PHOENIX TESTLAB

Königswinkel 10
32825 Blomberg, Germany
Phone: +49 (0) 52 35 / 95 00-0
Fax: +49 (0) 52 35 / 95 00-10
office@phoenix-testlab.de
www.phoenix-testlab.de

Test Report

Report Number:

F212284E5

Equipment under Test (EUT):

VCURM1

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] **789033 D02 General UNII Test Procedures New Rules v02r01**

[4] **662911 D01 Multiple Transmitter Output v02r01 (October 2013),** Emissions Testing of Transmitters with Multiple Outputs in the Same Band (e.g., MIMO, Smart Antenna, etc)

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

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

Test Result

The requirements of the tests performed as shown in the overview (clause 4) were fulfilled by the equipment under test. The complete test results are presented in the following.
“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 01.08.2022
	Signature	
Reviewed and approved by:		Bernward ROHDE 01.08.2022
	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

Name:	Robert Bosch GmbH
Address:	Robert-Bosch-Str. 200, 31139 Hildesheim
Country:	Germany
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
Phone:	+49 5121 49-2608
eMail address:	Dirk.Zamow@de.bosch.com
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-17186-01-05 and D-PL-17186-01-06, FCC Test Firm Accreditation 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: *	VCURM1
Model number: *	7.515.400.920-22
Order number: *	NA
FCC ID: *	2AUXS-VCURM1
IC certification number: *	25847-VCURM1
PMN: *	VCURM1
HVIN: *	VCURM1
FVIN: *	NA
HMN: *	NA

	EUT number		
	1 (conducted)	2 (radiated)	3
Serial number: *	112083A10001350	112083A10001340	
PCB identifier: *	8638912015 8638912040 8638912111	8638912015 8638912040 8638912111	
Hardware version: *	C1.2	C1.2	
Software version: *	RQBM-542 rb_my23_main_2022.15.7	RQBM-542 rb_my23_main_2022.15.7	

* Declared by the applicant

2 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 / 5.825* GHz		

* Highest internal frequency for the radio part in 5 GHz mode

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 3	2422 MHz
Channel 4	2427 MHz	Channel 4	2427 MHz
Channel 5	2432 MHz	Channel 5	2432 MHz
Channel 6	2437 MHz	Channel 6	2437 MHz
Channel 7	2442 MHz	Channel 7	2442 MHz
Channel 8	2447 MHz	Channel 8	2447 MHz
Channel 9	2452 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

Bluetooth® classic + EDR frequencies			
Channel 00	2402 MHz	Channel 01	2403 MHz
Channel 02	2404 MHz	Channel 03	2405 MHz
…	…	…	…
…	…	…	…
Channel 38	2440 MHz	Channel 39	2441 MHz
…	…	…	…
…	…	…	…
Channel 75	2476 MHz	Channel 76	2478 MHz
Channel 77	2479 MHz	Channel 78	2480 MHz

IEEE 802.11 frequencies (5 GHz)					
20 MHz		40 MHz		80 MHz	
Channel 36	5180 MHz	Channel 38	5190 MHz	-	-
Channel 40	5200 MHz	-	-	Channel 42	5210 MHz
Channel 44	5220 MHz	Channel 46	5230 MHz	-	-
Channel 48	5240 MHz	-	-	-	-
Channel 149	5745 MHz	-	-	-	-
Channel 153	5765 MHz	Channel 151	5755 MHz	-	-
Channel 157	5785 MHz	-	-	Channel 155	5775 MHz
Channel 161	5805 MHz	Channel 159	5795 MHz	-	-
Channel 165	5825 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 n (40 MHz) IEEE 802.11 ax (20 MHz) IEEE 802.11 ax (40 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 2.1 dBi 5.6 dBi
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) (up to 72.2 Mbit/s 1 spatial stream) (up to 144.4 Mbit/s 2 spatial stream)
	IEEE 802.11 n40	BPSK, QPSK, 16-QAM, 64-QAM (up to 150 Mbit/s 1 spatial stream) (up to 300 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)
	IEEE 802.11 ax40	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM (up to 286.8 Mbit/s 1 spatial stream) (up to 573.5 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 802.11n 40 MHz	2422 – 2452 MHz
	IEEE 802.11ax 20 MHz	2412 – 2462 MHz
	IEEE 802.11ax 40 MHz	2422 – 2452 MHz

IEEE 802.11 radio mode (2.4 GHz) (cont.)		
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 802.11n 40 MHz	7 (5 MHz channel spacing)
	IEEE 802.11ax 20 MHz	11 (5 MHz channel spacing)
	IEEE 802.11ax 40 MHz	7 (5 MHz channel spacing)

* Declared by the applicant

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.

IEEE 802.11 radio mode (5GHz)		
Fulfils radio specification: *	IEEE 802.11 a IEEE 802.11 n (20 MHz) IEEE 802.11 n (40 MHz) IEEE 802.11 ac (20 MHz) IEEE 802.11 ac (40 MHz) IEEE 802.11 ac (80 MHz) IEEE 802.11 ax (20 MHz) IEEE 802.11 ax (40 MHz) IEEE 802.11 ax (80 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:	4.9 dBi (typical) 2.8 dBi (typical) 6.9 dBi (typical)
Antenna connector: *	Internal antenna: External antenna:	- (none) FAKRA
Type of modulation: *	IEEE 802.11 a	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 n40	BPSK, QPSK, 16-QAM, 64-QAM (up to 150 Mbit/s 1 spatial stream) (up to 300 Mbit/s 2 spatial stream)
	IEEE 802.11 ac20	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM (up to 86.65 Mbit/s 1 spatial stream) (up to 173.3 Mbit/s 2 spatial stream)
	IEEE 802.11 ac40	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM (up to 200 Mbit/s 1 spatial stream) (up to 400 Mbit/s 2 spatial stream)
	IEEE 802.11 ac80	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM (up to 433.35 Mbit/s 1 spatial stream) (up to 866.7 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)
	IEEE 802.11 ax40	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM (up to 286.8 Mbit/s 1 spatial stream) (up to 573.5 Mbit/s 2 spatial stream)

IEEE 802.11 radio mode (5GHz)		
Type of modulation: * (cont.)	IEEE 802.11 ax80	BPSK, QPSK, 16-QAM, 64-QAM, 256-QAM, 1024-QAM (up to 600.5 Mbit/s 1 spatial stream) (up to 1201 Mbit/s 2 spatial stream)
Operating frequency range: *	IEEE 802.11a	5180 – 5240 MHz, 5745 – 5825 MHz
	IEEE 802.11n 20 MHz	5180 – 5240 MHz, 5745 – 5825 MHz
	IEEE 802.11n 40 MHz	5190 – 5230 MHz, 5755 – 5795 MHz
	IEEE 802.11ac 20 MHz	5180 – 5240 MHz, 5745 – 5825 MHz
	IEEE 802.11ac 40 MHz	5190 – 5230 MHz, 5755 – 5795 MHz
	IEEE 802.11ac 80 MHz	5210, 5755 MHz
	IEEE 802.11ax 20 MHz	5180 – 5240 MHz, 5745 – 5825 MHz
	IEEE 802.11ax 40 MHz	5190 – 5230 MHz, 5755 – 5795 MHz
	IEEE 802.11ax 80 MHz	5210, 5755 MHz

* Declared by the applicant

Bluetooth® classic + EDR radio mode		
Fulfils radio specification: *	Bluetooth® classic + EDR 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: *	BT classic (1 Mbps PHY)	GFSK
	BT EDR (2 Mbps PHY)	π/4 DPSK
	BT EDR (3 Mbps PHY)	8DPSK
Operating frequency range: *	BT classic (1 Mbps PHY)	2402 – 2480 MHz
	BT EDR (2 Mbps PHY)	2402 – 2480 MHz
	BT EDR (3 Mbps PHY)	2402 – 2480 MHz
Number of channels: *	BT classic (1 Mbps PHY)	79 (1 MHz channel spacing)
	BT EDR (2 Mbps PHY)	79 (1 MHz channel spacing)
	BT EDR (3 Mbps PHY)	79 (1 MHz channel spacing)

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
*2 Provided by the applicant

Ancillary equipment	
-	-

1.7 Dates

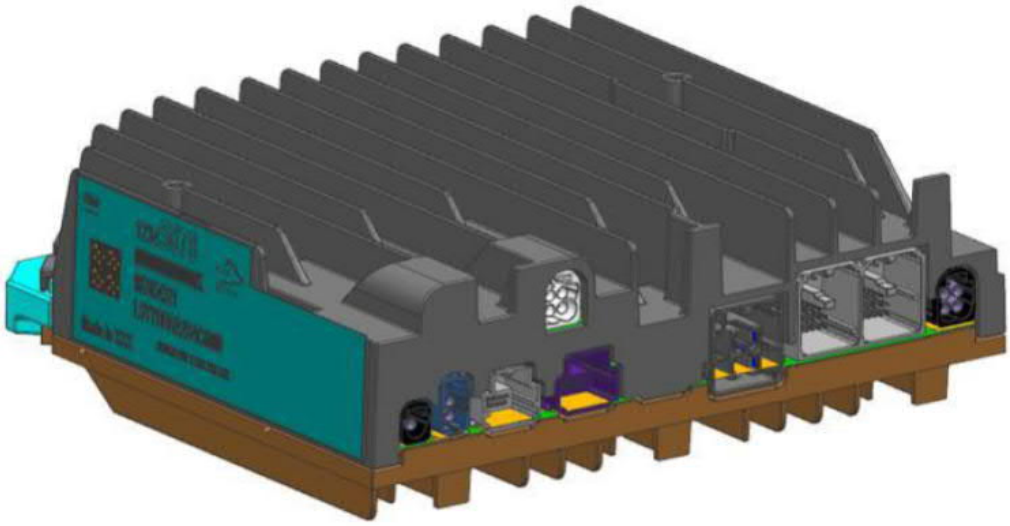
Date of receipt of test sample:	07.06.2022
Start of test:	27.06.2022
End of test:	29.06.2022

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 classic + EDR and 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 EUT has different power settings for the U-NII-1 band (5.15 – 5.25 GHz) for FCC and ISED. As declared by the applicant, the power settings will be set automatically, depending on the location of the vehicle.
For U-NII-3 band (5.725 – 5.85 GHz), the EUT has the same power settings.

The EUT has incorporate TPC functionality with at least 3 dB power reduction, as declared by the applicant. This allows the use of the maximum of 30 mW / 14.77 dBm for ISED in the U-NII-1 band (5.15 – 5.25 GHz).

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

2.1.1 Operation modes Simultaneous transmissions

Operation mode #	Radio technology*	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate*	Power setting
1	802.11b 802.11a	2462 5745	11 149	DQPSK 16-QAM	2 Mbit/s 36 Mbit/s	14.0 dBm 19.0 dBm

* The technology/Frequency which produced the highest emissions in the previous tests, were activate simultaneously for the tests reported in this document.
When transmitting WLAN + Bluetooth simultaneously, Bluetooth transmits on the internal antenna only and WLAN 5 GHz transmits on internal and external antenna simultaneously. Bluetooth and WLAN 2.4 GHz simultaneously is not possible.
When transmitting WLAN 2.4 + 5 GHz simultaneously, WLAN 2.4 GHz transmits on the internal and the external antenna and WLAN 5 GHz also transmits on the internal and external antenna simultaneously.
*2 Output power was fix and could not be set in the test software

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 [5] RSS-Gen [6]	Tested EUT	Status
Radiated emissions (transmitter)	0.009 - 40,000*	15.247 (d) 15.205 (a) 15.209 (a) 15.407 (b) 15.205 (a) 15.209 (a)	6.13 [5], 6.2.1.2[5] 6.2.2.2[5] 6.2.3.2[5] 6.2.4.2[5] 8.9 [6]	1 (>1 GHz), 2 (<1 GHz)	Passed

* As declared by the applicant the highest radio clock frequency is 6.264 GHz.
Therefore, the radiated emission measurement must be carried out up to the lower of the 10th of the highest radio clock frequency or 40 GHz, which in this case is 40 GHz.

5 Results

5.1 Test setup

5.1.1 Test Setup (radiated)

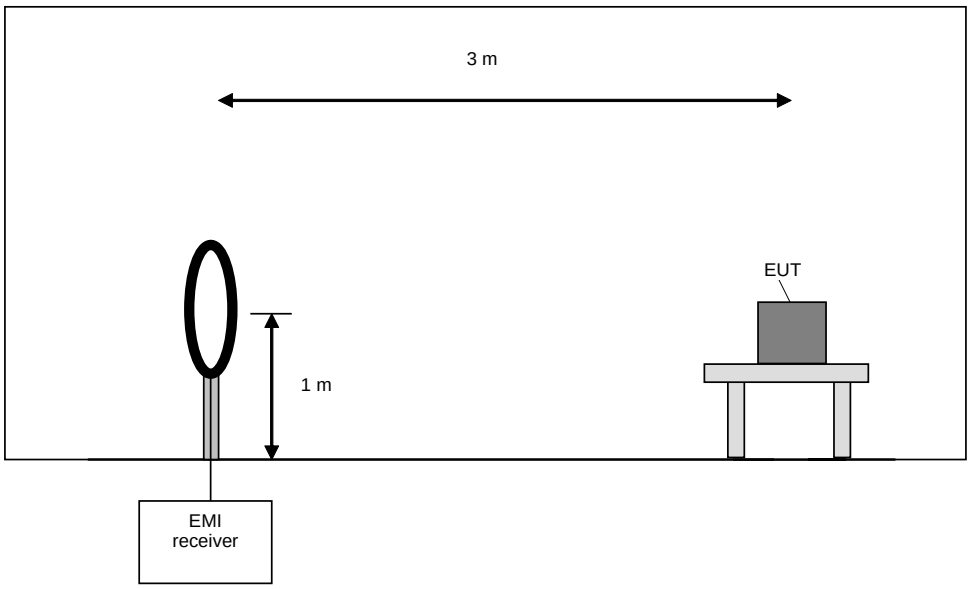
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

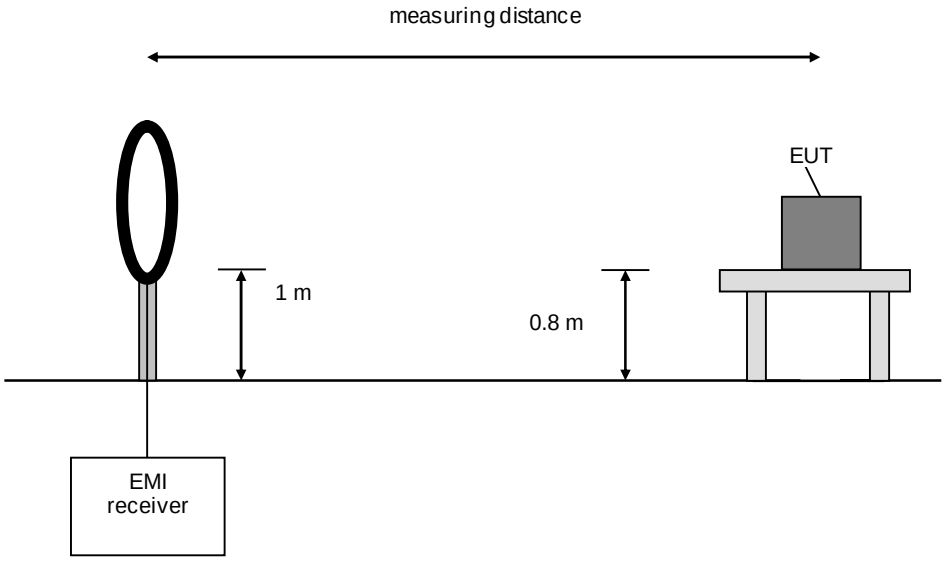
5.1.1.2 Final measurement 9 kHz to 30 MHz

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.

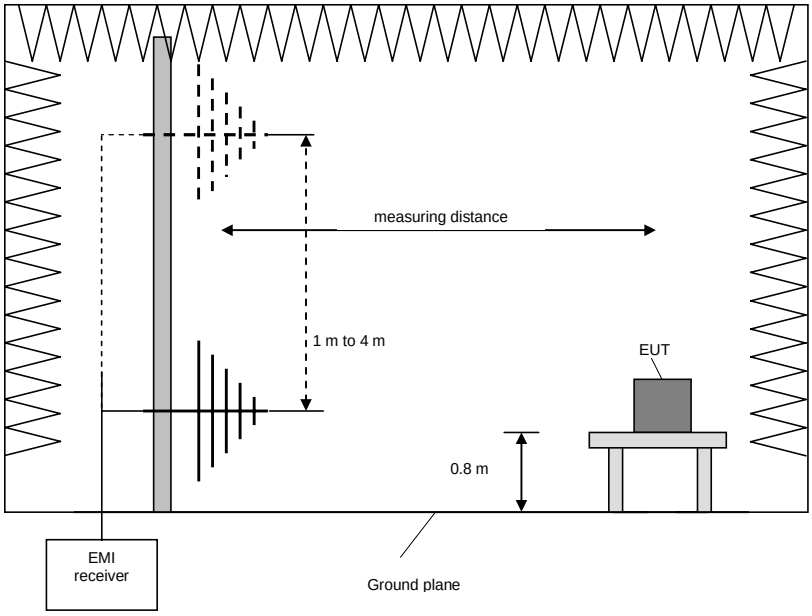
5.1.1.3 Preliminary and final measurement 30 MHz to 1 GHz

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])

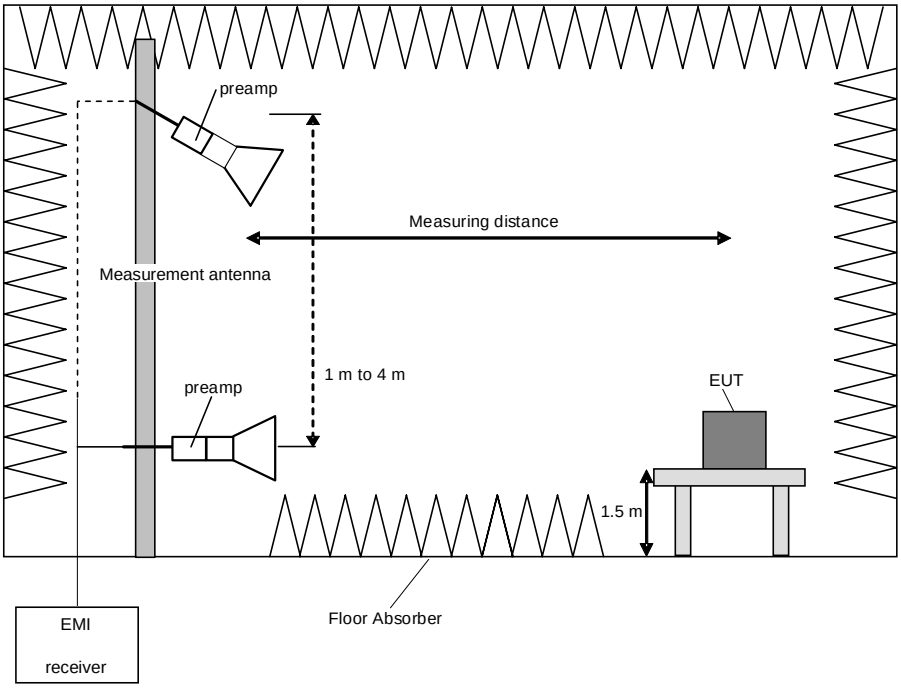
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. Floor standing devices will be placed directly on the turntable.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

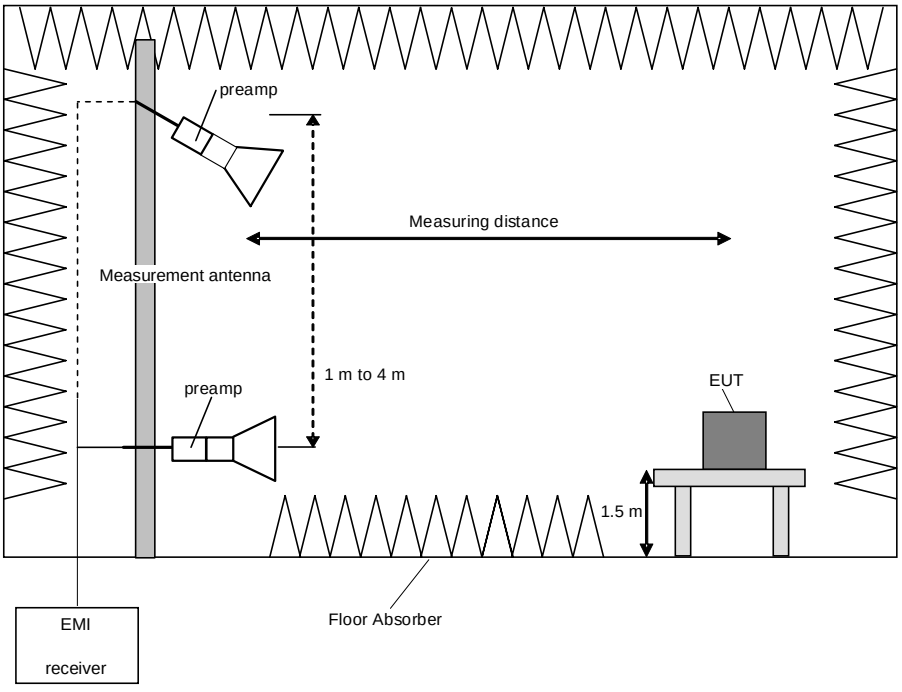
1. Set the measurement antenna to 1 m height.
2. Monitor the frequency range at vertical polarisation and a EUT azimuth of 0 °.
3. Rotate the EUT by 360° to maximize the detected signals.
4. Repeat steps 1. and 2. with the horizontal polarisation of the measuring antenna.
5. Increase the height of the 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])

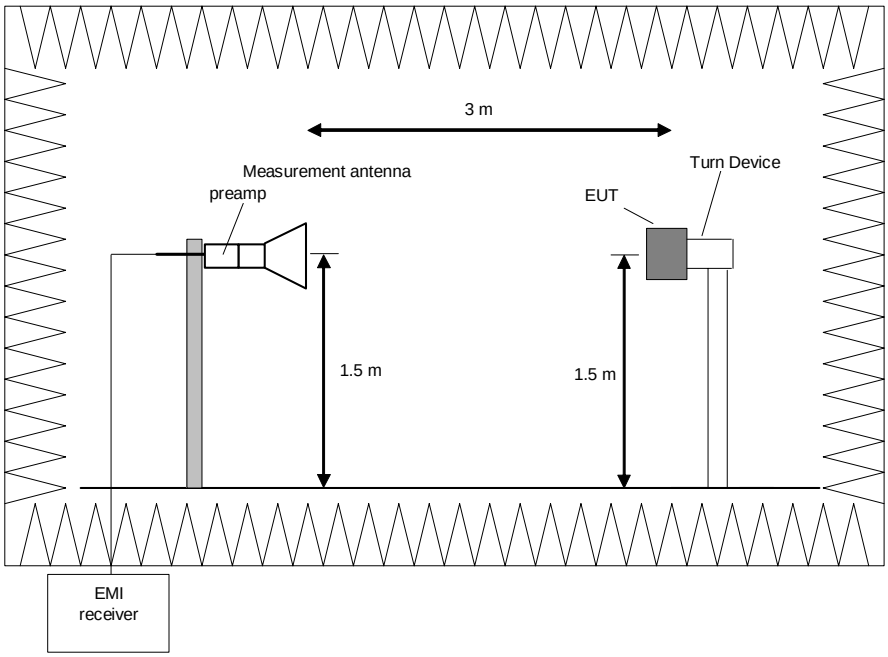
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [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 analyzer set to MAX Hold mode and a resolution bandwidth of 1 MHz. The measurement will be performed in horizontal and vertical polarization of the measuring antenna and while rotating the EUT in its vertical axis in the range of 0 ° to 360 °. This measurement is repeated after raising the EUT in 30° steps according 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:

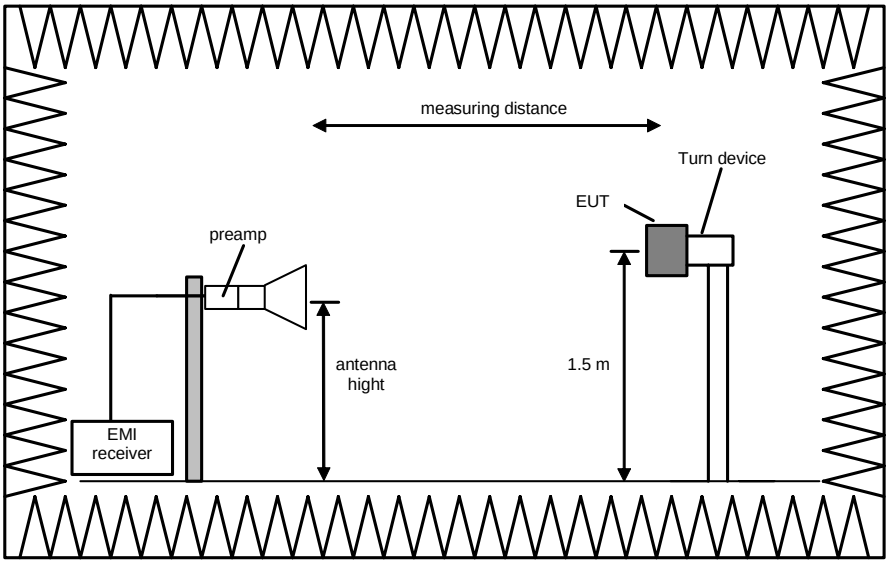
1. Monitor the frequency range at horizontal polarization and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarization of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an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

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

5.2 Maximum unwanted emissions

5.2.1 Test setup (Maximum unwanted emissions)

Test setup			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated – normal procedure)	5.1.1.4	f < 1 GHz
☐	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)	-	No limitations

5.2.2 Test method (Maximum unwanted emissions)

Test method				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	II G 2, 3 & 5.	Unwanted emissions outside restricted bands	No limitations	-
☒	II G 1 & 3 - 6	Unwanted Emissions in the restricted bands	No limitations	-

5.2.3 Test results (Maximum unwanted emissions)

5.2.3.1 Test results (9 kHz – 30 MHz)

Ambient temperature:	23 °C
Relative humidity:	43 %

Date	22.06.2022
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
No emissions from the radio part of the EUT were found during the preliminary tests, therefore no plots and results are submitted below

Test equipment (please refer to chapter 6 for details)
20 – 26, 29

5.2.3.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	23 °C
Relative humidity:	43 %

Date	22.06.2022
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.

Remark: All 3 orthogonal planes were tested separately
No emissions from the radio part of the EUT were found during the preliminary tests, therefore no plots and results are submitted below

Test equipment (please refer to chapter 6 for details)
20 - 28

5.2.3.3 Test results (above 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	51 - 65 %

Date	27-29.06.2022
Tested by	P. NEUFELD

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 above 1 GHz 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.

The peak limit is set to -27 dBm (68.3 dBµV/m). Since if the stricter unrestricted peak limit is passed for all frequencies, the peak limit for restricted bands (74 dBµV/m) is also fulfilled.

Calculation:

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

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

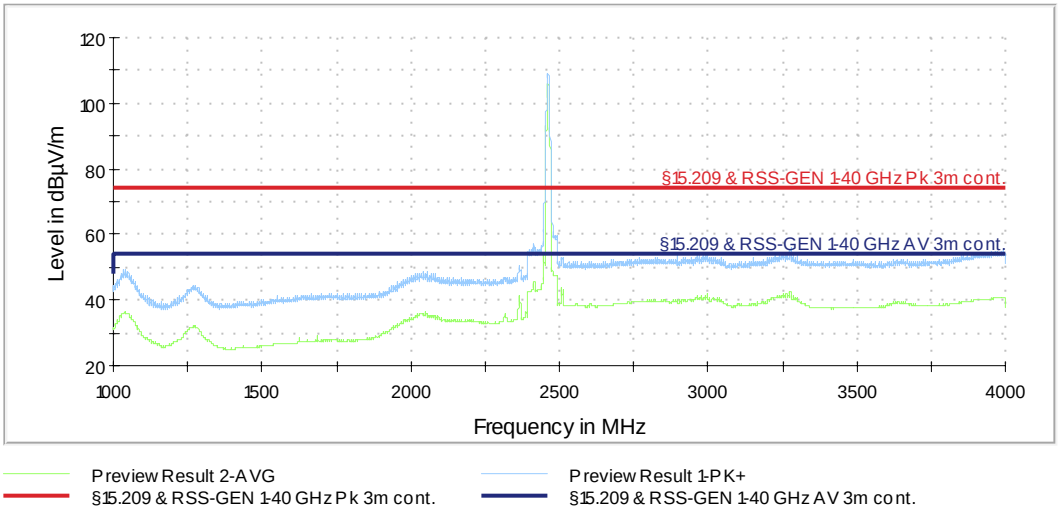
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF* [dB]
* (if applicable – only for Average values, that are fundamental related)

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

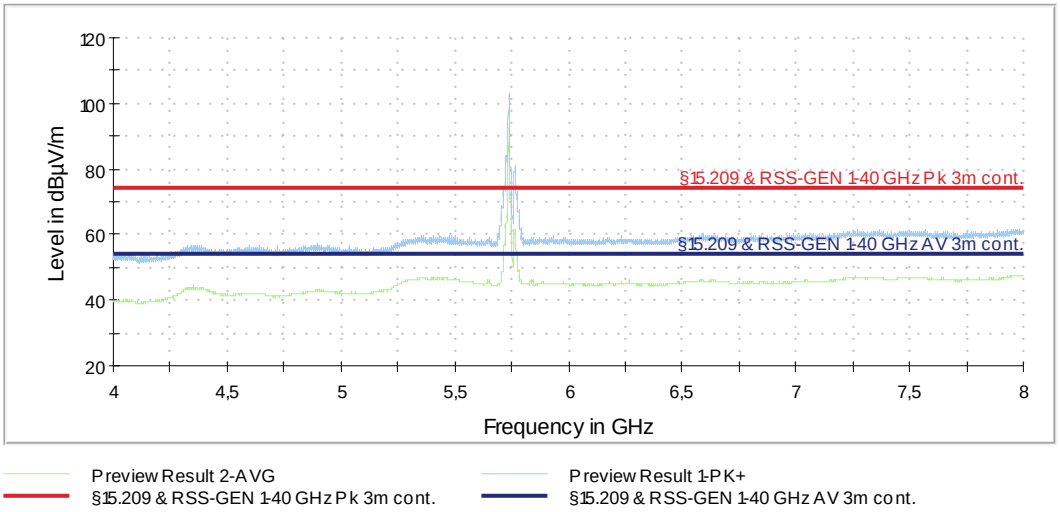
The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.
The top measured curve represents the peak measurement. The measured points marked with "♦" are frequency points 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 2.4 GHz + WLAN 5 GHz simultaneous:

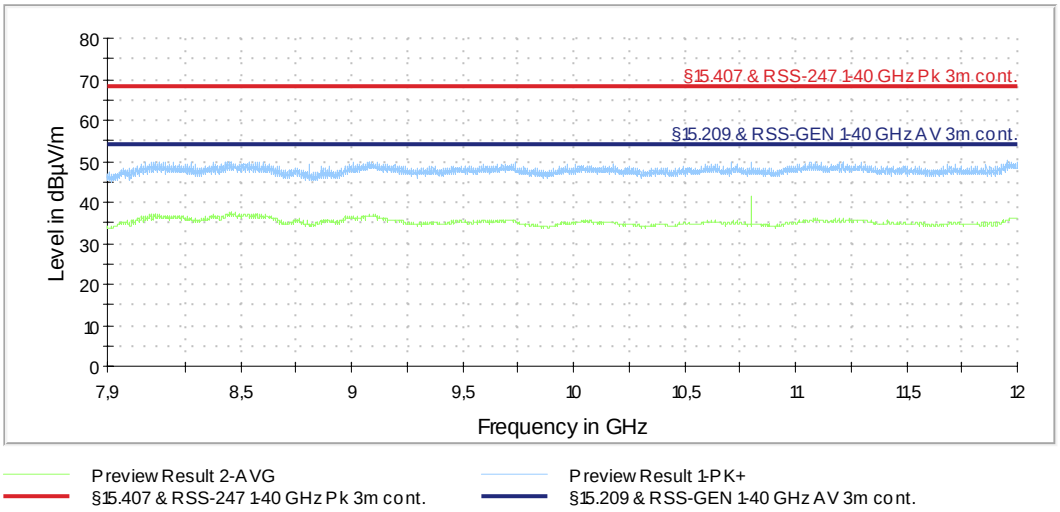
Spurious emissions from 1 GHz to 4 GHz (operation mode 1):



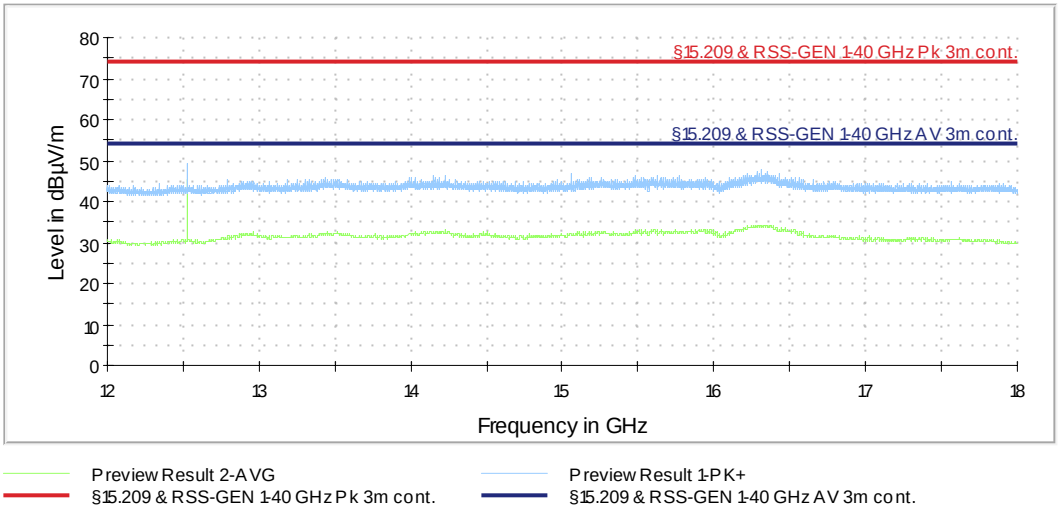
Spurious emissions from 4 GHz to 8 GHz (operation mode 1):



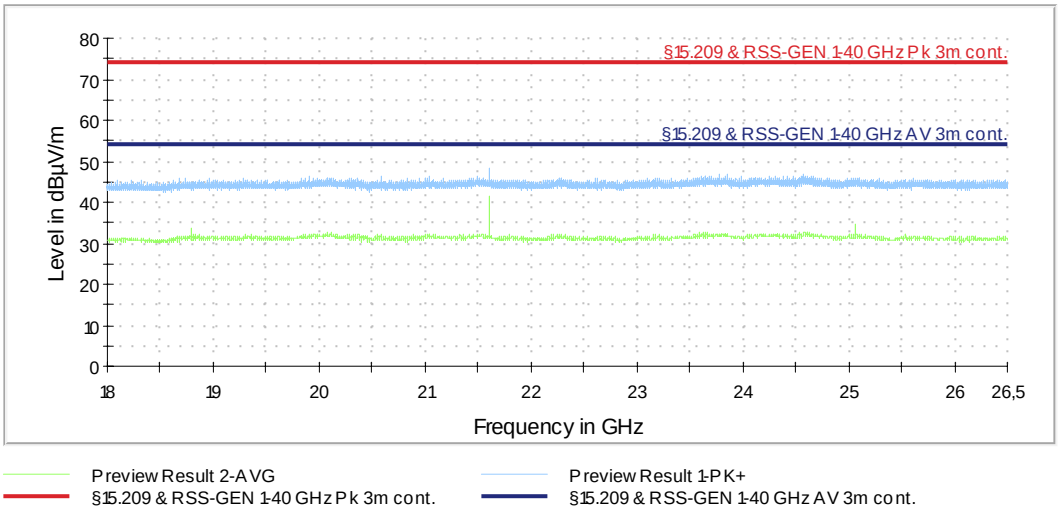
Spurious emissions from 8 GHz to 12 GHz (operation mode 1):



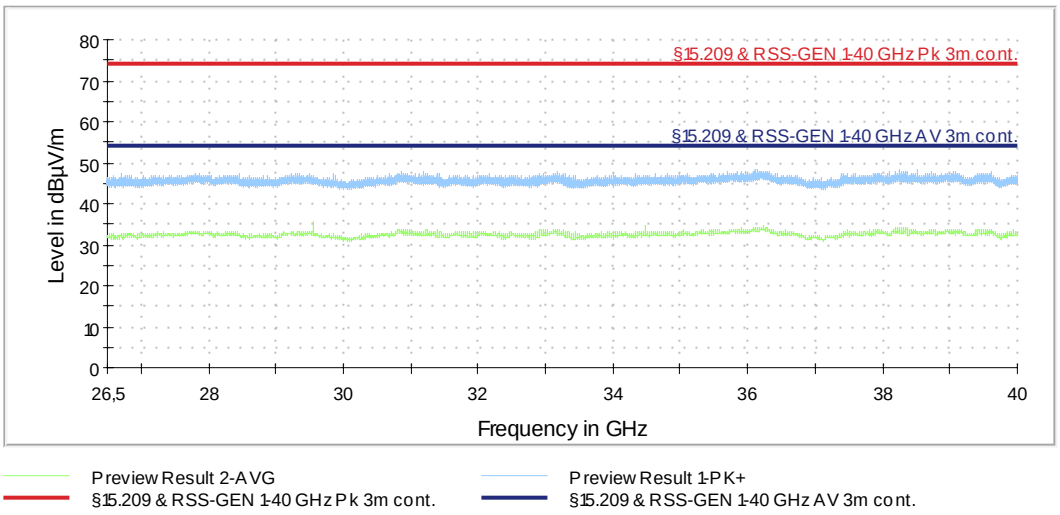
Spurious emissions from 12 GHz to 18 GHz (operation mode 1):



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



Spurious emissions from 26.5 GHz to 40 GHz (operation mode 1):



5.2.3.3.1 Result tables

No final emissions resulting from simultaneous transmissions were found during the measurements, therefore no final measurements were performed.

Test result: Passed

Test equipment (please refer to chapter 6 for details)
4 - 19, 30, 31

6 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	03.2023
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	22.02.2022	02.2024
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	17.02.2022	02.2024
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	17.02.2022	02.2024
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	17.02.2022	02.2024
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	22.02.2022	02.2024

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
30	Standard gain horn antenna	22240-20	Flann Microwave	468	480298	Calibration not necessary	
31	Preamplifier 26 - 40 GHz	JDM2-26004000-25-10P	Narda MITEQ	-	482806	17.02.2022	02.2024

7 Test site Validation

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	02.03.2023
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	18.08.2020	17.08.2022

8 Report History

Report Number	Date	Comment
F212284E5	01.08.2022	Initial Test Report
-	-	-
-	-	-

9 List of Annexes

Annex A Test Setup Photos 9 pages