PHOENIX TESTLAB

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Test Report

Report Number:

F220996E1

Equipment under Test (EUT):

NEARFI PD 2A ETH R

Applicant:

PHOENIX CONTACT Electronics GmbH

Manufacturer:

PHOENIX CONTACT GmbH & Co.KG

ilac-MRA

DAkkS
Deutsche
Akkreditierungsstelle
D-PL-17186-01-00

References

[1] **ANSI C63.10-2020**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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

[3] **RSS-210 Issue 11, June 2024**, Licence-Exempt Radio Apparatus: Category I Equipment

[4] **RSS-Gen Issue 5 February 2021 Amendment 2,** 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 1.4 of ANSI C63.10 (2020). However, the measurement uncertainty is calculated and shown in this test report.

Tested and written by:	Thomas Kühn 09.08.2024	Signature
Reviewed and approved by:	Bernd STEINER 09.08.2024	Signature

This test report is only valid in its original form.

The test results herein refer only to the tested sample. PHOENIX TESTLAB GmbH is not responsible for any generalisations or conclusions drawn from these test results concerning further samples. Any modification of the tested samples is prohibited and leads to the invalidity of this test report. Each page necessarily contains the PHOENIX TESTLAB Logo and the TEST REPORT NUMBER.

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1 Identification

1.1 Applicant

Name:	PHOENIX CONTACT Electronics GmbH
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Country:	Germany
Name for contact purposes:	Mr. Maik STEMME
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Applicant represented during the test by the following person:	-

1.2 Manufacturer

Name:	PHOENIX CONTACT GmbH & Co.KG
Address:	Flachsmarktstraße 8 32825 Blomberg
Country:	Germany
Name for contact purposes:	Mr. Maik STEMME
Phone:	+49 52 81 946 – 33 81
Fax:	+49 52 81 946 – 32 99
eMail Address:	mstemme@phoenixcontact.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-17186-01-00, 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: *	Energy and data coupler
Model name / PMN: *	NEARFI PD 2A ETH R
PCB identifier: *	08-057908 REV E Z (60 GHz PCB), 1184502_03 (Data PCB), 30007751 (Interface PCB), 30007724 (Energy PCB)
Serial No.	2035672041
Hardware version / HVIN: *	1234225
Software version / FVIN: *	N/A
FCC ID: *	YG3PD2AETHR
IC:	4720B-PD2AETHR
Lowest / highest internal frequency: *	100 kHz / 63 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

Ethernet communication part			
Operating frequency band: *	57,000 MHz to 71,000 MHz		
Number of channels: *	1		
Nominal channel bandwidth(s): *	N/A (one channel equipment)		
Antenna type: *	Internal patch antenna		
Antenna connector: *	None		
Antenna gain:	12 dBi (refer antenna documentation)		
Data rate: *	62.5 MBit		
Type of modulation: *	OOK		
Power supply: *	DC via WPT from NEARFI PD 2A ETH B (used directly for test purposes only)		
Supply voltage: *	U_{nom} = 24 V_{DC}	U_{min} = 19 V_{DC}	U_{max} = 30 V_{DC}
Temperature range: *	-20 °C to +65 °C		

*: Declared by the applicant.

Ports/Connectors			
Identification	Connector		Length
	EUT	Ancillary	
Power in	5 pole M12 connector	4 mm laboratory plug	3.0 m
Ethernet	5 pole M12 connector	RJ45	3.0 m

*: Length during the test

Ancillary equipment	
PHOENIX CONTACT MINI-PS-100-240AC/24DC/1.3 *2	For power line conducted tests
-	-

*1 Provided by the applicant
*2 Provided by the laboratory

1.6 Dates

Date of receipt of test sample:	13.06.2022
Start of test:	22.08.2022
End of test:	16.11.2022

2 Operational States

The EUT is intended to transmit and receive real time Ethernet data and receive energy contact-less over an air gap of a few millimetres. It is also possible to supply the EUT with an external power supply at the power output. With this supply method the microcontroller of the EUT and its Ethernet communication part operating normally, a power transfer communication is not possible.

All measurements were carried out with an unmodified sample, supplied with 24 V_{DC}, operating in normal operation mode after powered up. As pre-tests have shown, the modulation behaviour of the EUT is independent of an Ethernet connection, therefore all measurements were carried out with the Ethernet port of the EUT left open.

3 Additional Information

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

During the tests below 1 GHz, the EUT was positioned on a non-conducting support in three orthogonal directions:
Position 1: the antenna of the EUT shows to the measuring antenna, connectors are showing upwards;
Position 2: the antenna of the EUT shows to the measuring antenna, connectors are showing sidewards;
Position 3: the antenna of the EUT shows upwards, connectors away from the measurement antenna).
The plots in annex A of this test report are showing the maximum of all positions. Between 1 GHz and 40 GHz the EUT was mounted on a position device, which was rotated in 30 ° steps. Above 40 GHz, the EUT was setup on a non-conducting support and the measurement antenna was moved around the EUT.

The type-plate label of the tested sample is not the latest version.

Object of this test report is the Ethernet communication part of the EUT only, the power communication part of the EUT is documented under test report reference F220996E2 of the PHOENIX-TESTLAB GmbH.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-210 [3] / RSS-Gen [4]	Status
Fundamental emission bandwidth	57000 - 71000	15.255 (e (2))	J.3.3 (d) [3], 6.7 [4]	Passed
Fundamental emission	57000 - 71000	15.255 (c) (1) (i), 15.255 (e)	J.3.3 [3]	Passed
Frequency stability	57000 - 71000	15.255 (f)	J.6 [3], 6.11 [4]	Passed
Radiated emissions	0.009 – 200000	15.255 (d), 15.209	J.4 [3], 6.13 [4]	Passed
Conducted emissions on supply line	0.15 – 30	15.207	8.8 [4]	Passed

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

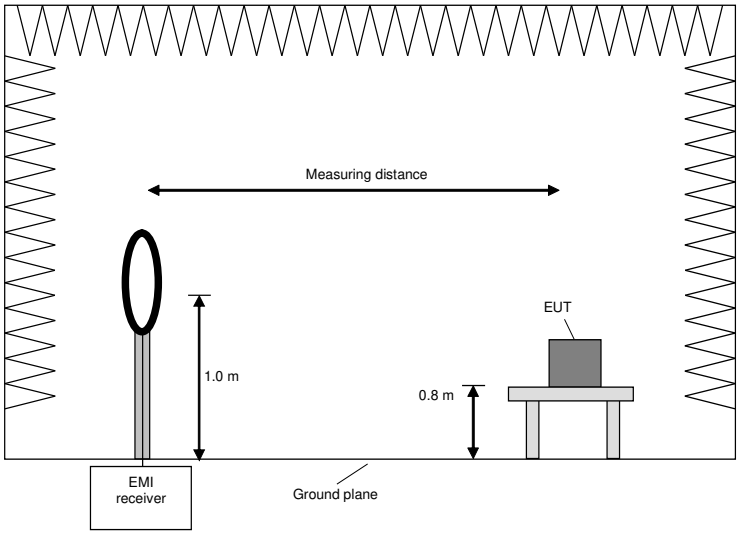
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

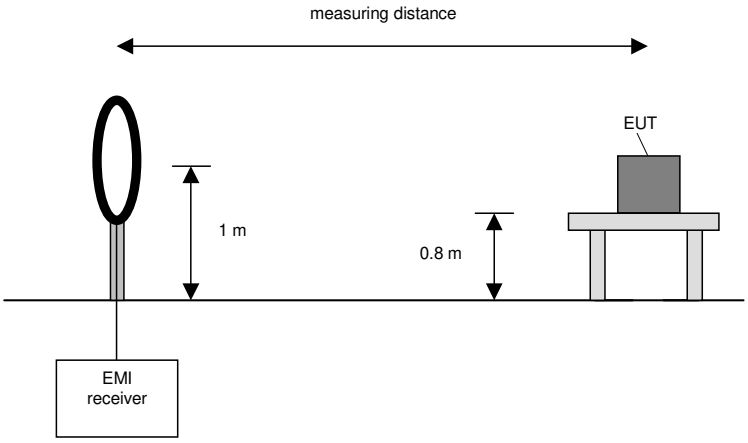
5.1.1.2 Final measurement 9 kHz to 30 MHz

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

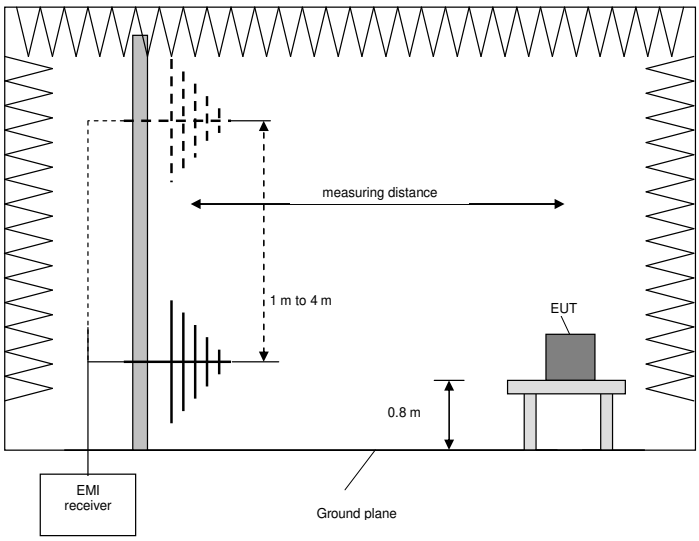
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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

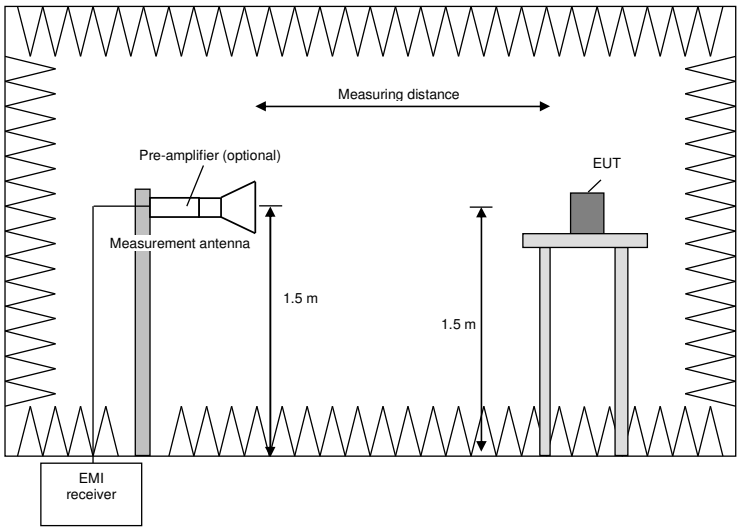
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz

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.

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 200 GHz

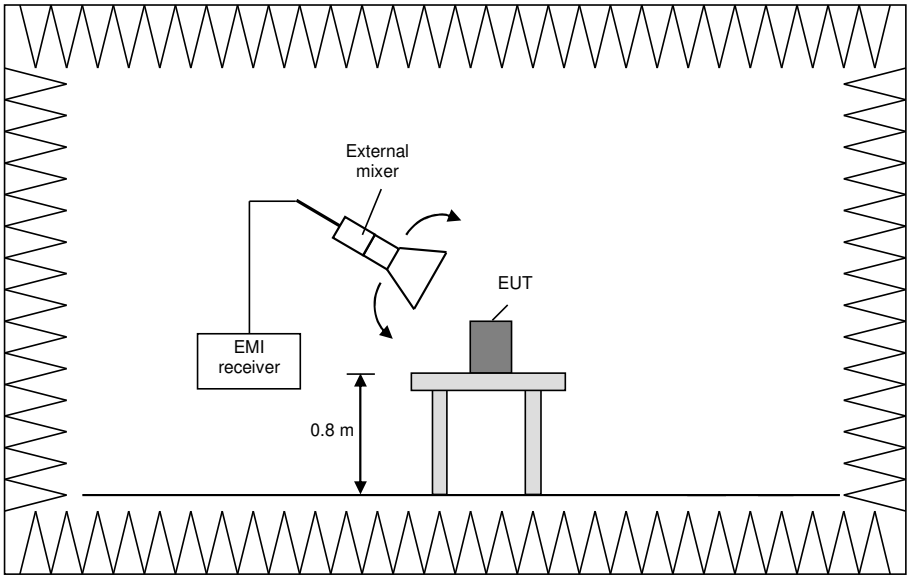
5.1.4.1 Preliminary and final measurement 40 GHz to 200 GHz

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 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.

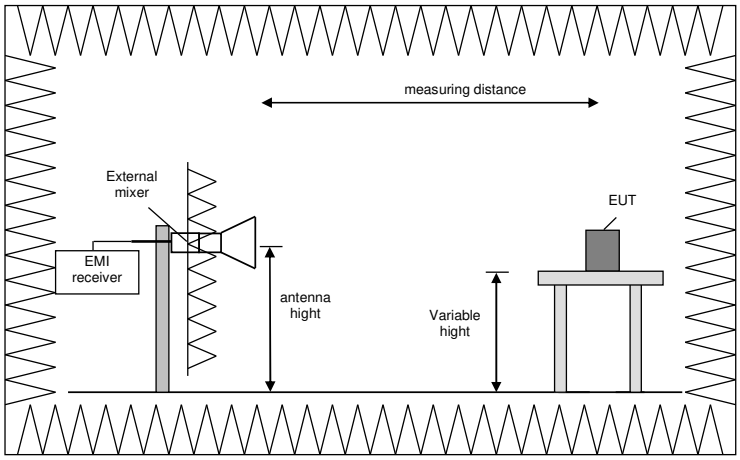
The resolution bandwidth of the EMI Receiver will be set to the following values:

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.

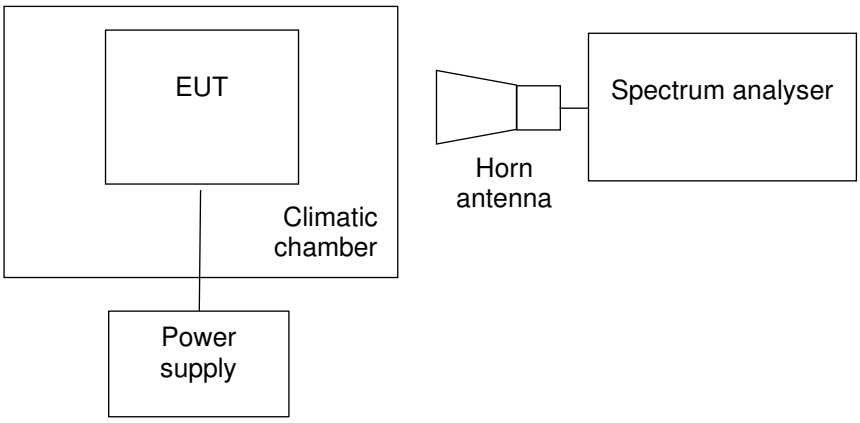
5.1.5 Frequency stability

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 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:

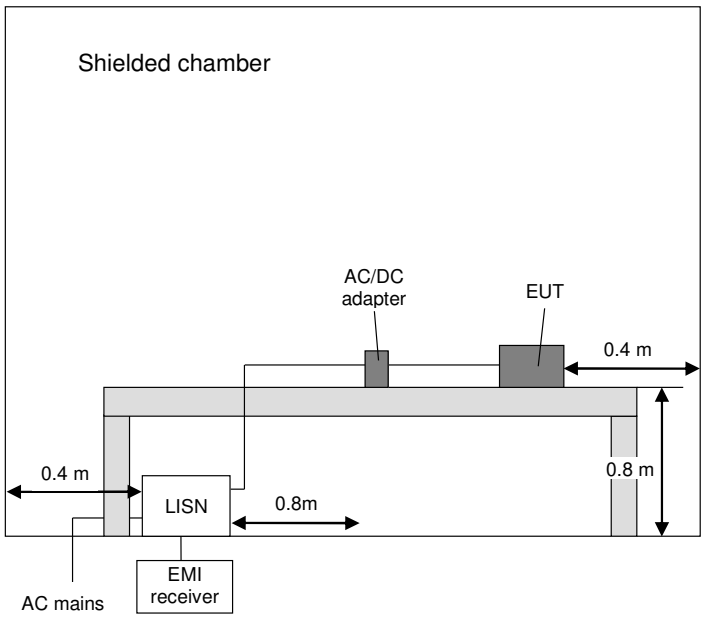


5.1.6 Conducted emission: AC power line

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 (-6 dB bandwidth)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.4	Evaluation of -6 dB bandwidth	No limitations	-

5.2.3 Test method (99 % bandwidth)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.4	99 % emission bandwidth	No limitations	-

5.2.4 Test results (fundamental emission bandwidth)

Ambient temperature:	22 °C
Relative humidity:	40 %

Date:	18.10.2022
Tested by:	Thomas KÜHN

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

-6 dB Bandwidth			
Lower -6 dB frequency	Upper -6 dB frequency	-6 dB bandwidth	Limit
58.008742 GHz	58.015238 GHz	6.496 MHz	The -6 dB bandwidth has to stay within the assigned frequency band (57 GHz to 71 GHz)

99 % bandwidth *		
Lower 99 % frequency	Upper 99 % frequency	99 % bandwidth
57.603479 GHz	58.440470 GHz	836.990 MHz

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 23, 24, 31, 32, 35, 36

5.3 Fundamental emission

5.3.1 Test setup (Fundamental emission)

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

5.3.2 Test method (peak emission)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.4	Radiated: 40 GHz to 200 GHz	No limitations	-

5.3.3 Test results (fundamental emission)

Ambient temperature:	22 °C
Relative humidity:	40 %

Date:	18.10.2022
Tested by:	Thomas KÜHN

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

Maximum peak transmitter power (EIRP)		
Maximum peak transmitter power	Limit	Margin
-3.8 dBm	43 dBm	46.8 dB

Maximum average transmitter power (EIRP) *		
Maximum average transmitter power	Limit	Margin
-12.3 dBm	40 dBm	52.3 dB

*: Because the EUT has a constant duty cycle of 100 %, therefore the average transmitter output power is measured and not calculated over the transmission time period.

Peak power density within the 57 GHz to 71 GHz band *
Peak power density (EIRP, peak)
10.3 dBm / 14 GHz

Because the EUT has no antenna connector, the maximum peak transmitter conducted output power was calculated with the following formula:

$P_{cond.} = P_{eirp} - G$

Where: $P_{cond.}$ = Maximum peak transmitter conducted output power [dBm],
P_{eirp} = Maximum peak transmitter power (EIRP) [dBm],
G = Antenna gain of the transmitting antenna [dBi].

The 6 dB bandwidth of the EUT is below 100 MHz, therefore the limit for maximum peak transmitter output power has to be calculated with the following formula:

Limit acc. 15.255 (e) (1) / J.3.3 (d): (500 mW x 6 dB bandwidth) / 100 MHz
With the 6 dB bandwidth of 6.496 MHz (refer clause 5.2.4 of this test report), the limit is calculated to 32.5 mW / 15.1 dBm.

Peak transmitter output power (conducted)				
Peak transmitter power within the band (EIRP)	Antenna gain	Peak transmitter output power (conducted)	Limit	Margin
10.3 dBm	12.0 dBi	-1.7 dBm	15.1 dBm	16.8 dB

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 23, 24, 31, 32, 35, 36

5.4 Frequency stability

5.4.1 Test setup (frequency stability)

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

5.4.2 Test method (frequency stability)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.5	Frequency stability	No limitations	-

5.4.3 Test result (frequency stability)

Ambient temperature:	22 °C
Relative humidity:	40 %

Date:	18.10.2022
Tested by:	Thomas KÜHN

Test set-up: For this test the EUT was fixed on a non-conducting support 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]	Lower Limit [GHz]	Upper frequency [GHz]	Upper Limit [GHz]	-6 dB bandwidth [kHz]	Peak frequency [GHz]	Result
50 °C	24 V_{DC} (U_{nom})	58.007742	57.000000	58.015638	71.000000	7896	58.01281	Passed
40 °C	24 V_{DC} (U_{nom})	58.008342	57.000000	58.015438	71.000000	7096	58.01129	Passed
30 °C	24 V_{DC} (U_{nom})	58.008393	57.000000	58.015638	71.000000	7246	58.01259	Passed
20 °C	19 V_{DC} (U_{min})	58.008442	57.000000	58.015188	71.000000	6746	58.01149	Passed
	24 V_{DC} (U_{nom})	58.008742	57.000000	58.015238	71.000000	6496	58.01189	Passed
	30 V_{DC} (U_{max})	58.008292	57.000000	58.015338	71.000000	7046	58.01229	Passed
10 °C	24 V_{DC} (U_{nom})	58.009941	57.000000	58.014889	71.000000	4948	58.01214	Passed
0 °C	24 V_{DC} (U_{nom})	58.010891	57.000000	58.015138	71.000000	4248	58.01264	Passed
-10 °C	24 V_{DC} (U_{nom})	58.008892	57.000000	58.017637	71.000000	8745	58.01254	Passed
-20 °C	24 V_{DC} (U_{nom})	58.008342	57.000000	58.017437	71.000000	9095	58.01294	Passed

Test result: Passed

Test equipment (please refer to chapter 6 for details)
9, 23, 24, 31 – 33, 35, 36

5.5 Unwanted emissions (radiated)

5.5.1 Test setup (Maximum unwanted emissions)

Used	Setup	See sub-clause	Comment
☒	Test setup (radiated)	5.1.1 to 5.1.4	-

5.5.2 Test method (Maximum unwanted emissions)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.1 to 5.1.4	Unwanted radiated emissions	No limitations	-

5.5.3 Test results (Maximum unwanted emissions)

5.5.3.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	23 °C
Relative humidity:	48 %

Date:	16.11.2022
Tested by:	Thomas KÜHN

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). The plot is submitted annex A.4 of this test report.

Remark: All three orthogonal planes were tested separately for all EUT positions, the plots in annex A.4 are showing the maximum values of all measurements.

Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-26.8 dBµV/m or -78.3 dBµA/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 (3.8 dBµV/m or -47.7 dBµA/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)
34 – 36, 39 – 45

5.5.3.2 Test results preliminary and final measurement 30 MHz to 1 GHz

Ambient temperature:	22 °C
Relative humidity:	26 %

Date:	14.11.2022
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]	Readings [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol. (H/V)	Position #
150.000	28.3	43.5	15.2	13.0	15.3	275	111	Hor.	2
208.530	20.4	43.5	23.1	4.1	16.3	125	117	Hor.	1
212.940	21.0	43.5	22.5	4.7	16.3	125	125	Hor.	1
249.990	35.9	46.0	10.1	18.6	17.3	125	127	Hor.	2
300.000	33.4	46.0	12.6	14.3	19.1	100	141	Hor.	2
399.990	35.8	46.0	10.2	13.8	22.0	100	141	Hor.	2
624.990	34.3	46.0	11.7	8.0	26.3	125	216	Hor.	2
650.010	36.1	46.0	10.0	9.1	27.0	125	215	Hor.	2
849.990	38.0	46.0	8.0	8.6	29.4	100	208	Hor.	2
874.980	36.9	46.0	9.1	7.3	29.6	100	267	Hor.	2

Test result: Passed

Test equipment (please refer to chapter 6 for details)
35 – 45

5.5.3.3 Test results measurement 1 GHz to 40 GHz

Ambient temperature:	22 °C
Relative humidity:	51 + 55 %

Date:	22.08.2022 + 05.09.2022
Tested by:	Thomas KÜHN

Position of EUT: The EUT was set-up on a position device at a height of 1.5 m. The distance between EUT and antenna was 3 m (1 GHz to 16.5 GHz) and 1 m (26.5 GHz to 40 GHz).

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] + preamplifier [dB] + antenna factor [1/dB] + Distance correction factor [dB] (if necessary)

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]	Dist. [m]	Dist. Corr. [dB]	Height [cm]	Azimuth [deg]	Elevation [deg]	Pol.
1649.897	41.2	74.0	32.8	54.2	-13.0	3	0	150	309	0	Hor.
2049.887	39.4	74.0	34.6	50.9	-11.5	3	0	150	0	60	Vert.
2149.885	40.8	74.0	33.2	51.6	-10.8	3	0	150	354	60	Vert.
2249.885	40.2	74.0	33.8	51.0	-10.8	3	0	150	0	60	Vert.
3149.874	41.3	74.0	32.7	47.6	-6.3	3	0	150	18	0	Hor.
9039.370	48.5	74.0	25.5	40.0	8.5	3	0	150	187	30	Vert.
9695.657	49.3	74.0	24.7	41.9	7.4	3	0	150	169	90	Vert.
11966.846	49.5	74.0	24.5	42.9	6.6	3	0	150	288	90	Vert.
16575.120	50.7	74.0	23.3	41.3	9.4	3	0	150	168	150	Vert.
18000.050	51.2	74.0	22.8	47.6	3.6	3	0	150	182	150	Hor.
33150.168	45.1	74.0	28.9	38.9	6.2	1	-9.5	150	32	0	Hor.
36000.220	50.3	74.0	23.7	44.0	6.3	1	-9.5	150	155	150	Hor.

Continued next page

Results measured with average detector											
Frequency [MHz]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Dist. [m]	Dist. Corr. [dB]	Height [cm]	Azimuth [deg]	Elevation [deg]	Pol.
1649.897	35.4	54.0	18.6	48.4	-13.0	3	0	150	309	0	Hor.
2049.887	34.7	54.0	19.3	46.2	-11.5	3	0	150	0	60	Vert.
2149.885	34.9	54.0	19.1	45.7	-10.8	3	0	150	354	60	Vert.
2249.885	34.3	54.0	19.7	45.1	-10.8	3	0	150	0	60	Vert.
3149.874	31.6	54.0	22.4	37.9	-6.3	3	0	150	18	0	Hor.
9039.370	36.0	54.0	18.0	27.5	8.5	3	0	150	187	30	Vert.
9695.657	35.3	54.0	18.7	27.9	7.4	3	0	150	169	90	Vert.
11966.846	37.1	54.0	16.9	30.5	6.6	3	0	150	288	90	Vert.
16575.120	48.1	54.0	5.9	38.7	9.4	3	0	150	168	150	Vert.
18000.050	47.8	54.0	6.2	44.2	3.6	3	0	150	182	150	Hor.
33150.168	32.6	54.0	21.4	35.9	6.2	1	-9.5	150	32	0	Hor.
36000.220	39.2	54.0	14.8	42.4	6.3	1	-9.5	150	155	150	Hor.

Test result: Passed

Test equipment (please refer to chapter 6 for details)
3, 9 – 12, 14 – 20, 36, 37

5.5.3.4 Test results measurement 40 GHz to 200 GHz

Ambient temperature:	22 °C
Relative humidity:	32 %

Date:	07.09.2022
Tested by:	Thomas KÜHN

Position of EUT: In this frequency range the EUT was positioned on a non-conducting support with a variable height and was tested in two orthogonal directions.

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: The limit of 90 pW/cm^2 is converted to an effective isotropic radiated power (EIRP) of -10 dBm with the following formular:

$$EIRP\ [dBm] = P_D \times 4 \times \pi \times d^2$$

Where: P_D = power density limit in W/m^2
d = distance, where the limit has to be reached (3 m)

Test result: No emissions were found in this frequency range. Therefore, the maximum noise level in each frequency range was reported in the table below.

Unwanted emissions level, measured with peak detector				
Frequency range	Max. peak emission level [dBm]	Used measurement distance [cm]	Limit [dBm]	Margin [dB]
40 GHz to 50 GHz	-33.9 *	100	-10.0	23.9
50 GHz to 57 GHz	-25.3 *	100	-10.0	15.3
71 GHz to 75 GHz	-27.3 *	100	-10.0	17.3
75 GHz to 110 GHz	-29.9 *	100	-10.0	19.9
110 GHz to 170 GHz	-36.7 *	30	-10.0	26.7
170 GHz to 200 GHz	-35.2 *	30	-10.0	25.2

*: 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, 21 – 32, 35, 36

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
☒	5.1.6	Tabletop equipment testing	5.1.6	The EUT is DC supplied, therefore, an AC / DC adaptor has to be used.

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

5.6.3 Test results (Conducted emissions on power supply lines)

Ambient temperature:	22 °C
Relative humidity:	44 %

Date:	16.11.2022
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 10 dB below the with 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 V10.60.17	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	11.2023
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	31.03.2021	03.2023
23	Standard gain horn 50 GHz - 75 GHz	25240-20	Flann	263443	482859	Calibration not necessary	
24	Harmonic mixer 50 GHz - 75 GHz	FS-Z75	Rohde & Schwarz	101067	482705	30.03.2021	03.2023
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	Rohde & Schwarz	101528	482707	31.03.2021	03.2023

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
27	Standard gain horn 110 GHz - 170 GHz	29240-20	Flann	263447	482861	Calibration not necessary	
28	Harmonic mixer 110 GHz - 170 GHz	FS-Z170	Rohde & Schwarz	100978	482838	07.04.2021	04.2023
29	Standard gain horn 140 GHz - 220 GHz	30240-20	Flann	263476	482864	Calibration not necessary	
30	Harmonic mixer 140 GHz - 220 GHz	FS-Z220	Rohde & Schwarz	101022	482839	07.04.2021	04.2023
31	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510210/2	483030	Calibration not necessary	
32	RF-cable 0.5 m	Sucoflex 102	Huber+Suhner	510213/2	483031	Calibration not necessary	
33	Dynamic temperature chamber	MK 240	Binder	05-79022	480462	07.12.2021	12.2022
34	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
35	Power Supply	TOE8752-32 (DC)	Toellner	31566	480010	Calibration not necessary	
36	Multimeter	971A	Hewlett Packard	JP39009358	480721	30.03.2022	03.2023
37	Attenuator 6 dB	WA2-6	Weinschel	-	482793	Calibration not necessary	
38	Ultralog antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
39	RF switch matrix	OSP220	Rohde & Schwarz	-	482976	Calibration not necessary	
40	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
41	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
42	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
43	Semi anechoic chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
44	EMC test software	Elektra V4.42	Rohde & Schwarz	100970	482972	Calibration not necessary	
45	EMI receiver / spectrum analyser	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		
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	17.08.2022	16.08.2024

9 Report History

Report Number	Date	Comment
F220996E1	09.08.2024	Initial test report
-	-	-
-	-	-

10 List of Annexes

Annex A	Measurement plots	8 pages
Annex B	Test setup photos	12 pages