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Test Report

Report Number:

F210861E2

Equipment under Test (EUT):

Marker Mini

Applicant:

TRUMPF Tracking Technologies

Manufacturer:

WEPTECH elektronik GmbH

ilac-MRA

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

References

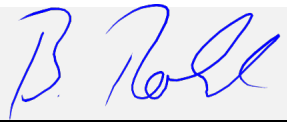
[1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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

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

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.

Tested and written by:		Bernward ROHDE 01.03.2022
	Signature	
Reviewed and approved by:		Paul NEUFELD 01.03.2022
	Signature	

This test report is only valid in its original form.

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1 Identification

1.1 Applicant

Name:	TRUMPF Tracking Technologies
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Country:	Germany
Name for contact purposes:	Mr. Benjamin SCHWARZ
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eMail Address:	Benjamin.Schwarz@trumpf.com
Applicant represented during the test by the following person:	-

1.2 Manufacturer

Name:	WEPTECH elektronik GmbH
Address:	Ostring 10, 76829 Landau
Country:	Germany
Name for contact purposes:	Mr. Jochen RIGA
Phone:	+49 63 41 92 55 - 331 / +49 160 97 72 58 61
eMail Address:	jochen.riga@weptech.de
Applicant 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-17186-01-05 and D-PL-17186-01-06, FCC Test Firm Accreditation designation number DE0004, FCC Test Firm Registration Number 469623.

1.4 EUT (Equipment under Test)

EUT	
Test object: *	Tag for indoor localization
PMN / Model name: *	Marker Mini
FCC ID: *	2A2TP-2677368

* Declared by the applicant

	EUT number		
	1	2	3
Serial number: *	1910154B00301EAA	-	-
PCB identifier: *	E001-3233-02	-	-
Hardware version: *	V1.0.0	-	-
Software version: *	3.3.2	-	-

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

1.5 Technical Data of Equipment

General EUT data			
Power supply EUT: *	Lithium battery 3.7 V / 2400 mAh		
Supply voltage EUT: *	U_{Nom}= 3.7 V_{DC}	U_{Min}= 3.1 V_{DC}	U_{Max}= 4.2 V_{DC}
Temperature range: *	-10 °C to 55 °C		
Lowest / highest internal clock frequency: *	32 kHz / 2.480 GHz		

Ports / Connectors				
Identification	Connector		Length during test	Shielding (Yes / No)
	EUT	Ancillary		
No ports / connectors are available.				

Bluetooth® Low Energy radio mode		
Fulfils radio specification: *	Bluetooth® Low Energy 4.2 (1 Mbit/s only)	
Radio chip: *	Nordic nRF52840	
Antenna type: *	Internal PCB antenna	
Antenna name: *	ANT	
Antenna gain: *	2 dBi	
Antenna connector: *	none	
Type of modulation: *	BLE 1 Mbit/s	GFSK (1 Mbit/s)
Operating frequency range: *	BLE 1 Mbit/s	2402 – 2480 MHz
Number of channels: *	BLE 1 Mbit/s	40 (2 MHz channel spacing)

Bluetooth® Low Energy frequencies				
Channel 0	RX	2402 MHz	TX	2402 MHz
Channel 1	RX	2404 MHz	TX	2404 MHz
…	…	…	…	…
Channel 19	RX	2440 MHz	TX	2440 MHz
…	…	…	…	…
Channel 38	RX	2478 MHz	TX	2478 MHz
Channel 39	RX	2480 MHz	TX	2480 MHz

1.5.1 Ancillary Equipment / Equipment used for testing

Equipment used for testing	
-	-

Ancillary equipment	
-	-

1.6 Dates

Date of receipt of test sample:	27.05.2021
Start of test:	18.05.2021
End of test:	01.07.2021

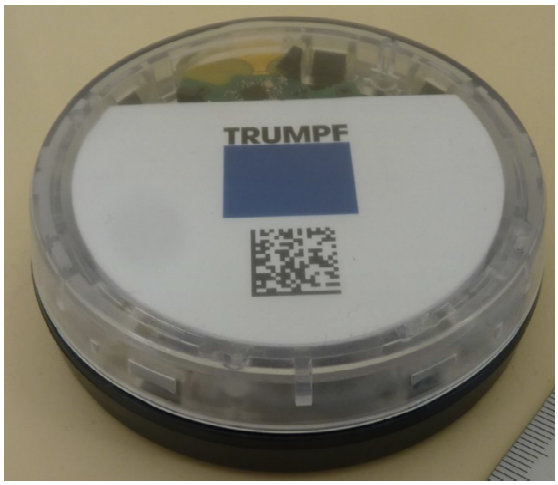
2 Operational States

2.1 Description of function of the EUT

The EUT is intended to be used as transceiver for locating of machine tools inside a factory building. It will be mounted onto machines.

2.2 The following states were defined as the operating conditions

All radiated tests were carried out with an unmodified test sample powered by an internal battery.



2.2.1 Operation modes

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate	TX / RX	EUT #	Power setting
1	Bluetooth® LE	2402	0	GFSK	1 Mbit/s	TX	1	Not settable
2	Bluetooth® LE	2440	19	GFSK	1 Mbit/s	TX	2	Not settable
3	Bluetooth® LE	2480	39	GFSK	1 Mbit/s	TX	3	Not settable

3 Additional Information

This test report contains only the results of the BLE part of the EUT.

F210861E1 contains: UWB relevant results
F210861E2 contains: BLE relevant results
F210861E3 contains: Simultaneous transmission of BLE and UWB relevant results

The tested sample was not labeled as required by the FCC.

The tests were done with an unmodified sample.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	Status	EUT
Maximum peak conducted output power	2400.0 - 2483.5	15.247 (b) (3), (4)	Passed	1
Maximum conducted output power	2400.0 - 2483.5	15.247 (b) (3), (4)	Passed	1
DTS Bandwidth / 99% Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	Passed	1
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	Passed	1
Average Power Spectral Density	2400.0 - 2483.5	15.247 (e)	Passed	1
Band edge compliance	2400.0 - 2483.5	15.247 (d) 15.205 (a) 15.209 (a)	Passed	1
Maximum unwanted emissions	0.009 – 26,500	15.247 (d) 15.205 (a) 15.209 (a)	Passed	1
Antenna Requirement	-	15.203 15.247 (b)	Passed	-
Conducted emissions on supply line	0.15 – 30	15.207 (a)	-	-

5 Results

5.1 Test setup

5.1.1 Test Setup (radiated)

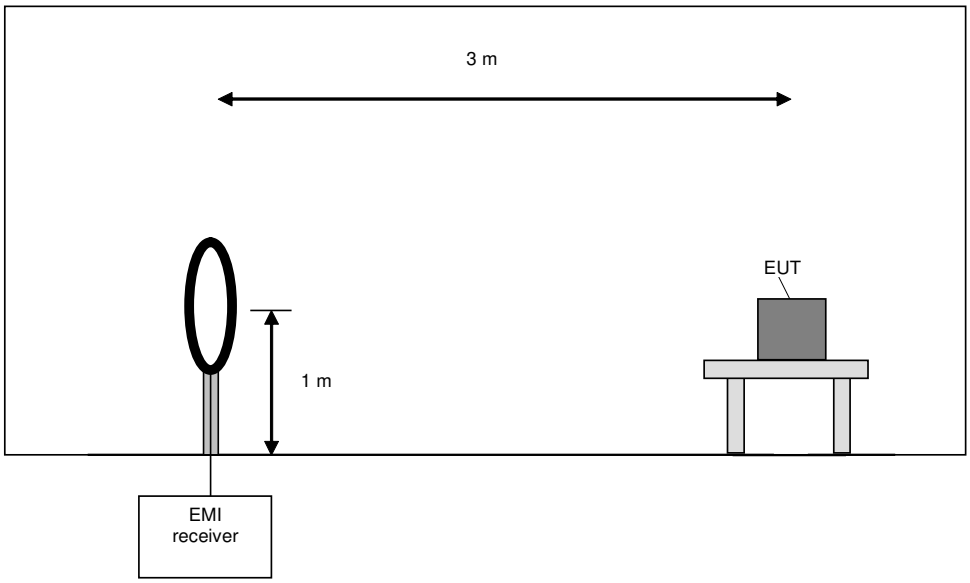
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

In the first stage a preliminary measurement is performed in an anechoic chamber with a measuring distance of 3 meters. Table-top and portable devices are set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. Floor-standing devices are placed directly on the turntable / ground plane. The setup of the equipment under test is in accordance to [1].

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

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

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



Procedure preliminary measurement:

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

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

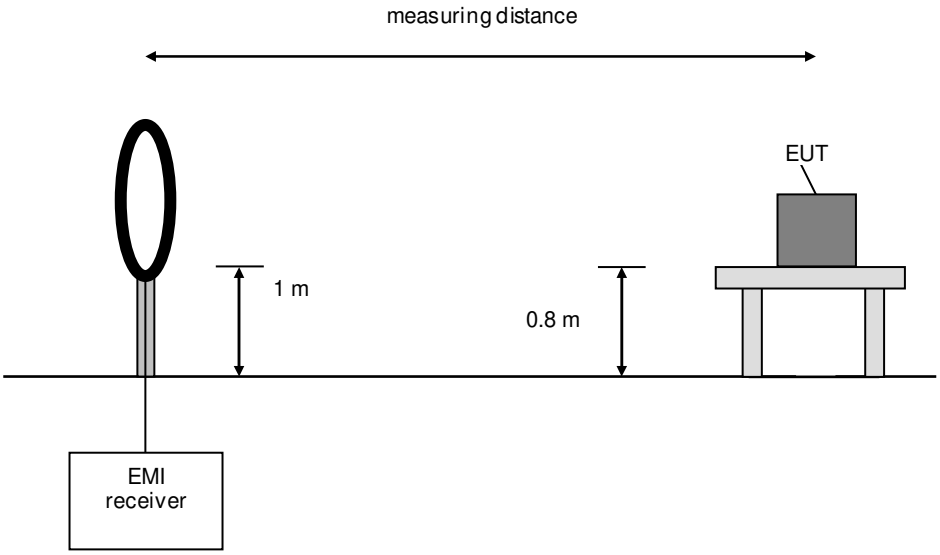
5.1.1.2 Final measurement 9 kHz to 30 MHz

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

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

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

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



Procedure final measurement:

The following procedure is used:

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

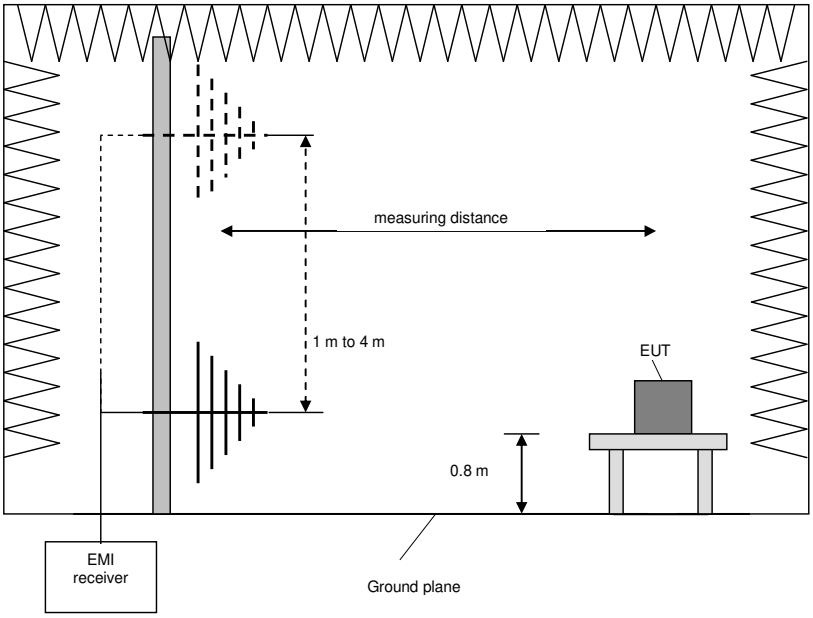
5.1.1.3 Preliminary and final measurement 30 MHz to 1 GHz

The preliminary and final measurements are performed in a semi-anechoic chamber with a metal ground plane in a 3 m distance. Table-top and portable devices are set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm. Floor-standing devices are placed directly on the turntable / ground plane.

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

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

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



Procedure preliminary measurement:

The following procedure is used:

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

Procedure final measurement:

The following procedure is used:

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

5.1.1.4 Preliminary and final measurement > 1 GHz

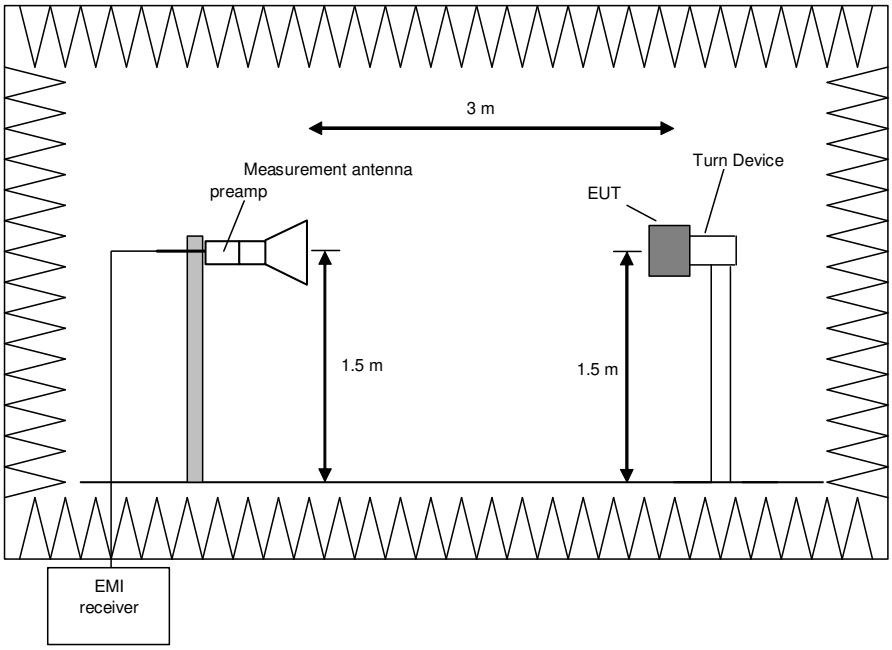
This measurement will be performed in a fully anechoic chamber. Tabletop and portable devices will set up on a non-conducting turn device on the height of 1.5m. The set-up of the Equipment under test will be in accordance to [1].

Preliminary measurement (1 GHz to 40 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used antenna. The spectrum analyser set to MAX Hold mode and a resolution bandwidth of 1 MHz. The measurement will be performed in horizontal and vertical polarisation of the measuring antenna and while rotating the EUT in its vertical axis in the range of 0 ° to 360 °. This measurement is repeated after raising the EUT in 30° steps according to 6.6.5.4 in [1].

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

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



Procedure preliminary measurement:

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

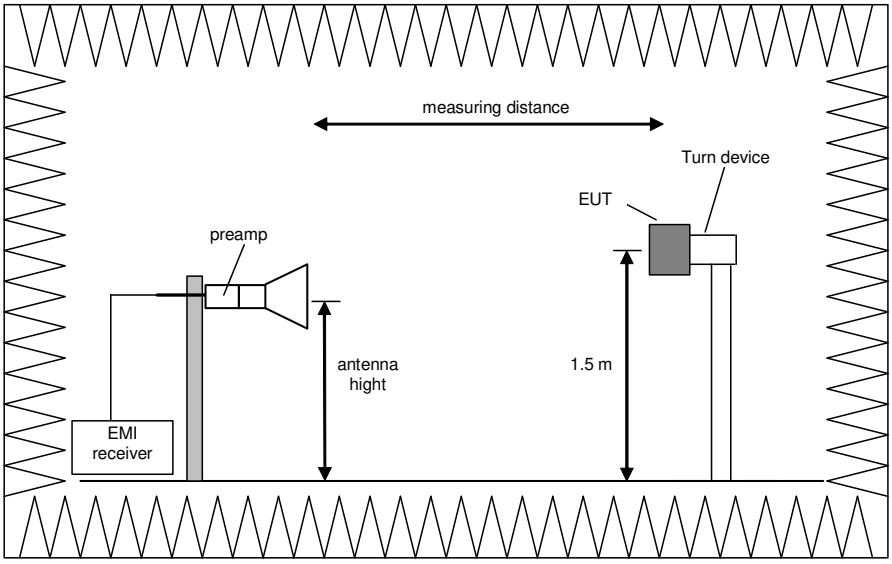
1. Monitor the frequency range at horizontal polarisation and a EUT azimuth of 0 °.
2. Rotate the EUT by 360° to maximize the detected signals.
3. Repeat 1) to 2) with the vertical polarisation of the measuring antenna.
4. Make a hardcopy of the spectrum.
5. Repeat 1) to 4) with the EUT raised by an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

Final measurement (1 GHz to 40 GHz)

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

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

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



Procedure of measurement:

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

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

5.2 Duty cycle

As declared by the applicant the EUT has a duty cycle ≥ 98%, so no DCCF is applied.

5.3 Transmit Antenna Performance considerations

Test result (Transmit antenna requirements)			
Integral antenna	Antenna gain ≤ 6dBi	Result	Comment
☒	☒	Passed	No output power reduction necessary

5.4 DTS bandwidth

5.4.1 Test setup (DTS bandwidth)

Test setup (Duty cycle)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

5.4.2 Test method (DTS bandwidth)

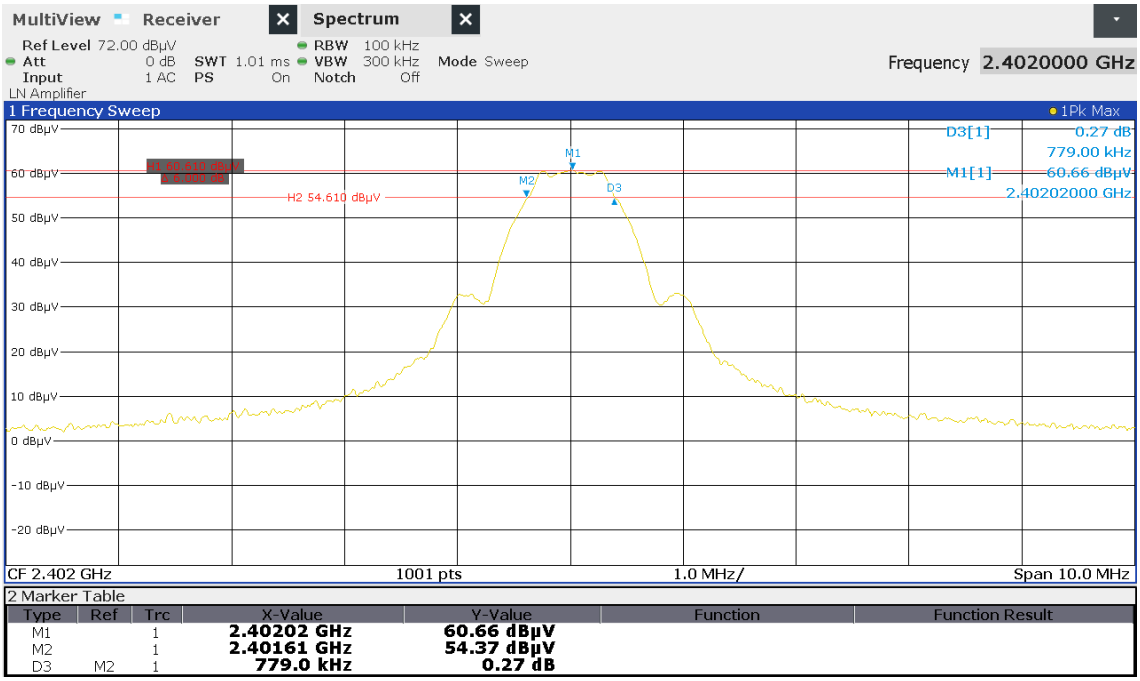
Test method (Maximum peak conducted output power)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.8.1	Option 1	No limitations	
☐	11.8.2	Option 2	No limitations	6 dB down function

5.4.3 Test results (DTS bandwidth)

Ambient temperature:	23 °C
Relative humidity:	34 %

Date	29.06.2021
Tested by	B. ROHDE

Worst case plot (operation mode 1):



Operation mode #	DTS bandwidth [MHz]	Minimum DTS bandwidth Limit [MHz]	Result
1	0.779	0.5	Passed
2	0.779	0.5	Passed
3	0.799	0.5	Passed
Measurement uncertainty: 9.0×10^{-8}			

Test equipment (please refer to chapter 6 for details)
1 - 8

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
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

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

Test method (Maximum peak conducted output power)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☐	6.9.2	relative measurement procedure		n-dB down
☒	6.9.3	power bandwidth (99%)	*1	99% power function

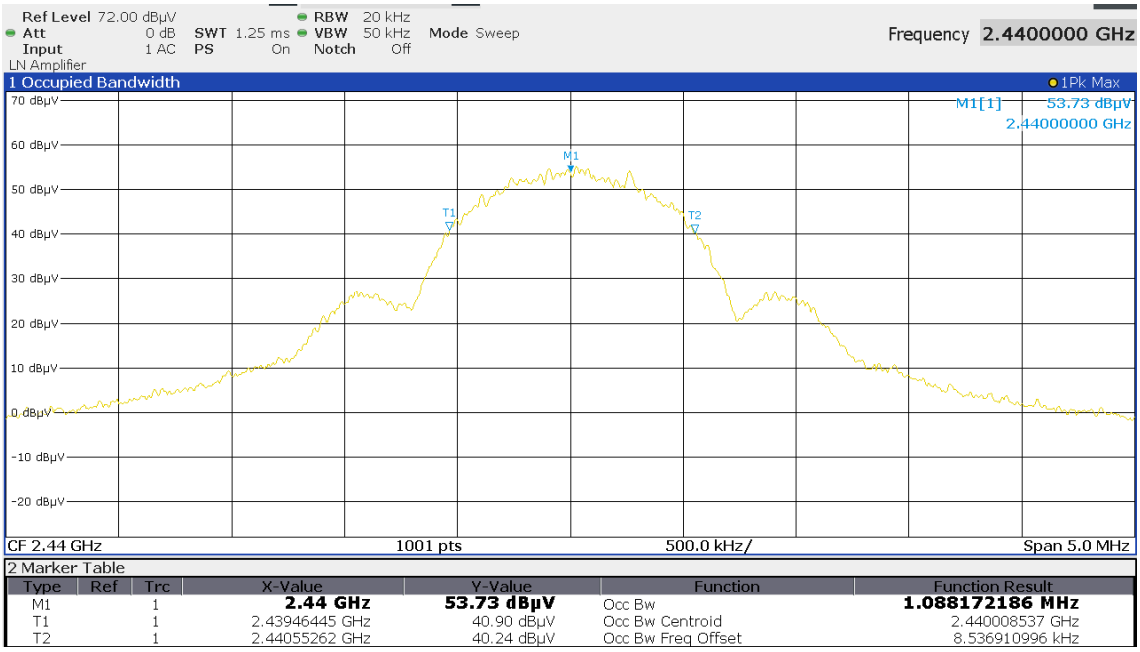
*1 See RSS-GEN Issue 5 (2018-05) sub-clause 6.7 for details.

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

Ambient temperature:	23 °C
Relative humidity:	34 %

Date	29.06.2021
Tested by	B. ROHDE

Worst case plot (operation mode):



Operation mode #	99% bandwidth [MHz]
1	1.073
2	1.088
3	1.082
Measurement uncertainty: 9.0×10^{-8}	

Test equipment (please refer to chapter 6 for details)
1 - 8

5.6 DTS fundamental emission output power

5.6.1 Test setup (DTS fundamental emission output power)

Test setup (DTS fundamental emission output power)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

5.6.2 Test method (DTS fundamental emission output power)

Test method (Maximum peak conducted output power)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.9.1.1	RBW ≥ DTS bandwidth		
☐	11.9.1.2	Integrated band power method	Not for DTS	
☐	11.9.1.3	PKPM1 Peak power meter method*1		

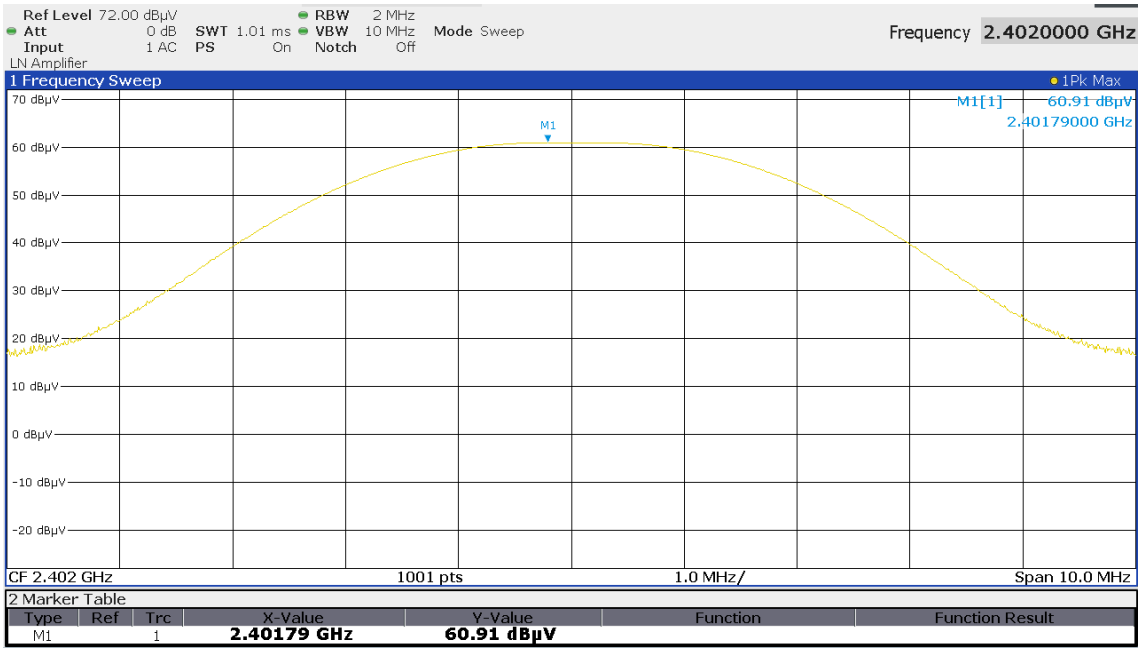
*1 VBW of the peak power meter has to be > OBW of the fundamental.

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

5.6.3 Test results (DTS fundamental emission output power)

Maximum peak conducted output power:

Worst case plot (operation mode 1):



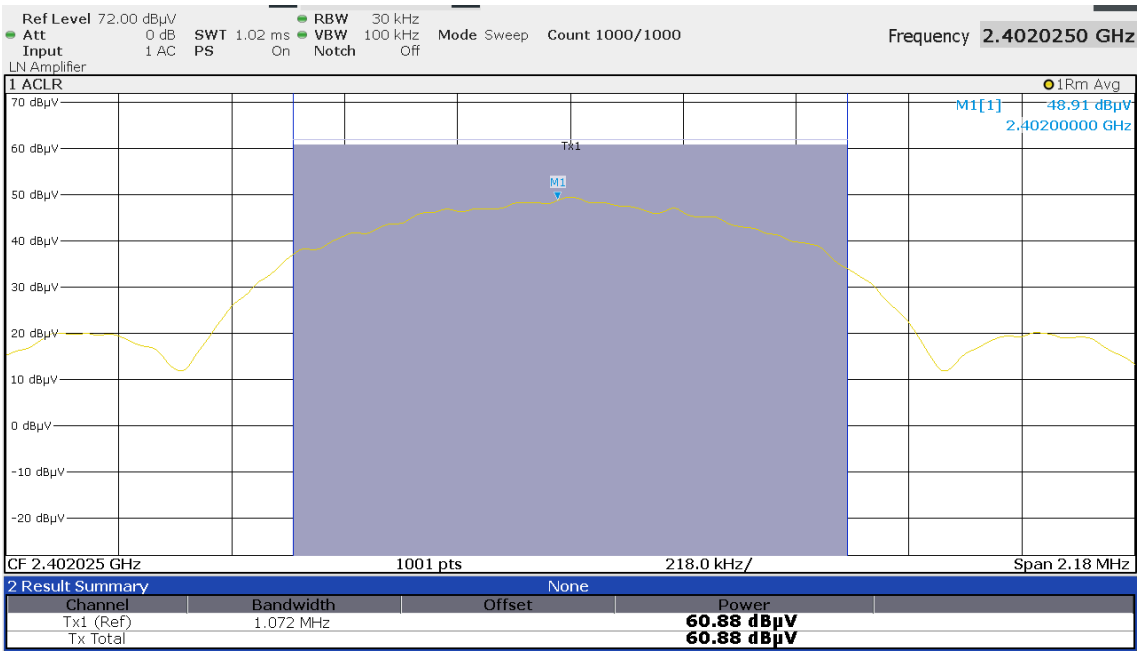
Operation mode	Reading [dBµV]	Correction Fact. @3m [dB/m]	Corr. Fact. @3m dBµV/m → dBm	Antenna Gain [dBi]	Result [dBm]	Limit [dBm]
1	60.9	35.3	-95.3	2.0	-1.1	30
2	60.5	35.4	-95.3	2.0	-1.4	30
3	59.7	35.4	-95.3	2.0	-2.2	30
Measurement uncertainty: +/- 2.3 dB						

Calculation: Correction [dB/m] = AF [dB/m] + Cable attenuation [dB]
Correction @3m dBµV/m → dBm = -95.3 (for details see [1] sub-clause 11.12.2.2 e))
Antenna Gain [dBi] as declared by the applicant
Result [dBm] = Reading [dBµV] + Corr. [dB/m] + Corr@3m – Antenna Gain [dBi]

Test: Passed

Maximum conducted (average) output power

Worst case plot (operation mode 1):



Operation mode	Reading [dBµV]	Correction Fact. @3m [dB/m]	Corr. Fact. @3m dBµV/m → dBm	Antenna Gain [dBi]	DCCF [dB]	Result [dBm]	Limit [dBm]
1	60.9	35.3	-95.3	2.0	0.0	-1.1	30
2	60.4	35.4	-95.3	2.0	0.0	-1.5	30
3	59.6	35.4	-95.3	2.0	0.0	-2.3	30
Measurement uncertainty: +/- 2.3 dB							

Calculation: Correction [dB/m] = AF [dB/m] + Cable attenuation [dB]
Correction @3m dBµV/m → dBm = -95.3 (for details see [1] sub-clause 11.12.2.2 e))
Antenna Gain [dBi] as declared by the applicant
Result [dBm] = Reading [dBµV] + Corr. [dB/m] + Corr@3m – Antenna Gain [dBi] + DCCF [dB]

Test: Passed

Test equipment (please refer to chapter 6 for details)
1 - 8

5.7 DTS maximum PSD level in the fundamental emission

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

Test setup (DTS fundamental emission output power)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

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

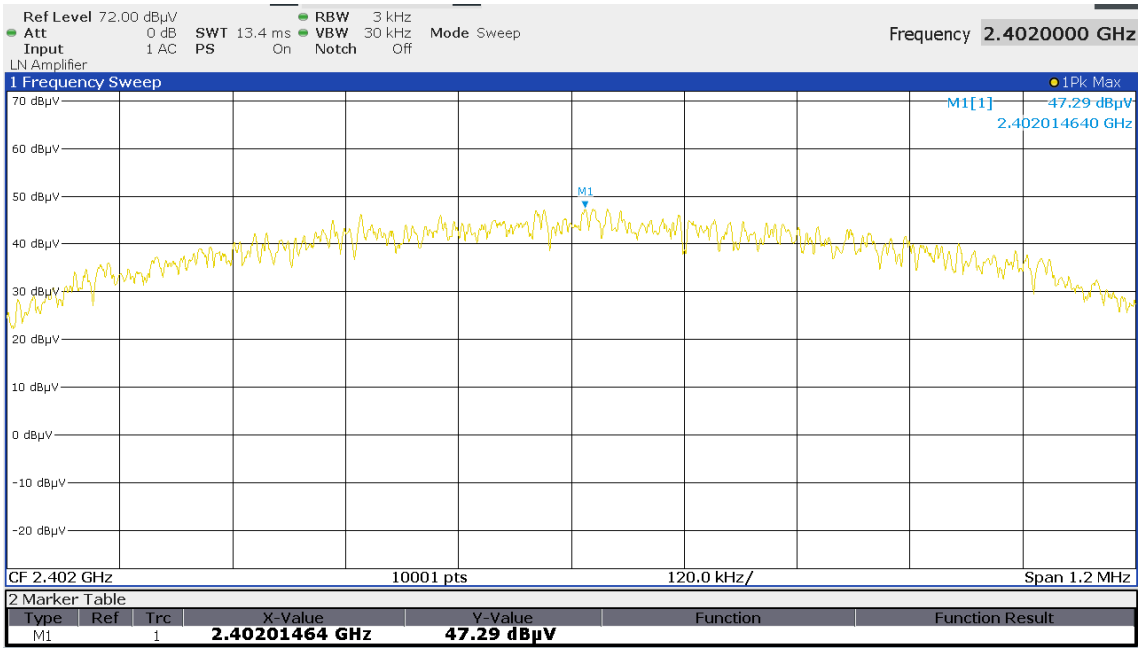
Test method (Maximum *peak* power spectral density level in the fundamental emission)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.10.2	Method PKPSD (peak PSD)	No limitations	

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

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

Maximum peak PSD:

Worst case plot (operation mode 1):

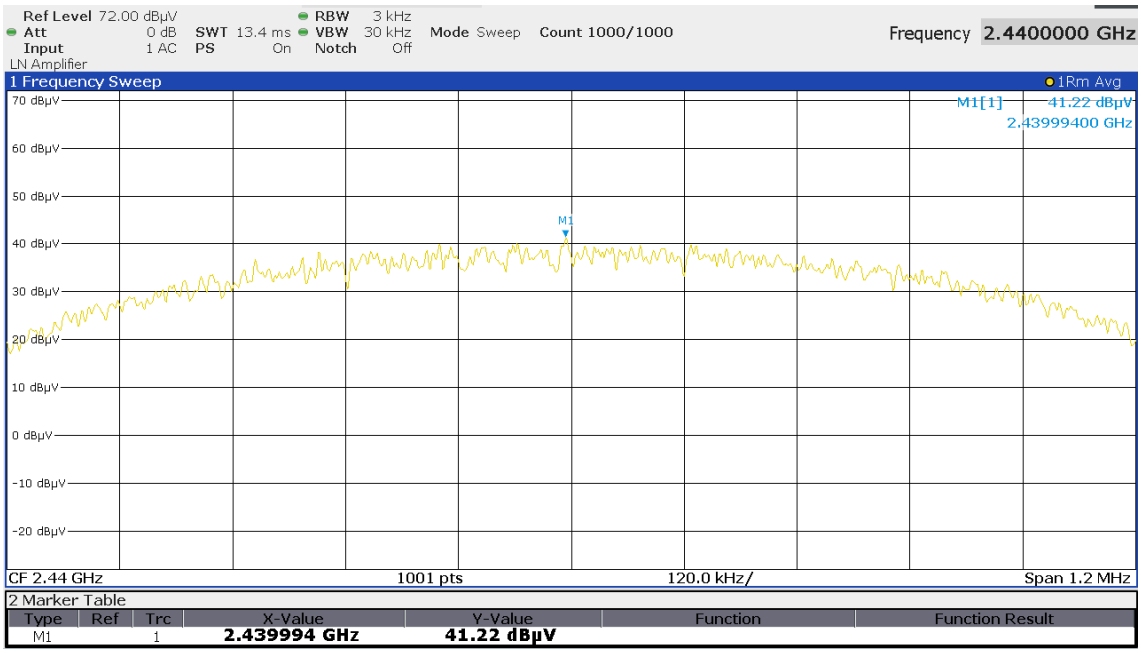


Operation mode	Reading [dBµV/3 kHz]	Corr. Fact. @3m [dB/m]	Corr. Fact. @3m dBµV/m → dBm	Antenna Gain [dBi]	Result [dBm/3 kHz]	Limit [dBm/3 kHz]
1	47.3	35.3	-95.3	2.0	-14.7	8
2	47.3	35.4	-95.3	2.0	-14.6	8
3	46.7	35.4	-95.3	2.0	-15.2	8
Measurement uncertainty: +/- 2.3 dB						

Calculation: Correction [dB/m] = AF [dB/m] + Cable attenuation [dB]
Correction @3m dBµV/m → dBm = -95.3 (for details see [1] sub-clause 11.12.2.2 e))
Antenna Gain [dBi] as declared by the applicant
Result [dBm/3kHz] = Reading [dBµV/3kHz] + Corr. [dB/m] + Corr@3m – Antenna Gain [dBi]

Maximum average PSD

Worst case plot (operation mode 2):



Operation mode	Reading [dBµV/3 kHz]	Corr. Fact. @3m [dB/m]	Corr. Fact. @3m dBµV/m → dBm	Antenna Gain [dBi]	DCCF [dB]	Result [dBm/3 kHz]	Limit [dBm/3 kHz]
1	41.2	35.3	-95.3	2.0	0.0	-20.8	8
2	41.2	35.4	-95.3	2.0	0.0	-20.7	8
3	39.4	35.4	-95.3	2.0	0.0	-22.5	8
Measurement uncertainty: +/- 2.3 dB							

Calculation: Correction [dB/m] = AF [dB/m] + Cable attenuation [dB]
Correction @3m dBµV/m → dBm = -95.3 (for details see [1] sub-clause 11.12.2.2 e))
Antenna Gain [dBi] as declared by the applicant
Result [dBm/3kHz] =
Reading [dBµV/3kHz] + Corr. [dB/m] + Corr@3m – Antenna Gain [dBi] + DCCF [dB]

Test equipment (please refer to chapter 6 for details)
1 - 8

5.1 Band edge

5.1.1 Test setup (Band edge – unrestricted bands)

Test setup (Band edge – unrestricted bands)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

5.1.2 Test method (Band edge – unrestricted bands)

Test method (Band edge – unrestricted bands)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.11.	20 dBc (Peak)	Peak power	*1
☐	11.11.	30 dBc (Average)	RMS power	*2

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

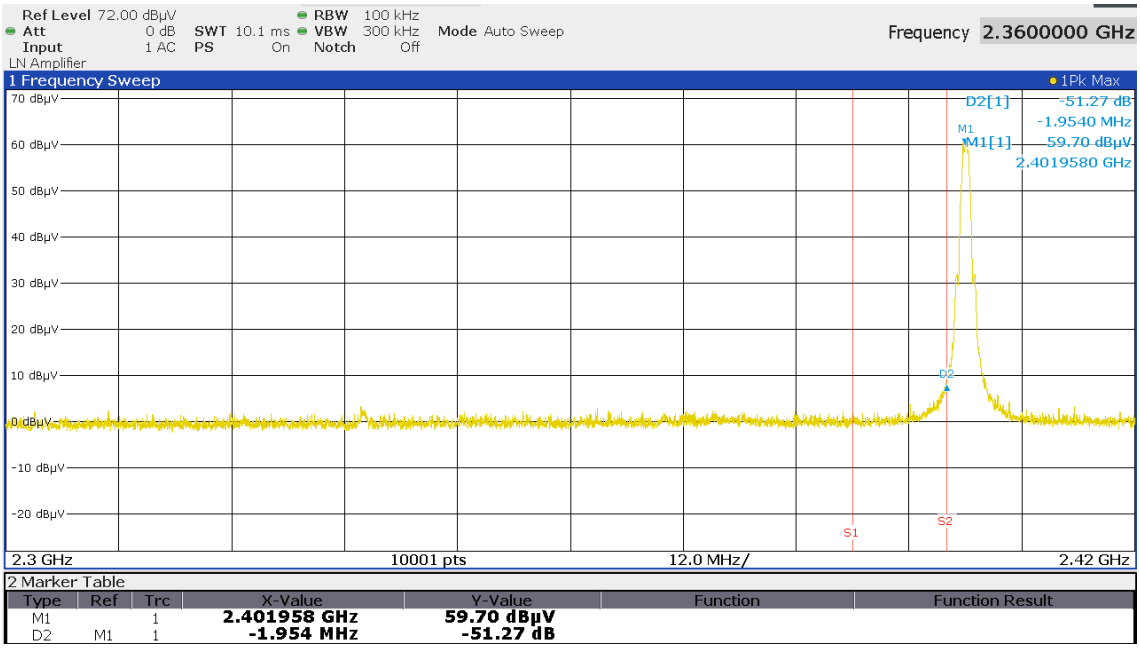
*2 If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

5.1.3 Test results (Band edge – unrestricted bands)

Ambient temperature:	22 °C
Relative humidity:	24 %

Date	29.06.2021
Tested by	B. ROHDE

Worst case plot Lower band edge (operation mode 1):



Lower band edge (operation mode 1):

Frequency [MHz]	Reference [dBµV]	Limit [dBµV/m]	Unrestricted band emission [dBµV/m]	Margin [dB]	Result
2400.000	59.7	39.7	8.4	31.3	Passed
Measurement uncertainty +/- 5.1 dB					

Test equipment (please refer to chapter 6 for details)
1 - 8

5.1.4 Test setup (Band edge – restricted bands)

Test setup (Band edge – restricted bands)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

5.1.5 Test method (Band edge – restricted bands)

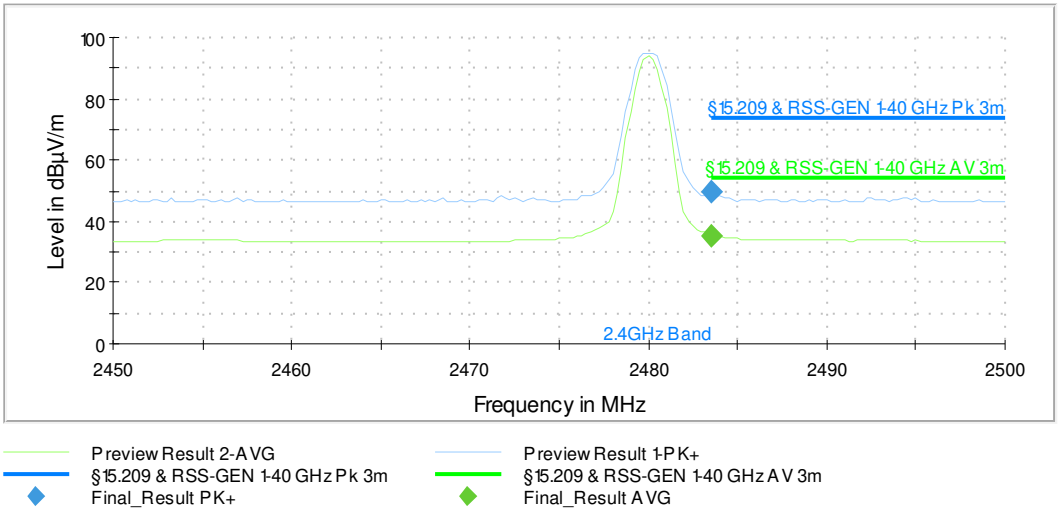
Test method (Band edge – restricted bands)				
Used	Sub-Clause [3]	Name of method	Applicability	Comment
☒	11.13.1	Standard method	No limitations	
☐	11.13.2	Marker-delta method		See 6.10.6 [3]
☐	11.13.3.2	Peak detection	Not for DTS testing	2 MHz from band
☐	11.13.3.3	Trace averaging with cont. EUT	D ≥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

5.1.6 Test results (Band edge – restricted bands)

Ambient temperature:	24 °C
Relative humidity:	32 %

Date	19.05.2021
Tested by	B. ROHDE

Worst case plot upper band edge (operation mode 3):



Upper band edge (operation mode 3):

Frequency [MHz]	Result (Pk) [dBµV/m]	Result (Av) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Result
2483.500	---	35.17	54.0	18.8	Passed
2483.500	49.56	---	74.0	24.4	Passed
Measurement uncertainty +/- 5.1 dB					

Test equipment (please refer to chapter 6 for details)
1 - 8

5.2 Maximum unwanted emissions

5.2.1 Test setup (Maximum unwanted emissions)

Test setup (Maximum unwanted emissions)			
Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1	
☐	Test setup (antenna port conducted)	-	

5.2.2 Test method (Maximum unwanted emissions)

☒ Test method (radiated) see sub-clause 5.1.1 as described herein

5.2.3 Test results (Maximum unwanted emissions)

5.2.3.1 Test results (9 kHz – 30 MHz)

Ambient temperature:	23 °C
Relative humidity:	51 %

Date	01.07.2021
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.

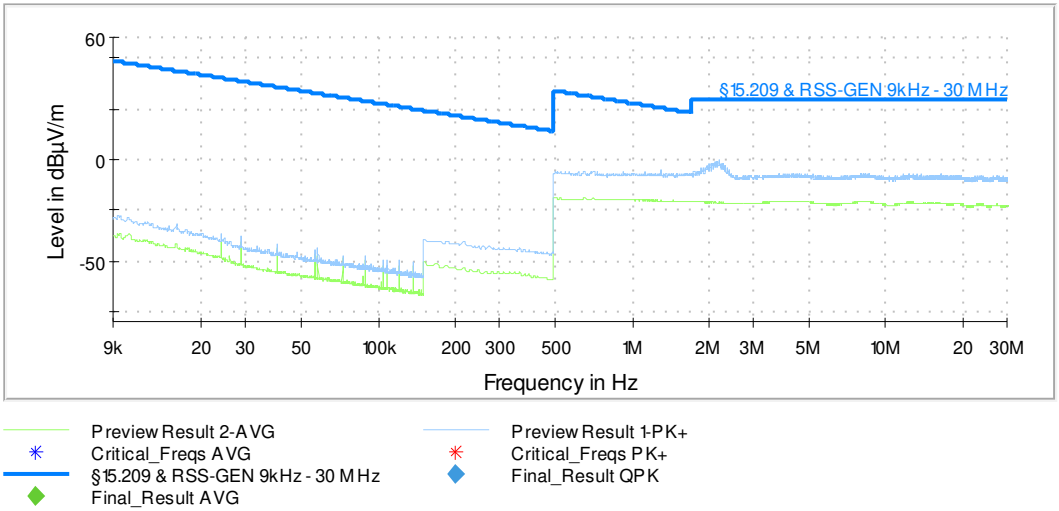
Cable guide: For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.

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

Remark: Result [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + distance correction factor [dB]
Margin [dB] = Limit [dBµV/m] - Result [dBµV/m]
All 3 orthogonal planes were tested separately

5.2.3.1.1 Worst case plot:

Spurious emissions from 9 kHz to 30 MHz (operation mode 1):



5.2.3.1.2 Result tables

5.2.3.1.2.1 (All operation modes):

No final measurement done; no emission close than 20 dB to the limit.

Test equipment (please refer to chapter 6 for details)
2 - 10

5.2.3.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	23 °C
Relative humidity:	34 %

Date	18.05.2021
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.

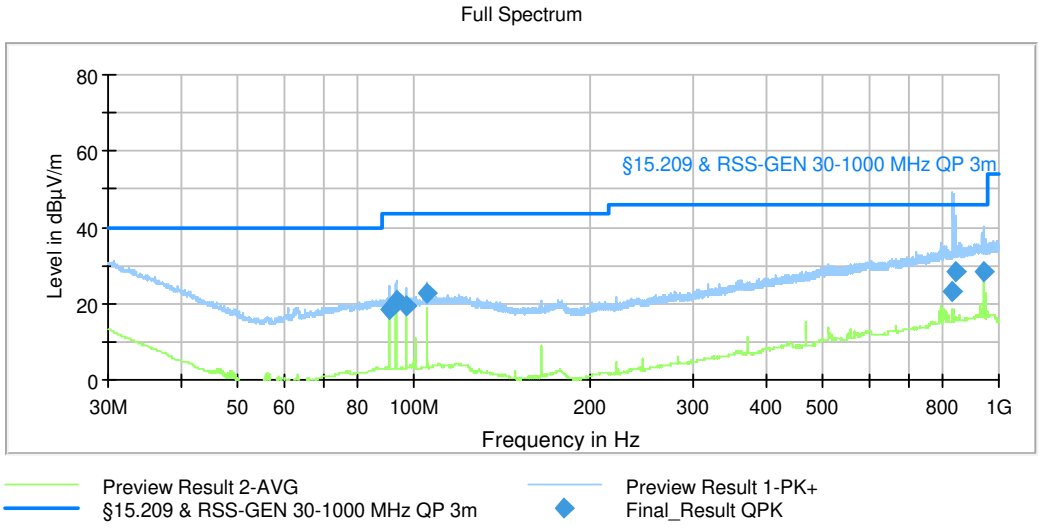
Cable guide: For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.

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

Remark: 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]
All 3 orthogonal planes were tested separately

5.2.3.2.1 Worst case plot:

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



5.2.3.2.2 Result tables

5.2.3.2.2.1 (all operation modes):

Frequency [MHz]	Result QP [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Readings [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Result
90.590	18.27	43.5	25.3	1.2	17.0	150.0	67	V	Passed
93.200	20.75	43.5	22.8	3.7	17.0	135.0	287	V	Passed
97.000	19.45	43.5	24.1	2.3	17.1	331.0	170	V	Passed
105.510	22.61	43.5	20.9	5.0	17.6	201.0	75	H	Passed
834.430	22.96	46.0	23.1	-6.4	29.3	186.0	101	V	Passed
841.300	28.56	46.0	17.5	-0.8	29.4	136.0	223	V	Passed
943.840	28.45	46.0	17.6	-1.7	30.2	115.0	185	V	Passed
Measurement uncertainty				±4.8 dB					

Test equipment (please refer to chapter 6 for details)
2 – 8, 11 - 12

5.2.3.3 Test results (above 1 GHz)

Ambient temperature:	24 °C
Relative humidity:	32 %

Date	19.05.2021
Tested by	B. ROHDE

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

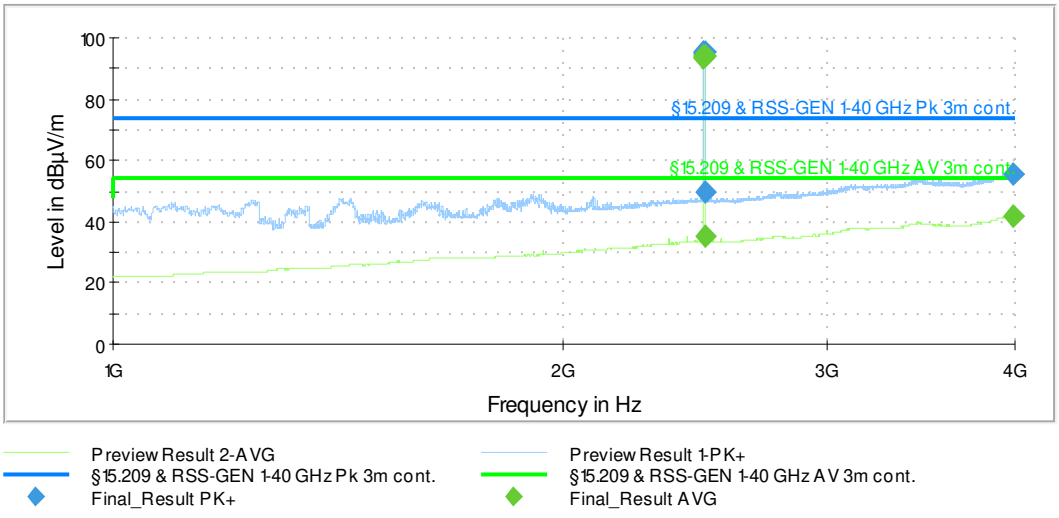
Cable guide: For detail information of test set-up and the cable guide refer to the pictures in the annex A in the test report.

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

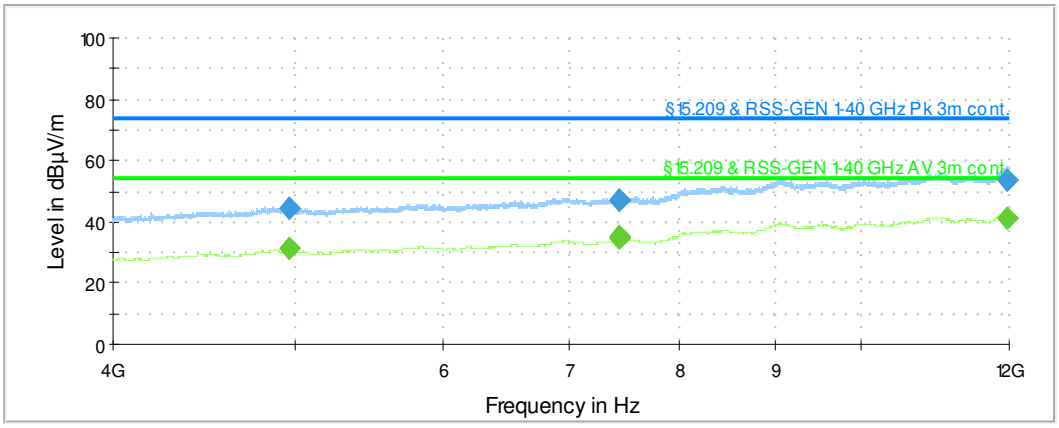
Remark:
Max Peak [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]
Average [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF [dB] (if applicable)
Margin [dB] = Limit [dBµV/m] – Max Peak // Average [dBµV/m]

5.2.3.3.1 Worst case plot:

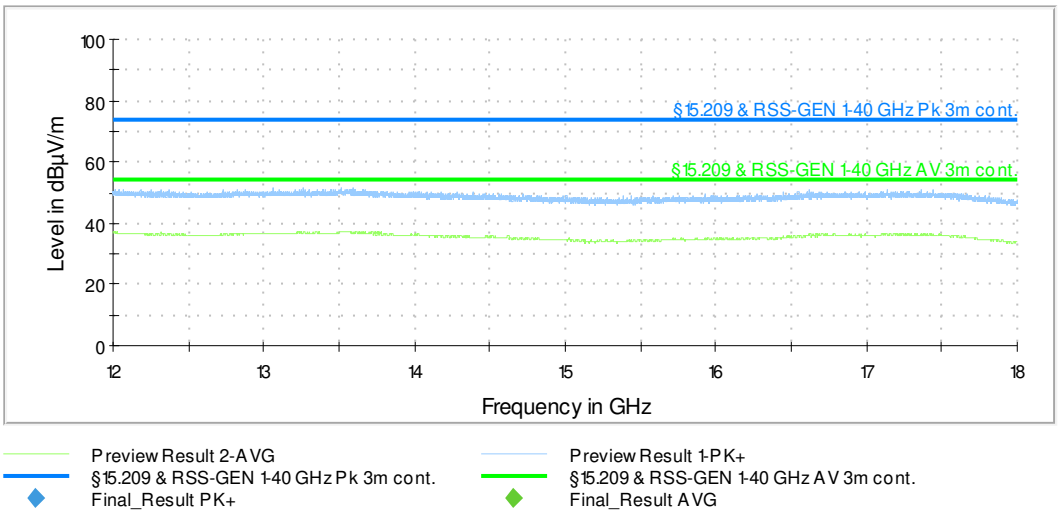
Spurious emissions from 1 GHz to 4 GHz (operation mode 1):



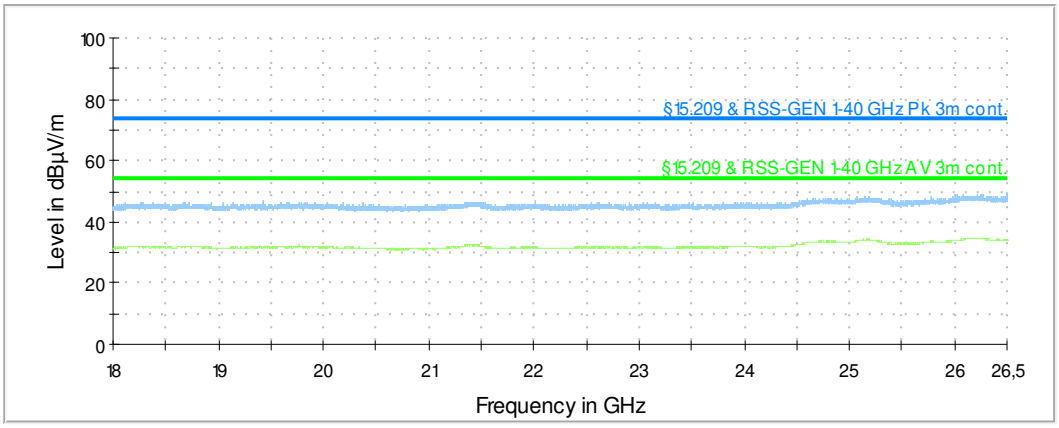
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



Spurious emissions from 12 GHz to 18 GHz (all operation modes):



Spurious emissions from 18 GHz to 26.5 GHz (all operation modes):



5.2.3.3.2 Result tables

5.2.3.3.2.1 (operation mode 1):

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Reading [dBµV]	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol	Comment
2401.750	---	94.90	---	---	59.6	35.3	60	267	V	Fund.
2401.750	96.19	---	---	---	60.9	35.3	60	267	V	Fund.
2402.000	---	95.70	---	---	60.4	35.3	60	266	V	Fund.
2402.000	96.15	---	---	---	60.9	35.3	60	266	V	Fund.
2402.250	---	95.04	---	---	59.8	35.3	60	267	V	Fund.
2402.250	96.24	---	---	---	61.0	35.3	60	267	V	Fund.
3989.250	---	41.62	54.0	12.4	0.6	41.0	90	216	V	Passed
3989.250	55.89	---	74.0	18.1	14.9	41.0	90	216	V	Passed
7205.350	48.17	---	74.0	25.8	34.6	13.5	30	291	V	Passed
7205.350	---	36.60	54.0	17.4	23.1	13.5	30	291	V	Passed
7206.750	47.88	---	74.0	26.1	34.3	13.6	60	118	V	Passed
7206.750	---	36.72	54.0	17.3	23.2	13.6	60	118	V	Passed
11924.200	---	40.31	54.0	13.7	17.5	22.8	30	342	H	Passed
11924.200	53.06	---	74.0	20.9	30.2	22.8	30	342	H	Passed
Measurement uncertainty					+/- 5.9 dB					

5.2.3.3.2.2 (operation mode 2):

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Reading [dBµV]	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol	Comment
2439.750	---	94.56	---	---	59.2	35.4	60	264	V	Fund.
2439.750	95.89	---	---	---	60.5	35.4	60	264	V	Fund.
2440.000	---	95.30	---	---	59.9	35.4	60	265	V	Fund.
2440.000	95.78	---	---	---	60.4	35.4	60	265	V	Fund.
2440.250	---	94.74	---	---	59.4	35.4	60	264	V	Fund.
2440.250	95.94	---	---	---	60.6	35.4	60	264	V	Fund.
3978.500	---	41.57	54.0	12.4	0.6	41.0	120	233	V	Passed
3978.500	57.00	---	74.0	17.0	16.0	41.0	120	233	V	Passed
7319.200	47.20	---	74.0	26.8	32.7	14.5	60	32.7	V	Passed
7319.200	---	35.78	54.0	18.2	21.3	14.5	60	21.3	V	Passed
7320.700	---	34.84	54.0	19.2	20.4	14.5	60	20.4	V	Passed
7320.700	46.87	---	74.0	27.1	32.4	14.5	60	32.4	V	Passed
11974.700	53.33	---	74.0	20.7	30.0	23.3	0	30.0	H	Passed
11974.700	---	40.88	54.0	13.1	17.6	23.3	0	17.6	H	Passed
Measurement uncertainty					+/- 5.9 dB					

5.2.3.3.2.3 (operation mode 3):

Frequency [MHz]	MaxPeak [dBµV/m]	Average [dBµV/m]	Limit [dBµV/m]	Margin (dB)	Reading [dBµV]	Corr. [dB/m]	Elevation [deg]	Azimuth [deg]	Pol	Comment
2479.750	---	93.77	---	---	58.4	35.4	0	254	H	Fund.
2479.750	95.16	---	---	---	59.8	35.4	0	254	H	Fund.
2480.000	---	94.44	---	---	59.1	35.4	0	255	H	Fund.
2480.000	94.93	---	---	---	59.6	35.4	0	255	H	Fund.
2480.250	---	94.02	---	---	58.6	35.4	0	254	H	Fund.
2480.250	95.18	---	---	---	59.8	35.4	0	254	H	Fund.
2483.500	---	35.17	54.0	18.8	-0.2	35.4	0	243	H	Passed
2483.500	49.56	---	74.0	24.4	14.2	35.4	0	243	H	Passed
3992.750	---	41.68	54.0	12.3	0.6	41.0	30	38	V	Passed
3992.750	55.84	---	74.0	18.2	14.8	41.0	30	38	V	Passed
4960.600	44.15	---	74.0	29.9	34.1	10.1	0	283	V	Passed
4960.600	---	31.61	54.0	22.4	21.5	10.1	0	283	V	Passed
7439.750	46.94	---	74.0	27.1	31.8	15.1	60	87	V	Passed
7439.750	---	34.76	54.0	19.2	19.6	15.1	60	87	V	Passed
7440.500	---	35.28	54.0	18.7	20.1	15.1	60	109	V	Passed
7440.500	47.06	---	74.0	26.9	31.9	15.1	60	109	V	Passed
11979.350	---	40.98	54.0	13.0	17.7	23.3	150	124	H	Passed
11979.350	53.30	---	74.0	20.7	30.0	23.3	150	124	H	Passed
Measurement uncertainty				+/- 5.9 dB						

Test equipment (please refer to chapter 6 for details)
1 – 8, 13 – 17

6 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Log.-Per. antenna	HL050	Rohde & Schwarz	100908	482977	13.08.2019	08.2022
2	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
3	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
4	Antennasupport	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
5	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
6	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
7	Measuring software EMC32 M276	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
8	EMI Test receiver	ESW44	Rohde & Schwarz	101828	482979	14.11.2019	11.2021
9	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	14.02.2020	02.2022
10	loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	25.02.2021	02.2022
11	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
12	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
13	Low Noise Amplifier 100 MHz - 18 GHz	LNA-30-00101800-25-10P	Narda-Miteq	2110917	482967	18.02.2020	02.2022
14	Low Noise Amplifier 12 GHz - 18 GHz	LNA-30-12001800-13-10P	Narda-Miteq	2089798	482968	Calibration not necessary	
15	Standard Gain Horn 20 dB, 12 GHz-18 GHz	18240-20	Flann	267220	483025	Calibration not necessary	
16	Low Noise Amplifier 18 GHz - 26.5 GHz	LNA-30-18002650-20-10P	Narda-Miteq	2110911	482969	17.02.2020	02.2022
17	Standard Gain Horn 20 dB, 18 GHz -26 GHz	20240-20	Flann	266399	483026	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	03.03.2021	02.03.2023
Semi anechoic chamber M276	483227	1 -18 GHz	SVSWR	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	25.02.2021	24.02.2023

8 Report History

Report Number	Date	Comment
F210861E2	21.01.2022	Initial Test Report
-	-	-
-	-	-

9 List of Annexes

Annex A Test Setup Photos 8 pages