

Test Report

Report Number:

F231195E2

Equipment under Test (EUT):

TrackSense Pro SKY

Applicant:

Ellab A/S

Manufacturer:

Ellab A/S



Deutsche
Akkreditierungsstelle
D-PL-17186-01-00

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 3 (2023-08)** Digital Transmission Systems (DTSS), 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.

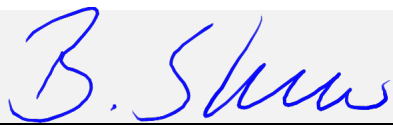
“Passed” indicates that the equipment under test conforms with the relevant limits of the testing standard without taking any measurement uncertainty into account as stated in clause 1.3 of ANSI C63.10 (2013). However, the measurement uncertainty is calculated and shown in this test report.

Tested and written
by:


Signature

Bernward ROHDE
15.12.2023

Reviewed and
approved by:


Signature

Bernd STEINER
21.12.2023

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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

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eMail address:	JJA@ELLAB.COM
Applicant represented during the test by the following person:	-

1.2 Manufacturer

Name:	Ellab A/S
Address:	Trollesmindealle 25, 3400 Hilleroed
Country:	Denmark
Name for contact purposes:	James Jacobsson
Phone:	+45-4452-0500
eMail address:	JJA@ELLAB.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-17186-01-05 and D-PL-17186-01-06, 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: *	TrackSense Pro SKY radio module
Model name: *	TrackSense Pro SKY
Model number: *	66110382
FCC ID: *	XUS-SKYDL2
IC certification number: *	8758A-SKYDL2
PMN: *	TrackSense Pro SKY
HVIN: *	66110382
FVIN: *	---

	EUT number		
	1 (conducted)	2 (radiated)	3
Serial number: *	NA	NA	-
PCB identifier: *	610000155 +610000156 +610000157	610000155 +610000156 +610000157	-
Hardware version: *	01	01	-
Software version: *	20.00	20.00	-

* 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.

1.5 Technical Data of Equipment

General EUT data	
Power supply EUT: *	DC (by internal lithium battery)
Supply voltage EUT: *	$U_{nom} = 3.6 \text{ V}_{DC}$
Temperature range: *	-80°C to +140°C
Lowest / highest internal clock frequency: *	32.768 kHz / 16 MHz

Ports / Connectors				
Identification	Connector		Length during test	Shielding (Yes / No)
	EUT	Ancillary		
Serial-2-Logger	Samtec-BKS-27	Samtec-BKT-27	-	no
Serial-2-Sensor	Samtec-BKT-27	Samtec-BKS-27	-	no
-	-	-	-	-

Proprietary frequencies				
Channel 11	RX	2405 MHz	TX	2405 MHz
Channel 12	RX	2410 MHz	TX	2410 MHz
Channel 13	RX	2415 MHz	TX	2415 MHz
Channel 14	RX	2420 MHz	TX	2420 MHz
Channel 15	RX	2425 MHz	TX	2425 MHz
Channel 16	RX	2430 MHz	TX	2430 MHz
Channel 17	RX	2435 MHz	TX	2435 MHz
Channel 18	RX	2440 MHz	TX	2440 MHz
Channel 19	RX	2445 MHz	TX	2445 MHz
Channel 20	RX	2450 MHz	TX	2450 MHz
Channel 21	RX	2455 MHz	TX	2455 MHz
Channel 22	RX	2460 MHz	TX	2460 MHz
Channel 23	RX	2465 MHz	TX	2465 MHz
Channel 24	RX	2470 MHz	TX	2470 MHz
Channel 25	RX	2475 MHz	TX	2475 MHz

Proprietary radio mode	
Fulfil radio specification: *1	---
Radio chip: *1	ATSAMR21G17A
Antenna type: *1	SMD Antenna
Antenna name: *1	Johanson Technology 2450AT18D0100
Antenna gain: *2	Peak: 4.1 dBi (typical)
Antenna connector: *1	-
Supply voltage WLAN module: *1	$U_{nom} = 3.6 V_{DC}$
Type of modulation: *1	O-QPSK (250 kbit/s)
Operating frequency range: *1	2405 – 2475 MHz
Number of channels: *1	15 (5 MHz channel spacing)

*1 declared by the applicant

*2 based on the antenna tests, see Transmit antenna performance considerations

1.5.1 Ancillary Equipment / Equipment used for testing

Equipment used for testing	
Temp sensor	Sensor Temperature Dual
Logger	Logger Pro3 XL
Reader Station	TrackSense Pro Reader Station
Access Point	TrackSense Pro SKY AccessPoint

*1 Provided by the applicant

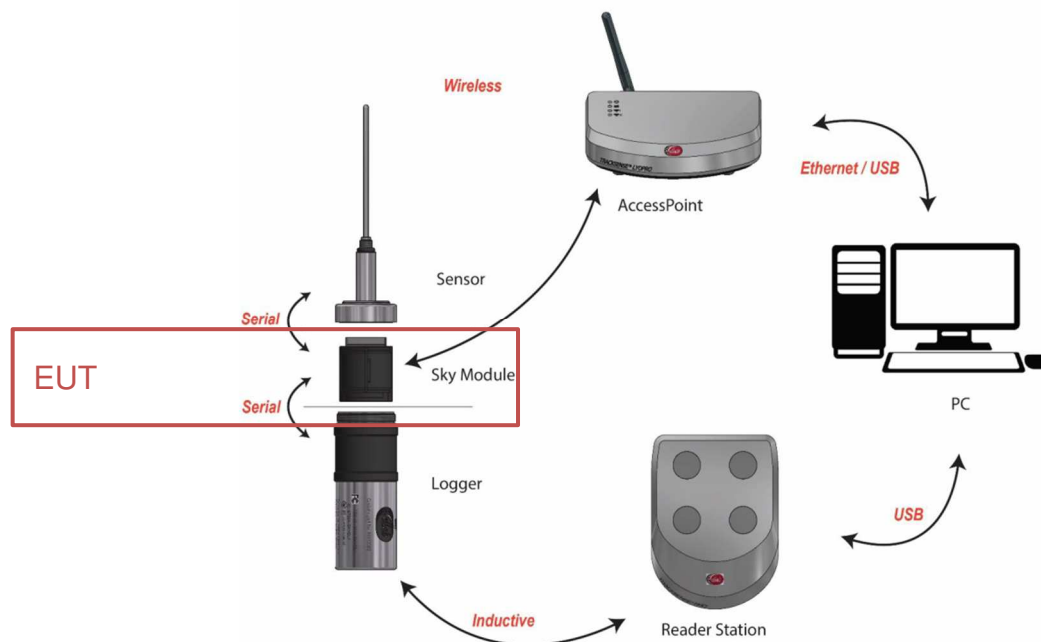
1.6 Dates

Date of receipt of test sample:	17.07.2023
Start of test:	07.08.2023
End of test:	18.08.2023

2 Operational States

2.1 Description of function of the EUT

The offline system consists of PC software, Reader Station to start-up and read measured samples from the logger with a replaceable sensor. The logger is battery driven. The online system consists of an AccessPoint and an add on to the logger - the SKY module.



2.1.1 Operation modes

Operation mode #	Radio technology	Frequency [MHz]	Channel / Band	Modulation / Mode	Data rate	Power setting
1	Proprietary	2405	0	OQPSK	250 kbit/s	-
2	Proprietary	2440	16	OQPSK	250 kbit/s	-
3	Proprietary	2475	25	OQPSK	250 kbit/s	-

Power not set able

3 Additional Information

The radiated tests were done with an unmodified sample, conducted tests were done with a modified EUT.
Modifications shown below:



Modification for conducted tests

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) (3), (4)	5.4 (d) [4]	EUT1	Passed
Maximum conducted output power	2400.0 - 2483.5	15.247 (b) (3), (4)	5.4 (d) [4]	EUT1	Passed
DTS Bandwidth / 99% Bandwidth	2400.0 - 2483.5	15.247 (a) (2)	5.2 (a) [4]	EUT1	Passed
Peak Power Spectral Density	2400.0 - 2483.5	15.247 (e)	5.2 (b) [4]	EUT1	Passed
Average Power Spectral Density	2400.0 - 2483.5	15.247 (e)	5.2 (b) [4]	EUT1	Passed
Band edge compliance	2400.0 - 2483.5	15.247 (d) 15.205 (a) 15.209 (a)	5.5 [4]	EUT1 EUT2	Passed
Maximum unwanted emissions	0.009 – 26,500*	15.247 (d) 15.205 (a) 15.209 (a)	8.9 [5]	EUT2	Passed*
Antenna Requirement	-	15.203 15.247 (b)	6.8 [5] 5.4 (f) (ii) [4]	-	Passed
Conducted emissions on supply line	0.15 – 30	15.207 (a)	8.8 [5]	-	---*2

*: Therefore, the radiated emission measurement must be carried out up to 10th of the highest radio clock frequency in this case 26.5 GHz.

*2: The EUT is battery powered, no connection to the AC mains network.

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

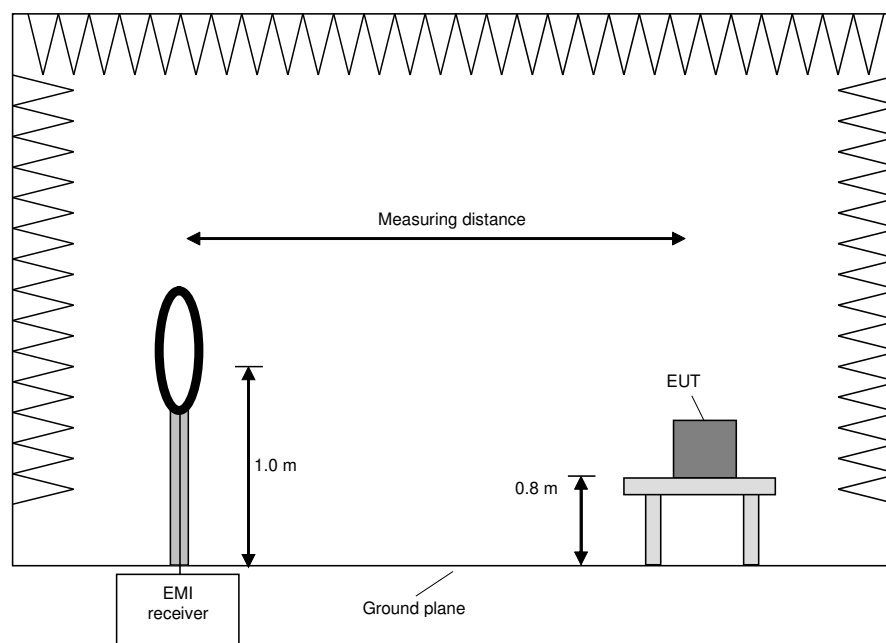
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

5.1.2 Radiated: 30 MHz to 1 GHz

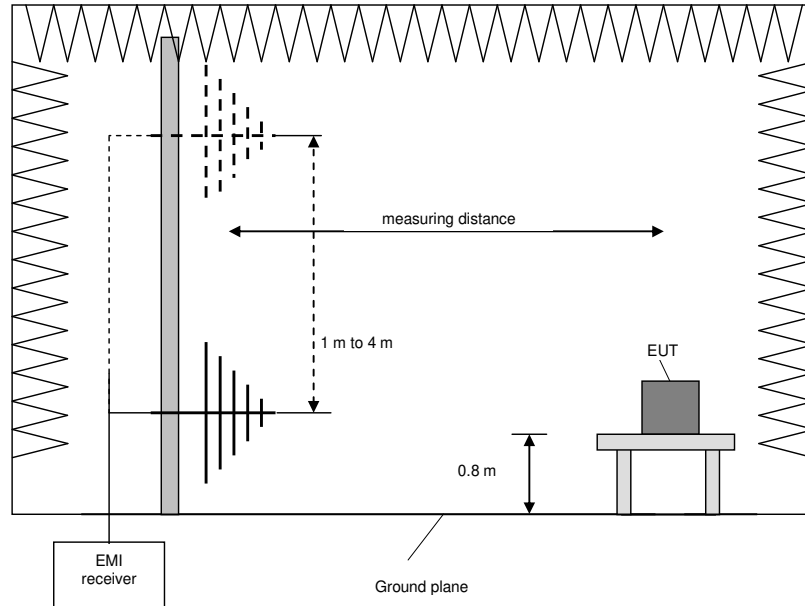
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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	± 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

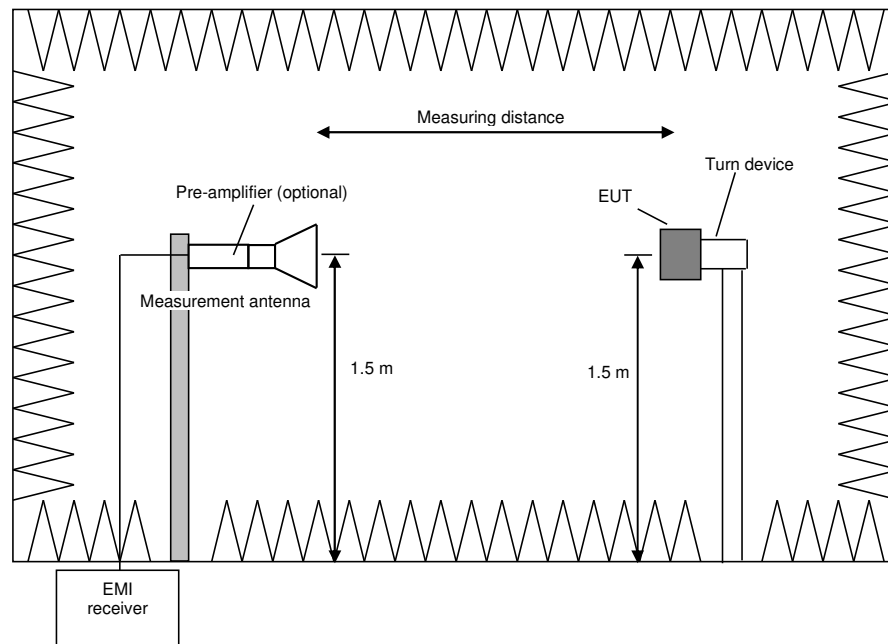
5.1.3.1 Preliminary and final measurement 1 to 40 GHz

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.

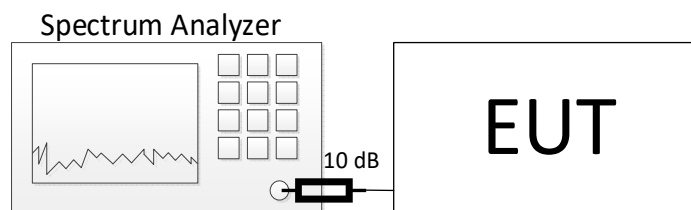
Procedure final measurement:

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
☒	Temporary antenna connector	As provided by the applicant
☐	Normal antenna connector	-



The 10 dB external attenuation are considered in all relevant plots

5.2 Duty cycle

5.2.1 Test setup (Duty cycle)

Test setup (Duty cycle)			
Used	Setup	See sub-clause	Comment
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	Conducted: Antenna port	5.1.4	-

5.2.2 Test method (Duty cycle)

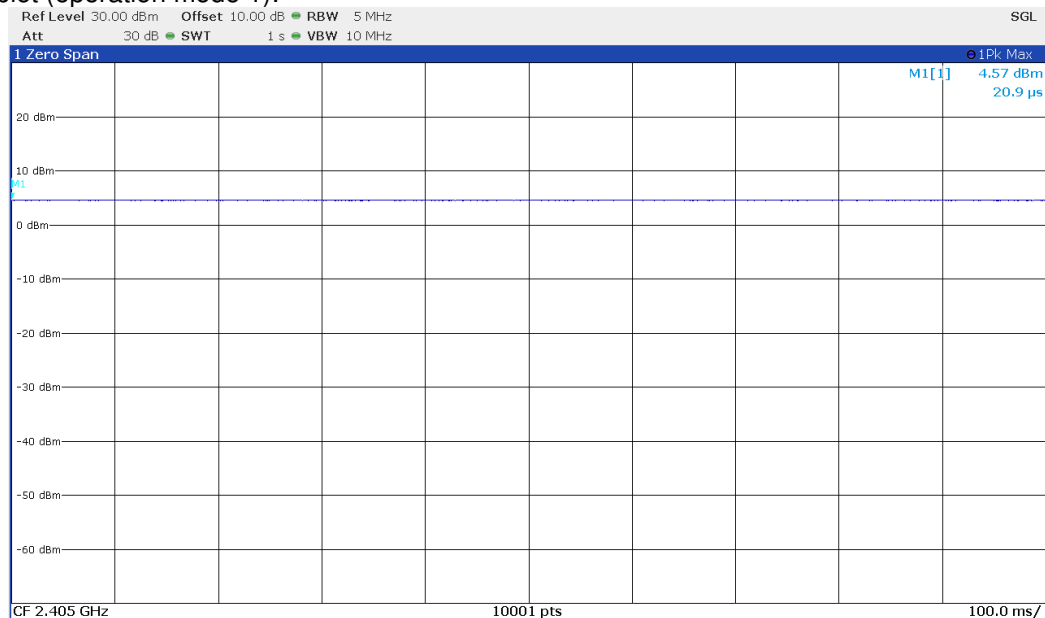
Test method (Duty cycle)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☐	11.6. a)	Diode detector	No limitation	-
☒	11.6. b)	Zero span	No limitation	-

5.2.3 Test results (Duty cycle)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE

Worst case plot (operation mode 1):



No DCCF is applied, duty cycle $\geq 98\%$.

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

5.3 Transmit antenna performance considerations

Test setup (Transmit antenna performance considerations)		
Integral antenna	Antenna gain $\leq 6\text{dBi}$	Comment
☒	☒	No output power reduction necessary

Antenna gain calculation				
		f_{low}	f_{mid}	f_{high}
Antenna Gain [dBi]		4.1	3.3	1.7
Position		Position 1	Position 1	Position 1
Position of maximum gain	Azimuth	220	220	220
	Elevation	0	0	0
	Polarisation	H	H	H

For details see document: F231195E4

5.4 DTS bandwidth

5.4.1 Test setup (DTS bandwidth)

Test setup (DTS bandwidth)			
Used	Setup	See sub-clause	Comment
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	Conducted: Antenna port	5.1.4	-

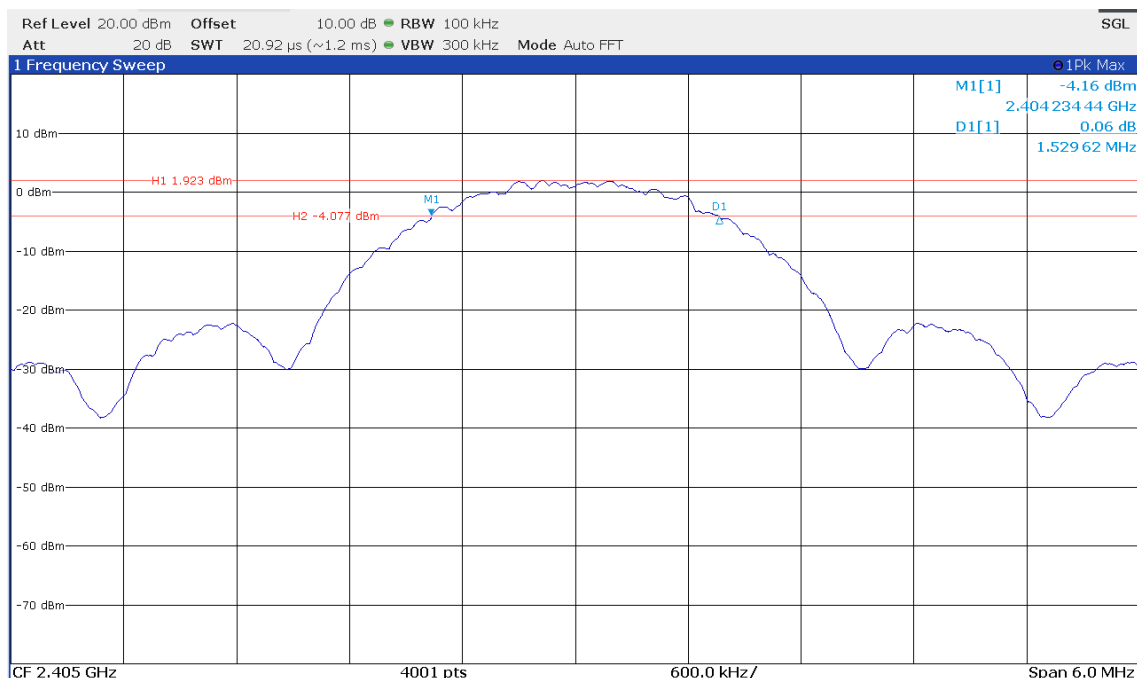
5.4.2 Test method (DTS bandwidth)

Test method (DTS bandwidth)				
Used	Sub-Clause [1]	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:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE



Operation mode #	DTS bandwidth [MHz]	Minimum DTS bandwidth Limit [MHz]
1	1.529618	0.5
2	1.582104	0.5
3	1.673582	0.5

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
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	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
☐	6.9.2	Relative measurement procedure	-	n-dB down
☒	6.9.3	Power bandwidth (99%)	*1	99% power function

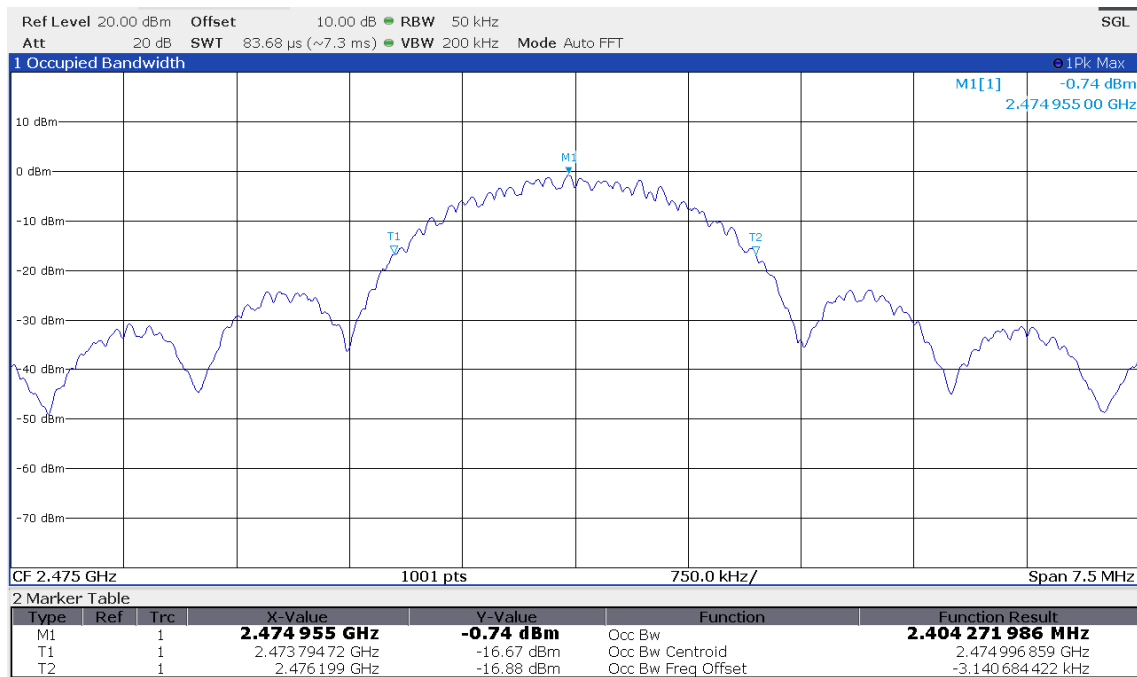
*1 See RSS-GEN Issue 5 (2018-05) sub-clause 6.7 for details.

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

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE

Worst case plot (operation mode 3):



Operation mode #	99% bandwidth [MHz]
1	2.342379
2	2.359885
3	2.404272

Test result: Passed

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

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
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	Conducted: Antenna port	5.1.4	-

5.6.2 Test method (DTS fundamental emission output power)

Test method (Maximum peak conducted output power)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.9.1.1	RBW $\geq$ DTS bandwidth	-	Zero span mode
☐	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 [1]	Name of method	Applicability	Comment
☐	11.9.2.2.2	Method AVGSA-1	$D \geq 98\%$	-
☐	11.9.2.2.3	Method AVGSA-1A (alternative)	$D \geq 98\%$	-
☒	11.9.2.2.4	Method AVGSA-2	Constant D ($\pm 2\%$)	-
☐	11.9.2.2.5	Method AVGSA-2A (alternative)	Constant D ($\pm 2\%$)	-
☐	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 ($\pm 2\%$)	-
☐	11.9.2.3.2	Method AVGPM-G	-	-

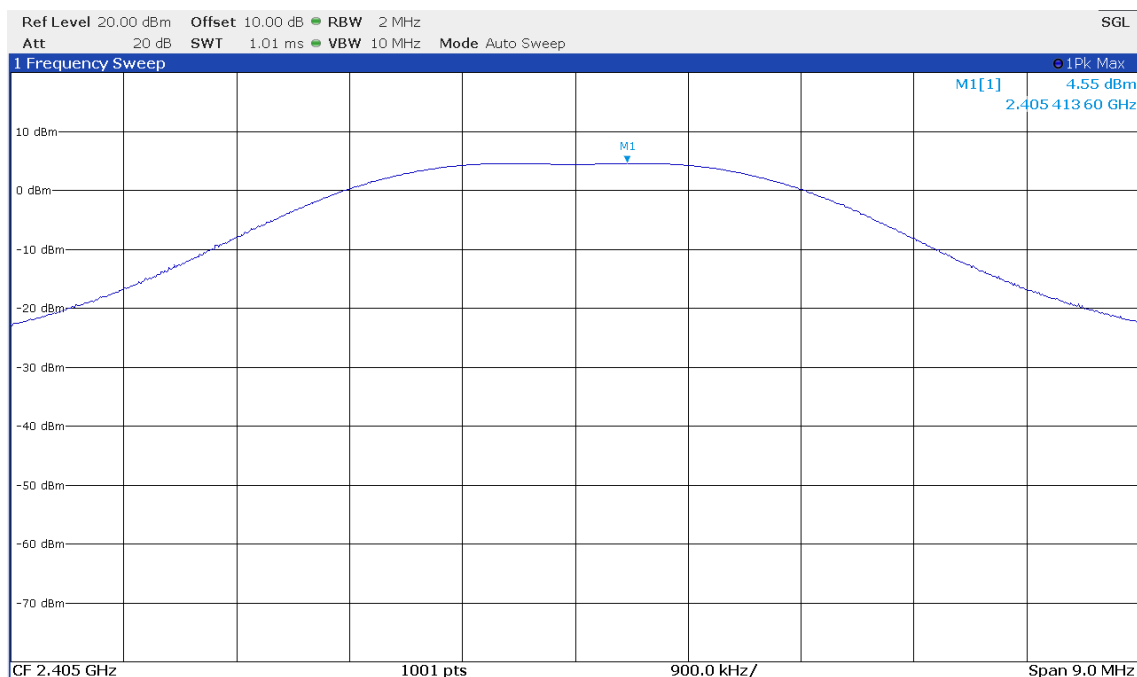
5.6.3 Test results (DTS fundamental emission output power)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE

5.6.3.1 Maximum peak conducted output power:

Worst case plot (operation mode 1):

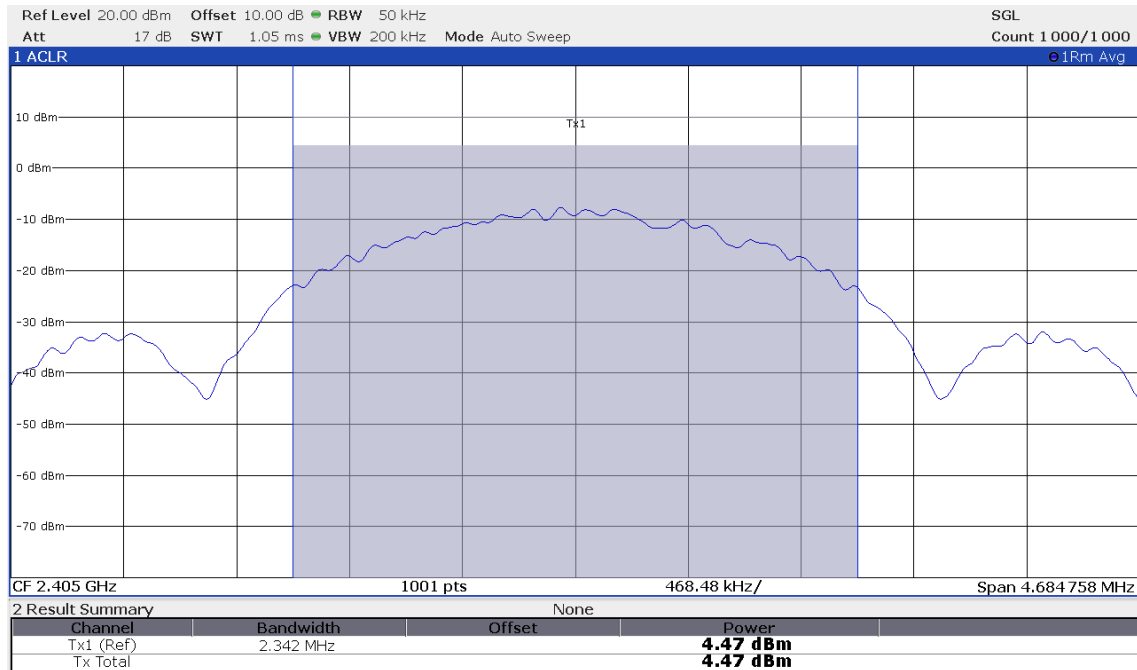


Operation mode	Reading [dBm]	Corr. Fact. [dB]	Result [dBm]	Limit [dBm]
1	4.6	0.0	4.6	30
2	4.4	0.0	4.4	30
3	4.2	0.0	4.2	30

Test result: Passed

5.6.3.2 Maximum conducted (average) output power

Worst case plot (operation mode 1):



Operation mode	Reading [dBm]	Corr. Fact. [dB]	DCCF [dB]	Result [dBm]	Limit [dBm]
1	4.5	0.0	0.0	4.5	30
2	4.3	0.0	0.0	4.3	30
3	4.0	0.0	0.0	4.0	30

Test result: Passed

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

5.7 DTS maximum power spectral density

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
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	Conducted: Antenna port	5.1.4	-

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

Test method (Maximum <i>peak</i> power spectral density level in the fundamental emission)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.10.2	Method PKPSD (peak PSD)	No limitations	-

Test method (Maximum <i>average</i> power spectral density level in the fundamental emission)				
Used	Sub-Clause [1]	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	-

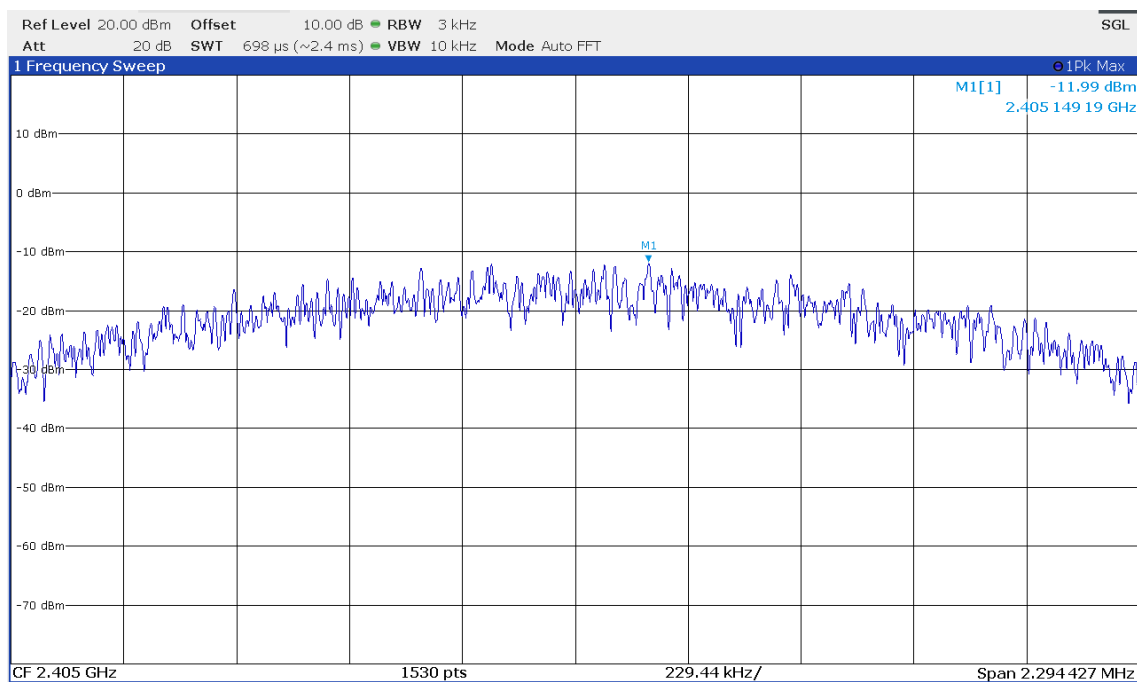
5.7.3 Test results (DTS maximum PSD level in the fundamental emission)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE

5.7.3.1 Maximum peak PSD:

Worst case plot (operation mode 1):

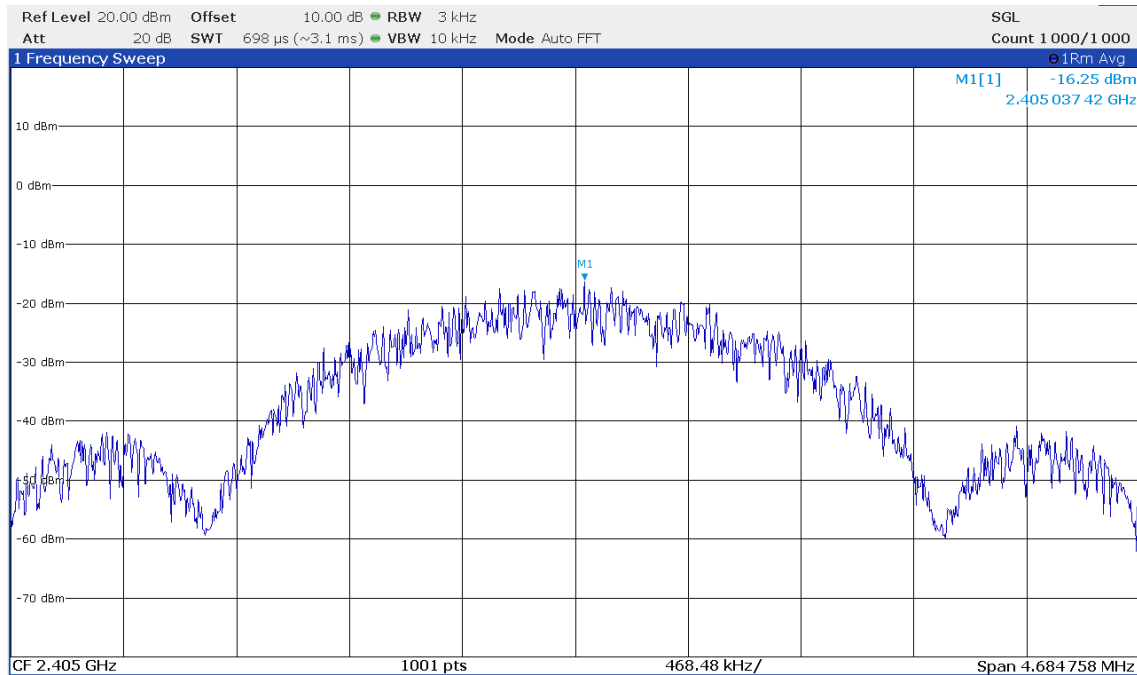


Operation mode	Reading [dBm/3 kHz]	Corr. Fact. [dB]	Result [dBm/3 kHz]	Limit [dBm/3 kHz]
1	-12.0	0.0	-12.0	8.0
2	-12.5	0.0	-12.5	8.0
3	-12.7	0.0	-12.7	8.0

Test result: Passed

5.7.3.2 Maximum average PSD

Worst case plot (operation mode 1):



Operation mode	Reading [dBm/3 kHz]	Corr. Fact. [dB]	DCCF [dB]	Result [dBm/3 kHz]	Limit [dBm/3 kHz]
1	-16.3	0.0	0.0	-16.3	8.0
2	-16.9	0.0	0.0	-16.9	8.0
3	-18.2	0.0	0.0	-18.2	8.0

Test result: Passed

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

5.8 DTS band-edge emission measurements

5.8.1 Test setup (Band edge – unrestricted bands)

Test setup (Band edge – unrestricted bands)			
Used	Setup	See sub-clause	Comment
☐	Radiated: 1 GHz to 40 GHz	5.1.3	-
☒	Conducted: Antenna port	5.1.4	-

5.8.2 Test method (Band edge – unrestricted bands)

Test method (Band edge – unrestricted bands)				
Used	Sub-Clause [1]	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

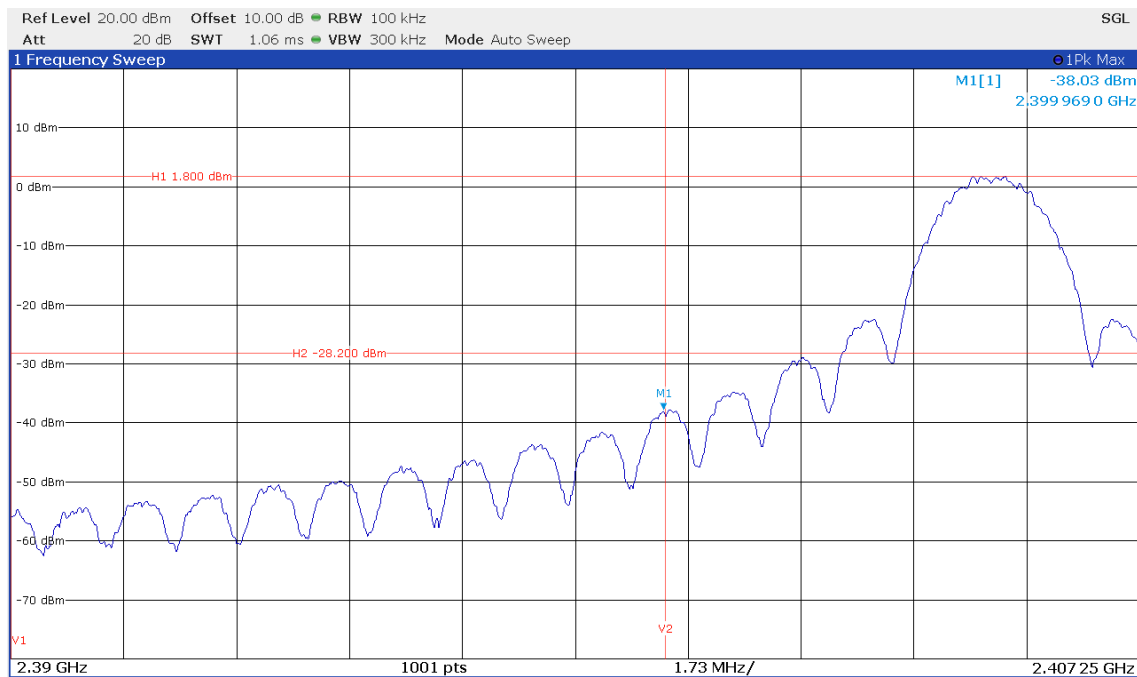
*2 If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

5.8.3 Test results (Band edge – unrestricted bands)

Ambient temperature:	22 °C
Relative humidity:	65 %

Date:	07.08.2023
Tested by:	B. ROHDE

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



Lower band edge (operation mode 1):

Frequency [MHz]	Reference [dBm]	Limit [dBm]	Unrestricted band emission [dBm]	Margin [dB]
2399.969	1.8	-28.2	-38.0	9.8

Test result: Passed

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

5.8.4 Test setup (Band edge – restricted bands)

Test setup (Band edge – restricted bands)			
Used	Setup	See sub-clause	Comment
☒	Radiated: 1 GHz to 40 GHz	5.1.3	
☐	Conducted: Antenna port	5.1.4	

5.8.5 Test method (Band edge – restricted bands)

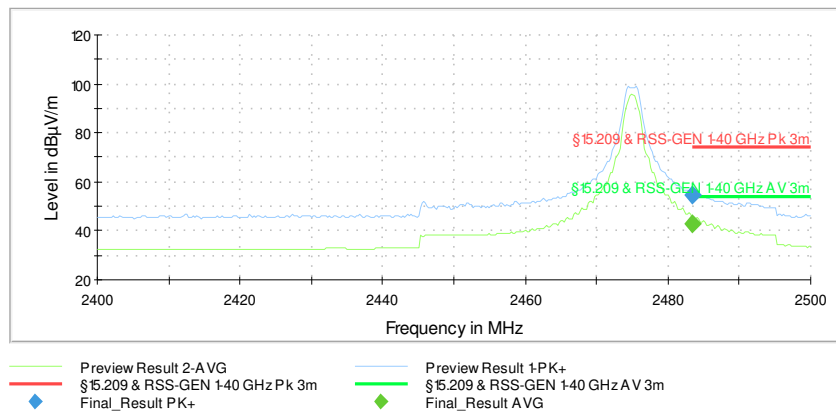
Test method (Band edge – restricted bands)				
Used	Sub-Clause [1]	Name of method	Applicability	Comment
☒	11.13.1	Standard method	No limitations	
☐	11.13.2	Marker-delta method		See 6.10.6 [3]
☐	11.13.3.2	Peak detection	Not for DTS testing	2 MHz from band
☐	11.13.3.3	Trace averaging with cont. EUT	D ≥ 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

5.8.6 Test results (Band edge – restricted bands)

Ambient temperature:	21 °C
Relative humidity:	58 %

Date:	10.08.2023
Tested by:	B. ROHDE

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



Upper band edge (operation mode 3):

Frequency [MHz]	Result (Pk) [dB(μV/m)]	Result (Av) [dB(μV/m)]	Limit [dB(μV/m)]	Margin [dB]
2483.500	54.6	---	74.0	19.4
2483.500	---	43.2	54.0	10.8

Test result: Passed

Test equipment (please refer to chapter 7 for details)
2, 10 – 11, 13 – 18, 20

5.9 Radiated emissions

5.9.1 Test setup (Maximum unwanted emissions)

Test setup (Maximum unwanted emissions)			
Used	Setup	See sub-clause	Comment
☒	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	-
☐	Conducted: Antenna port	5.1.4	-

5.9.2 Test method (Maximum unwanted emissions)

☒ Test method (radiated) see sub-clause 5.1.1 / 5.1.2 / 5.1.3 as described herein

5.9.3 Test results (Maximum unwanted emissions)

5.9.3.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	23 °C	Date:	16.08.2023
Relative humidity:	71 %	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:

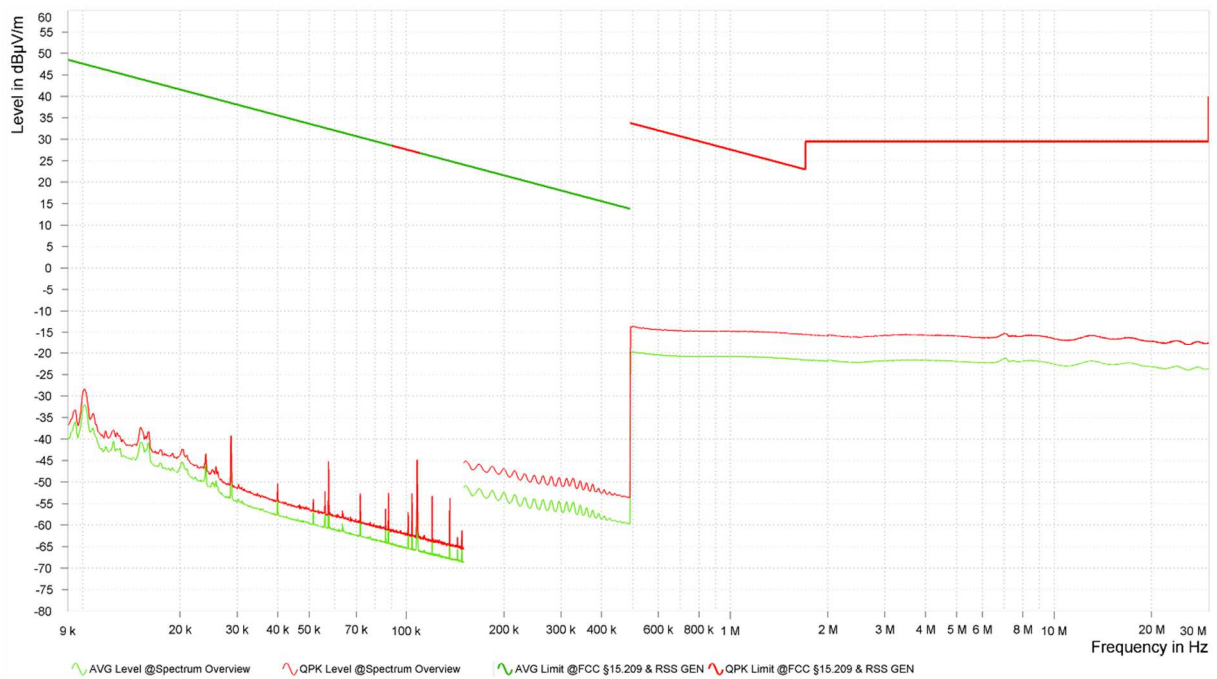
Result @ norm. dist. [dBμV/m] = Reading [dBμV] + AF [dB/m] + Distance corr. fact. [dBμV/m]

Result @ norm. dist. [dBμA/m] = Result @ norm. dist. [dBμV/m] – 20 x log₁₀ (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 1 - standing):



Remark: No further emissions close than 20 dB to the limit.

Test equipment (please refer to chapter 7 for details)

21 - 28

5.9.3.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	70 %

Date:	15.08.2023
Tested by:	A. Dückmann

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]

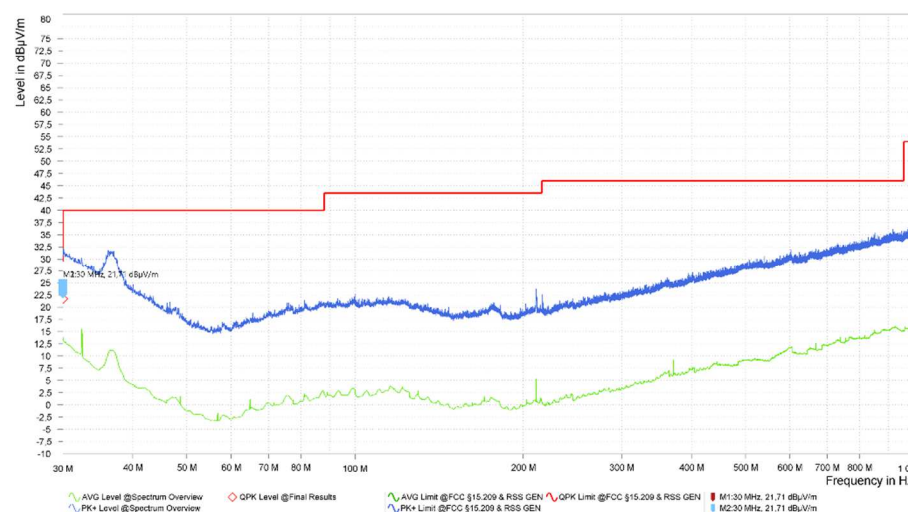
Correction [dBμV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

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 1 - standing):



Result tables:

(Operation mode 1):

Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol. (H/V)	Position #
30.000	21.71	29.50	7.79	25.98	392	86	V	1

(Operation mode 2):

Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol. (H/V)	Position #
30.000	21.46	29.50	8.04	25.98	386	56	V	2

(Operation mode 3):

Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol. (H/V)	Position #
30.000	20.82	29.50	8.68	25.98	325	325	V	3

Remark: No further emissions close than 20 dB to the limit.

Test result: Passed

Test equipment (please refer to chapter 7 for details)
22 - 30

5.9.3.3 Test results (radiated 1 to 40 GHz)

Ambient temperature:	21°C - 22°C
Relative humidity:	58% - 71%

Date:	08.08.2023 to 18.08.2023
Tested by:	A. Dückmann 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: -

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)

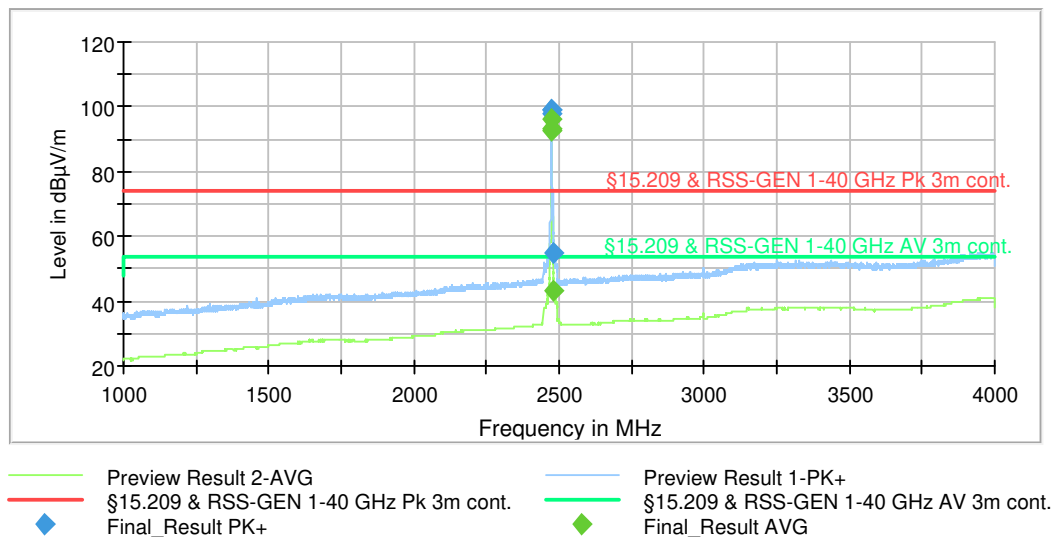
Margin [dB] = Limit [dBμV/m] – Max Peak | Average [dBμV/m]

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.

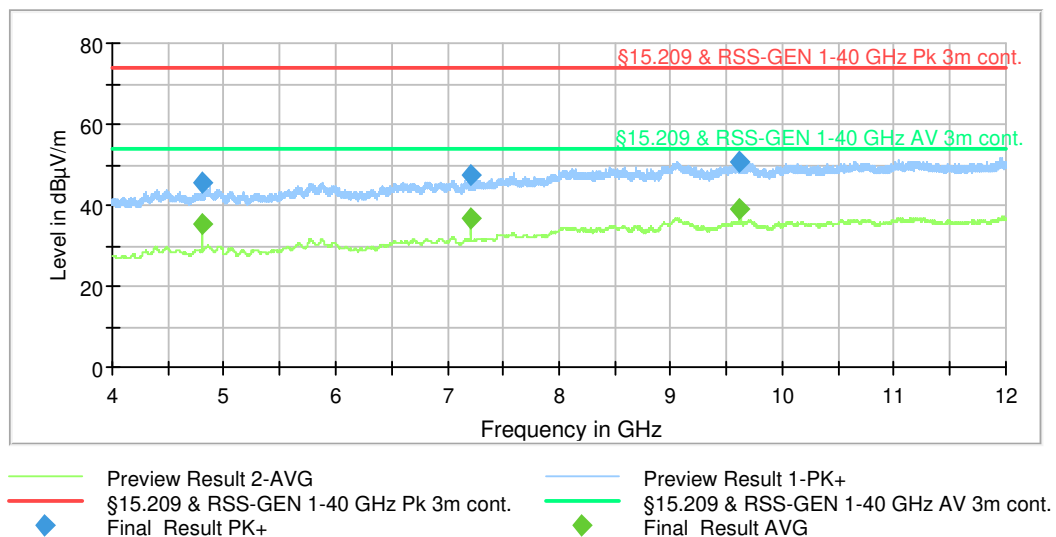
The top measured curve represents the peak measurement. The measured points marked with "◆" are frequency points for the final peak detector measurement. These values are indicated in the following table. The bottom measured curve represents the average measurement. The measured points marked with "◆"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

Worst case plots:

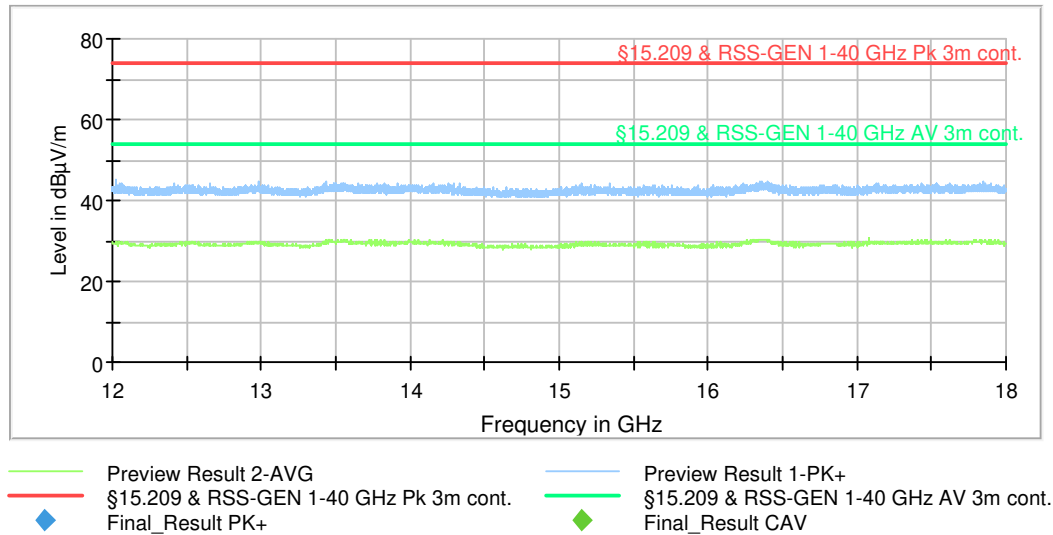
Spurious emissions from 1 GHz to 4 GHz (operation mode 3):



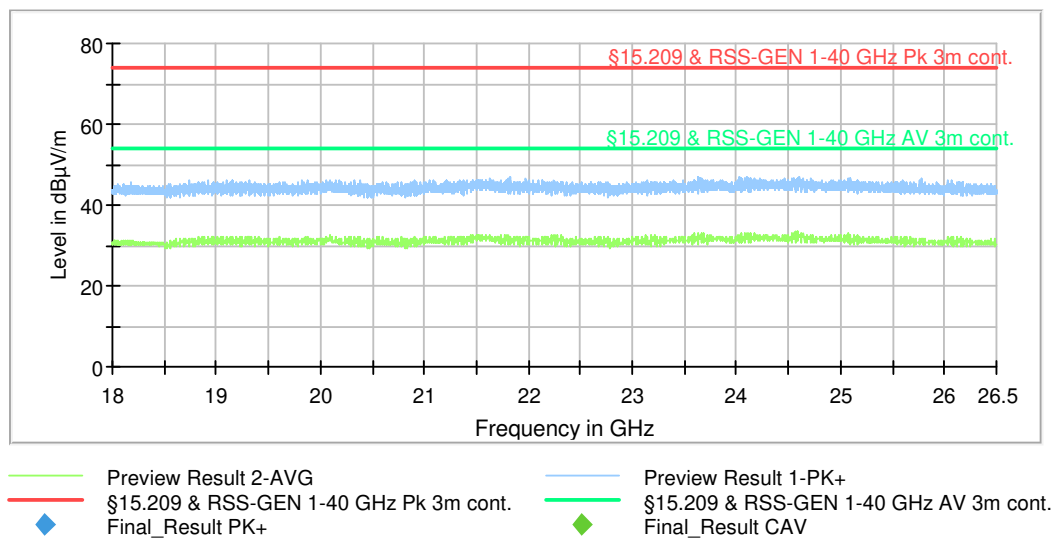
Spurious emissions from 4 GHz to 12 GHz (operation mode 1):



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



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



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]
2390.000	48.6	---	74.0	25.4	H	59	90	33.4
2390.000	---	37.8	54.0	16.2	H	59	90	33.4
4809.000	---	35.1	54.0	18.9	V	80	120	-1.8
4809.000	45.4	---	74.0	28.6	V	80	120	-1.8
7213.750	---	36.9	54.0	17.1	V	36	150	4.1
7213.750	47.7	---	74.0	26.3	V	36	150	4.1
9621.750	---	39.2	54.0	14.8	V	60	150	7.6
9621.750	50.7	---	74.0	23.3	V	60	150	7.6

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]
4879.000	46.9	---	74.0	27.1	V	283	0	-1.4
4879.000	---	36.3	54.0	17.7	V	283	0	-1.4
7318.750	48.7	---	74.0	25.3	V	71	120	4.3
7318.750	---	38.4	54.0	15.6	V	71	120	4.3
9758.000	---	39.0	54.0	15.0	H	12	150	7.0
9758.000	50.5	---	74.0	23.5	H	12	150	7.0

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]
2483.500	54.6	---	74.0	19.4	H	40	90	33.6
2483.500	---	43.2	54.0	10.8	H	40	90	33.6
4949.000	---	35.4	54.0	18.6	V	85	150	-1.4
4949.000	45.8	---	74.0	28.2	V	85	150	-1.4
7423.500	47.7	---	74.0	26.3	V	33	150	4.5
7423.500	---	36.2	54.0	17.8	V	33	150	4.5
9902.000	47.5	---	74.0	26.5	V	41	150	6.8
9902.000	---	36.0	54.0	18.0	V	41	150	6.8

Test result: Passed

Test equipment (please refer to chapter 7 for details)
2 - 20

6 Measurement Uncertainties

Conducted measurements		
Measurement method	Standard used for calculating measurement uncertainty	Expanded measurement uncertainty (95 %) U_{lab}
Frequency error	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements	-	9.0×10^{-8}
Conducted emissions using a spectrum analyzer		
< 3.6 GHz	ETSI TR 100 028	2.3 dB
3.6 – 8 GHz	ETSI TR 100 028	2.8 dB
8 – 22 GHz	ETSI TR 100 028	3.2 dB
22 – 40 GHz	ETSI TR 100 028	3.6 dB
Power measurements		
Power meter	ETSI TR 100 028	0.9 dB
Conducted emissions from 150 kHz to 30 MHz with LISN		
	CISPR 16-4-2	2.8 dB

Radiated measurements		
Frequency error		
(Semi-) Anechoic chamber	ETSI TR 100 028	4.5×10^{-8}
OATS	ETSI TR 100 028	4.5×10^{-8}
Test fixture	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements		
(Semi-) Anechoic chamber	-	9.0×10^{-8}
OATS	-	9.0×10^{-8}
Test fixture	-	9.1×10^{-8}
Radiated field strength M20		
CBL6112B @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	5.3 dB
R&S HL050 @ 3 m		
1 – 6 GHz	CISPR 16-4-2	5.1 dB
6 – 18 GHz	CISPR 16-4-2	5.4 dB
Flann Standard Gain Horns 12 – 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 12 – 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	17.03.2023	03.2025
2	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	Calibration not necessary	
3	standard gain horn antenna	18240-20	Flann Microwave	483	480294	Calibration not necessary	
4	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ Hauppauge N.Y.	571667	480343	17.02.2022	02.2024
5	standard gain horn antenna	20240-20	Flann Microwave	411	480297	Calibration not necessary	
6	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ Hauppauge N.Y.	658697	480342	17.02.2022	02.2024
7	standard gain horn antenna	22240-20	Flann Microwave	469	480299	Calibration not necessary	
8	Preamplifier 26 GHz - 40 GHz	JS4-26004000-25-5A	MITEQ Hauppauge N.Y.	563593	480344	Calibration not necessary	
9	High pass filter	WHKX4.0/18G-8SS	Wainwright Instruments GmbH	1	480587	Calibration not necessary	
10	RF-cable No.38	Sucoflex 106B	Suhner	0709/6B / Kabel 38	481328	Calibration not necessary	
11	RF Cable	Sucoflex 104	Huber+Suhner	517402	482392	Calibration not necessary	
12	Microwave cable 2m	Insulated Wire Inc.	Insulated Wire	KPS-1533-800-KPS	480302	Calibration not necessary	
13	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
14	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
15	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
16	Multiple Control Unit	MCU	Maturo GmbH	MCU/043/971107	480832	Calibration not necessary	
17	Positioners	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
18	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	22.02.2022	02.2024
19	Preamplifier 100 MHz - 16 GHz	AFS6-00101600-23-10P-6-R	Narda MITEQ	2011215	482333	17.02.2022	02.2024
20	Software	EMC32 V10.60.20	Rohde & Schwarz		483261	Calibration not necessary	
21	loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
22	RF Switch Matrix	OSP220	Rohde & Schwarz		482976	Calibration not necessary	
23	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
24	Antennasupport	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
25	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
26	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
27	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
28	Measuring software M276	Elektra	Rohde&Schwarz	101381	483755	Calibration not necessary	
29	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
30	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024

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	01.03.2023	28.02.2026
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	17.08.2022	16.08.2024

9 Report History

Report Number	Date	Comment
F231195E2	15.12.2023	Initial Test Report
-	-	-
-	-	-

10 List of Annexes

Annex A Test Setup Photos

8 pages