

Test Report

Report Number:

F220320E1

Equipment under Test (EUT):

**Level probing radar
Optiwave x400 series**

Applicant:

KROHNE Messtechnik GmbH

Manufacturer:

KROHNE S.A.S



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] **KDB publication 890966 D01**, Measurement procedure for Level Probing Radars v01 (April 2014)
- [4] **RSS-211 March 2015**, Level Probing Radar Equipment
- [5] **RSS-Gen Issue 5 February 2021 Amendment 2**, General Requirements for Compliance of Radio Apparatus
- [6] **ETSI EN 302 729 V2.1.1 (2016-12)**, Short Range Devices (SRD); Level Probing Radar (LPR) equipment operating in the frequency ranges 6 GHz to 8,5 GHz, 24,05 GHz to 26,5 GHz, 57 GHz to 64 GHz, 75 GHz to 85 GHz; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU

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

Reviewed and
approved by:

Signature

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1 Identification

1.1 Applicant

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Applicant represented during the test by the following person:	Mr. Charalambos OUZOUNIS (partly)

1.2 Manufacturer

Name:	KROHNE S.A.S
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Name for contact purposes:	Mr. Vincent PICHOT
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Fax:	+33 475 05 00 48
eMail Address:	V.Pichot@krohne.com
Manufacturer represented during the test by the following person:	Mr. Charalambos OUZOUNIS (partly)

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 ISD# 3469A.

1.4 EUT (Equipment under Test)

Test object: *	Level probing radar
Model name PMN: *	Refer "ISED Application_Form_Annex A_List of PMN.pdf"
PCB identifier: *	Radar board: 4002332104b Converter board: 4002260705b Display: 4002636501b Terminal board: 4002997701a Connector board: 4002363401_
Serial No.	Prototype
Hardware version / HVIN: *	24GHZ-L-C
Software version: *	SW 1.36.05_
FVIN: *	N/A
FCC ID:	Q6BFMCW24G74L
IC:	1991D-FMCW24GX4L
Lowest / highest internal frequency: *	32 kHz / 84 GHz

*: Declared by the applicant.

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

Antenna type: *	PP / DN150 (6") Drop max. gain = 30.4 dBi, max. -3 dB beam width = 4.3 ° max side lobe gain at 60 ° (rel. to the main beam): = <-27 dB		
Operating frequency band: *	24050 MHz to 29000 MHz		
Nominal channel bandwidth(s): *	1.4 GHz / 2 GHz		
Type of modulation: *	FMCW		
Bus system: *	HART 7		
Temperature range: *	-40 °C to +80 °C		
Supply voltage range: *	$U_{nom} = 24.0 \text{ V}_{DC}$	$U_{min} = 12.0 \text{ V}_{DC}$	$U_{max} = 30.0 \text{ V}_{DC}$

*: Declared by the applicant.

Ports/Connectors

Identification	Connector		Length
	EUT	Ancillary	
DC and data	Fixed	-	2.0 m
-	-	-	-

*: Length during the test

Ancillary equipment	
PHOENIX CONTACT MINI-PS-100-240AC/24DC/1.3 * ²	For power line conducted tests
Waveguide to SMA adapter * ¹	For fundamental emission measurements

*¹ Provided by the applicant

*² Provided by the laboratory

1.6 Dates

Date of receipt of test sample:	07.06.2022
Start of test:	07.06.2022
End of test:	06.07.2022

2 Operational States

The EUT is a level probing radar.

All measurements were carried out with an unmodified sample, supplied with 24 V_{DC}, operating in normal operation mode after powered up.

It was possible to choose the operating bandwidth by adjusting a height of a “tank” in the password protected setup section of the EUT.

If not otherwise stated, all tests were carried out with an operating bandwidth of 2 GHz

As declared by the applicant the EUT powers up on lowest frequency of the operating bandwidth and then starts a up chirp to highest frequency of the operating bandwidth.

During the tests, the EUT was positioned on a non-conducting support in two orthogonal directions (position 1: the antenna of the EUT shows to the measuring antenna; position 2: the antenna of the EUT shows downwards). The plots in annex A of this test report are showing the maximum of both positions.

During all tests, the EUT was connected to the antenna, listed in clause 1.5 of this test report.

3 Additional Information

The EUT is already certified, reason for the tests, documented in this test report are hardware changes, classified as class two permissive change. The tests, documented in this test report were carried out according to the applicants test plan.

The antenna requirements were not tested. The required antenna data were provided by the applicant.

To determine the necessary measurement times for transmitter measurements the transmitter timing of the EUT was measured. This timing was used as base for the sweep time calculation when using a spectrum analyser with RMS detection.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-211 [4] / RSS-Gen [5]	Status
Fundamental emission bandwidth	25050 – 29000	15.256 (f)	5.2 (b) [4], 6.7 [5]	Passed
Fundamental emission	25050 – 29000	15.256 (g)	5.2 (b) [4]	Passed
Frequency stability	25050 – 29000	15.256 (f)	5.1 (b) [4]	Not ordered
Radiated emissions	0.009 – 100000	15.256 (h) + (k), 15.209	6.13 [5]	Passed
Conducted emissions on supply line	0.15 – 30	15.207	8.8 [5]	Passed
Antenna requirement	25050 – 29000	15.256 (b), (i) and (j)	5.2 (a + c) [4]	Not ordered

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

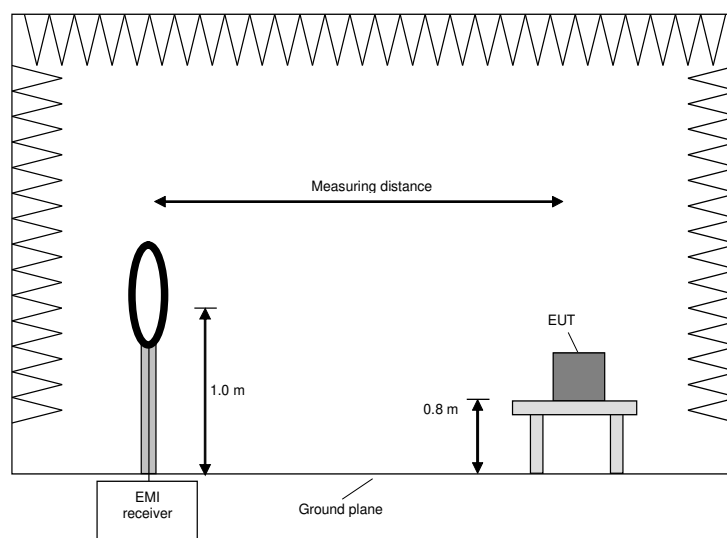
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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	10 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.

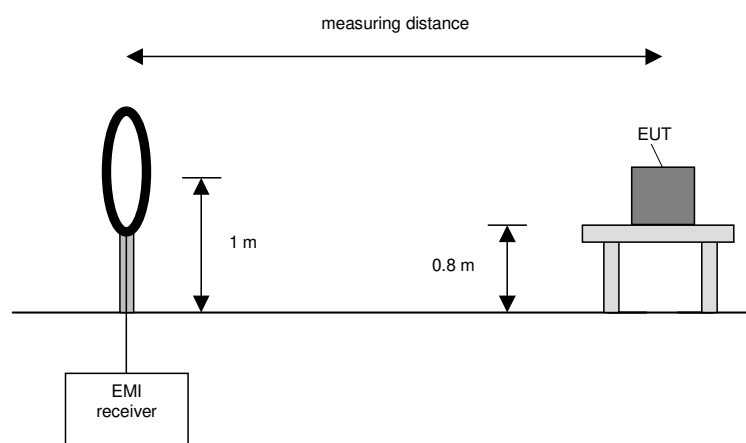
5.1.1.2 Final measurement 9 kHz to 30 MHz

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 to section 15.209 (d) [2].

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

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

Frequency range	Resolution bandwidth	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

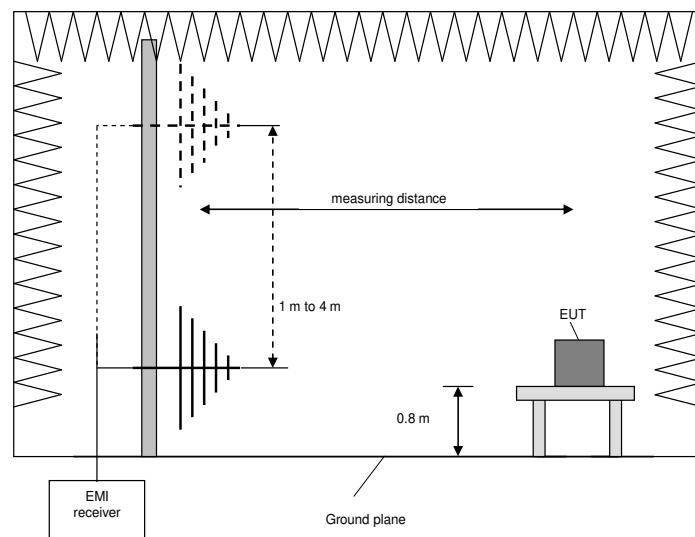
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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	± 120 kHz	10 kHz	120 kHz	1 s	Peak
Final measurement	30 MHz to 960 MHz	-	120 kHz	1 s	QuasiPeak
Final measurement	960 MHz to 1 GHz	-	120 kHz	1 s	RMS average



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 $\pm 30^\circ$ 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

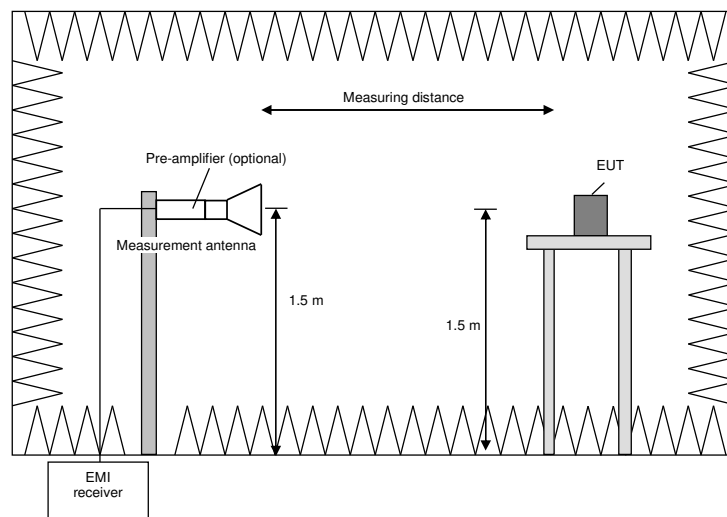
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz

The preliminary and final measurements are performed in a fully anechoic chamber at a measuring distance of 1 or 3 meters (depending on the frequency range). 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.

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 GHz - 40 GHz	-	1 MHz	-	Peak
Final measurement	1 GHz - 40 GHz	-	1 MHz	1 ms per sweep point	Peak and 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) 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 Radiated: 40 GHz to 100 GHz

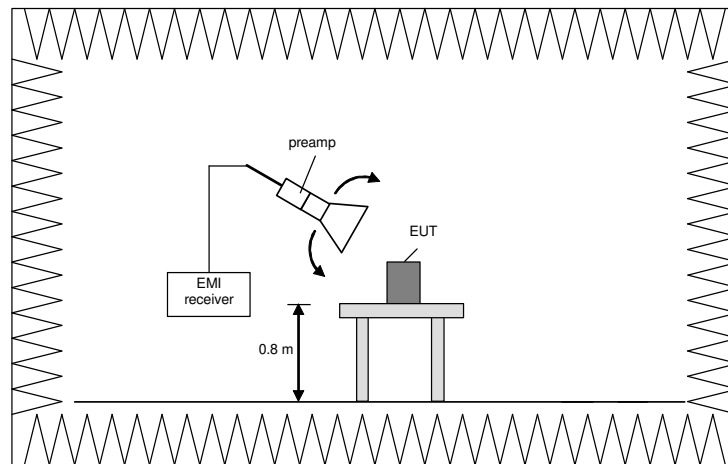
5.1.4.1 Preliminary and final measurement (40 GHz to 100 GHz)

The frequency range will be divided into different sub ranges depending on the frequency range of the used horn antennas and frequency mixers. 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, the antenna close to the EUT and while moving the antenna over all sides of the EUT. With the spectrum analyser in CLEAR / WRITE mode the cone of the emission should be found. After that the measuring distance will be set to the final measurement distance with the receiving antenna moving in this cone of emission. At this position the final measurement will be carried out.

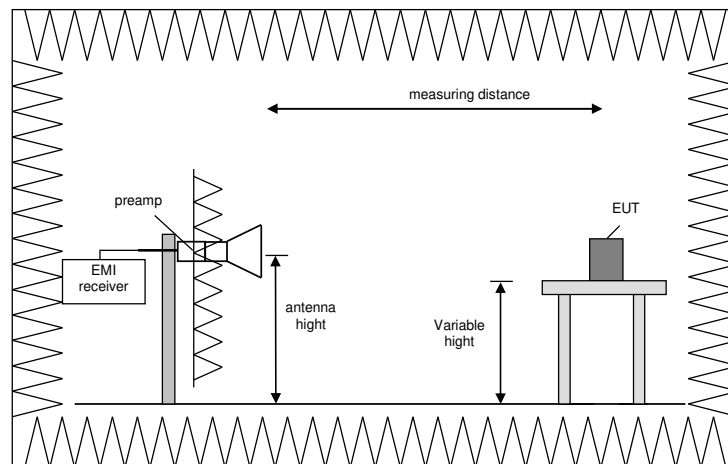
The resolution bandwidth of the EMI Receiver will be set to the following values:

Test	Frequency range	Resolution bandwidth	Measuring time	Detector
Preliminary measurement	40 GHz - 100 GHz	1 MHz	-	Peak
Final measurement	40 GHz - 100 GHz	1 MHz	1 ms per sweep point	Peak and average

Set up preliminary measurement:



Set up final measurement:



Procedure of measurement:

The measurements were performed in the frequency range 40 GHz to 50 GHz, 50 GHz to 75 GHz and 75 GHz to 100 GHz.

The following procedure will be used:

- 1) Monitor the frequency range at horizontal polarisation and move the antenna over all sides of the EUT (if necessary) move the EUT to another orthogonal axis.
- 2) Change the antenna polarisation and repeat 1) with vertical polarisation.
- 3) Make a hardcopy of the spectrum.
- 4) Measure the frequency of the detected emissions with a lower span and resolution bandwidth to increase the accuracy and note the frequency value.
- 5) Change the analyser mode to Clear / Write and found the cone of emission.
- 6) Rotate and move the EUT, so that the measuring distance can be enlarged to 3 m and the antenna will be still inside the cone of emission.
- 7) Measure the level of the detected frequency with the correct resolution bandwidth, with the antenna polarisation and azimuth and the peak and average detector, which causes the maximum emission.
- 8) Repeat steps 1) to 7) for the next antenna spot if the EUT is larger than the antenna beamwidth.

Step 1) to 6) are defined as preliminary measurement.

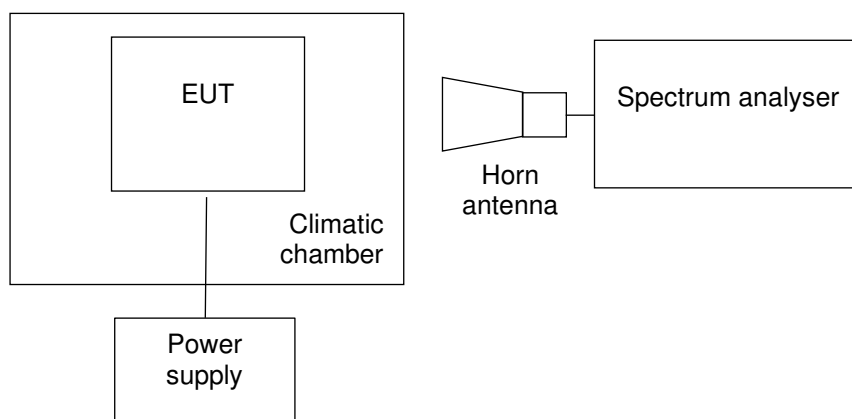
5.1.5 Frequency stability

5.1.5.1 Method of measurement (frequency stability)

The following procedure will be used:

- 1) Place the EUT in the climatic chamber.
- 2) Switch on the EUT and check the correct function and the settings of the spectrum analyser.
- 3) Switch off the EUT and tune the climatic chamber to a temperature of 50 °C or the highest temperature specified for the EUT. Wait until the thermal balance is obtained.
- 4) Switch the EUT on with nominal supply voltage and record the frequencies according to the procedure described under clause 4.1 of this test report within 1 minute after start-up. Switch the EUT off and wait for ten minutes.
- 5) Only at 20 ° C: Switch the EUT on with minimum supply voltage (85 %) and record the frequencies according to the procedure described under clause 4.1 of this test report within 1 minute after start-up. Switch the EUT off and wait for ten minutes.
- 6) Only at 20 ° C: Switch the EUT on with maximum supply voltage (115 %) and record the frequencies according to the procedure described under clause 4.1 of this test report within 1 minute after start-up.
- 7) Switch off the EUT and tune the climatic chamber to a temperature range of 50 °C (or the highest temperature specified for the EUT) to –20 °C (or the lowest temperature specified for the EUT) in ten-degree steps. Wait until the thermal balance is obtained for every step and repeat step 4) to 7) with the next temperature step until –20 °C or the lowest temperature specified for the EUT were reached.

Test set-up:

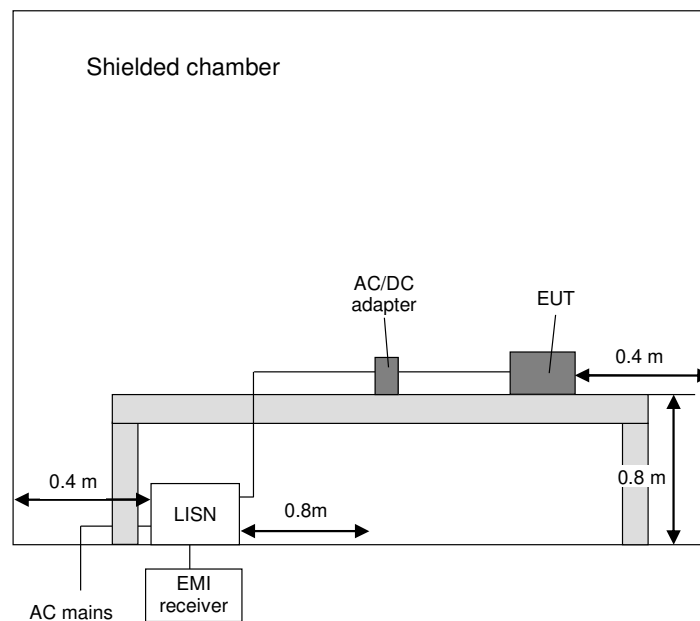


5.1.6 Conducted: AC power line

The test is carried out in a shielded chamber. 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 above the ground plane. Floor-standing devices are placed directly on the ground plane. In case of DC powered equipment, which is not exclusively powered by a battery, it is connected to the LISN via a suitable AC/DC adaptor. The setup of the equipment under test is in accordance with [1].

The frequency range 150 kHz to 30 MHz is measured with an EMI receiver set to MAX hold mode with Peak and Average detectors and a resolution bandwidth of 9 kHz. A scan is carried out on the phase and neutral line of the AC mains network. If emissions less than 10 dB below the appropriate limit are detected, these emissions are measured with an Average and Quasi-Peak detector on all lines.

Frequency range	Resolution bandwidth	Measuring time
150 kHz to 30 MHz	9 kHz	5 s



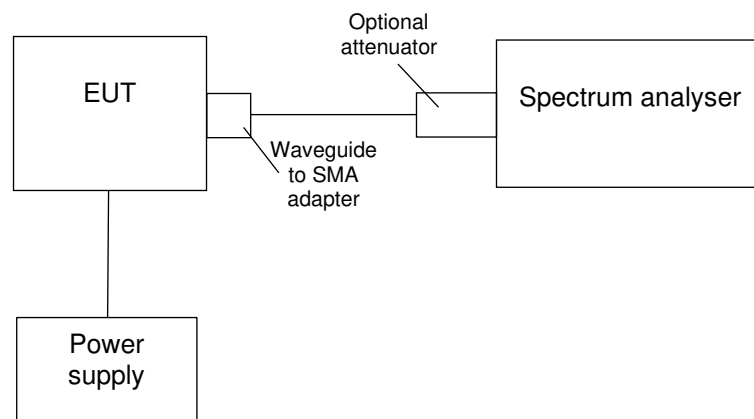
5.1.7 Fundamental emission (conducted)

5.1.7.1 Method of measurement (fundamental emission (conducted))

Connect the EUT with the spectrum analyser via suitable waveguide adapter and if necessary, an attenuator.

Use Spectrum analyser settings as required. Switch on the EUT and make the required measurements / plots.

Test set-up:



5.2 Fundamental emissions bandwidth

5.2.1 Test setup (Fundamental emission bandwidth)

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	5.1.7	-

5.2.2 Test method (-10 dB bandwidth)

Used	Sub-Clause	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	D [3], 2.4 [4], 4 [4]	Evaluation of -10 dB bandwidth	No limitations	-

5.2.3 Test method (99 % bandwidth)

Used	Sub-Clause	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	6.9.3 [1] 6.7 [5]	99 % emission bandwidth	No limitations	-

5.2.4 Test results (fundamental emission bandwidth)

Ambient temperature:	21 °C
Relative humidity:	47 %

Date:	07.06.2022
Tested by:	Thomas KÜHN

The plots of this measurement are shown in A.1 and A.2 of annex A of this test report.

Operating bandwidth				
Bandwidth setting	Lower -10 dB frequency	Upper -10 dB frequency	-10 dB bandwidth	Limit
1.4 GHz	24.3784 GHz	25.7827 GHz	1.4043 GHz	50 MHz (required minimum), furthermore the 10 dB bandwidth has to stay within the assigned frequency band (24.05 to 29.00)
2 GHz	24.0783 GHz	26.0847 GHz	2.0064 GHz	

99 % bandwidth *			
Bandwidth setting	Lower 99 % frequency	Upper 99 % frequency	99 % bandwidth
1.4 GHz	24.32841 GHz	25.77577 GHz	1.3936 GHz
2 GHz	24.08475 GHz	26.06964 GHz	1.9849 GHz

*: The RSS-211 [4] requires the measurement of the -10 dB bandwidth. In order, to reduce the frequency error of the measurement, the same span / RBW / VBW settings for the 99 % bandwidth measurement were used as required for the -10 dB measurement and not as required in RSS-Gen [5].

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 20, 31,32

5.3 Fundamental emission

5.3.1 Test setup (Fundamental emission)

Used	Setup	See sub-clause	Comment
<input type="checkbox"/>	Radiated: 1 GHz to 40 GHz	5.1.3	Measured at boresight
<input checked="" type="checkbox"/>	Conducted: Antenna port	5.1.7	-

5.3.2 Test method (average emission)

Used	Sub-Clause	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	F [3], 5.2 [4], 6.5.5.1 [6]	Mean power spectral density	No limitations	-

5.3.3 Test method (peak emission)

Used	Sub-Clause	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	F [3]	Fundamental emission for FMCW transmitters	No limitations	-
<input checked="" type="checkbox"/>	6.5.6.1 [6]	Peak power measurements	No limitations	-

5.3.4 Test results (fundamental emission)

Ambient temperature:	21 °C
Relative humidity:	47 %

Date:	07.06.2022
Tested by:	Thomas KÜHN

The plots of this measurement are shown in A.3 of annex A of this test report.

Fundamental emission (peak)					
Bandwidth setting	Level fundamental (peak) [dBm/50 MHz]	Antenna gain [dBi]	Level fundamental (EIRP, peak) [dBm/50 MHz]	Limit [dBm/50 MHz]	Margin [dB]
1.4 GHz	-5.6	30.4	24.8	26.0	1.2
2 GHz	-5.6	30.4	24.8	26.0	1.2

Fundamental emission (peak)			
Bandwidth setting	Level fundamental (peak) [dBm/MHz]	Antenna gain [dBi]	Level fundamental (EIRP, peak) [dBm/MHz]
1.4 GHz	-6.3	30.4	24.1
2 GHz	-5.8	30.4	24.6

The EUT uses FMCW modulation with a sweep of 7 ms up chirp. According to [1] + [3] the average fundamental emission level will be calculated with the measured peak emission level and a calculated averaging factor. The following formulas were used:

Dwell time (T_D) = $T_S / \Delta f$

Averaging factor (AF) = $10 \times \log (T_D / \text{cycle time})$

The fundamental emission level (average) then is calculated with the fundamental emission level (peak, measured with 1 MHz RBW) + averaging factor

Averaging factor calculation									
Bandwidth setting	Bandwidth (Δf) [MHz]	Sweep time (T_S) [ms]	Dwell time (T_D) [μ s/MHz]	Cycle time [ms]	Averaging factor [dB]	Level fundamental (EIRP, peak) [dBm/MHz]	Calculated fundamental average level (EIRP) [dBm/MHz]	Limit [dBm/MHz]	Margin [dB]
1.4 GHz	1404.3	7	4.985	100	-43.0	24.1	-18.9	-14.0	4.9
2 GHz	2006.4	7	3.489	100	-44.6	24.6	-20.0	-14.0	6.0

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 20, 31,32

5.4 Unwanted emissions (radiated)

5.4.1 Test setup (Maximum unwanted emissions)

Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Test setup (radiated)	5.1.1 to 5.1.4	-

5.4.2 Test method (Maximum unwanted emissions)

Used	Sub-Clause	Name of method	Applicability	Comment
<input checked="" type="checkbox"/>	6.3 [1], G [3], 4 [4], 8.5 [5], 6.5.5.1 [6]	Unwanted radiated emissions	No limitations	-

5.4.3 Test results (Maximum unwanted emissions)

5.4.3.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	22 °C	Date:	04.07.2022
Relative humidity:	48 %	Tested by:	Thomas KÜHN

Position of EUT: For tests for between 9 kHz to 30 MHz, the EUT was set-up on a non-conducting support at 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 B in the test report.

Remark: All three orthogonal planes were tested separately for both EUT positions, the plots below are showing the maximum values of all measurements.
The plots of this measurement are shown in annex A.4 of this test report.

Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-39.6 dBμV/m (QP) in 300 m distance, measured at 3 m and converted with 40 dB / decade correction factor) were found during the preliminary radiated emission test, so no measurements were carried out on the outdoor test site.
150 kHz to 30 MHz	No significant frequencies above the noise floor of the system (-16 dBμV/m (QP) in 30 m distance, measured at 3 m and converted with 40 dB / decade correction factor) were found during the preliminary radiated emission test, so no measurements were carried out on the outdoor test site.

Test result: Passed

Test equipment (please refer to chapter 6 for details)
30, 31, 32, 35, 38 – 41

5.4.3.2 Test results preliminary measurement 30 MHz – 1 GHz

Ambient temperature:	22 °C
Relative humidity:	48 %

Date:	04.07.2022
Tested by:	Thomas KÜHN

Position of EUT: For tests for f between 30 MHz to 1 GHz, the EUT was set-up on a non-conducting support at 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 B in the test report.

Test record: Plots are submitted annex A.4 of this test report.

Calculations:

The test results above 30 MHz and below 1 GHz were calculated with the following formula:

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

Correction [dBμV/m] = AF [dB/m] + Cable attenuation [dB] + attenuator [dB]

Margin [dB] = Limit [dBμV/m] - Result [dBμV/m]

Result measured with the Quasi-peak detector above 30 MHz and below 1 GHz:

Frequency [MHz]	Result (QP) [dBμV/m]	Limit [dBμV/m]	Margin [dB]	Reading [dBμV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position #
30.720	19.7	40.0	20.3	-5.8	25.5	129	202	Hor.	1
65.190	16.0	40.0	24.1	2.4	13.6	211	190	Vert.	1
74.250	16.1	40.0	23.9	0.6	15.5	140	128	Vert.	1
297.030	23.4	46.0	22.6	4.4	19.0	285	212	Vert.	1
312.000	19.6	46.0	26.4	0.2	19.4	127	286	Vert.	1
371.280	32.6	46.0	13.4	11.4	21.2	100	342	Vert.	1

Test result: Passed

Test equipment (please refer to chapter 6 for details)
31 - 41

5.4.3.3 Test results measurement 1 GHz to 40 GHz)

Ambient temperature:	22 °C
Relative humidity:	49 %

Date:	05.07.2022
Tested by:	Thomas KÜHN

Position of EUT: The EUT was set-up on a non-conducting support at a height of 1.5 m. In this frequency range, the EUT was tested in two orthogonal directions. 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 B in the test report.

Test record: The plots submitted annex A.4 of this test report showing the maximum emissions level position.

Calculation:

Result [dBμV/m] = Reading [dBμV] + Correction [dBμV/m]
 Correction [dBμV/m] = Cable attenuation [dB] + pre amplifier [dB] + antenna factor [1/dB]
 Margin [dB] = Limit [dBμV/m] - Result [dBμV/m]

Results measured with peak detector									
Frequency [MHz]	Result (PK) [dBμV/m]	Limit [dBμV/m]	Margin [dB]	Reading [dBμV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position #
1531.605	30.9	74.0	43.1	44.7	-13.8	150	264	Hor.	1
1593.770	31.8	74.0	42.2	45.5	-13.7	150	301	Hor.	1
12999.780	41.4	74.0	32.6	31.0	10.4	150	254	Vert.	2
13978.860	40.6	74.0	33.4	30.1	10.5	150	110	Hor.	2
14178.120	40.6	74.0	33.4	30.2	10.4	150	127	Vert.	2
38296.705	45.9	74.0	28.1	40.5	5.4	150	155	Hor.	2

Results measured with average detector									
Frequency [MHz]	Result (AV) [dBμV/m]	Limit [dBμV/m]	Margin [dB]	Reading [dBμV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position #
1531.605	18.7	54.0	35.3	32.5	-13.8	150	264	Hor.	1
1593.770	19.0	54.0	35.0	32.7	-13.7	150	301	Hor.	1
12999.780	28.2	54.0	25.8	17.8	10.4	150	254	Vert.	2
13978.860	28.5	54.0	25.6	18.0	10.5	150	110	Hor.	2
14178.120	28.2	54.0	25.8	17.8	10.4	150	127	Vert.	2
38296.705	32.0	54.0	22.0	26.6	5.4	150	155	Hor.	2

Test result: Passed

Test equipment (please refer to chapter 6 for details)
6 – 8, 10, 11, 13, 14 – 20, 31, 32

5.4.3.4 Test results measurement 40 GHz to 100 GHz)

Ambient temperature:	22 °C
Relative humidity:	46 %

Date:	06.07.2022
Tested by:	Thomas KÜHN

Position of EUT: In the frequency range 1 GHz to 40 GHz, the EUT was set-up on a non-conducting support at a height of 1.5 m. In this frequency range, the EUT was tested in two orthogonal directions. For all other frequency ranges the EUT was positioned on a non-conducting support with a variable height.

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

Test record: The plots submitted annex A.4 of this test report showing the maximum emissions level position.

Calculation:

Result @ 3 m = Max. emission level [dBμV] - distance correction [dB]

Margin [dB] = Limit [dBμV/m] – Result @ 3 m [dBμV/m]

Unwanted emissions level, measured with peak detector			
Frequency range	Max. peak emission level [dBμV/m]	Limit [dBμV/m]	Margin [dBμV/m]
40 GHz to 50 GHz	72.9	74.0	1.1
50 GHz to 75 GHz	73.8	74.0	0.2
75 GHz to 100 GHz	63.3	74.0	10.7

Unwanted emissions level, measured with RMS detector			
Frequency range	Max. emission level [dBμV/m]	Limit [dBμV/m]	Margin [dBμV/m]
40 GHz to 50 GHz	46.1	54.0	7.9
50 GHz to 75 GHz	45.4	54.0	8.6
75 GHz to 100 GHz	50.6	54.0	3.4

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 21 – 28, 31, 32

5.5 AC power-line conducted emissions

5.5.1 Test setup (AC power-line conducted emissions)

Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Conducted: AC power line	5.1.6	-
<input type="checkbox"/>	Not applicable, because ...	-	-

5.5.2 Test method (AC power-line conducted emissions)

Used	Clause	Name of method	Sub-clause	Comment
<input checked="" type="checkbox"/>	6.2 [1], 8.8 [5]	Tabletop equipment testing	5.1.6	The EUT is DC supplied, therefore, an AC / DC adaptor has to be used.
<input type="checkbox"/>	6.2 [1] 8.8 [5]	Floor-standing equipment testing	-	-

During the measurement the EUT was supplied with 24.0 V DC by an AC / DC adaptor MINI-PS-100-240AC/24DC/1.3. The adaptor itself was supplied by an AC mains network with 120V_{AC} 60Hz.

5.5.3 Test results (Conducted emissions on power supply lines)

Ambient temperature:	22 °C	Date:	05.07.2022
Relative humidity:	47 %	Tested by:	Thomas KÜHN

The curves in the diagrams in A.6 of annex A of this test report only represent for each frequency point the maximum measured value of all preliminary measurements which were made for each power supply line. The top measured curves representing the peak measurement and the bottom measured curves the average measurement.

Remark: No final measurements with quasi peak or average detector were carried out, because the preliminary measurement results (measured with peak detector) already were below the average limit.

Test result: Passed

Test equipment (please refer to chapter 6 for details)
1 – 5

6 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Transient Filter Limiter	CFL 9206A	Teseq	38268	481982	15.02.2022	02.2024
2	LISN	NSLK8128	Schwarzbeck	8128161	480138	15.02.2022	02.2024
3	Software	EMC32	Rohde & Schwarz	100061	481022	Calibration not necessary	
4	Shielded chamber M4	B83117-S1-X158	Siemens	190075	480088	Calibration not necessary	
5	EMI Receiver / Spectrum Analyser	ESIB 26	Rohde & Schwarz	100292	481182	16.02.2022	02.2024
6	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	Calibration not necessary	
7	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
8	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	22.02.2022	02.2024
9	Spectrum Analyser	FSW43	Rohde & Schwarz	100586 & 100926	481720	19.11.2021	11.2022
10	Log.-Per. antenna	HL050	Rohde & Schwarz	100438	481170	09.10.2020	10.2023
11	Preamplifier 100 MHz – 16 GHz	AFS6-00101600-23-10P-6-R	MITEQ	2011215	482333	17.02.2022	02.2024
12	RF-cable No. 36	Sucoflex 106B	Suhner	500219/6B	482416	Calibration not necessary	
13	RF-cable No. 38	Sucoflex 106B	Suhner	500218/6B	482415	Calibration not necessary	
14	Standard Gain Horn 12 GHz – 18 GHz	18240-20	Flann	483	480294	Calibration not necessary	
15	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ	571667	480343	17.02.2022	02.2024
16	Standard Gain Horn 18 GHz – 26.5 GHz	20240-20	Flann	411	480297	Calibration not necessary	
17	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ	658697	480342	13.02.2020 + 17.02.2022	02.2024
18	Standard Gain Horn 26.5 GHz – 40 GHz	22240-20	Flann	468	480298	Calibration not necessary	
19	Preamplifier 26 GHz - 40 GHz	JDM2-26004000-25-10P	MITEQ	128746	482806	17.02.2022	02.2024
20	RF-cable 2 m	KPS-1533-800-KPS	Insulated Wire	-	480302	Calibration not necessary	
21	Standard Gain Horn 40 GHz - 60 GHz	24240-20	Flann	263442	482858	Calibration not necessary	
22	Harmonic mixer 40 GHz - 60 GHz	FS-Z60	Radiometer Physics	100980	482708	31.03.2021	03.2023
23	Standard Gain Horn 50 GHz - 75 GHz	25240-20	Flann	263443	482859	Calibration not necessary	
24	Spektrum Analyzer Extension Module 50 GHz - 75 GHz	WR15SAX-M6-UP	Virginia Diode	SAX 683	483364	Calibration not necessary	
25	Standard Gain Horn 75 GHz - 110 GHz	27240-20	Flann	263447	482861	Calibration not necessary	
26	Harmonic mixer 75 GHz - 110 GHz	FS-Z110	Radiometer Physics	101528	482707	31.03.2021	03.2023

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
27	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510210/2	483030	Calibration not necessary	
28	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510213/2	483031	Calibration not necessary	
29	Dynamic temperature chamber	MK 240	Binder	05-79022	480462	07.12.2021	12.2022
30	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
31	Power Supply	TOE8752-32 (DC)	Toellner	31566	480010	Calibration not necessary	
32	Multimeter	971A	Hewlett Packard	JP39009358	480721	30.03.2022	03.2023
33	Attenuator 6 dB	WA2-6	Weinschel	-	482793	Calibration not necessary	
34	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
35	RF Switch Matrix	OSP220	Rohde & Schwarz	-	482976	Calibration not necessary	
36	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
37	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
38	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
39	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
40	Software	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
41	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023

7 Measurement Uncertainties

Measurement method	Standard used for calculating measurement uncertainty	Expanded measurement uncertainty (95 %) U_{lab}
Conducted measurements		
Conducted emissions from 150 kHz to 30 MHz with LISN	CISPR 16-4-2	2.8 dB
Radiated measurements		
Frequency error		
(Semi-) Anechoic chamber	ETSI TR 100 028	4.5×10^{-8}
OATS	ETSI TR 100 028	4.5×10^{-8}
Test fixture	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements		
(Semi-) Anechoic chamber	-	9.0×10^{-8}
OATS	-	9.0×10^{-8}
Test fixture	-	9.1×10^{-8}
Radiated field strength M20		
CBL6112B @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	5.3 dB
R&S HL050 @ 3 m		
1 – 6 GHz	CISPR 16-4-2	5.1 dB
6 – 18 GHz	CISPR 16-4-2	5.4 dB
Flann Standard Gain Horns 18 – 40 GHz	-	5.9 dB
Radiated field strength M276		
R&S HL562E @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	4.8 dB
Radiated emissions above 40 GHz		
40 – 60 GHz	-	7.0 dB
50 – 75 GHz	-	7.0 dB
60 – 90 GHz	-	7.0 dB
75 – 110 GHz	-	7.0 dB
90 – 140 GHz	-	7.6 dB
110 – 170 GHz	-	6.9 dB
140 – 220 GHz	-	7.8 dB
220 – 325 GHz	-	8.1 dB

8 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Shielded chamber M4	480088	9 kHz – 30 MHz	GND-Plane	ANSI C63.4-2014	21.12.2020	20.12.2022
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
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
F220320E1	26.07.2022	Initial Test Report
-	-	-
-	-	-

10 List of Annexes

Annex A	Measurement plots	9 pages
Annex B	Test Setup Photos	7 pages
Annex C	External Photos	5 pages
Annex D	Internal Photos	20 pages