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:

F212286E2 2nd Version

Equipment under Test (EUT):

VCUNM1

Applicant:

Robert Bosch Car Multimedia 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 (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 16.02.2022
	Signature	
Reviewed and approved by:		Bernd STEINER 16.02.2022
	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: *	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 / 6.264 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.

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

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)	

* Declared by the applicant
*2 Bluetooth® Classic 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

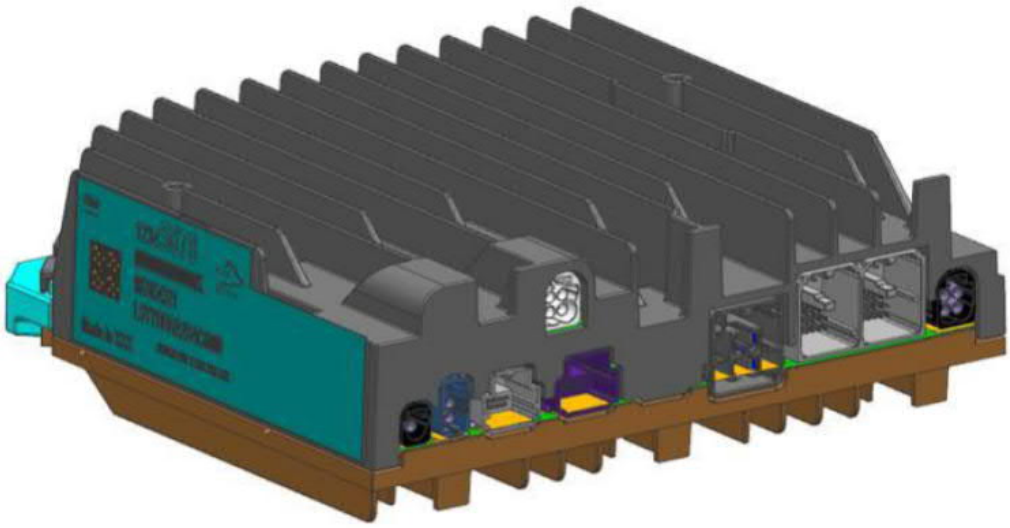
Date of receipt of test sample:	10.12.2021
Start of test:	10.12.2021
End of test:	13.01.2022

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.

For the Bluetooth classic + EDR 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.
See the photographs of the temporary antenna connector cable below.

Internal antenna: Temporary antenna connector

Bluetooth classic+EDR:
For Bluetooth classic+EDR, only the internal antenna is used by the EUT.

2.1.1 Operation modes

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Hopping on/off	Modulation / Mode	Data rate	Power setting
1	Bluetooth classic	2402	00	off	GFSK	1 Mbit/s	0x09*
2	Bluetooth classic	2441	39	off	GFSK	1 Mbit/s	0x09*
3	Bluetooth classic	2480	78	off	GFSK	1 Mbit/s	0x09*
4	Bluetooth EDR	2402	00	off	π/4 DPSK	2 Mbit/s	0x09*
5	Bluetooth EDR	2441	39	off	π/4 DPSK	2 Mbit/s	0x09*
6	Bluetooth EDR	2480	78	off	π/4 DPSK	2 Mbit/s	0x09*
7	Bluetooth EDR	2402	00	off	8DPSK	3 Mbit/s	0x09*
8	Bluetooth EDR	2441	39	off	8DPSK	3 Mbit/s	0x09*
9	Bluetooth EDR	2480	78	off	8DPSK	3 Mbit/s	0x09*
10	Bluetooth classic	2402 - 2480	00 - 78	on	GFSK	1 Mbit/s	0x09*
11	Bluetooth EDR	2402 - 2480	00 - 78	on	π/4 DPSK	2 Mbit/s	0x09*
12	Bluetooth EDR	2402 - 2480	00 - 78	on	8DPSK	3 Mbit/s	0x09*

* 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 [MHz]	FCC 47 CFR Part 15 section [2]	RSS-247 [4] RSS-Gen [5]	Status	EUT
20 dB bandwitdh	2400.0 - 2483.5	15.247 (a) (1)	A8.1 (a) [4]	Passed	1
99% bandwidth	2400.0 - 2483.5	-	6.7 [5]	Performed	1
Carrier frequency separation	2400.0 - 2483.5	15.247 (a) (1)	A8.1 (b) [4]	Passed	1
Number of hopping channels	2400.0 - 2483.5	15.247 (a) (1) (iii)	A8.1 (c) [4]	Passed	1
Dwell time	2400.0 - 2483.5	15.247 (a) (1) (iii)	A8.1 (d) [4]	Passed	1
Maximum peak output power	2400.0 - 2483.5	15.247 (b) (1)	A8.4 (2) [4]	Passed	2
Band edge compliance	2400.0 - 2483.5	15.247 (d)	A8.5 [4]	Passed	1, 2-
Radiated emissions (transmitter)	0.009 - 26,500*	15.205 (a)	A8.5 [4]	Passed*1	2 > 1GHz 3 < 1GHz
Conducted emissions on supply line	0.15 - 30	15.209 (a)	2.5 [4]	-	n/a*2

*1 As declared by the applicant the highest radio clock frequency is 2.480 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 setup

5.1.1 Test Setup (radiated)

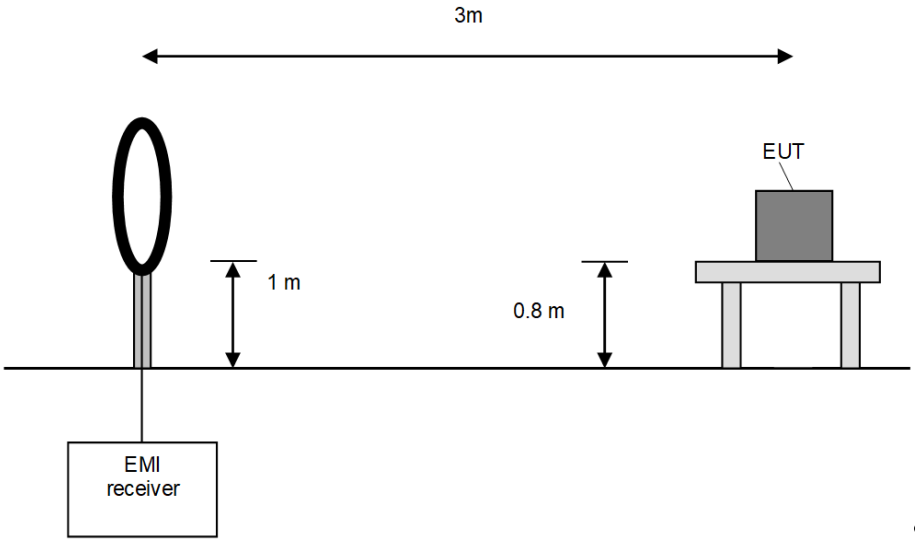
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

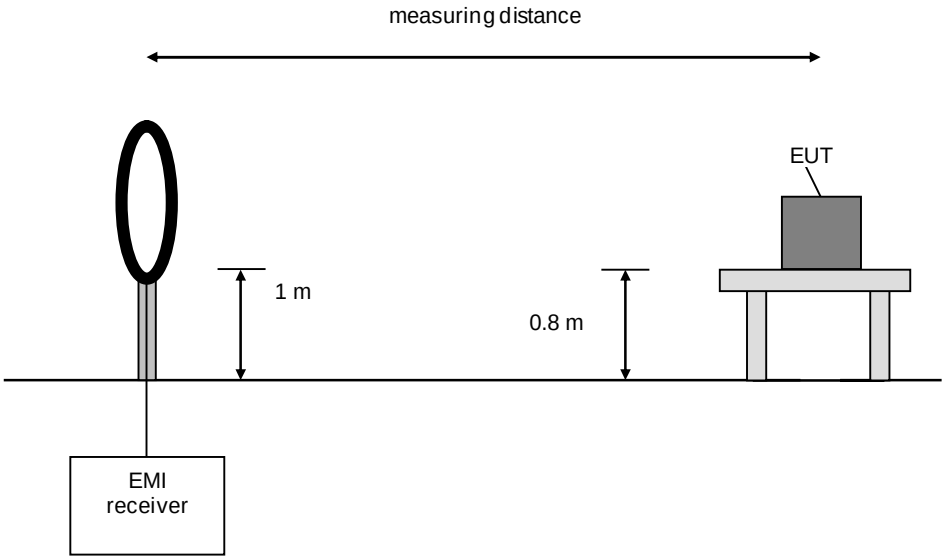
5.1.1.2 Final measurement 9 kHz to 30 MHz

In the second stage a final measurement is performed on an open area test site with no conducting ground plane in 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 to 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.

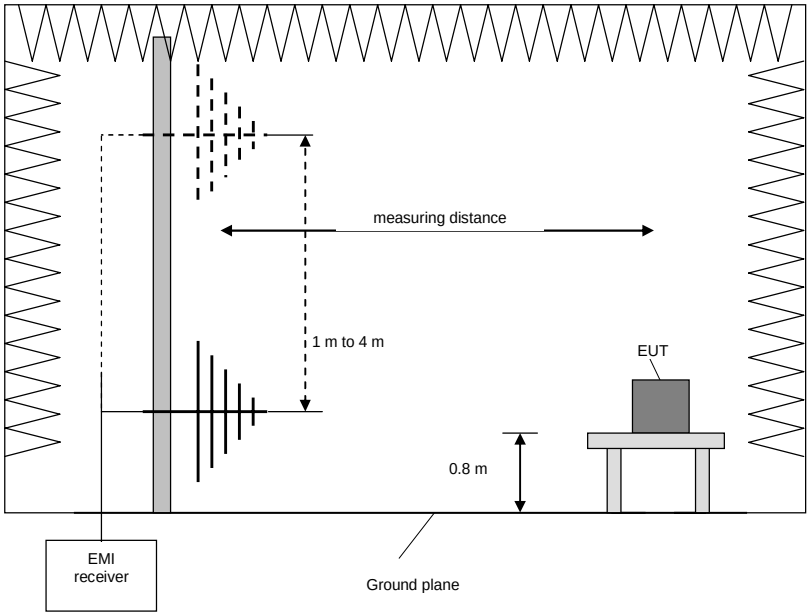
5.1.1.3 Preliminary and final measurement 30 MHz to 1 GHz

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])

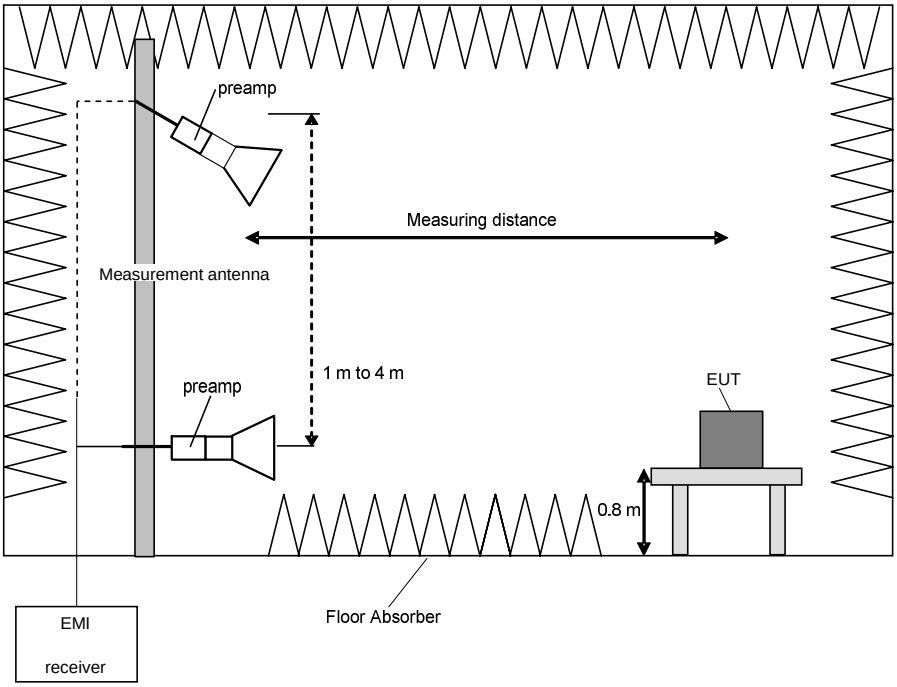
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. Floor standing devices will be placed directly on the turntable. 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 4 m. 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:

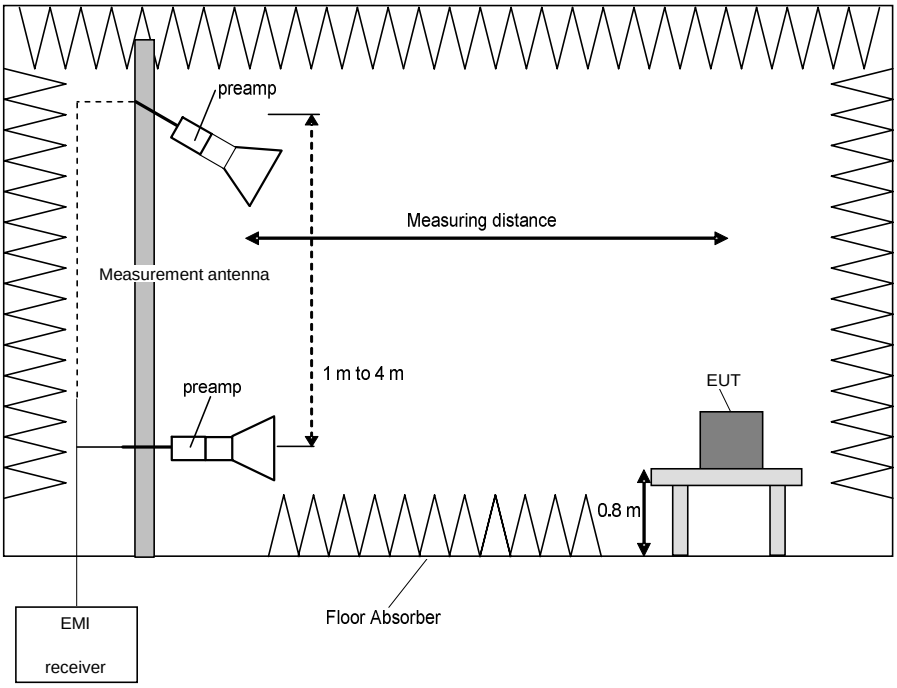
1. Set the measurement antenna to 1 m height.
2. Monitor the frequency range at vertical polarisation and a EUT azimuth of 0 °.
3. Rotate the EUT by 360° to maximize the detected signals.
4. Repeat steps 1. and 2. with the horizontal polarisation of the measuring antenna.
5. Increase the height of the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

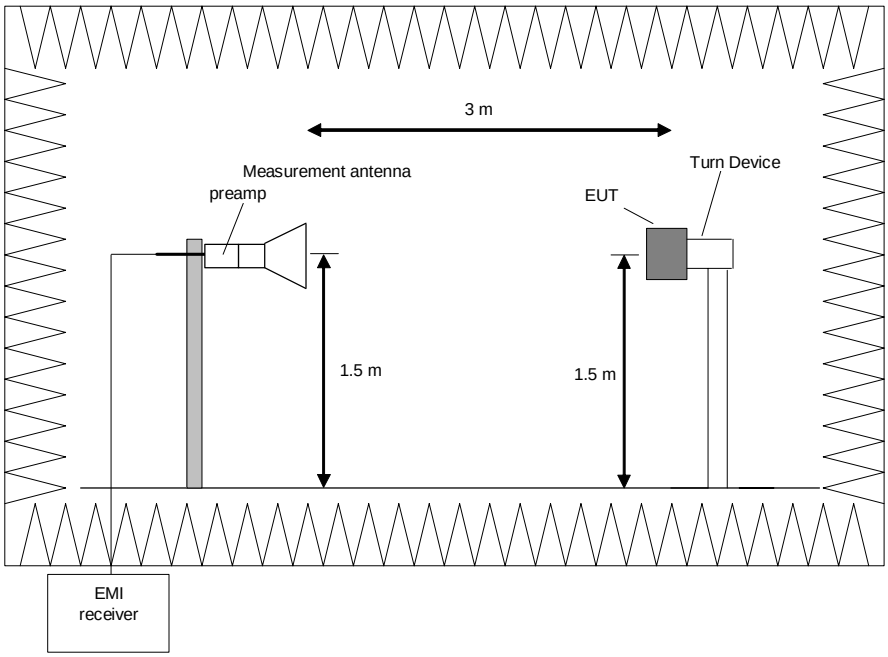
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to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

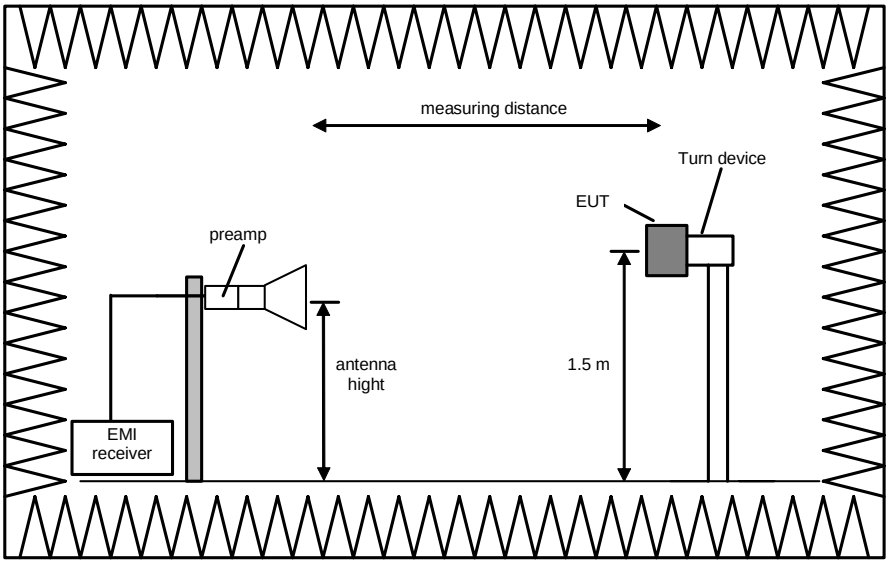
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an 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



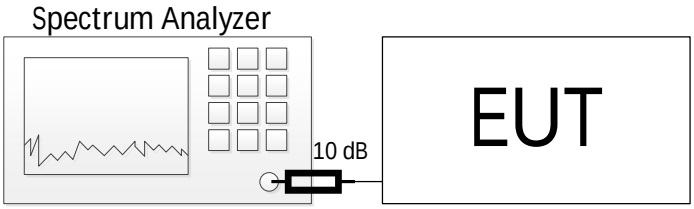
Procedure of measurement:

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	As provided by the applicant
☐	Normal antenna connector	-



The 10 dB external attenuation are 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)

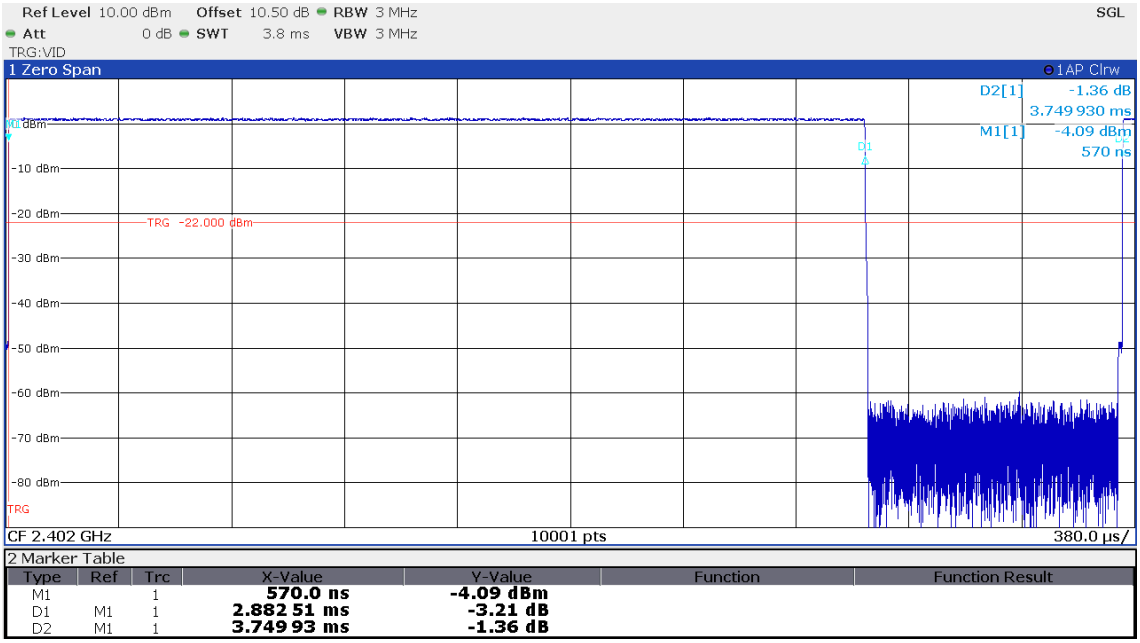
Test method				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☐	11.6. a)	Diode detector	No limitation	-
☒	11.6. b)	Zero span	No limitation	-

5.2.3 Test results (Duty cycle)

Ambient temperature:	21 °C
Relative humidity:	22 %

Date	11.12.2021
Tested by	P. NEUFELD

Worst case plot (operation mode 1 - Internal Antenna):



Operation Mode #	TX_{On} [µs]	TX_{Cycle} [µs]	RBW [MHz]	50/T [kHz]	50/T < RBW?
1 - 3	2883	3750	3	17.346	☒
4 – 6	2916	3750	3	17.145	☒
7 – 9	2887	3750	3	17.319	☒

Operation Mode #	Sweep points	Sweep time [µs]	Meas points For TX_{On}	Meas points >100?	Duty cycle %	$DCCF_{Power}$ [dB]	$DCCF_{FS}$ [dB]
1 - 3	10001	3800	7586	☒	76.9	1.1	2.2
4 – 6	10001	3800	7675	☒	77.8	1.1	2.2
7 – 9	10001	3800	7598	☒	77.0	1.1	2.2

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 1.1 dB is used for all tests.

Test equipment (please refer to chapter 6 for details)
1 - 3

5.3 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

G_1 = $gain_{internal\ antenna}$ = 3.0 dBi

5.4 20 dB bandwidth

5.4.1 Test setup (20 dB 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	-

5.4.2 Test method (20 dB bandwidth)

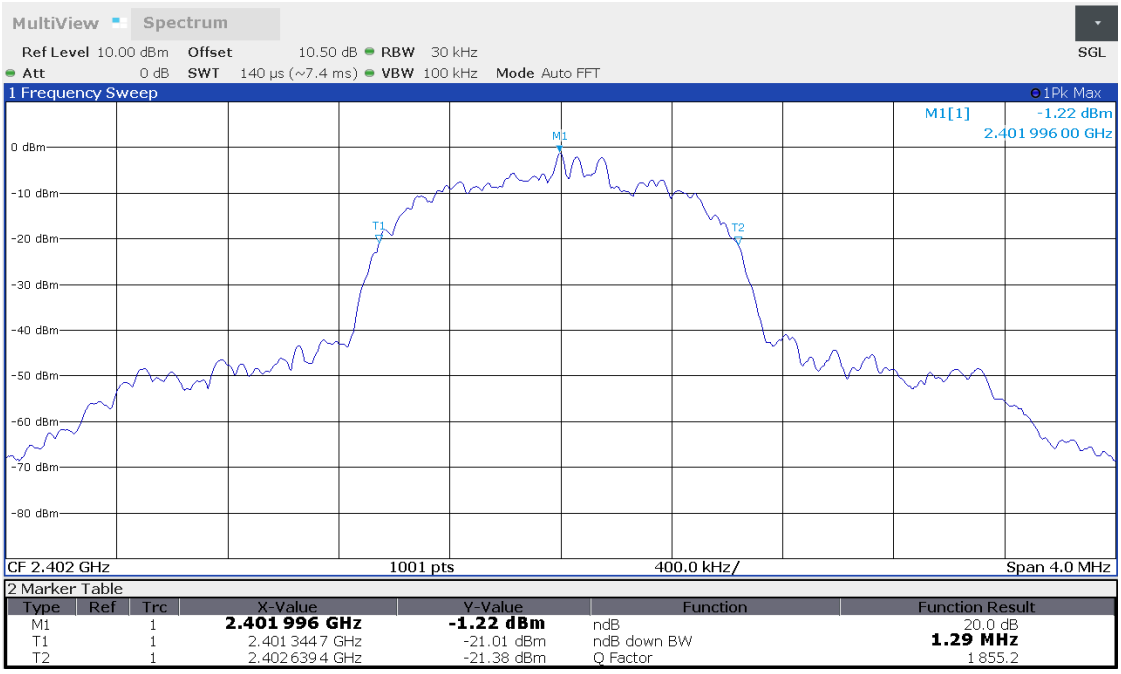
Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	6.9.2	Occupied bandwidth—relative measurement procedure	No limitations	-20 dB

5.4.3 Test results (20 dB bandwidth)

Ambient temperature:	21 °C
Relative humidity:	22 %

Date	11.12.2021
Tested by	P. NEUFELD

Worst case plot (operation mode 7):



Operation mode #	20 dB bandwidth [MHz]
1	0.8062
2	0.8062
3	0.8062
4	1.2867
5	1.2867
6	1.2867
7	**1.2947**
8	1.2907
9	1.2907
Measurement uncertainty: 9.0×10^{-8}	

Test equipment (please refer to chapter 6 for details)
1 - 3

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%))

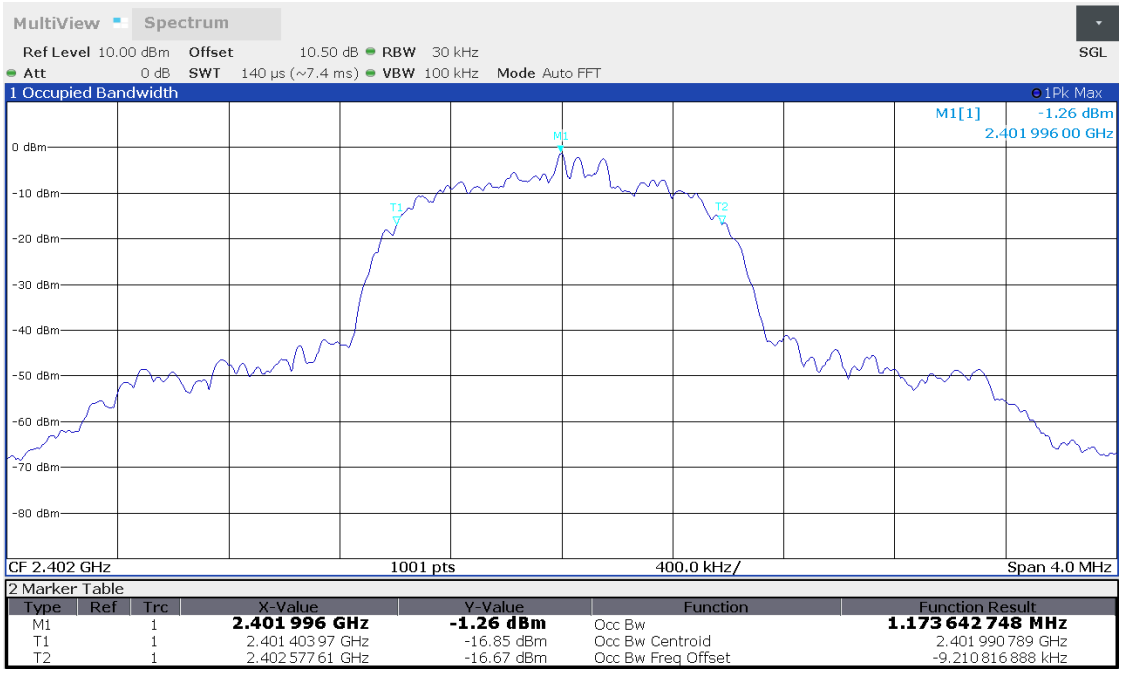
Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	6.9.2	relative measurement procedure	No limitations	n-dB down
☒	6.9.3	power bandwidth (99%)	No limitations	99% power function

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

Ambient temperature:	21 °C
Relative humidity:	22 %

Date	11.12.2021
Tested by	P. NEUFELD

Worst case plot (operation mode 7):



Operation mode #	99% bandwidth [MHz]
1	0.842873
2	0.840020
3	0.845959
4	1.170480
5	1.169384
6	1.169866
7	**1.173643**
8	1.172600
9	1.172246

Test equipment (please refer to chapter 6 for details)
1 - 3

5.6 Carrier frequency separation

5.6.1 Test setup (Carrier frequency separation)

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 (Carrier frequency separation)

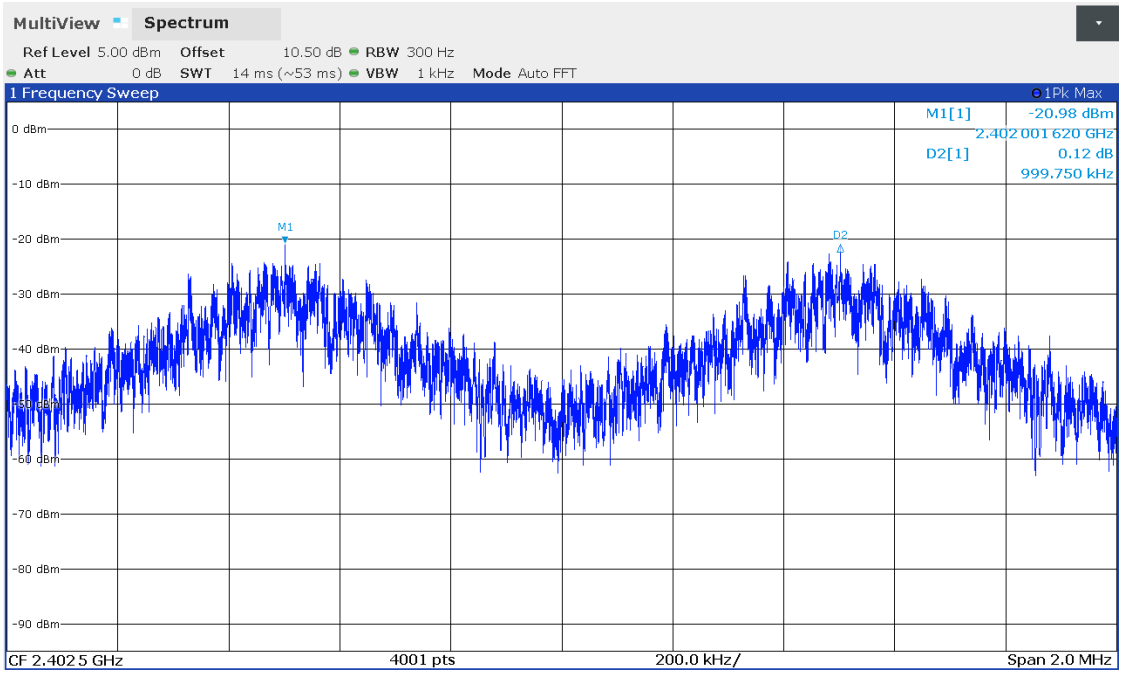
Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	7.8.2	Carrier frequency separation	EUT hopping	-

5.6.3 Test results (Carrier frequency separation)

Ambient temperature:	22 °C
Relative humidity:	26 %

Date	26.01.2022
Tested by	P. NEUFELD

Worst case plot (operation mode 10):



Operation mode	Channel frequency [MHz]	Channel Separation* [kHz]	Minimum limit*2 [kHz]	Result
10	2402	999.750	431.567	Passed
10	2441	999.750	431.567	Passed
10	2480	1000.250	431.567	Passed

* The test was performed with the EUT transmitting with GFSK or 1 Mbps. When transmitting with the higher modulations, the channel separation cannot be determined on the plot of the spectrum analyser.
*2 The worst-case limit occurs for the modulation with the highest 20 dB bandwidth, which is 8DPSK modulation or 3 Mbps. Limit is 2/3 * 20 dB BW.

Test equipment (please refer to chapter 6 for details)
1 - 3

5.7 Number of hopping frequencies

5.7.1 Test setup (Number of hopping frequencies)

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 (Number of hopping frequencies)

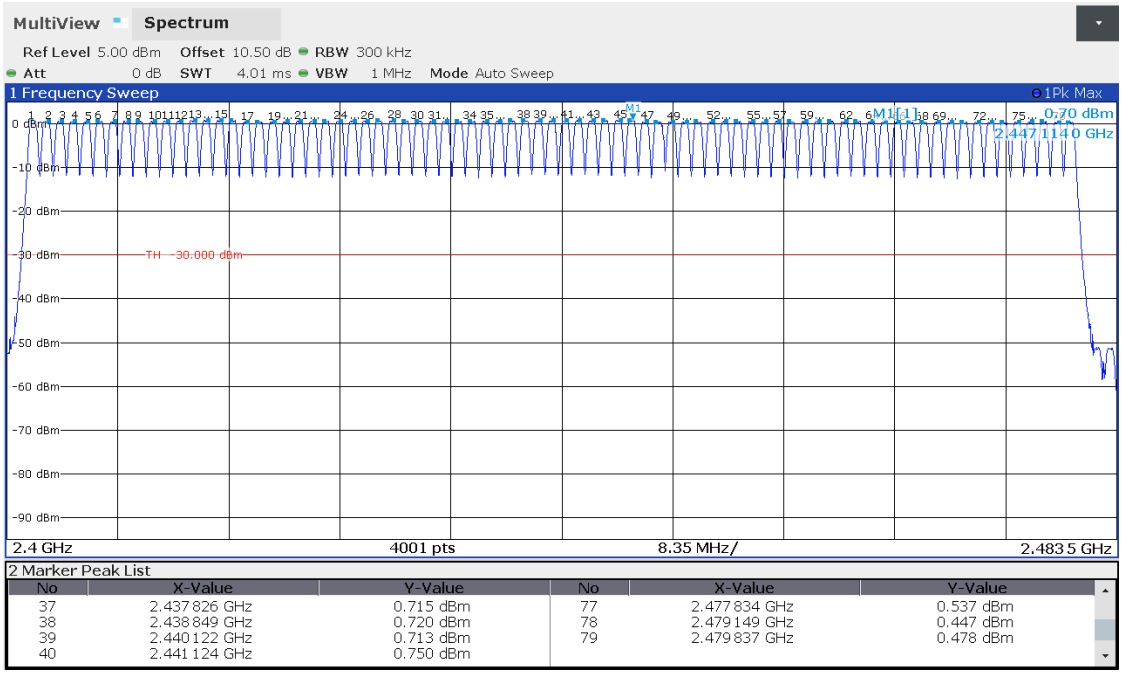
Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	7.8.3	Number of hopping frequencies	EUT hopping	-

5.7.3 Test results (Number of hopping frequencies)

Ambient temperature:	22 °C
Relative humidity:	26 %

Date	26.01.2022
Tested by	P. NEUFELD

Worst case plot (operation mode 10):



Number of hopping frequencies*	Limit (minimum)	Result
79	15	Passed

* Since the number of of hopping frequencies does not depend on the modulation, only one modulation is tested. The number of channels can only be seen, when the EUT transmits with 1 Mbps, because the Bluetooth channels overlap with 2 and 3 Mbps data rates.

Test equipment (please refer to chapter 6 for details)
1 - 3

5.8 Time of occupancy (dwell time)

5.8.1 Test setup (Time of occupancy (dwell time))

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 (Time of occupancy (dwell time))

Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	7.8.4	Number of hopping frequencies	EUT hopping	-

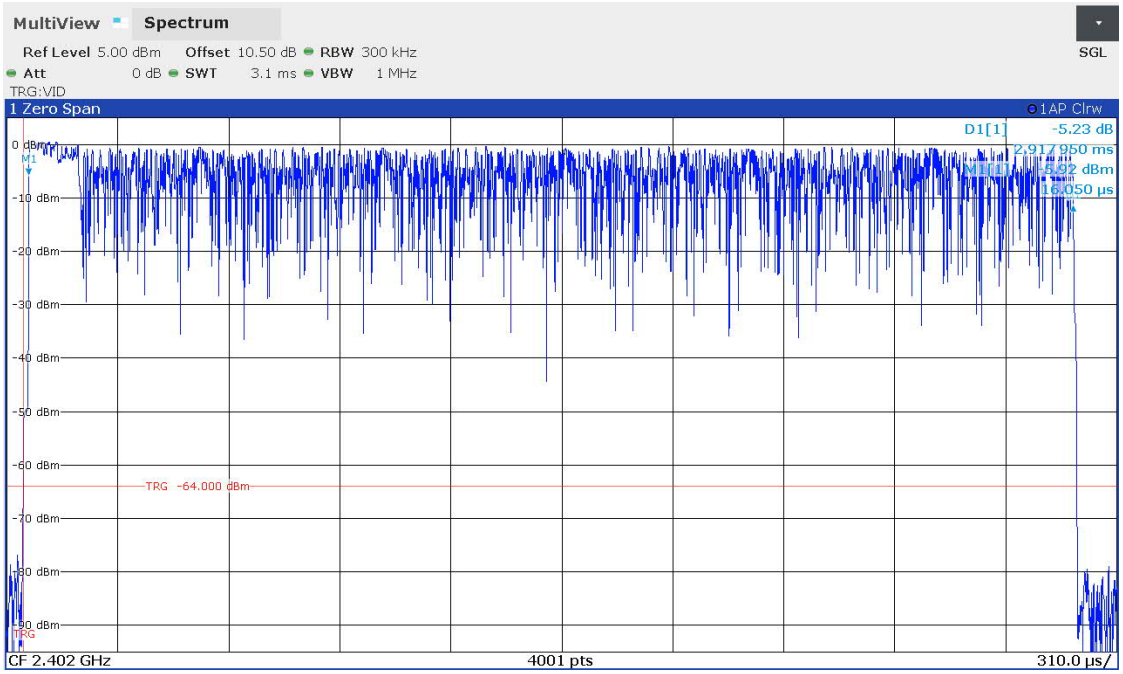
*2 VBW of the peak power meter has to be > OBW of the fundamental.

5.8.3 Test results (Time of occupancy (dwell time))

Ambient temperature:	22 °C
Relative humidity:	26 %

Date	26.01.2022
Tested by	P. NEUFELD

Worst case plot (operation mode 11):



Paket type	Worst case Hopping channels	Hops / second	Transmit time / hop [ms]	Tx On / 1s* [ms]	Limit Tx On / s [ms]
DH5	15	106.67	2.882	307.423	400
2DH5	15	106.67	2.918	311.263	400
3DH5	15	106.67	2.888	308.063	400

Max Tx time for a single Bluetooth slot (1 hop): 625 µs.
Maximum Bluetooth TX rate on 1 channel: DH5 packet (5 TX slots) followed by one RX slot of 625.
Worst case number of hops per second (625 µs per hop -> 1 s / 625 µs): 1600
Hops per second on one single channel when hopping equally distributed on 79 channels (1600/79): 20.25
Hops per second on one single channel when hopping equally distributed on 15 channels (1600/15): 106.67
Tx On / 1s* = Hops / second * Transmit time / hop [ms]

*Transmit time on a single channel during 1 second in milliseconds

Test equipment (please refer to chapter 6 for details)
1 - 3

5.9 Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices

5.9.1 Test setup (Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices)

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	-

5.9.2 Test method (Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices)

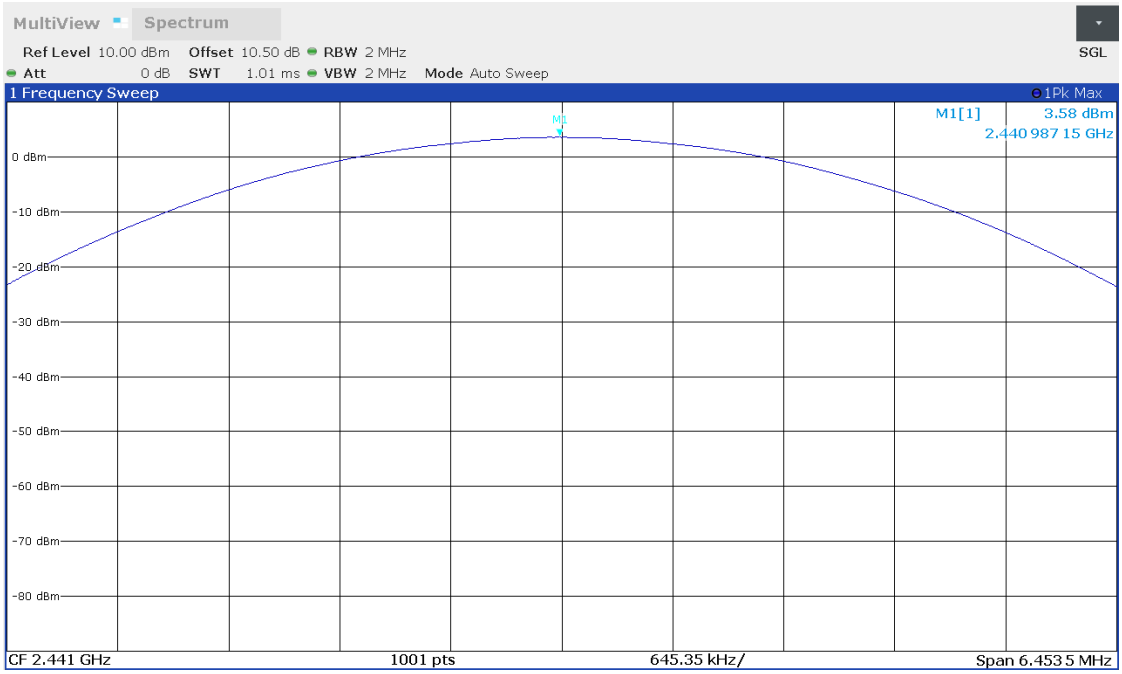
Test method				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	7.8.5	Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices	No limitations	-

5.9.3 Test results (Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices)

Ambient temperature:	21 °C
Relative humidity:	22 %

Date	11.12.2021
Tested by	P. NEUFELD

Worst case plot (operation mode 8):



Operation mode	Reading [dBm]	Corr. Fact.* [dB]	Result [dBm]	Limit [dBm]
1	1.1	0.0	1.1	30
2	1.3	0.0	1.3	30
3	1.0	0.0	1.0	30
4	2.9	0.0	2.9	21
5	3.0	0.0	3.0	21
6	2.7	0.0	2.7	21
7	3.4	0.0	3.4	21
8	**3.6**	0.0	**3.6**	21
9	3.3	0.0	3.3	21

* 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 equipment (please refer to chapter 6 for details)
1 - 3

5.1 Band edge

5.1.1 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	-

5.1.2 Test method (Band edge – unrestricted bands)

Test method Band edge – unrestricted bands				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	6.10.4	20 dBc (Peak)	No limitations	*1

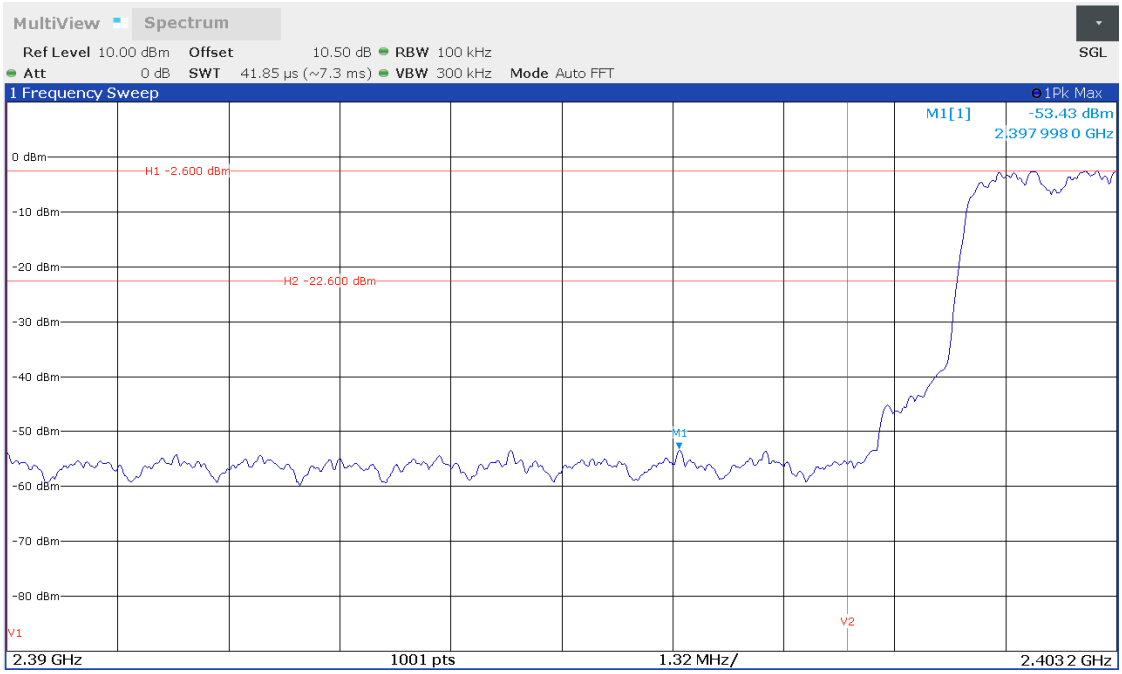
*1 As declared in “47 CFR 15.247(d)” In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth 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

5.1.3 Test results (Band edge – unrestricted bands)

Ambient temperature:	21 °C
Relative humidity:	22 %

Date	11.12.2021
Tested by	P. NEUFELD

Worst case plot Lower band edge (operation mode 11):



	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	2399.955	0.2	-19.8	-60	40.2	-	-	-	-	-
4	2400.002	-0.5	-20.5	-56.4	35.9	-	-	-	-	-
7	2399.659	-0.7	-20.7	-60	39.3	-	-	-	-	-
10	2397.998	-0.2	-20.2	-53	32.8	-	-	-	-	-
11	2397.998	-2.6	-22.6	-53.4	**30.8**	-	-	-	-	-
12	2395.018	-2	-22	-53.6	31.6	-	-	-	-	-

Test: Passed

Test equipment (please refer to chapter 6 for details)
1 - 3

5.1.4 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.

5.1.5 Test method (Band edge – restricted bands)

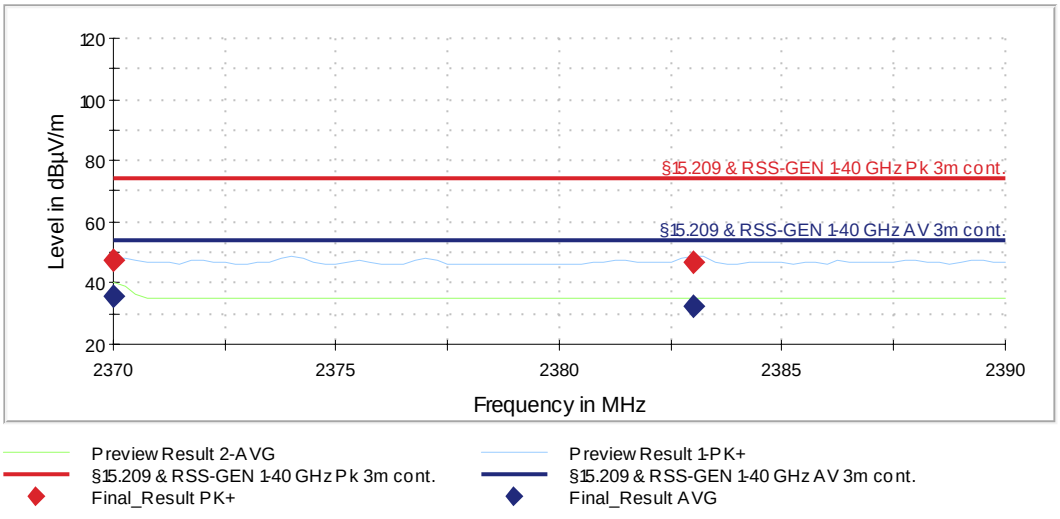
Test method (Band edge – restricted bands)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	6.10.5.2	Standard method	No limitations	-
☐	6.10.6.1	Marker-delta method	< 2 MHz from BE*	See 6.10.6 [3]
☐	11.13.3.2	Peak detection	Not for DTS testing	2 MHz from band
☐	11.13.3.3	Trace averaging 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	No limitations	2 MHz from band

5.1.6 Test results (Band edge – restricted bands)

Ambient temperature:	22 °C
Relative humidity:	42 %

Date	15.12.2021
Tested by	P. NEUFELD

Worst case plot (operation mode 1):



Only the worst-case emissions from the antenna port conducted pre-tests were repeated as radiated tests.

Operation mode #	Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]
1	2370.000	---	36.79	54.0	**17.2**	V	233	0	33.2
1	2370.000	47.37	---	74.0	26.6	V	233	0	33.2
1	2383.000	---	33.71	54.0	20.3	V	183	0	33.3
1	2383.000	47.00	---	74.0	27.0	V	183	0	33.3
-	-	-	-	-	-	-	-	-	-
3	2483.500	---	34.08	54.0	19.9	V	140	0	33.6
3	2483.500	47.53	---	74.0	26.5	V	140	0	33.6
3	2493.250	---	34.35	54.0	19.6	V	140	0	33.5
3	2493.250	47.39	---	74.0	26.6	V	140	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]
10	2372.000	---	33.91	54.0	20.1	V	252	0	33.2
10	2372.000	53.69	---	74.0	20.3	V	252	0	33.2
10	2381.000	---	34.66	54.0	19.3	V	246	0	33.3
10	2381.000	53.96	---	74.0	20.0	V	246	0	33.3
10	2387.250	---	32.44	54.0	21.6	V	192	0	33.4
10	2387.250	46.47	---	74.0	27.5	V	192	0	33.4
-	-	-	-	-	-	-	-	-	-
12	2485.000	---	31.89	54.0	22.1	V	237	0	33.6
12	2485.000	48.29	---	74.0	25.7	V	237	0	33.6
12	2487.000	---	34.40	54.0	19.6	V	242	0	33.6
12	2487.000	51.47	---	74.0	22.5	V	242	0	33.6

Test: Passed

Test equipment (please refer to chapter 6 for details)
4 - 12

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 – alternative procedure)*[1]	5.1.1.5	f > 1 GHz
☐	Test setup (antenna port conducted)	5.1.2	-

5.2.2 Test method (Maximum unwanted emissions)

Test method				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.12	Emissions in restricted frequency bands	No limitations	-

5.2.3 Test results (Maximum unwanted emissions)

5.2.3.1 Test results (9 kHz – 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:

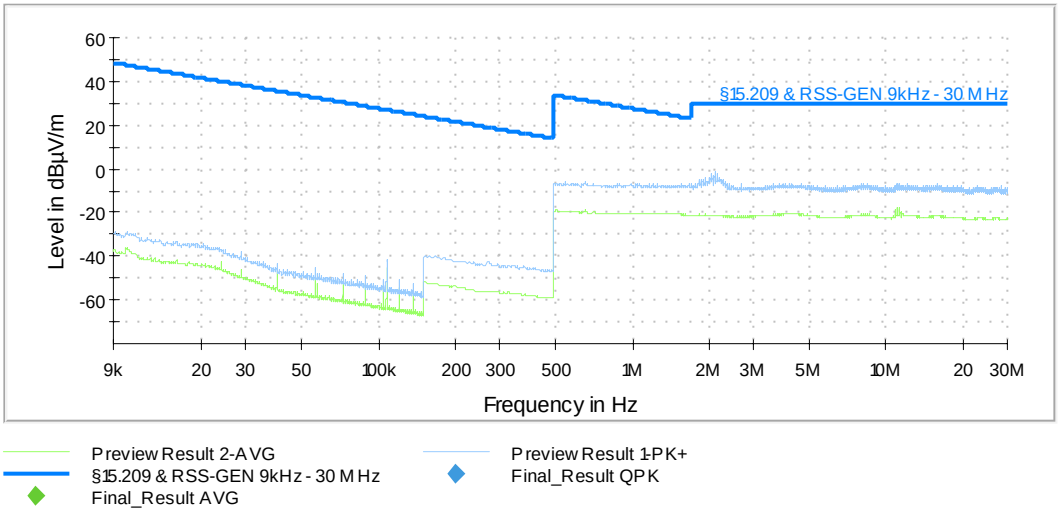
Result @ norm. dist. [dBµV/m] = Reading [dBµV] + AF [dB/m] + Distance corr. fact. [dBµV/m]

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:

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



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

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

5.2.3.2 Test results (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]

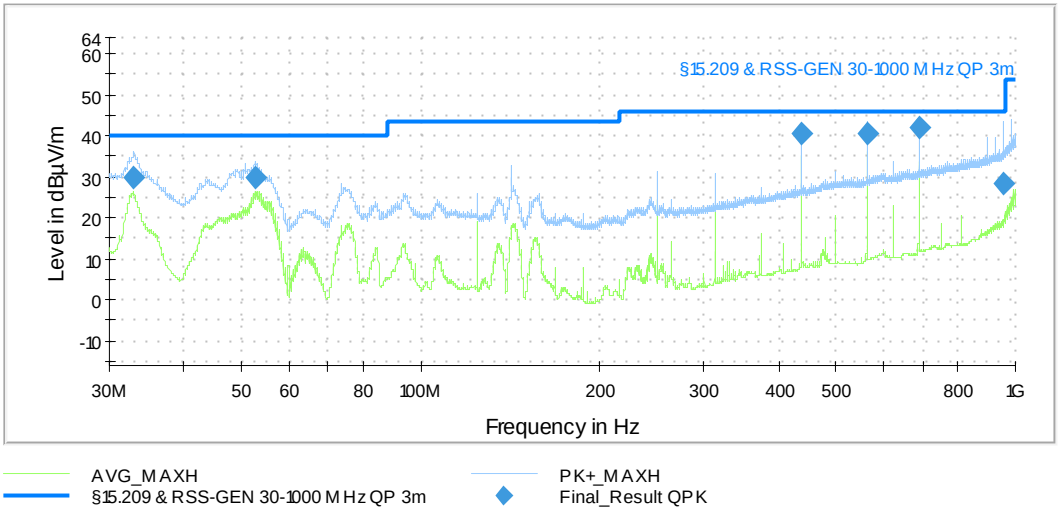
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

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 #
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 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 #
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 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 #
36.450	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 6 for details)
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5.2.3.3 Test results (above 1 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 emissons.

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)

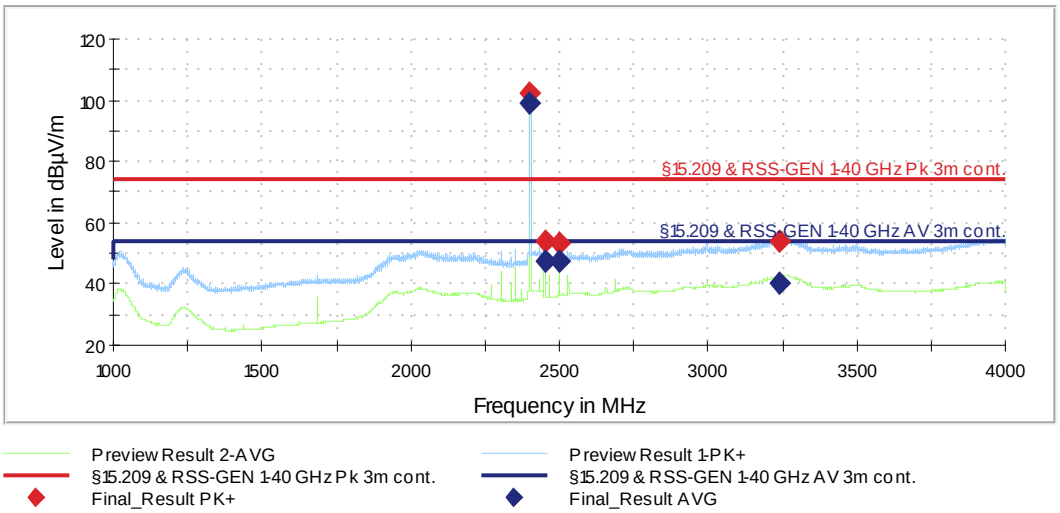
Margin [dB] = Limit [dBµV/m] – Max Peak | Average [dBµV/m]

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.

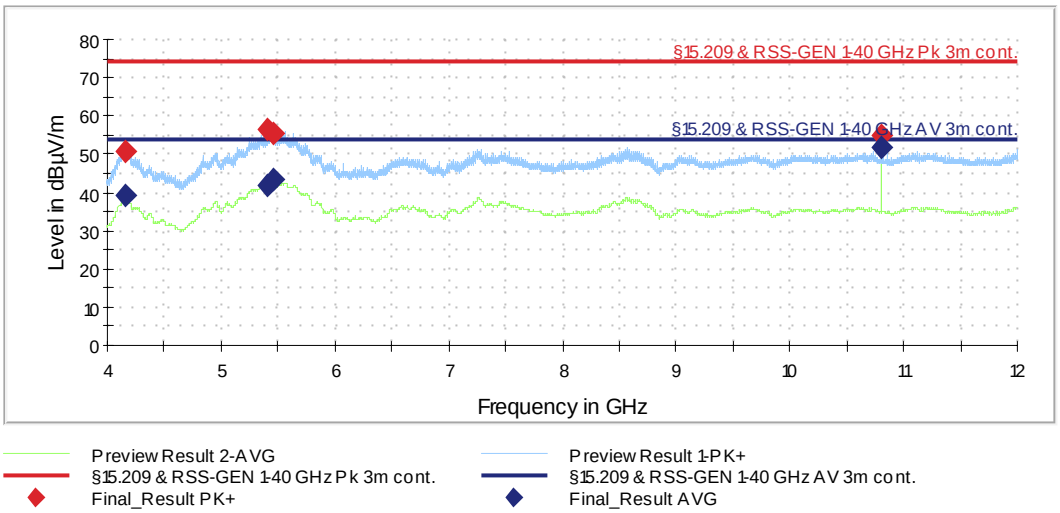
5.2.3.3.1 Plots

Only the plots from the worst-case emissions are submitted below.

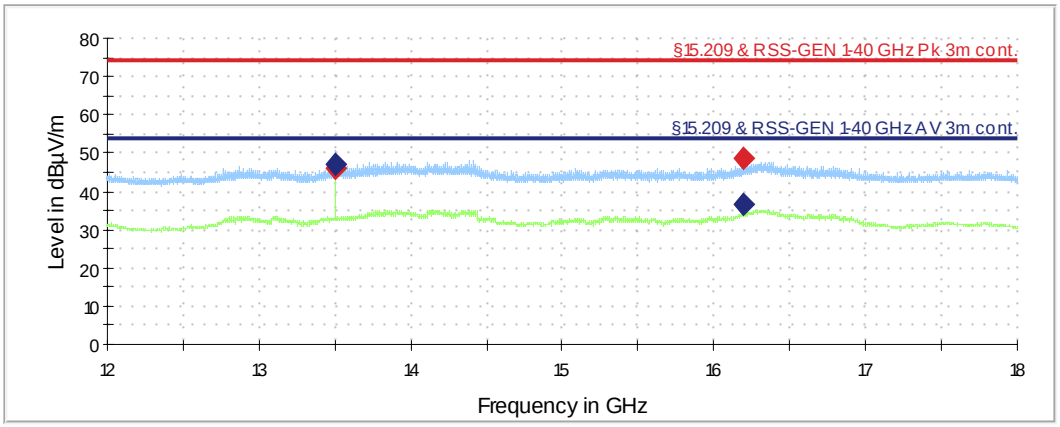
Spurious emissions from 1 GHz to 4 GHz (operation mode 1):



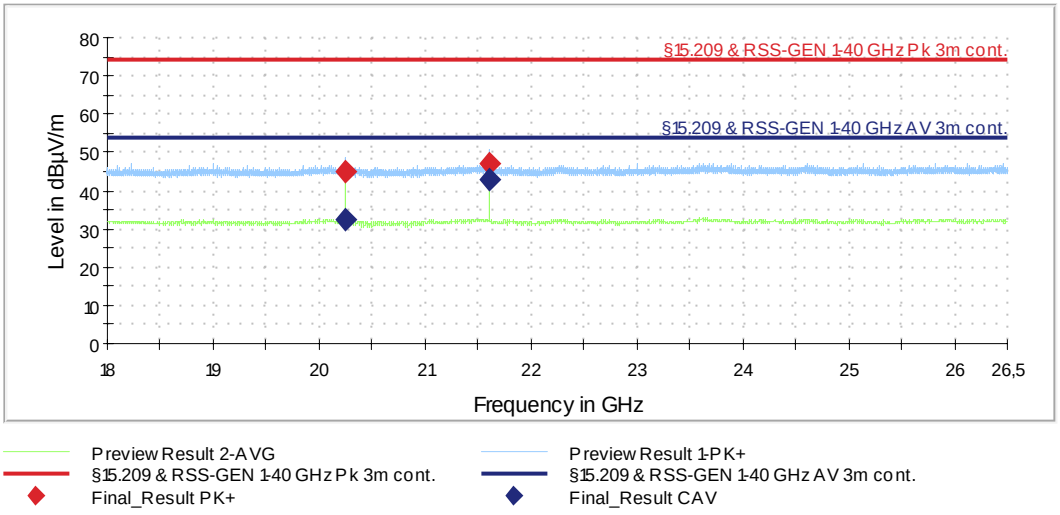
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



Spurious emissions from 12 GHz to 18 GHz (operation mode 3):



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



5.2.3.3.2 Result tables

Operation mode 1:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2402.000	---	99.21	---	---	V	250	0	33.5	65.7
2402.000	102.05	---	---	---	V	250	0	33.5	68.6
2450.000	53.67	---	74.0	20.33	V	245	0	33.9	19.8
2450.000	---	47.65	54.0	6.35	V	245	0	33.9	13.8
2498.000	---	47.67	54.0	6.33	V	251	0	33.6	14.1
2498.000	53.50	---	74.0	20.50	V	251	0	33.6	19.9
3243.000	---	40.28	54.0	13.72	V	124	0	36.9	3.4
3243.000	53.84	---	74.0	20.16	V	124	0	36.9	16.9
4164.750	---	39.11	54.0	14.89	V	151	30	-4.2	43.3
4164.750	50.82	---	74.0	23.18	V	151	30	-4.2	55.0
5400.000	---	41.84	54.0	12.16	H	162	90	-0.2	42.0
5400.000	56.21	---	74.0	17.79	H	162	90	-0.2	56.4
5457.250	---	43.46	54.0	10.54	V	158	30	0.1	43.4
5457.250	55.39	---	74.0	18.61	V	158	30	0.1	55.3
10800.000	---	51.59	54.0	2.41	H	232	60	7.2	44.4
10800.000	55.11	---	74.0	18.89	H	232	60	7.2	47.9
13500.000	50.08	---	74.0	23.92	V	156	30	10.7	39.4
13500.000	---	44.96	54.0	9.04	V	156	30	10.7	34.3
16200.000	44.83	---	74.0	29.17	V	160	60	10.2	34.6
16200.000	---	34	54.0	20.00	V	160	60	10.2	23.8
16874.75	---	32.99	54.0	21.01	H	242	120	9.8	23.2
16874.75	42.78	---	74.0	31.22	H	242	120	9.8	33.0
20249.750	---	32.67	54.0	21.33	V	211	120	4.6	28.1
20249.750	44.84	---	74.0	29.16	V	211	120	4.6	40.2
21599.750	---	42.88	54.0	11.12	V	212	120	5.3	37.6
21599.750	47.07	---	74.0	26.93	V	212	120	5.3	41.8

Operation mode 2:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2393.000	52.77	---	74.0	21.23	V	254	0	33.4	19.4
2393.000	---	46.76	54.0	7.24	V	254	0	33.4	13.4
2440.750	101.36	---	---	---	V	248	0	33.8	67.6
2440.750	---	97.41	---	---	V	248	0	33.8	63.6
2537.000	---	47.23	54.0	6.77	V	247	0	33.9	13.3
2537.000	53.35	---	74.0	20.65	V	247	0	33.9	19.5
4149.250	---	38.03	54.0	15.97	H	156	120	-4.2	42.2
4149.250	50.73	---	74.0	23.27	H	156	120	-4.2	54.9
5400.000	---	42.81	54.0	11.19	V	161	0	-0.2	43.0
5400.000	54.67	---	74.0	19.33	V	161	0	-0.2	54.9
5459.000	---	43.39	54.0	10.61	V	158	30	0.1	43.3
5459.000	55.42	---	74.0	18.58	V	158	30	0.1	55.3
10800.000	---	51.12	54.0	2.88	H	232	60	7.2	43.9
10800.000	55.23	---	74.0	18.77	H	232	60	7.2	48.0
13500.000	50.91	---	74.0	23.09	V	154	60	10.7	40.2
13500.000	---	31.92	54.0	22.08	V	154	60	10.7	21.2
16199.750	47.86	---	74.0	26.14	H	159	90	10.2	37.7
16199.750	---	37.05	54.0	16.95	H	159	90	10.2	26.9
20249.750	---	41.71	54.0	12.29	H	253	120	4.6	37.1
20249.750	44.26	---	74.0	29.74	H	253	120	4.6	39.7
21599.750	---	41.62	54.0	12.38	V	206	120	5.3	36.3
21599.750	46.28	---	74.0	27.72	V	206	120	5.3	41.0

Operation mode 3:

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Pol	Azimuth [deg]	Elevation [deg]	Corr. [dB/m]	Reading [dBµV]
2384.000	53.39	---	74.0	20.61	V	244	0	33.3	20.1
2384.000	---	47.45	54.0	6.55	V	244	0	33.3	14.2
2480.000	---	96.34	---	---	V	249	0	33.6	62.7
2480.000	99.08	---	---	---	V	249	0	33.6	65.5
2489.500	---	30.25	54.0	23.75	V	223	0	33.5	-3.3
2489.500	45.36	---	74.0	28.64	V	223	0	33.5	11.9
2512.000	---	34.92	54.0	19.08	H	156	90	33.8	1.1
2512.000	49.33	---	74.0	24.67	H	156	90	33.8	15.5
2528.000	---	43.82	54.0	10.18	V	239	0	33.8	10.0
2528.000	52.14	---	74.0	21.86	V	239	0	33.8	18.3
2576.000	---	46.46	54.0	7.54	H	146	30	34.1	12.4
2576.000	53.32	---	74.0	20.68	H	146	30	34.1	19.2
3260.500	53.53	---	74.0	20.47	V	132	0	37.1	16.4
3260.500	---	40.29	54.0	13.71	V	132	0	37.1	3.2
4164.750	---	38.42	54.0	15.58	H	152	150	-4.2	42.6
4164.750	50.66	---	74.0	23.34	H	152	150	-4.2	54.9
5400.000	---	42.93	54.0	11.07	V	161	0	-0.2	43.1
5400.000	55.83	---	74.0	18.17	V	161	0	-0.2	56.0
5456.750	---	43.53	54.0	10.47	V	158	30	0.1	43.4
5456.750	55.47	---	74.0	18.53	V	158	30	0.1	55.4
10800.000	---	51.08	54.0	2.92	H	234	60	7.2	43.9
10800.000	55.07	---	74.0	18.93	H	234	60	7.2	47.9
13500.000	46.16	---	74.0	27.84	V	155	60	10.7	35.5
13500.000	---	47.19	54.0	6.81	V	155	60	10.7	36.5
16199.750	48.68	---	74.0	25.32	H	161	90	10.2	38.5
16199.750	---	36.61	54.0	17.39	H	161	90	10.2	26.4
20250.000	---	33.42	54.0	20.58	H	138	60	4.6	28.8
20250.000	44.01	---	74.0	29.99	H	138	60	4.6	39.4
21600.000	---	36.56	54.0	17.44	V	210	120	5.3	31.3
21600.000	49.14	---	74.0	24.86	V	210	120	5.3	43.8

Test equipment (please refer to chapter 6 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	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	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	Test software 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	High pass 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 Test receiver	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 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

9 Report History

Report Number	Date	Comment
F212286E2	14.02.2022	Initial Test Report
F212286E2 2nd Version	16.02.2022	clause 1.1: name of applicant changed to Robert Bosch GmbH
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10 List of Annexes

Annex A Test Setup Photos 12 pages