PHOENIX TESTLAB

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Test Report

Report Number:

F212286E1 3rd Version

Equipment under Test (EUT):

VCUNM1

Applicant:

Robert Bosch GmbH

Manufacturer:

Robert Bosch GmbH

ilac-MRA

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-17186-01-01
D-PL-17186-01-02
D-PL-17186-01-03

References

[1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

[2] **FCC CFR 47 Part 15**, Radio Frequency Devices

[3] **558074 D01 15.247 Meas Guidance v05r02 (April 2019),** GUIDANCE FOR COMPLIANCE MEASUREMENTS ON DIGITAL TRANSMISSION SYSTEM, FREQUENCY HOPPING SPREAD SPECTRUM SYSTEM, AND HYBRID SYSTEM DEVICES OPERATING UNDER SECTION 15.247 OF THE FCC RULES

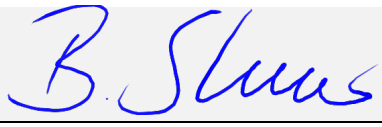
[4] **RSS-247, Issue 2 (2017-02)** Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

[5] **RSS-Gen, Issue 5 Amendment 2 (2021-02)** General Requirements for Compliance of Radio Apparatus

[6] **662911 D01 Multiple Transmitter Output v02r01 (October 2013),** Emissions Testing of Transmitters with Multiple Outputs in the Same Band

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.
“Passed” indicates that the equipment under test conforms with the relevant limits of the testing standard without taking any measurement uncertainty into account as stated in clause 1.3 of ANSI C63.10 (2013). However, the measurement uncertainty is calculated and shown in this test report.

Tested and written by:		Paul NEUFELD 21.08.2023
	Signature	
Reviewed and approved by:		Bernd STEINER 21.08.2023
	Signature	

This test report is only valid in its original form.

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

Contents: Page

1 Identification

1.1 Applicant

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Name for contact purposes:	Mr. Tilman ALMSTEDT
Phone:	+49 5121 49-4226
eMail address:	Eike-Tilman.Almstedt@de.bosch.com
Applicant represented during the test by the following person:	-

1.2 Manufacturer

Name:	Robert Bosch GmbH
Address:	Robert-Bosch-Str. 200, 31139 Hildesheim
Country:	Germany
Name for contact purposes:	Mr. Dirk ZAMOW
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Manufacturer represented during the test by the following person:	-

1.3 Production facility

Name:	Robert Bosch (Malaysia) Sdn Bhd
Address:	Free Industrial Zone 1, 11900 Bayan Lepas, Penang
Country:	Malaysia
Name for contact purposes:	Mr. Dr. Siegfried SKIRL
Phone:	-
eMail address:	Siegfried.Skirl@my.bosch.com
Manufacturer represented during the test by the following person:	-

1.4 Test Laboratory

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

Accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-06 and D-PL-17186-01-05, FCC Test Firm Designation Number DE0004, FCC Test Firm Registration Number 469623, CAB Identifier DE0003 and ISED# 3469A.

1.5 EUT (Equipment under Test)

EUT	
Test object: *	Virtual Cockpit Unit
Model name: *	VCUNM1
Model number: *	7.515.400.919-22
Order number: *	NA
FCC ID: *	2AUXS-VCUNM1
IC certification number: *	25847-VCUNM1
PMN: *	Virtual Cockpit Unit
HVIN: *	VCUNM1
FVIN: *	NA
HMN: *	NA

	EUT number		
	1 (conducted)	2 (radiated)	3 (radiated)
Serial number: *	1121322A10000190 (marked #C1*2)	1121322A10000120 (marked #R1*2)	1121322A10000130 NA (marked #R2*2)
PCB identifier: *	8638912015 8638912040 8638912111	8638912015 8638912040 8638912111	8638912015 8638912040 8638912111
Hardware version: *	C1.2	C1.2	C1.2
Software version: *	162.4.10 my23_main_2021.45.7 built SW 43.8	162.4.10 my23_main_2021.45.7 built SW 43.8	162.4.10 my23_main_2021.45.7 built SW 43.8

* Declared by the applicant
*2 marked by the test laboratory to unambiguously identify the EUTs

3 EUTs were used for the tests. In the overview (chapter 4) is shown which EUT was used for each test case.

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

1.6 Technical Data of Equipment

General EUT data			
Power supply EUT: *	DC		
Supply voltage EUT: *	U_{Nom}= 13.5 V_{DC}	U_{Min}= 6.0 V_{DC}	U_{Max}= 16.0 V_{DC}
Temperature range: *	-40°C to +85°C		
Lowest / highest internal clock frequency: *	1 Hz / 2.462 GHz		

Ports / Connectors				
Identification	Connector		Length during test	Shielding (Yes / No)
	EUT	Ancillary		
J1 Quad-HFM	Harness	-*	-*	-*
J2 56 way STAK50H SYSTEM	Harness	Laboratory power supply	~ 1.5 m	No
J3 AMEC Mixed 12 way	Harness	-*	-*	-*
J4 HSAL-II	Harness	-*	-*	-*
J6 HSAL-II	Harness	Laptop computer*2	~ 1.5 m	Yes
J7 Double-HFM	Harness	-*	-*	-*
J8 Single-HFM	Harness	-*	-*	-*
J9 Quad-HFM	Harness	-*	-*	-*
J10 Quad-HFM	Harness	-*	-*	-*

* Interface was not connected during the radio tests.
*2 Only the USB 3.0 interface was connected during the tests.

IEEE 802.11 frequencies (2.4 GHz)			
20 MHz		40 MHz	
Channel 1	2412 MHz	-	-
Channel 2	2417 MHz	-	-
Channel 3	2422 MHz	-	-
Channel 4	2427 MHz	-	-
Channel 5	2432 MHz	-	-
Channel 6	2437 MHz	-	-
Channel 7	2442 MHz	-	-
Channel 8	2447 MHz	-	-
Channel 9	2452 MHz	-	-
Channel 10	2457 MHz	-	-
Channel 11	2462 MHz	-	-

Bluetooth® low energy frequencies			
Channel 00	2402 MHz	Channel 01	2404 MHz
Channel 02	2406 MHz	Channel 03	2408 MHz
…	…	…	…
…	…	…	…
Channel 18	2438 MHz	Channel 19	2440 MHz
…	…	…	…
…	…	…	…
Channel 36	2474 MHz	Channel 37	2476 MHz
Channel 38	2478 MHz	Channel 39	2480 MHz

IEEE 802.11 radio mode (2.4 GHz)		
Fulfils radio specification: *	IEEE 802.11 b IEEE 802.11 g IEEE 802.11 n (20 MHz) IEEE 802.11 ax (20 MHz)	
Radio chip: *	Qualcomm QCA6696 / Alps UGKZDA2001AB	
Antenna type: *	Internal antenna: External antenna:	Inverted F-antenna Dipole printed (passive unfiltered)
Antenna name: *	Internal antenna: External antenna:	NA WIFI Antenna Part Number 2310901
Antenna gain: *	Internal antenna: External antenna: Combined antenna gain:	3.0 dBi (typical) 2.1 dBi (typical) 5.6 dBi (typical)
Antenna connector: *	Internal antenna: External antenna:	- (none) Fakra
Type of modulation: *	IEEE 802.11 b	BPSK, DQPSK, CCK (1/2/5.5/11 Mbit/s)
	IEEE 802.11 g	BPSK, QPSK, 16-QAM, 64-QAM (6/9/12/18/24/36/48/54 Mbit/s)
	IEEE 802.11 n20	BPSK, QPSK, 16-QAM, 64-QAM (up to 72.2 Mbit/s 1 spatial stream) (up to 144.4 Mbit/s 2 spatial stream)
	IEEE 802.11 ax20	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM (up to 143.4 Mbit/s 1 spatial stream) (up to 286.8 Mbit/s 2 spatial stream)
Operating frequency range: *	IEEE 802.11b	2412 – 2462 MHz
	IEEE 802.11g	2412 – 2462 MHz
	IEEE 802.11n 20 MHz	2412 – 2462 MHz
	IEEE 802.11ax 20 MHz	2412 – 2462 MHz
Number of channels: *	IEEE 802.11b	11 (5 MHz channel spacing)
	IEEE 802.11g	11 (5 MHz channel spacing)
	IEEE 802.11n 20 MHz	11 (5 MHz channel spacing)
	IEEE 802.11ax 20 MHz	11 (5 MHz channel spacing)

* The external antenna was only active for WLAN, Bluetooth Low Energy can only be transmitted from the internal antenna

Bluetooth® low energy radio mode		
Fulfils radio specification: *	Bluetooth® Low Energy (BLE) 5.2	
Radio chip: *	Qualcomm QCA6696 / Alps UGKZDA2001AB	
Antenna type: *	Internal antenna*2:	Inverted F-antenna
Antenna name: *	Internal antenna*2:	NA
Antenna gain: *	Internal antenna*2:	3.0 dBi (typical)
Antenna connector: *	Internal antenna*2:	None*3
Type of modulation: *	BLE (1 Mbps PHY)	GFSK
	BLE (2 Mbps PHY)	GFSK
Operating frequency range: *	BLE (1 Mbps PHY)	2402 – 2480 MHz
	BLE (2 Mbps PHY)	2402 – 2480 MHz
Number of channels: *	BLE (1 Mbps PHY)	40 (2 MHz channel spacing)
	BLE (2 Mbps PHY)	40 (2 MHz channel spacing)

* Declared by the applicant
*2 Bluetooth Low Energy only uses the internal antenna
*3 Temporary antenna connector for test-purposes was provided by the applicant.

1.6.1 Ancillary Equipment / Equipment used for testing

Equipment used for testing	
Laboratory power supply *1	Toellner TOE 8752 (PM. NO. 480009); additionally 12 V vehicular battery
Test Laptop*1	Fujitsu Lifebook S760 (PM. No: 200759)

*1 Provided by the laboratory

Ancillary Equipment	
-	-

1.7 Dates

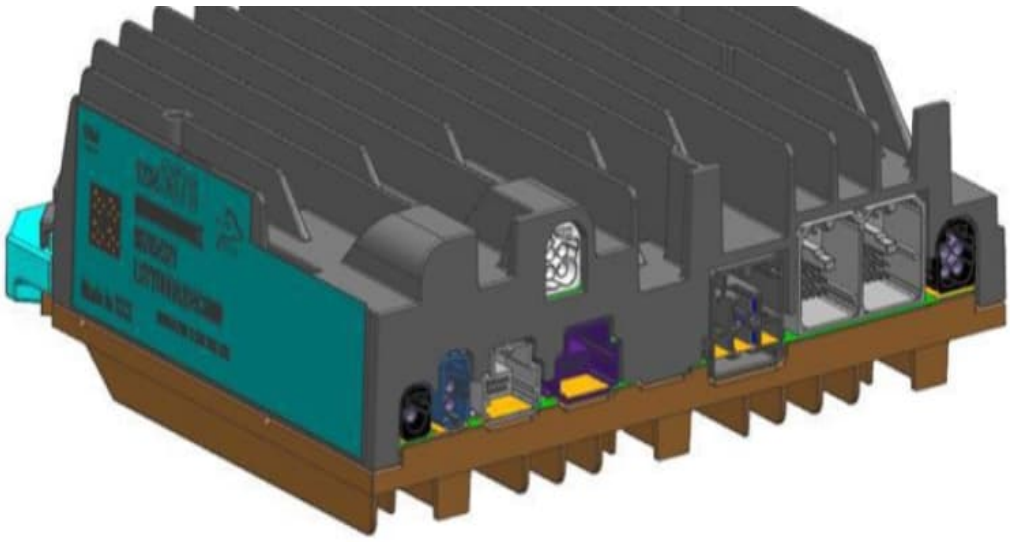
Date of receipt of test sample:	10.12.2021
Start of test:	10.12.2021
End of test:	07.03.2023

2 Operational States

2.1 Description of function of the EUT

The EUT is a Virtual Cockpit Unit (VCU), providing interfaces to Displays, Speakers, Sensors and optional components of the VCS and includes Bluetooth and WiFi capabilities. This is a product produced in collaboration with OEM. This device will be fitted in different OEM vehicles.

The EUT:



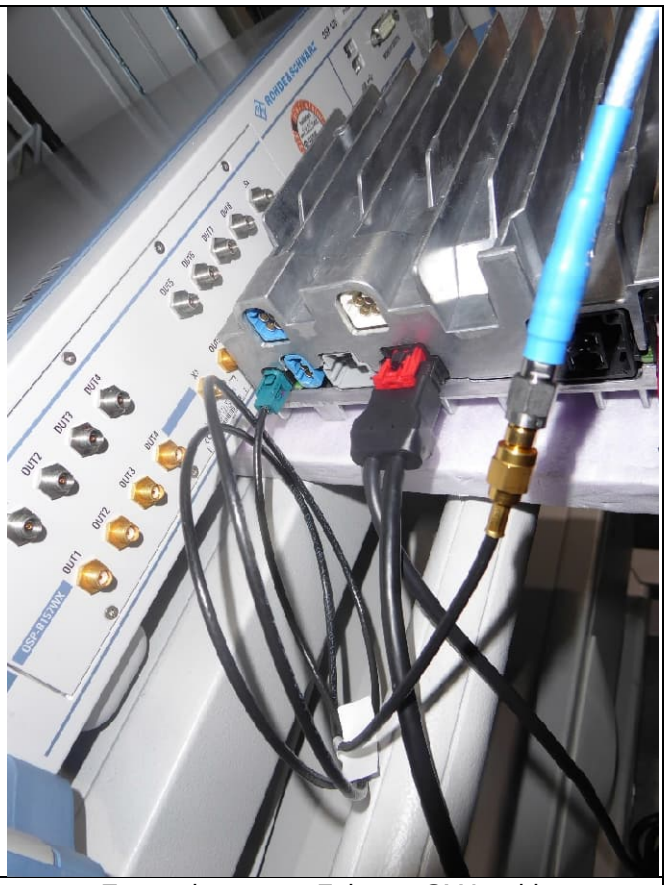
During all test the EUT was supplied with 13.5 V DC via a laboratory power supply. During the tests, a USB connection was established to the EUT via USB-2-optic converter. All relevant HF parameters could be set with a Laptop.

All operation modes for WLAN were set with a software called “GM VCU WLAN RTA Tool”, as provided by the applicant.

For the Bluetooth Low Energy tests, the commands for the tests were generated using a software called “BT RTA Tool”, as provided by the applicant. The commands were executed using adb.exe via Windows PowerShell and pasting the commands generated by the “BT RTA Tool” application.

The antenna port conducted tests on the internal antenna were performed using the temporary SMA antenna connector, which was provided by the applicant.
The antenna port conducted tests on the external antenna connector were performed using a Fakra-to-SMA cable (length ~ 1m), which was provided by the applicant. As declared by the applicant, the length of this cable corresponds to the length of the cable between the mounted EUT in the vehicle and the external antenna.
See the photographs of the temporary antenna connector and the Fakra-to-SMA cable.

Internal antenna: Temporary antenna connector



External antenna: Fakra-to-SMA cable

WLAN:
No difference in power setting or output power (at a single port) when transmitting one antenna port or when transmitting on both antenna ports. Therefore, all tests were performed with both antenna ports active.

Bluetooth Low Energy:
For Bluetooth Low Energy, only the internal antenna port is usable/active.

2.1.1 Operation modes

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate*	Power setting
1	IEEE 802.11b*3	2412	01	DQPSK	2 Mbit/s	14 dBm
2	IEEE 802.11b*3	2437	06	DQPSK	2 Mbit/s	14 dBm
3	IEEE 802.11b*3	2462	11	DQPSK	2 Mbit/s	14 dBm
4	IEEE 802.11g*3	2412	01	16-QAM	36 Mbit/s	14 dBm
5	IEEE 802.11g*3	2437	06	16-QAM	36 Mbit/s	14 dBm
6	IEEE 802.11g*3	2462	11	16-QAM	36 Mbit/s	14 dBm
7	IEEE 802.11n20*3	2412	01	64-QAM	MCS7	14 dBm
8	IEEE 802.11n20*3	2437	06	64-QAM	MCS7	14 dBm
9	IEEE 802.11n20*3	2462	11	64-QAM	MCS7	14 dBm
10	IEEE 802.11ax20*3	2412	01	64-QAM	MCS5	14 dBm
11	IEEE 802.11ax20*3	2437	06	64-QAM	MCS5	14 dBm
12	IEEE 802.11ax20*3	2462	11	64-QAM	MCS5	14 dBm
13	IEEE 802.11ax20-RU*3*4	2412	01	64-QAM	MCS5	14 dBm
14	IEEE 802.11ax20-RU*3*4	2437	06	64-QAM	MCS5	14 dBm
15	IEEE 802.11ax20-RU*3*4	2462	11	64-QAM	MCS5	14 dBm
16	Bluetooth© LE	2402	0	GFSK	1 Mbit/s	0x09*2
17	Bluetooth© LE	2440	19	GFSK	1 Mbit/s	0x09*2
18	Bluetooth© LE	2480	39	GFSK	1 Mbit/s	0x09*2
19	Bluetooth© LE	2402	0	GFSK	2 Mbit/s	0x09*2
20	Bluetooth© LE	2440	19	GFSK	2 Mbit/s	0x09*2
21	Bluetooth© LE	2480	39	GFSK	2 Mbit/s	0x09*2

* As pre-tests have shown, these data rates produced the highest output power.
*2 Output power was fix and could not be set in the test software
*3 During all radiated IEEE 802.11 tests both antennas/MIMO were active
*4 The worst-case RU modes as defined by the applicant were set automatically by the test software. The test software was provided by the applicant.

Pre-tests have shown that the non-ax-RU modes produced the highest unwanted emissions. Therefore, no additional radiated tests had to be performed using the ax RU modes.

3 Additional Information

The EUT was not labeled as required by FCC / IC.
All radiated tests were performed using an unmodified EUT.

4 Overview

Application	Frequency range in MHz	FCC 47 CFR Part 15 section [2]	RSS-247 [4] RSS-Gen [5]	Tested EUT	Status
Maximum peak conducted output power	2400.0 - 2483.5	15.247 (b) (3), (4)	5.4 (d) [4]	1	Passed
DTS Bandwidth / 99% Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	5.2 (a) [4]	1	Passed
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	5.2 (b) [4]	1	Passed
Band edge compliance	2400.0 - 2483.5	15.247 (d) 15.205 (a) 15.209 (a)	5.5 [4]	1, 2	Passed
Maximum unwanted emissions	0.009 – 26,500*	15.247 (d) 15.205 (a) 15.209 (a)	8.9 [5]	2 > 1GHz 3 < 1GHz	Passed*
Antenna Requirement	-	15.203 15.247 (b)	6.8 [5] 5.4 (f) (ii) [4]	-	Passed
Conducted emissions on supply line	0.15 – 30	15.207 (a)	8.8 [4]	-	n/a*2

*: As declared by the applicant the highest radio clock frequency is 2.462 GHz. Therefore the radiated emission measurement must be carried out up to 10th of the highest radio clock frequency in this case 26.5 GHz. As declared by the applicant the highest emission of the non-radio part is 6.264 GHz, therefore the emissions for the 15B part are carried out up to 40 GHz.

*2 As declared by the applicant, the EUT is to be used in vehicular environment and will not be connected to the AC mains network, therefore the EUT is exempted from this test.

5 Results

5.1 Test setups

5.1.1 Test setup (radiated)

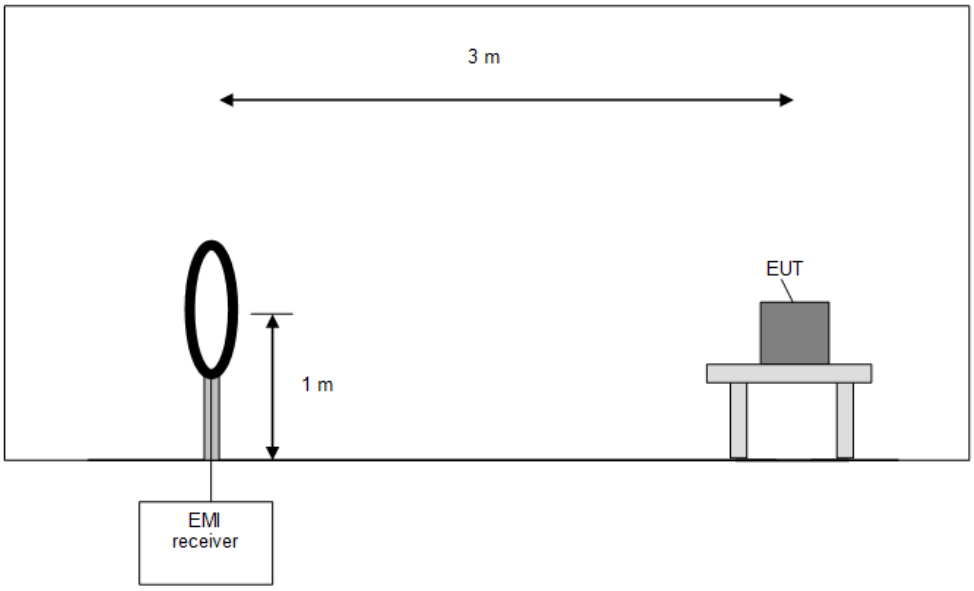
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

In the first stage a preliminary measurement is performed in an anechoic chamber with a measuring distance of 3 meters. Table-top and portable devices are 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 are placed directly on the turntable / ground plane. The setup of the equipment under test is in accordance to [1].

The frequency range 9 kHz to 30 MHz is monitored with an EMI receiver while the system and its cables are manipulated to find out the configuration with the maximum emission levels if applicable. The EMI receiver is set to MAX hold mode. The EUT and the measuring antenna are rotated around their vertical axis to find the maximum emission levels.

The resolution bandwidth of the EMI receiver is set to the following values:

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



Procedure preliminary measurement:

Pre-scans are performed in the frequency range 9 kHz to 150 kHz and 150 kHz to 30 MHz.
The following procedure is used:

1) Monitor the frequency range with the measuring antenna facing the EUT and an EUT / turntable azimuth of 0 °.
2) Manipulate the system cables to produce the maximum levels of emissions.
3) Rotate the EUT by 360 ° to maximize the detected signals.
4) Measure the frequencies of the highest detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency values.
5) If the EUT is portable or ceiling mounted, repeat steps 1 to 4 with other orientations (x,y,z) of the EUT.
6) Rotate the measuring antenna and repeat steps 1 to 5.

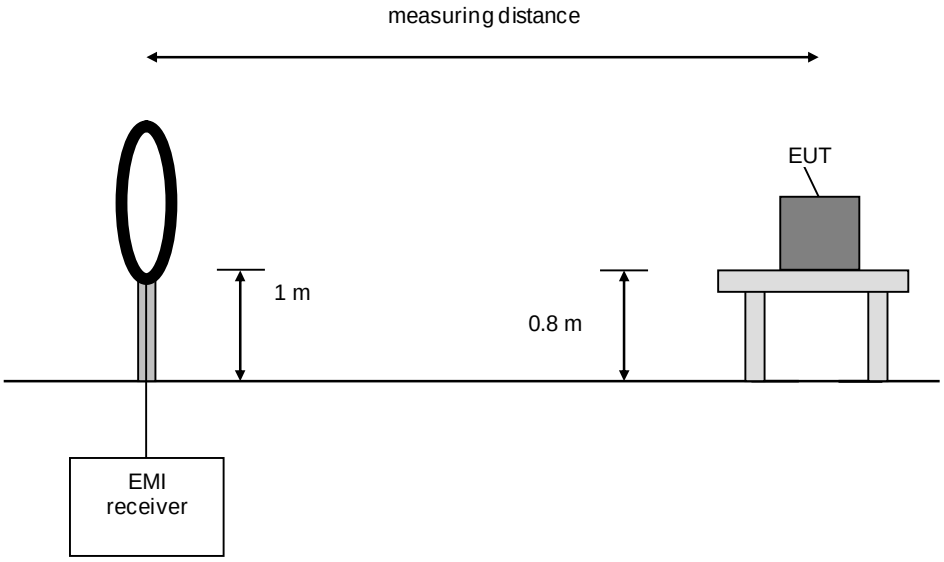
5.1.1.2 Final measurement 9 kHz to 30 MHz

In the second stage a final measurement is performed on an open area test site with no conducting ground plane in a measuring distances of 3 m, 10 m or 30 m. In the case where larger measuring distances are required the results are extrapolated based on the values measured on the closer distances according to section 15.31 (f) (2) [2]. The final measurement is performed with an 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 is used according section 15.209 (d) [2].

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

The resolution bandwidth of the EMI receiver is set to the following values:

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



Procedure final measurement:

The following procedure is used:

1) Monitor the selected frequencies from the preliminary measurement with the measuring antenna facing the EUT and an EUT azimuth of 0 °.
2) Rotate the EUT by 360 ° to maximize the detected signals.
3) Rotate the measuring antenna and repeat steps 1 to 2 until the maximum value is found and note it.
4) If the EUT is portable or ceiling mounted, repeat steps 1 to 3 with other orientations (x,y,z) of the EUT.

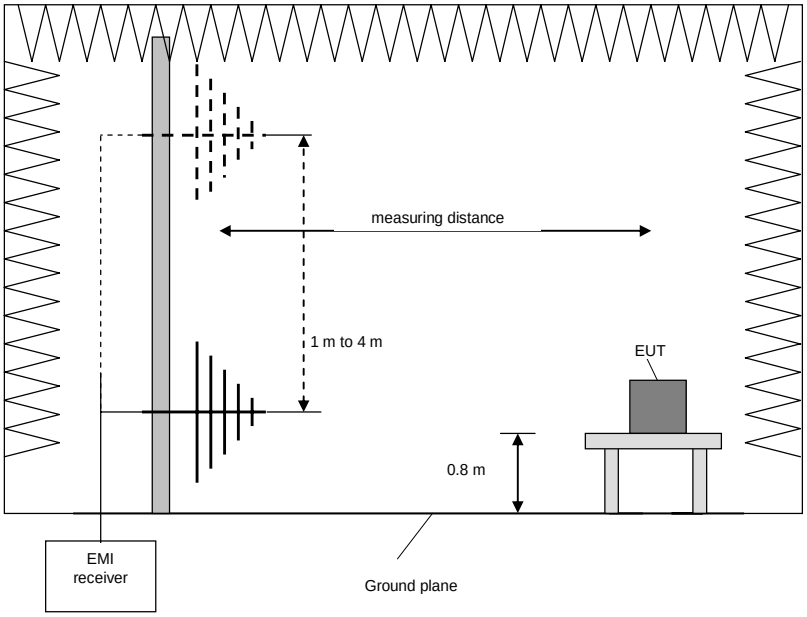
5.1.1.3 Preliminary and final measurement 30 MHz to 1 GHz

The preliminary and final measurements are performed in a semi-anechoic chamber with a metal ground plane in a 3 m distance. Table-top and portable devices are 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 are placed directly on the turntable / ground plane.

During the tests the EUT is rotated in the range of 0 ° to 360 °, the measuring antenna is set to horizontal and vertical polarization and raised and lowered in the range from 1 m to 4 m to find the maximum level of emissions.

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

Test	Frequency range	Step-size	Resolution bandwidth	Detector
Preliminary measurement	30 MHz to 1 GHz	30 kHz	120 kHz	Peak Average
Frequency peak search	± 120 kHz	10 kHz	120 kHz	Peak
Final measurement	30 MHz to 1 GHz	-	120 kHz	QuasiPeak



Procedure preliminary measurement:

The following procedure is used:

1) Set the measuring antenna to 1 m height.
2) Monitor the frequency range at horizontal polarization of the measuring antenna and an EUT / turntable azimuth of 0 °.
3) Rotate the EUT by 360° to maximize the detected signals.
4) Repeat steps 2 to 3 with the vertical polarization of the measuring antenna.
5) Increase the height of the measuring antenna for 0.5 m and repeat steps 2 to 4 until the final height of 4 m is reached.
6) The highest values for each frequency are saved by the software, including the measuring antenna height and polarization and the turntable azimuth for that value.

Procedure final measurement:

The following procedure is used:

1) Select the highest frequency peaks (lowest margin to the limit) for the final measurement.
2) The software determines the exact peak frequencies by doing a partial scan with reduced step size of the pre-scan of the selected peaks.
3) If the EUT is portable or ceiling mounted, find the worst-case EUT orientation (x,y,z) for the final test.
4) The worst-case measuring antenna height is found via varying the height by +/- 0.5 m from the value obtained in the preliminary measurement while monitoring the emission level.
5) The worst-case turntable position is found via varying the turntable azimuth by +/- 30° from the value obtained in the preliminary measurement while monitoring the emission level.
6) The final measurement is performed at the worst-case measuring antenna height and the worst-case turntable azimuth.
7) Steps 2 to 6 are repeated for each frequency peak selected in step 1.

5.1.1.4 Preliminary and final measurement > 1 GHz (Normal procedure 6.6.4 in [1])

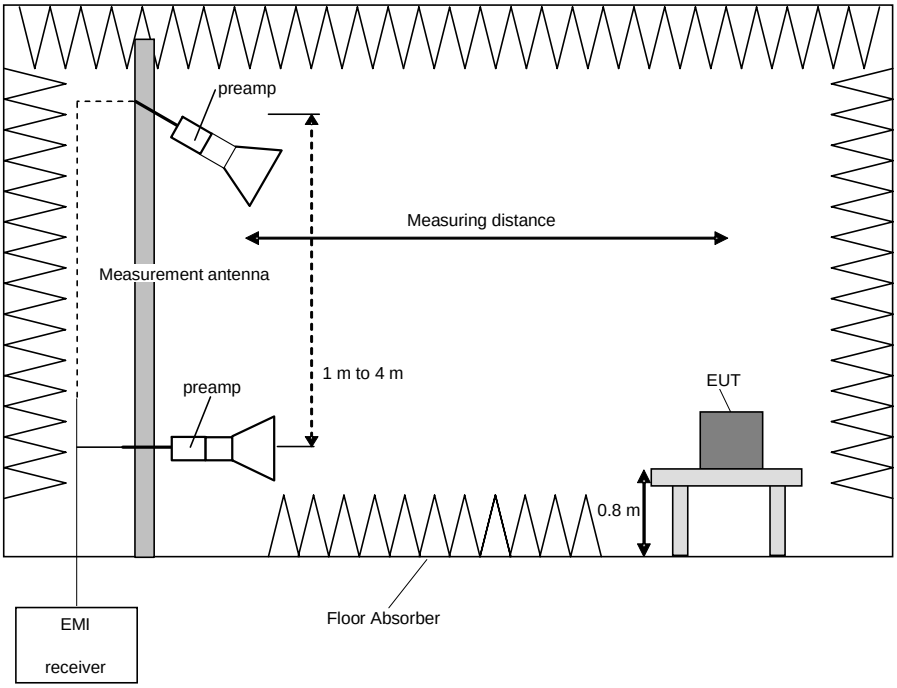
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. Floor standing devices will be placed directly on the turntable. The set-up of the Equipment under test will be in accordance to [1].

Preliminary measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used antenna. The spectrum analyser set to MAX Hold 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 °. This measurement is repeated with antenna-height-steps of 50 cm starting from 1 m up to 4m . When the EUT is manipulated through three different orientations, the scan height upper range for the measurement antenna is limited to 2.5 m or 0.5 m above the top of the EUT, whichever is higher. At the different height positions, the EUT is always directed at the EUT.

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

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



Procedure preliminary measurement:

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

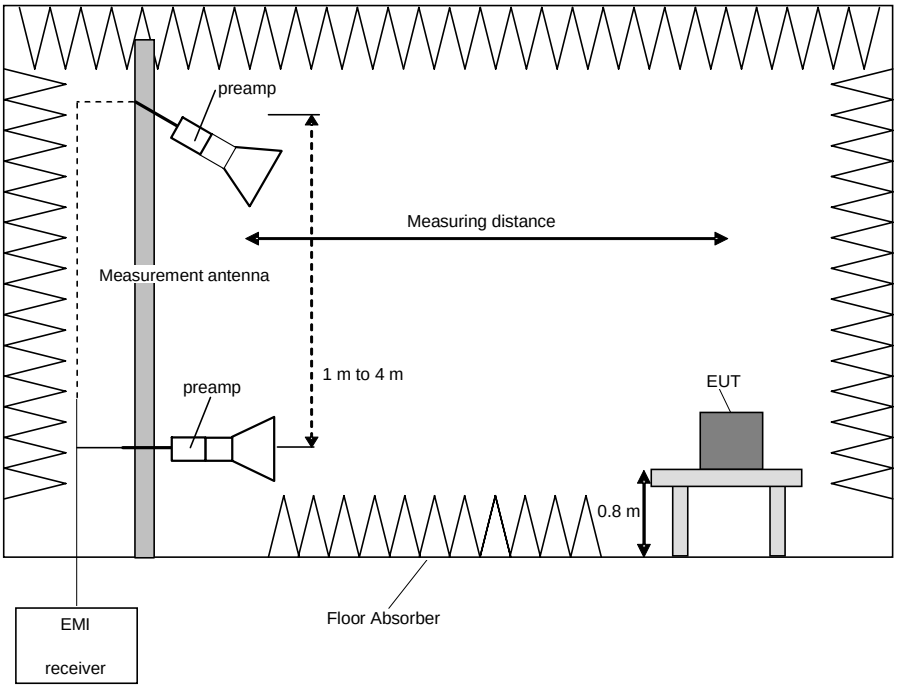
1. Set the measurement antenna to 1 m height.
2. Monitor the frequency range at vertical polarisation and a EUT azimuth of 0 °.
3. Rotate the EUT by 360° to maximize the detected signals.
4. Repeat steps 1. and 2. with the horizontal polarisation of the measuring antenna.
5. Increase the height of the antenna for 0.5 m and repeat steps 2 – 4 until the final height of 4 m is reached. (If the EUT is tested in 3 orientations, the maximum height is 2.5 m or or 0.5 m above the top of the EUT, whichever is higher.)
6. The highest values for each frequency will be saved by the software, including the antenna height, measurement antenna polarization and turntable azimuth for the for each frequency step.

Final measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used antenna. The EMI Receiver set to peak and average mode and a resolution bandwidth of 1 MHz. The measurement will be performed by rotating the turntable through 0 to 360° in the worst-case EUT orientation which was obtained during the preliminary measurements.

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

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



Procedure of measurement:

The measurements were performed in the frequency ranges 1 GHz to 4 GHz, 4 GHz to 12 GHz, 12 GHz to 18 GHz, 18 GHz to 25 /26.5 GHz and 26.5 GHz to 40 GHz.

The following procedure is used:

1. Select the highest frequency peaks to the limit for the final measurement.
2. The software will determine the exact peak frequencies by doing a partial scan with reduced RBW with +/- 10 times the RBW of the pre-scan of the selected peaks.
3. If the EUT is portable or ceiling mounted, find the worst case EUT orientation (x,y,z) for the final test.
4. The worst measurement antenna height is found by the measurement software by varying the measurement antenna height by +/- 0.5 m from the worst-case value obtained in the preliminary measurement, and to monitor the emission level.
5. The worst azimuth turntable position is found by varying the turntable azimuth by +/- 30° from the worst-case value obtained in the preliminary measurement, and to monitor the emission level.
6. The final measurement is performed at the worst-case antenna height and the worst case turntable azimuth.
7. Steps 2 – 6 will be repeated for each frequency peak selected in step 1.

5.1.1.5 Preliminary and final measurement > 1 GHz (Alternative procedure 6.6.5 in [1])

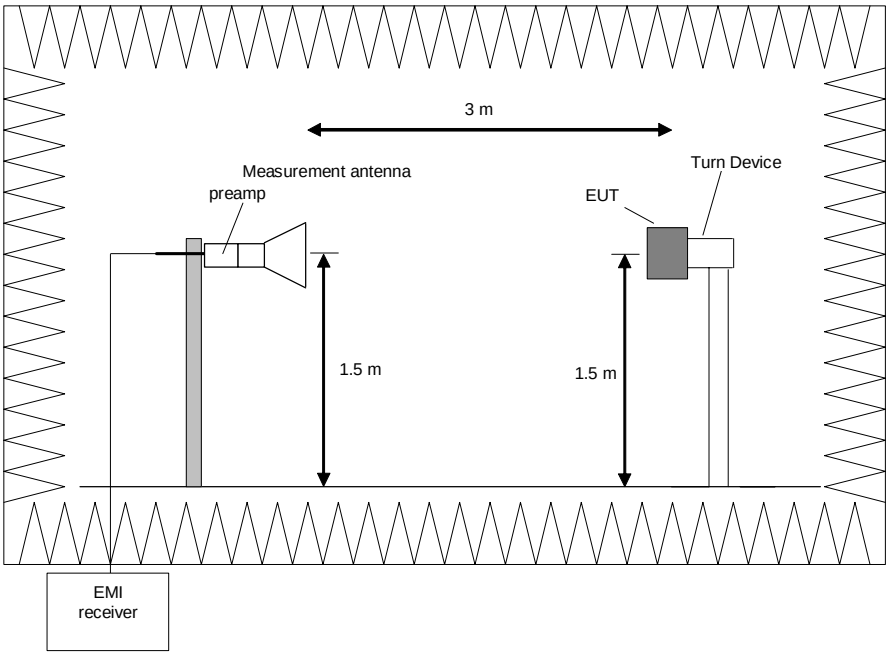
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1]. Devices with any dimension larger than the beamwidth of the measurement antenna are not suitable for testing with this method; such devices shall be evaluated as tabletop equipment (see procedure 5.1.1.4 above).

Preliminary measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used antenna. The spectrum analyser set to MAX Hold 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 °. This measurement is repeated after raising the EUT in 30° steps according to 6.6.5.4 in [1].

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

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



Procedure preliminary measurement:

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

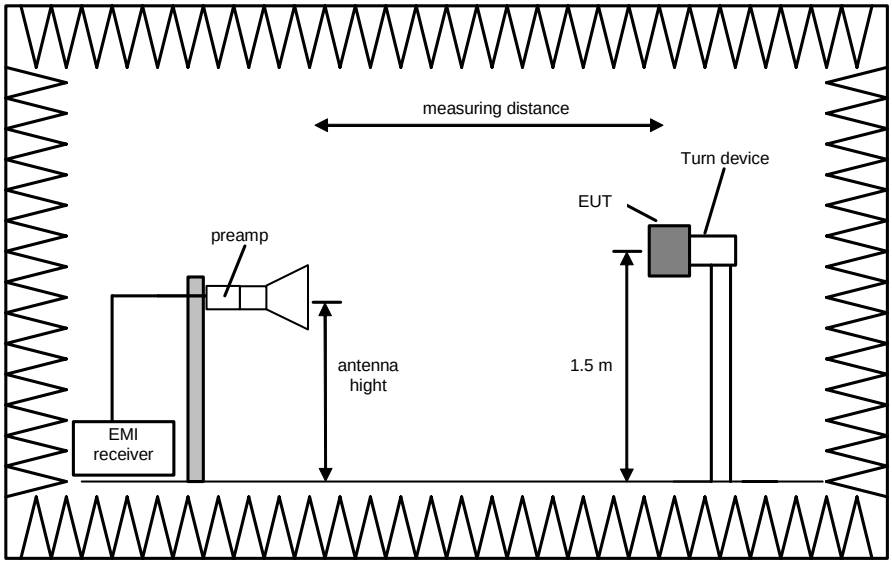
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an angle of 30° (60°, 90°, 120° and 150°) according to 6.6.5.4 in [1].
6. Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
7. The measurement antenna polarisation, with the according EUT position (Turntable and Turn device) which produces the highest emission for each frequency will be used for the final measurement. The six closest values to the applicable limit will be used for the final measurement.

Final measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used antenna. The EMI Receiver set to peak and average mode and a resolution bandwidth of 1 MHz. The measurement will be performed by rotating the turntable through 0 to 360° in the worst-case EUT orientation which was obtained during the preliminary measurements.

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

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



Procedure of measurement:

The measurements were performed in the frequency ranges 1 GHz to 4 GHz, 4 GHz to 12 GHz, 12 GHz to 18 GHz, 18 GHz to 25 /26.5 GHz and 26.5 GHz to 40 GHz.
The following procedure will be used:

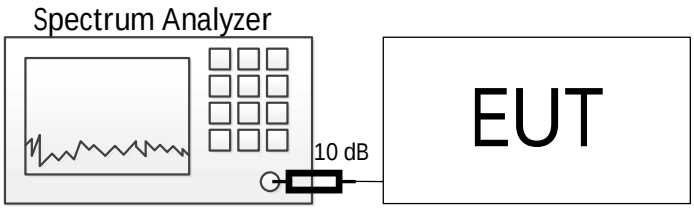
1) Set the turntable and the turn device to obtain the worst-case emission for the first frequency identified in the preliminary measurements.
2) The worst-case turntable position is found via varying the turntable azimuth by +/- 30° from the value obtained in the preliminary measurement while monitoring the emission level.
3) Set the measurement antenna polarisation to the orientation with the highest emission for the first frequency identified in the preliminary measurements.
4) Set the spectrum analyser to EMI mode with peak and average detector activated.
5) Rotate the turntable from 0° to 360° to find the TT Pos. that produces the highest emissions.
6) Note the highest displayed peak and average values
7) Repeat the steps 1) to 5) for each frequency detected during the preliminary measurements.

5.1.2 Test setup (conducted)

Test setup (conducted)		
Used	Antenna connector	Comment
☒	Temporary antenna connector*1	As provided by the applicant
☒	Normal antenna connector*2	

*1 for the internal antenna, a temporary antenna connector was used for the conducted tests
*2 for the external antenna, the normal antenna connector was used for the conducted tests

5.1.2.1 Conducted (Spectrum Analyzer)



The 10 dB external attenuation is considered in all relevant plots

5.2 Duty Cycle

5.2.1 Test setup (Duty cycle)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.2.2 Test method (Duty cycle)

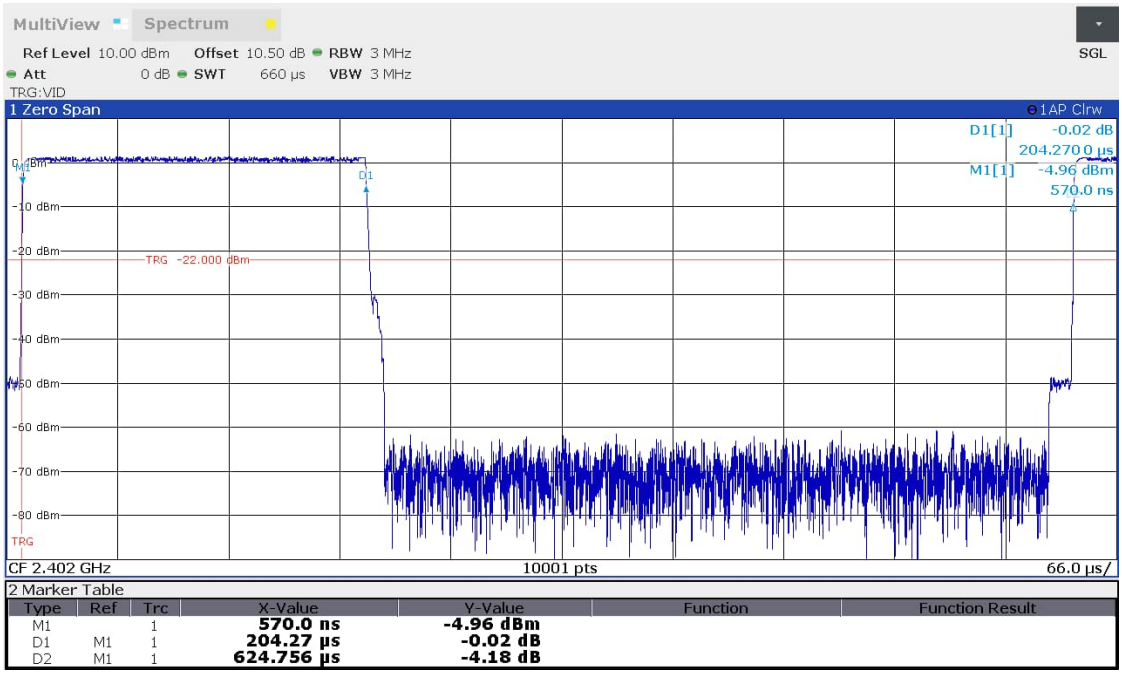
Test method (Duty cycle)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	11.6. a)	Diode detector	No limitation	-
☒	11.6. b)	Zero span	No limitation	-

Test results (Duty cycle)

Ambient temperature:	21 - 22 °C
Relative humidity:	20 - 27 %

Date:	11.12.2021 – 07.03.2023
Tested by:	P. NEUFELD

Worst case plot (operation mode 23 - Internal Antenna):



Modulation	TX_{On} [µs]	TX_{Cycle} [µs]	RBW [MHz]	50/T [kHz]	50/T < RBW?
802.11b	6312	6325	20	7.922	☒
802.11g	368	384	30	135.864	☒
802.11n20	5429	5445	30	9.210	☒
802.11ax20	5445	5461	30	9.183	☒
BLE 1 Mbps	388	625	3	128.774	☒
BLE 2 Mbps	204	625	3	244.774	☒

Modulation	Sweep points	Sweep time [µs]	Meas points for TX_{On}	Meas points >100?	Duty cycle %	$DCCF_{Power}$ [dB]	$DCCF_{FS}$ [dB]
802.11b	10001	6600	9565	☒	99.8	0.0	0.0
802.11g	10001	410	8977	☒	95.8	0.2	0.4
802.11n20	10001	5600	9696	☒	99.7	0.0	0.0
802.11ax20	10001	5600	9724	☒	99.7	0.0	0.0
BLE 1 Mbps	10001	660	5879	☒	62.1	2.1	4.2
BLE 2 Mbps	10001	660	3091	☒	32.6	4.9	9.8

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

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

$$DCCF_{Fieldstrength} = 20 * log_{10}\left(\frac{1}{Duty\ cycle}\right)$$

For average measurements a correction factor of 0.2 dB is used for all tests with 802.11a modulation.
For average measurements a correction factor of 2.1 dB is used for all tests in test mode BLE with 1 Mbps.
For average measurements a correction factor of 4.9 dB is used for all tests in test mode BLE with 2 Mbps.
No DCCF is applied for all other test cases, because there the duty cycle ≥ 98%.

Test equipment (please refer to chapter 7 for details)
1 - 3

5.3 DTS bandwidth

5.3.1 Test setup (DTS bandwidth)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.3.2 Test method (DTS bandwidth)

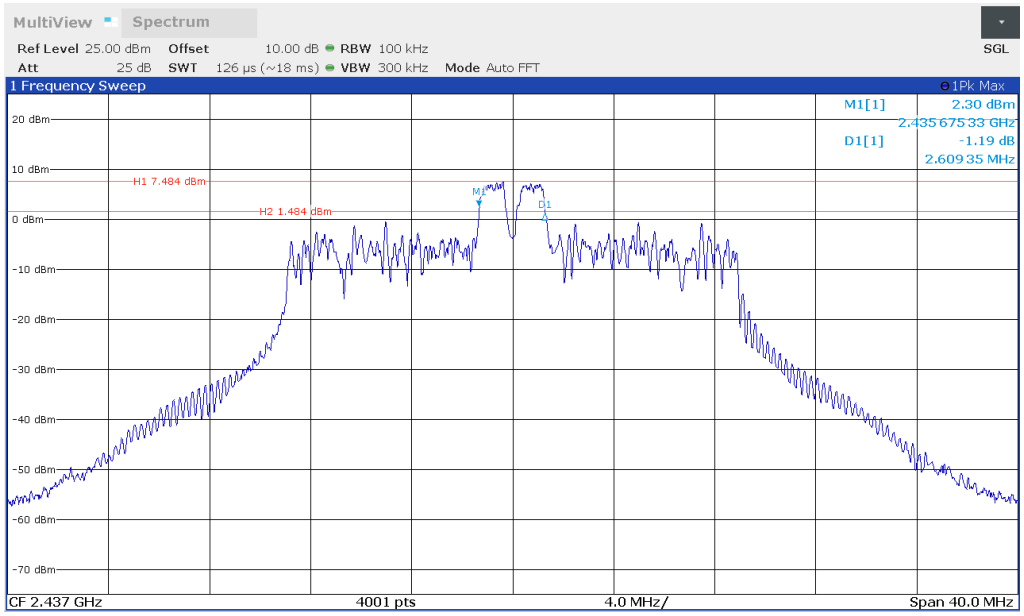
Test method (Maximum peak conducted output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.8.1	Option 1	No limitations	-
☐	11.8.2	Option 2	No limitations	6 dB down function

5.3.3 Test results 802.11g (DTS bandwidth)

Ambient temperature:	21 - 22 °C
Relative humidity:	20 - 27 %

Date	11.12.2021 – 07.03.2023
Tested by	P. NEUFELD

Worst case plot (operation mode 14 - Internal Antenna):

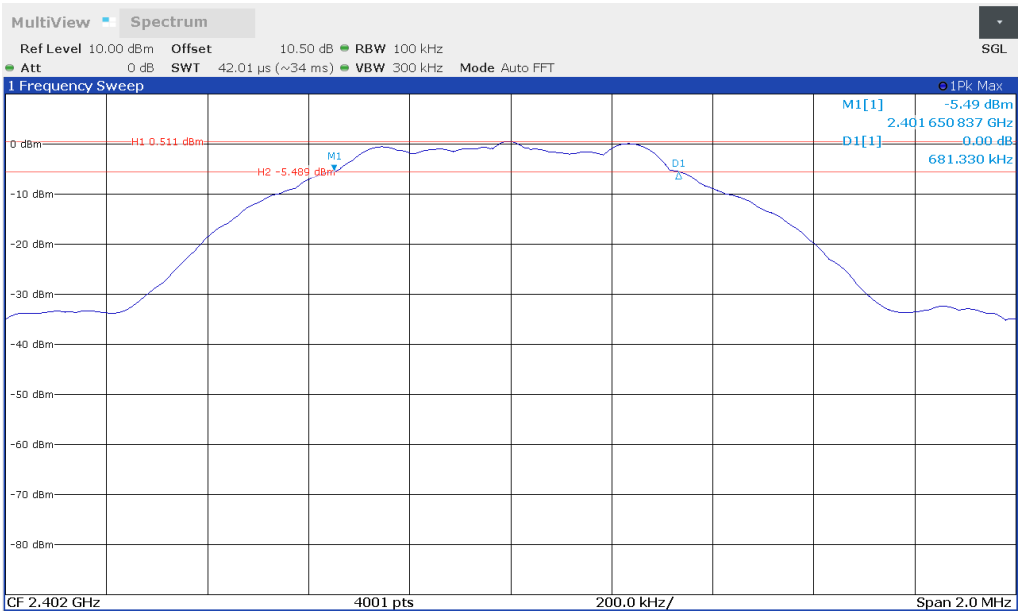


Operation mode #	DTS bandwidth IntAnt [MHz]	DTS bandwidth ExtAnt [MHz]	Minimum DTS bandwidth Limit [MHz]	Result
1	6.470882	6.488378	0.5	Passed
2	8.067983	6.298425	0.5	Passed
3	6.103474	6.248438	0.5	Passed
4	16.525869	16.515871	0.5	Passed
5	16.525869	16.525869	0.5	Passed
6	16.485879	16.515871	0.5	Passed
7	17.625594	17.575606	0.5	Passed
8	17.445639	17.815546	0.5	Passed
9	17.555611	17.625594	0.5	Passed
10	18.675331	18.688328	0.5	Passed
11	18.565359	18.465384	0.5	Passed
12	18.765309	18.075481	0.5	Passed
13	19.115221	19.125219	0.5	Passed
14	**2.609348**	**2.639340**	**0.5**	**Passed**
15	19.125219	19.105224	0.5	Passed

Test: Passed

5.3.4 Test results BLE (DTS bandwidth)

Worst case plot (operation mode 16 - Internal Antenna):



Operation mode #	DTS bandwidth IntAnt [MHz]	DTS bandwidth ExtAnt [MHz]	Minimum DTS bandwidth Limit [MHz]	Result
16	**0.681330**	**-**	**0.5**	Passed
17	0.749813	-	0.5	Passed
18	0.755811	-	0.5	Passed
19	1.384154	-	0.5	Passed
20	1.239240	-	0.5	Passed
21	1.390652	-	0.5	Passed

Test: Passed

Test equipment (please refer to chapter 7 for details)
1 - 3

5.4 Transmit Antenna Performance considerations

Test setup (Transmit antenna performance considerations)			
Integral and/or dedicated antenna	Antenna gain ≤ 6dBi	Result	Comment
☒	☒	Passed	No output power reduction necessary

As declared by the applicant for all WLAN modes (mode 1 – 18) “Maximum Ratio Transmission (MRT)” is used.

Antenna gain calculation for WLAN modes (mode 1 – 18) as described in **[6]**, sub-clause F) 2) d) (i)

$$Directional\ gain = 10\ log_{10}\left[\frac{\left(10^{G_1/20} + 10^{G_2/20}\right)^2}{N_{Ant}}\right] dBi$$

Herein:

G_1 = $gain_{external\ antenna}$ = 3.0 dBi
G_1 = $gain_{internal\ antenna}$ = 2.1 dBi
N_{Ant} = number of antennas = 2
Directional gain for correlated signals = **5.6 dBi** < 6 dBi

5.5 Occupied bandwidth – power bandwidth (99%)

5.5.1 Test Setup (Occupied bandwidth – power bandwidth (99%))

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.5.2 Test method (Occupied bandwidth – power bandwidth (99%))

Test method (Maximum peak conducted output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	6.9.2	relative measurement procedure		n-dB down
☒	6.9.3	power bandwidth (99%)	*1	99% power function

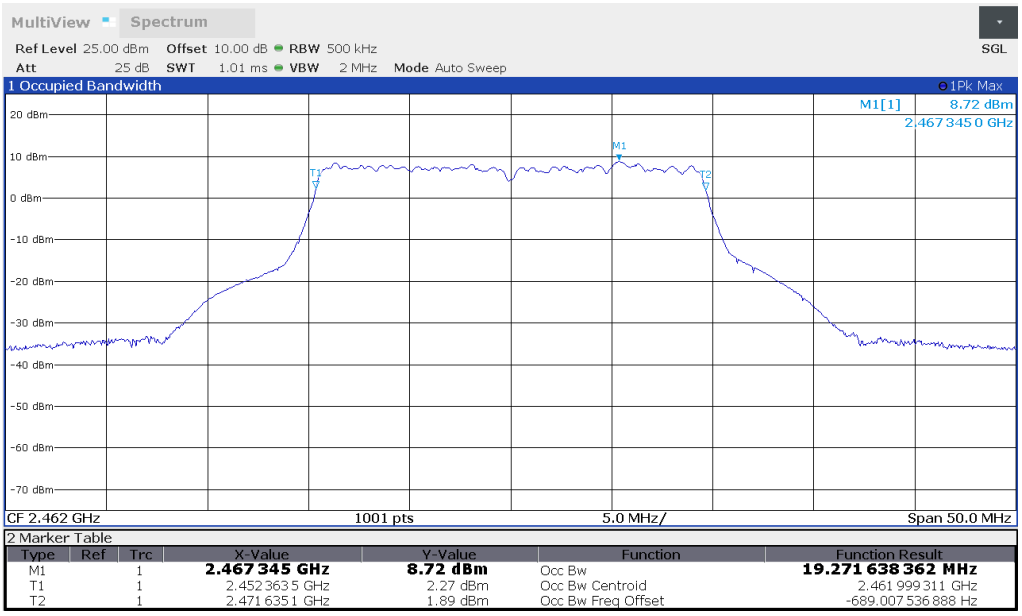
*1 See RSS-GEN Issue 5 (2018-05) sub-clause 6.7 for details.

5.5.3 Test results 802.11 (Occupied bandwidth – power bandwidth (99%))

Ambient temperature:	21 - 22 °C
Relative humidity:	20 - 27 %

Date	11.12.2021 – 07.03.2023
Tested by	P. NEUFELD

Worst case plot (operation mode 15 Internal Antenna):

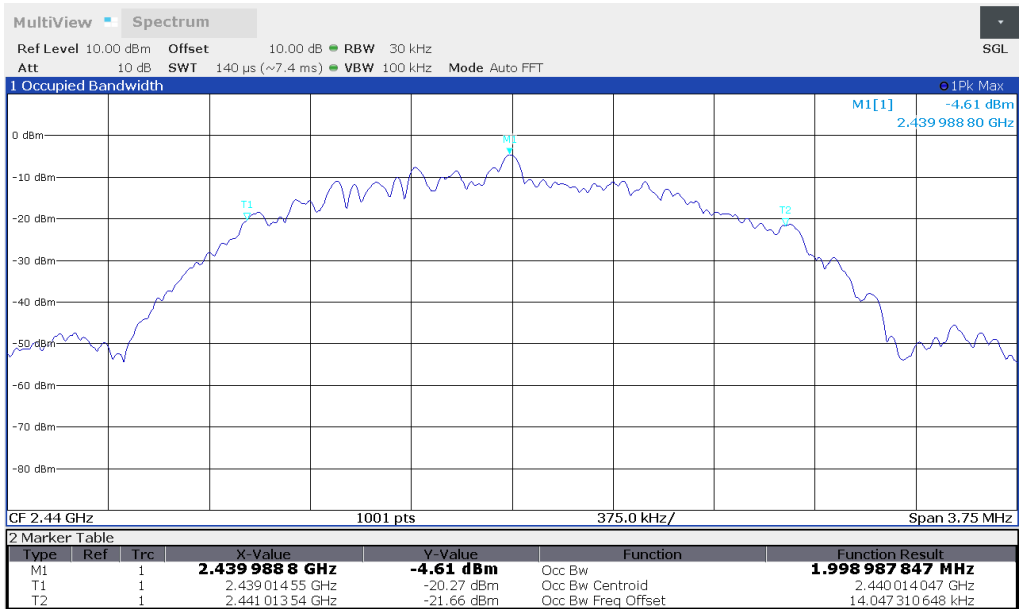


Operation mode #	99% bandwidth – internal antenna [MHz]	99% bandwidth – external antenna [MHz]
1	13.646700	13.593306
2	13.639992	13.605204
3	13.654584	13.620465
4	16.943314	16.926494
5	16.907610	16.988380
6	16.975321	17.209460
7	17.873797	17.867456
8	17.841892	17.881170
9	17.875955	17.845968
10	19.001515	19.047595
11	18.980918	19.031933
12	18.991239	19.028102
13	19.263772	19.264363
14	17.386047	17.377044
15	**19.271638**	19.265854

Test: Passed

5.5.4 Test results BLE (Occupied bandwidth – power bandwidth (99%))

Worst case plot (operation mode 20 Internal Antenna):



Operation mode #	99% bandwidth – internal antenna [MHz]	99% bandwidth – external antenna [MHz]
16	1.020048	-
17	1.017552	-
18	1.021678	-
19	1.995698	-
20	**1.998988**	-
21	1.989280	-

Test: Passed

Test equipment (please refer to chapter 7 for details)
1 - 3

5.6 DTS fundamental emission output power

5.6.1 Test setup (DTS fundamental emission output power)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.6.2 Test method (DTS fundamental emission output power)

Test method (Maximum peak conducted output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	11.9.1.1	RBW ≥ DTS bandwidth	For BLE tests	
☐	11.9.1.2	Integrated band power method	Not for DTS	-
☐	11.9.1.3	PKPM1 Peak power meter method*1	For 802.11 tests	-

*1 VBW of the peak power meter has to be > OBW of the fundamental.

Test method (Maximum conducted (average) output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.9.2.2.2	Method AVGSA-1	D ≥ 98%	-
☐	11.9.2.2.3	Method AVGSA-1A (alternative)	D ≥ 98%	-
☐	11.9.2.2.4	Method AVGSA-2	Constant D (±2%)	-
☐	11.9.2.2.5	Method AVGSA-2A (alternative)	Constant D (±2%)	-
☐	11.9.2.2.6	Method AVGSA-3A		-
☐	11.9.2.2.7	Method AVGSA-3A (alternative)		-
☐	11.9.2.3.1	Method AVGPM	Constant D (±2%)	-
☐	11.9.2.3.2	Method AVGPM-G		-

5.6.3 Test results (DTS fundamental emission output power)

11.12.2021	21 - 22 °C
Relative humidity:	20 - 27 %

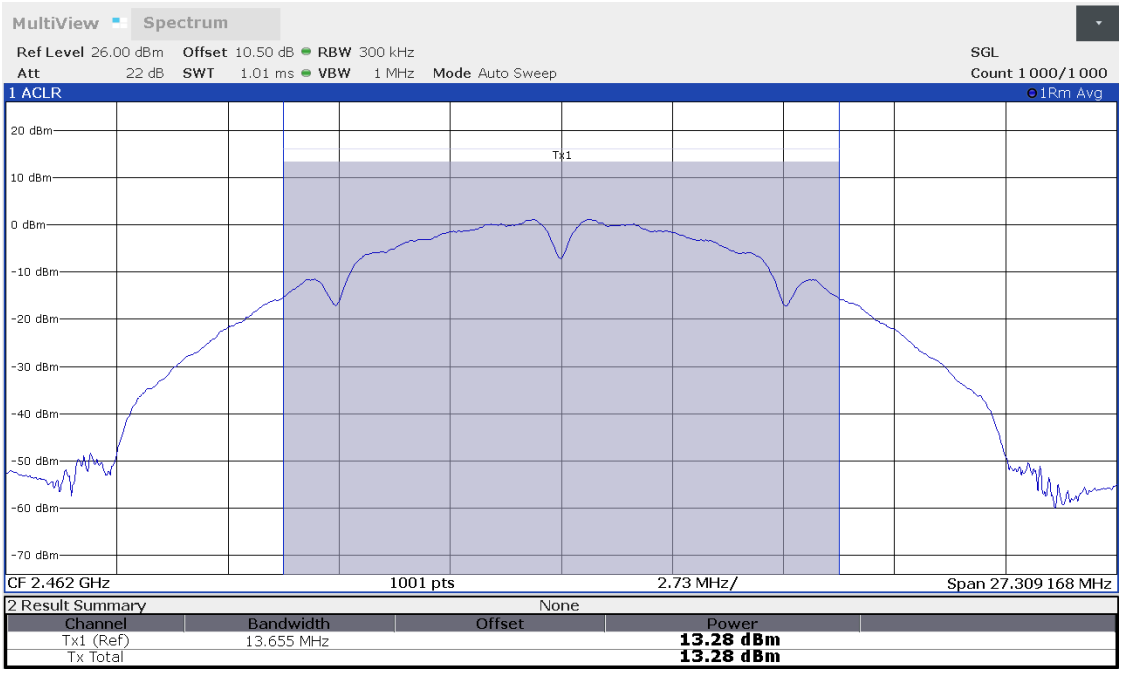
Date	11.12.2021 – 07.03.2023
Tested by	P. NEUFELD

5.6.3.1 Maximum (average) conducted output power (802.11 WLAN):

Calculations:
Result Corr. Ant. [dBm]= $10x \log_{10}$(Reading Internal Ant [mW] + Reading External Ant [mW]) + 2x DCCF

See **[6]** E 1) for details

Worst case plot (operation mode 3 – internal antenna):



Operation mode	Reading Internal Ant [dBm]	Reading External Ant [dBm]	DCCF [dB]	Ext. Att.* [dB]	Result Corr. Ant. [dBm]	Limit [dBm]
1	13.2	11.4	0.0	0.0	15.4	30.0
2	13.2	11.3	0.0	0.0	15.4	30.0
3	**13.3**	**11.4**	**0.0**	**0.0**	**15.5**	30.0
4	13.0	10.9	0.4	0.0	15.5	30.0
5	12.9	10.8	0.4	0.0	15.4	30.0
6	13.0	10.8	0.4	0.0	15.4	30.0
7	13.2	11.0	0.0	0.0	15.2	30.0
8	13.1	10.9	0.0	0.0	15.1	30.0
9	13.3	10.9	0.0	0.0	15.3	30.0
10	13.2	11.1	0.0	0.0	15.3	30.0
11	13.2	11.0	0.0	0.0	15.2	30.0
12	13.3	11.0	0.0	0.0	15.3	30.0
13	13.1	11.0	0.0	0.2	15.4	30.0
14	12.6	10.4	0.0	0.2	14.8	30.0
15	13.1	11.0	0.0	0.2	15.4	30.0

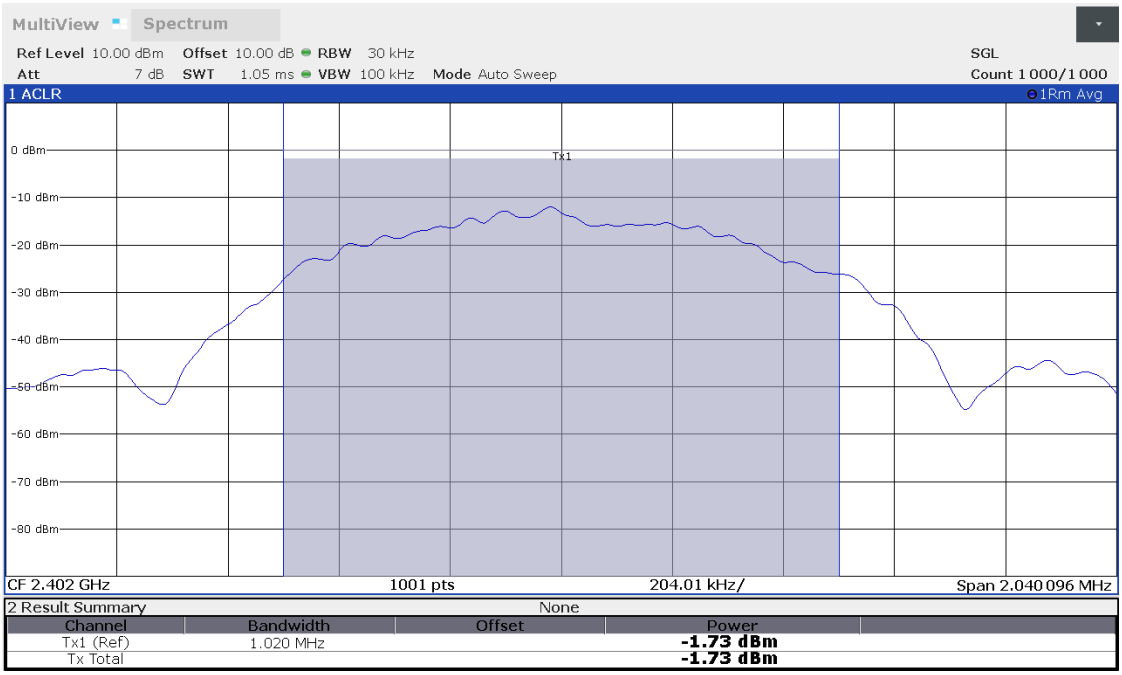
* The external attenuation is already taken into account with the reference 10.5 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator and the measurement cable.

Test: Passed

5.6.3.2 Maximum (average) conducted output power (Bluetooth Low Energy):

Calculations:
Result Corr. Ant. [dBm]= Reading Internal Ant [dBm]
See **[6]** E 1) for details

Worst case plot (operation mode 19):



Operation mode	Reading Internal Ant [dBm]	Reading External Ant [dBm]	DCCF [dB]	Ext. Att.* [dB]	Result Corr. Ant. [dBm]	Limit [dBm]
16	-1.7	-	2.1	0.5	0.9	30.0
17	-2.0	-	2.1	0.5	0.6	30.0
18	-2.3	-	2.1	0.5	0.3	30.0
19	-5.1	-	4.9	0.5	0.3	30.0
20	-4.8	-	4.9	0.5	0.6	30.0
21	-5.0	-	4.9	0.5	0.4	30.0

* The external attenuation of the external attenuator is already taken into account with the reference 10.0 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator. Only the 0.5 dB attenuation of the external cable is respected in the table above.

Test: Passed

Test equipment (please refer to chapter 7 for details)
1 - 3

5.7 DTS maximum power spectral density

5.7.1 Test setup (DTS maximum PSD level in the fundamental emission)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.7.2 Test method (DTS maximum PSD level in the fundamental emission)

Test method (Maximum *peak* power spectral density level in the fundamental emission)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.10.2	Method PKPSD (peak PSD)	No limitations	-

Test method (Maximum *average* power spectral density level in the fundamental emission)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.10.3	Method AVGPSD-1	D ≥ 98%	-
☐	11.10.4	Method AVGPSD-1A (alternative)	D ≥ 98%	-
☐	11.10.5	Method AVGPSD-2	Constant D (±2%)	-
☐	11.10.6	Method AVGPSD-2A (alternative)	Constant D (±2%)	-
☐	11.10.7	Method AVGPSD-3	No limitations	-
☐	11.10.8	Method AVGPSD-3A (alternative)	No limitations	-

5.7.3 Test results (DTS maximum PSD level in the fundamental emission)

Ambient temperature:	21 - 22 °C
Relative humidity:	20 - 27 %

Date	11.12.2021 – 07.03.2023
Tested by	P. NEUFELD

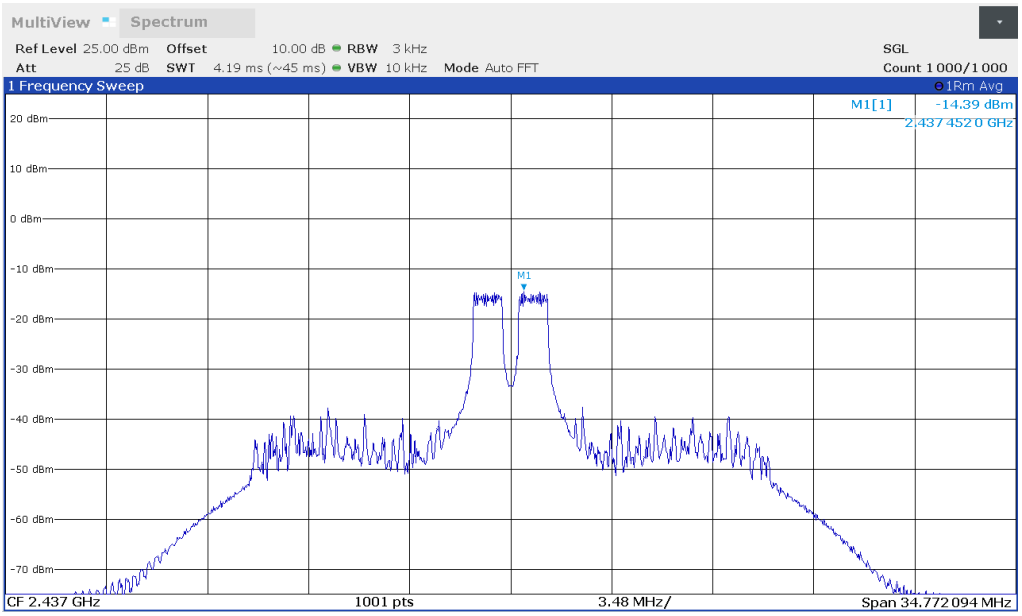
Calculations:
Result Corr. Ant. 1 [dBm/3kHz]= Reading Internal Ant [dBm/3kHz] + Ext. Att [dB]

5.7.3.1 Maximum average PSD (802.11 WLAN):

Calculations:
Result Corr. Ant. [dBm/3kHz]= Reading Ant [dBm/3kHz] + Correction 2 Antennas [dB]
+ Ext. Att [dB] + DCCF [dB]

See **[6]** E 2) c) for details

Worst case plot (operation mode 14 – internal antenna):



Operation mode	Antenna	Reading Ant [dBm/3 kHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result Corr. Ant. [dBm/3 kHz]	Limit [dBm/3 kHz]
1	Int. Ant.	-16.2	3.0	0.0	0.0	-13.2	8.0
2	Int. Ant.	-16.2	3.0	0.0	0.0	-13.2	8.0
3	Int. Ant.	-16.3	3.0	0.0	0.0	-13.3	8.0
4	Int. Ant.	-21.2	3.0	0.0	0.2	-18.0	8.0
5	Int. Ant.	-21.3	3.0	0.0	0.2	-18.1	8.0
6	Int. Ant.	-21.6	3.0	0.0	0.2	-18.4	8.0
7	Int. Ant.	-22.9	3.0	0.0	0.0	-19.9	8.0
8	Int. Ant.	-23.1	3.0	0.0	0.0	-20.1	8.0
9	Int. Ant.	-22.7	3.0	0.0	0.0	-19.7	8.0
10	Int. Ant.	-24.1	3.0	0.0	0.0	-21.1	8.0
11	Int. Ant.	-24.1	3.0	0.0	0.0	-21.1	8.0
12	Int. Ant.	-23.9	3.0	0.0	0.0	-20.9	8.0
13	Int. Ant.	-23.5	3.0	0.2	0.0	-20.3	8.0
14	**Int. Ant.**	**-14.4**	**3.0**	**0.2**	**0.0**	**-11.2**	8.0
15	Int. Ant.	-23.6	3.0	0.2	0.0	-20.4	8.0
1	Ext. Ant.	-17.9	3.0	0.0	0.0	-14.9	8.0
2	Ext. Ant.	-18.0	3.0	0.0	0.0	-15.0	8.0
3	Ext. Ant.	-17.9	3.0	0.0	0.0	-14.9	8.0
4	Ext. Ant.	-23.4	3.0	0.0	0.2	-20.2	8.0
5	Ext. Ant.	-23.7	3.0	0.0	0.2	-20.5	8.0
6	Ext. Ant.	-23.8	3.0	0.0	0.2	-20.6	8.0
7	Ext. Ant.	-25.1	3.0	0.0	0.0	-22.1	8.0
8	Ext. Ant.	-25.3	3.0	0.0	0.0	-22.3	8.0
9	Ext. Ant.	-25.2	3.0	0.0	0.0	-22.2	8.0
10	Ext. Ant.	-25.9	3.0	0.0	0.0	-22.9	8.0
11	Ext. Ant.	-26.2	3.0	0.0	0.0	-23.2	8.0
12	Ext. Ant.	-26.2	3.0	0.0	0.0	-23.2	8.0
13	Ext. Ant.	-25.4	3.0	0.2	0.0	-22.2	8.0
14	Ext. Ant.	-16.8	3.0	0.2	0.0	-13.6	8.0
15	Ext. Ant.	-25.6	3.0	0.2	0.0	-22.4	8.0

* The external attenuation is already taken into account with the reference 10.5 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator and the measurement cable.

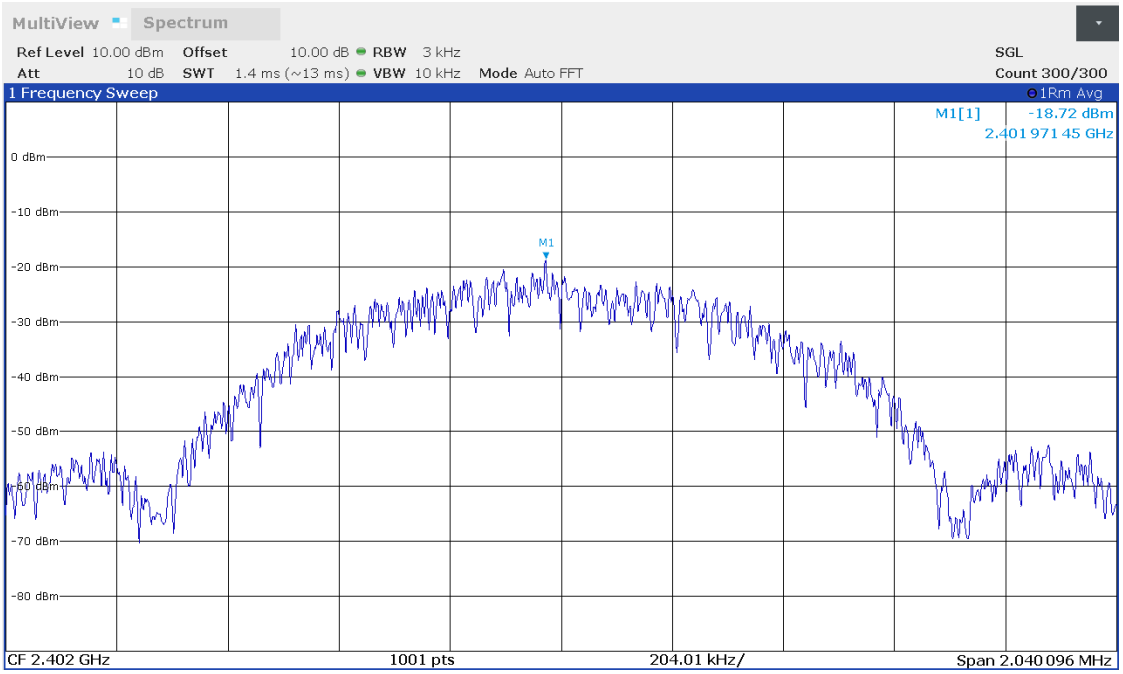
Test: Passed

5.7.3.2 Maximum average PSD (Bluetooth Low Energy):

Calculations:
Result Corr. Ant. 1 [dBm/3kHz]= Reading Internal Ant [dBm/3kHz] + Ext. Att [dB]

See **[6]** E 2) c) for details

Worst case plot BLE (operation mode 16 – internal antenna):



Operation mode	Antenna	Reading Ant [dBm/3 kHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result Corr. Ant. [dBm/3 kHz]	Limit [dBm/3 kHz]
16	**Int. Ant.**	**-18.7**	**0.0**	**0.5**	**2.1**	**-16.1**	8.0
17	Int. Ant.	-19.1	0.0	0.5	2.1	-16.5	8.0
18	Int. Ant.	-19.7	0.0	0.5	2.1	-17.1	8.0
19	Int. Ant.	-24.0	0.0	0.5	4.9	-18.6	8.0
20	Int. Ant.	-23.6	0.0	0.5	4.9	-18.2	8.0
21	Int. Ant.	-23.9	0.0	0.5	4.9	-18.5	8.0

* The external attenuation of the external attenuator is already taken into account with the reference 10.0 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator. Only the 0.5 dB attenuation of the external cable is respected in the table above.

Test: Passed

Test equipment (please refer to chapter 7 for details)
1 - 3

5.8 DTS band-edge emission measurements

5.8.1 Test setup (Band edge – unrestricted bands)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☐	Test setup (radiated – alternative procedure)	5.1.1.5	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.8.2 Test method (Band edge – unrestricted bands)

Test method (Band edge – unrestricted bands)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	11.11.	20 dBc (Peak)	Peak power	*1
☒	11.11.	30 dBc (Average)	RMS power	*2

*1 As declared in “47 CFR 15.247(d)” In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the 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 a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits

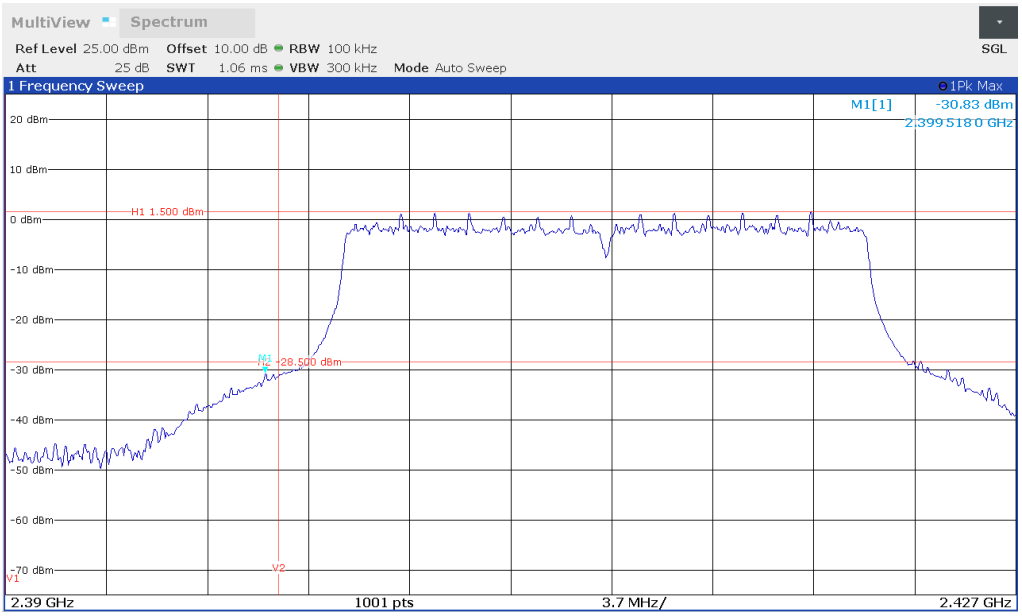
*2 If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

5.8.3 Test results (Band edge – unrestricted bands) – 30 dBc (802.11 WLAN)

Ambient temperature:	21 - 22 °C
Relative humidity:	20 - 27 %

Date	11.12.2021 – 07.03.2023
Tested by	P. NEUFELD

Worst case plot Lower band edge (operation mode 13 – internal antenna):

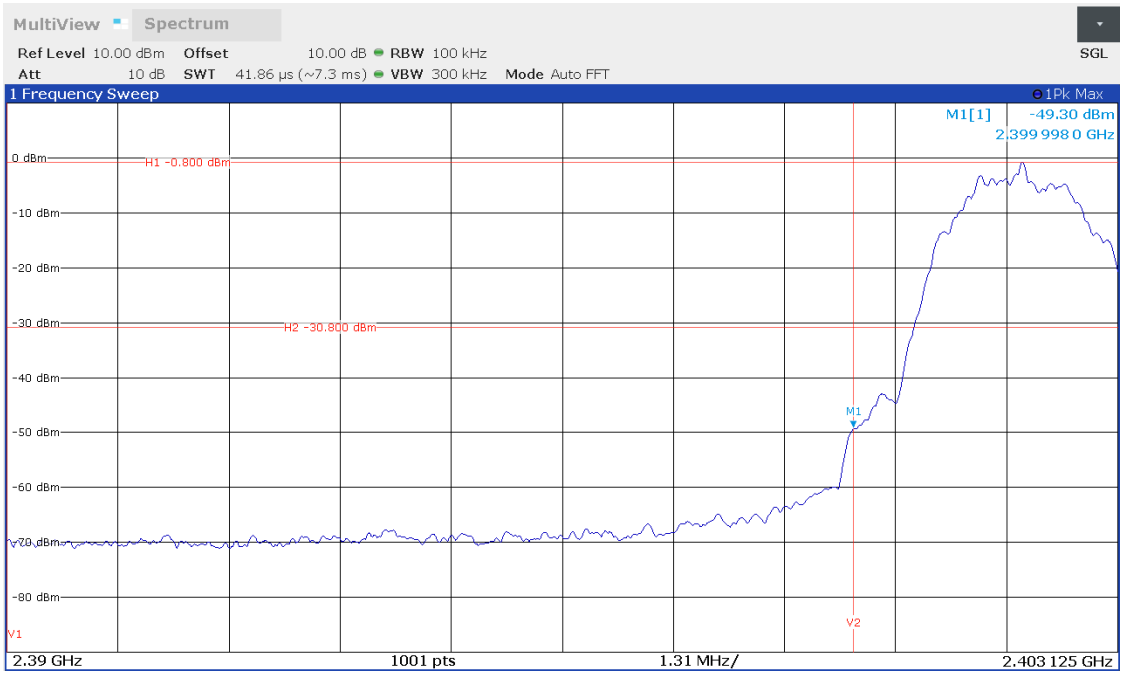


	Internal Antenna					External Antenna				
Operation Mode #	Emission Frequency [MHz]	Reference [dBm]	Limit [dBm]	Emission level [dBm]	Margin [dB]	Emission Frequency [MHz]	Reference [dBm]	Limit [dBm]	Emission level [dBm]	Margin [dB]
1	2399.925	7.0	-23.0	-27.6	4.6	2399.925	6.0	-24.0	-30.0	6.0
2	-	-	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-	-	-
4	2399.851	5.2	-24.8	-28.2	3.4	2399.851	4.3	-25.7	-30.3	4.6
5	-	-	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-	-	-
7	2399.962	5.2	-24.8	-27.6	2.8	2399.925	3.8	-26.2	-29.0	2.8
8	-	-	-	-	-	-	-	-	-	-
9	-	-	-	-	-	-	-	-	-	-
10	2399.962	6.4	-23.6	-29.9	6.3	2399.851	4.0	-26.0	-32.5	6.5
11	-	-	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-	-	-
13	**2399.518**	**1.5**	**-28.5**	**-30.8**	**2.3**	2399.814	-0.4	-30.4	-34.2	3.8
14	-	-	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-	-	-

Test: Passed

5.8.4 Test results (Band edge – unrestricted bands) – 30 dBc (Bluetooth Low Energy)

Worst case plot Lower band edge (operation mode 19 – internal antenna):



	Internal Antenna					External Antenna				
Operation Mode #	Emission Frequency [MHz]	Reference [dBm]	Limit [dBm]	Emission level [dBm]	Margin [dB]	Emission Frequency [MHz]	Reference [dBm]	Limit [dBm]	Emission level [dBm]	Margin [dB]
16	2399.998	0.1	-29.9	-58.7	28.8	-	-	-	-	-
17	-	-	-	-	-	-	-	-	-	-
18	-	-	-	-	-	-	-	-	-	-
19	2399.998	-0.8	-30.8	-49.3	**18.5**	-	-	-	-	-
20	-	-	-	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-	-	-	-

Test: Passed

Test equipment (please refer to chapter 7 for details)
1 - 3

5.8.5 Test setup (Band edge – restricted bands)

Test setup			
Used	Setup	See sub-clause	Comment
☐	Test setup (radiated – normal procedure)	5.1.1.4	-
☒	Test setup (radiated – alternative procedure)*1	5.1.1.5	-
☐	Test setup (antenna port conducted)	5.1.2	-

*1 Only worst-case modes from the antenna port conducted pretests were tested as radiated tests.

5.8.6 Test method (Band edge – restricted bands)

Test method (Band edge – restricted bands)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.13.1	Standard method	No limitations	-
☐	11.13.2	Marker-delta method		See 6.10.6 [1]
☐	11.13.3.2	Peak detection	Not for DTS testing	2 MHz from band
☐	11.13.3.3	Trace averaging with cont. EUT	D ≥ 98%	2 MHz from band
☐	11.13.3.4	Trace averaging with cont. EUT & D	Constant D (±2%)	2 MHz from band
☐	11.13.3.5	Reduced VBW		2 MHz from band

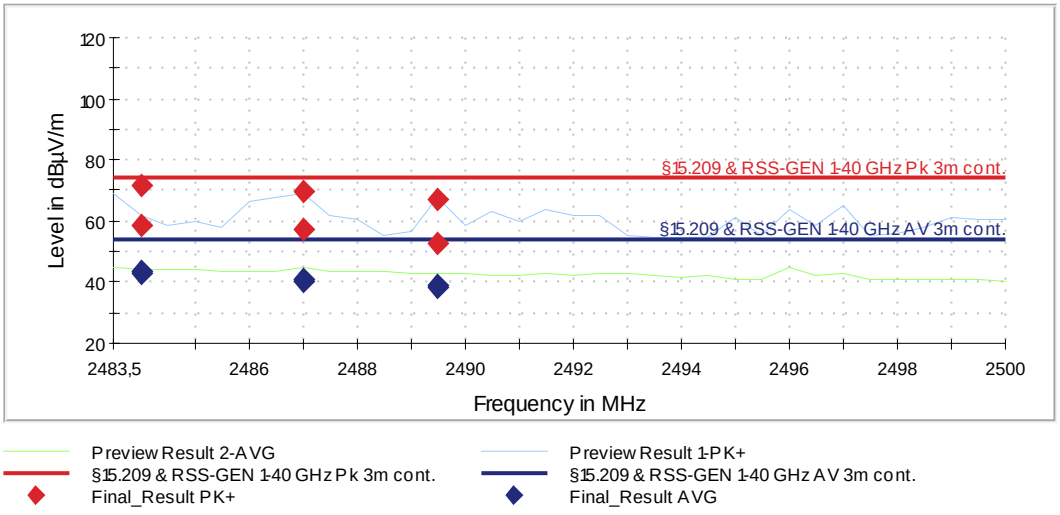
5.8.7 Test results (Band edge – restricted bands) - radiated

5.8.7.1 WLAN

Ambient temperature:	21 - 22 °C
Relative humidity:	21 - 24 %

Date	20+21.12.2021
Tested by	B. ROHDE

Worst case plot WLAN (operation mode 12):



Operation mode #	Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]
1	2379.750	---	33.28	54.00	20.72	V	259.0	90.0	33.3
1	2379.750	47.57	---	74.00	26.43	V	259.0	90.0	33.3
1	2383.750	---	37.22	54.00	16.78	V	252.0	90.0	33.3
1	2383.750	50.31	---	74.00	23.69	V	252.0	90.0	33.3
1	2389.500	---	37.25	54.00	16.75	V	252.0	90.0	33.4
1	2389.500	50.45	---	74.00	23.55	V	252.0	90.0	33.4
1	2390.000	---	39.92	54.00	14.08	V	251.0	90.0	33.4
1	2390.000	60.53	---	74.00	13.47	V	251.0	90.0	33.4
-	-	-	-	-	-	-	-	-	-
3	2484.000	---	41.31	54.00	12.69	V	116.0	90.0	33.6
3	2484.000	65.60	---	74.00	8.40	V	116.0	90.0	33.6
3	2489.500	57.76	---	74.00	16.24	V	46.0	90.0	33.5
3	2489.500	---	37.98	54.00	16.02	V	46.0	90.0	33.5
3	2493.000	---	40.50	54.00	13.50	V	254.0	90.0	33.5
3	2493.000	63.17	---	74.00	10.83	V	254.0	90.0	33.5

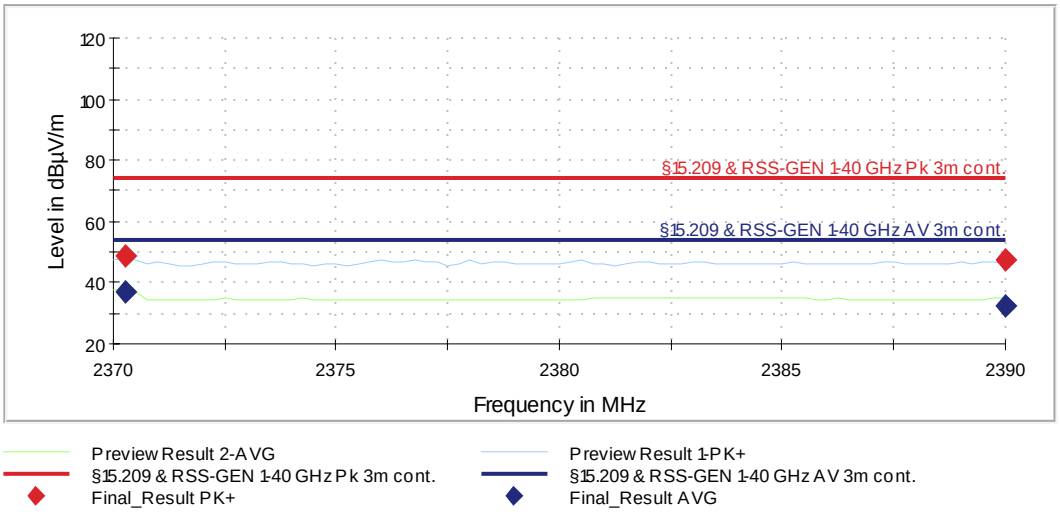
Operation mode #	Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]
12	2484.000	---	43.65	54.00	10.35	H	72.0	0.0	33.6
12	2484.000	71.35	---	74.00	**2.65**	H	72.0	0.0	33.6
12	2487.000	69.65	---	74.00	4.35	H	136.0	0.0	33.6
12	2487.000	---	40.00	54.00	14.00	H	136.0	0.0	33.6
12	2489.500	---	38.64	54.00	15.36	H	223.0	0.0	33.5
12	2489.500	67.11	---	74.00	6.89	H	223.0	0.0	33.5
-	-	-	-	-	-	-	-	-	-
15	2484.000	---	40.63	54.00	13.37	V	7.0	0.0	33.6
15	2484.000	58.19	---	74.00	15.81	V	7.0	0.0	33.6
-	-	-	-	-	-	-	-	-	-
16	2388.750	---	41.69	54.00	12.31	V	-19.0	90.0	33.4
16	2388.750	60.44	---	74.00	13.56	V	-19.0	90.0	33.4
16	2390.000	---	42.84	54.00	11.16	V	14.0	90.0	33.4
16	2390.000	61.64	---	74.00	12.36	V	14.0	90.0	33.4
-	-	-	-	-	-	-	-	-	-
18	2484.000	---	34.82	54.00	19.18	H	0.0	0.0	33.6
18	2484.000	66.21	---	74.00	7.79	H	0.0	0.0	33.6
18	2486.500	---	37.56	54.00	16.44	H	304.0	0.0	33.6
18	2486.500	67.23	---	74.00	6.77	H	304.0	0.0	33.6
18	2488.500	---	38.67	54.00	15.33	H	255.0	0.0	33.6
18	2488.500	67.37	---	74.00	6.63	H	255.0	0.0	33.6

5.8.7.2 BLE

Ambient temperature:	22 °C
Relative humidity:	42 %

Date	15.12.2021
Tested by	R. BRAUN

Worst case plot BLE (operation mode 19):



Operation mode #	Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]
19	2370.250	48.59	---	74.00	25.41	V	246.0	0.0	33.2
19	2370.250	---	36.74	54.00	**17.26**	V	247.0	0.0	33.2
19	2390.000	47.25	---	74.00	26.75	V	185.0	0.0	33.4
19	2390.000	---	32.32	54.00	21.68	V	185.0	0.0	33.4
-	-	-	-	-	-	-	-	-	-
21	2483.750	46.74	---	74.00	27.26	V	140.0	0.0	33.6
21	2483.750	---	32.32	54.00	21.68	V	140.0	0.0	33.6
21	2492.000	46.53	---	74.00	27.47	V	145.0	0.0	33.5
21	2492.000	---	31.50	54.00	22.50	V	145.0	0.0	33.5

Test: Passed

Test equipment (please refer to chapter 7 for details)
4 - 12

5.9 Radiated emissions

Test setup (Maximum unwanted emissions)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated – normal procedure)	5.1.1.4	f < 1 GHz
☒	Test setup (radiated – alternative procedure)	5.1.1.5	f > 1 GHz
☐	Test setup (antenna port conducted)	5.1.2	-

5.9.1 Test results (Maximum unwanted emissions)

5.9.1.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	22 °C
Relative humidity:	28 %

Date	13.01.2022
Tested by	P. NEUFELD

Position of EUT: For tests for f between 9 kHz to 30 MHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.

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

Test record: The measurement value was already corrected by 40 dB/decade as described in 47 CFR 15.31(f)(2) regarding to the measurement distance as requested in 47 CFR 15.209(a)

Remark: All 3 orthogonal planes were tested separately

Calculations:

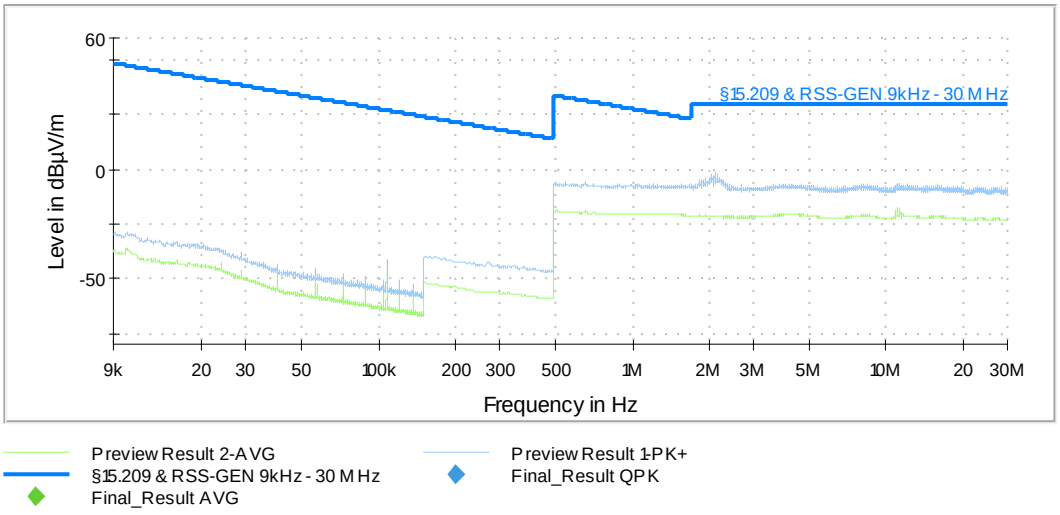
Result @ norm. dist. [dBµV/m] = Reading [dBµV] + AF [dB/m] + Distance corr. fact. [dBµV/m]

Result @ norm. dist. [dBµA/m] = Result @ norm. dist. [dBµV/m] – 20 x $\log_{10}$ (377 Ω)

Margin [dB] = Limit [dB(µV|µA)/m] - Result [dB(µV|µA)/m

Worst case plot (WLAN & BLE):

Spurious emissions from 9 kHz to 30 MHz (operation mode 3 - Pos 3):



Remark: No emissions closer than 20 dB to the limit, so no final measurement will be carried out.

Test equipment (please refer to chapter 7 for details)
20 – 26, 29

5.9.1.2 Test results WLAN (30 MHz – 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	28 %

Date	11.01.2022
Tested by	P. NEUFELD

Position of EUT: For tests for f between 30 MHz to 1 GHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: All 3 orthogonal planes were tested separately

Calculations:

Result [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]

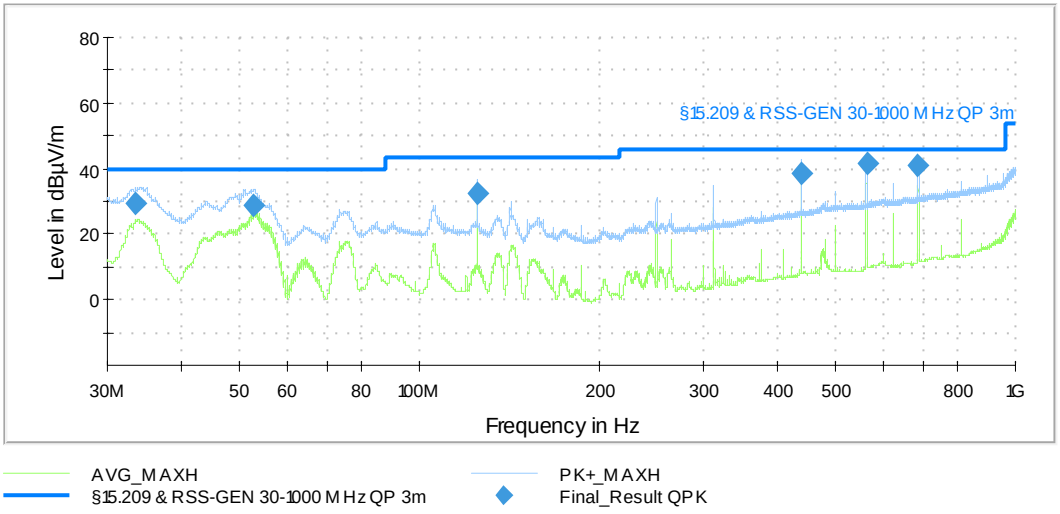
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

Margin [dB] = Limit [dBµV/m] - Result [dBµV/m]

The measured points and the limit line in the following diagram refer to the standard measurement of the emitted interference in compliance with the above-mentioned standard. The measured points marked with "◆" are the measured results of the standard subsequent measurement in a semi-anechoic chamber.

Worst case plot:

Spurious emissions from 30 MHz to 1 GHz (operation mode 2 – Pos 2):



Result tables

(operation mode 1):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
34.61	29.3	40.0	10.7	100.0	V	127	23.2	6.1	1
52.69	30.2	40.0	9.8	102.0	V	68	12.6	17.6	1
125.00	35.0	43.5	8.5	110.0	V	76	17.2	17.8	1
437.50	40.5	46.0	5.6	102.0	V	-17	22.7	17.6	1
562.49	39.1	46.0	6.9	166.0	H	294	25.4	13.7	1
687.49	43.2	46.0	2.8	100.0	V	165	27.1	16.1	1
984.33	26.4	54.0	27.6	190.0	H	268	30.8	-4.4	1

(operation mode 2):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
33.37	29.4	40.0	10.6	103.0	V	22	24.0	5.4	2
52.71	28.9	40.0	11.2	117.0	V	52	12.6	16.3	2
125.00	32.3	43.5	11.3	102.0	V	112	17.2	15.1	2
437.50	38.7	46.0	7.3	103.0	V	-14	22.7	16.0	2
562.49	41.3	46.0	4.8	104.0	V	-2	25.4	15.9	2
687.49	40.8	46.0	5.2	103.0	V	162	27.1	13.8	2

(operation mode 3):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
36.40	32.4	40.0	7.6	101.0	V	24	22.2	10.2	3
53.04	31.5	40.0	8.5	101.0	V	102	12.5	19.0	3
562.49	40.5	46.0	5.5	167.0	V	22	25.4	15.1	3
687.49	37.8	46.0	8.3	130.0	V	330	27.1	10.7	3
984.38	25.8	54.0	28.2	122.0	V	107	30.8	-5.0	3

Test result: Passed

Test equipment (please refer to chapter 7 for details)
20 - 28

5.9.1.3 Test results BLE (30 MHz – 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	28 %

Date	11.01.2022
Tested by	P. NEUFELD

Position of EUT: For tests for f between 30 MHz to 1 GHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: All 3 orthogonal planes were tested separately

Calculations:

Result [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]

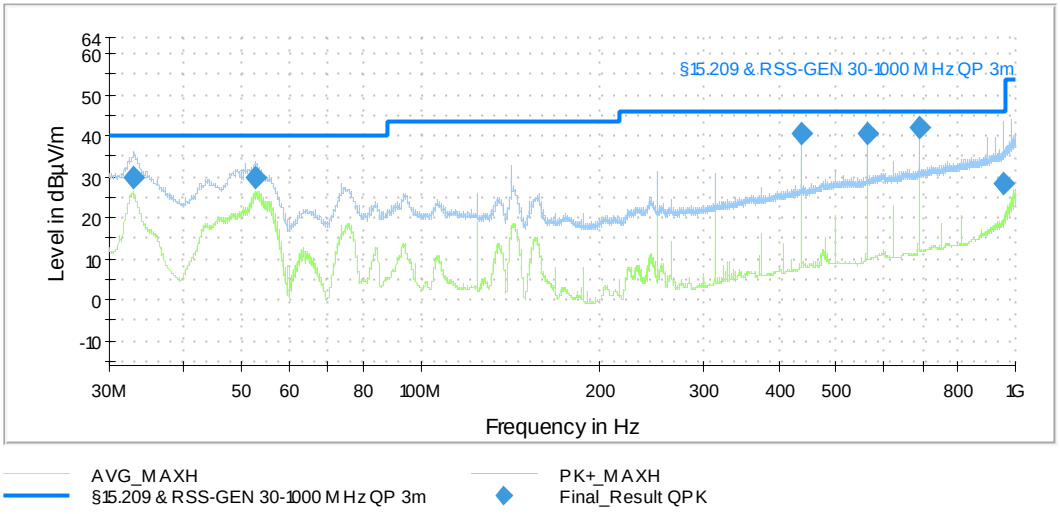
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

Margin [dB] = Limit [dBµV/m] - Result [dBµV/m]

The measured points and the limit line in the following diagram refer to the standard measurement of the emitted interference in compliance with the above-mentioned standard. The measured points marked with "◆" are the measured results of the standard subsequent measurement in a semi-anechoic chamber.

Worst case plot:

Spurious emissions from 30 MHz to 1 GHz (operation mode 20 – Pos 2):



Result tables

(operation mode 19):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
55.500	26.7	40.0	13.3	118.0	V	190	12.0	14.7	1
374.990	41.0	46.0	5.0	100.0	V	157	21.3	19.7	1
437.500	34.0	46.0	12.0	101.0	V	22	22.7	11.3	1
562.490	31.8	46.0	14.2	104.0	V	26	25.4	6.4	1
624.990	35.7	46.0	10.3	186.0	V	187	26.3	9.4	1
956.260	32.8	46.0	13.2	126.0	V	4	30.3	2.5	1

(operation mode 20):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
32.940	29.7	40.0	10.3	102.0	V	312	24.3	5.4	2
52.690	29.7	40.0	10.3	103.0	V	57	12.6	17.1	2
437.500	40.8	46.0	5.2	106.0	V	182	22.7	18.1	2
562.500	40.4	46.0	5.6	113.0	V	0	25.4	15.0	2
687.490	42.1	46.0	3.9	102.0	V	161	27.1	15.0	2
956.250	28.5	46.0	17.5	130.0	H	199	30.3	-1.8	2

(operation mode 21):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Height [cm]	Pol. (H/V)	Azimuth [deg]	Correction [dB/m]	Readings [dBµV]	Position #
36.450	31.4	40.0	8.6	111.0	V	22	22.2	9.2	3
54.040	32.0	40.0	8.0	109.0	V	150	12.3	19.7	3
125.000	33.6	43.5	9.9	100.0	V	195	17.2	16.4	3
562.490	36.3	46.0	9.7	182.0	V	24	25.4	10.9	3
624.990	36.7	46.0	9.3	100.0	V	100	26.3	10.4	3
687.490	41.2	46.0	4.8	100.0	V	9	27.1	14.1	3

Test result: Passed

Test equipment (please refer to chapter 7 for details)
20 – 28

5.9.1.4 Test results WLAN (radiated 1 to 26.5 GHz)

Ambient temperature:	20 - 21°C
Relative humidity:	25 - 28%

Date	20 + 21.12.2021
Tested by	B. ROHDE

Position of EUT: For tests for f between 1 GHz and the 10th harmonic, the EUT was set-up on a positioner device with a height of 150 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: No spurious emissions were found during the antenna port conducted pre-tests. Therefore, the emission with the highest power spectral density was used for the radiated emissions tests, namely 802.11 b with 2 Mbps.

Calculation:

Max Peak [dBµV/m] = Reading (Pk+) [dBµV] + Correction [dBµV/m]

Average [dBµV/m] = Reading (Av) [dBµV] + Correction [dBµV/m]

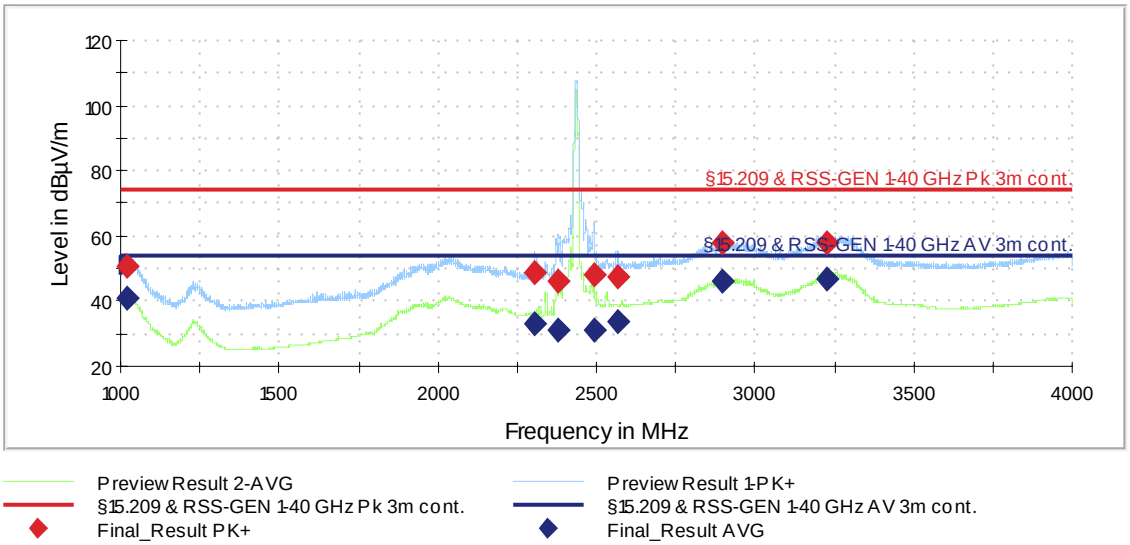
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF* [dB]
* (if applicable – only for Average values, that are fundamental related)

Margin [dB] = Limit [dBµV/m] – Max Peak | Average [dBµV/m]

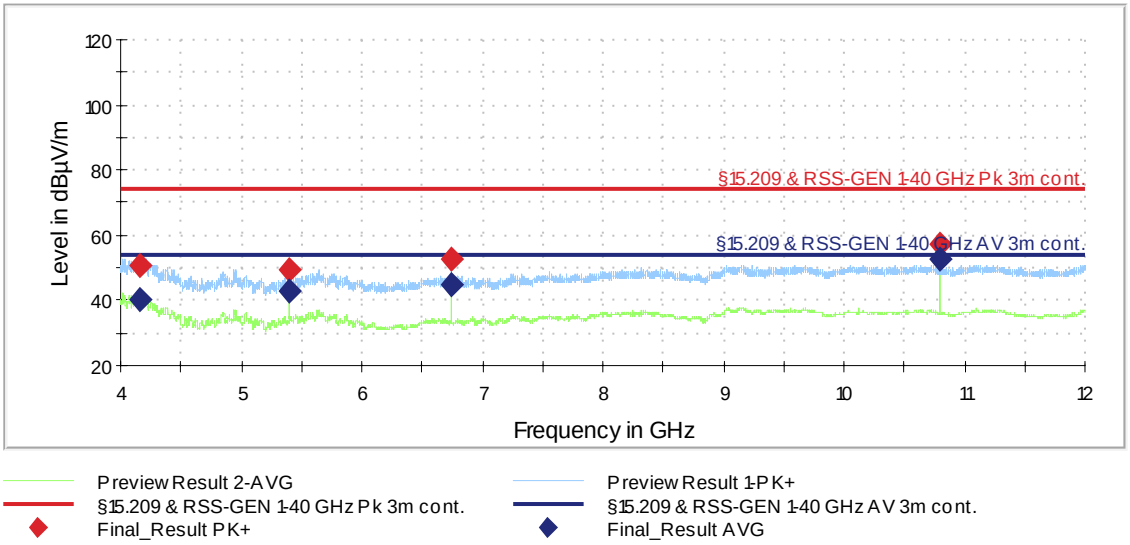
The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.
The top measured curve represents the peak measurement. The measured points marked with "♦" are frequency points for the final peak detector measurement. These values are indicated in the following table. The bottom measured curve represents the average measurement. The measured points marked with "♦" are frequency points for the final average detector measurement.

Worst case plots WLAN:

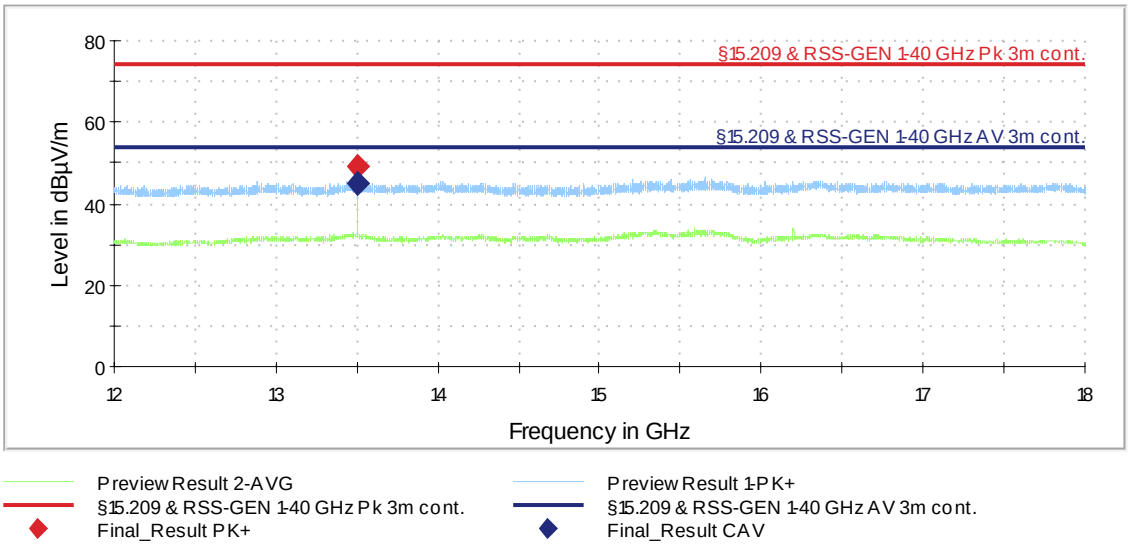
Spurious emissions from 1 GHz to 4 GHz (operation mode 2):



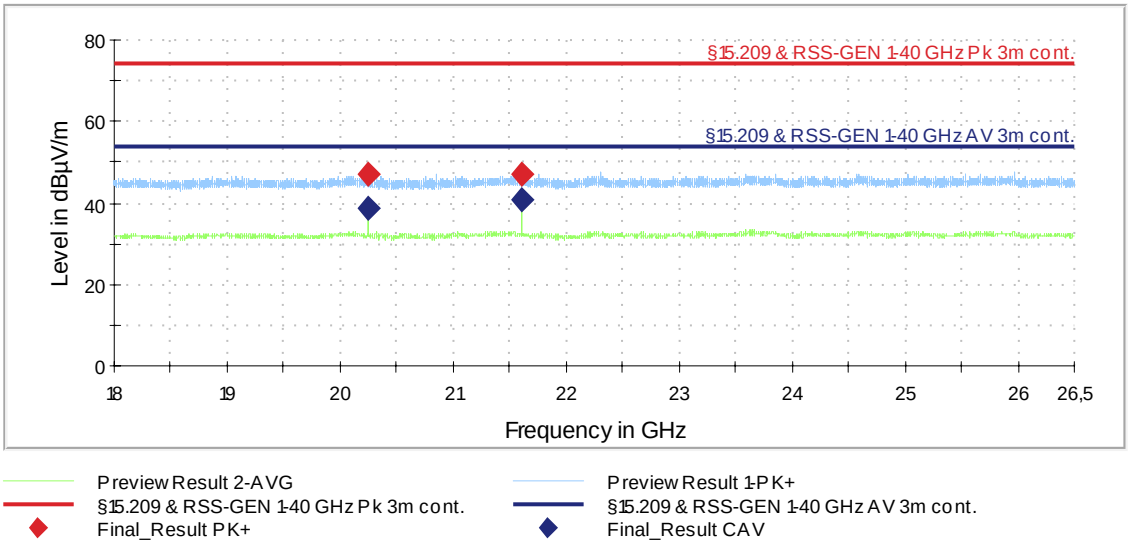
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



Spurious emissions from 12 GHz to 18 GHz (operation mode 1):



Spurious emissions from 18 GHz to 26.5 GHz (operation mode 1):



5.9.1.4.1 Result tables

Operation mode 1:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol
1019.000	---	41.6	54	12.4	24.7	150	168	V
1019.000	52.4	---	74	21.6	24.7	150	168	V
2025.000	50.0	---	74	24.0	31.5	30	-15	V
2025.000	---	39.1	54	14.9	31.5	30	-15	V
2355.500	---	30.0	54	24.0	33.2	0	-14	H
2355.500	45.2	---	74	28.8	33.2	0	-14	H
2355.750	---	29.5	54	24.5	33.2	0	-9	H
2355.750	45.0	---	74	29.0	33.2	0	-9	H
2383.750	45.9	---	74	28.1	33.3	0	-13	H
2383.750	---	29.9	54	24.1	33.3	0	-13	H
2389.500	45.5	---	74	28.5	33.4	0	-17	H
2389.500	---	29.8	54	24.2	33.4	0	-17	H
2507.000	51.8	---	74	22.2	33.7	90	23	V
2507.000	---	42.7	54	11.3	33.7	90	23	V
2508.750	---	41.1	54	12.9	33.7	90	18	V
2508.750	52.0	---	74	22.0	33.7	90	18	V
2539.000	48.0	---	74	26.0	33.9	60	332	V
2539.000	---	34.1	54	19.9	33.9	60	332	V
2934.750	55.9	---	74	18.1	35.4	30	346	V
2934.750	---	45.2	54	8.8	35.4	30	346	V
3257.750	---	44.4	54	9.6	37.1	150	252	V
3257.750	56.5	---	74	17.5	37.1	150	252	V
4161.750	---	40.4	54	13.6	-4.2	30	24	V
4161.750	51.0	---	74	23.0	-4.2	30	24	V
5400.000	---	43.1	54	10.9	-0.2	30	351	V
5400.000	49.3	---	74	24.7	-0.2	30	351	V
6750.000	52.5	---	74	21.5	3.4	30	-5	V
6750.000	---	44.8	54	9.2	3.4	30	-5	V
10800.000	57.4	---	74	16.6	7.2	120	133	V
10800.000	---	52.9	54	1.1	7.2	120	133	V
13500.000	---	44.8	54	9.2	10.7	150	182	V
13500.000	48.9	---	74	25.1	10.7	150	182	V
20249.750	---	38.7	54	15.3	4.6	150	175	V
20249.750	47.3	---	74	26.7	4.6	150	175	V
21599.750	---	40.6	54	13.4	5.3	150	166	V
21599.750	47.3	---	74	26.7	5.3	150	166	V

Operation mode 2:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol
1021.000	50.5	---	74	23.5	24.7	120	180	V
1021.000	---	40.7	54	13.3	24.7	120	180	V
2308.000	48.6	---	74	25.4	32.9	30	347	V
2308.000	---	33.0	54	21.0	32.9	30	347	V
2380.000	---	31.4	54	22.6	33.3	30	62	V
2380.000	46.4	---	74	27.6	33.3	30	62	V
2493.500	47.9	---	74	26.1	33.5	30	233	H
2493.500	---	31.4	54	22.6	33.5	30	233	H
2565.750	---	33.5	54	20.5	34.1	90	315	V
2565.750	47.6	---	74	26.4	34.1	90	315	V
2896.750	57.7	---	74	16.3	35.6	30	339	V
2896.750	---	46.1	54	7.9	35.6	30	339	V
3226.250	---	47.1	54	6.9	36.8	150	226	V
3226.250	58.1	---	74	15.9	36.8	150	226	V
4165.250	---	41.4	54	12.6	-4.2	120	72	V
4165.250	52.0	---	74	22.0	-4.2	120	72	V
5400.000	---	42.8	54	11.2	-0.2	150	205	V
5400.000	48.7	---	74	25.3	-0.2	150	205	V
6750.000	---	43.2	54	10.8	3.4	30	4	H
6750.000	49.8	---	74	24.2	3.4	30	4	H
10800.000	---	45.0	54	9.0	7.2	0	38	V
10800.000	56.0	---	74	18.0	7.2	0	38	V
13500.000	---	43.0	54	11.0	10.7	150	194	V
13500.000	48.2	---	74	25.8	10.7	150	194	V
20249.750	48.1	---	74	25.9	4.6	150	210	V
20249.750	---	40.2	54	13.8	4.6	150	210	V
21599.750	---	39.1	54	14.9	5.3	150	165	V
21599.750	51.5	---	74	22.5	5.3	150	165	V

Operation mode 3:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol
1004.750	---	39.3	54	14.7	24.7	90	194	V
1004.750	49.0	---	74	25.0	24.7	90	194	V
2332.750	---	33.1	54	20.9	33.0	30	7	V
2332.750	47.7	---	74	26.3	33.0	30	7	V
2484.000	---	36.2	54	17.8	33.6	0	262	H
2484.000	51.8	---	74	22.2	33.6	0	262	H
2495.250	---	33.3	54	20.7	33.5	150	204	V
2495.250	47.9	---	74	26.1	33.5	150	204	V
2501.500	---	32.3	54	21.7	33.6	150	218	V
2501.500	47.1	---	74	26.9	33.6	150	218	V
2518.500	---	32.4	54	21.6	33.8	150	199	V
2518.500	47.6	---	74	26.4	33.8	150	199	V
2588.250	---	30.9	54	23.1	34.2	0	160	H
2588.250	46.4	---	74	27.6	34.2	0	160	H
2925.000	---	45.2	54	8.8	35.5	30	346	V
2925.000	58.3	---	74	15.7	35.5	30	346	V
3214.750	---	45.6	54	8.4	36.8	150	230	V
3214.750	58.2	---	74	15.8	36.8	150	230	V
4081.500	54.8	---	74	19.2	-4.0	120	69	V
4081.500	---	42.8	54	11.2	-4.0	120	69	V
5400.000	47.8	---	74	26.2	-0.2	120	69	V
5400.000	---	42.4	54	11.6	-0.2	120	69	V
6750.000	52.9	---	74	21.1	3.4	120	69	V
6750.000	---	47.8	54	6.2	3.4	120	69	V
10800.000	56.2	---	74	17.8	7.2	120	69	V
10800.000	---	52.0	54	2.0	7.2	120	69	V
13500.000	51.2	---	74	22.8	10.7	30	342	H
13500.000	---	40.6	54	13.4	10.7	30	342	H
20249.700	---	40.3	54	13.7	4.6	150	180	V
20249.750	47.7	---	74	26.3	4.6	150	180	V
21599.750	---	43.2	54	10.8	5.3	150	163	V
21599.750	50.3	---	74	23.7	5.3	150	163	V

Test result: Passed

Test equipment (please refer to chapter 7 for details)
4 - 19

5.9.1.5 Test results BLE (radiated 1 to 26.5 GHz)

Ambient temperature:	20 - 22°C
Relative humidity:	25 - 38%

Date	13 - 17.12.2021
Tested by	R. BRAUN

Position of EUT: For tests for f between 1 GHz and the 10th harmonic, the EUT was set-up on a positioner device with a height of 150 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: Antenna port conducted pre-tests showed, that the mode with 1 Mbps and GFSK modulation produced the highest spurious emissions. Therefore, only this mode was tested for the radiated emissions.

Calculation:

Max Peak [dBµV/m] = Reading (Pk+) [dBµV] + Correction [dBµV/m]

Average [dBµV/m] = Reading (Av) [dBµV] + Correction [dBµV/m]

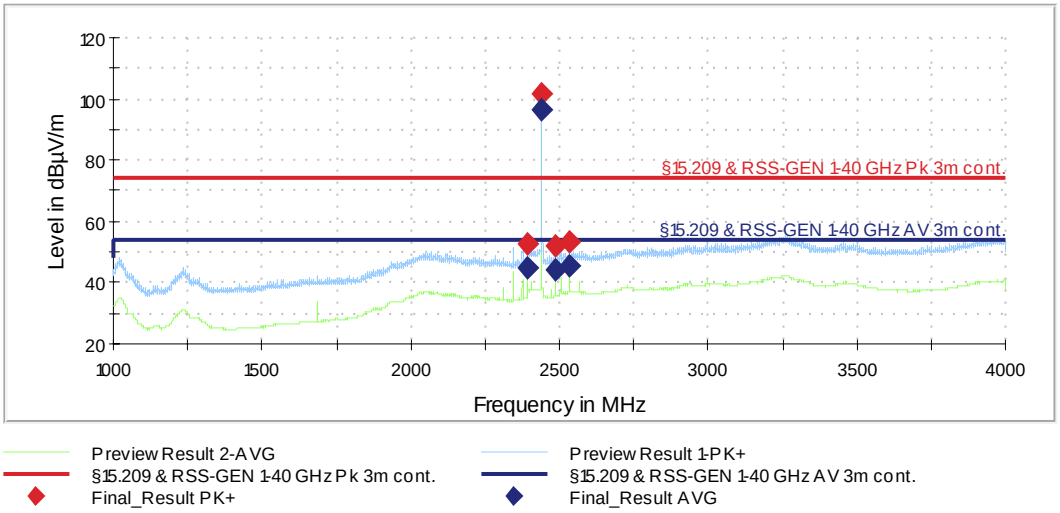
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF* [dB]
* (if applicable – only for Average values, that are fundamental related)

Margin [dB] = Limit [dBµV/m] – Max Peak | Average [dBµV/m]

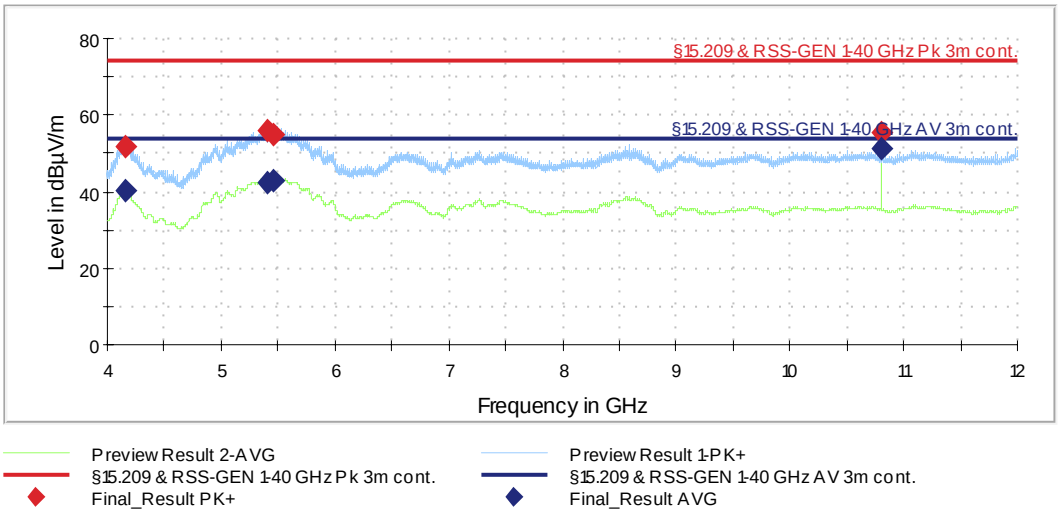
The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.
The top measured curve represents the peak measurement. The measured points marked with "♦" are frequency points for the final peak detector measurement. These values are indicated in the following table. The bottom measured curve represents the average measurement. The measured points marked with "♦" are frequency points for the final average detector measurement.

Worst case plots:

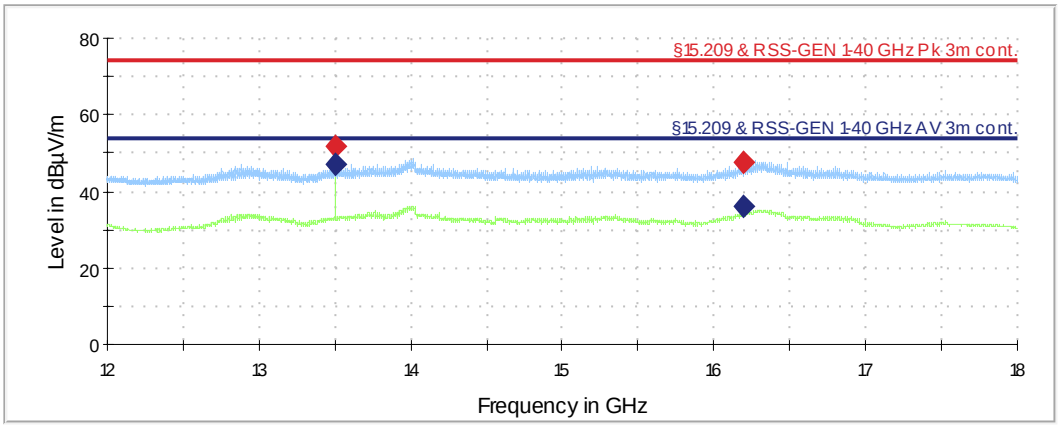
Spurious emissions from 1 GHz to 4 GHz (operation mode 20):



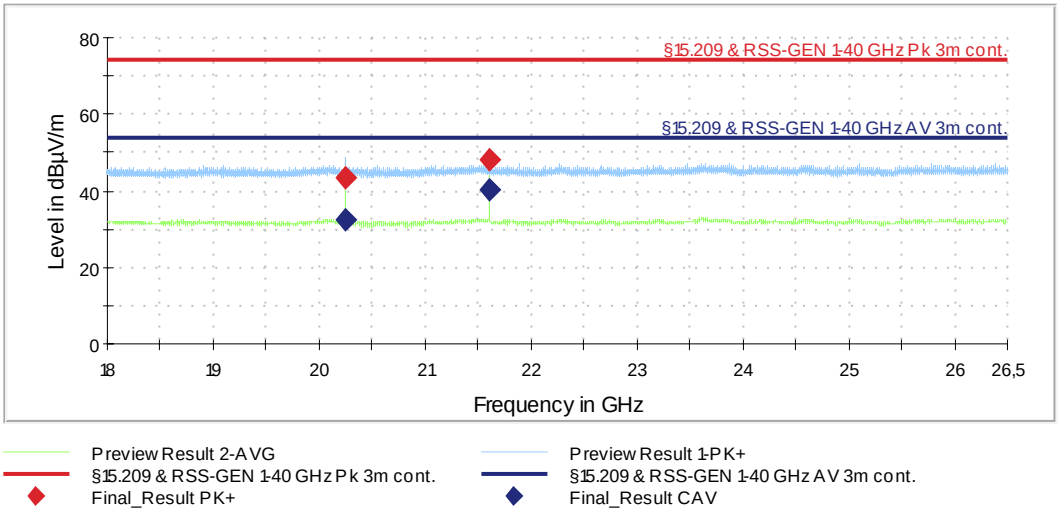
Spurious emissions from 4 GHz to 12 GHz (operation mode 19):



Spurious emissions from 12 GHz to 18 GHz (operation mode 20):



Spurious emissions from 18 GHz to 26.5 GHz (operation mode 20):



5.9.1.5.1 Result tables

Operation mode 19:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2353.750	---	41.4	54	12.6	V	253	0	33.2	8.2
2353.750	51.3	---	74	22.7	V	253	0	33.2	18.1
2354.000	51.1	---	74	22.9	V	250	0	33.2	17.9
2354.000	---	42.5	54	11.5	V	250	0	33.2	9.3
2401.750	---	95.9	---	---	V	249	0	33.5	62.4
2401.750	102.1	---	---	---	V	249	0	33.5	68.6
2449.750	---	45.0	54	9.0	V	248	0	33.9	11.1
2449.750	53.8	---	74	20.2	V	248	0	33.9	19.9
2498.000	---	45.6	54	8.4	V	249	0	33.6	12.0
2498.000	54.4	---	74	19.7	V	249	0	33.6	20.8
3262.250	54.3	---	74	19.8	V	140	0	37.1	17.2
3262.250	---	40.7	54	13.3	V	140	0	37.1	3.6
4164.750	52.2	---	74	21.8	V	153	30	-4.2	56.4
4164.750	---	39.2	54	14.8	V	153	30	-4.2	43.4
5400.000	56.0	---	74	18.0	H	160	90	-0.2	56.2
5400.000	---	42.6	54	11.4	H	160	90	-0.2	42.8
5457.500	54.9	---	74	19.1	V	155	30	0.1	54.8
5457.500	---	42.8	54	11.3	V	155	30	0.1	42.7
10800.000	55.1	---	74	18.9	H	234	60	7.2	47.9
10800.000	---	51.3	54	2.8	H	234	60	7.2	44.1
13500.000	50.7	---	74	23.3	V	164	90	10.7	40.0
13500.000	---	45.4	54	8.6	V	164	90	10.7	34.7
16199.750	---	33.1	54	20.9	H	155	120	10.2	22.9
16199.750	45.0	---	74	29.0	H	155	120	10.2	34.8
16874.750	---	33.9	54	20.2	H	230	120	9.8	24.1
16874.750	44.5	---	74	29.5	H	230	120	9.8	34.7
20249.750	---	42.2	54	11.8	V	208	120	4.6	37.6
20249.750	49.1	---	74	25.0	V	208	120	4.6	44.5
21599.750	---	37.3	54	16.7	H	213	120	5.3	32.0
21599.750	47.5	---	74	26.5	H	213	120	5.3	42.2

Operation mode 20:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2392.000	53.0	---	74	21.0	V	250	0	33.4	19.6
2392.000	---	45.1	54	8.9	V	250	0	33.4	11.7
2440.000	---	96.4	---	---	V	248	0	33.8	62.6
2440.000	101.4	---	---	---	V	248	0	33.8	67.6
2488.000	52.2	---	74	21.8	V	249	0	33.6	18.6
2488.000	---	44.0	54	10.0	V	249	0	33.6	10.4
2536.000	---	45.4	54	8.6	V	249	0	33.9	11.5
2536.000	53.5	---	74	20.5	V	249	0	33.9	19.6
4165.750	50.4	---	74	23.6	V	153	30	-4.2	54.6
4165.750	---	39.1	54	14.9	V	153	30	-4.2	43.3
5400.000	54.6	---	74	19.4	V	161	0	-0.2	54.8
5400.000	---	42.8	54	11.2	V	161	0	-0.2	43.0
5457.500	55.4	---	74	18.6	V	157	30	0.1	55.3
5457.500	---	43.5	54	10.5	V	157	30	0.1	43.4
10800.000	55.5	---	74	18.5	V	210	150	7.2	48.3
10800.000	---	51.1	54	3.0	V	210	150	7.2	43.9
13500.000	51.6	---	74	22.4	V	158	90	10.7	40.9
13500.000	---	47.2	54	6.9	V	158	90	10.7	36.5
16200.000	47.5	---	74	26.5	H	160	90	10.2	37.3
16200.000	---	36.0	54	18.0	H	160	90	10.2	25.8
20249.750	---	42.8	54	11.2	V	148	90	4.6	38.2
20249.750	43.3	---	74	30.7	V	148	90	4.6	38.7
21599.750	48.3	---	74	25.7	V	210	120	5.3	43.0
21599.750	---	40.1	54	13.9	V	210	120	5.3	34.8

Operation mode 21:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2383.750	---	44.7	54	9.3	V	248	0	33.3	11.4
2383.750	53.4	---	74	20.6	V	248	0	33.3	20.1
2479.750	---	94.1	---	---	H	141	0	33.6	60.5
2479.750	100.3	---	---	---	H	141	0	33.6	66.7
2492.000	---	28.6	54	25.4	H	131	0	33.5	-4.9
2492.000	44.8	---	74	29.3	H	131	0	33.5	11.2
2528.000	51.0	---	74	23.0	H	217	90	33.8	17.2
2528.000	---	40.0	54	14.0	H	217	90	33.8	6.2
2575.750	---	43.5	54	10.6	H	148	30	34.1	9.3
2575.750	53.2	---	74	20.8	H	148	30	34.1	19.1
2997.250	---	37.5	54	16.5	V	140	0	35.4	2.1
2997.250	51.0	---	74	23.0	V	140	0	35.4	15.6
3266.000	---	39.3	54	14.7	V	154	0	37.1	2.2
3266.000	52.9	---	74	21.1	V	154	0	37.1	15.8
4164.500	52.0	---	74	22.0	V	158	60	-4.2	56.2
4164.500	---	40.0	54	14.0	V	158	60	-4.2	44.2
5400.000	55.7	---	74	18.3	H	160	90	-0.2	55.9
5400.000	---	42.2	54	11.8	H	160	90	-0.2	42.4
5457.750	54.8	---	74	19.2	V	155	30	0.1	54.7
5457.750	---	43.1	54	10.9	V	155	30	0.1	43.0
10800.000	55.2	---	74	18.8	H	233	60	7.2	48.0
10800.000	---	51.4	54	2.6	H	233	60	7.2	44.2
13500.000	---	45.4	54	8.6	V	155	60	10.7	34.7
13500.000	44.7	---	74	29.3	V	155	60	10.7	34.0
16874.750	---	30.7	54	23.3	H	226	120	9.8	20.9
16874.750	43.5	---	74	30.5	H	226	120	9.8	33.7
20249.750	---	42.7	54	11.3	V	211	120	4.6	38.1
20249.750	48.8	---	74	25.2	V	211	120	4.6	44.2
21599.750	---	39.7	54	14.3	H	210	120	5.3	34.4
21599.750	51.6	---	74	22.4	H	210	120	5.3	46.3

Test result: Passed

Test equipment (please refer to chapter 7 for details)
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6 Measurement Uncertainties

Conducted measurements:		
Measurement method	Standard used for calculating measurement uncertainty	Expanded measurement uncertainty (95 %) U_{lab}
Frequency error	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements	-	9.0×10^{-8}
Conducted emissions using a spectrum analyzer		
< 3.6 GHz	ETSI TR 100 028	2.3 dB
3.6 – 8 GHz	ETSI TR 100 028	2.8 dB
8 – 22 GHz	ETSI TR 100 028	3.2 dB
22 – 40 GHz	ETSI TR 100 028	3.6 dB
Power measurements		
Power meter	ETSI TR 100 028	0.9 dB
Conducted emissions from 150 kHz to 30 MHz with LISN	CISPR 16-4-2	2.8 dB
Radiated measurements:		
Frequency error		
(Semi-) Anechoic chamber	ETSI TR 100 028	4.5×10^{-8}
OATS	ETSI TR 100 028	4.5×10^{-8}
Test fixture	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements		
(Semi-) Anechoic chamber	-	9.0×10^{-8}
OATS	-	9.0×10^{-8}
Test fixture	-	9.1×10^{-8}
Radiated field strength M20		
CBL6112B @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	5.3 dB
R&S HL050 @ 3 m		
1 – 6 GHz	CISPR 16-4-2	5.1 dB
6 – 18 GHz	CISPR 16-4-2	5.4 dB
Flann Standard Gain Horns 18 – 40 GHz	-	5.9 dB
Radiated field strength M276		
R&S HL562E @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	4.8 dB
R&S HL050 @ 3 m	-	
1 – 6 GHz	CISPR 16-4-2	5.1 dB
6 – 18 GHz	CISPR 16-4-2	5.4 dB
Flann Standard Gain Horns 18 – 40 GHz	-	5.9 dB
OATS		
Field strength measurements below 30 MHz on OATS without ground plane	-	4.4 dB

7 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Signal & Spectrum Analyzer	FSW43	Rohde & Schwarz	100586 & 100926	481720	30.03.2021 17.03.2023	03.2023 03.2025
2	Attenuator	WA54-10-12	Weinschel	1	481620	Calibration not necessary	
3	RF cable	SF 102	Huber+Suhner	510211/2	483032	Calibration not necessary	
4	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
5	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
6	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
7	Multiple Control Unit	MCU	Maturo	MCU/043/971107	480832	Calibration not necessary	
8	Positioners	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
9	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	18.02.2020	02.2022
10	RF cable	SF106B/11N/11N/4500.0	Huber & Suhner	500218/6B	482415	Calibration not necessary	
11	Log.-Per. antenna	HL050	Rohde & Schwarz	100908	482977	13.08.2019	08.2022
12	Testsoftware M20	EMC32	Rohde & Schwarz		483261	Calibration not necessary	
13	Standard gain horn antenna	18240-20	Flann Microwave	483	480294	Calibration not necessary	
14	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ Hauppauge N.Y.	571667	480343	13.02.2020	02.2022
15	Standard gain horn antenna	20240-20	Flann Microwave	411	480297	Calibration not necessary	
16	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ Hauppauge N.Y.	658697	480342	13.02.2020	02.2022
17	Highpass Filter	WHK2.8/18G-10SS	Wainwright Instuments	1	480867	Calibration not necessary	
18	Microwave cable 2m	Insulated Wire Inc.	Insulated Wire	KPS-1533-800-KPS	480302	Calibration not necessary	
19	Preamplifier 100 MHz - 16 GHz	AFS6-00101600-23-10P-6-R	Narda MITEQ	2011215	482333	13.02.2020	02.2022
20	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
21	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
22	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
23	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
24	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
25	Measuring software EMC32 M276	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
26	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
27	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
28	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
29	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	25.02.2021	02.2022

8 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	03.03.2021 01.03.2023	02.03.2023 28.08.2025
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	18.08.2020 17.08.2022	17.08.2022 16.08.2024

9 Report History

Report Number	Date	Comment
F212286E1	15.02.2022	Initial Test Report
F212286E1 2nd Version	16.02.2022	clause 1.1: name of applicant changed to Robert Bosch GmbH
F212286E1 3rd Version	21.08.2023	Remove 40 MHz channels; Adding ax RU measurement results; Splitting up 802.11 & Bluetooth LE in separate chapters where applicable

10 List of Annexes

Annex A	Test Setup Photos	12 pages