PHOENIX TESTLAB

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

Test Report

Report Number:

F230978E3

Equipment under Test (EUT):

Tank level probing radar
FMR43

Applicant:

Endress+Hauser SE+Co. KG

Manufacturer:

Endress+Hauser SE+Co. KG

ilac-MRA

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

References

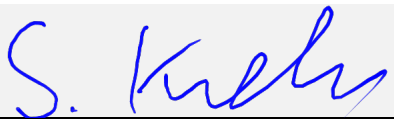
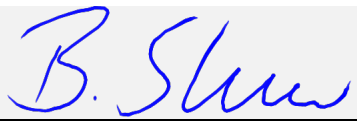
[1] **ANSI C63.10-2013**, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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

[3] **KDB publication 890966 D01**, Measurement procedure for Level Probing Radars v01 (April 2014)

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 by:	 Signature	Sebastian Krehs 06.02.2024
Tested and written by:	 Signature	Thomas Kühn 06.02.2024
Reviewed and approved by:	 Signature	Bernd STEINER 06.02.2024

This test report is only valid in its original form.

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1 Identification

1.1 Applicant

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Ralf REIMELT
Phone:	+49 76 22 28 – 18 90
Fax:	+49 76 22 28 – 15 890
eMail Address:	ralf.reimelt@endress.com
Applicant represented during the test by the following person:	Mr. Ralf REIMELT (partly)

1.2 Manufacturer

Name:	Endress+Hauser SE+Co. KG
Address:	Hauptstr. 1 79689 Maulburg
Country:	Germany
Name for contact purposes:	Mr. Ralf REIMELT
Phone:	+49 76 22 28 – 18 90
Fax:	+49 76 22 28 – 15 890
eMail Address:	ralf.reimelt@endress.com
Manufacturer represented during the test by the following person:	Mr. Ralf REIMELT (partly)

1.3 Test Laboratory

The tests were carried out by:

PHOENIX TESTLAB GmbH
Königswinkel 10
32825 Blomberg
Germany

Accredited by Deutsche Akkreditierungsstelle GmbH (DAkkS) in compliance with DIN EN ISO/IEC 17025 under Reg. No. D-PL-17186-01-05 and D-PL-17186-01-06, FCC Test Firm Designation Number DE0004, FCC Test Firm Registration Number 469623, CAB Identifier DE0003 and ISED# 3469A.

1.4 EUT (Equipment under Test)

EUT number	Model name	Serial number	Sensor board	Display board	Mainboard	Power board	Terminal board	Hardware version	Software version
1	FMR43	FMR43_IOL_025	71502194	71599584	71439136	71502179	71508546	01.00.00	01.00.00
4		FMR43_IOL_034	71502194	71548029	71439136	71502179	71508546	01.00.00	01.00.00

EUT number	Display type	Housing material	Antenna	Antenna gain
1	Front Foil display	Stainless steel	PEEK M24	19.7 dBi
4	Front Foil LED	Stainless steel	PTFE DN50	25.18 dBi

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): *	76000 MHz to 84000 MHz		
Type of modulation: *	FMCW		
Antenna connector: *	None		
FCC ID:	LCGFMR43T		
Temperature range: *	-50 °C to +80 °C		
Supply voltage range: *	U_{nom} =24.0 V_{DC}	U_{min} =12.0 V_{DC}	U_{max} =30.0 V_{DC}
Lowest internal frequency: *	32 MHz		

*: Declared by the applicant.

Ports/Connectors

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

*: Length during the test

Ancillary equipment	
PHOENIX CONTACT MINI-PS-100-240AC/24DC/1.3 *2	For power line conducted tests
Stainless-steel tank *1	-
Adapter plate for tank mounting *1	-
Bluetooth USB stick *1	-
Siemens Fujitsu Lifebook E780 *2	With installed test software RampConfigBluetooth *1

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

1.6 Dates

Date of receipt of test sample:	10.10.2023
Start of test:	17.10.2023
End of test:	22.11.2023

2 Operational States

The EUTs are tank level probing radars. All measurements were carried out with unmodified samples, supplied with 24 V_{DC}, operating in normal operation mode after powered up.

Bluetooth was active in normal operation mode during all measurements.

During the normal operation mode, the EUT powers up on 76 GHz and then starts a up chirp to 84 GHz. As required for testing, the EUT has to transmit on a frequency near top, middle and upper range of the FMCW frequency range. These operation modes were adjustable with the help of Bluetooth USB stick, connected to a laptop PC with a programming software (RampConfigBluetooth). With this software tool, the EUT transmits on the selected frequency with its normal operation duty cycle (transmit duration 1 ms, pulse repetition 50 ms) on the three operation frequencies (76 GHz, 80 GHz or 84 GHz) or do a normal sweep.

3 Additional Information

All unwanted emission measurements were carried out with the EUTs mounted on the top of a stainless-steel tank with the following dimensions: Height 260 mm, diameter 220 mm, wall-thickness 2 mm, bottom and top thickness 5 mm. The tank was provided by the applicant. Because the tank has no screws for fixing the EUTs, they were mounted on the adaptor plate and just laid on the tank without fixing. The holes of the adaptor plate and the gap between the tank and the adaptor plate was covered with copper tape as requested by the applicant. The adaptor plate was also provided by the applicant. For details of the tank, the adaptor plate and the mounting, please refer the external photographs of the EUTs.

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 76 GHz and then starts a up chirp to 84 GHz.

The tested sample was not labelled as required by the FCC.

The measurements were carried out under the following PHOENIX-TESTLAB order numbers: 23-110975 and 23-110978. It was requested by the applicant to document the results of these orders in one test report.

The EUTs also contain a Bluetooth transceiver which is operational during all measurements. The measuring results of the Bluetooth transceiver are documented in a separate test report with the PHOENIX TESTLAB test report reference F230978E5. Object of this test report is the radar portion of the EUTs only.

4 Overview

Application	Frequency range [MHz]	FCC CFR 47 Part 15 [2]	Tested with EUT number	Status
Radiated emissions	0.009 – 200000	15.209 (a) to (g)	1 and 4	Passed
Conducted emissions on supply line	0.15 – 30	15.207 (a)	1 and 4	Passed

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

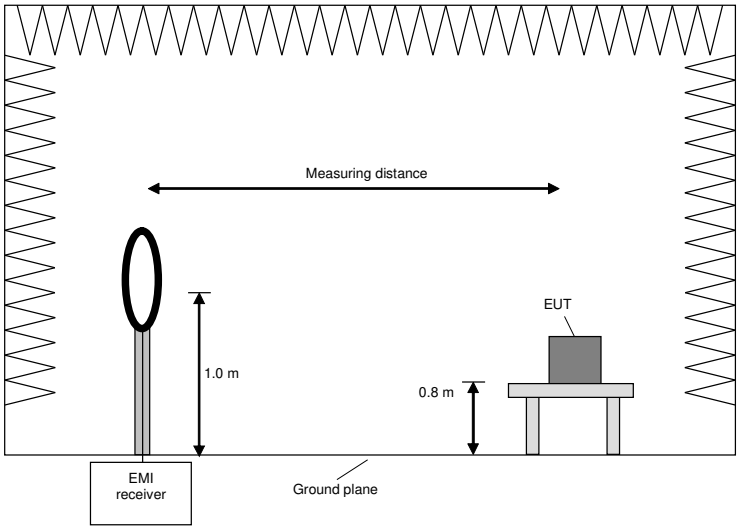
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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.

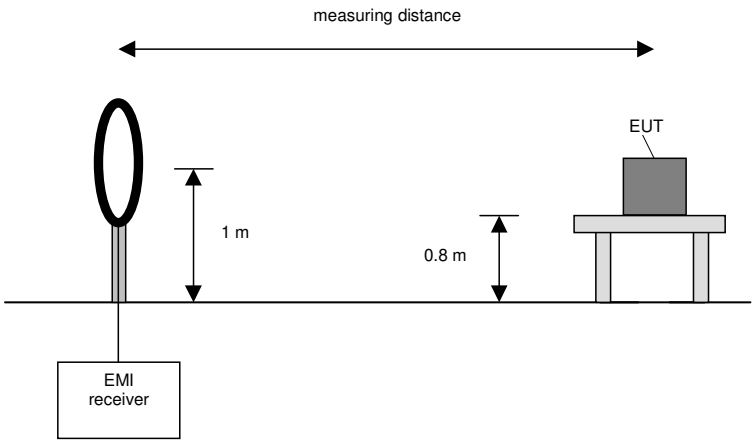
5.1.1.2 Final measurement 9 kHz to 30 MHz

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

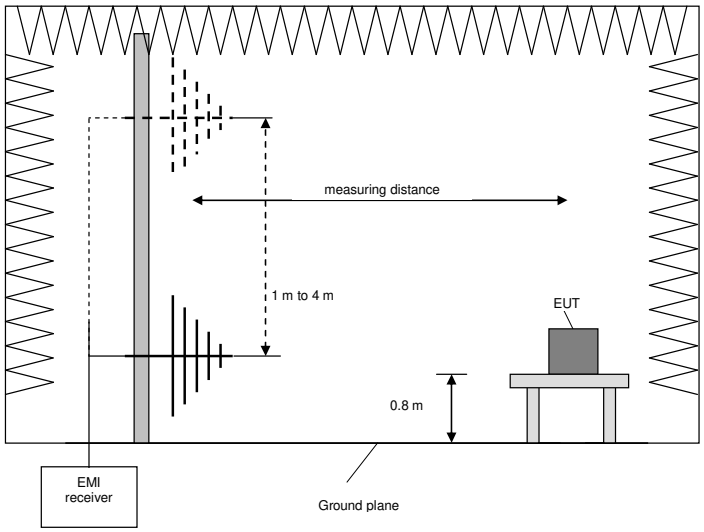
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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

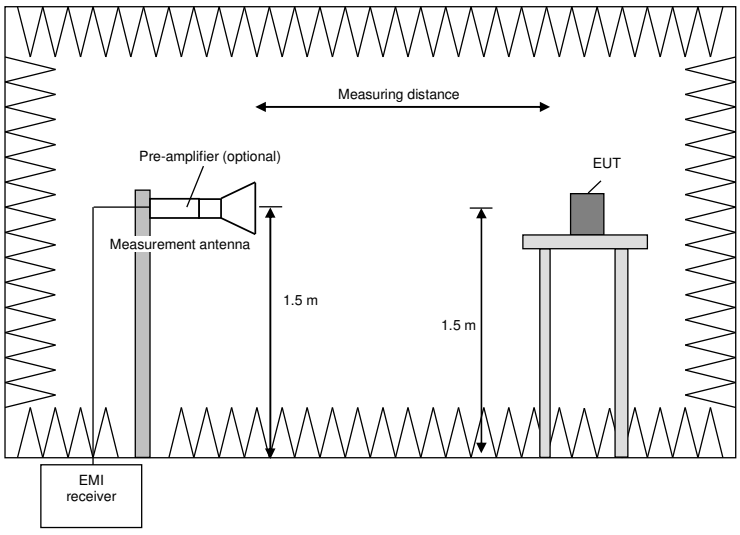
5.1.3.1 Preliminary and final measurement 1 GHz to 40 GHz

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

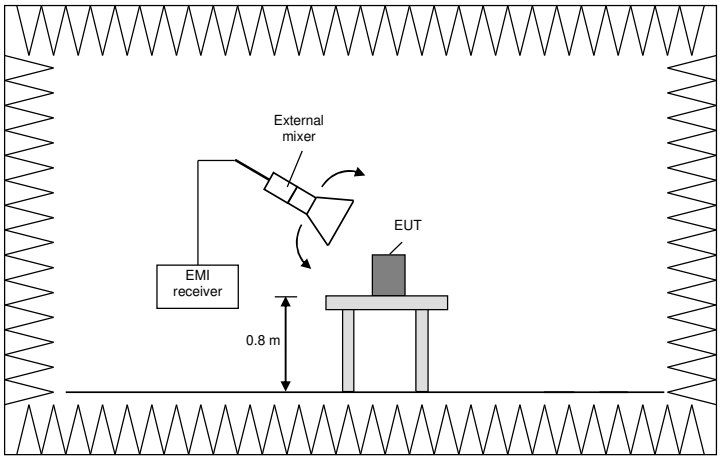
5.1.4.1 Preliminary and final measurement (40 GHz to 200 GHz)

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.

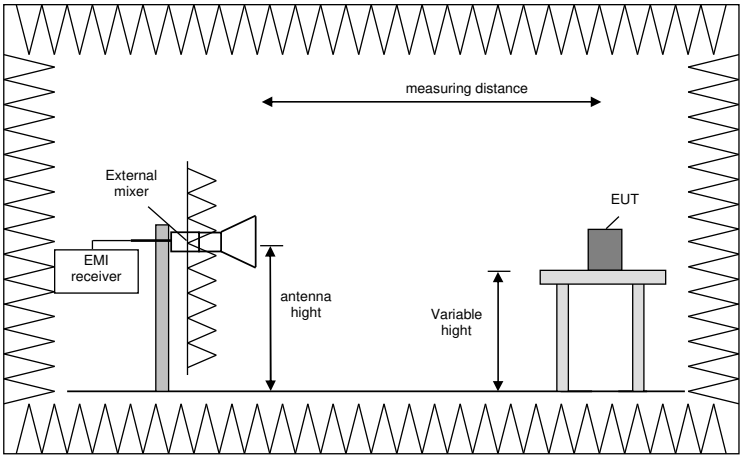
The resolution bandwidth of the EMI Receiver will be set to the following values:

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 50 GHz, 50 GHz to 75 GHz, 75 GHz to 110 GHz, 110 GHz to 155 GHz and 155 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.

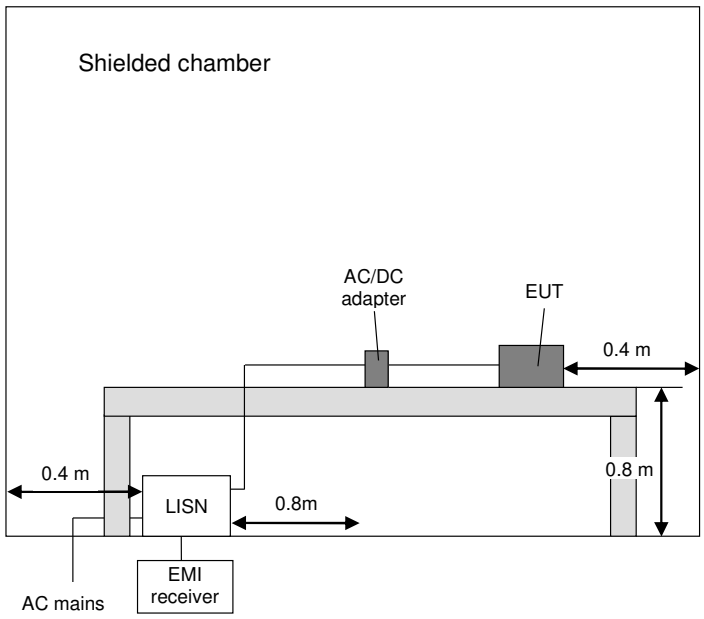
Step 1) to 6) are defined as preliminary measurement.

5.1.5 Conducted: AC power line

The test is carried out in a shielded chamber. Table-top devices are set up on a non-conducting support with a size of 1 m by 1.5 m and a height of 80 cm above the ground plane. Floor-standing devices are placed directly on the ground plane. In case of DC powered equipment, which is not exclusively powered by a battery, it is connected to the LISN via a suitable AC/DC adaptor. The setup of the equipment under test is in accordance with [1].

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

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



5.2 Unwanted emissions (radiated)

5.2.1 Test setup (Maximum unwanted emissions)

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

5.2.2 Test method (Maximum unwanted emissions)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	6.3, 6.4, 6.5, 9 [all 1]	Unwanted radiated emissions	No limitations	-

5.2.3 Test results (Maximum unwanted emissions)

5.2.3.1 Test results measurement (9 kHz to 30 MHz)

Ambient temperature:	22 °C (pre) -1 °C (final)
Relative humidity:	37 % (pre) 90 % (final)

Date:	27.10.2023 (pre) 22.11.2023 (final)
Tested by:	Sebastian KREHS Thomas KÜHN

Position of EUT: For tests for between 9 kHz to 30 MHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.

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

Operation mode: EUT (mounted inside tank) transmits with normal timing on the either on 76 GHz, 80 GHz or 84 GHz.

Test record: The plot for this measurement is submitted annex A.1 of this test report shows the maximum emission of all three operation modes. Because there is no measurable difference between the three operation modes, only the plot for the middle of the operation frequency range is documented.

Calculations:

Result @ norm dist. = Reading + Antenna factor (including cable attenuation [dB]) - Distance correction factor
Margin [dB] = Limit [dBµV/m] - Result [dBµV/m]

Results of EUT 1 transmitting @ 80 GHz								
Frequency [MHz]	Reading [dBµV]	Result @ normative distance [dBµV/m]	Limit acc. FCC CFR 47 part 15.209 [2] [dBµV/m]	Margin [dB]	Detector	Antenna factor [dB/m]	Measuring Distance [m]	Distance correction factor* [dB]
0.010	24.7	-34.4 @ 300 m	47.6	82.0	AV	20.9	3	80
2.126	19.9	0.2 @ 30 m	29.5	29.3	QP	20.3	3	40
Results of EUT 4 transmitting @ 80 GHz								
Frequency [MHz]	Reading [dBµV]	Result @ normative distance [dBµV/m]	Limit acc. FCC CFR 47 part 15.209 [2] [dBµV/m]	Margin [dB]	Detector	Antenna factor [dB/m]	Measuring Distance [m]	Distance correction factor* [dB]
0.010	21.0	-38.1 @ 300 m	47.6	85.7	AV	20.9	3	80
2.189	5.4	-14.3 @ 30 m	29.5	43.8	QP	20.3	3	40

*: Because the measurement was carried out with a 3 m distance, the limit was corrected with 40 dB/decade and according to [1].

Test result: Passed

Test equipment (please refer to chapter 6 for details)
33 – 35, 38 - 44 (pre), 33, 35, 45, 46 (final)

5.2.3.2 Test results measurement (30 MHz to 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	38 % to 43 %

Date:	26. and 27.10.2023
Tested by:	Sebastian KREHS

Position of EUT: For tests 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.

Operation mode: EUT (mounted inside tank) transmits on 76 GHz, 80 GHz or 84 GHz with normal timing.

Test record: The plot for this measurement is submitted annex A.1 of this test report shows the maximum emission of all three operation modes. Because there is no measurable difference between the three operation modes, only the plots for the middle of the operation frequency range are documented.

EUT number	Frequency range	Frequencies for final measurement
1	30 MHz to 1 GHz	No significant frequencies above the noise floor of the system (36.0 dBµV/m (peak) measured at 3 m) were found during the preliminary radiated emission test, so no final measurements were carried out.
4	30 MHz to 1 GHz	

Test result: Passed

Test equipment (please refer to chapter 6 for details)
34 - 44

5.2.3.3 Test results measurement (1 GHz to 12 GHz)

Ambient temperature:	21 °C to 22 °C
Relative humidity:	41 % to 53 %

Date:	20.10.2023 till 26.10.2023
Tested by:	Sebastian KREHS Thomas KÜHN

Position of EUT: The EUT was set-up on a non-conducting support with a height of 150 cm.

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

Operation mode: EUT (mounted inside tank) transmits on 76 GHz, 80 GHz or 84 GHz with normal timing.

Test record: The plots for this measurement are submitted annex A.1.

Calculation:
Result = Reading [dBµV] + Correction (including antenna factor and cable attenuation) [dB/m]
Margin [dB] = Limit [dBµV/m] – Result @ 3 m [dBµV/m]

Results of EUT 1 operating on 76 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
4803.750	59.2	---	74.0	34.2	57.4	-1.8	155.0	-5	H
	---	27.4	54.0	26.6	25.6				
4852.500	57.5	---	74.0	16.5	56.0	-1.5	155.0	18	H
	---	27.8	54.0	26.2	26.3				
4959.500	63.0	---	74.0	11.0	61.5	-1.5	155.0	-7	H
	---	27.7	54.0	26.3	26.2				
9349.750	55.0	---	74.0	19.0	61.4	6.4	155.0	212	H
	---	35.8	54.0	18.2	42.2				
9500.000	55.8	---	74.0	18.2	62.8	7.0	155.0	138	H
	---	36.8	54.0	17.2	43.8				

Results of EUT 1 operating on 80 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
4803.500	---	27.9	54.0	26.1	26.1	-1.8	155.0	20	H
	52.5	---	74.0	15.5	50.7				
4851.500	57.4	---	74.0	34.6	55.9	-1.5	155.0	16	H
	---	27.3	54.0	26.7	25.8				
4959.500	---	27.5	54.0	26.5	26.0	-1.5	155.0	97	V
	60.6	---	74.0	13.4	59.1				
5000.000	54.3	---	74.0	19.7	52.6	-1.7	155.0	314	V
	---	31.5	54.0	22.5	29.8				
9349.750	55.6	---	74.0	18.4	62.0	6.4	155.0	219	H
	---	35.3	54.0	18.7	41.7				

Results of EUT 1 operating on 84 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
4803.500	---	28.0	54.0	26.0	26.2	-1.8	155.0	-5	H
	59.1	---	74.0	14.9	57.3				
4851.250	55.3	---	74.0	34.7	53.8	-1.5	155.0	278	V
	---	27.4	54.0	26.6	25.9				
4959.500	63.0	---	74.0	11.0	61.5	-1.5	155.0	-1	H
	---	27.7	54.0	26.3	26.2				
5250.000	57.4	---	74.0	16.6	56.5	-0.9	155.0	159	V
	---	33.5	54.0	20.5	32.6				
9349.750	---	36.0	54.0	18.0	42.4	6.4	155.0	224	H
	55.3	---	74.0	18.7	61.7				
10500.000	---	36.3	54.0	17.7	42.9	6.6	155.0	226	H
	56.2	---	74.0	17.8	62.8				

Results of EUT 4 operating on 76 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
9312.000	55.7	---	74.0	18.3	62.1	6.4	155.0	291	V
	---	35.9	54.0	18.1	42.3				
9342.250	54.4	---	74.0	19.6	60.8	6.4	155.0	294	V
	---	33.5	54.0	20.5	39.9				
9500.250	56.8	---	74.0	17.2	63.8	7.0	155.0	292	V
	---	36.3	54.0	17.7	43.3				
9535.500	---	34.9	54.0	19.1	42.2	7.3	155.0	170	V
	53.3	---	74.0	20.7	60.6				

Results of EUT 4 operating on 80 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
5000.000	---	32.6	54.0	21.4	30.9	-1.7	155.0	29	V
	57.8	---	74.0	16.2	56.1				
9312.500	56.5	---	74.0	17.5	62.9	6.4	155.0	322	V
	---	36.2	54.0	17.8	42.6				
10000.000	56.4	---	74.0	17.6	63.9	7.5	155.0	288	V
	---	36.5	54.0	17.5	44.0				

Results of EUT 4 operating on 84 GHz									
Frequency [MHz]	Result (PK) [dBµV/m]	Result (AV) [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Reading [dBµV]	Correction [dB/m]	Height [cm]	Azimuth [deg]	Pol.
5139.750	55.3	---	74.0	18.7	53.6	-1.7	155.0	34	V
	---	26.5	54.0	27.5	24.8				
5249.750	59.5	---	74.0	14.5	58.6	-0.9	155.0	-10	V
	---	32.9	54.0	21.1	32.0				
5272.750	56.7	---	74.0	17.3	55.9	-0.8	155.0	11	V
	---	27.3	54.0	26.7	26.5				
9312.500	56.3	---	74.0	17.7	62.7	6.4	155.0	320	V
	---	36.2	54.0	17.8	42.6				
10500.000	---	36.6	54.0	17.4	43.2	6.6	155.0	220	H
	56.6	---	74.0	17.4	63.2				
10545.500	---	35.7	54.0	18.3	42.5	6.8	155.0	221	H
	54.8	---	74.0	19.2	61.6				

Test result: Passed

Test equipment (please refer to chapter 6 for details)
7, 8, 10, 11, 13, 34, 35, 47, 48

5.2.3.4 Test results measurement (12 GHz to 40 GHz)

Ambient temperature:	21 °C to 22 °C
Relative humidity:	41 % to 53 %

Date:	23.10.2023 till 27.10.2023
Tested by:	Sebastian KREHS Thomas KÜHN

Position of EUT: The EUT was set-up on a non-conducting support with a height of 150 cm.

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

Operation mode: EUT (mounted inside tank) transmits on 76 GHz, 80 GHz or 84 GHz with normal timing.

Test record: Plots are submitted annex A.1 of this test report.

Calculation:
Result @ 3 m = Measured max. level [dBµV] - distance correction [dB]
Distance correction [dB] = 20 log (normative distance [m] / used distance [m]), according to [1]
Margin [dB] = Limit [dBµV/m] – Result @ 3 m [dBµV/m]

Unwanted emissions level, measured with peak detector EUT 1 operating on 76 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	48.9	3	0	48.9 *	74.0	25.1
18 to 26.5	47.4	3	0	47.4 *	74.0	26.6
26.5 to 40	49.0	1	9.5	39.5 *	74.0	34.5
Unwanted emissions level, measured with peak detector EUT 1 operating on 80 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	49.3	3	0	49.3 *	74.0	24.7
18 to 26.5	47.2	3	0	47.2 *	74.0	26.8
26.5 to 40	49.3	1	9.5	39.8 *	74.0	34.2
Unwanted emissions level, measured with peak detector EUT 1 operating on 84 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	49.4	3	0	49.4 *	74.0	24.6
18 to 26.5	47.3	3	0	47.3 *	74.0	26.7
26.5 to 40	49.0	1	9.5	39.5 *	74.0	34.5

*: Measured with peak detector, only, because the peak value is already below the average limit (54.0 dBµV/m).

Unwanted emissions level, measured with peak detector EUT 4 operating on 76 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	51.9	3	0	51.9 *	74.0	22.1
18 to 26.5	53.2	3	0	53.2 *	74.0	20.8
26.5 to 40	49.1	1	9.5	39.6 *	74.0	34.4
Unwanted emissions level, measured with peak detector EUT 4 operating on 80 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	51.7	3	0	51.7 *	74.0	22.3
18 to 26.5	52.9	3	0	52.9 *	74.0	21.1
26.5 to 40	48.5	1	9.5	39.0 *	74.0	35.0
Unwanted emissions level, measured with peak detector EUT 4 operating on 84 GHz						
Frequency range [GHz]	Measured max. peak emission level [dBµV/m]	Measuring distance [m]	Distance correction [dB]	Result @ 3 m [dBµV/m]	Limit (peak) [dBµV/m]	Margin [dB]
12 to 18	51.4	3	0	51.4 *	74.0	22.6
18 to 26.5	52.8	3	0	52.8 *	74.0	21.2
26.5 to 40	49.4	1	9.5	39.9 *	74.0	34.1

*: Measured with peak detector, only, because the peak value is already below the average limit (54.0 dBµV/m).

Test result: Passed

Test equipment (please refer to chapter 6 for details)
7, 8, 14 – 20, 34, 35

5.2.3.5 Test results measurement (40 GHz to 200 GHz)

Ambient temperature:	20 °C to 24 °C
Relative humidity:	22 % to 53 %

Date:	24.10.2023 till 03.11.2023
Tested by:	Sebastian KREHS Thomas KÜHN

Position of EUT: The EUT was positioned on a non-conducting support with a variable height.

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

Operation mode: EUT (mounted inside tank) transmits on 76 GHz, 80 GHz or 84 GHz with normal timing.

Test record: The plots submitted annex A.1 of this test report showing the maximum emissions of all three operation modes. Because there is no measurable difference between the three operation modes, only the plots for the middle of the operation frequency range are documented. The actual distance correction factor is displayed in the plot as level offset and is according to [1] calculated with the following formula:
Distance correction [dB] = 20 log (normative distance [m] / used distance [m]).
So, the displayed emission level represents the level at the normative distance.

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

Unwanted emissions level of EUT 1, measured with peak detector					
Frequency range	Max. peak emission level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Measuring distance [m]	Distance correction [dB]
40 GHz to 55 GHz	51.1	74.0	22.9	0.3	20.0
55 GHz to 75 GHz	60.5	74.0	13.5	0.3	20.0
75 GHz to 110 GHz	58.3	74.0	15.7	0.3	20.0
110 GHz to 155 GHz	63.5	74.0	10.5	0.1	29.5
155 GHz to 200 GHz	56.3	74.0	17.7	0.1	29.5
Unwanted emissions level of EUT 4. measured with peak detector					
Frequency range	Max. peak emission level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Mesuring distance [m]	Distance correction [dB]
40 GHz to 55 GHz	50.9	74.0	23.1	0.3	20.0
55 GHz to 75 GHz	60.2	74.0	13.8	0.3	20.0
75 GHz to 110 GHz	57.8	74.0	16.2	0.3	20.0
110 GHz to 155 GHz	63.1	74.0	10.9	0.1	29.5
155 GHz to 200 GHz	56.3	74.0	17.7	0.1	29.5

Unwanted emissions level of EUT 1. measured with RMS detector					
Frequency range	Max. RMS emission level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Measuring distance [m]	Distance correction [dB]
40 GHz to 55 GHz	39.3	54.0	14.7	0.3	20.0
55 GHz to 75 GHz	48.4	54.0	5.6	0.3	20.0
75 GHz to 110 GHz	45.9	54.0	8.1	0.3	20.0
110 GHz to 155 GHz	51.7	54.0	2.3	0.1	29.5
155 GHz to 200 GHz	44.5	54.0	9.5	0.1	29.5
Unwanted emissions level of EUT 4. measured with RMS detector					
Frequency range	Max. RMS emission level [dBµV/m]	Limit [dBµV/m]	Margin [dB]	Mesuring distance [m]	Distance correction [dB]
40 GHz to 55 GHz	39.2	54.0	14.8	0.3	20.0
55 GHz to 75 GHz	48.3	54.0	5.7	0.3	20.0
75 GHz to 110 GHz	45.8	54.0	8.2	0.3	20.0
110 GHz to 155 GHz	51.6	54.0	2.4	0.1	29.5
155 GHz to 200 GHz	44.3	54.0	9.7	0.1	29.5

Test result: Passed

Test equipment (please refer to chapter 6 for details)
4, 9, 21 – 32, 34, 35

5.3 AC power-line conducted emissions

5.3.1 Test setup (AC power-line conducted emissions)

Used	Setup	See sub-clause	Comment
☒	Conducted: AC power line	5.1.5	-
☐	Not applicable, because …	-	-

5.3.2 Test method (AC power-line conducted emissions)

Used	Clause	Name of method	Sub-clause	Comment
☒	6.2 [1]	Tabletop equipment testing	5.1.5	The EUT is DC supplied, therefore, an AC / DC adaptor has to be used.
☐	6.2 [1]	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.

5.3.3 Test results (Conducted emissions on power supply lines)

Ambient temperature:	21 °C to 22 °C
Relative humidity:	38 % to 43 %

Date:	17.10.2023 + 23.10.2023
Tested by:	Thomas KÜHN

Operation mode: EUT (mounted inside tank) transmits with normal sweep and normal timing.

The curves in the diagrams in A.2 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.

Conducted emissions on power supply lines of EUT 1							
Frequency [MHz]	QuasiPeak level [dB(µV)]	Average level [dB(µV)]	Limit [dB(µV)]	Margin [dB]	Line	PE	Corr. [dB]
0.164400	---	37.0	55.2	18.2	L1	GND	9.8
0.164400	46.2	---	65.2	19.0	L1	GND	9.8
15.488700	49.4	---	60.0	10.6	L1	GND	10.8
15.732600	---	48.0	50.0	2.0	L1	GND	10.8
15.775800	---	47.8	50.0	2.2	N	FLO	10.9
15.776700	50.4	---	60.0	9.6	N	GND	10.9
Conducted emissions on power supply lines of EUT 4							
Frequency [MHz]	QuasiPeak level [dB(µV)]	Average level [dB(µV)]	Limit [dB(µV)]	Margin [dB]	Line	PE	Corr. [dB]
0.164400	---	36.9	55.2	18.3	L1	FLO	9.8
0.165300	45.7	---	65.2	19.5	L1	FLO	9.8
15.592200	49.1	---	60.0	10.9	L1	GND	10.8
15.879300	---	47.6	50.0	2.409	L1	GND	10.8
15.880200	50.1	---	60.0	9.9	L1	FLO	10.8
15.919800	---	47.5	50.0	2.5	L1	GND	10.8

Test result: Passed

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

6 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Transient Filter Limiter	CFL 9206A	Teseq	38268	481982	15.02.2022	02.2024
2	LISN	NSLK8128	Schwarzbeck	8128161	480138	15.02.2022	02.2024
3	Software	EMC32	Rohde & Schwarz	100061	481022	Calibration not necessary	
4	Shielded chamber M4	B83117-S1-X158	Siemens	190075	480088	Calibration not necessary	
5	EMI Receiver / Spectrum Analyser	ESIB 26	Rohde & Schwarz	100292	481182	16.02.2022	02.2024
6	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	Calibration not necessary	
7	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
8	EMI Receiver / Spectrum Analyser	ESW44	Rohde & Schwarz	101635	482467	22.02.2022	02.2024
9	Spectrum Analyser	FSW43	Rohde & Schwarz	100586 & 100926	481720	17.03.2023	03.2025
10	Log.-Per. antenna	HL050	Rohde & Schwarz	100977	483511	05.03.2021	03.2024
11	Preamplifier 100 MHz – 16 GHz	AFS6-00101600-23-10P-6-R	MITEQ	2011215	482333	17.02.2022	02.2024
12	RF-cable No. 36	Sucoflex 106B	Suhner	500219/6B	482416	Calibration not necessary	
13	RF-cable No. 38	Sucoflex 106B	Suhner	500218/6B	482415	Calibration not necessary	
14	Standard Gain Horn 12 GHz – 18 GHz	18240-20	Flann	483	480294	Calibration not necessary	
15	Preamplifier 12 GHz - 18 GHz	JS3-12001800-16-5A	MITEQ	571667	480343	17.02.2022	02.2024
16	Standard Gain Horn 18 GHz – 26.5 GHz	20240-20	Flann	411	480297	Calibration not necessary	
17	Preamplifier 18 GHz - 26 GHz	JS4-18002600-20-5A	MITEQ	658697	480342	17.02.2022	02.2024
18	Standard Gain Horn 26.5 GHz – 40 GHz	22240-20	Flann	468	480298	Calibration not necessary	
19	Preamplifier 26 GHz - 40 GHz	JDM2-26004000-25-10P	MITEQ	128746	482806	17.02.2022	02.2024
20	RF-cable 2 m	KPS-1533-800-KPS	Insulated Wire	-	480302	Calibration not necessary	
21	Standard Gain Horn 40 GHz - 60 GHz	24240-20	Flann	263442	482858	Calibration not necessary	
22	Harmonic mixer 40 GHz - 60 GHz	FS-Z60	Radiometer Physics	100980	482708	22.03.2023	03.2025
23	Standard Gain Horn 50 GHz - 75 GHz	25240-20	Flann		483369	Calibration not necessary	
24	Spektrum Analyzer Extension Module 50 GHz - 75 GHz	WR15SAX-M6-UP	Virginia Diode	SAX 683	483364	Calibration not necessary	
25	Standard Gain Horn 75 GHz - 110 GHz	27240-20	Flann	263447	482861	Calibration not necessary	
26	Harmonic mixer 75 GHz - 110 GHz	FS-Z110	Radiometer Physics	101528	482707	22.03.2023	03.2025

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
27	Standard Gain Horn 110 GHz - 170 GHz	29240-20	Flann	274466	483370	Calibration not necessary	
28	Spektrum Analyzer Extension Module 110 GHz - 170 GHz	WWR6.5SAX-M12-UP	Virginia Diode	SAX 684	483365	Calibration not necessary	
29	Standard Gain Horn 140 GHz - 220 GHz	30240-20	Flann	274470	483371	Calibration not necessary	
30	Spektrum Analyzer Extension Module 140 GHz - 220 GHz	WR5.1SAX-M18-UP	Virginia Diode	SAX 685	483366	Calibration not necessary	
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	Loop antenna	HFH2-Z2	Rohde & Schwarz	100417	481912	22.02.2022	02.2024
34	Power Supply	TOE8752-32 (DC)	Toellner	31566	480010	Calibration not necessary	
35	Multimeter	971A	Hewlett Packard	JP39009358	480721	07.09.2023	09.2024
36	Attenuator 6 dB	WA2-6	Weinschel	-	482793	Calibration not necessary	
37	Ultralog Antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
38	RF Switch Matrix	OSP220	Rohde & Schwarz	-	482976	Calibration not necessary	
39	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
40	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
41	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
42	Semi Anechoic Chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
43	Software	EMC32	Rohde & Schwarz	100970	482972	Calibration not necessary	
44	EMI Testreceiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
45	EMI Receiver / Spectrum Analyser	ESI 40	Rohde & Schwarz	100064/040	480355	18.02.2022	02.2024
46	Outdoor test site	-	PHOENIX-TESTLAB	-	480293	Calibration not necessary	
47	Band Reject Filter	WRCJV8-2350-2400-2483.5-2533.5-40EE-150	Wainwright	1	482710	Calibration not necessary	
48	Highpass filter	WHKX4.0/18G-8SS	Wainwright	1	480587	Calibration not necessary	

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		
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 HFH2-Z2 9 kHz to 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
220 – 325 GHz	-	8.1 dB

8 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Shielded chamber M4	480088	9 kHz – 30 MHz	GND-Plane	ANSI C63.4-2014	08.11.2022	11.2024
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	01.03.2023	03.2025
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	17.08.2022	08.2025

9 Report History

Report Number	Date	Comment
F230978E3	01.02.2024	Initial Test Report
-	-	-
-	-	-

10 List of Annexes

Annex A	Measurement plots	23 pages
Annex B	Test Setup Photos	16 pages