

Test Report

Report Number:

F231416E1, 2nd version

Equipment under Test (EUT):

**Level probing radar
FMR10B, FMR20B, FMR30B**

Applicant:

Endress+Hauser SE+Co. KG

Manufacturer:

Endress+Hauser SE+Co. KG



Deutsche
Akkreditierungsstelle
D-PL-17186-01-00

References

- [1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices
- [2] **FCC CFR 47 Part 15**, Radio Frequency Devices
- [3] **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

This test report is only valid in its original form.

Any reproduction of its contents in extracts without written permission of the accredited test laboratory PHOENIX TESTLAB GmbH is prohibited.

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.

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	7
1.6 Dates	7
2 Operational States	7
3 Additional Information	8
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.....	16
5.1.5.1 Method of measurement (frequency stability).....	16
5.1.6 Conducted: AC power line	17
5.2 Fundamental emissions bandwidth.....	18
5.2.1 Test setup (Fundamental emission bandwidth).....	18
5.2.2 Test method (-10 dB bandwidth)	18
5.2.3 Test method (99 % bandwidth).....	18
5.2.4 Test results (fundamental emission bandwidth)	19
5.3 Fundamental emission	20
5.3.1 Test setup (Fundamental emission)	20
5.3.2 Test method (average emission)	20
5.3.3 Test method (peak emission)	20
5.3.4 Test results (fundamental emission).....	21

5.4	Unwanted emissions (radiated).....	22
5.4.1	Test setup (Maximum unwanted emissions).....	22
5.4.2	Test method (Maximum unwanted emissions).....	22
5.4.3	Test results (Maximum unwanted emissions).....	23
5.4.3.1	Test results preliminary measurement 9 kHz to 30 MHz.....	23
5.4.3.2	Test results preliminary measurement 30 MHz – 1 GHz.....	24
5.4.3.3	Test results measurement 1 GHz to 40 GHz.....	26
5.4.3.4	Test results measurement 40 GHz to 200 GHz.....	29
5.5	Frequency stability.....	31
5.5.1	Test setup (frequency stability).....	31
5.5.2	Test method (frequency stability).....	31
5.5.3	Test result (frequency stability).....	31
5.6	AC power-line conducted emissions.....	33
5.6.1	Test setup (AC power-line conducted emissions).....	33
5.6.2	Test method (AC power-line conducted emissions).....	33
5.6.3	Test results (Conducted emissions on power supply lines).....	33
6	Test Equipment used for Tests.....	35
7	Measurement Uncertainties.....	37
8	Test site Verification.....	38
9	Report History.....	38
10	List of Annexes.....	38

1 Identification

1.1 Applicant

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Florian SEIDLER, Mr. Ralf REIMELT
Phone:	+49 76 22 28 14 50, +49 76 22 28 18 90
eMail Address:	florian.seidler@endress.com, ralf.reimelt@endress.com
Applicant represented during the test by the following person:	None

1.2 Manufacturer

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Florian SEIDLER, Mr. Ralf REIMELT
Phone:	+49 76 22 28 14 50, +49 76 22 28 18 90
eMail Address:	florian.seidler@endress.com, ralf.reimelt@endress.com
Manufacturer represented during the test by the following person:	None

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)

EUT number	Model name / PMN	Serial number	Display	Sensor-Board	Power-Board	Main-Board	Terminal-Board
1A	FMR10B	FMR10B_ANA_0277	None	71574004	71502179	71603017	71581272
2A	FMR20B	FMR20B_HA2W_0276					
2B		FMR20B_HA2W_0258					
3	FMR30B	FMR30B_HA2W_0234	VU231C			71499710	71581366
4		FMR30B_HA2W_0235					

EUT number	Hardware version	Software version	Housing	Housing material	Antenna	Antenna gain
1A	V01.00.00	V01.00.00	Top: Threaded cable to top Bottom: Threaded 1-1/2"	Plastic	Encapsulated, PVDF, 40mm/1-1*2"	27.5 dBi
2A		V01.00.00	Top: Threaded cable to top Bottom: Prepared for Flange		Encapsulated, PVDF, 80mm/3"	30.8 dBi
2B		V01.00.00	Top: Threaded cable to top Bottom: Threaded 1-1/2"		Encapsulated, PVDF, 40mm/1-1*2"	27.5 dBi
3		V01.00.00	Top: Display Bottom: Threaded 1-1/2"		Encapsulated, PVDF, 40mm/1-1*2"	27.5 dBi
4		V01.00.00	Top: Display Bottom: Prepared for Flange		Encapsulated, PVDF, 80mm/3"	30.8 dBi

EUT number	FCC ID	IC number:	HVIN	FVIN
1A	LCGFMR10BL	2519A-10BL	FMR10B	N/A
2A	LCGFMR20BL	2519A-20BL	FMR20B-BN	N/A
2B			FMR20B-BM	
3	LCGFMR30BL	2519A-30BL	FMR30B-BM	N/A
4			FMR30B-BN	

All data in the above tables are 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

Rated rf-output power: *	20 dBm/MHz		
Antenna type: *	Refer table above		
Operating frequency band: *	75000 MHz to 85000 MHz		
Nominal channel bandwidth(s): *	77000 MHz to 81000 MHz		
Type of modulation: *	FMCW		
Antenna connector: *	None		
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

1.6 Dates

Date of receipt of test sample:	22.07.2024
Start of test:	26.08.2024
End of test:	23.10.2024

2 Operational States

The EUTs are level probing radars.

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

Bluetooth was active during all measurements but not connected to a companion device.

3 Additional Information

The antenna requirements were not tested. The required antenna data were provided by the applicant. Refer also the document "FMRx0B_Antenna_pattern.pdf".

As declared by the applicant, all EUTs are equipped with the same sensor board and power board (refer also the table in clause 1.4 of this test report). The tests, documented in this test report were carried out according to the applicants test plan, which selected the combination of different housings, displays, main boards, terminal boards and antennas.

The fundamental emission bandwidth and the fundamental emission tests were carried out on all EUTs. The test cases frequency stability, radiated emissions and conducted emissions on supply line were carried out only on the EUTs 1A, 2A, and 3. These tests are not carried out on EUT 2B, as the EUT 2B is identical to the EUT 2A except for the antenna, but the antenna was tested with the same sensor board on the EUT 1A. These tests are not carried out on EUT 4, as the EUT 4 is identical to the EUT 3 except for the antenna, but the antenna was tested with the same sensor board on the EUT 2A.

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 up chirp to 81 GHz.

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.

The EUTs were encapsulated, so internal Photographs of the EUTs were provided by the applicant (refer to annex D).

The measurements were carried out under the following PHOENIX-TESTLAB order numbers: 23-11412 and 23-11414 to 23-110416. It was requested by the applicant to document the results of these orders in one test report.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-211 [4] / RSS-Gen [5]	Tested EUT	Status
Fundamental emission bandwidth	75000 – 85000	15.256 (f)	5.2 (b) [4], 6.7 [5]	1A, 2A, 2B, 3, 4	Passed
Fundamental emission	75000 – 85000	15.256 (g)	5.2 (b) [4]	1A, 2A, 2B, 3, 4	Passed
Frequency stability	75000 – 85000	15.256 (f)	5.1 (b) [4]	1A, 2A, 3	Passed
Radiated emissions	0.009 – 200000	15.256 (h) + (k), 15.209	6.13 [5]	1A, 2A, 3	Passed
Conducted emissions on supply line	0.15 – 30	15.207	8.8 [5]	1, 2A, 3	Passed
Antenna requirement	75000 – 85000	15.256 (b), (i) and (j)	5.2 (a) + (c) [4]	-	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

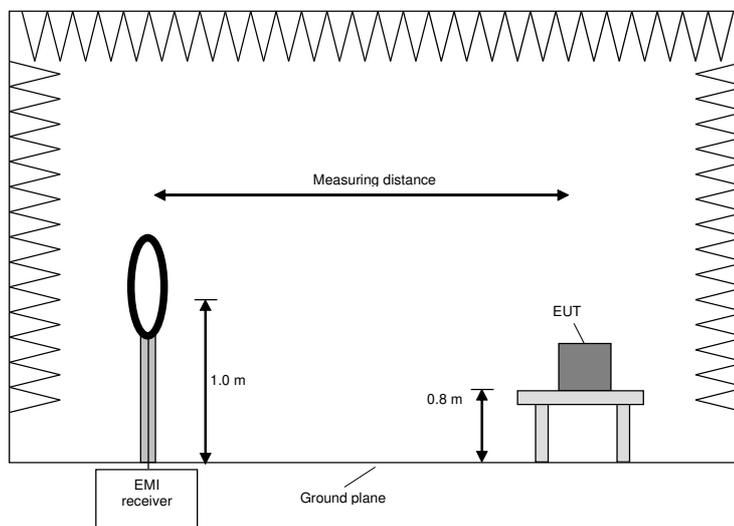
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

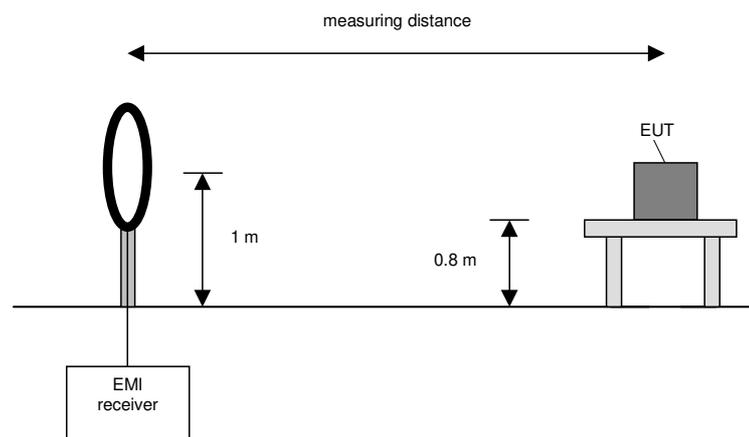
5.1.1.2 Final measurement 9 kHz to 30 MHz

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

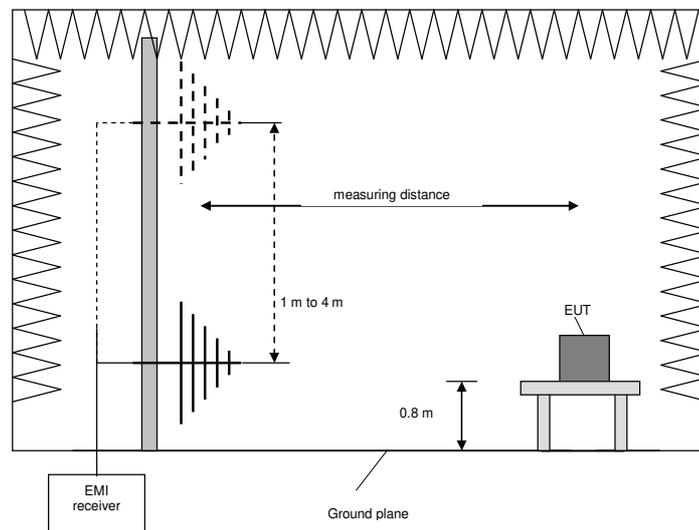
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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

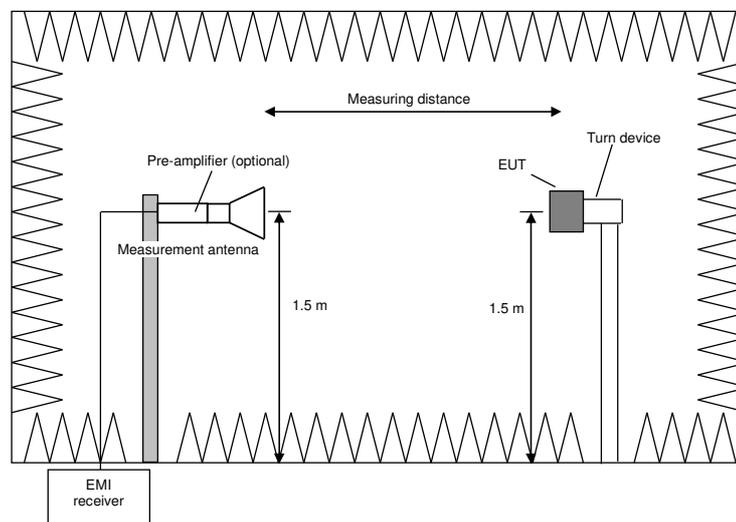
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz

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

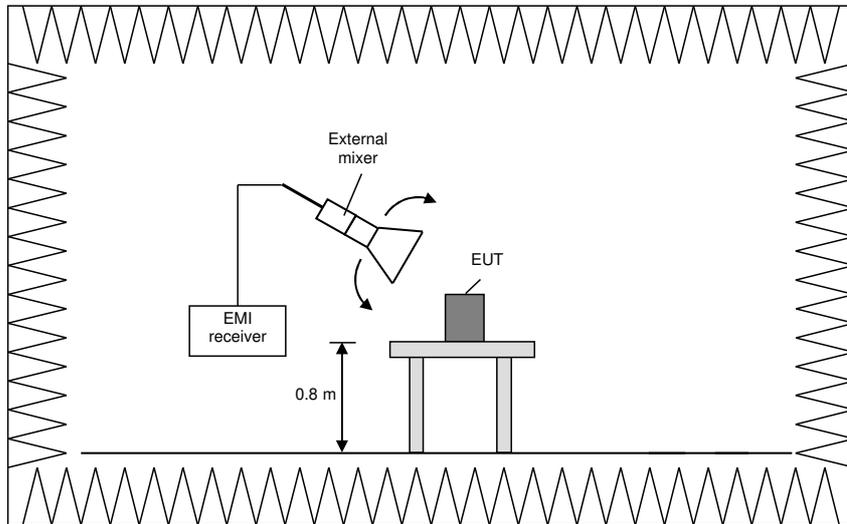
5.1.4.1 Preliminary and final measurement 40 GHz to 200 GHz

The frequency range 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 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.

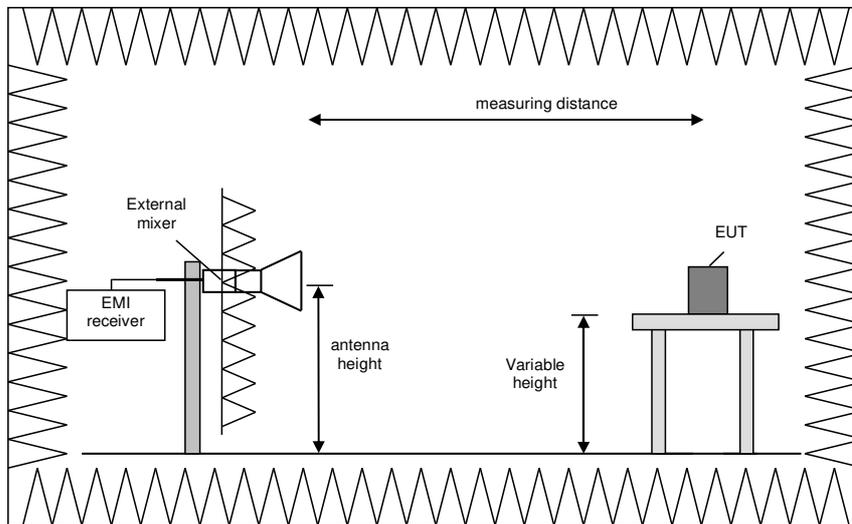
The resolution bandwidth of the EMI Receiver will be set to the following values:

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, 85 GHz to 110 GHz, 110 GHz to 130 GHz, 130 GHz to 150 GHz, 150 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 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.

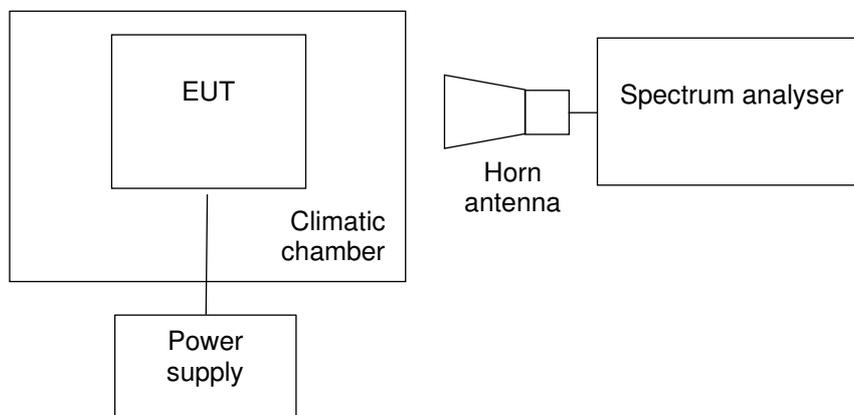
5.1.5 Frequency stability

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 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 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:

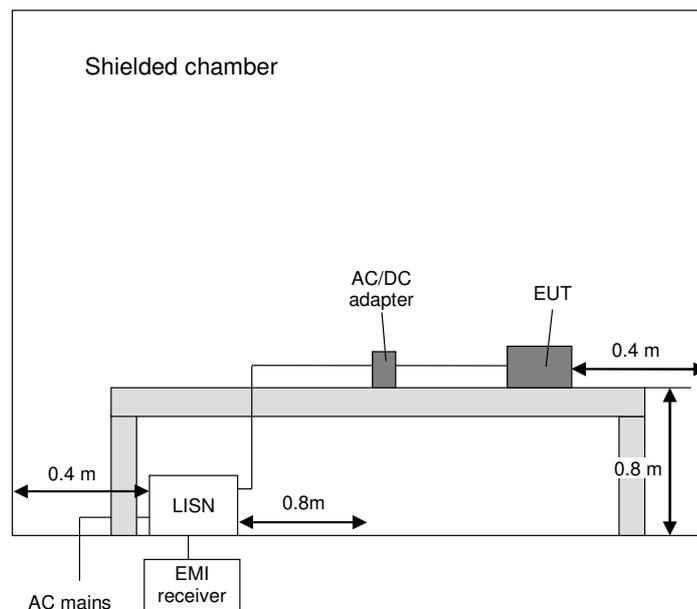


5.1.6 Conducted: AC power line

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



5.2 Fundamental emissions bandwidth

5.2.1 Test setup (Fundamental emission bandwidth)

Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Radiated: 40 GHz to 200 GHz	5.1.4	Measured at boresight
<input type="checkbox"/>	Conducted: Antenna port		EUT has no antenna connector

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:	22 °C
Relative humidity:	52 - 80 %

Date:	27.08.2024 till 09.09.2024
Tested by:	S. KREHS

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

Operating bandwidth				
EUT number	Lower -10 dB frequency	Upper -10 dB frequency	-10 dB bandwidth	Limit
1A	77.0104 GHz	80.9927 GHz	3.9823 GHz	50 MHz (required minimum), furthermore the 10 dB bandwidth has to stay within the assigned frequency band (75.00 to 85.00)
2A	77.0064 GHz	80.9920 GHz	3.9856 GHz	
2B	77.0054 GHz	80.9924 GHz	3.9870 GHz	
3	77.0084 GHz	80.9926 GHz	3.9628 GHz	
4	77.0024 GHz	80.9937 GHz	3.9916 GHz	

99 % bandwidth			
EUT number	Lower frequency	Upper frequency	99 % bandwidth
1A	77.02940 GHz	80.99707 GHz	3.99027 GHz
2A	77.00318 GHz	80.99649 GHz	3.99331 GHz
2B	77.00019 GHz	80.99642 GHz	3.99623 GHz
3	77.00203 GHz	80.99745 GHz	3.99542 GHz
4	77.00079 GHz	80.99443 GHz	3.99364 GHz

Test result: Passed

Test equipment (please refer to chapter 6 for details)
1 – 6, 48, 49

5.3 Fundamental emission

5.3.1 Test setup (Fundamental emission)

Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Radiated: 40 GHz to 200 GHz	5.1.4	Measured at boresight
<input type="checkbox"/>	Conducted: Antenna port	-	EUT has no antenna connector

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:	22 °C
Relative humidity:	52 - 80 %

Date:	27.08.2024 till 09.09.2024
Tested by:	S. KREHS

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

Fundamental emission (peak)					
EUT number	Frequency [MHz]	Measuring distance [m]	Level fundamental (EIRP) [dBm]	Limit [dBm]	Margin [dB]
1A	77812.000	1	29.1	34.0	4.9
2A	78152.000	1	32.8	34.0	1.2
2B	80390.000	1	29.3	34.0	4.7
3	77802.000	1	29.7	34.0	4.3
4	78212.000	1	32.8	34.0	1.2

As documented in A.4 of annex A of this test report, the EUTs are using FMCW modulation with a sweep of 1.06 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:

$$\text{Dwell time } (T_D) = T_s / \Delta f$$

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

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

Averaging factor calculation									
EUT number	Bandwidth (Δf) [MHz]	Sweep time (T_s) [ms]	Dwell time (T_D) [$\mu\text{s}/\text{MHz}$]	Cycle time [ms]	Averaging factor [dB]	Level fundamental (EIRP, peak) [dBm/MHz]	Calculated fundamental average level (EIRP) [dBm/MHz]	Limit [dBm/MHz]	Margin [dB]
1A	3982	1.06	0.266	75	-54.5	28.6	-25.9	-3.0	22.9
2A	3986	1.06	0.266	75	-54.5	32.0	-22.5	-3.0	19.5
2B	3987	1.06	0.266	75	-54.5	28.5	-26.0	-3.0	23.0
3	3963	1.06	0.267	75	-54.5	28.5	-26.0	-3.0	23.0
4	3992	1.06	0.266	75	-54.5	32.3	-22.0	-3.0	19.0

Test result: Passed

Test equipment (please refer to chapter 6 for details)
1 – 9, 48, 49

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 - 23 °C	Date:	10.09.2024 till 18.10.2024
Relative humidity:	41 - 52 %	Tested by:	S. KREHS

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 number 1A	
Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-33.6 dB μ V/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 (-14.8 dB μ V/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.

EUT number 2A	
Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-31.7 dB μ V/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 (-13.8 dB μ V/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.

EUT number 3	
Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-34.7 dB μ V/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 (-6.0 dB μ V/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)
10 – 17, 48, 49

5.4.3.2 Test results preliminary measurement 30 MHz – 1 GHz

Ambient temperature:	22 - 23 °C
Relative humidity:	41 - 52%

Date:	10.09.2024 till 18.10.2024
Tested by:	S. KREHS

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.5 of this test report.

Calculation:

Result [dB μ V] = reading [dB μ V] + Correction [dB μ V/m]

Correction [dB μ V/m] = Cable attenuation [dB] + pre amplifier [dB] + antenna factor [1/dB]

Margin [dB] = Limit [dB μ V/m] – Result [dB μ V/m]

EUT 1A									
Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position
30.220	24.7	40.00	15.3	-1.8	26.5	100	199	Vert.	1
30.320	24.4	40.00	15.6	-2.1	26.5	125	214	Vert.	2
48.040	29.0	40.00	11.0	14.1	14.9	267	330	Vert.	2
223.990	29.9	46.00	16.1	13.8	16.1	101	245	Hor.	2
256.000	35.8	46.00	10.2	18.3	17.5	100	129	Hor.	2
271.990	33.4	46.00	12.6	15.4	18.0	100	233	Hor.	2
288.010	34.4	46.00	11.6	15.8	18.6	100	237	Hor.	1

EUT 2A									
Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position
47.970	34.7	40.00	5.3	19.8	14.9	103	33	Vert.	2
48.030	35.3	40.00	4.7	20.4	14.9	101	3	Vert.	1
224.010	33.5	46.00	12.5	17.4	16.1	101	343	Vert.	1
240.000	28.7	46.00	17.3	11.7	17.0	101	344	Vert.	1
255.990	40.7	46.00	5.3	23.2	17.5	169	187	Vert.	2
271.980	34.9	46.00	11.1	16.9	18.0	147	183	Vert.	2
288.000	32.6	46.00	13.4	14.0	18.6	151	188	Vert.	2
303.990	27.9	46.00	18.1	8.8	19.1	152	179	Vert.	1

EUT 3									
Frequency [MHz]	Result (QP) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.	Position
42.000	31.1	40.0	8.9	12.1	19.0	101	24	Vert.	2
66.000	22.4	40.0	17.6	8.8	13.6	139	188	Vert.	2
137.970	25.0	43.5	18.5	8.9	16.1	221	275	Hor.	1
224.010	29.2	46.0	16.8	13.1	16.1	241	241	Hor.	2
255.990	33.4	46.0	12.6	15.9	17.5	113	113	Hor.	2
288.000	25.9	46.0	20.1	7.3	18.6	107	127	Hor.	1
303.990	24.5	46.0	21.5	5.4	19.1	100	136	Hor.	1

Test result: Passed

Test equipment (please refer to chapter 6 for details)
11 – 19, 48, 49

5.4.3.3 Test results measurement 1 GHz to 40 GHz

Ambient temperature:	22 °C
Relative humidity:	59 – 66 %

Date:	30.08.2024 till 06.09. 2024
Tested by:	S. KREHS

Position of EUT: In the frequency range 1 GHz to 40 GHz, the EUTs were set-up on a positioner device with a height of 150 cm. The measuring distance was 3m in the frequency range 1 GHz to 26.5 GHz and 1 m in the frequency range 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: Plots for each EUT position are submitted annex A.5 of this test report.

Calculation:

Result [dB μ V] = reading [dB μ V] + Correction [dB μ V/m]

Correction [dB μ V/m] = Cable attenuation [dB] + pre amplifier [dB] + antenna factor [1/dB]

Margin [dB] = Limit [dB μ V/m] – Result [dB μ V/m]

Results of EUT 1A										
Frequency [MHz]	Result (PK) [dB μ V/m]	Result (AV) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Elevation [deg]	Pol.
2248.000	47.0	---	74.0	27.0	15.0	32.0	155.0	144	90	Hor.
	---	36.8	54.0	17.2	4.8					
2632.000	48.8	---	74.0	25.2	14.8	34.0	155.0	198	30	Hor.
	---	37.9	54.0	16.1	3.9					
2984.000	48.2	---	74.0	25.8	13.3	34.9	155.0	268	90	Vert.
	---	36.9	54.0	17.1	2.0					
4848.250	61.4	---	74.0	12.6	63.1	-1.7	155.0	218	60	Hor.
	---	27.8	54.0	26.2	29.5					
4880.000	52.6	---	74.0	21.4	54.2	-1.6	155.0	266	60	Vert.
	---	37.7	54.0	16.3	39.3					
7319.500	58.1	---	74.0	15.9	54.0	4.1	155.0	237	230	Vert.
	---	51.9	54.0	2.1	47.8					
9629.000	66.5	---	74.0	7.5	59.2	7.3	155.0	123	60	Hor.
	---	35.1	54.0	18.9	27.8					
9759.000	66.8	---	74.0	7.2	60.5	6.3	155.0	130	60	Hor.
	---	41.7	54.0	12.3	35.4					
12401.000	52.3	---	74.0	21.7	41.9	10.4	155.0	250	90	Vert.
	---	44.5	54.0	9.5	34.1					
14443.250	54.6	---	74.0	19.4	44.4	10.2	155.0	127	0	Hor.
	---	28.4	54.0	25.6	18.2					
14881.250	50.1	---	74.0	23.9	40.1	10.0	155.0	323	120	Vert.
	---	41.4	54.0	12.6	31.4					
19699.000	58.4	---	74.0	15.6	54.7	3.7	155.0	121	60	Hor.
	---	30.5	54.0	23.5	26.8					
19772.750	56.1	---	74.0	17.9	52.4	3.7	155.0	151	60	Hor.
	---	30.6	54.0	23.4	26.9					

Results of EUT 2A										
Frequency [MHz]	Result (PK) [dB μ V/m]	Result (AV) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Elevation [deg]	Pol.
2248.000	46.0	---	74.0	28.0	13.9	32.1	155.0	259	90	Vert.
	---	36.7	54.0	17.3	4.6					
2632.000	46.5	---	74.0	27.5	12.4	34.1	155.0	307	90	Vert.
	---	34.4	54.0	19.6	0.3					
3992.000	52.2	---	74.0	21.8	14.2	38.0	155.0	260	120	Hor.
	---	37.9	54.0	16.1	-0.1					
4879.750	47.8	---	74.0	26.2	49.4	-1.6	155.0	156	0	Hor.
	---	31.4	54.0	22.6	33.0					
5050.250	56.6	---	74.0	17.4	58.9	-2.3	155.0	104	150	Vert.
	---	26.8	54.0	27.2	29.1					
7319.250	59.7	---	74.0	14.3	55.6	4.1	155.0	149	60	Vert.
	---	53.1	54.0	0.9	49.0					
9628.750	65.6	---	74.0	8.4	58.3	7.3	155.0	281	30	Vert.
	---	35.4	54.0	18.6	28.1					
9759.000	62.5	---	74.0	11.5	56.2	6.3	155.0	271	60	Vert.
	---	40.0	54.0	14.0	33.7					
12201.500	48.0	---	74.0	26.0	37.9	10.1	155.0	87	30	Hor.
	---	36.8	54.0	17.2	26.7					
14444.000	54.5	---	74.0	19.5	44.3	10.2	155.0	276	30	Vert.
	---	28.1	54.0	25.9	17.9					
14638.750	47.9	---	74.0	26.1	37.7	10.2	155.0	137	0	Hor.
	---	38.5	54.0	15.5	28.3					
15173.000	39.9	---	74.0	34.1	29.9	10.0	155.0	82	30	Vert.
	---	28.1	54.0	25.9	18.1					
19849.750	55.4	---	74.0	18.6	51.6	3.8	155.0	261	0	Vert.
	---	30.5	54.0	23.5	26.7					
24071.750	56.1	---	74.0	17.9	52.1	4.0	155.0	191	120	Vert.
	---	31.6	54.0	22.4	27.6					
28966.500	41.1	---	74.0	32.9	34.6	6.5	155.0	273	30	Vert.
	---	21.7	54.0	31.4	15.2					

Results of EUT 3										
Frequency [MHz]	Result (PK) [dB μ V/m]	Result (AV) [dB μ V/m]	Limit [dB μ V/m]	Margin [dB]	Reading [dB μ V]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Elevation [deg]	Pol.
3972.500	52.8	---	74.0	21.2	14.2	38.0	155.0	300	30	Hor.
	---	37.6	54.0	16.4	-0.4					
4861.000	60.8	---	74.0	13.2	62.5	-1.7	155.0	231	90	Hor.
	---	28.1	54.0	25.9	29.8					
5059.000	59.0	---	74.0	15.0	61.1	-2.1	155.0	69	30	Hor.
	---	27.3	54.0	26.7	29.4					
9620.000	62.4	---	74.0	11.6	55.0	7.4	155.0	155	30	Vert.
	---	35.0	54.0	19.0	27.6					
9628.750	64.0	---	74.0	10.0	56.7	7.3	155.0	246	150	Vert.
	---	35.3	54.0	18.7	28.0					
14443.000	54.5	---	74.0	19.5	44.3	10.2	155.0	224	0	Hor.
	---	28.4	54.0	25.6	18.2					
14520.750	53.3	---	74.0	20.7	43.1	10.2	155.0	225	0	Hor.
	---	28.0	54.0	26.0	17.8					
19255.250	57.0	---	74.0	17.0	53.4	3.6	155.0	196	120	Hor.
	---	30.3	54.0	23.7	26.7					
19846.500	58.7	---	74.0	15.3	54.9	3.8	155.0	208	30	Vert.
	---	30.3	54.0	23.7	26.5					
24071.750	51.2	---	74.0	22.8	47.2	4.0	155.0	193	150	Hor.
	---	31.3	54.0	22.7	27.3					
29208.250	36.1	---	74.0	37.9	29.0	7.1	155.0	59	60	Hor.
	---	23.2	54.0	30.8	16.1					

Test result: Passed

Test equipment (please refer to chapter 6 for details)
20 – 38, 48, 49, 52

5.4.3.4 Test results measurement 40 GHz to 200 GHz

Ambient temperature:	22 °C
Relative humidity:	41 – 80 %

Date:	26.08.2024 till 23.10.2024
Tested by:	S. KREHS

- 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.5 of this test report showing the maximum emission level position.
- 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 [dB μ V] - distance correction [dB]
- Distance correction [dB]** = $20 \log(\text{normative distance [m]} / \text{used distance [m]})$, according to [1]
- Margin [dB]** = Limit [dB μ V/m] – Result @ 3 m [dB μ V/m]

Unwanted emissions of EUT 1A						
Frequency range	Max noise floor level [dB μ V/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dB μ V/m]	Limit [dB μ V/m]	Margin [dB μ V/m]
40 GHz to 55 GHz	59.4	0.3	20.0	39.4	54.0	14.6
55 GHz to 75 GHz	63.4	0.5	15.5	47.9	54.0	6.1
85 GHz to 110 GHz	65.3	0.3	20.0	45.3	54.0	8.7
110 GHz to 130 GHz	72.3	0.1	29.5	42.8	54.0	12.2
130 GHz to 150 GHz	68.5	0.1	29.5	39.0	54.0	15.0
150 GHz to 170 GHz	68.5	0.1	29.5	39.0	54.0	15.0
170 GHz to 200 GHz	67.6	0.1	29.5	38.1	54.0	15.9

Unwanted emissions of EUT 2A						
Frequency range	Max noise floor level [dB μ V/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dB μ V/m]	Limit [dB μ V/m]	Margin [dB μ V/m]
40 GHz to 55 GHz	59.4	0.3	20.0	39.4	54.0	14.6
55 GHz to 75 GHz	63.8	0.5	15.5	48.3	54.0	5.7
85 GHz to 110 GHz	68.2	0.3	20.0	48.2	54.0	5.8
110 GHz to 130 GHz	70.1	0.1	29.5	40.6	54.0	13.4
130 GHz to 150 GHz	66.2	0.1	29.5	36.7	54.0	17.3
150 GHz to 170 GHz	66.2	0.1	29.5	36.7	54.0	17.3
170 GHz to 200 GHz	69.6	0.1	29.5	40.1	54.0	13.9

Unwanted emissions of EUT 3						
Frequency range	Max noise floor level [dB μ V/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dB μ V/m]	Limit [dB μ V/m]	Margin [dB μ V/m]
40 GHz to 55 GHz	59.4	0.3	20.0	39.4	54.0	14.6
55 GHz to 75 GHz	61.7	0.5	15.5	46.2	54.0	7.8
85 GHz to 110 GHz	66.5	0.3	20.0	46.5	54.0	7.5
110 GHz to 130 GHz	72.4	0.1	29.5	42.9	54.0	11.1
130 GHz to 150 GHz	68.5	0.1	29.5	39.0	54.0	15.0
150 GHz to 170 GHz	68.6	0.1	29.5	39.1	54.0	14.9
170 GHz to 200 GHz	70.3	0.1	29.5	40.8	54.0	13.2

Test result: Passed

Test equipment (please refer to chapter 6 for details)
3 - 7, 39 - 49

5.5 Frequency stability.

5.5.1 Test setup (frequency stability)

Used	Setup	See sub-clause	Comment
<input checked="" type="checkbox"/>	Frequency stability	5.1.5	-

5.5.2 Test method (frequency stability)

Used	Clause	Name of method	Sub-clause	Comment
<input checked="" type="checkbox"/>	9.14 [1], H [3]	Frequency stability for mm-wave devices	5.1.5	-

5.5.3 Test result (frequency stability)

Ambient temperature:	22 °C
Relative humidity:	43 – 59 %

Date:	17.10.2024 till 23.10.2024
Tested by:	S. KREHS

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.

EUT 1A						
Temperature	Supply voltage	Lower frequency [GHz]	Upper frequency [GHz]	-10 dB bandwidth [GHz]	Peak frequency [GHz]	Result
50 °C	24 V _{DC} (U _{nom})	77.0121	80.9913	3.9792	77.0294	Passed
40 °C	24 V _{DC} (U _{nom})	77.0111	80.9923	3.9812	77.0284	Passed
30 °C	24 V _{DC} (U _{nom})	77.0111	80.9913	3.9802	77.0294	Passed
22 °C	10.5 V _{DC} (U _{min})	77.0124	80.9926	3.9801	77.0294	Passed
	24 V _{DC} (U _{nom})	77.0114	80.9926	3.9811	77.0304	Passed
	30.0 V _{DC} (U _{max})	77.0114	80.9926	3.9811	77.0294	Passed
10 °C	24 V _{DC} (U _{nom})	77.0111	80.9923	3.9812	77.0294	Passed
0 °C	24 V _{DC} (U _{nom})	77.0101	80.9923	3.9822	77.0314	Passed
-10 °C	24 V _{DC} (U _{nom})	77.0101	80.9923	3.9822	77.0304	Passed
-20 °C	24 V _{DC} (U _{nom})	77.0101	80.9913	3.9812	77.0304	Passed

EUT 2A						
Temperature	Supply voltage	Lower frequency [GHz]	Upper frequency [GHz]	-10 dB bandwidth [GHz]	Peak frequency [GHz]	Result
50 °C	24.0 V _{DC} (U _{nom})	77.0015	80.9915	3.9900	77.0284	Passed
40 °C	24.0 V _{DC} (U _{nom})	77.0018	80.9920	3.9902	77.0314	Passed
30 °C	24.0 V _{DC} (U _{nom})	77.0008	80.9916	3.9908	77.0314	Passed
22 °C	10.5 V _{DC} (U _{min})	77.0008	80.9926	3.9918	77.0314	Passed
	24.0 V _{DC} (U _{nom})	77.0008	80.9916	3.9908	77.0314	Passed
	30.0 V _{DC} (U _{max})	77.0008	80.9916	3.9908	77.0244	Passed
10 °C	24.0 V _{DC} (U _{nom})	76.9985	80.9925	3.9940	77.0294	Passed
0 °C	24.0 V _{DC} (U _{nom})	76.9975	80.9925	3.9950	77.0294	Passed
-10 °C	24.0 V _{DC} (U _{nom})	76.9965	80.9925	3.9961	77.0284	Passed
-20 °C	24.0 V _{DC} (U _{nom})	76.9965	80.9925	3.9961	77.0324	Passed

EUT 3						
Temperature	Supply voltage	Lower frequency [GHz]	Upper frequency [GHz]	-10 dB bandwidth [GHz]	Peak frequency [GHz]	Result
50 °C	24 V _{DC} (U _{nom})	77.0081	80.9920	3.9839	77.0284	Passed
40 °C	24 V _{DC} (U _{nom})	77.0081	80.9919	3.9838	77.0284	Passed
30 °C	24 V _{DC} (U _{nom})	77.0071	80.9919	3.9848	77.0284	Passed
22 °C	10.5 V _{DC} (U _{min})	77.0073	80.9912	3.9839	77.0284	Passed
	24 V _{DC} (U _{nom})	77.0074	80.9917	3.9843	77.0294	Passed
	30.0 V _{DC} (U _{max})	77.0083	80.9912	3.9829	77.0294	Passed
10 °C	24 V _{DC} (U _{nom})	77.0061	80.9929	3.9867	77.0294	Passed
0 °C	24 V _{DC} (U _{nom})	77.0051	80.9929	3.9877	77.0294	Passed
-10 °C	24 V _{DC} (U _{nom})	77.0041	80.9929	3.9887	77.0314	Passed
-20 °C	24 V _{DC} (U _{nom})	77.0031	80.9929	3.9897	77.0294	Passed

Test result: Passed

Test equipment (please refer to chapter 6 for details)
1 - 6, 48 - 50

5.6 AC power-line conducted emissions

5.6.1 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 ...	-	-

5.6.2 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.

5.6.3 Test results (Conducted emissions on power supply lines)

Ambient temperature:	22 °C
Relative humidity:	42 %

Date:	15.10.2024
Tested by:	S. KREHS

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 curve represents the peak measurement and the bottom measured curve the average measurement. The quasi-peak measured points are marked by ◆ and the average measured points by ◆.

Results of EUT 1A							
Frequency [MHz]	QuasiPeak [dB(μV)]	Average [dB(μV)]	Limit [dB(μV)]	Margin [dB]	Line	PE	Corr. [dB]
0.159900	---	40.5	55.5	15.0	L1	GND	9.8
0.160800	49.9	---	65.4	15.5	L1	GND	9.8
0.200400	---	40.7	53.6	12.9	L1	GND	9.8
0.201300	44.4	---	63.6	19.2	L1	GND	9.8
13.410600	---	43.6	50.0	6.4	L1	GND	10.7
13.410600	45.8	---	60.0	14.2	N	GND	10.8
13.451100	46.7	---	60.0	13.3	L1	GND	10.7
13.451100	---	43.9	50.0	6.1	N	GND	10.8
13.491600	---	43.8	50.0	6.2	L1	GND	10.7
13.491600	46.6	---	60.0	13.4	N	GND	10.8

Results of EUT 2A							
Frequency [MHz]	QuasiPeak [dB(μV)]	Average [dB(μV)]	Limit [dB(μV)]	Margin [dB]	Line	PE	Corr. [dB]
0.159900	---	40.1	55.5	15.4	L1	GND	9.8
0.159900	49.6	---	65.5	15.9	L1	GND	9.8
0.200400	---	40.1	53.6	13.5	L1	GND	9.8
0.200400	44.3	---	63.6	19.3	L1	GND	9.8
14.933400	---	42.2	50.0	7.83	L1	GND	10.8
14.933400	44.9	---	60.0	15.1	N	GND	10.8
15.013500	---	43.0	50.0	7.0	N	GND	10.8
15.013500	45.1	---	60.0	14.9	N	GND	10.8
15.054000	---	43.1	50.0	6.9	N	GND	10.8
15.054900	45.2	---	60.0	14.8	L1	GND	10.8

Results of EUT 3							
Frequency [MHz]	QuasiPeak [dB(μV)]	Average [dB(μV)]	Limit [dB(μV)]	Margin [dB]	Line	PE	Corr. [dB]
0.159900	---	37.4	55.5	18.1	L1	GND	9.8
0.160800	47.9	---	65.4	17.5	L1	GND	9.8
0.200400	---	40.4	53.6	13.2	L1	GND	9.8
0.201300	43.9	---	63.6	19.7	L1	GND	9.8
0.440700	---	34.7	47.1	12.4	L1	GND	9.9
0.441600	36.8	---	57.0	20.2	L1	GND	9.9
0.841200	---	28.5	46.0	17.5	L1	GND	9.9
0.842100	30.7	---	56.0	25.3	L1	GND	9.9

Test result: Passed

Test equipment (please refer to chapter 6 for details)
5, 51 - 54

6 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Harmonic mixer 60 GHz - 90 GHz	FS-Z90	Rohde & Schwarz	101795	482706	22.03.2023	03.2025
2	Standard gain horn 60 GHz - 90 GHz	26240-20	Flann	262498	482860	Calibration not necessary	
3	RF cable 0.5 m	Sucoflex 102	Huber+Suhner	510210/2	483030	Calibration not necessary	
4	RF cable 0.5 m	Sucoflex 102	Huber+Suhner	510213/2	483031	Calibration not necessary	
5	Shielded chamber M4	B83117-S1-X158	Siemens	190075	480088	Calibration not necessary	
6	Signal & spectrum analyzer	FSW43	Rohde & Schwarz	100586 & 100926	481720	07.05.2024	05.2026
7	Standard gain horn 75 GHz - 110 GHz	27240-20	Flann	132148	483752	Calibration not necessary	
8	Waveguide Detector 75 GHz - 110 GHz	SFD-753114- 10SF-P1-M	Eravant	28906-01	483889	Calibration not necessary	
9	Digital Oscilloscope	HD O6054B	Teledyne GmbH	LCRY5101N10206	483627	20.02.2024	02.2026
10	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	21.02.2024	02.2026
11	EMC test software	Elektra V5.05.00	Rohde&Schwarz		483755	Calibration not necessary	
12	RF Switch Matrix	OSP220	Rohde & Schwarz	101391	482976	Calibration not necessary	
13	Turntable	TT3.0-3t	Maturo	825/2612/01	483224	Calibration not necessary	
14	Antennasupport	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
15	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
16	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540- A138-10-0006	483227	Calibration not necessary	
17	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	21.02.2024	02.2026
18	Attenuator 6 dB	WA2-6	Weinschel		482793	Calibration not necessary	
19	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	24.04.2024	04.2027
20	Standard gain horn 12 GHz - 18 GHz	18240-20	Flann	483	480294	Calibration not necessary	
21	Standard gain horn 18 GHz - 26 GHz	20240-20	Flann	411	480297	Calibration not necessary	
22	Microwave cable 2m	Insulated Wire Inc.	Insulated Wire	KPS-1533-800- KPS	480302	Calibration not necessary	
23	Fully anechoic chamber M20	B83117-E2439- T232	Albatross Projects	103	480303	Calibration not necessary	
24	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
25	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
26	Preamplifier 100 MHz - 13 GHz	AFS6-00101600- 23	MITEQ Hauppauge N.Y.	2011215	482333	20.02.2024	02.2026
27	Preamplifier 18 GHz - 26 GHz	JS4-18002600- 20-5A	MITEQ Hauppauge N.Y.	658697	480342	19.02.2024	02.2026
28	Preamplifier 12 GHz - 18 GHz	JS3-12001800- 16-5A	MITEQ Hauppauge N.Y.	571667	480343	19.02.2024	02.2026
29	RF-cable No.3	Sucoflex 106B	Suhner	0563/6B / Kabel 3	480670	Calibration not necessary	

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
30	Multiple Control Unit	MCU	Maturo GmbH	MCU/043/971107	480832	Calibration not necessary	
31	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100977	483511	25.04.2024	04.2027
32	RF-Cable No. 40	Sucoflex 106B	Suhner	0708/6B / Kabel 40	481330	Calibration not necessary	
33	Software	EMC32 V10.60.20	Rohde & Schwarz	---	483261	Calibration not necessary	
34	Highpass Filter	WHK2.8/18G- 10SS	Wainwright Instuments GmbH	1	480867	Calibration not necessary	
35	Positioner	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
36	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	27.02.2024	02.2026
37	Standard gain horn 26 GHz - 40 GHz	22240-20	Flann	469	480299	Calibration not necessary	
38	Preamplifier 26 GHz - 40 GHz	JS4-26004000- 25-5A	MITEQ Hauppauge N.Y.	563593	480344	Calibration not necessary	
39	Spectrum analyzer extension module 110 GHz - 170 GHz	WWR6.5SAX- M12-UP	Virginia Diode	SAX 684	483365	30.03.2023	03.2025
40	Standard gain horn 110 GHz - 175 GHz	29240-20	Flann	274466	483370	Calibration not necessary	
41	Spectrum analyzer extension module 140 GHz - 220 GHz	WR5.1SAX-M18- UP	Virginia Diode	SAX 685	483366	28.03.2023	03.2025
42	Standard gain horn 140 GHz - 220 GHz	30240-20	Flann	274470	483371	Calibration not necessary	
43	Harmonic mixer 40 GHz - 60 GHz	FS-Z60	Rohde & Schwarz	100980	482708	22.03.2023	03.2025
44	Standard gain horn 40 GHz - 60 GHz	24240-20	Flann	263442	482858	Calibration not necessary	
45	Spectrum analyzer extension module 50 GHz - 75 GHz	WR15SAX-M6- UP	Virginia Diode	SAX 683	483364	22.03.2023	03.2025
46	Standard gain horn 50 GHz 75 GHz	25240-20	Flann	273464	483369	Calibration not necessary	
47	Spectrum analyzer extension module 75 GHz - 110 GHz	WR10SAX-F-UP	Virginia Diode	SAX 939	483707	22.03.2023	03.2025
48	Power Supply	TOE8852 (DC)	Toellner Electronic Inst.	51712	480233	Calibration not necessary	
49	Multimeter	971A	Hewlett Packard	JP40010640	480724	02.04.2024	04.2026
50	Dynamic temperature chamber	MK 240	WTB Binder Labortechnik GmbH	05-79022	480462	21.11.2023	11.2024
51	LISN	NSLK8128	Schwarzbeck	8128155	480058	28.02.2024	02.2026
52	Software	EMC32 V10.60.20	Rohde & Schwarz	100061	481022	Calibration not necessary	
53	EMI Receiver / Spectrum Analyser	ESIB 26	Rohde & Schwarz	100292	481182	22.02.2024	02.2026
54	Transient Filter Limiter	CFL 9206A	Teseq GmbH	38268	481982	28.03.2024	03.2026

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 field strength outdoor test site		
R&S HFH ⁺ -Z2 9 kHz – 30 MHz	CISPR 25	4.4 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

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	07.11.2024
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	01.03.2023	28.02.2025
Semi anechoic chamber M276	483227	1 -18 GHz	SVSWR	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	28.02.2023	27.02.2025
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	17.08.2022	16.08.2025

9 Report History

Report Number	Date	Comment
F231416E1	15.01.2025	Initial Test Report
F231416E1, 2 nd version	21.01.2025	Page 6: HVINs of EUT 2A and EUT 2B corrected
-	-	-

10 List of Annexes

Annex A	Measurement plots	39 pages
Annex B	Test Setup Photos	25 pages
Annex C	External EUT Photographs	10 pages
Annex D	Internal EUT Photographs	15 pages

----- end of test report -----