

# Test Report

Report Number:

**F220818E4**

Equipment under Test (EUT):

**NT03 RMI-RD**

Applicant:

**Topcon Electronics GmbH & Co KG**

Manufacturer:

**Topcon Electronics GmbH & Co KG**



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 (DTs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices
- [5] **RSS-Gen, Issue 5 Amendment 2 (2021-02)** General Requirements for Compliance of Radio Apparatus

## 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:

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Signature

Reviewed and  
approved by:

---

Signature

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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.

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# 1 Identification

## 1.1 Applicant

Name:	Topcon Electronics GmbH & Co KG
Address:	Industriestr. 7, 65366 Geisenheim
Country:	Germany
Name for contact purposes:	-
Phone:	06722-4026-0
eMail address:	dl-opus-info@topcon.com
Applicant represented during the test by the following person:	-

## 1.2 Manufacturer

Name:	Topcon Electronics GmbH & Co KG
Address:	Industriestr. 7, 65366 Geisenheim
Country:	Germany
Name for contact purposes:	-
Phone:	06722-4026-0
eMail address:	dl-opus-info@topcon.com
Manufacturer represented during the test by the following person:	-

## 1.3 Test Laboratory

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

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

## 1.4 EUT (Equipment under Test)

Test object: *	Tractor Terminal
Model name: *	NT03 RMI-RD
Model number: *	OPNT03VA3CAN001
Order number: *	OPNT03VA3CAN001
FCC ID: *	WR4-NT03RMIRD
IC certification number: *	6050B-NT03RMIRD
PMN: *	NT03 RMI-RD
HVIN: *	NT03 RMI-RD
FVIN: *	-

	EUT number		
	1	2	3
Serial number: *	2212312AA	-	-
PCB identifier: *	APNT03MBF01_BA	-	-
Hardware version: *	BA	-	-
Software version: *	4.1.15-nt03-2.2.0-1 NT03 Test-App (Build May 12 2022)	-	-

\* Declared by the applicant

One EUT was used for all tests.

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

## 1.5 Technical Data of Equipment

General EUT data			
Power supply EUT: *	DC		
Supply voltage EUT: *	$U_{nom} = 12 \text{ V}_{DC}$	$U_{min} = 5.5 \text{ V}_{DC}$	$U_{max} = 16 \text{ V}_{DC}$
Temperature range: *	-20°C to +70°C		
Lowest / highest internal clock frequency: *	32768 Hz / 2480 MHz		

Ports / Connectors				
Identification	Connector		Length during test	Shielding (Yes / No)
	EUT	Ancillary		
V <sub>cc</sub>	Amphenol AMPSEAL 23 Pin	Banana plug (4 mm)	1.85 m	No
RS232	DSub (RS232)	DSub (RS232)	1.85 m	No
CAN 1 - 4	DSub (RS232)	DSub (RS232)	-	No
Digital IO	Amphenol AMPSEAL 23 Pin	Banana plug (4 mm)	-	No
Frequency input	Amphenol AMPSEAL 23 Pin	Banana plug (4 mm)	-	No
Analog input	Amphenol AMPSEAL 23 Pin	Banana plug (4 mm)	-	No
Automotive Ethernet	M8	M8	-	No
Video	M12	M12	-	Yes
USB 2.0	USB (Type A)	Mini-USB	-	Yes

Bluetooth® frequencies			
Channel 00	2402 MHz	Channel 01	2403 MHz
Channel 02	2404 MHz	Channel 03	2405 MHz
...	...	...	...
...	...	...	...
Channel 37	2439 MHz	Channel 38	2440 MHz
...	...	...	...
...	...	...	...
Channel 75	2477 MHz	Channel 76	2478 MHz
Channel 77	2479 MHz	Channel 78	2480 MHz

Bluetooth® radio mode	
Fulfils radio specification: *	Bluetooth 4.2 + EDR
Radio chip: *	PAN1316C (ENW89823C4KF) Panasonic
Antenna type: *	2.4 GHz Flex PCB Antenna with 105mm 1.37mm coaxial cable
Antenna name: *	FXP76B.07.0105C.et
Antenna gain: * <sup>2</sup>	-3.1 dBi (typical)
Antenna connector: *	IPEX MHFI (U.FL) on main PCB
Supply voltage module: *	$U_{nom} = 1.8\text{ V}$ $U_{min} = 1.62\text{ V}$ $U_{max} = 1.92\text{ V}$
Type of modulation: *	BT (1 Mbps PHY)      GFSK
	BT (2 Mbps PHY) $\pi/4$ -DQPSK
	BT (3 Mbps PHY)      8DPSK
Operating frequency range: *	BT (1 Mbps PHY)      2402 – 2480 MHz
	BT (2 Mbps PHY)      2402 – 2480 MHz
	BT (3 Mbps PHY)      2402 – 2480 MHz
Number of channels: *	BT (1 Mbps PHY)      79 (1 MHz channel spacing)
	BT (2 Mbps PHY)      79 (1 MHz channel spacing)
	BT (3 Mbps PHY)      79 (1 MHz channel spacing)

\* As declared by the applicant

\*<sup>2</sup> As shown by antenna test report as provided by the applicant



### 1.5.1 Ancillary Equipment / Equipment used for testing

Equipment used for testing	
Laptop: *1	Dell Latitude E5510
Power supply: *2	Laboratory power supply
RS232 Converter: *2	Opto RS232, Mk Messtechnik (PM No. 482206)

\*1 Provided by the applicant

\*2 Provided by the laboratory

Ancillary Equipment	
-	-

### 1.6 Dates

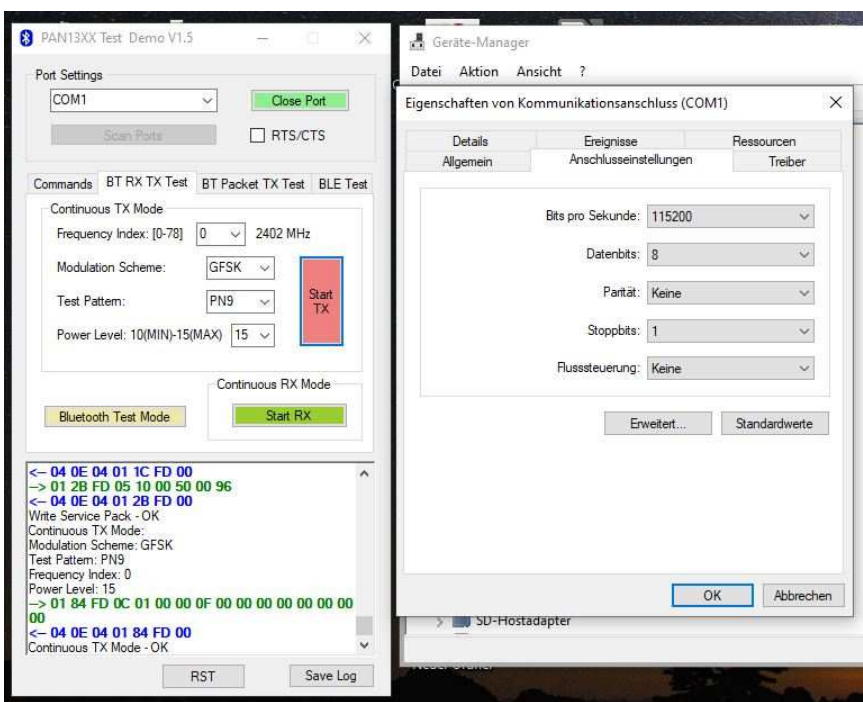
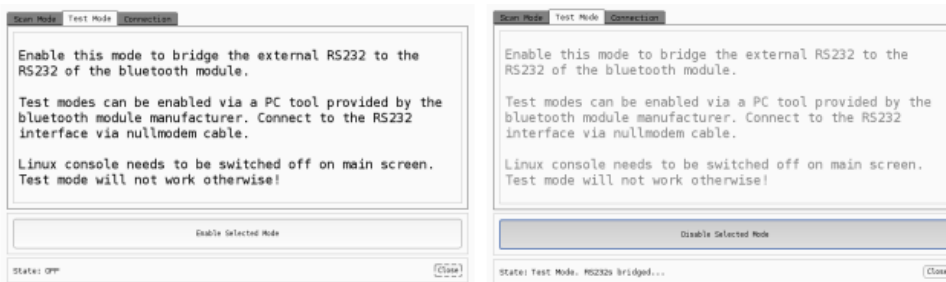
Date of receipt of test sample:	17.05.2022
Start of test:	18.05.2022
End of test:	31.05.2022

## 2 Operational States

### 2.1 Description of function of the EUT

The EUT is human interface device for vehicular use cases in the agriculture market. Bluetooth is used for data transfer between the EUT and a second device similar to the EUT, as well as other controllers.

The EUT:



### 2.1.1 Operation modes

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate	Power setting
1	Bluetooth®	2402	0	GFSK	1 Mbit/s	"14"
2	Bluetooth®	2440	38	GFSK	1 Mbit/s	"14"
3	Bluetooth®	2480	78	GFSK	1 Mbit/s	"14"
4	Bluetooth®	2402	0	$\pi/4$ -DQPSK	2 Mbit/s	"14"
5	Bluetooth®	2440	38	$\pi/4$ -DQPSK	2 Mbit/s	"14"
6	Bluetooth®	2480	78	$\pi/4$ -DQPSK	2 Mbit/s	"14"
7	Bluetooth®	2402	0	8DPSK	3 Mbit/s	"14"
8	Bluetooth®	2440	38	8DPSK	3 Mbit/s	"14"
9	Bluetooth®	2480	78	8DPSK	3 Mbit/s	"14"
10	Bluetooth®	2402 - 2480	0 - 78	GFSK	1 Mbit/s	"14"
11	Bluetooth®	2402 - 2480	0 - 78	$\pi/4$ -DQPSK	2 Mbit/s	"14"
12	Bluetooth®	2402 - 2480	0 - 78	8DPSK	3 Mbit/s	"14"

## 3 Additional Information

The EUT was not labeled as required by FCC / IC.

## 4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-247 [4] RSS-Gen [5]	Tested EUT	Status
Maximum peak conducted output power	2400.0 - 2483.5	15.247 (b) (1)	5.4 (b) [4]	1	Passed
20 dB bandwidth	2400.0 - 2483.5	15.247 (a) (1)	5.1 (a) [4]	1	Passed
Carrier frequency separation	2400.0 - 2483.5	15.247 (a) (1)	5.1 (b) [4]	1	Passed
Number of hopping channels	2400.0 - 2483.5	15.247 (a) (1) (iii)	5.1 (d) [4]	1	Passed
Dwell time	2400.0 - 2483.5	15.247 (a) (1) (iii)	5.1 (d) [4]	1	Passed
Band edge compliance	2400.0 - 2483.5	15.247 (d) 15.205 (a) 15.209 (a)	5.5 [4]	1	Passed
Maximum unwanted emissions	0.009 – 26,500*	15.247 (d) 15.205 (a) 15.209 (a)	8.9 [5]	1	Passed*
Antenna requirement	-	15.203 15.247 (b)	6.8 [5] 5.4 (f) (ii) [4]	1	Passed
Conducted emissions on supply line	0.15 – 30	15.207 (a)	8.8 [5]	-	_*2

- \*: As declared by the applicant the highest radio clock frequency is 2.48 GHz. Therefore, the radiated emission measurement must be carried out up to 10<sup>th</sup> of the highest radio clock frequency in this case 26.5 GHz.
- \*2 Not tested, because not applicable. As declared by the applicant the EUT is vehicular use only.

## 5 Results

### 5.1 Test setups

#### 5.1.1 Radiated: 9 kHz to 30 MHz

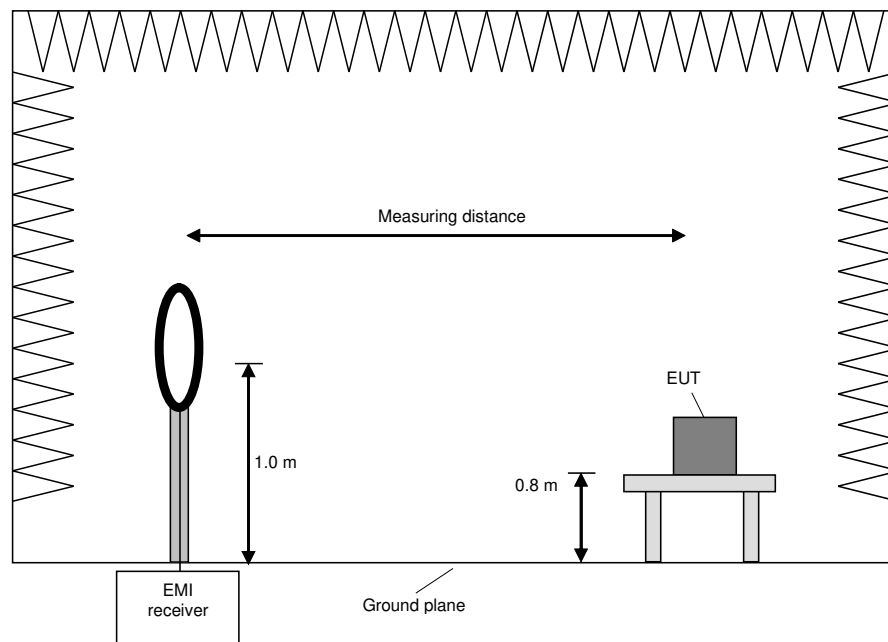
##### 5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

In the first stage a preliminary measurement is performed in a semi-anechoic chamber at a measuring distance of 3 meters. Table-top 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 with [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.

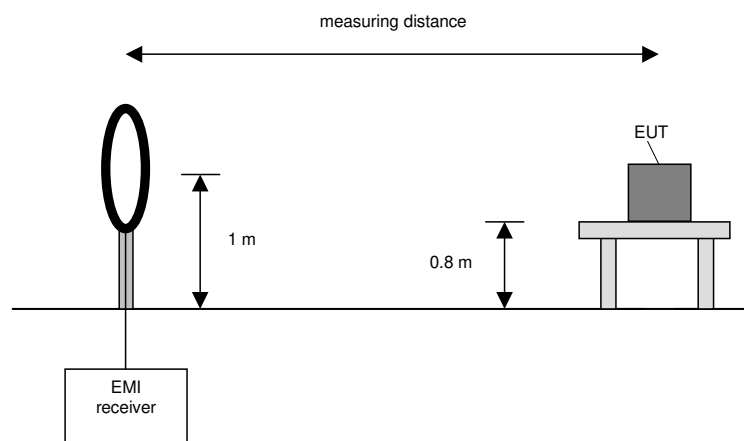
### 5.1.1.2 Final measurement 9 kHz to 30 MHz

In the second stage a final measurement is performed on an open area test site with no conducting ground plane at a measuring distance of 3 m, 10 m, or 30 m. If the standard requires larger measuring distances for a given frequency, the results are extrapolated according to section 15.31 (f) (2) [2]. The final measurement is performed with an EMI receiver set to Quasi-Peak detector, except for the frequency bands 9 kHz to 90 kHz and 110 kHz to 490 kHz where an Average detector is used according section 15.209 (d) [2].

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

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

Frequency range	Resolution bandwidth	Measuring time
9 kHz to 150 kHz	200 Hz	1 s
150 kHz to 30 MHz	9 kHz	1 s



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.

## 5.1.2 Radiated: 30 MHz to 1 GHz

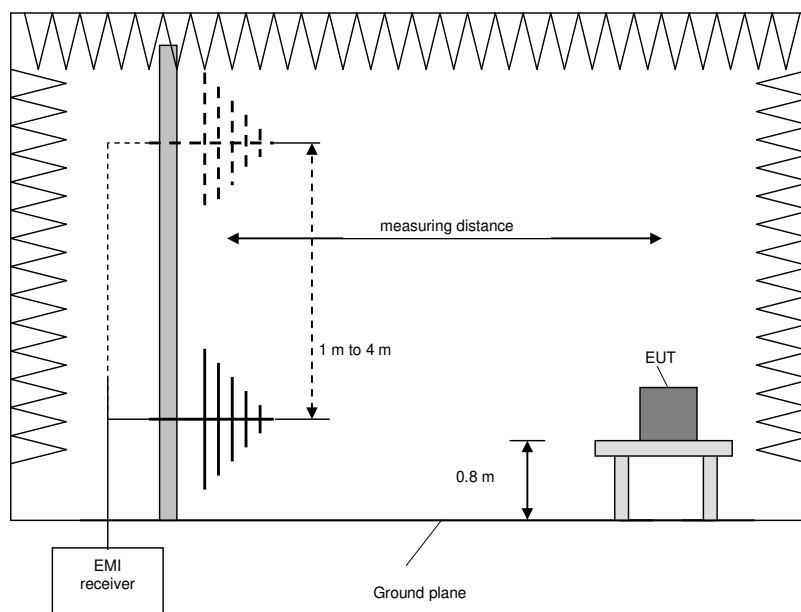
### 5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

The preliminary and final measurements are performed in a semi-anechoic chamber with a metal ground plane at a measuring distance of 3 meters. Table-top 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 with [1].

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	Measuring time	Detector
Preliminary measurement	30 MHz to 1 GHz	30 kHz	120 kHz	-	Peak Average
Frequency peak search	$\pm 120$ kHz	10 kHz	120 kHz	1 s	Peak
Final measurement	30 MHz to 1 GHz	-	120 kHz	1 s	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.

### 5.1.3 Radiated: 1 GHz to 40 GHz

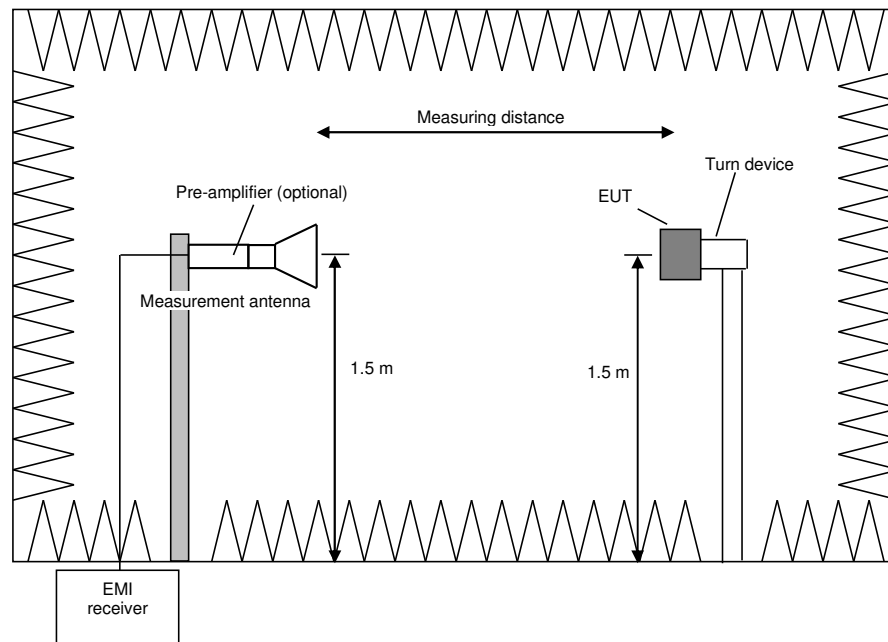
#### 5.1.3.1 Preliminary and final measurement 1 to 40 GHz

The preliminary and final measurements are performed in a fully anechoic chamber at a measuring distance of 3 meters. Table-top devices are set up on a non-conducting turn device at the height of 1.5 m. The setup of the equipment under test is in accordance with [1].

During the tests the EUT is rotated in the range of 0 ° to 360 ° and the measuring antenna is set to horizontal and vertical polarization to find the maximum level of emissions. After these steps, the measurement is repeated after reorientating the EUT in 30 ° steps.

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

Test	Frequency range	Step-size	Resolution bandwidth	Measuring time	Detector
Preliminary measurement	1 - 40 GHz	250 kHz	1 MHz	-	Peak Average
Final measurement	1 - 40 GHz	-	1 MHz	100 ms	Peak Average



Procedure preliminary measurement:

The following procedure is used:

- 1) Monitor the frequency range at horizontal polarisation of the measuring antenna and an EUT / turntable azimuth of 0 °.
- 2) Rotate the EUT by 360° to maximize the detected signals.
- 3) Repeat steps 1 to 2 with the vertical polarisation of the measuring antenna.
- 4) Repeat steps 1 to 3 with the EUT reorientated by an angle of 30° (60°, 90°, 120° and 150°), according to 6.6.5.4 in [1].
- 5) The highest values for each frequency are saved by the software, including the measuring antenna polarization, the turntable azimuth and the turn device elevation for that value.

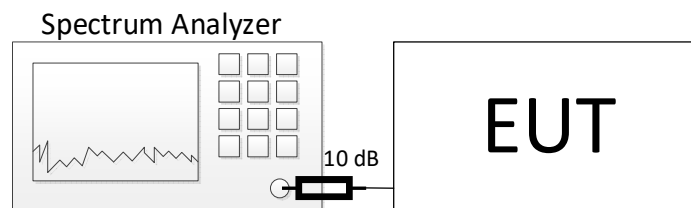
Procedure final measurement:

The following procedure is used:

- 1) Set the turntable and the turn device to the position which leads to the highest emission for the first frequency identified in the preliminary measurements.
- 2) Set the measurement antenna to the polarisation which leads to the highest emission for the first frequency identified in the preliminary measurements.
- 3) Set the spectrum analyser to EMI mode with Peak and Average detector activated.
- 4) 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.
- 5) The final measurement is performed at the worst-case turntable azimuth.
- 6) Repeat steps 1 to 5 for each frequency detected during the preliminary measurements.

#### 5.1.4 Conducted: Antenna port

Test setup (conducted)		
Used	Antenna connector	Comment
<input type="checkbox"/>	Temporary antenna connector	As provided by the applicant
<input checked="" type="checkbox"/>	Normal antenna connector	



The 10 dB external attenuation are considered in all relevant plots

## 5.2 Duty cycle

As declared by the applicant, the duty cycle in test modes #1-#9 is 100%, therefore no DCCF is applicable.

## 5.3 Transmit antenna performance considerations

Test setup (Transmit antenna performance considerations)		
Integral antenna	Antenna gain $\leq$ 6dBi	Comment
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	No output power reduction necessary

## 5.4 20 dB bandwidth

### 5.4.1 Test setup (20 dB bandwidth)

Test setup			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	-
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	-

### 5.4.2 Test method (20 dB bandwidth)

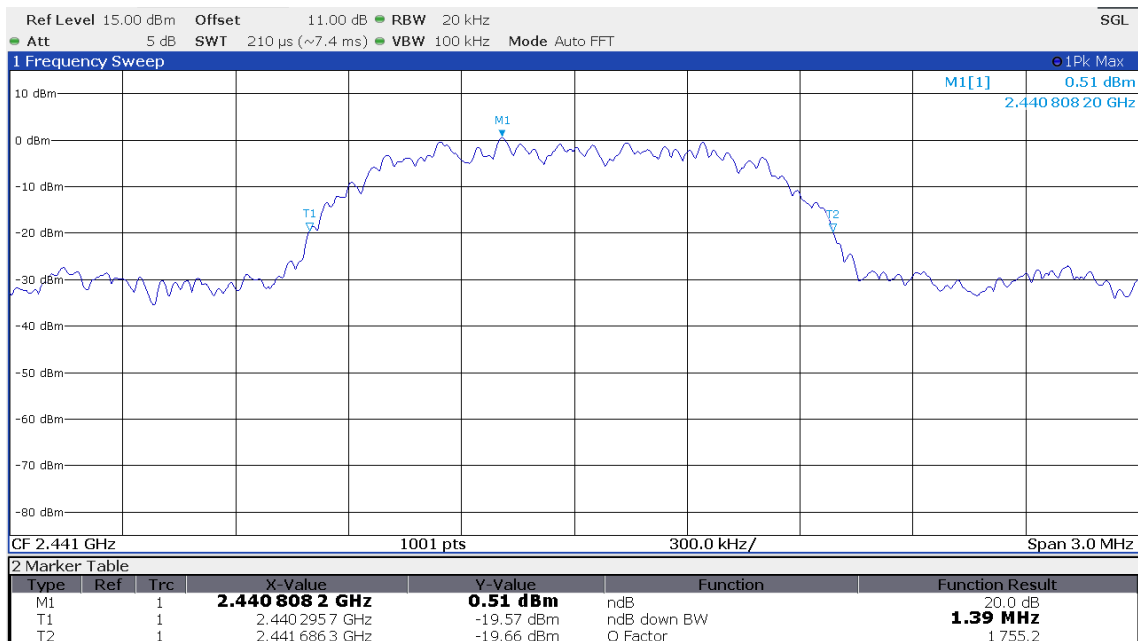
Test method (20 dB bandwidth)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	6.9.2	Occupied bandwidth - relative measurement procedure	No limitations	-

### 5.4.3 Test results (20 dB bandwidth)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	18.05.2022
Tested by:	P. NEUFELD

Worst case plot (operation mode 5):



Operation mode #	20 dB bandwidth [MHz]
1	0.8122
2	0.8122
3	0.8122
4	1.3876
5	<b>1.3906</b>
6	<b>1.3906</b>
7	1.3786
8	1.3756
9	1.3756

Test result: Passed

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

## 5.5 Occupied bandwidth – power bandwidth (99%)

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

Test setup (Occupied bandwidth – power bandwidth (99%))			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	-
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	-

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

Test method (Occupied bandwidth – power bandwidth (99%))				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input type="checkbox"/>	6.9.2	Relative measurement procedure		n-dB down
<input checked="" type="checkbox"/>	6.9.3	Power bandwidth (99%)	*1	99% power function

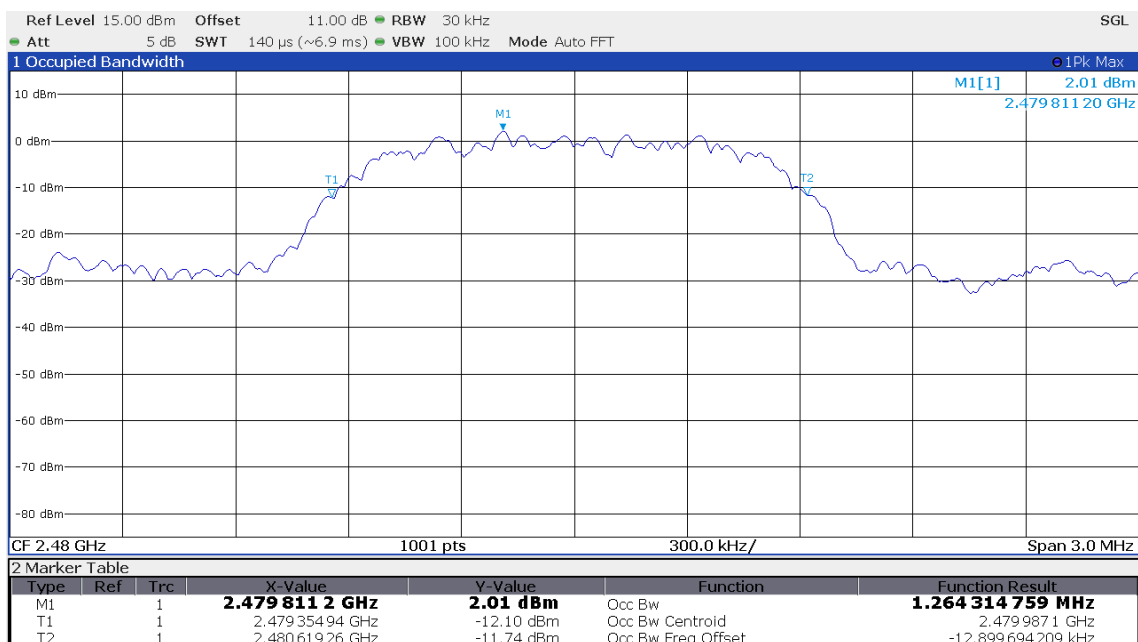
\*1 See RSS-GEN Issue 5 (2018-05) sub-clause 6.7 for details.

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

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	18.05.2022
Tested by:	P. NEUFELD

Worst case plot (operation mode 6):



Operation mode #	99% bandwidth [MHz]
1	0.874895
2	0.874587
3	0.867012
4	1.252543
5	1.256699
6	<b>1.264315</b>
7	1.251166
8	1.255164
9	1.262286

Test result: Passed

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



## 5.6 Carrier frequency separation

### 5.6.1 Test setup (Carrier frequency separation)

Test setup (Carrier frequency separation)			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	-
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	-

### 5.6.2 Test method (Carrier frequency separation)

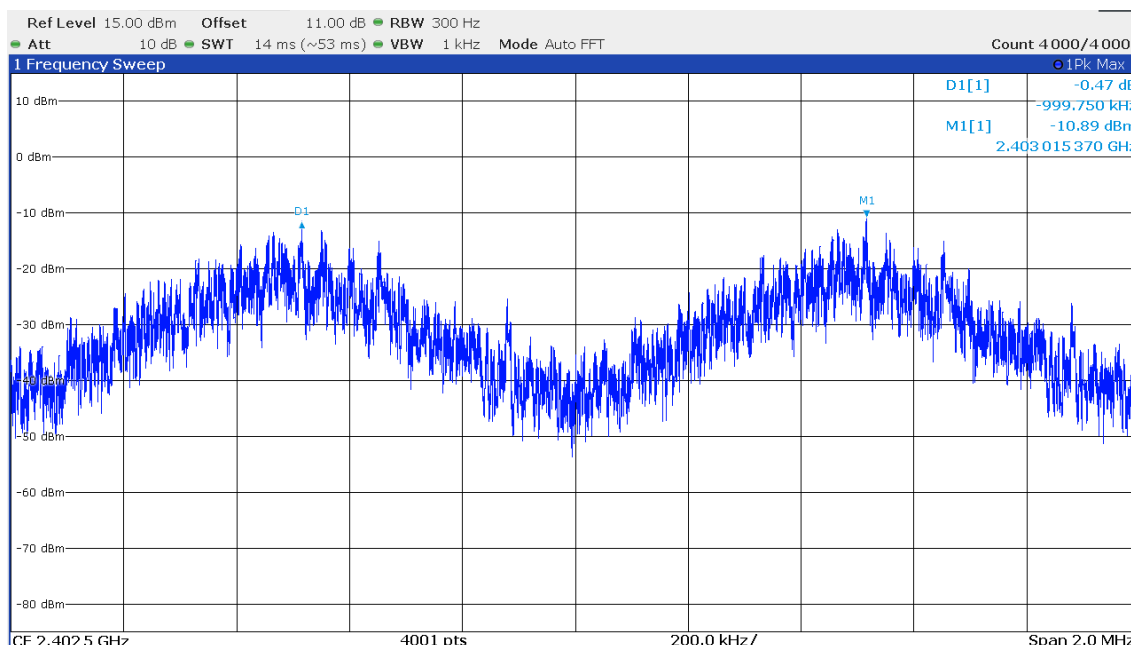
Test method (Carrier frequency separation)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	7.8.2	Carrier frequency separation	EUT hopping	-

### 5.6.3 Test results (Carrier frequency separation)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	18.05.2022
Tested by:	P. NEUFELD

Worst case plot (operation mode 1):



Operation mode	Channel frequency [MHz]	Channel Separation* [kHz]	Minimum limit* <sup>2</sup> [kHz]
1	2402	999.750	541.567
2	2441	999.750	541.567
3	2480	1000.250	541.567

\* The test will be 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.

\*<sup>2</sup> The worst-case limit occurs for the modulation with the highest 20 dB bandwidth, which is  $\pi/4$  DPSK /8DPSK modulation or 2 Mbps/3 Mbps. Limit is  $2/3 * 20$  dB BW.

Test result: Passed

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

## 5.7 Number of hopping frequencies

### 5.7.1 Test setup (Number of hopping frequencies)

Test setup (Number of hopping frequencies)			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	-
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	-

### 5.7.2 Test method (Number of hopping frequencies)

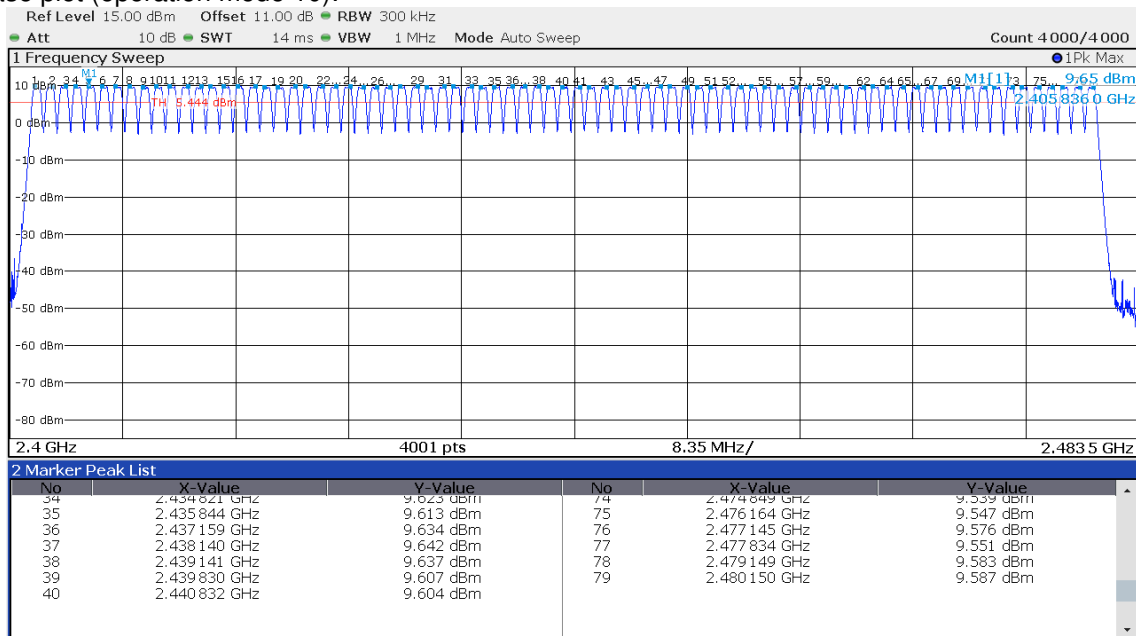
Test method (Number of hopping frequencies)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	7.8.3	Number of hopping frequencies	EUT hopping	-

### 5.7.3 Test results (Number of hopping frequencies)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	18.05.2022
Tested by:	P. NEUFELD

Worst case plot (operation mode 10):



Number of hopping frequencies*	Limit (minimum)
79	15

\* Since the number 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 result: Passed

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



Operation mode	Paket type	Worst case Hopping channels	Hops / second	Transmit time / hop [ms]	Tx On / 1s* [ms]	Limit Tx On / s [ms]
10	DH5	15	106.67	2.219	236.7	400
11	2DH5	15	106.67	1.198	127.8	400
12	3DH5	15	106.67	0.853	91.0	400

Max Tx time for a single Bluetooth slot (1 hop): 625  $\mu$ s.

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  $\mu$ s per hop -> 1 s / 625  $\mu$ s): 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 in 1 second in milliseconds

Test result: Passed

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

## 5.9 FHS fundamental emission output power

### 5.9.1 Test setup (FHS fundamental emission output power)

Test setup (FHS fundamental emission output power)			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	-
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	-

### 5.9.2 Test method (FHS fundamental emission output power)

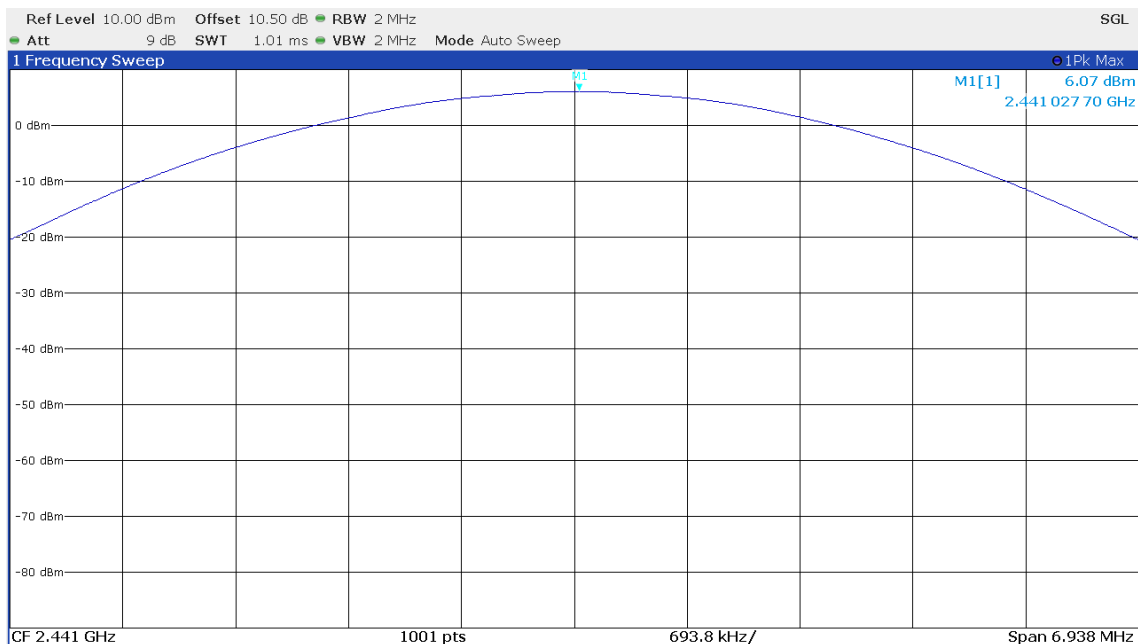
Test method (FHS fundamental emissions output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	7.8.5	Output power test procedure for frequency-hopping spread-spectrum (FHSS) devices	No limitations	-

### 5.9.3 Test results (FHS fundamental emission output power)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	18.05.2022
Tested by:	P. NEUFELD

Worst case plot (operation mode 8):



Operation mode	Reading [dBm]	Corr. Fact.* [dB]	Result [dBm]	Ant gain [dBi]	Calc EIRP [dBm]	Limit [dBm]	Result
1	5.3	0.0	5.3	-3.1	2.2	30	Passed
2	5.4	0.0	5.4	-3.1	2.3	30	Passed
3	5.3	0.0	5.3	-3.1	2.2	30	Passed
4	5.8	0.0	5.8	-3.1	2.7	30	Passed
5	5.6	0.0	5.6	-3.1	2.5	30	Passed
6	5.6	0.0	5.6	-3.1	2.5	30	Passed
7	5.9	0.0	5.9	-3.1	2.8	30	Passed
8	6.1	0.0	<b>6.1</b>	-3.1	<b>3.0</b>	30	Passed
9	5.8	0.0	5.8	-3.1	2.7	30	Passed

\* External cables, attenuation etc. (cable attenuation in offset included)

Calc EIRP [dBm] = Result [dBm] + Ant gain [dBi]

Test result: Passed

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



## 5.10 FHS band-edge emission measurements

### 5.10.1 Test setup (Band edge – unrestricted bands)

Test setup (Band edge – unrestricted bands)			
Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.4	

### 5.10.2 Test method (Band edge – unrestricted bands)

Test method (Band edge – unrestricted bands)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	11.11.	20 dBc (Peak)	Peak power	*1
<input type="checkbox"/>	11.11.	30 dBc (Average)	RMS power	*2

\*1 As declared in "47 CFR 15.247(d)" in any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits

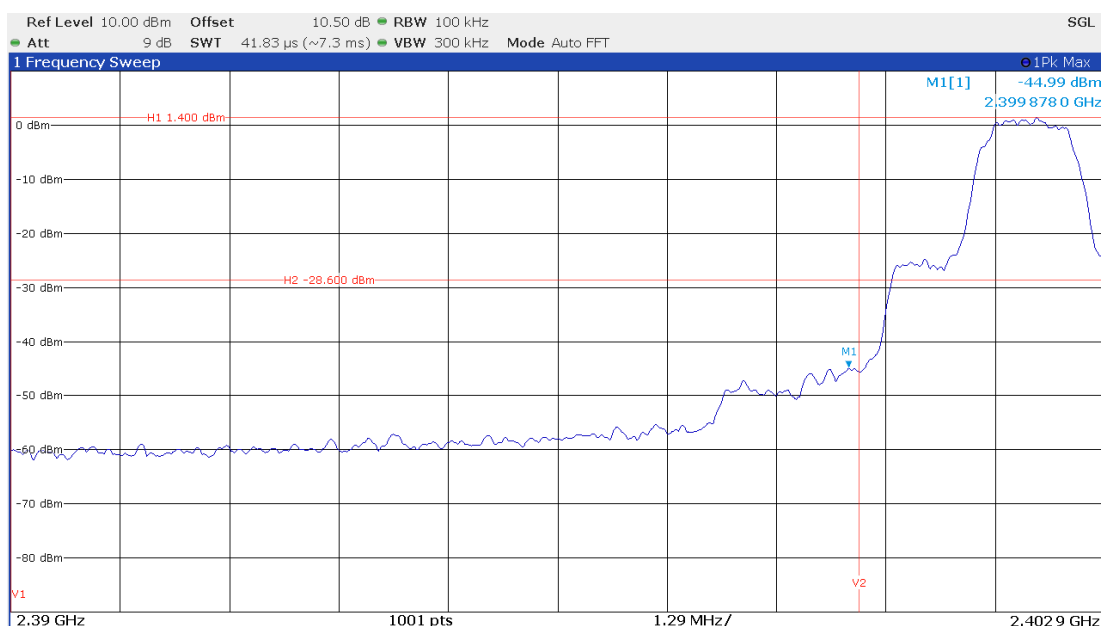
\*2 If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

### 5.10.3 Test results (Band edge – unrestricted bands)

Ambient temperature:	22 °C
Relative humidity:	44 %

Date:	29.06.2022
Tested by:	P. NEUFELD

#### Worst case plot Lower band edge (operation mode 7):



**Lower band edges:**

Operation mode	Frequency [MHz]	Reference [dBm]	Limit [dBm]	Unrestricted band emission [dBm]	Margin [dB]
1	2400.005	1.1	-18.9	-43.3	24.4
4	2399.878	1.4	-28.6	-45	16.4
7	2395.585	4.6	-15.4	-54.9	39.5

Test result: Passed

Test equipment (please refer to chapter 7 for details)
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1
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#### 5.10.4 Test setup (Band edge – restricted bands)

Test setup (Band edge – restricted bands)			
Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	
<input type="checkbox"/>	Conducted: Antenna port	5.1.4	

#### 5.10.5 Test method (Band edge – restricted bands)

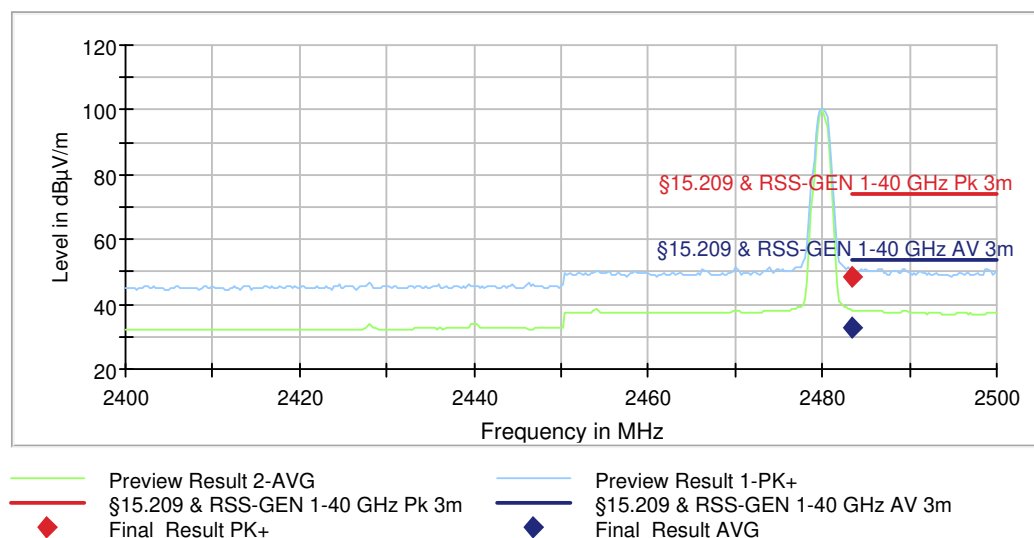
Test method (Band edge – restricted bands)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	11.13.1	Standard method	No limitations	
<input type="checkbox"/>	11.13.2	Marker-delta method		See 6.10.6 [3]
<input type="checkbox"/>	11.13.3.2	Peak detection	Not for DTS testing	2 MHz from band
<input type="checkbox"/>	11.13.3.3	Trace averaging with cont. EUT	D ≥ 98%	2 MHz from band
<input type="checkbox"/>	11.13.3.4	Trace averaging with cont. EUT & D	Constant D (±2%)	2 MHz from band
<input type="checkbox"/>	11.13.3.5	Reduced VBW		2 MHz from band

#### 5.10.6 Test results (Band edge – restricted bands)

Ambient temperature:	22 °C
Relative humidity:	64 %

Date:	24.05.2022
Tested by:	B. ROHDE

#### Worst case plot upper band edge (operation mode 9):



Operation Mode	Frequency [MHz]	MaxPeak [dB(μV/m)]	Average [dB(μV/m)]	Limit [dB(μV/m)]	Margin [dB(μV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
3	2483.500	---	30.40	54.00	23.60	V	164.0	120.0	33.6
3	2483.500	45.62	---	74.00	28.38	V	164.0	120.0	33.6
6	2483.500	---	29.80	54.00	24.20	V	168.0	120.0	33.6
6	2483.500	45.81	---	74.00	28.19	V	168.0	120.0	33.6
6	2484.000	---	30.10	54.00	23.90	V	159.0	120.0	33.6
6	2484.000	45.77	---	74.00	28.23	V	159.0	120.0	33.6
9	2483.500	---	32.84	54.00	21.16	V	154.0	120.0	33.6
9	2483.500	48.21	---	74.00	25.79	V	154.0	120.0	33.6

Test result: Passed

Test equipment (please refer to chapter 7 for details)
19 – 25, 26 - 28

## 5.11 Radiated emissions

### 5.11.1 Test setup (Maximum unwanted emissions)

Test setup (Maximum unwanted emissions)			
Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Radiated: 9 kHz to 30 MHz 30 MHz to 1 GHz 1 GHz to 40 GHz	5.1.1 5.1.2 5.1.3	-
<input type="checkbox"/>	Conducted: Antenna port	5.1.4	-

### 5.11.2 Test method (Maximum unwanted emissions)

- Test method (radiated) see sub-clause 5.1.3 as described herein

### 5.11.3 Test results (Maximum unwanted emissions)

#### 5.11.3.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	23 °C	Date:	31.05.2022
Relative humidity:	41 %	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:

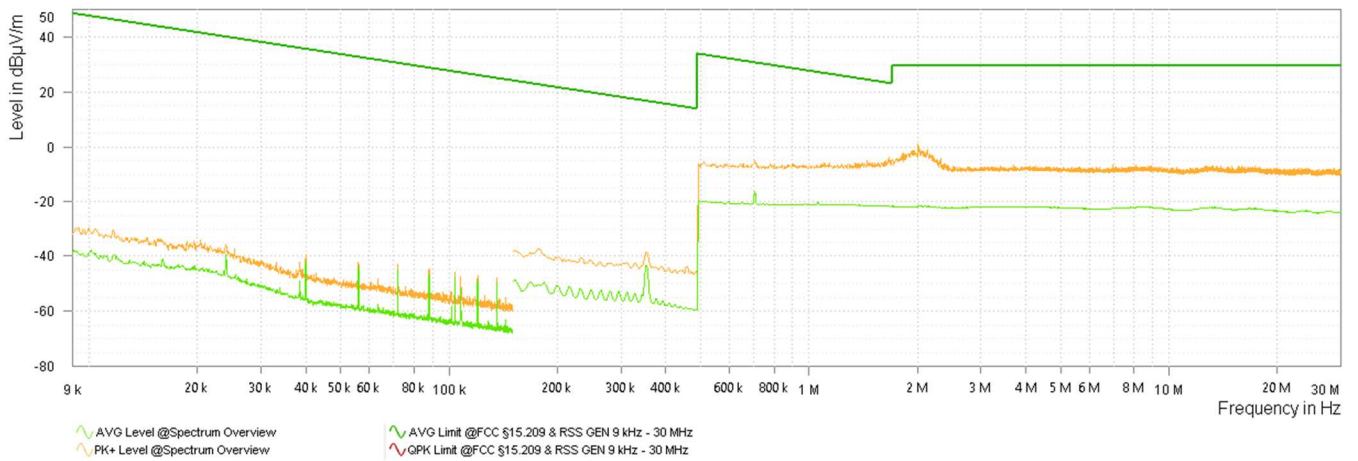
Result @ norm. dist. [dBμV/m] = Reading [dBμV] + AF [dB/m] + Distance corr. fact. [dBμV/m]

Result @ norm. dist. [dBμA/m] = Result @ norm. dist. [dBμV/m] – 20 x log<sub>10</sub>(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 - standing):



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

Test result: Passed

Test equipment (please refer to chapter 7 for details)
2 - 10

### 5.11.3.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	23 °C
Relative humidity:	41 %

Date:	31.05.2022
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 [dB $\mu$ V/m] = Reading [dB $\mu$ V] + Correction [dB $\mu$ V/m]

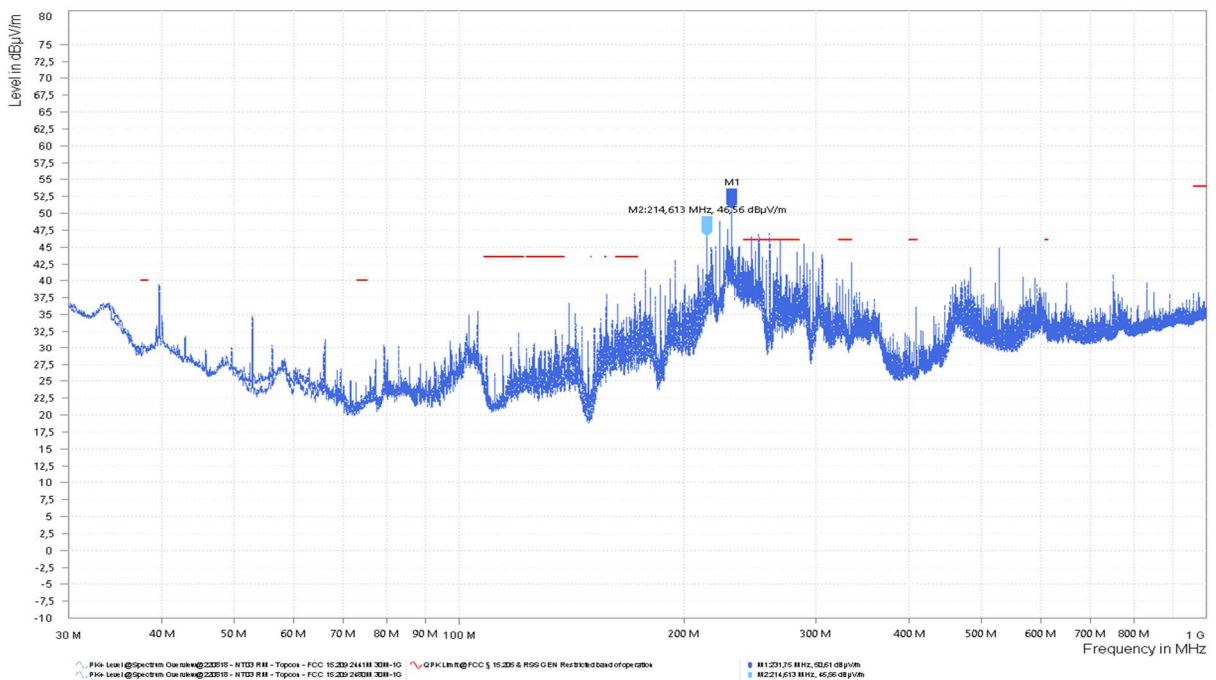
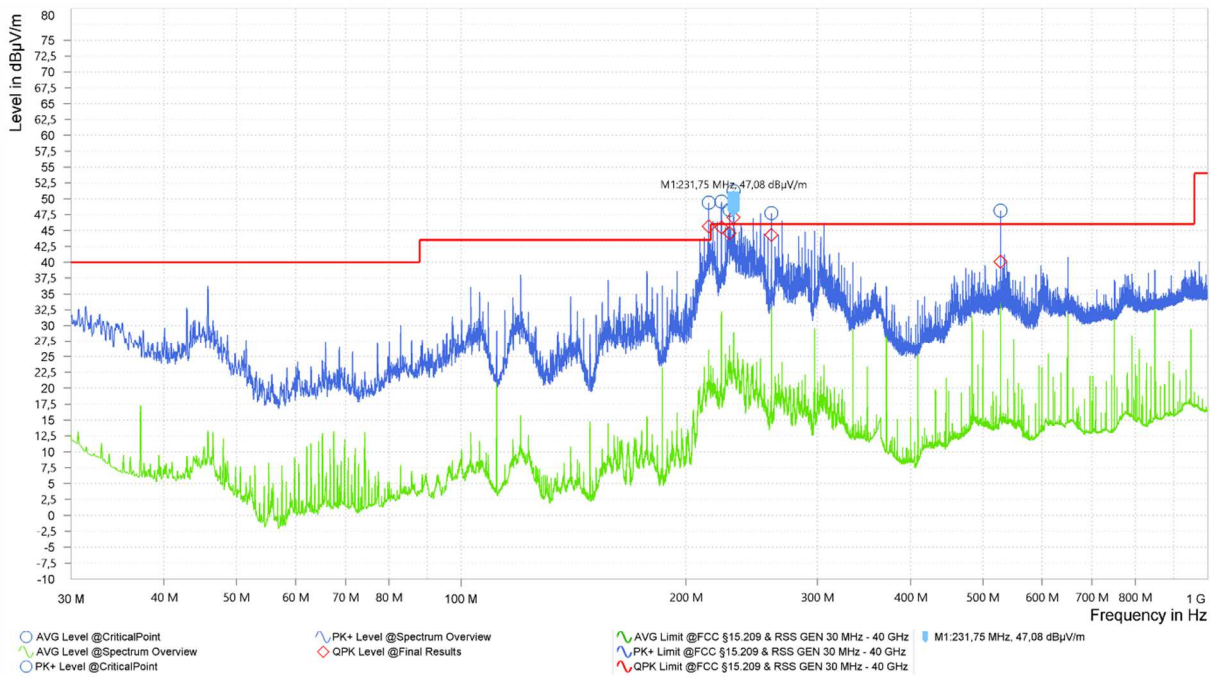
Correction [dB $\mu$ V/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

Margin [dB] = Limit [dB $\mu$ V/m] - Result [dB $\mu$ V/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 - standing):





**Result tables:**

(Operation mode 2):

Frequency [MHz]	Result (QP) [dBμV/m]	Limit [dBμV/m]	Margin [dB]	Correction [dB/m]	Height [m]	Azimuth [deg]	Pol. (H/V)	Position #
223.170	45.48	46.00	0.52	16.15	1	245	H	2
228.900	44.56	46.00	1.44	16.68	1.25	88	H	2
260.370	44.32	46.00	1.68	17.90	1.02	117	H	2
527.940	40.06	46.00	5.94	24.85	1	-2	V	2

Frequency [MHz]	Result (Pk) [dBμV/m]	Limit* [dBμV/m]	Margin [dB]	Correction [dB/m]	Height [m]	Azimuth [deg]	Pol. (H/V)	Position #	Restricted Band
214.59	47.2	66.6	19.4	16.30	1.02	245	H	2	No
231.75	50.6	66.6	16.0	16.68	1.25	88	H	2	No
223.80	48.8	66.6	17.8	16.20	1.00	66	H	2	No

\* Limit = Max emissions(Pk)/100 kHz = 86.6 dBμV/m – 20 dB

Test result: Passed

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

### 5.11.3.3 Test results (radiated 1 to 40 GHz)

Ambient temperature:	22 °C
Relative humidity:	45 %

Date:	25.05.2022
Tested by:	B. ROHDE

Position of EUT: For tests for f between 1 GHz and the 10<sup>th</sup> 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: -

Calculation:

Max Peak [dBμV/m] = Reading [dBμV] + Correction [dBμV/m]

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

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

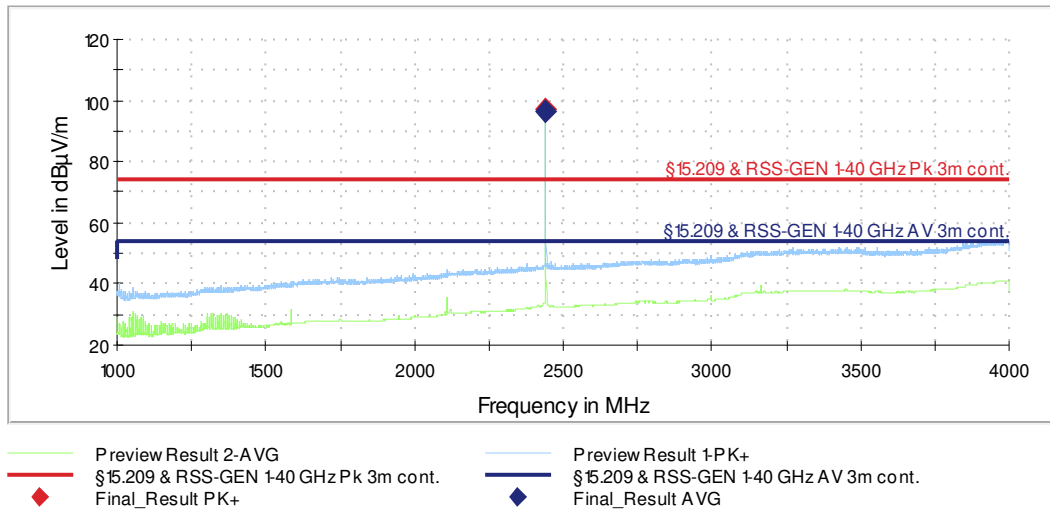
Margin [dB] = Limit [dBμV/m] – Max Peak | Average [dBμV/m]

The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.

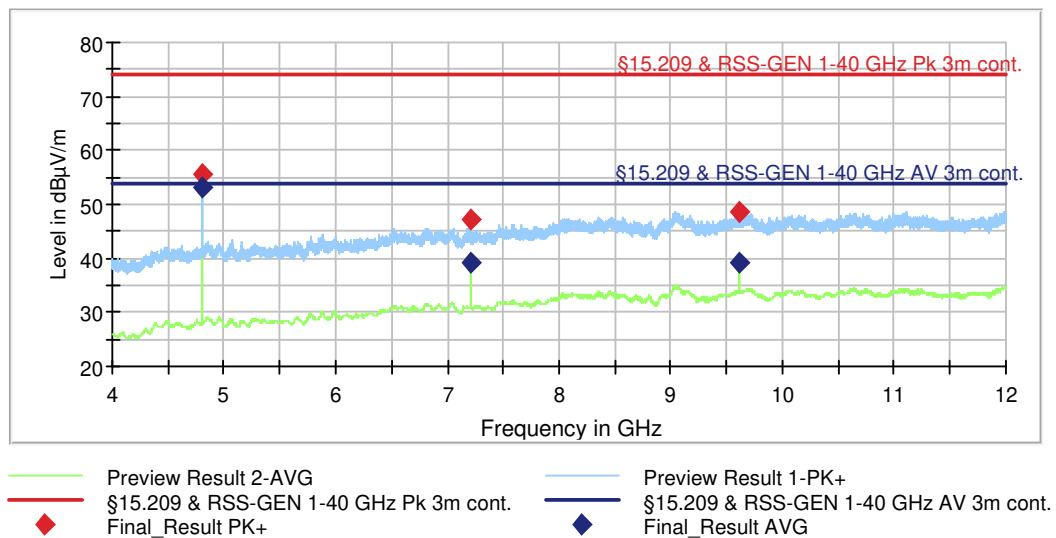
The top measured curve represents the peak measurement. The measured points marked with "♦" are frequency points for the final peak detector measurement. These values are indicated in the following table. The bottom measured curve represents the average measurement. The measured points marked with "◆" are frequency points for the final average detector measurement.

**Worst case plots:**

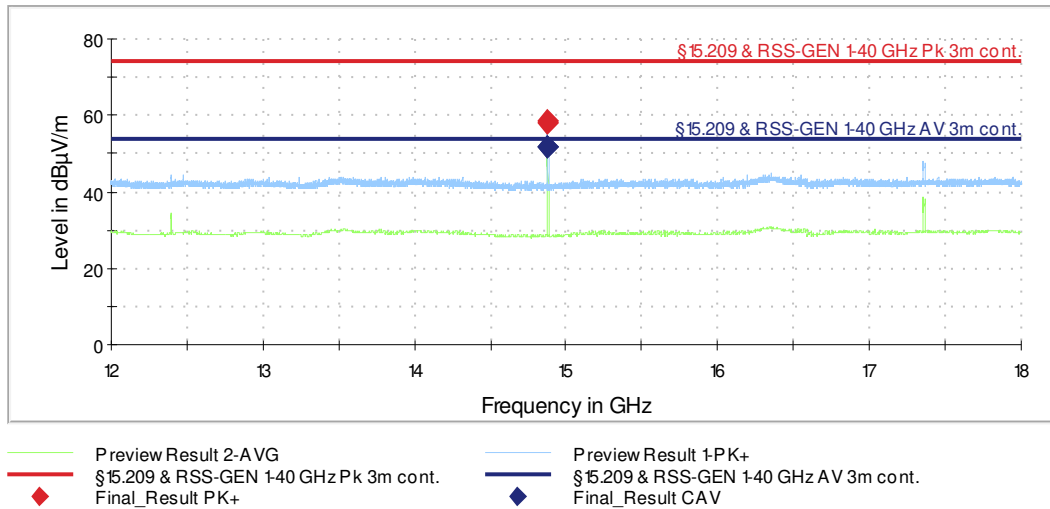
Spurious emissions from 1 GHz to 4 GHz (operation mode 2):



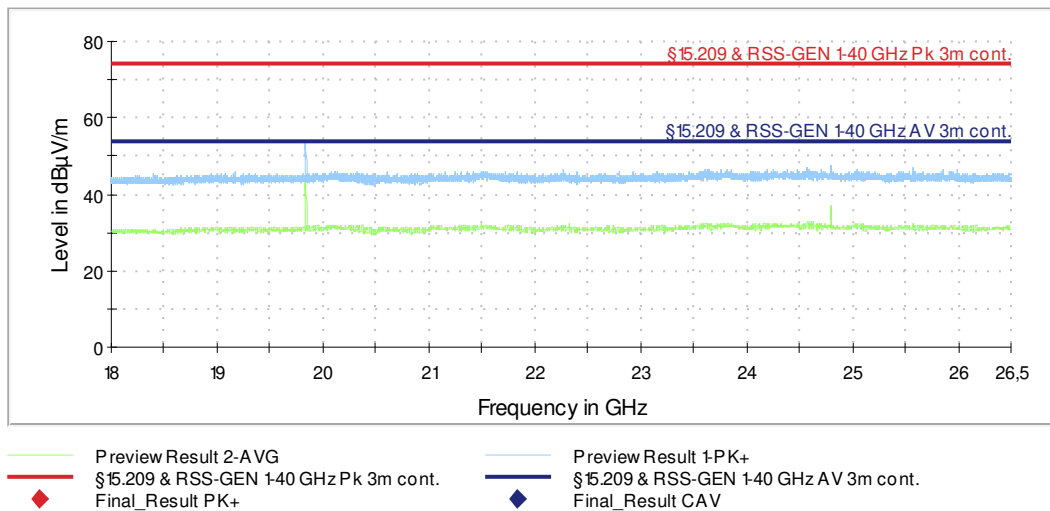
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



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



Spurious emissions from 18 GHz to 26.5 GHz (operation mode 3):



**Result tables:**

Operation mode 1:

Frequency [MHz]	MaxPeak [dB(μV/m)]	Average [dB(μV/m)]	Limit [dB(μV/m)]	Margin [dB(μV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
2402.000	---	95.18	---	---	V	157	120	33.5
2402.000	95.57	---	---	---	V	157	120	33.5
4804.000	---	53.25	54.00	0.75	H	24	150	-1.8
4804.000	55.66	---	74.00	18.34	H	24	150	-1.8
7206.000	---	39.11	54.00	14.89	H	307	150	4.0
7206.000	47.29	---	74.00	26.71	H	307	150	4.0
9608.000	---	39.19	54.00	14.81	H	216	0	7.6
9608.000	48.67	---	74.00	25.33	H	216	0	7.6
16812.750	---	43.84	54.00	10.16	H	301	150	9.5
16812.750	52.99	---	74.00	21.01	H	301	150	9.5
16814.750	---	44.35	54.00	9.65	H	302	150	9.5
16814.750	51.83	---	74.00	22.17	H	302	150	9.5

Operation mode 2:

Frequency [MHz]	MaxPeak [dB(μV/m)]	Average [dB(μV/m)]	Limit [dB(μV/m)]	Margin [dB(μV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
2441.000	---	96.59	---	---	V	154	120	33.8
2441.000	96.93	---	---	---	V	154	120	33.8
4882.000	---	41.45	54.00	12.55	H	179	0	-1.4
4882.000	46.94	---	74.00	27.06	H	179	0	-1.4
7323.000	---	39.72	54.00	14.28	H	252	0	4.4
7323.000	47.48	---	74.00	26.52	H	252	0	4.4
14645.250	---	49.26	54.00	4.74	H	350	150	10.2
14645.250	55.94	---	74.00	18.06	H	350	150	10.2
14646.750	---	49.21	54.00	4.79	H	350	150	10.2
14646.750	56.25	---	74.00	17.75	H	350	150	10.2

Operation mode 3:

Frequency [MHz]	MaxPeak [dB(μV/m)]	Average [dB(μV/m)]	Limit [dB(μV/m)]	Margin [dB(μV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
2480.000	---	96.05	---	---	V	154	120	33.6
2480.000	96.38	---	---	---	V	154	120	33.6
4960.000	---	40.27	54.00	13.73	H	0	150	-1.5
4960.000	46.60	---	74.00	27.40	H	0	150	-1.5
7440.000	---	45.72	54.00	8.28	H	328	150	4.7
7440.000	51.75	---	74.00	22.25	H	328	150	4.7
9920.000	---	38.69	54.00	15.31	H	10	150	6.8
9920.000	48.53	---	74.00	25.47	H	10	150	6.8
14879.250	---	47.37	54.00	6.63	V	282	120	10.0
14879.250	54.34	---	74.00	19.66	V	282	120	10.0
14880.750	---	47.24	54.00	6.76	V	282	120	10.0
14880.750	54.80	---	74.00	19.20	V	282	120	10.0

Test result: Passed

Test equipment (please refer to chapter 7 for details)

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## 6 Measurement Uncertainties

Conducted measurements		
Measurement method	Standard used for calculating measurement uncertainty	Expanded measurement uncertainty (95 %) $U_{lab}$
Frequency error	ETSI TR 100 028	$4.5 \times 10^{-8}$
Bandwidth measurements	-	$9.0 \times 10^{-8}$
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	$4.5 \times 10^{-8}$
OATS	ETSI TR 100 028	$4.5 \times 10^{-8}$
Test fixture	ETSI TR 100 028	$4.5 \times 10^{-8}$
Bandwidth measurements		
(Semi-) Anechoic chamber	-	$9.0 \times 10^{-8}$
OATS	-	$9.0 \times 10^{-8}$
Test fixture	-	$9.1 \times 10^{-8}$
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	19.11.2021	11.2022
2	Test software M276	Elektra	Rohde&Schwarz		483755	Calibration not necessary	
3	loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
4	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
5	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
6	Antennasupport	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
7	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
8	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
9	Testsoftware M276	EMC32 V11.30	Rohde & Schwarz	100970	482972	Calibration not necessary	
10	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
11	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
12	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
13	standard gain horn antenna	18240-20	Flann Microwave	483	480294	Calibration not necessary	
14	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ Hauppauge N.Y.	571667	480343	17.02.2022	02.2024
15	standard gain horn antenna	20240-20	Flann Microwave	411	480297	Calibration not necessary	
16	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ Hauppauge N.Y.	658697	480342	17.02.2022	02.2024
17	High pass Filter	WHKX4.0/18G-8SS	Wainwright Instruments GmbH	1	480587	Calibration not necessary	
18	Microwave cable 2m	Insulated Wire Inc.	Insulated Wire	KPS-1533-800-KPS	480302	Calibration not necessary	
19	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
20	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
21	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
22	Multiple Control Unit	MCU	Maturo GmbH	MCU/043/971107	480832	Calibration not necessary	
23	Positioners	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
24	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	22.02.2022	02.2024
25	Testsoftware M20	EMC32 V10.60.15	Rohde & Schwarz		483261	Calibration not necessary	



No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
26	Preamplifier 100 MHz - 16 GHz	AFS6-00101600-23-10P-6-R	Narda MITEQ	2011215	482333	17.02.2022	02.2024
27	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	Calibration not necessary	
28	RF cable	SF106B/11N/11 N/4500.0	Huber & Suhner	500218/6B	482415	Calibration not necessary	

## 8 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	03.03.2021	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
F220818E4	20.02.2023	Initial Test Report
-	-	-
-	-	-

## 10 List of Annexes

Annex A          Test Setup Photos

7 pages