PHOENIX TESTLAB

Königswinkel 10
32825 Blomberg, Germany
Phone: +49 (0) 52 35 / 95 00-0
Fax: +49 (0) 52 35 / 95 00-10
office@phoenix-testlab.de
www.phoenix-testlab.de

Test Report

Report Number:

F230509E2

Equipment under Test (EUT):

Level probing radar module USR30

Applicant:

Endress+Hauser SE+Co. KG

Manufacturer:

Endress+Hauser SE+Co. KG

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] **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:	Thomas Kühn 14.07.2023	Signature
Reviewed and approved by:	Bernd STEINER 14.07.2023	Signature

This test report is only valid in its original form.

Contents: Page

1 Identification 5
1.1 Applicant 5
1.2 Manufacturer 5
1.3 Test Laboratory 5
1.4 EUT (Equipment under Test) 6
1.5 Technical Data of Equipment 6
1.6 Dates 7
2 Operational States 7
3 Additional Information 7
4 Overview 8
5 Results 9
5.1 Test setups 9
5.1.1 Radiated: 9 kHz to 30 MHz 9
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz 9
5.1.1.2 Final measurement 9 kHz to 30 MHz 10
5.1.2 Radiated: 30 MHz to 1 GHz 10
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz 10
5.1.3 Radiated: 1 GHz to 40 GHz 12
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz 12
5.1.4 Radiated: 40 GHz to 200 GHz 13
5.1.4.1 Preliminary and final measurement (40 GHz to 200 GHz) 13
5.1.5 Frequency stability 15
5.1.5.1 Method of measurement (frequency stability) 15
5.1.6 Conducted: AC power line 16
5.2 Fundamental emissions bandwidth 17
5.2.1 Test setup (Fundamental emission bandwidth) 17
5.2.2 Test method (-10 dB bandwidth) 17
5.2.3 Test method (99 % bandwidth) 17
5.2.4 Test results (fundamental emission bandwidth) 18
5.3 Fundamental emission 19
5.3.1 Test setup (Fundamental emission) 19
5.3.2 Test method (average emission) 19
5.3.3 Test method (peak emission) 19
5.3.4 Test results (fundamental emission) 20

5.4 Unwanted emissions (radiated) 21
5.4.1 Test setup (Maximum unwanted emissions) 21
5.4.2 Test method (Maximum unwanted emissions) 21
5.4.3 Test results (Maximum unwanted emissions) 21
5.4.3.1 Test results preliminary measurement 9 kHz to 30 MHz 21
5.4.3.2 Test results preliminary measurement 30 MHz – 1 GHz 22
5.4.3.3 Test results final measurement 30 MHz – 1 GHz 23
5.4.3.4 Test results measurement 1 GHz to 200 GHz) 24
5.5 Frequency stability 25
5.5.1 Test setup (frequency stability) 25
5.5.2 Test method (frequency stability) 25
5.5.3 Test result (frequency stability) 25
5.6 AC power-line conducted emissions 26
5.6.1 Test setup (AC power-line conducted emissions) 26
5.6.2 Test method (AC power-line conducted emissions) 26
5.6.3 Test results (Conducted emissions on power supply lines) 26
6 Test Equipment used for Tests 27
7 Measurement Uncertainties 29
8 Test site Verification 30
9 Report History 30
10 List of Annexes 30

1 Identification

1.1 Applicant

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Alexander LOPATIN
Phone:	+49 76 22 28 41 52
eMail Address:	alexander.lopatin@endress.com
Applicant represented during the test by the following person:	---

1.2 Manufacturer

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Alexander LOPATIN
Phone:	+49 76 22 28 41 52
Fax:	alexander.lopatin@endress.com
eMail Address:	Endress+Hauser SE+Co. KG
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: *	Level probing radar
Model name / HVIN: *	USR30
PMN: *	UXR30
Order number: *	USR30-AADA
Serial number: *	None
PCB identifier: *	71439890
FVIN: *	N/A
FCC ID: *	LCGUXR3XYEL
IC: *	2519A-YEL
Lowest / highest internal frequency: *	32 MHz / 82 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

Operation frequency range: *	77 to 82 GHz		
Rated rf-output power: *	20 dBm/MHz		
Antenna type: *	Integrated		
Antenna connector: *	None		
Temperature range: *	-40 °C to 85 °C		
Supply voltage range (digital interface of the sensor): *	U_{nom} = 3.0 V_{DC}	U_{min} = 1.7 V_{DC}	U_{max} = 3.6 V_{DC}
Supply voltage range (radar part of the sensor): *	U_{nom} = 4.5 V_{DC}	U_{min} = 3.5 V_{DC}	U_{max} = 5.5 V_{DC}
Supply voltage range (Demo board): *	U_{nom} = 5.0 V_{DC}	U_{min} = 4.5 V_{DC}	U_{max} = 5.25 V_{DC}
Ancillary	None		

* declared by the applicant.

Ports/Connectors

Identification	Connector		Length
	EUT	Ancillary	
USB (power supply line only)	USB-C	-	3 m
-	-	-	-
-	-	-	-

*: Length during the test

1.6 Dates

Date of receipt of test sample:	19.04.2023
Start of test:	10.05.2023
End of test:	17.05.2023

2 Operational States

The EUT is a radar module intended to be used in level probing applications.

All measurements were carried out with an unmodified sensor module, mounted on a demo board, supplied with 5 V_{DC} via an USB connector, operating in normal operation mode after powered up.

3 Additional Information

The antenna requirements were not tested. The required antenna data were provided by the applicant. Refer also to the document tr.50511-74558 (FCC) Ed.2 Annex C.pdf.

The transmitter unwanted emission measurements between 1 GHz and 40 GHz were carried out with the EUT mounted on a positioner device inside the fully anechoic chamber. The vertical axis was rotated in 30 ° steps. The measurement plots in this frequency range are showing the maximum value from all positions. In all other frequency ranges the 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).

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.

As declared by the applicant the EUT powers up on 77 GHz and then starts a chirp up to 81 GHz within one ms.

The tested samples were not labelled.

It was requested by the applicant to test the frequency stability within the normative temperature range of -20 °C to 50 ° C only.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-211 [211] / RSS-Gen [Gen]	Status
Fundamental emission bandwidth	75000 – 85000	15.256 (f)	5.2 (b) [211], 6.7 [Gen]	Passed
Fundamental emission	75000 – 85000	15.256 (g)	5.2 (b) [211]	Passed
Frequency stability	75000 – 85000	15.256 (f)	5.1 (b) [211]	Passed
Radiated emissions	0.009 – 200000	15.256 (h) + (k), 15.209	6.13 [Gen]	Passed
Conducted emissions on supply line	0.15 – 30	15.207	8.8 [Gen]	Passed
Antenna requirement	75000 – 85000	15.256 (b), (i) and (j)	5.2 (a) + (c) [211]	Passed *

*: Integrated antenna only, Antenna data sheet is provided by the applicant, requirement fulfilled.

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

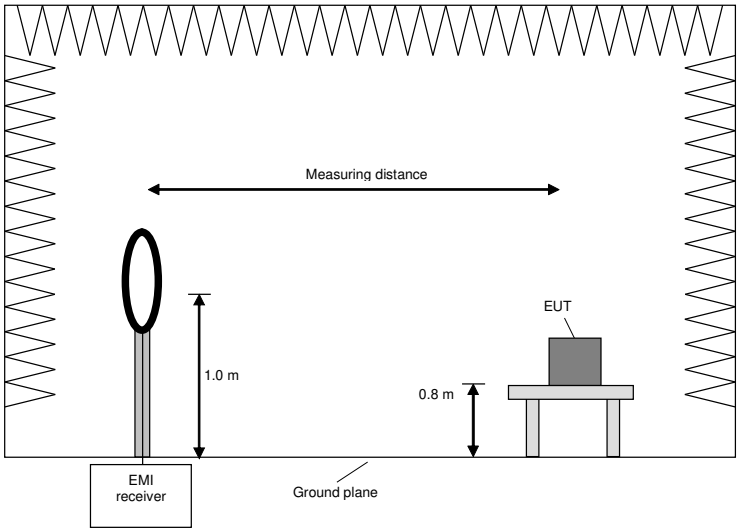
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

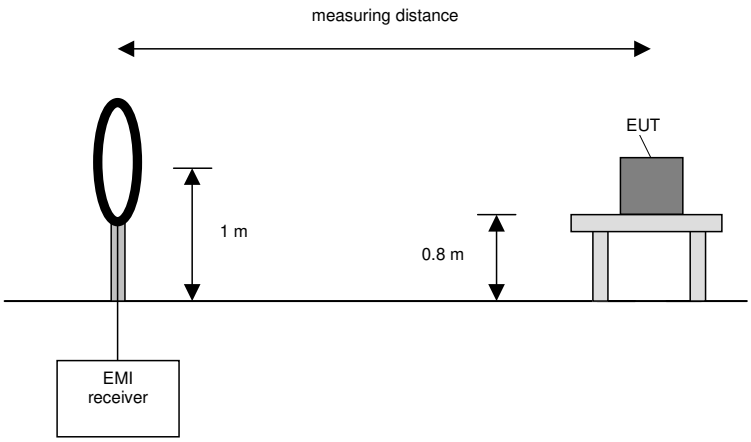
5.1.1.2 Final measurement 9 kHz to 30 MHz

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

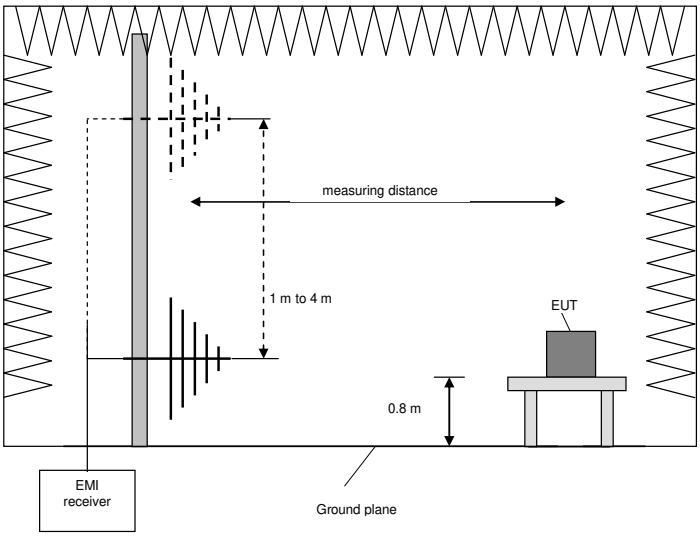
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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 +/- 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

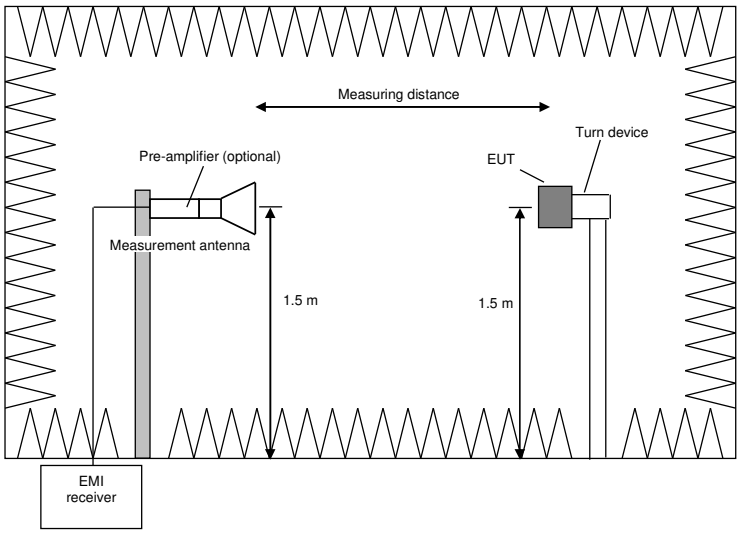
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz

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. 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 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) 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 Radiated: 40 GHz to 200 GHz

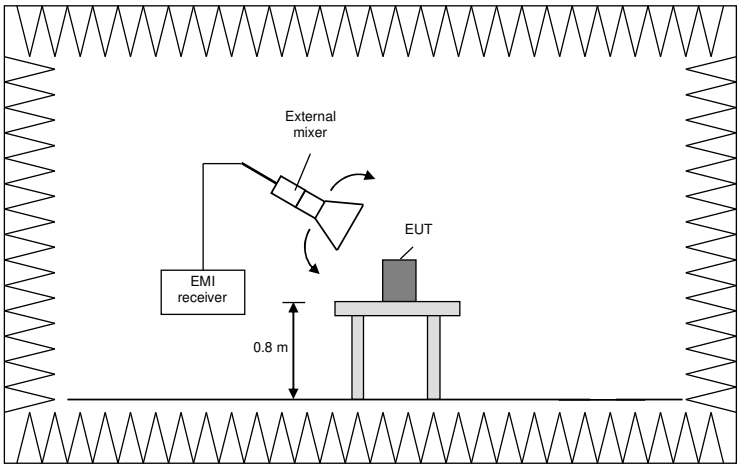
5.1.4.1 Preliminary and final measurement (40 GHz to 200 GHz)

The frequency range to be investigated will be divided into different sub ranges depending on the frequency range of the used horn antennas and frequency mixers. The spectrum analyser is set to MAX Hold mode with a resolution bandwidth of 1 MHz. The measurement will be performed in horizontal and vertical polarisation of the measuring antenna, positioned 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 with using the Auto ID functionality of the analyser. The used measuring distance for the used antenna has to be above the minimum measuring distance calculated for accreditation.

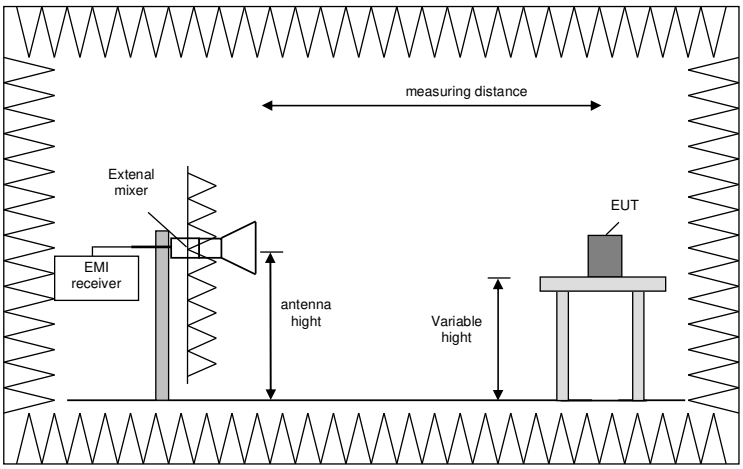
The resolution bandwidth of the EMI Receiver will be set to the following values:

Test	Frequency range	Resolution bandwidth	Measuring time	Detector
Preliminary measurement	40 GHz - 200 GHz	1 MHz	-	Peak
Final measurement	40 GHz - 200 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 55 GHz, 55 GHz to 75 GHz, 75 GHz to 90 GHz, 90GHz to 110 GHz, 110 GHz to 140 GHz, 140 GHz to 170 GHz and 170 GHz to 200 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 the final measurement distance 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.

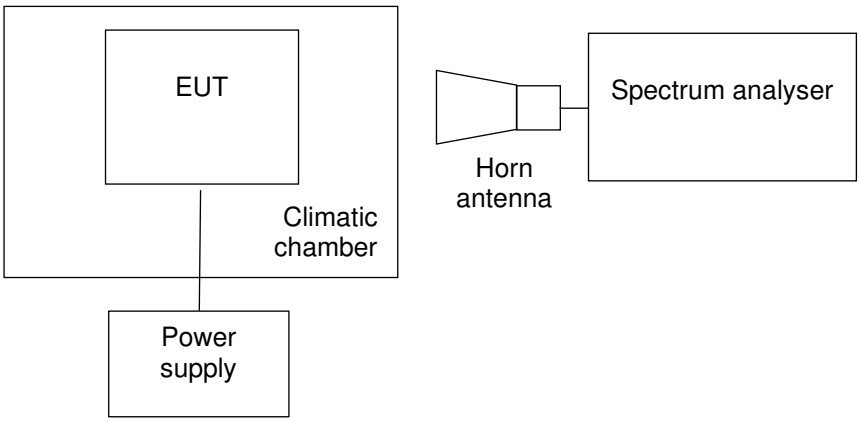
5.1.5 Frequency stability

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 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:

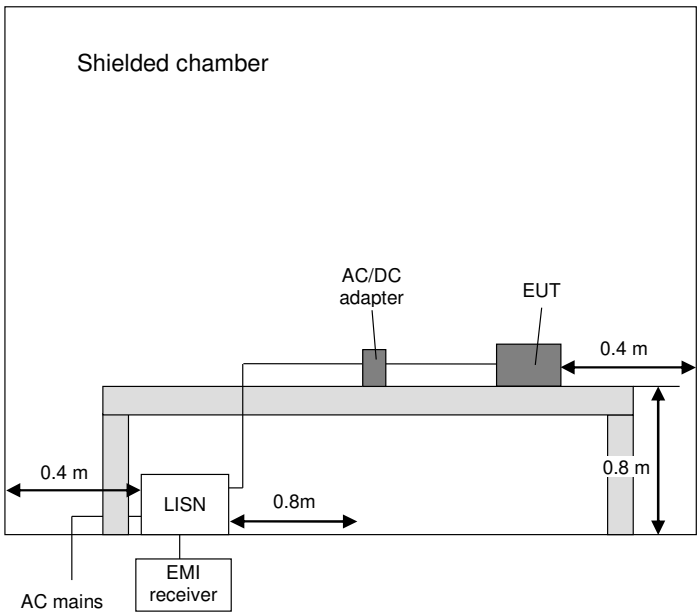


5.1.6 Conducted: AC power line

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 appropriable 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



5.2 Fundamental emissions bandwidth

5.2.1 Test setup (Fundamental emission bandwidth)

Used	Setup	See sub-clause	Comment
☒	Radiated: 40 GHz to 200 GHz	5.1.4	Measured at boresight
☐	Conducted: Antenna port		EUT has no antenna connector

5.2.2 Test method (-10 dB bandwidth)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	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
☒	6.9.3 [1] 6.7 [5]	99 % emission bandwidth	No limitations	-

5.2.4 Test results (fundamental emission bandwidth)

Ambient temperature:	24 °C
Relative humidity:	31 %

Date:	10.05.2023
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			
Lower -10 dB frequency	Upper -10 dB frequency	-10 dB bandwidth	Limit
76.9934 GHz	81.0056 GHz	4.0122 GHz	50 MHz (required minimum), furthermore the 10 dB bandwidth has to stay within the assigned frequency band (75.00 to 85.00)

99 % bandwidth *		
Lower frequency	Upper frequency	99 % bandwidth
77.011687 GHz	80.983445 GHz	3.9718 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, 25,26, 34, 35, 38, 39

5.3 Fundamental emission

5.3.1 Test setup (Fundamental emission)

Used	Setup	See sub-clause	Comment
☒	Radiated: 40 GHz to 200 GHz	5.1.3	Measured at boresight
☐	Conducted: Antenna port	-	EUT has no antenna connector

5.3.2 Test method (average emission)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	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
☒	F [3]	Fundamental emission for FMCW transmitters	No limitations	-
☒	6.5.6.1 [6]	Peak power measurements	No limitations	-

5.3.4 Test results (fundamental emission)

Ambient temperature:	24 °C
Relative humidity:	31 %

Date:	10.05.2023
Tested by:	Thomas KÜHN

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

Fundamental emission (peak)				
Frequency [MHz]	Measuring distance [m]	Level fundamental (EIRP) [dBm]	Limit [dBm]	Margin [dB]
77761.200	1.0	23.3	34.0	10.7

The EUT uses FMCW modulation with a sweep of 1 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 / Δf
Averaging factor (AF) = 10 x log (T_D / 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 (Δf) [GHz]	Sweep time (T_S) [ms]	Dwell time (T_D) [µs/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]
4.0122	1.0	0.249	56.6	-53.3	23.3	-30.3	-3.0	27.3

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 25,26, 34, 35, 38, 39

5.4 Unwanted emissions (radiated)

5.4.1 Test setup (Maximum unwanted emissions)

Used	Setup	See sub-clause	Comment
☒	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
☒	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:	23 °C
Relative humidity:	43 %

Date:	15.05.2023
Tested by:	Thomas KÜHN

Position of EUT: For tests for 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 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.5 of this test report.

EUT position 1	
Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-27.6 dBµV/m (peak) 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 (4.6 dBµV/m (peak) 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.
EUT position 2	
Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-27.5 dBµV/m (peak) 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 (6.1 dBµV/m (peak) 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)
37 - 48

5.4.3.2 Test results preliminary measurement 30 MHz – 1 GHz

Ambient temperature:	22 °C
Relative humidity:	43 %

Date:	15.05.2023
Tested by:	Thomas KÜHN

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 B in the test report.

Test record: Plots for each EUT position are submitted annex A.4 of this test report.

The following emissions were found during the preliminary emission measurement:

- 31.200 MHz, 35.400 MHz, 38.610 MHz, 43.020 MHz, 120.420 MHz, 735.480 MHz and 981.900 MHz.

On these frequencies a final measurement has to be carried out, the results of this final measurement are presented in the following.

Test equipment (please refer to chapter 6 for details)
38 - 48

5.4.3.3 Test results final measurement 30 MHz – 1 GHz

Ambient temperature:	22 °C
Relative humidity:	43 %

Date:	15.05.2023
Tested by:	Thomas KÜHN

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 B in the test report.

Test record: Plots for each EUT position 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]	Readings [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol. (H/V)	Position #
31.200	16.8	40.0	23.2	-8.5	25.3	325	296	Vert.	1
35.400	15.2	40.0	24.8	-7.6	22.8	275	147	Vert.	1
38.610	14.1	40.0	25.9	-6.8	20.9	225	177	Vert.	2
43.020	20.2	40.0	19.8	2.0	18.2	102	297	Vert.	1
120.420	8.7	43.5	34.8	-8.9	17.6	277	131	Vert.	2
735.480	19.6	46.0	26.4	-8.5	28.1	190	303	Hor.	1
981.900	22.2	54.0	31.8	-8.5	30.7	325	57	Vert.	1

Test result: Passed

Test equipment (please refer to chapter 6 for details)
38 - 48

5.4.3.4 Test results measurement 1 GHz to 200 GHz)

Ambient temperature:	21 to 24 °C
Relative humidity:	31 to 41 %

Date:	10. to 17.05.2023
Tested by:	Thomas KÜHN

Position of EUT: In the frequency range 1 GHz to 40 GHz,
EUT 1 was set-up on a positioner device with a height of 150 cm
EUT 5 on a non-conducting support with a height of 150 cm.
In this frequency range, EUT 5 was tested in two orthogonal directions.
For all other frequency ranges both EUTs were positioned on a non-conducting support with a height of 120 cm.

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 for each EUT position are submitted annex A.4 of this test report.

Remark: Because no emission except the wanted signal found, the maximum noise floor level was documented below.

Calculation:

Result @ 3 m = Max noise floor level [dBµV] - distance correction [dB]

Distance correction [dB] = 20 log (normative distance [m] / used distance [m]), according to [1]

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

Unwanted emissions						
Frequency range	Max noise floor level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit [dBµV/m]	Margin [dBµV/m]
1 GHz to 12 GHz	41.0 *	3.0	-	41.0	54.0	13.0
12 GHz to 18 GHz	45.4 *	3.0	-	45.4	54.0	8.6
18 GHz to 26.5 GHz	47.2 *	3.0	-	47.2	54.0	6.8
26.4 GHz to 40 GHz	49.3 *	1.0	9.5	39.8	54.0	14.2
40 GHz to 55 GHz	58.3	0.3	20.0	38.3	54.0	15.7
55 GHz to 75 GHz	67.5	0.3	20.0	47.5	54.0	6.5
75 GHz to 90 GHz	64.3	0.3	20.0	44.3	54.0	9.7
90 GHz to 110 GHz	64.3	0.3	20.0	44.3	54.0	9.7
110 GHz to 150 GHz	70.9	0.1	29.5	41.4	54.0	12.6
150 GHz to 200 GHz	70.2	0.1	29.5	40.7	54.0	13.3

*: Measured with peak detector, only, because the peak value is already below the average limit

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9 – 35, 38, 39

5.5 Frequency stability

5.5.1 Test setup (frequency stability)

Used	Setup	See sub-clause	Comment
☒	Frequency stability	5.1.5	-

5.5.2 Test method (frequency stability)

Used	Clause	Name of method	Sub-clause	Comment
☒	9.14 [1], H [3]	Frequency stability for mm-wave devices	5.1.5	-

5.5.3 Test result (frequency stability)

Ambient temperature:	23 to 24 °C
Relative humidity:	31 %

Date:	11. + 12.05.2023
Tested by:	Thomas KÜHN

Test set-up: For this test the EUT was fixed on a wooden table inside the climatic chamber. For further information of the cable guide refer to the pictures in annex B of this test report.

Remark: As ordered by the applicant the measurement was carried out in the temperature range 50 °C to -20 °C.

Frequency stability						
Temperature	Supply voltage	Lower frequency [GHz]	Upper frequency [GHz]	-10 dB bandwidth [GHz]	Peak frequency [GHz]	Result
50 °C	5.0 V_{DC} (U_{nom})	76.9924	81.0045	4.0121	76.9994	Passed
40 °C	5.0 V_{DC} (U_{nom})	76.9934	81.0045	4.0111	76.9994	Passed
30 °C	5.0 V_{DC} (U_{nom})	76.9934	81.0056	4.0121	77.0004	Passed
20 °C	4.5 V_{DC} (U_{min})	76.9934	81.0046	4.0112	76.9994	Passed
	5.0 V_{DC} (U_{nom})	76.9934	81.0056	4.0122	77.0004	Passed
	5.25 V_{DC} (U_{max})	76.9934	81.0056	4.0122	76.9994	Passed
10 °C	5.0 V_{DC} (U_{nom})	76.9934	81.0046	4.0112	77.0004	Passed
0 °C	5.0 V_{DC} (U_{nom})	76.9944	81.0056	4.0112	77.0004	Passed
-10 °C	5.0 V_{DC} (U_{nom})	76.9934	81.0056	4.0122	77.0014	Passed
-20 °C	5.0 V_{DC} (U_{nom})	76.9924	81.0056	4.0132	77.0004	Passed

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 25, 26, 34 – 36, 38, 39

5.6 AC power-line conducted emissions

5.6.1 Test setup (AC power-line conducted emissions)

Used	Setup	See sub-clause	Comment
☒	Conducted: AC power line	5.1.6	-
☐	Not applicable, because …	-	-

5.6.2 Test method (AC power-line conducted emissions)

Used	Clause	Name of method	Sub-clause	Comment
☒	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.
☐	6.2 [1] 8.8 [5]	Floor-standing equipment testing	-	-

During the measurement the EUT was supplied with 5.0 V_{DC} by an AC / DC adaptor
Enercell type CAT. NO. 273-316. The adaptor itself was supplied by an AC mains network with 120 V_{AC} / 60 Hz.

5.6.3 Test results (Conducted emissions on power supply lines)

Ambient temperature:	22 °C
Relative humidity:	31 %

Date:	12.05.2023
Tested by:	Thomas KÜHN

The curves in the diagrams in A.5 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 where at least 15 dB below the 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	17.03.2023	03.2025
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	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	22.03.2023	03.2025
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 60 GHz - 90 GHz	26240-20	Flann	262498	482860	Calibration not necessary	
26	Harmonic mixer 60 GHz - 90 GHz	FS-Z90	Radiometer Physics	101795	482706	22.03.2023	03.2025

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
28	Standard Gain Horn 75 GHz - 110 GHz	27240-20	Flann	263447	482861	Calibration not necessary	
29	Harmonic mixer 75 GHz - 110 GHz	FS-Z110	Radiometer Physics	101528	482707	22.03.2023	03.2025
30	Standard Gain Horn 110 GHz - 175 GHz	29240-20	Flann	274466	483370	Calibration not necessary	
31	Spektrum Analyzer Extension Module 110 GHz - 170 GHz	WWR6.5SAX-M12-UP	Virginia Diode	SAX 684	483365	30.03.2023	03.2024
32	Standard Gain Horn 140 GHz - 220 GHz	30240-20	Flann	274470	483371	Calibration not necessary	
33	Spektrum Analyzer Extension Module 140 GHz - 220 GHz	WR5.1SAX-M18-UP	Virginia Diode	SAX 685	483366	28.03.2023	03.2024
34	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510210/2	483030	Calibration not necessary	
35	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510213/2	483031	Calibration not necessary	
36	Dynamic temperature chamber	MK 240	Binder	05-79022	480462	09.12.2022	12.2023
37	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
38	Power Supply	TOE8752-32 (DC)	Toellner	31566	480010	Calibration not necessary	
39	Digital multimeter	175	Fluke	79750428	480365	05.09.2022	09.2024
40	Attenuator 6 dB	WA2-6	Weinschel	-	482793	Calibration not necessary	
41	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
42	RF Switch Matrix	OSP220	Rohde & Schwarz	-	482976	Calibration not necessary	
43	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
44	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
45	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
46	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
47	Software	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
48	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	08.11.2022	11.2024
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	01.03.2023	03.2025
Semi anechoic chamber M276	483227	1 -18 GHz	SVSWR	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	28.02.2023	02.2025
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	17.08.2022	08.2024

9 Report History

Report Number	Date	Comment
F230509E2	13.06.2023	Initial Test Report
-	-	-
-	-	-

10 List of Annexes

Annex A	Measurement plots	10 pages
Annex B	Test Setup Photos	13 pages
Annex C	EUT Photos	9 pages