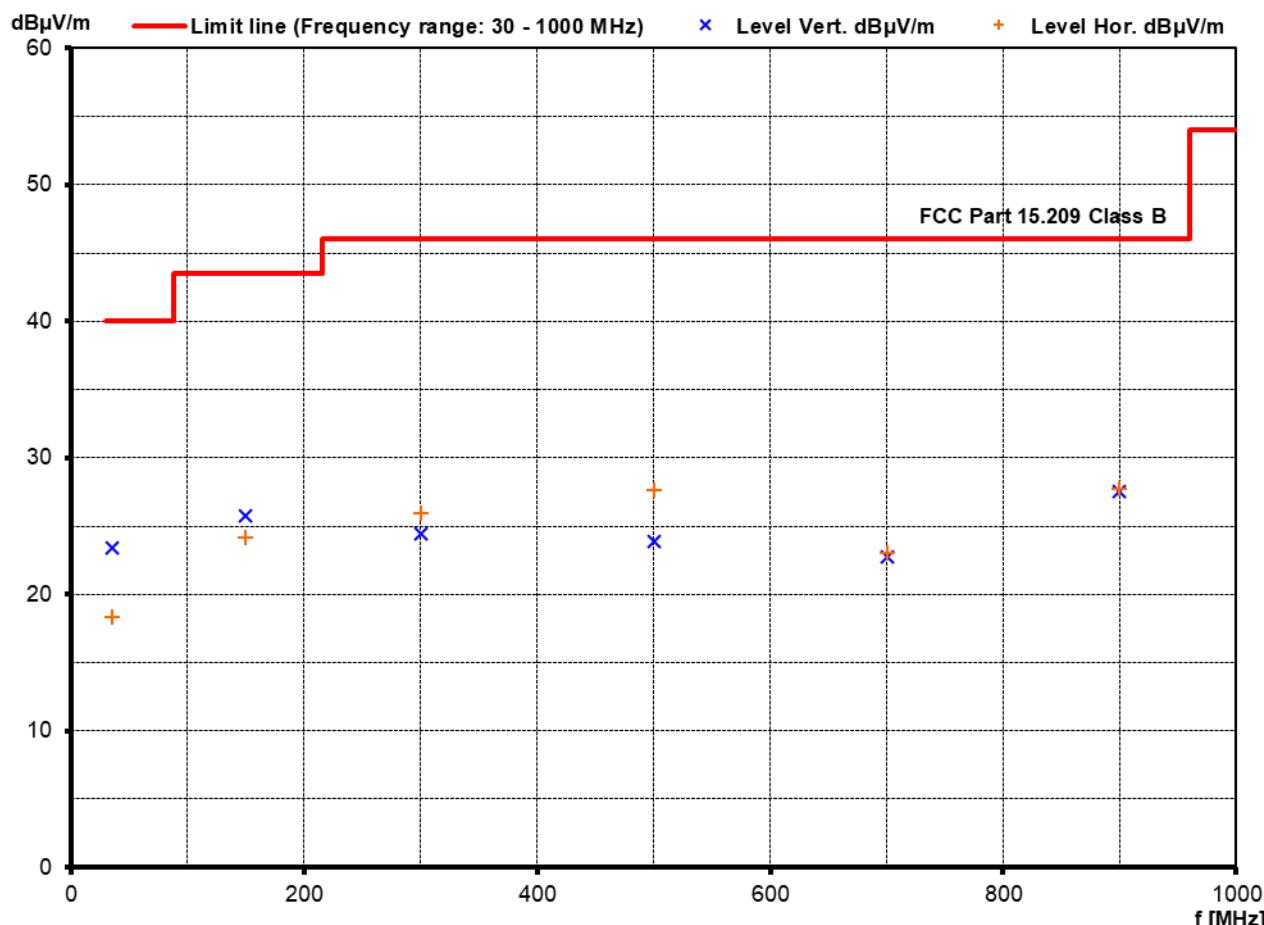
RBW: 1 MHz, VBW: 3 MHz, Detector: Max. peak (blue); RMS (black), Trace: Max. hold, Sweep: Auto

5.4.4 Test result

Standard 802.15.1

Emissions 30 MHz – 1000 MHz, SER2:

Frequency (MHz)	Reading Vert. (dB μ V)	Reading Hor. (dB μ V)	Correct. Vert. (dB)	Correct. Hor. (dB)	Level Vert. (dB μ V/m)	Level Hor. (dB μ V/m)	Limit (dB μ V/m)	Dlimit (dB)
35.00	10.2	4.2	13.2	14.2	23.4	18.4	40.0	-16.6
150.00	9.3	8.	16.5	15.7	25.8	24.1	43.5	-17.7
300.00	7.2	8.2	17.2	17.7	24.4	25.9	46.0	-20.1
500.00	1.1	4.6	22.7	23.1	23.8	27.7	46.0	-18.3
700.00	-3.9	-4.3	26.7	27.3	22.8	23.0	46.0	-23.0
900.00	-2.3	-2.5	29.8	30.2	27.5	27.7	46.0	-18.3



Note: No emissions below 1 GHz were detected. Results above show noise values of the OATS.

Emissions 1 GHz – 26 GHz, SER3:

See test protocols below.

Radiated limits according to FCC Part 15 Section 15.209(a) for spurious emissions which fall in restricted bands:

Frequency (MHz)	Field strength of spurious emissions (μ V/m)		Measurement distance (metres)
		dB(μ V/m)	
0.009-0.490	2400/F (kHz)		300
0.490-1.705	24000/F (kHz)		30
1.705-30	30	29.5	30
30-88	100	40	3
88-216	150	43.5	3
216-960	200	46	3
Above 960	500	54	3

Restricted bands of operation:

The field strength of emissions appearing within these frequency bands shall not exceed the limits shown in Section 15.209

MHz	MHz	MHz	GHz
0.090 – 0.110	16.42 – 16.423	399.9 – 410	4.5 – 5.15
0.495 – 0.505	16.69475 – 16.69525	608 – 614	5.35 – 5.46
2.1735 – 2.1905	16.80425 – 16.80475	960 – 1240	7.25 – 7.75
4.125 – 4.128	25.5 – 25.67	1300 – 1427	8.025 – 8.5
4.17725 – 4.17775	37.5 – 38.25	1435 – 1626.5	9.0 – 9.2
4.20725 – 4.20775	73 – 74.6	1645.5 – 1646.5	9.3 – 9.5
6.215 – 6.218	74.8 – 75.2	1660 – 1710	10.6 – 12.7
6.26775 – 6.26825	108 – 121.94	1718.8 – 1722.2	13.25 – 13.4
6.31175 – 6.31225	123 – 138	2200 – 2300	14.47 – 14.5
8.291 – 8.294	149.9 – 150.05	2310 – 2390	15.35 – 16.2
8.362 – 8.366	156.52475 – 156.52525	2483.5 – 2500	17.7 – 21.4
8.37625 – 8.38675	156.7 – 156.9	2690 – 2900	22.01 – 23.12
8.41425 – 8.41475	162.0125 – 167.17	3260 – 3267	23.6 – 24.0
12.29 – 12.293	167.72 – 173.2	3332 – 3339	31.2 – 31.8
12.51975 – 12.52025	240 – 285	3345.8 – 3358	36.43 – 36.5
12.57675 – 12.57725	322 – 335.4	3600 – 4400	Above 38.6

RSS-Gen, Table 6 – Restricted Frequency Bands

MHz	MHz	MHz	GHz
0.090 - 0.110	12.57675 - 12.57725	399.9 - 410	7.250 - 7.750
0.495 - 0.505	13.36 - 13.41	608 - 614	8.025 - 8.500
2.1735 - 2.1905	16.42 - 16.423	960 - 1427	9.0 - 9.2
3.020 - 3.026	16.69475 - 16.69525	1435 - 1626.5	9.3 - 9.5
4.125 - 4.128	16.80425 - 16.80475	1645.5 - 1646.5	10.6 - 12.7
4.17725 - 4.17775	25.5 - 25.67	1660 - 1710	13.25 - 13.4
4.20725 - 4.20775	37.5 - 38.25	1718.8 - 1722.2	14.47 - 14.5
5.677 - 5.683	73 - 74.6	2200 - 2300	15.35 - 16.2
6.215 - 6.218	74.8 - 75.2	2310 - 2390	17.7 - 21.4
6.26775 - 6.26825	108 - 138	2483.5 - 2500	22.01 - 23.12
6.31175 - 6.31225	149.9 - 150.05	2655 - 2900	23.6 - 24.0
8.291 - 8.294	156.52475 - 156.52525	3260 - 3267	31.2 - 31.8
8.362 - 8.366	156.7 - 156.9	3332 - 3339	36.43 - 36.5
8.37625 - 8.38675	162.0125 - 167.17	3345.8 - 3358	Above 38.6
8.41425 - 8.41475	167.72 - 173.2	3500 - 4400	
12.29 - 12.293	240 - 285	4500 - 5150	
12.51975 - 12.52025	322 - 335.4	5350 - 5460	

The requirements are **FULFILLED**.

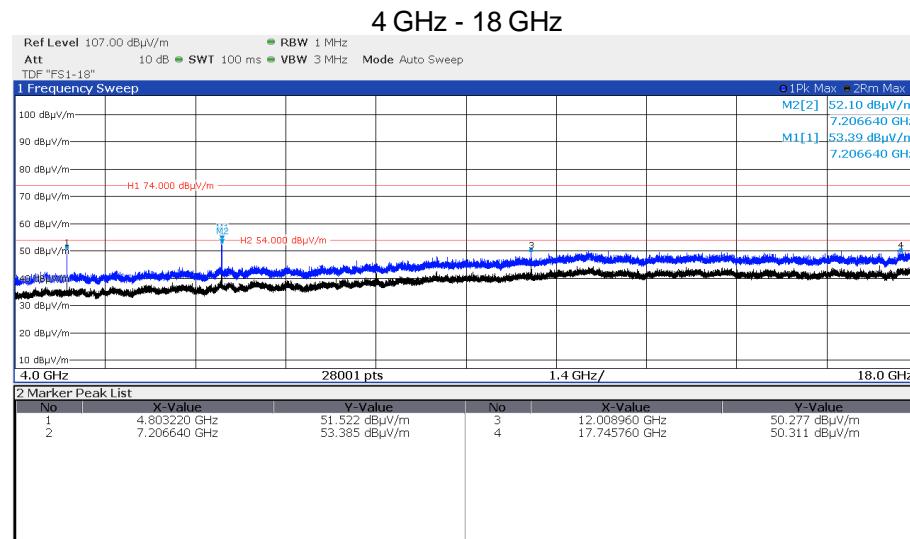
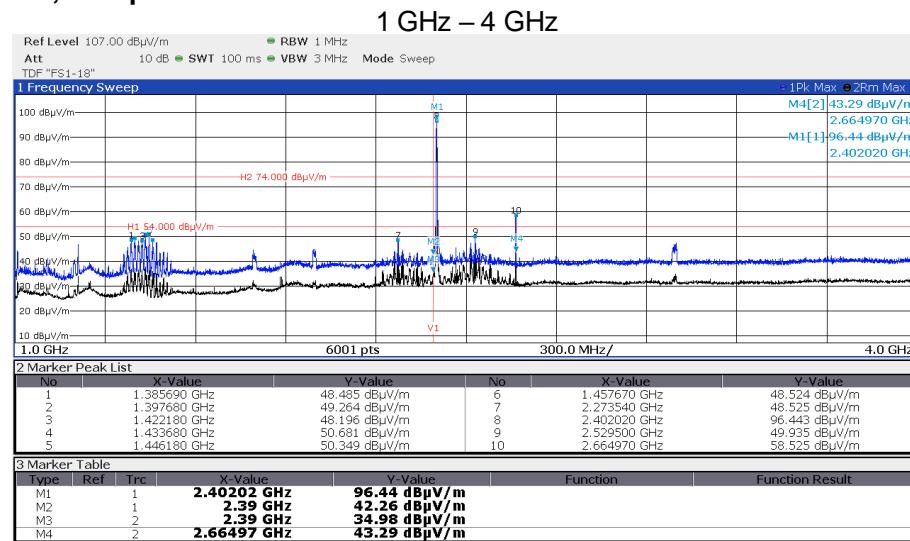
Remarks: The measurement was performed up to the 10th harmonic. For detailed test results please see the following test protocols.

5.4.5 Test protocols radiated emissions SER3

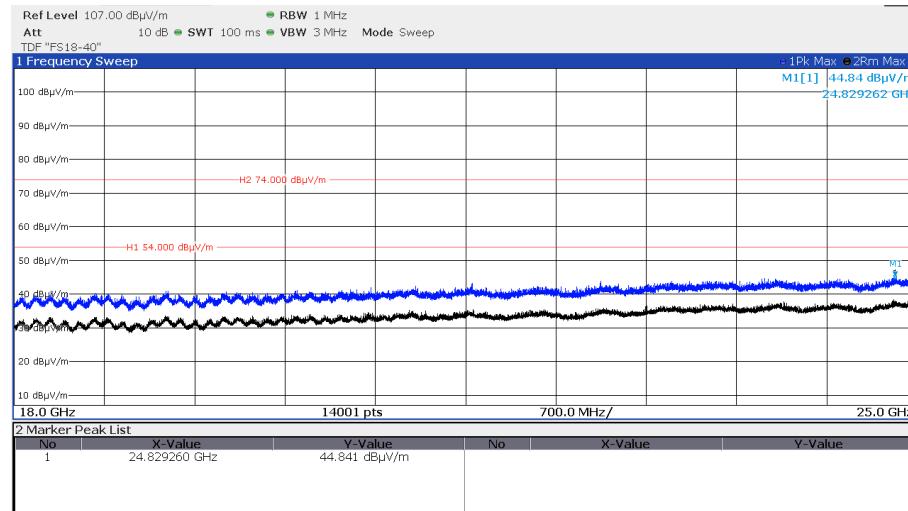
Note: *Marker Peak List* shows measured peak values.
 Marker data in top right corner *MX[1]* shows peak value, *MX[2]* shows RMS value.
Marker Table column *Trc*: 1 shows peak marker; 2 shows RMS marker.

All measured emissions comply with the general limits 74 dB(μ V/m) Peak and 54 dB(μ V/m) RMS.

802.15.1, Channel 37, 1 Mbps

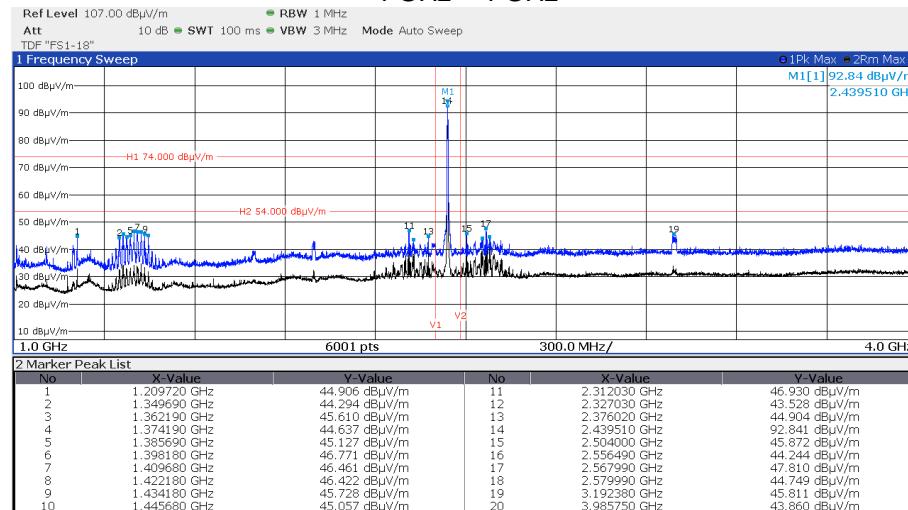


18 GHz – 26 GHz

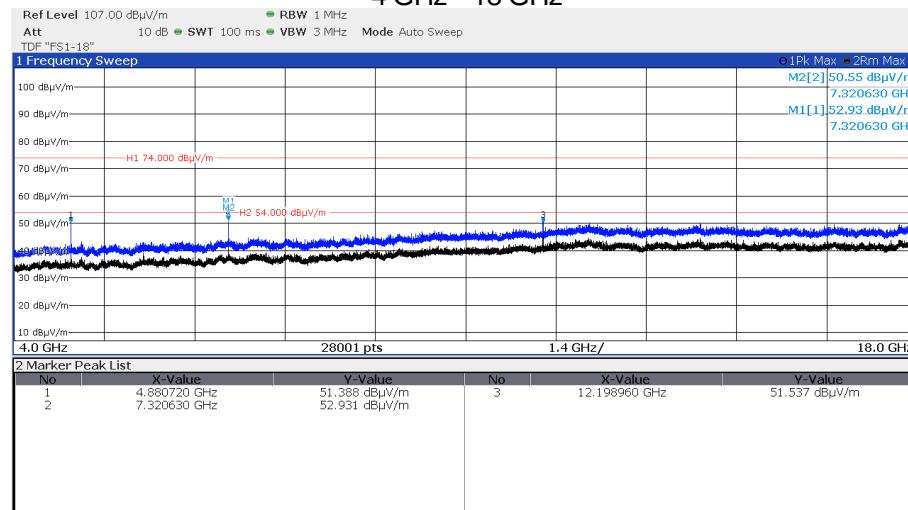


802.15.1, Channel 17, 1 Mbps

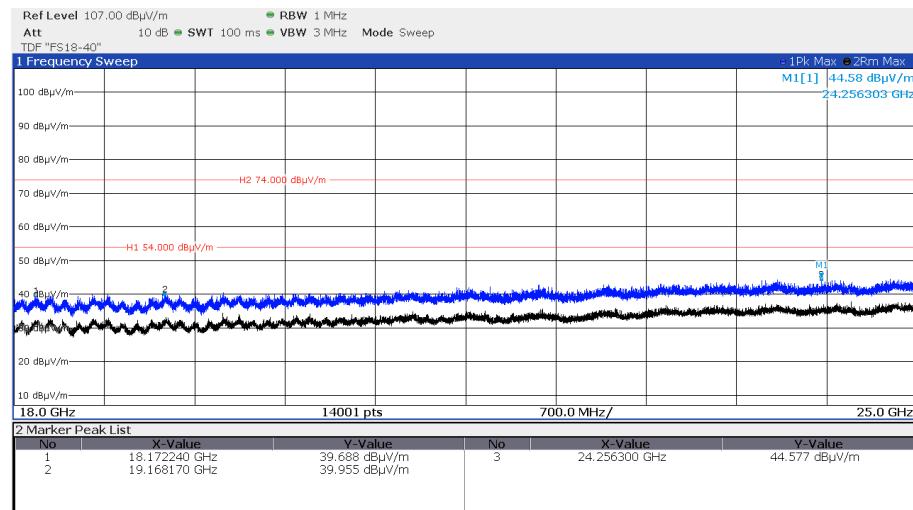
1 GHz – 4 GHz



4 GHz - 18 GHz



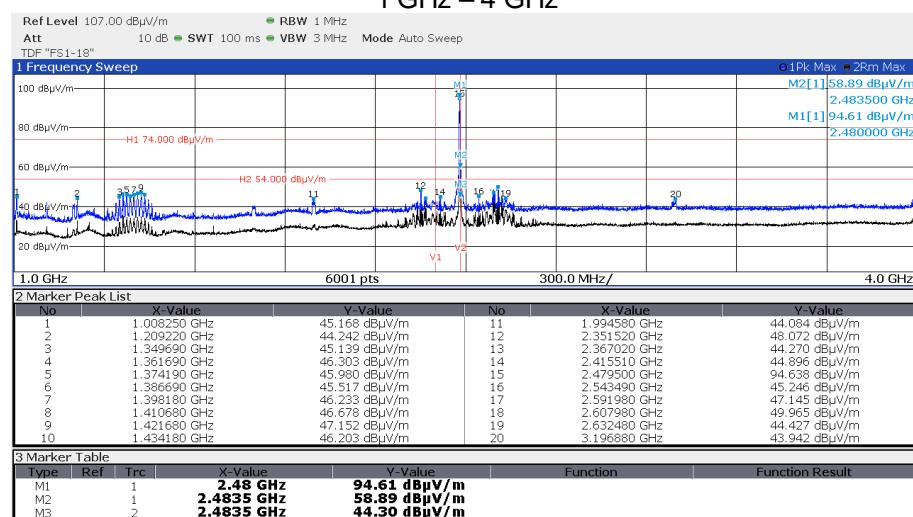
18 GHz – 26 GHz



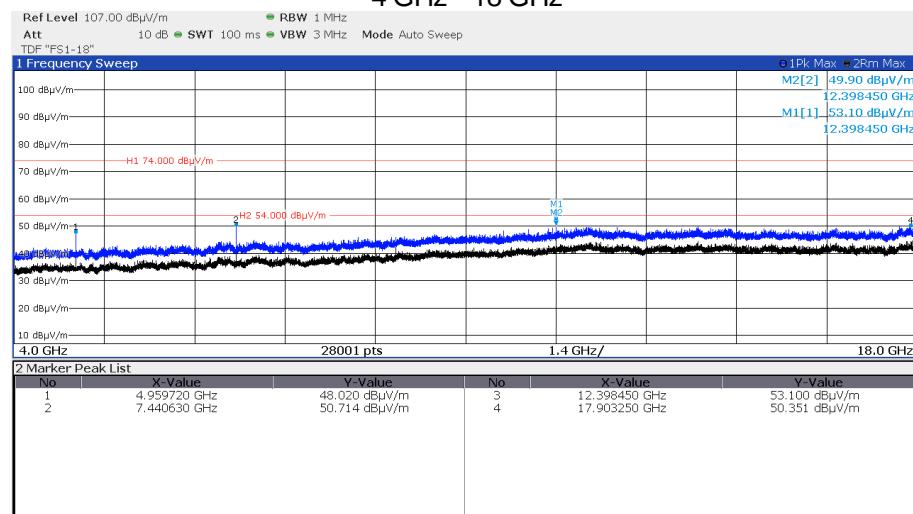
The test report merely corresponds to the test sample. It is not permitted to copy extracts of these test results without the written permission of the test laboratory.

802.15.1, Channel 39, 1 Mbps

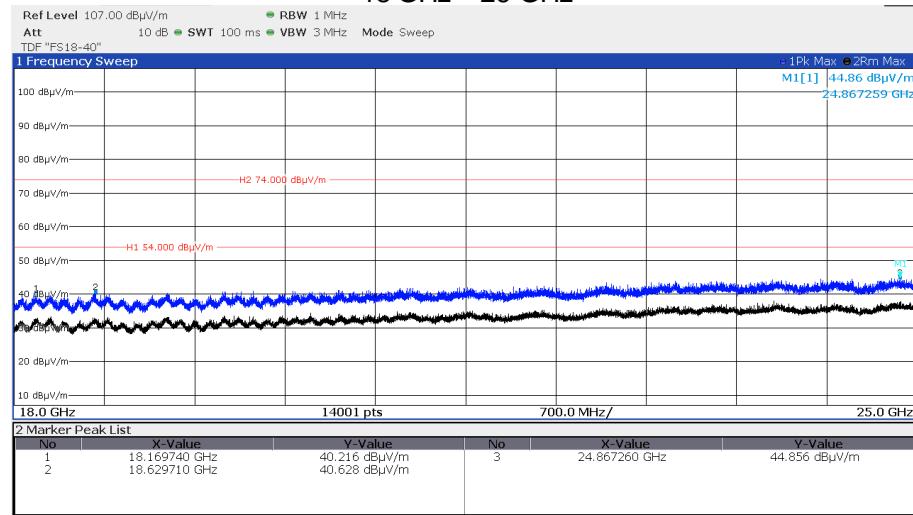
1 GHz – 4 GHz



4 GHz - 18 GHz

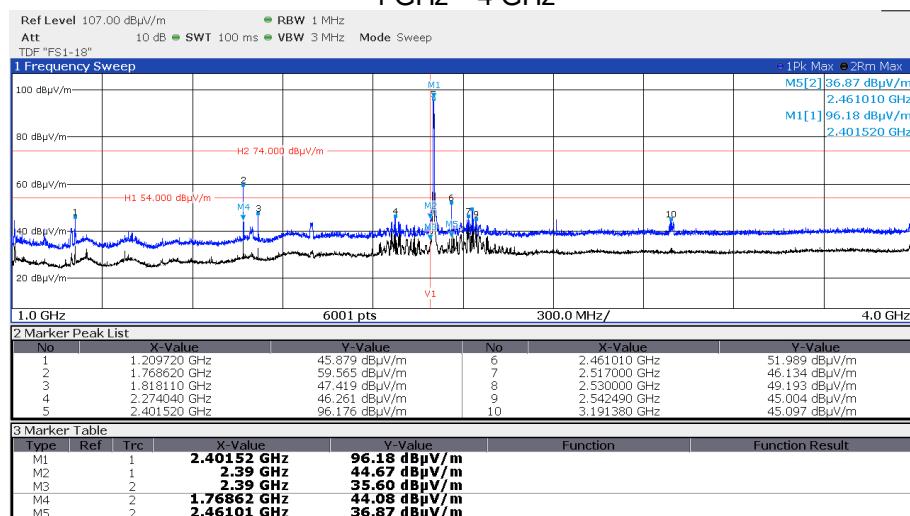


18 GHz – 26 GHz

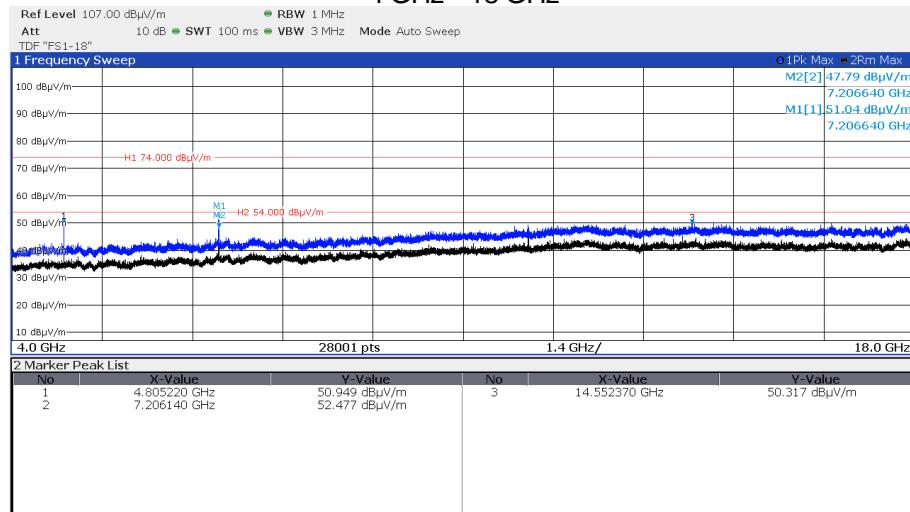


802.15.1, Channel 37, 2 Mbps

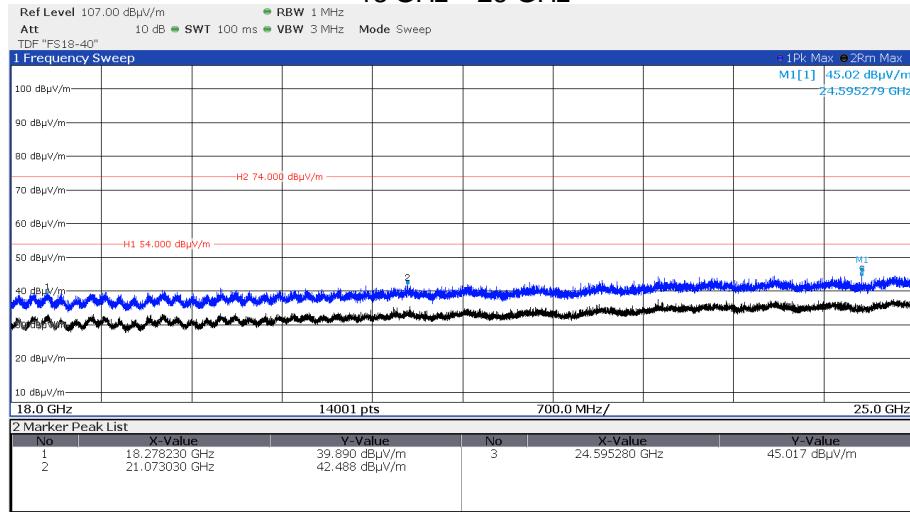
1 GHz – 4 GHz



4 GHz - 18 GHz

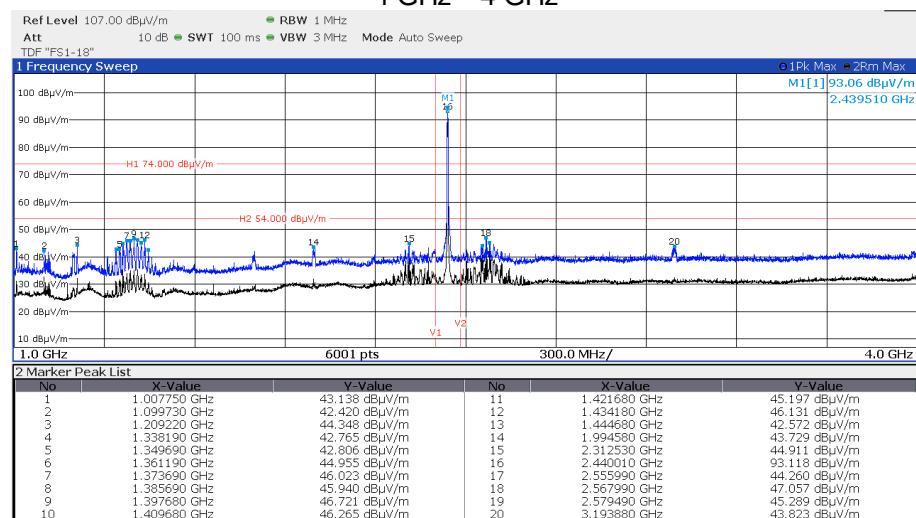


18 GHz – 26 GHz

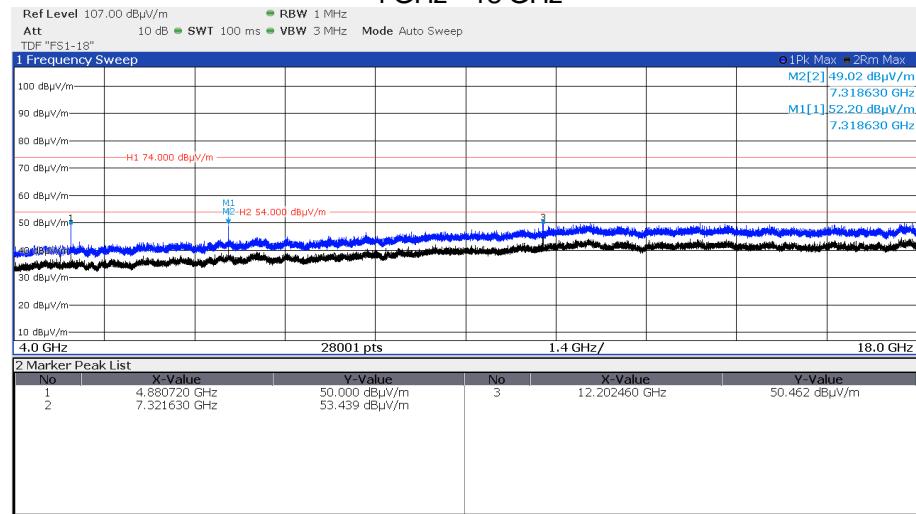


802.15.1, Channel 17, 2 Mbps

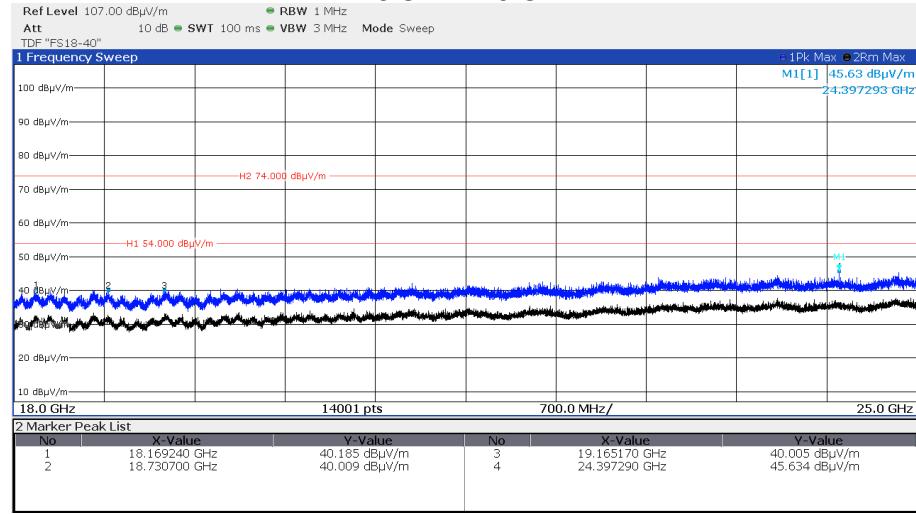
1 GHz – 4 GHz



4 GHz - 18 GHz

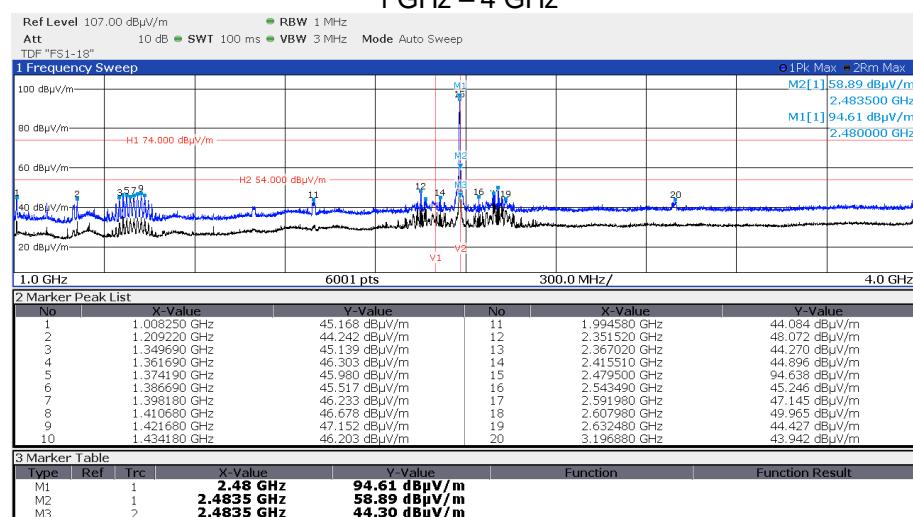


18 GHz – 26 GHz

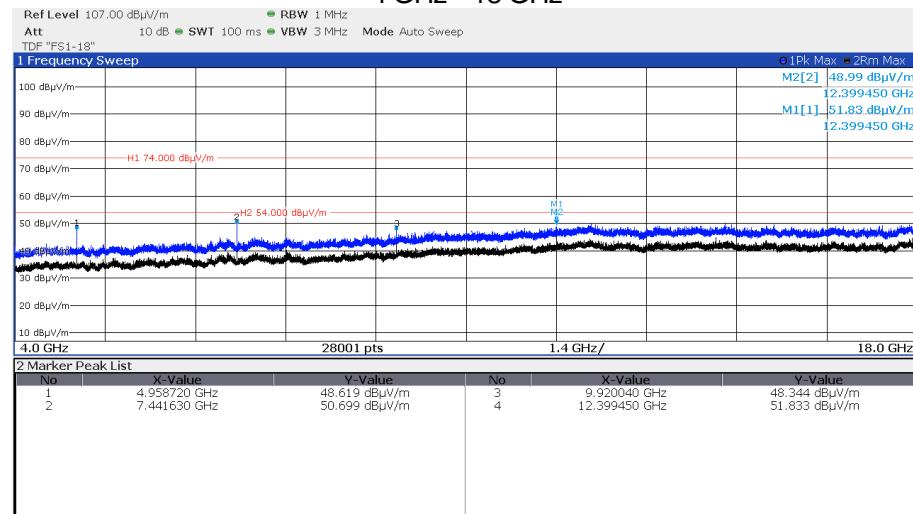


802.15.1, Channel 39, 2 Mbps

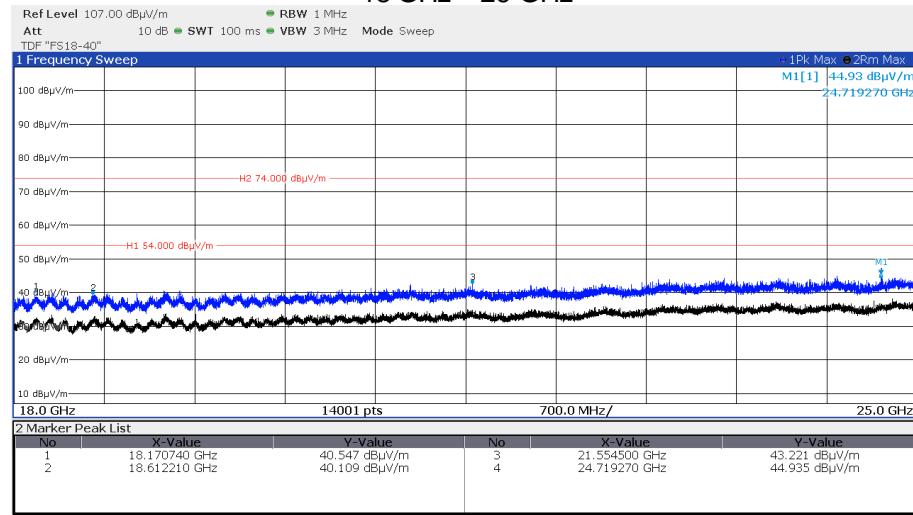
1 GHz – 4 GHz



4 GHz - 18 GHz



18 GHz – 26 GHz



5.5 Spurious emissions radiated

For test instruments and accessories used see section 6 Part **SER 2, SER 3**.

5.5.1 Description of the test location

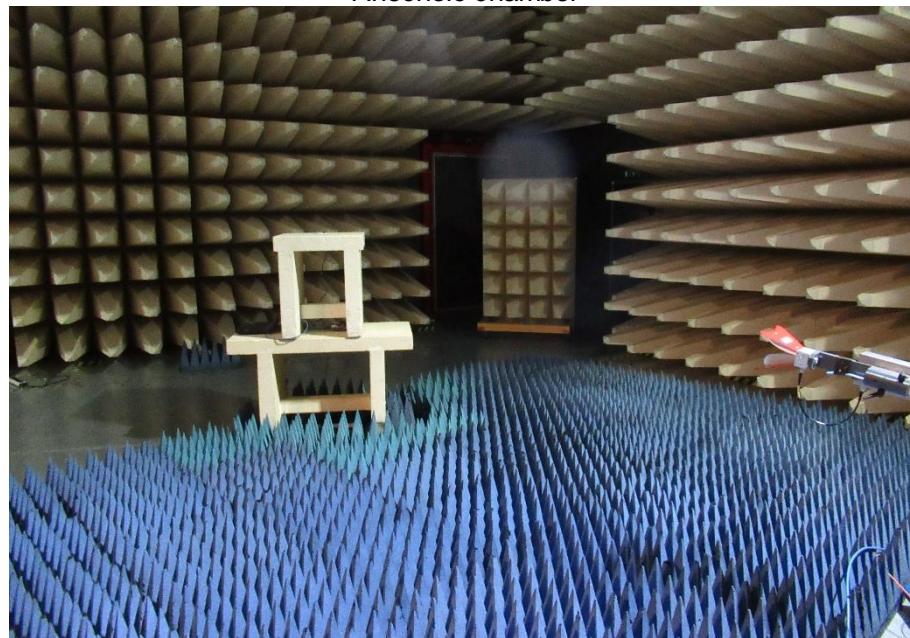
Test location: OATS 1
Test distance: 3 m

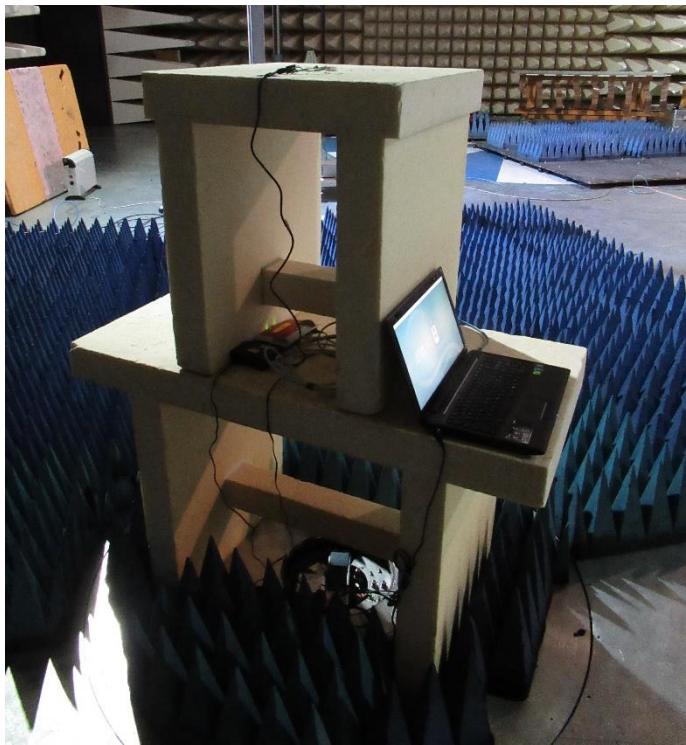
5.5.2 Photo documentation of the test set-up

Open area test site



Anechoic chamber





5.5.3 Applicable standard

According to FCC Part 15, Section 15.247(d):

In any 100 kHz bandwidth outside the frequency bands 2400 – 2483.50 MHz and 5725 – 5850 MHz, the digitally modulated radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or an radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limit specified in Section 15.209(a) (see Section 15.205(c)).

5.5.4 Description of Measurement

The radiated power of the spurious emission from the EUT is measured in a test setup following the procedures set out in ANSI C63.10. If the emission level of the EUT in peak mode complies with the average limit is 20 dB lower, then testing will be stopped and peak values of the EUT will be reported, otherwise the emission will be measured in average mode again and reported.

Test receiver settings for SER2:

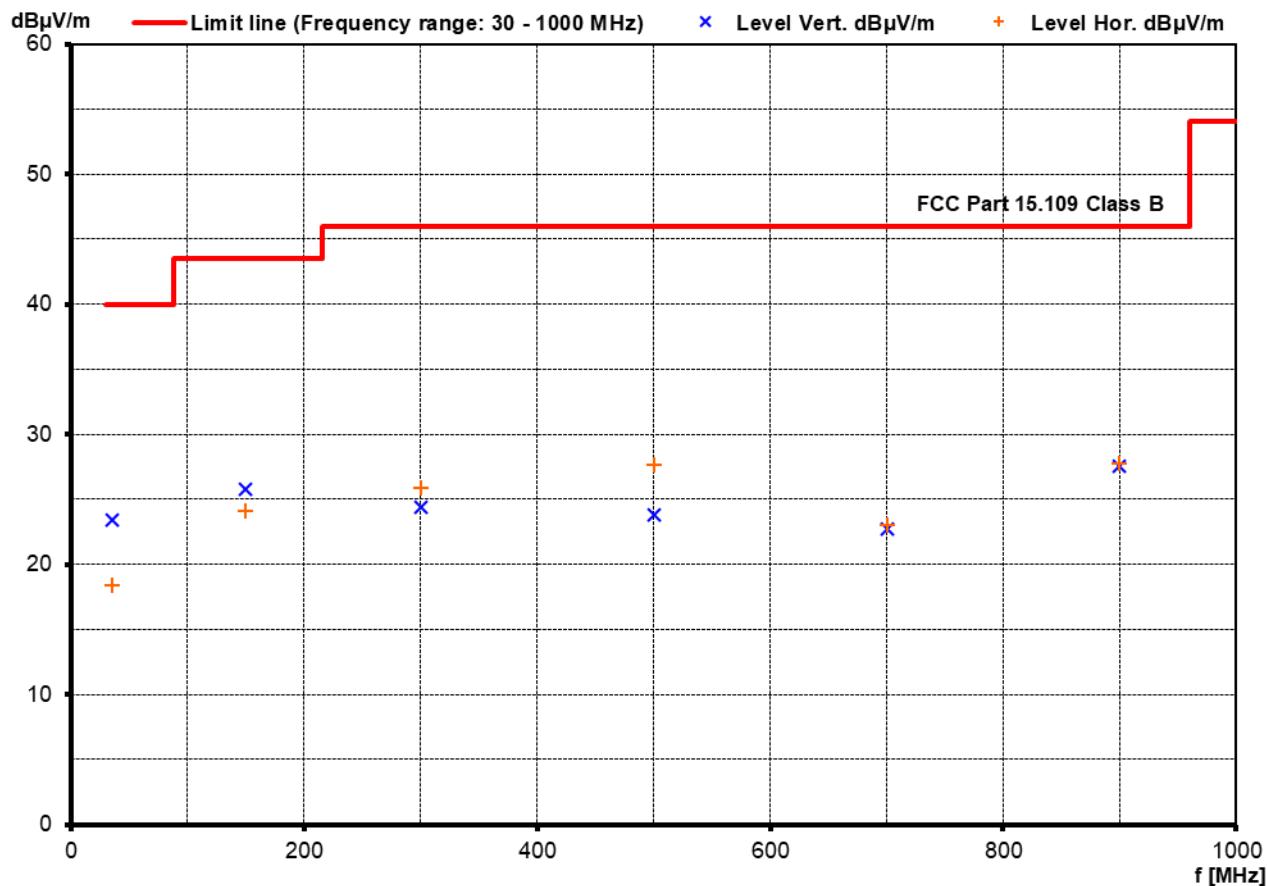
RBW: 120 MHz, Detector: Quasi peak, Mes. Time: 1 s,

Spectrum analyser settings for SER3:

RBW: 100 kHz, VBW: 300 kHz, Detector: Max. peak (blue); RMS (black), Trace: Max. hold, Sweep: Auto

5.5.5 Test result

Frequency (MHz)	Reading Vert. (dB μ V)	Reading Hor. (dB μ V)	Correct. Vert. (dB)	Correct. Hor. (dB)	Level Vert. (dB μ V/m)	Level Hor. (dB μ V/m)	Limit (dB μ V/m)	Dlimit (dB)
35.00	10.2	4.2	13.2	14.2	23.4	18.4	40.0	-16.6
150.00	9.3	8.4	16.5	15.7	25.8	24.1	43.5	-17.7
300.00	7.2	8.2	17.2	17.7	24.4	25.9	46.0	-20.1
500.00	1.1	4.6	22.7	23.1	23.8	27.7	46.0	-18.3
700.00	-3.9	-4.3	26.7	27.3	22.8	23.0	46.0	-23.0
900.00	-2.3	-2.5	29.8	30.2	27.5	27.7	46.0	-18.3



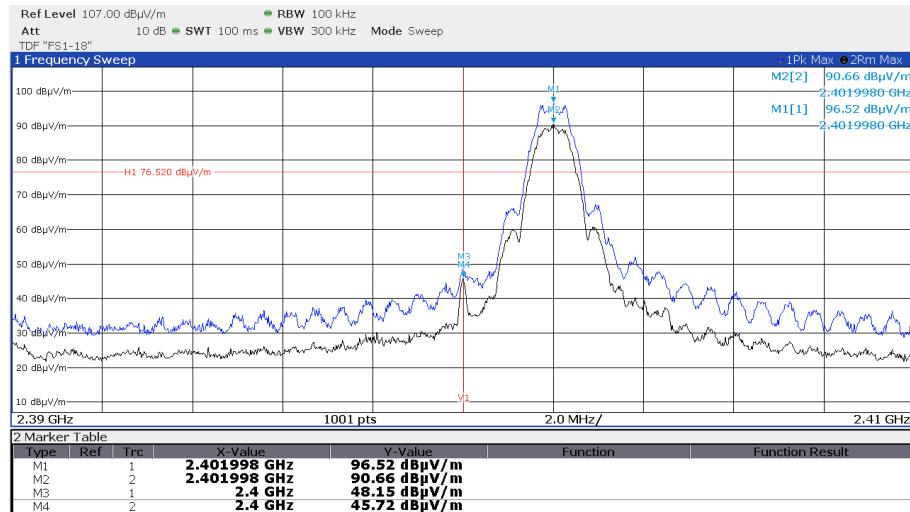
Note: No emissions below 1 GHz were detected. Results above show noise values of the OATS.

5.5.5.1 Test Results > 1 GHz

As results of 5.4.5 show compliance of spurious emissions ≤ 2.39 GHz and ≥ 2.4835 GHz with the stricter general limits, following data shows compliance at the lower band edge at 2.39 GHz to 2.4 GHz to the spurious emission limit.

802.15.1, Channel 37, 1 Mbps

2.39 GHz – 2.41 GHz



802.15.1, Channel 37, 2 Mbps

2.39 GHz – 2.41 GHz



Note:

Measurements were performed in the frequency range from 1 GHz up to 26 GHz with the analyser settings for restricted band measurements to show compliance for emissions falling into restricted bands, else the band edge compliance is fulfilled. In the frequency ranges from 9 kHz up to 30 MHz and from 18 GHz up to 25 GHz no emission can be detected.

According to FCC Part 15, Section 15.205(a):

In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limit specified in Section 15.209(a).

Limit according to FCC Part 15, Section 15.247(d) for emissions falling not in restricted bands:

In any 100 kHz bandwidth outside the frequency bands 2400 – 2483.50 MHz and 5725 – 5850 MHz, the digitally modulated radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or an radiated measurement. Attenuation below the general limits specified in Section 15.209(a) is not required.

Frequency (MHz)	Spurious emission limit
Below 1000	20 dB below the highest level of the desired power
Above 1000	20 dB below the highest level of the desired power

The requirements are **FULFILLED**.

Remarks:

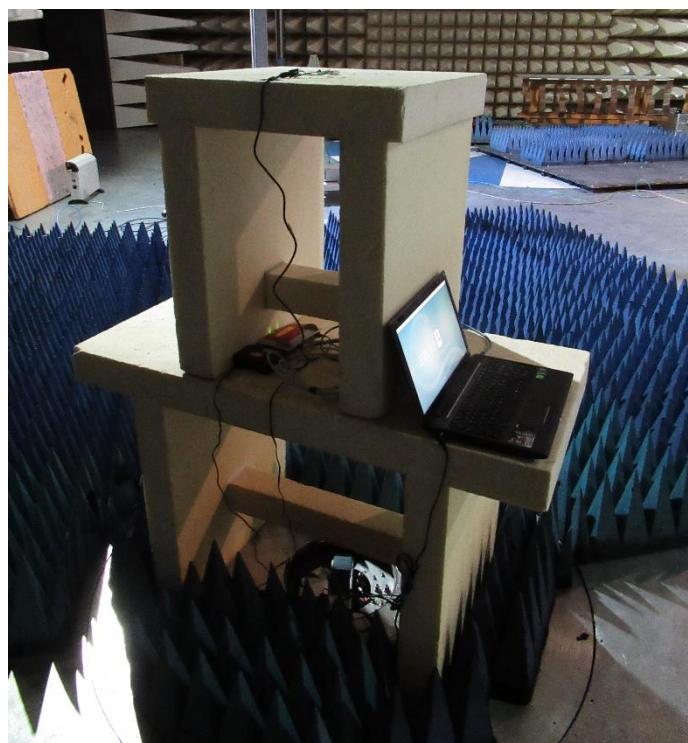
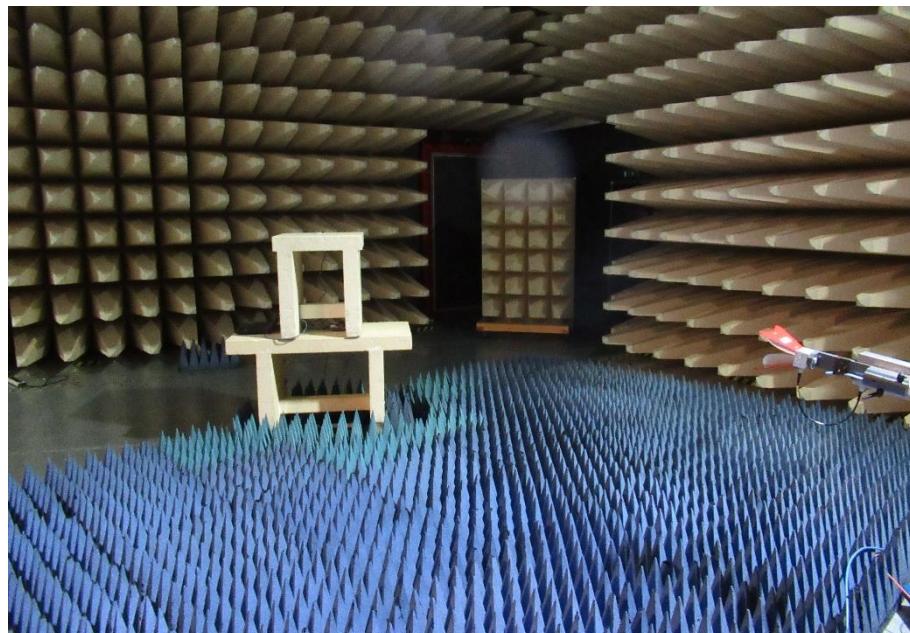
5.6 Antenna application

For test instruments and accessories used see section 6 Part **CPR3**.

5.6.1 Description of the test location

Test location: Anechoic chamber 1

5.6.2 Photo documentation of the test set-up



Applicable standard

According to FCC Part 15C, Section 15.203:

An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit that broken antennas can be replaced by the user, but the use of a standard antenna jack is prohibited.

The EUT has an integrated antenna. No other antenna can be used with the device. Additional to that a conducted output power measurement was performed. According to the following formula the maximum gain of the antenna was calculated.

$$\text{EIRP} = P + G$$

Where:

EIRP = Equivalent isotropic radiated power

P = Conducted output power

G = Calculated gain of the antenna

Result:

802.15.1, 1 Mbps, TX		measured conducted Power (dBm)	measured EIRP (dBm)	calculated Antenna Gain (dBi)
Lowest frequency: CH37, 2402 MHz				
T_{nom}	V_{nom}	4.2	-2.1	-6.3
Middle frequency: CH17, 2440 MHz				
T_{nom}	V_{nom}	4.2	0.6	-3.6
Highest frequency: CH39, 2480 MHz				
T_{nom}	V_{nom}	3.9	0.4	-3.4

802.15.1, 2 Mbps, TX		measured conducted Power (dBm)	measured EIRP (dBm)	calculated Antenna Gain (dBi)
Lowest frequency: CH37, 2402 MHz				
T_{nom}	V_{nom}	4.1	0.4	-3.7
Middle frequency: CH17, 2440 MHz				
T_{nom}	V_{nom}	4.2	0.7	-3.5
Highest frequency: CH39, 2480 MHz				
T_{nom}	V_{nom}	3.9	0.3	-3.6

Maximum calculated antenna gain	- 3.4 dBi
---------------------------------	-----------

The supplied antenna meets the requirements of part 15.203 and 15.204.

5.6.3 Antenna requirements

According to FCC Part 15C, Section 15.247(b)(4):

The conducted output power limit specified in paragraph (b) of 15.247 is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from intentional radiator shall be reduced below the stated values in paragraph (b)(1), (b)(2) and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

The output power has not to be reduced.

6 USED TEST EQUIPMENT AND ACCESSORIES

All test instruments used are calibrated and verified regularly. The calibration history is available on request.

Test ID	Model Type	Equipment No.	Next Calib.	Last Calib.	Next Verif.	Last Verif.	
CPC 3	ESW26	02-02/03-17-002	10/02/2022	10/02/2021			
CPR 3	FSW43 AMF-6D-01002000-22-10P 3117 18N-20 BAM 4.5-P NCD KK-SF106-2X11N-6,5M BAT-EMC 3.19.1.24	02-02/11-15-001 02-02/17-15-004 02-02/24-05-009 02-02/50-17-003 02-02/50-17-024 02-02/50-17-025 02-02/50-18-016 02-02/68-13-001	02/04/2021	02/04/2020	18/06/2021	18/06/2020	
MB	FSW43 AMF-6D-01002000-22-10P 3117 18N-20 BAM 4.5-P NCD KK-SF106-2X11N-6,5M BAT-EMC 3.19.1.24	02-02/11-15-001 02-02/17-15-004 02-02/24-05-009 02-02/50-17-003 02-02/50-17-024 02-02/50-17-025 02-02/50-18-016 02-02/68-13-001	02/04/2021	02/04/2020	18/06/2021	18/06/2020	
SER 2	ESVS 30 VULB 9168 NW-2000-NB KK-EF393/U-16N-21N20 m KK-SD_7/8-2X21N-33,0M	02-02/03-05-006 02-02/24-05-005 02-02/50-05-113 02-02/50-12-018 02-02/50-15-028	15/07/2021	15/07/2020	18/12/2021	18/12/2020	
SER 3	FSP 40 FSW43 AMF-6D-01002000-22-10P LNA-40-18004000-33-5P 3117 BBHA 9170 18N-20 BAM 4.5-P NCD KK-SF106-2X11N-6,5M KMS116-GL140SE-KMS116- BAT-EMC 3.19.1.24	02-02/11-11-001 02-02/11-15-001 02-02/17-15-004 02-02/17-20-002 02-02/24-05-009 02-02/24-05-013 02-02/50-17-003 02-02/50-17-024 02-02/50-17-025 02-02/50-18-016 02-02/50-20-026 02-02/68-13-001	01/10/2021 02/04/2021	01/10/2020 02/04/2020	18/06/2021 19/05/2023	18/06/2020 19/05/2020	04/02/2022 04/02/2021