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:

F231447E1

Equipment under Test (EUT):

VCUNH1

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)

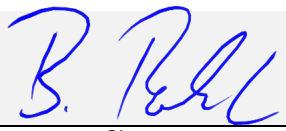
[5] **RSS-247, Issue 2 (2017-02)** Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

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

[6] **789033 D02 General UNII Test Procedures New Rules v02r01 (December 2017),** GUIDELINES FOR COMPLIANCE TESTING OF UNLICENSED NATIONAL INFORMATION INFRASTRUCTURE (U-NII) DEVICES PART 15, SUBPART E

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:		Bernward ROHDE 14.09.2023
	Signature	
Reviewed and approved by:		Bernd STEINER 14.09.2023
	Signature	

This test report is only valid in its original form.

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

Contents: Page

1 Identification

1.1 Applicant

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:	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: *	VCUNH1
Model number: *	7511.401.147-08
Order number: *	NA
FCC ID: *	2AUXS-VCUNH1
IC certification number: *	25847-VCUNH1
PMN: *	Virtual Cockpit Unit
HVIN: *	VCUNH1
FVIN: *	NA
HMN: *	NA

	EUT number		
	1 (conducted)	2 (radiated)	3
Serial number: *	9000003	9000011	-
Hardware version: *	C3	C3	-
Software version: *	SQBR4-20	SQBR4-20	-

* 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 / 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.

IEEE 802.11 frequencies (5 GHz)					
20 MHz		40 MHz		80 MHz	
Channel 36	5180 MHz*1	Channel 38 *1, 2	5190 MHz	-	-
Channel 40	5200 MHz*1	-	-	Channel 42*1, 2	5210 MHz
Channel 44	5220 MHz*1	Channel 46*1, 2	5230 MHz	-	-
Channel 48	5240 MHz*1	-	-	-	-
Channel 149	5745 MHz*1	-	-	-	-
Channel 153	5765 MHz*1	Channel 151*1, 2	5755 MHz	-	-
Channel 157	5785 MHz*1	-	-	Channel 155*1, 2	5775 MHz
Channel 161	5805 MHz*1	Channel 159*1, 2	5795 MHz	-	-
Channel 165	5825 MHz*1	-	-	-	-

*1 Refer test report B23N00972_FCC_WLAN 5GHz by SAICT (Shenzhen Academy of Information and Communications Technology)

*2 This test report contains just the results of the operation modes IEEE 802.11ax40-RU modes and IEEE 802.11ax80-RU modes

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) 2.2 dBi (typical) 6.7 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 MHz – 5240 MHz, 5745 MHz – 5825 MHz
	IEEE 802.11n 20 MHz	5180 MHz – 5240 MHz, 5745 MHz – 5825 MHz
	IEEE 802.11n 40 MHz	5190 MHz – 5230 MHz, 5755 MHz – 5795 MHz
	IEEE 802.11ac 20 MHz	5180 MHz – 5240 MHz, 5745 MHz – 5825 MHz
	IEEE 802.11ac 40 MHz	5190 MHz – 5230 MHz, 5755 MHz– 5795 MHz
	IEEE 802.11ac 80 MHz	5210 MHz, 5755 MHz
	IEEE 802.11ax 20 MHz	5180 MHz – 5240 MHz, 5745 MHz – 5825 MHz
	IEEE 802.11ax 40 MHz	5190 MHz – 5230 MHz, 5755 MHz – 5795 MHz
	IEEE 802.11ax 80 MHz	5210 MHz, 5755 MHz

* Declared by the applicant

1.6.1 Ancillary Equipment / Equipment used for testing

Equipment used for testing	
Laboratory power supply *1	Toellner TOE 8852 (PM. NO. 480233)
Test Laptop*1	Fujitsu Lifebook E752 (PM. No: 201161)

*1 Provided by the laboratory

Ancillary equipment	
-	-

1.7 Dates

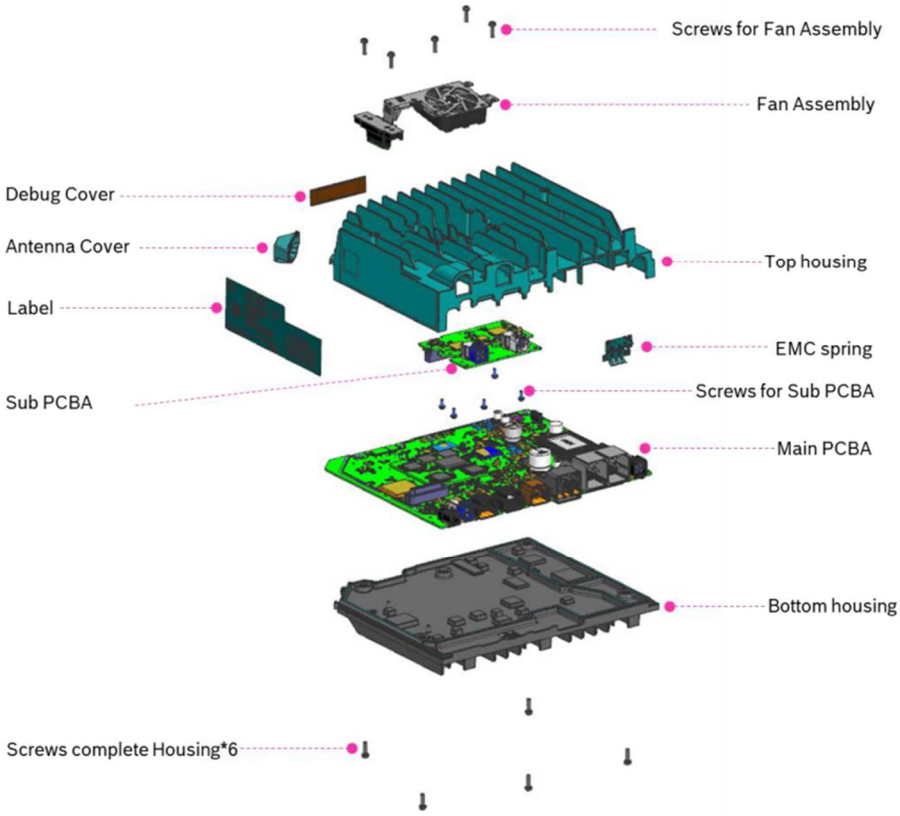
Date of receipt of test sample:	30.08.2023
Start of test:	30.08.2023
End of test:	12.09.2023

2 Operational States

2.1 Description of function of the EUT

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

The EUT:

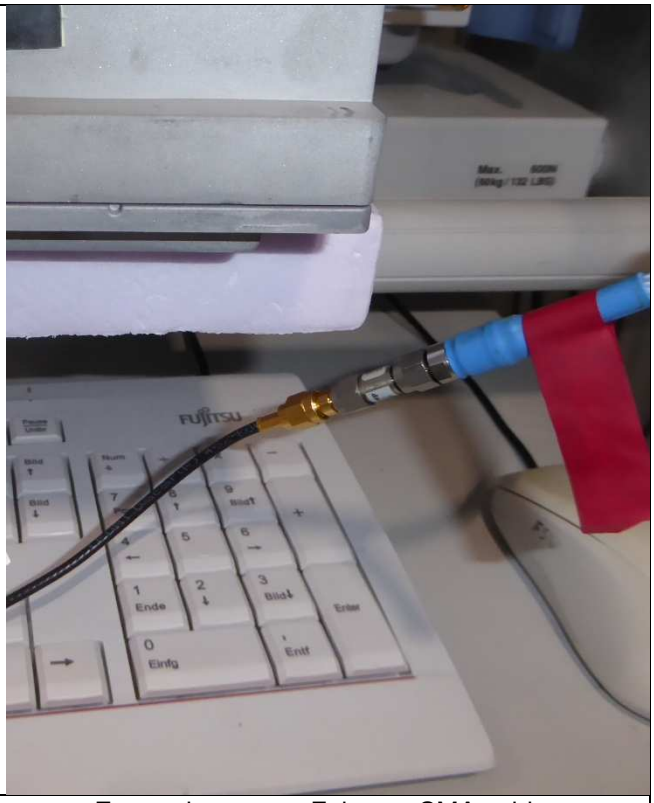


During all test the EUT was supplied with 13.5 V DC via a laboratory power supply. During the tests, a USB connection was established between the EUT and a laptop computer via USB-2-optic converter.

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

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

2.1.1.1 Modifications

	
Internal antenna: Temporary antenna connector	External antenna: Fakra-to-SMA cable

As declared by the applicant the same power settings were used while transmitting on one antenna only or on both. Therefore, all tests were performed with both antenna ports active.

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 position of the vehicle.
For U-NII-3 band (5.725 – 5.85 GHz), the EUT has the same power settings for FCC and ISED.

The EUT has incorporated 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).

2.1.2 Operation modes 5 GHz (FCC)

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate*	Power setting
1	IEEE 802.11ax40-RU26_0*2	5190	38	BPSK	MCS0	“11”
2	IEEE 802.11ax40-RU26_17*2	5230	46	BPSK	MCS0	“11”
3	IEEE 802.11ax80-RU996_0*2	5210	42	BPSK	MCS0	“11”

* As pre-tests have shown, these data rated produced the highest output power. Refer test report B23N00972_FCC_WLAN 5GHz by SAICT (Shenzhen Academy of Information and Communications Technology)
*2 The worst-case RU modes as defined by the applicant were set automatically by the test software. The test software was provided by the applicant.

2.1.3 Operation modes 5 GHz (ISED)

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate*	Power setting
4	IEEE 802.11ax40-RU26_0*2	5190	38	BPSK	MCS0	“3”
5	IEEE 802.11ax40-RU26_17*2	5230	46	BPSK	MCS0	“3”
6	IEEE 802.11ax80-RU996_0*2	5210	42	BPSK	MCS0	“3”

* As pre-tests have shown, these data rated produced the highest output power. Refer test report B23N00972_FCC_WLAN 5GHz by SAICT (Shenzhen Academy of Information and Communications Technology)
*2 The worst-case RU modes as defined by the applicant were set automatically by the test software. The test software was provided by the applicant.

2.1.4 Operation modes 5 GHz (FCC&ISED)

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate*	Power setting
7	IEEE 802.11ax40-RU26_0*2	5755	151	BPSK	MCS0	“16”
8	IEEE 802.11ax40-RU26_17*2	5795	159	BPSK	MCS0	“16”
9	IEEE 802.11ax80-RU996_0*2	5775	155	BPSK	MCS0	“16”

* As pre-tests have shown, these data rated produced the highest output power. Refer test report B23N00972_FCC_WLAN 5GHz by SAICT (Shenzhen Academy of Information and Communications Technology)
*2 The worst-case RU modes as defined by the applicant were set automatically by the test software. The test software was provided by the applicant.

3 Additional Information

The EUT was not labeled as required by FCC / IC.
All radiated tests were performed using an unmodified EUT except the temporary antenna connector.
This test report contains just the results of the operation modes IEEE 802.11ax40-RU modes and IEEE 802.11ax80-RU modes

4 Overview

Application	Frequency range in MHz	FCC 47 CFR Part 15 section [2]	RSS-247 [5] RSS-Gen [6]	Tested EUT	Status
Maximum Output Power	5150 – 5250 5725 - 5850	15.407 (a)	6.2.1.1 [5] 6.2.4.1 [5]	1	verified
UNII Bandwidth 99% Bandwidth	5150 – 5250 5725 - 5850	-	-	1	Performed
6 dB Bandwidth	5725 - 5850	15.407(e)	6.2.4.1 [5]	1	Passed
26 dB Bandwidth Emission Bandwidth	5150 – 5250 5725 - 5850	15.403	6.2.1.2	1	Performed
Maximum Power Spectral Density	5150 – 5250 5725 - 5850	15.407 (a)(5)	6.2.1.1 [5] 6.2.4.1 [5]	1	Passed
Band edge compliance*[2]	5150 – 5250 5725 - 5850	15.407 (b)	6.2.1.2[5] 6.2.4.2[5]	1, 2	Passed
Radiated emissions (transmitter)*[2]	0.009 - 40,000	15.407 (b) 15.205 (a) 15.209 (a)	6.13 [6], 6.2.1.2[5] 6.2.2.2[5] 6.2.3.2[5] 6.2.4.2[5]	2	Passed
Antenna Requirement	-	15.203 15.247 (b)	6.8 [6] 5.4 (f) (ii) [5]	-	Passed
Conducted emissions on supply line	0.15 - 30	15.207 (a)	7.2 [6]	-	n/a*

* Not applicable, because the EUT is only used in vehicular environments.

5 Results

5.1 Test setup

5.1.1 Test Setup (radiated)

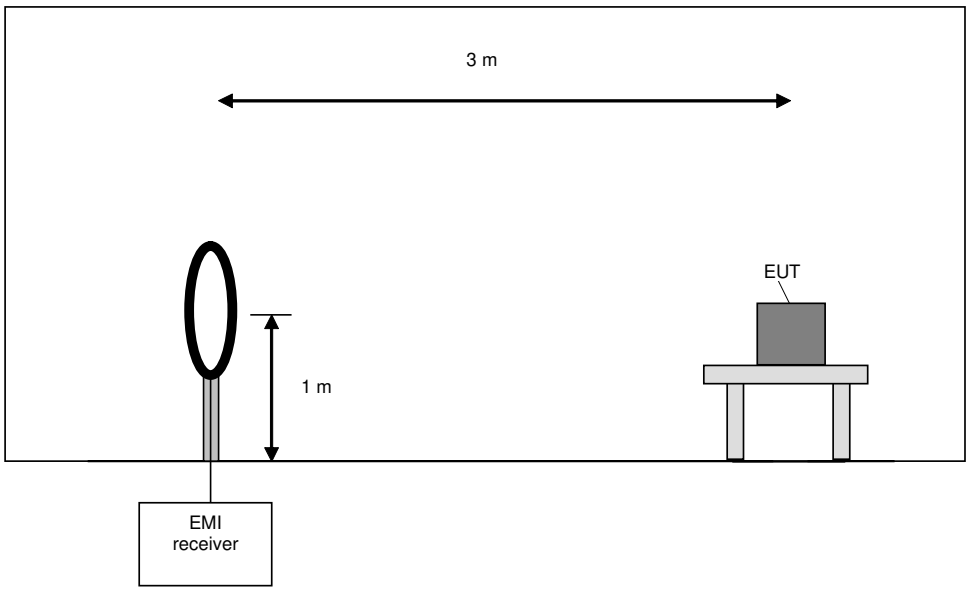
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

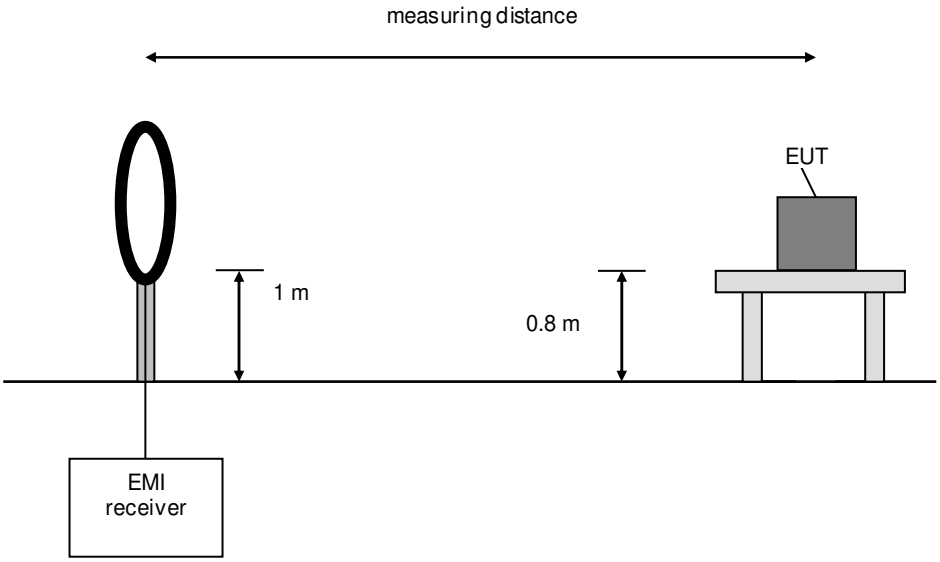
5.1.1.2 Final measurement 9 kHz to 30 MHz

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.

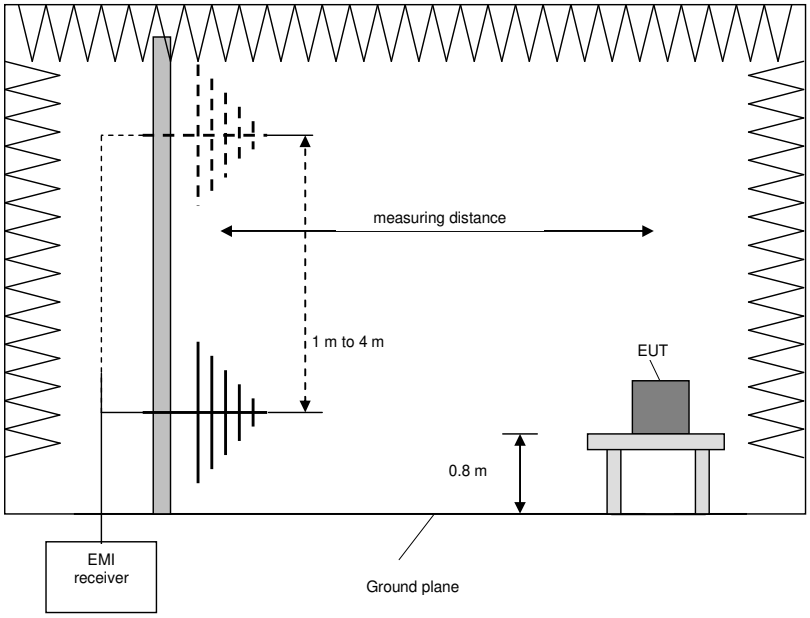
5.1.1.3 Preliminary and final measurement 30 MHz to 1 GHz

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 (Alternative procedure 6.6.5 in [1])

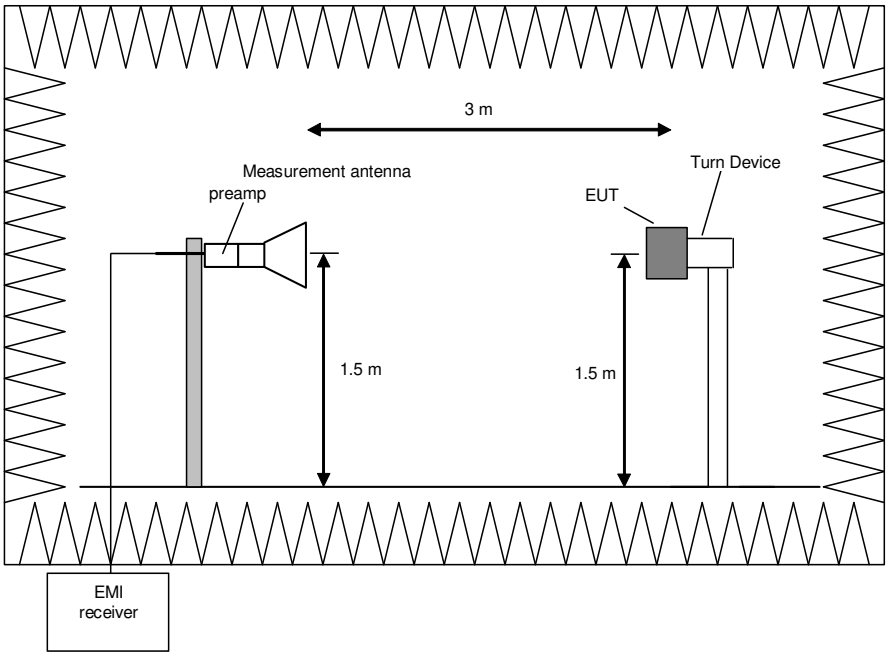
This measurement will be performed in a fully anechoic chamber or in a semi-anechoic chamber with ground absorbers between antenna and EUT. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to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

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:

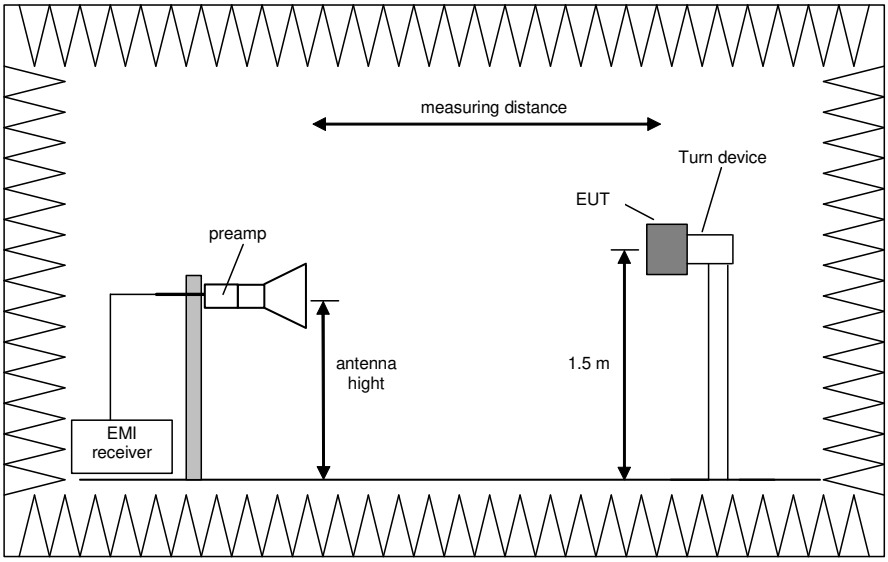
1. Monitor the frequency range at horizontal polarization and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarization of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an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

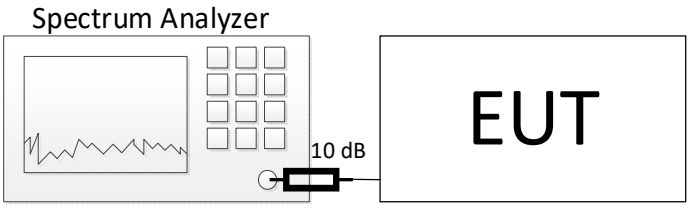
The measurements were performed in the frequency ranges 1 GHz to 4 GHz, 4 GHz to 12 GHz, 12 GHz to 18 GHz, 18 GHz to 25 /26.5 GHz and 26.5 GHz to 40 GHz.
The following procedure will be used:

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.

5.1.2 Test setup (conducted)

Test setup (conducted)		
Used	Antenna connector	Comment
☒☒☐	Temporary antenna connector	As provided by the applicant
☒☒☐	Normal antenna connector	-

For test at the internal antenna, a temporary antenna connector was used, as provided by the applicant (see 2.1.1.1)
For test at the external antenna, the normal antenna connector was used.



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 – alternative procedure)	5.1.1.4	-
☒	Test setup (antenna port conducted)	5.1.2	-

5.2.2 Test method (Duty cycle)

Test method (Duty cycle)				
Used	Sub-Clause [6]	Name of method	Applicability	Comment
☐	II B. 2. a)	Diode detector	No limitation	-
☒	II B. 2. b)	Zero span (analyzer or EMI receiver)	No limitation	-

5.2.3 Test results (Duty cycle)

Ambient temperature:	21 °C
Relative humidity:	65 %

Date	12.09.2023
Tested by	B. ROHDE

Duty cycle > 98%, therefore no DCCF applicable

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

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

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

No DCCF is applied for all other test cases because the duty cycle is > 98%, and therefore no DCCF is necessary.

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

5.3 Transmit Antenna Performance considerations

Test result (Transmit antenna requirements)			
Integral antenna	Antenna gain ≤ 6dBi	Result	Comment
☒	☐	Passed	Output power reduction necessary, calculation see below

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

Antenna gain calculation for WLAN modes (mode 1 – 60) as described in [4], sub-clause F) 2) d) (i)

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

Herein:

G_1 = $gain_{external\ antenna}$ = 4.9 dBi
G_1 = $gain_{internal\ antenna}$ = 2.22 dBi
N_{Ant} = number of antennas = 2
Directional gain for correlated signals = **6.67 dBi** > 6 dBi

All conducted limits will be reduced by 0.7 dB.

5.4 Emission Bandwidth (EBW)

5.4.1 Test setup (EBW)

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

5.4.2 Test method (EBW)

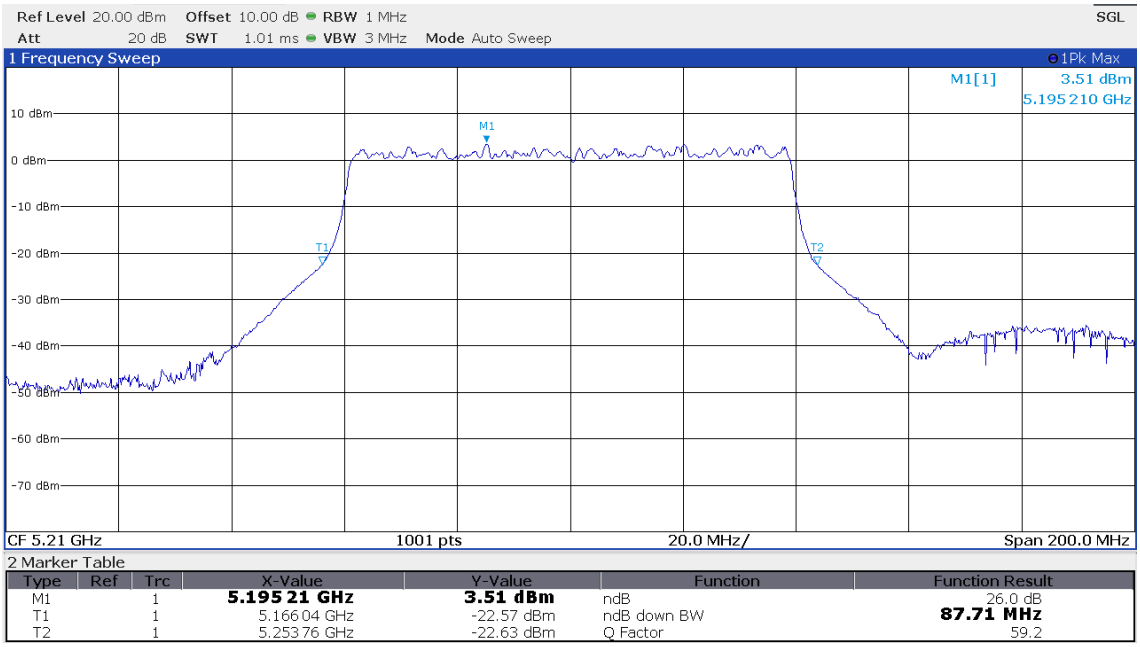
Test method (Maximum peak conducted output power)				
Used	Sub-Clause [6]	Name of method	Applicability	Comment
☒	II C. 1	26 dB Bandwidth	All but 5.725 – 5.85 GHz	-
☒	II C. 2	6 dB Bandwidth	Only 5.725 – 5.85 GHz	-

5.4.3 Test results (EBW - 26 dB BW) for FCC - 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

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



Results internal antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
1	19.88	5169.12	5189	5150.000	5250.000
2	38.07	5211.73	5249.80	5150.000	5250.000
3	**88.11**	**5166.04**	**5254.16***	5150.000	5250.000

* As permitted in TCB Workshop 2017-05-03-3.1 Panel UNII Updates-DT, the 99 % Bandwidth instead of the 26 dB bandwidth is used to determine if the signal is inside an DFS band and subsequently must be implement DFS detection.

Test: Passed

Results external antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
1	19.88	5169.12	5189	5150.000	5250.000
2	19.88	5230.9	5250.78*	5150.000	5250.000
3	87.71	5165.84	5253.56*	5150.000	5250.000

* As permitted in TCB Workshop 2017-05-03-3.1 Panel UNII Updates-DT, the 99 % Bandwidth instead of the 26 dB bandwidth is used to determine if the signal is inside an DFS band and subsequently must be implement DFS detection.

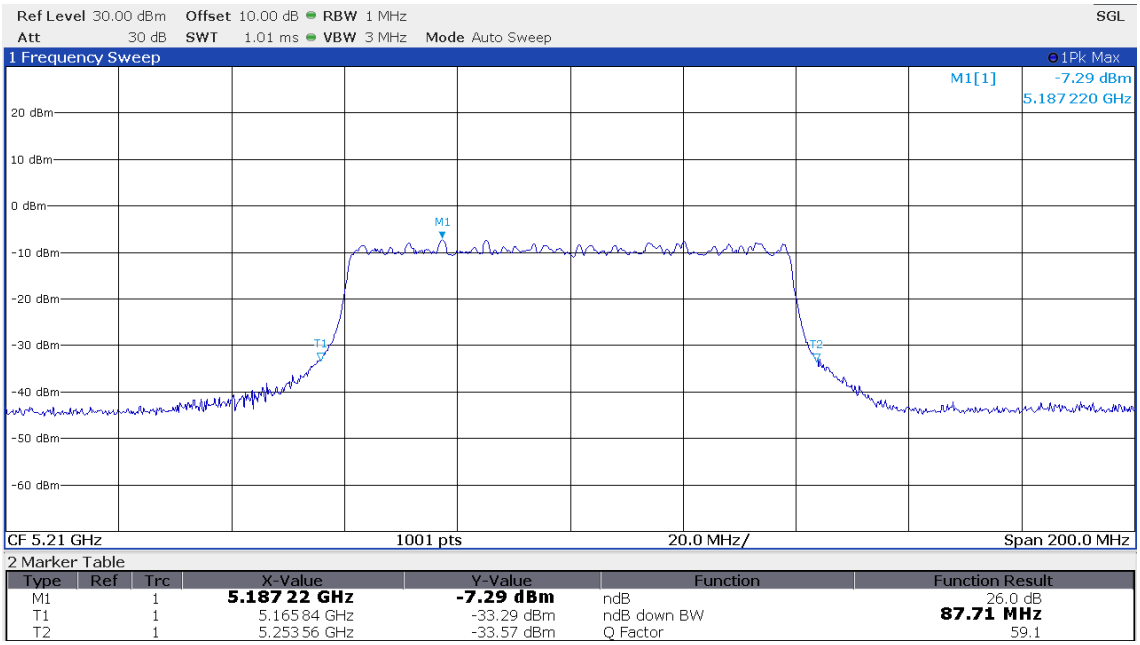
Test: Passed

5.4.4 Test results (EBW - 26 dB BW) for ISED – 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 6 – internal antenna):



Results internal antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low}[MHz]	f_{High}[MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
4	20.08	5168.92	5189.00	5150.000	5250.000
5	19.98	5230.90	5250.88*	5150.000	5250.000
6	**88.91**	**5165.64**	**5254.56***	5150.000	5250.000

* As permitted in TCB Workshop 2017-05-03-3.1 Panel UNII Updates-DT, the 99 % Bandwidth instead of the 26 dB bandwidth is used to determine if the signal is inside an DFS band and subsequently must be implement DFS detection.

Results external antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low}[MHz]	f_{High}[MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
4	19.88	5169.12	5189.00	5150.000	5250.000
5	20.18	5230.90	5251.08*	5150.000	5250.000
6	**88.91**	**5166.04**	**5254.96***	5150.000	5250.000

* As permitted in TCB Workshop 2017-05-03-3.1 Panel UNII Updates-DT, the 99 % Bandwidth instead of the 26 dB bandwidth is used to determine if the signal is inside an DFS band and subsequently must be implement DFS detection.

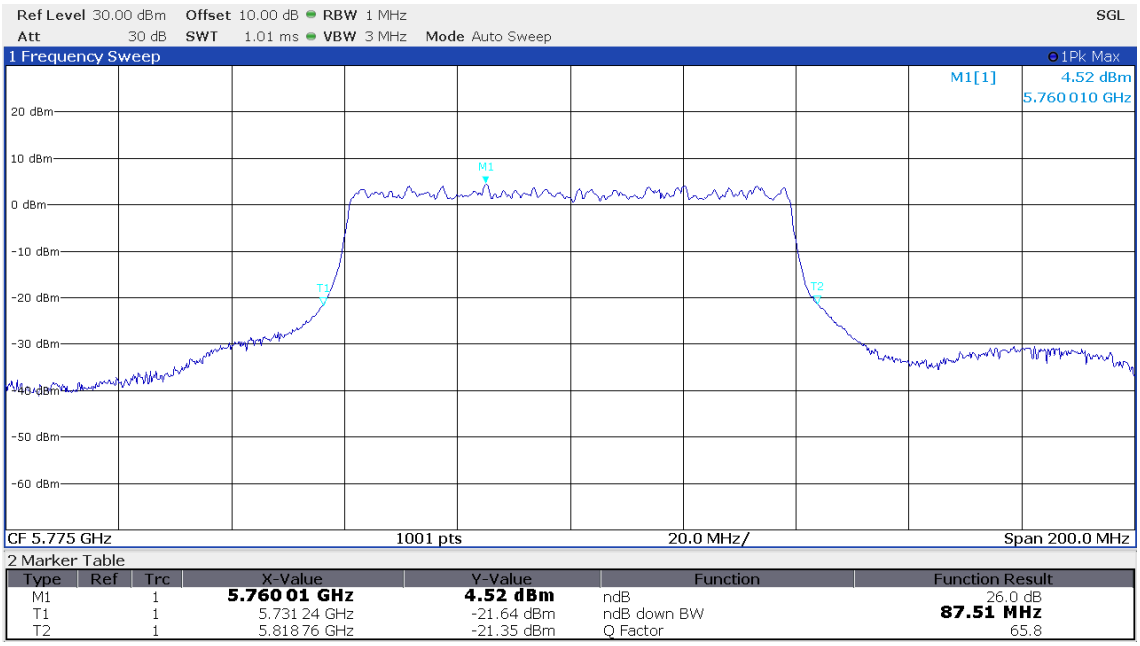
Test: Passed

5.4.5 Test results (EBW - 26 dB BW) for FCC&ISED – 5725 – 5850 MHz

Ambient temperature:	22 - 24 °C
Relative humidity:	26 – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 9 – internal antenna):



Results internal antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low}[f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
7	19.88	5734.12	5754.00	5725.000	5850.000
8	19.88	5795.90	5815.78	5725.000	5850.000
9	**87.51**	**5731.24**	**5818.76**	5725.000	5850.000

Results external antenna

Operation mode #	26 dB bandwidth [MHz]	f_{Low}[MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
7	19.78	5734.22	5754.00	5725.000	5850.000
8	19.88	5795.90	5815.78	5725.000	5850.000
9	87.11	5731.24	5818.36	5725.000	5850.000

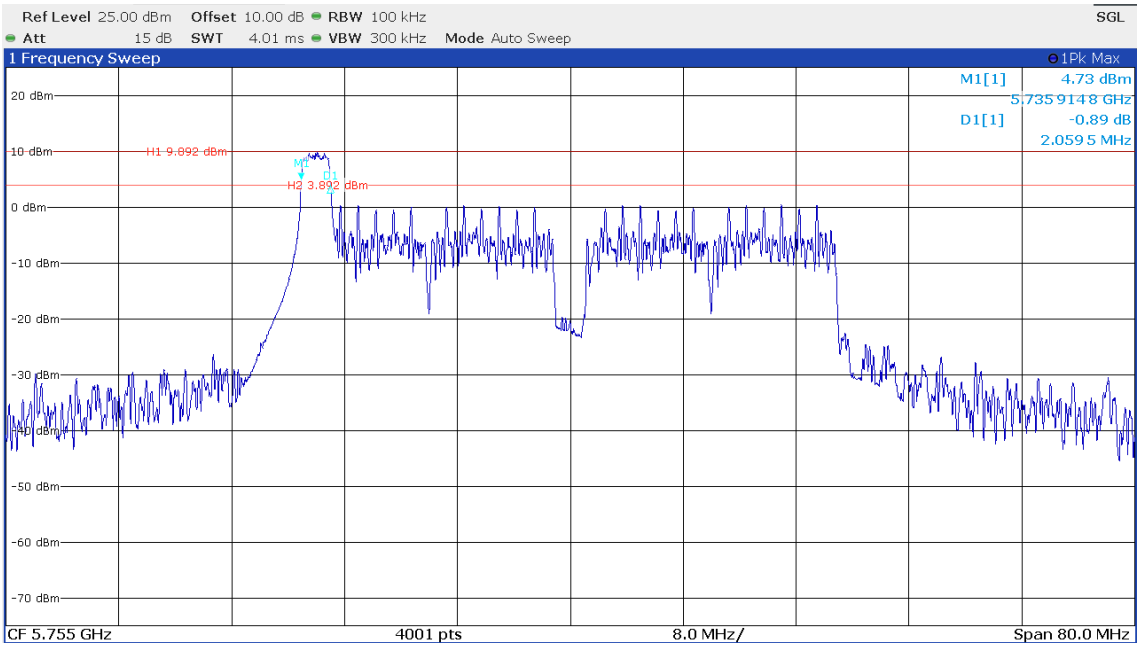
Test: Passed

5.4.6 Test results (EBW - 6 dB BW) for FCC&ISED – 5725 – 5850 MHz

Ambient temperature:	22 - 24 °C
Relative humidity:	26 – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 7 – internal antenna):



Operation mode #	6 dB bandwidth Internal antenna [MHz]	6 dB bandwidth External antenna [MHz]	Minimum 6 dB bandwidth [MHz]
7	**2.059485**	2.099475	0.5
8	2.07948	2.099475	0.5
9	78.175	78.175	0.5

Test: Passed

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 – alternative procedure)	5.1.1.4	-
☒	Test setup (antenna port conducted)	5.1.2	-

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

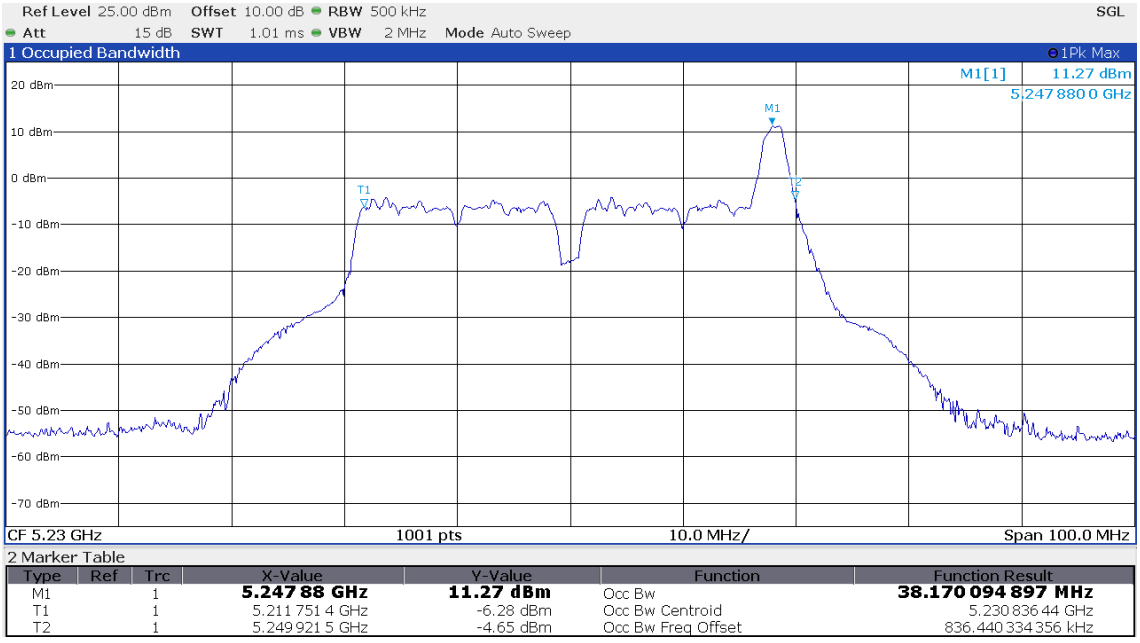
Test method (Maximum peak conducted output power)				
Used	Sub-Clause [6]	Name of method	Applicability	Comment
☒	II D	99% Occupied Bandwidth	No limitations	-

5.5.3 Test results (Occupied bandwidth – power bandwidth (99%)) for FCC - 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 2 – external antenna):



Results internal antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
1	38.608382	5169.50764	5208.11602	5150.000	5250.000
2	38.073409	5211.72777	5249.80118	5150.000	5250.000
3	77.993712	5170.96361	5248.95733	5150.000	5250.000

Results external antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
1	38.564451	5169.50596	5208.07041	5150.000	5250.000
2	**38.170095**	**5211.75139**	**5249.92149**	5150.000	5250.000
3	77.919491	5170.97029	5248.88978	5150.000	5250.000

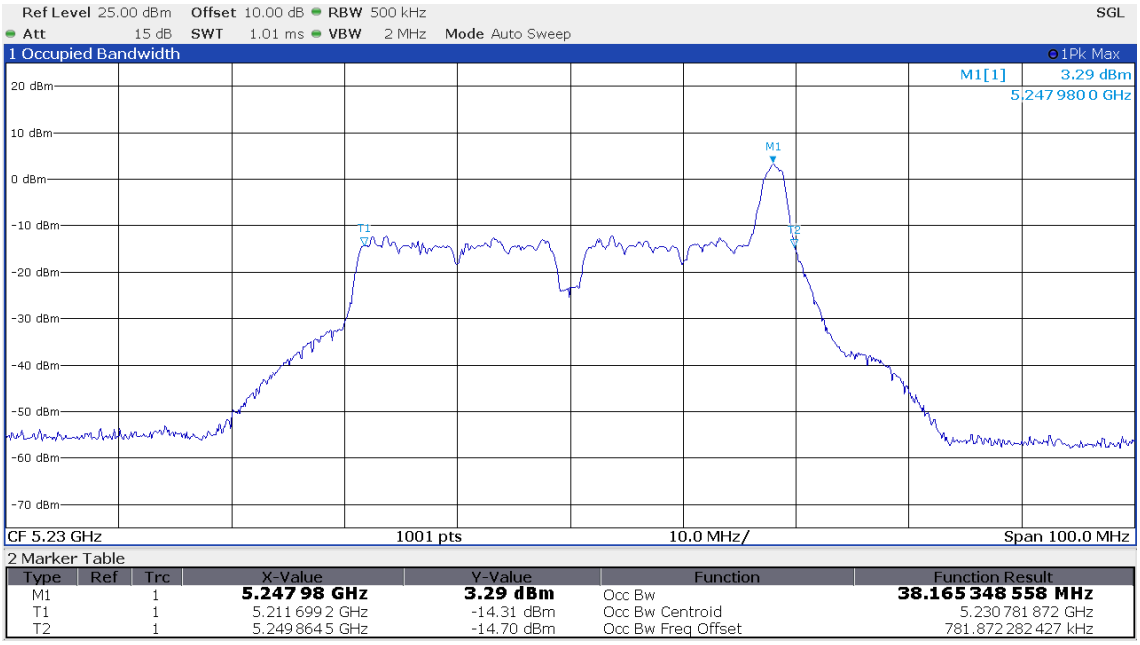
Test: Passed

5.5.4 Test results (Occupied bandwidth – power bandwidth (99%)) for ISED - 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 5 – external antenna):



Results internal antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
4	38.652751	5169.43258	5208.08533	5150.000	5250.000
5	37.958469	5211.79772	5249.75618	5150.000	5250.000
6	77.945766	5170.94635	5248.89212	5150.000	5250.000

Results external antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
4	38.55332	5169.5551	5208.1084	5150.000	5250.000
5	**38.165349**	**5211.6992**	**5249.8646**	5150.000	5250.000
6	77.91754	5171.0051	5248.9226	5150.000	5250.000

Test: Passed

5.5.5 Test results (Occupied bandwidth – power bandwidth (99%)) for FCC&ISED – 5725 – 5850 MHz

Ambient temperature:	22 - 24 °C
Relative humidity:	26 – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Worst case plot (operation mode 7 – internal antenna):

Results internal antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
7	**38.695128**	**5734.47521**	**5773.17033**	5725.000	5850.000
8	38.909304	5776.46983	5815.37913	5725.000	5850.000
9	77.969883	5735.97500	5813.94488	5725.000	5850.000

Results external antenna

Operation mode #	99% bandwidth [MHz]	f_{Low} [MHz]	f_{High} [MHz]	Limit f_{Low} [MHz]	Limit f_{High} [MHz]
7	38.631546	5734.50812	5773.13967	5725.000	5850.000
8	38.820002	5776.47859	5815.29859	5725.000	5850.000
9	77.921803	5735.96106	5813.88287	5725.000	5850.000

Test: Passed

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

5.6 Maximum (average) Conducted Output Power

5.6.1 Test setup (Maximum (average) Conducted Output Power)

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

5.6.2 Test method (Maximum (average) Conducted Output Power)

Test method (Maximum conducted (average) output power)				
Used	Sub-Clause [6]	Name of method	Applicability	Comment
☐	II E 2. b)	Method SA-1	D ≥ 98% or video trigger	-
☐	II E 2. c)	Method SA-1A (alternative)	D ≥ 98%	-
☒	II E 2. d)	Method SA-2	Constant D (±2%)	-
☐	II E 2. e)	Method SA-2A (alternative)	Constant D (±2%)	-
☐	II E 2. f)	Method SA-3A	No limitations	-
☐	II E 2. g)	Method SA-3A (alternative)	No limitations	-
☐	II E 3 a)	Method Power Meter	D ≥ 98% or Constant D (±2%)	-
☐	II E 3 a)	Method gated Power Meter	Measure only On time	-

5.6.3 Test results Maximum (Average) Conducted Output Power for FCC - 5150 – 5250 MHz

RF output power verification done, results is within the tune-up range.

5.6.4 Test results Maximum (Average) Conducted Output Power for ISED – 5150 – 5250 MHz

RF output power verification done, results is within the tune-up range.

5.6.5 Test results Maximum (Average) Conducted Output Power for FCC&ISED – 5725 – 5850 MHz

RF output power verification done, results is within the tune-up range.

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

5.7 Maximum (average) Power Spectral Density

5.7.1 Test setup (Maximum (average) Power Spectral Density)

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

5.7.2 Test method (Maximum (average) Power Spectral Density)

Test method (Maximum peak power spectral density level in the fundamental emission)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	II E 2. b)	Method SA-1	D ≥ 98% or video trigger	Peak Search*
☐	II E 2. c)	Method SA-1A (alternative)	D ≥ 98%	Peak Search*
☐	II E 2. d)	Method SA-2	Constant D (±2%)	Peak Search*
☐	II E 2. e)	Method SA-2A (alternative)	Constant D (±2%)	Peak Search*
☐	II E 2. f)	Method SA-3A	No limitations	Peak Search*
☐	II E 2. g)	Method SA-3A (alternative)	No limitations	Peak Search*

* Use the peak search function on the instrument to find the peak of the spectrum and record its value.
(see II F 2 in document [3] for details.)
The result is the Maximum PSD over 1 MHz reference bandwidth.
For devices operating in the band 5.725–5.85 GHz, the rules specify a measurement bandwidth of 500 kHz.

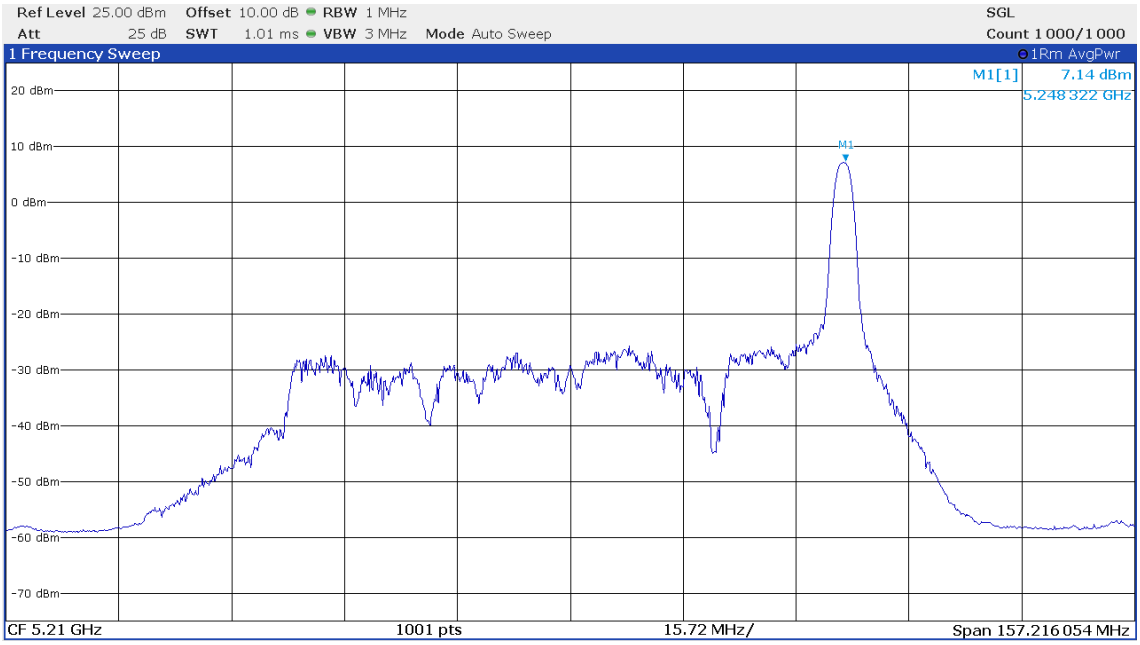
5.7.3 Test results (Maximum (average) Power Spectral Density) for FCC - 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Calculations:
Result [dBm/MHz]= Reading [dBm/MHz] + Correction 2 Antennas [dB]
+ Ext. Att [dB] + DCCF [dB]

Worst case plot (operation mode 2 – internal antenna):



Internal antenna

Operation mode	Reading [dBm/MHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result [dBm/MHz]	Limit conducted*2 [dBm/MHz]
1	7.1	3.0	0.0	0.0	10.1	10.3
2	**7.1**	**3.0**	**0.0**	**0.0**	**10.1**	10.3
3	-8.2	3.0	0.0	0.0	-5.2	10.3

*2 Limit = 11 dBm/MHz – 0.7 dB for Antenna gain correction, see Transmit Antenna Performance considerations for details

External antenna

Operation mode	Reading [dBm/MHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result [dBm/MHz]	Limit conducted*2 [dBm/MHz]
1	3.3	3.0	0.5	0.0	6.8	10.1
2	4.8	3.0	0.5	0.0	8.3	10.1
3	-12.1	3.0	0.5	0.0	-8.6	10.1

*2 Limit = 11 dBm/MHz – 0.7 dB for Antenna correction, see Transmit Antenna Performance considerations for details

Test: Passed

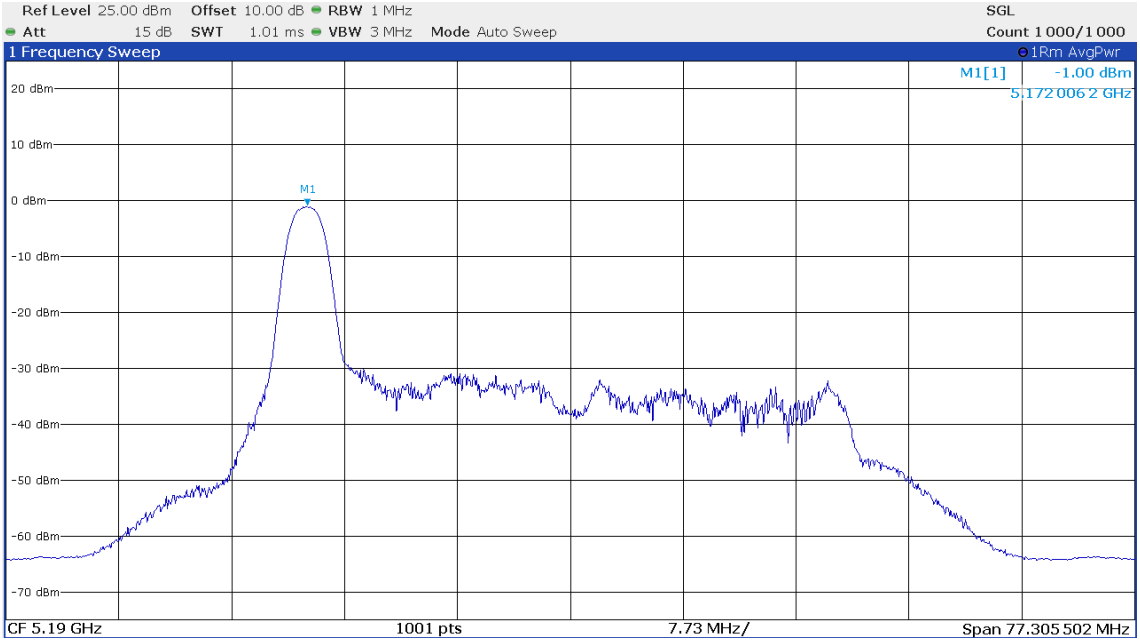
5.7.4 Test results (Maximum (average) Power Spectral Density) for ISED – 5150 – 5250 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Calculations:
Result [dBm/MHz]= Reading [dBm/MHz] + Correction 2 Antennas [dB]
+ Ext. Att [dB] + DCCF [dB] + Antenna gain [dBi]

Worst case plot (operation mode 4 – internal antenna):



Internal antenna

Operation mode	Reading [dBm/MHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Antenna gain [dBi]	Result [dBm/MHz]	Limit EIRP [dBm/MHz]
4	**-1.0**	**3.0**	**0.0**	**0.0**	**6.7**	**8.7**	10.0
5	-1.1	3.0	0.0	0.0	6.7	8.6	10.0
6	-16.3	3.0	0.0	0.0	6.7	-6.6	10.0

* The external attenuation is already considered with the reference 10.0 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator.

External antenna

Operation mode	Reading [dBm/MHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Antenna gain [dBi]	Result [dBm/MHz]	Limit EIRP [dBm/MHz]
29	-4.2	3.0	0.5	0.0	6.7	6.0	10.0
30	-4.3	3.0	0.5	0.0	6.7	5.9	10.0
31	-19.0	3.0	0.5	0.0	6.7	-8.8	10.0

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

Test: Passed

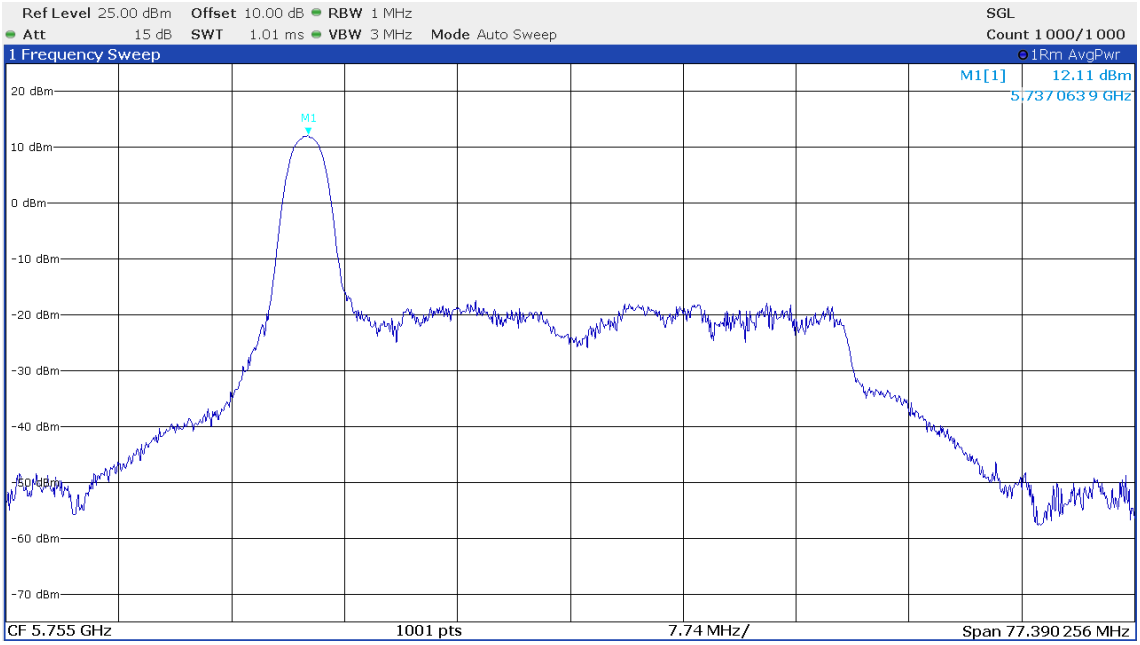
5.7.5 Test results (Maximum (average) Power Spectral Density) for FCC&ISED – 5725 – 5850 MHz

Ambient temperature:	22 °C - 24 °C
Relative humidity:	26 % – 65 %

Date	30.08.2023 – 12.09.2023
Tested by	P. NEUFELD / B. ROHDE

Calculations:
Result [dBm/MHz]= Reading [dBm/MHz] + Correction 2 Antennas [dB] + Ext. Att [dB] + DCCF [dB]

Worst case plot (operation mode 8 – internal antenna):



Internal antenna

Operation mode	Reading [dBm/500kHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result [dBm/500kHz]	Limit conducted*2 [dBm/500kHz]
7	12.1	3.0	0.0	0.0	15.1	29.3
8	**12.3**	**3.0**	**0.0**	**0.0**	**15.3**	29.3
9	-7.4	3.0	0.0	0.0	-4.4	29.3

*2 Limit = 30 dBm/MHz – 0.7 dB for Antenna correction, see Transmit Antenna Performance considerations for details

External antenna

Operation mode	Reading [dBm/500kHz]	Correction 2 Antennas [dB]	Ext. Att.* [dB]	DCCF [dB]	Result [dBm/500kHz]	Limit conducted*2 [dBm/500kHz]
7	8.5	3.0	0.5	0.0	12.0	29.3
8	8.6	3.0	0.5	0.0	12.1	29.3
9	-10.3	3.0	0.5	0.0	-6.8	29.3

* The external attenuation is already considered with the reference 10.0 dB level offset in the spectrum analyzer plot, which represents the attenuation of the 10 dB external attenuator.

*2 Limit = 30 dBm/MHz – 0.7 dB for Antenna correction, see Transmit Antenna Performance considerations for details

Test: Passed

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 – alternative procedure)	5.1.1.4	-
☐	Test setup (antenna port conducted)	5.1.2	-

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

5.1.2 Test method (Band edge – unrestricted bands)

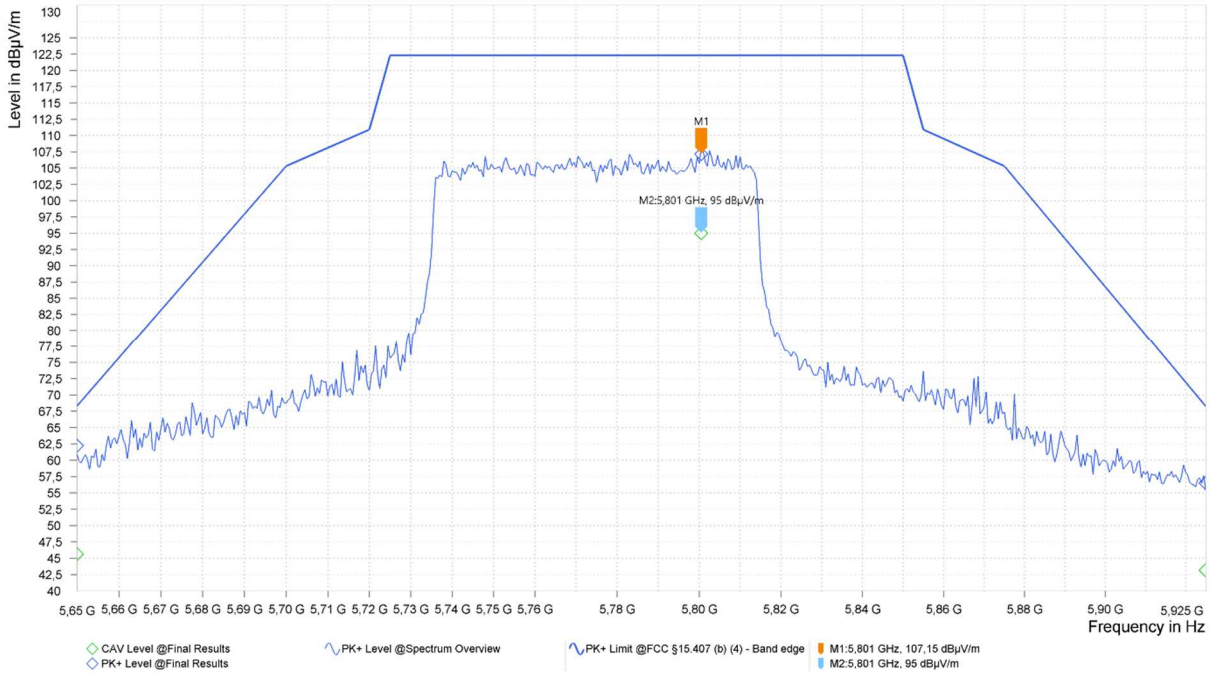
Test method (Band edge – unrestricted bands)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	II G 2, 3 & 5.	Unwanted emissions outside restricted bands	No limitations	-

5.1.3 Test results (Band edge – unrestricted bands) for FCC&ISED – 5725 – 5850 MHz

Ambient temperature:	24 °C
Relative humidity:	63 %

Date	06.09.2023
Tested by	B. ROHDE

Worst case plot (operation mode 9):



Lower+ upper band edge (operation mode 9):

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AVG Level [dBµV/m]	AVG Limit [dBµV/m]	AVG Margin [dB]	Correction [dB]	Polarization	Elevation [deg]	Azimuth [deg]
5,149.500	63.6	68.3	4.7	42.9	54.0	11.1	20.0	V	60	157
5,150.000	62.6	68.3	5.7	42.8	54.0	11.2	20.0	V	60	159

Test equipment (please refer to chapter 6 for details)
5-11, 14-15

5.1.4 Test setup (Band edge – restricted bands)

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

5.1.5 Test method (Band edge – restricted bands)

Test method (Band edge – restricted bands)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	II G 1 & 3 - 6	Unwanted Emissions in the restricted bands	No limitations	-

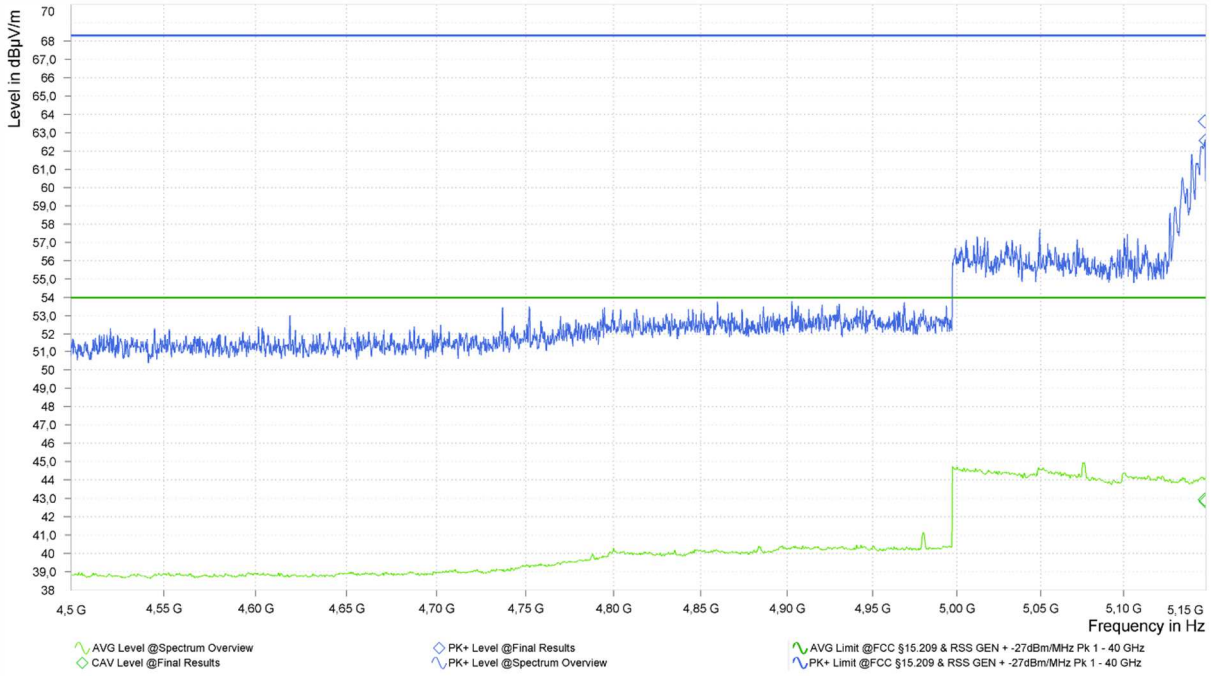
5.1.6 Test results (Band edge – restricted bands) for FCC - 5150 – 5250 MHz*

Ambient temperature:	24 °C
Relative humidity:	63 %

Date	06.09.2023
Tested by	B. ROHDE

* The tests in this band-edge were only performed for FCC power settings, because test with the highest output power settings result in the worst case for the tests.

Worst case plot (operation mode 1):



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

Lower band edge (operation mode 1):

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.

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	CAV Level [dBµV/m]	CAV: AVG Limit [dBµV/m]	CAV Margin [dB]	Correction [dB]	Polarization	Elevation [deg]	Azimuth [deg]
5,149.500	63.6	68.3	4.7	42.9	54.0	11.1	20.0	V	60	157
5,150.000	62.6	68.3	5.7	42.8	54.0	11.2	20.0	V	60	159

Test equipment (please refer to chapter 6 for details)
5 – 11, 14 - 15

5.2 Maximum unwanted emissions

5.2.1 Test setup (Maximum unwanted emissions)

Test setup			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated – alternative procedure)	5.1.1.4	f > 1 GHz
☐	Test setup (antenna port conducted)	5.1.2	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:	24 °C
Relative humidity:	63 %

Date	06.09.2023
Tested by	B. ROHDE

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 9 - 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)
4 - 11

5.2.3.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	24 °C
Relative humidity:	63 %

Date	06.09.2023
Tested by	B. ROHDE

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]

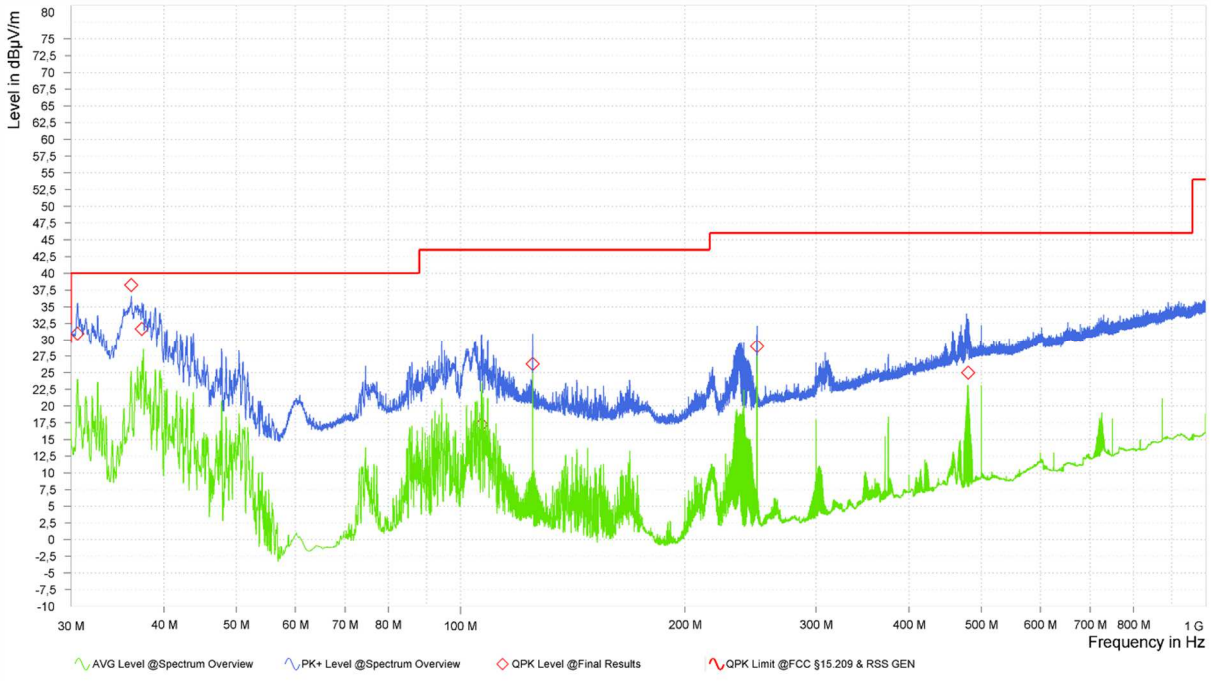
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

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]	Correction [dB/m]	Pol. (H/V)	Azimuth [deg]	Height [m]	Position #
38.970	23.5	40.0	16.5	20.7	V	356	1.41	1
43.800	27.2	40.0	12.8	17.7	V	86	1.02	1
106.710	26.7	43.5	16.8	17.7	V	207	1.10	1
125.010	27.0	43.5	16.5	17.2	H	92	3.14	1
249.990	28.6	46.0	17.4	17.3	V	197	1.05	1
499.980	20.8	46.0	25.2	24.5	V	296	1.03	1

(operation mode 2):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Correction [dB/m]	Pol. (H/V)	Azimuth [deg]	Height [m]	Position #
30.600	31.0	40.0	9.0	25.6	V	116	3.27	2
36.150	38.3	40.0	1.7	22.4	V	182	3.36	2
37.350	31.7	40.0	8.3	21.7	V	326	3.31	2
106.710	17.2	43.5	26.3	17.7	V	226	1.01	2
125.010	26.3	43.5	17.2	17.2	V	117	1.04	2
249.990	29.0	46.0	17.0	17.3	V	191	1.01	2

(operation mode 7):

Frequency [MHz]	Result (QP) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Correction [dB/m]	Pol. (H/V)	Azimuth [deg]	Height [m]	Position #
32.580	19.4	40.0	20.6	24.4	V	326	1.43	3
34.650	37.2	40.0	2.8	23.2	V	206	1.77	3
38.940	31.6	40.0	8.4	20.7	V	56	1.32	3
50.430	25.2	40.0	14.8	13.6	V	210	1.09	3
77.190	17.2	40.0	22.8	16.0	V	57	2.10	3
125.010	24.0	43.5	19.5	17.2	H	87	1.89	3

Test result: Passed

Test equipment (please refer to chapter 6 for details)
5 - 13

5.2.3.3 Test results (above 1 GHz)

Ambient temperature:	22 - 23°C
Relative humidity:	50 - 63 %

Date	31.08.2023 – 05.09.2023
Tested by	B. ROHDE

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

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

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

Remark: For the frequency range 5.15 – 5.25 GHz, only the worst-case emissions from the antenna port conducted pre-tests were tested in the radiated tests, namely 802.11ax40 modulation.
In the frequency range 5.725 – 5.85 GHz, no spurious emissions were found in the antenna port conducted pre-tests. Therefore, the emission with the highest PSD result was tested during the radiated measurements, namely the 802.11ax40 modulation.

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]

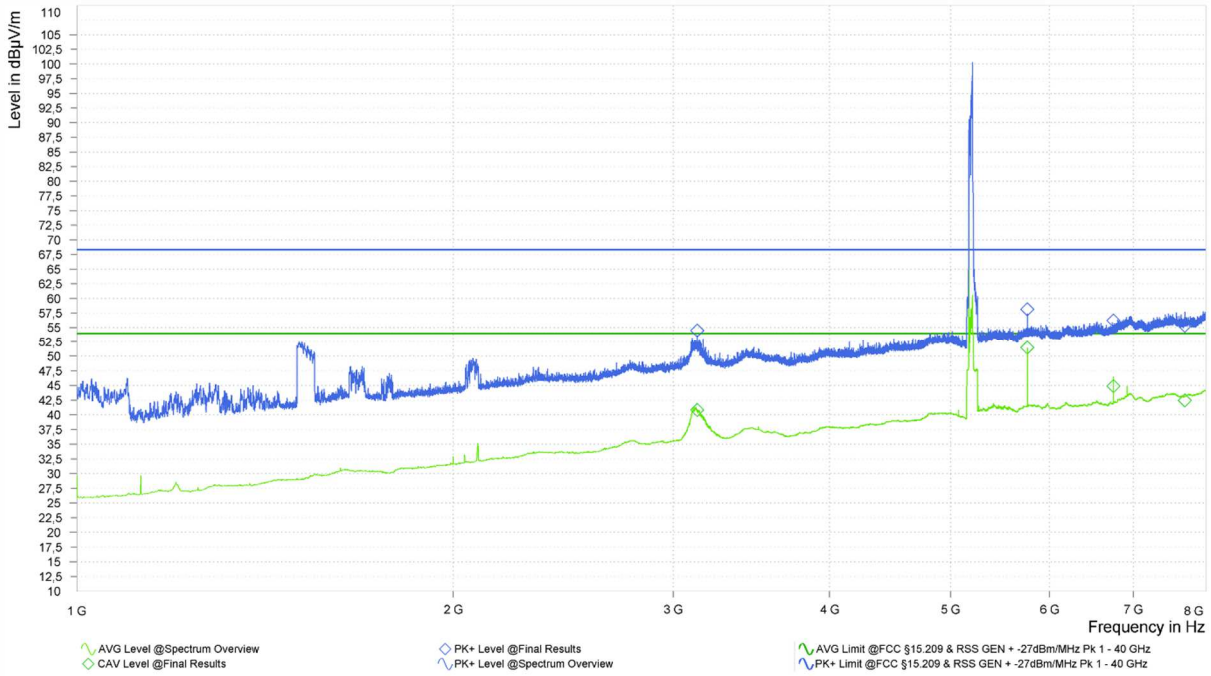
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF* [dB]
* (if applicable – only for Average values, that are fundamental related)

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

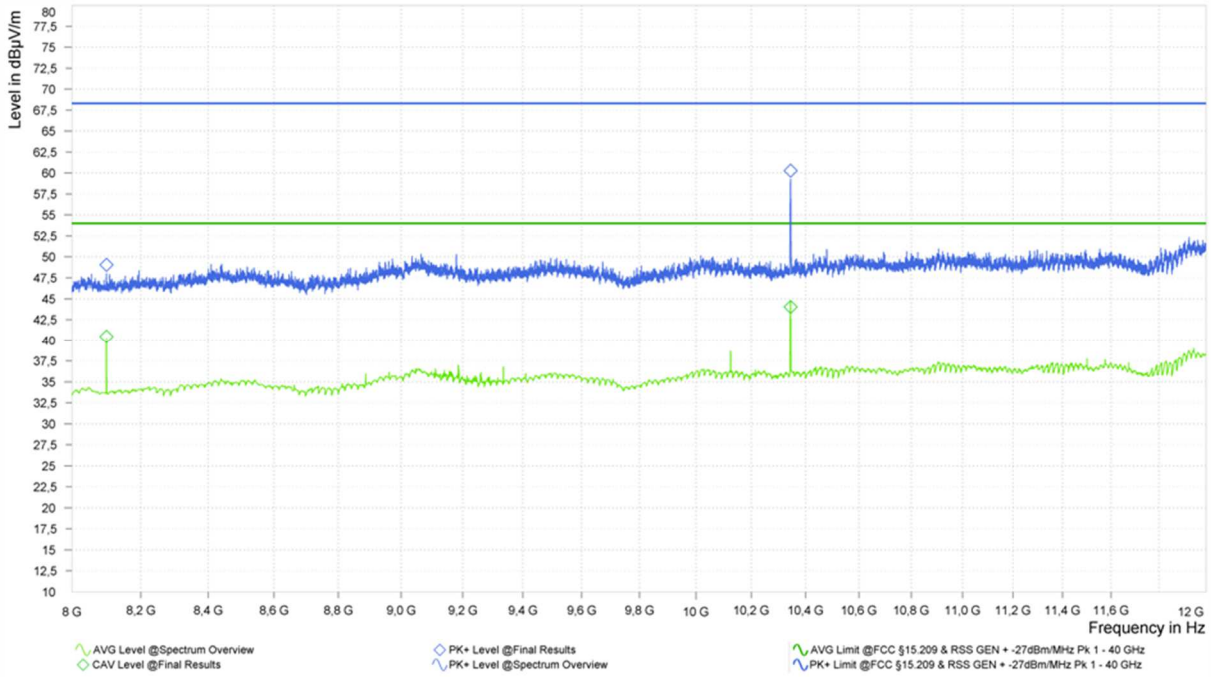
The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.
The top measured curve represents the peak measurement. The measured points marked with "◇" are frequency points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

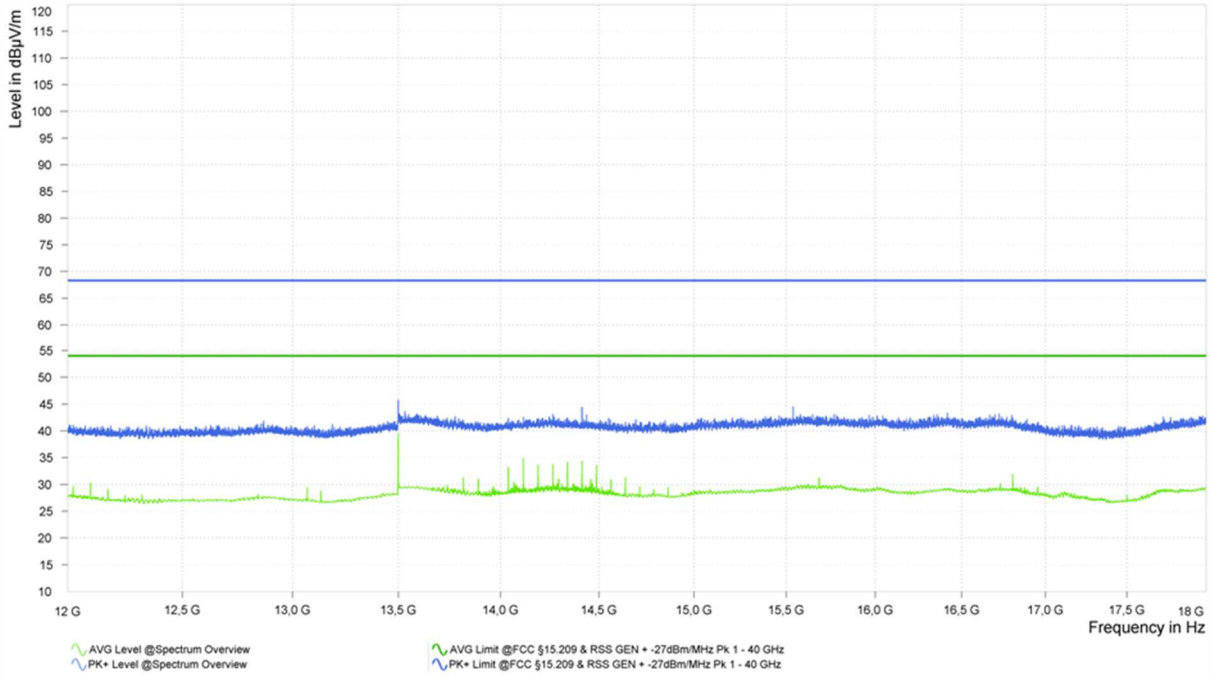
Spurious emissions from 1 GHz to 8 GHz (operation mode 1):



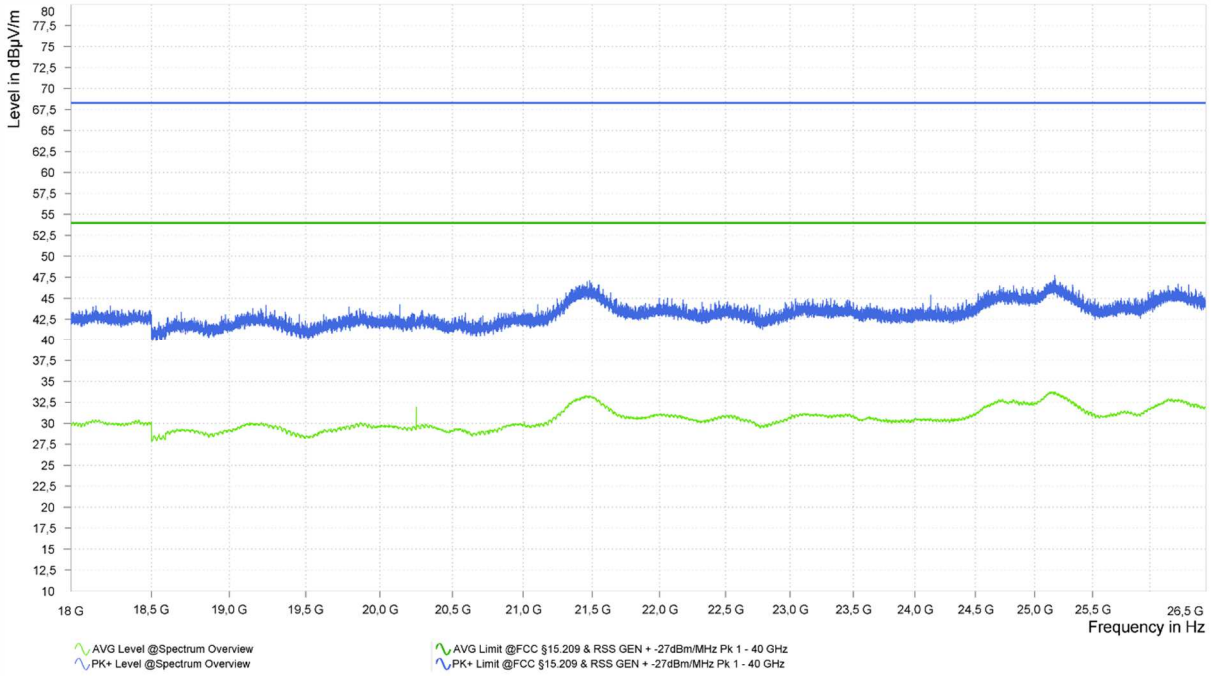
Spurious emissions from 8 GHz to 12 GHz (operation mode 1):



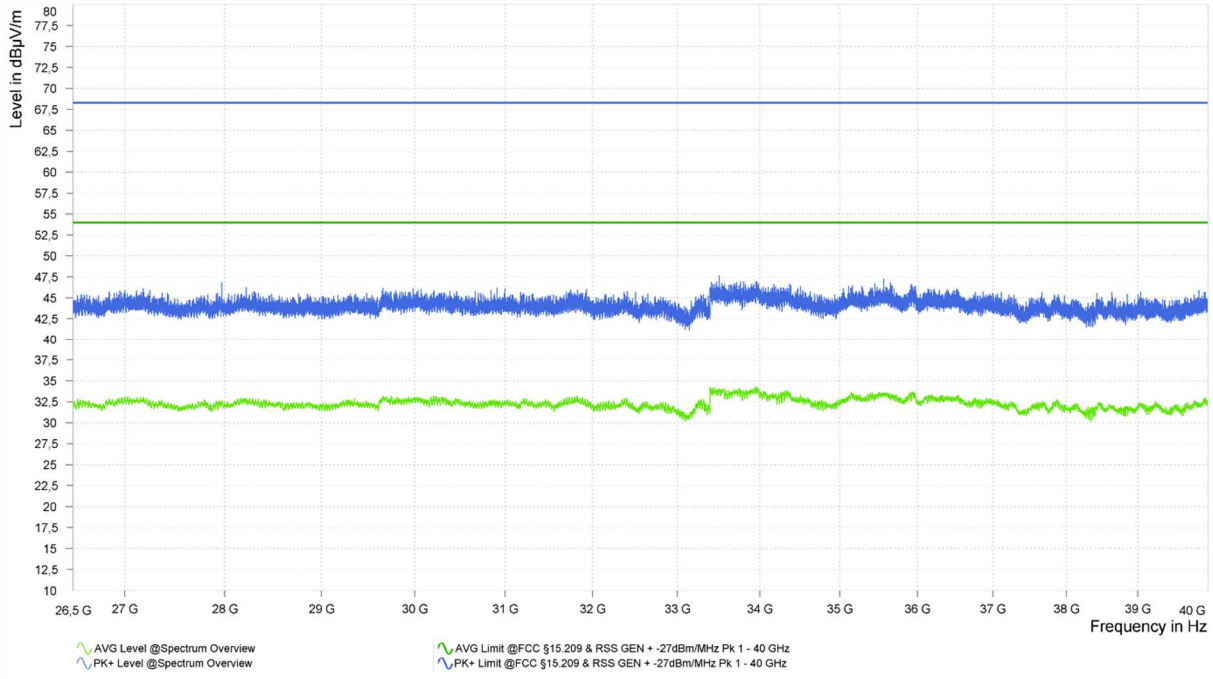
Spurious emissions from 12 GHz to 18 GHz (operation mode 1):



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

Operation mode 1:

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AV Level [dBµV/m]	AV Limit [dBµV/m]	AV Margin [dB]	Correction [dB]	Elevation [deg]	Azimuth [deg]
3,135.250	54.49	68.3	13.81	40.82	54.0	13.18	13.77	H	90
5,760.000	58.13	68.3	10.17	51.46	54.0	2.54	22.07	V	90
6,750.000	56.20	68.3	12.10	44.87	54.0	9.13	23.14	V	30
7,699.750	55.32	68.3	12.98	42.45	54.0	11.55	24.59	H	30
8,100.000	49.06	68.3	19.24	40.46	54.0	13.54	16.00	V	150
10,344.250	60.29	68.3	8.01	44.02	54.0	9.98	19.56	H	30

Operation mode 2:

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AV Level [dBµV/m]	AV Limit [dBµV/m]	AV Margin [dB]	Correction [dB]	Elevation [deg]	Azimuth [deg]
3,134.500	55.75	74.0	18.25	41.32	54.0	12.68	13.78	90	154
5,252.250	**73.31**	**74.0**	**0.69**	**47.26**	**54.0**	**6.74**	**20.30**	**60**	**134**
5,760.000	58.96	74.0	15.04	52.74	54.0	1.26	22.07	90	80
6,750.000	56.28	74.0	17.72	44.84	54.0	9.16	23.14	30	223
8,100.000	48.59	74.0	25.41	38.21	54.0	15.79	16.00	150	185
10,125.000	50.80	74.0	23.20	38.58	54.0	15.42	19.95	150	179
10,424.000	60.42	74.0	13.58	44.58	54.0	9.42	19.75	30	87

Operation mode 7:

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AV Level [dBµV/m]	AV Limit [dBµV/m]	AV Margin [dB]	Correction [dB]	Elevation [deg]	Azimuth [deg]
2,893.250	48.11	74.0	25.89	34.27	54.0	19.73	12.11	V	30
4,371.250	50.16	74.0	23.84	37.30	54.0	16.70	17.57	V	30
5,641.000	58.33	74.0	15.67	45.64	54.0	8.36	20.90	V	90
6,750.000	53.56	74.0	20.44	41.04	54.0	12.96	23.14	H	150
7,976.000	55.99	74.0	18.01	43.72	54.0	10.28	26.20	V	60
8,100.000	48.5	68.3	19.8	36.2	54.0	17.8	16.0	V	60
10,124.750	50.0	68.3	18.3	38.2	54.0	15.8	20.0	H	90
11,473.250	54.6	68.3	13.7	40.6	54.0	13.4	21.6	V	0

Operation mode 8:

Frequency [MHz]	PK+ Level [dBµV/m]	PK+ Limit [dBµV/m]	PK+ Margin [dB]	AV Level [dBµV/m]	AV Limit [dBµV/m]	AV Margin [dB]	Correction [dB]	Elevation [deg]	Azimuth [deg]
5,974.500	61.8	68.3	6.5	48.7	54.0	5.3	22.0	V	90
6,230.250	58.2	68.3	10.1	44.9	54.0	9.1	22.6	V	90
6,543.500	54.8	68.3	13.5	41.8	54.0	12.2	23.3	V	120
8,100.000	48.1	68.3	20.2	38.3	54.0	15.7	16.0	H	30
10,124.750	49.7	68.3	18.6	37.2	54.0	16.8	20.0	V	150
11,554.250	53.3	68.3	15.0	39.8	54.0	14.2	21.4	V	0

Test result: Passed

Test equipment (please refer to chapter 6 for details)
5 - 11, 14 - 21

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	19.11.2021	11.2023
2	Attenuator	WA54-10-12	Weinschel	-	481620	Calibration not necessary	
3	RF cable	SF 102	Huber+Suhner	510211/2	483032	Calibration not necessary	
4	loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
5	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
6	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
7	Antennasupport	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
8	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
9	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
10	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
11	Test software M276	Elektra	Rohde&Schwarz	101381	483755	Calibration not necessary	
12	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
13	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
14	Low Noise Amplifier 100 MHz - 18 GHz	LNA-30-00101800-25-10P	Narda-Miteq	2110917	482967	18.02.2022	02.2024
15	Log.-Per. antenna	HL050	Rohde & Schwarz	100908	482977	22.09.2022	09.2025
16	Low Noise Amplifier 12 GHz - 18 GHz	LNA-30-12001800-13-10P	Narda-Miteq	2089798	482968	Calibration not necessary	
17	Standard Gain Horn 20 dB, 12 GHz-18 GHz	18240-20	Flann	267220	483025	Calibration not necessary	
18	Low Noise Amplifier 18 GHz - 26.5 GHz	LNA-30-18002650-20-10P	Narda-Miteq	2110911	482969	18.02.2022	02.2024
19	Standard Gain Horn 20 dB, 18 GHz -26 GHz	20240-20	Flann	266399	483026	Calibration not necessary	
20	Low Noise Amplifier 26 MHz – 40 GHz	LNA-30-26004000-27-10P	Narda-Miteq	2110293	482970	18.02.2022	02.2024
21	Standard Gain Horn 20 dB, 26 GHz - 40 GHz	22240-20	Flann	266405	483027	Calibration not necessary	
22	Tunable notch filter	WRCJ5100/5850-20/50-8SSK	Wainwright Instruments GmbH	1	480681	Calibration not necessary	

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	01.03.2023	28.02.2026
Semi anechoic chamber M276	483227	1 -18 GHz	SVSWR	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	28.02.2023	27.02.2026

8 Report History

Report Number	Date	Comment
F231447E1	07.09.2023	Initial Test Report
-	-	-

9 List of Annexes

Annex A Test Setup Photos 14 pages