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Test Report

Report Number:

F222097E2

Equipment under Test (EUT):

Passive entry car key

MS6

Applicant:

Marquardt GmbH

Manufacturer:

Marquardt GmbH

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] RSS-210 Issue 10 (December 2019)
Licence-exempt Radio Apparatus (All Frequency Bands): Category I Equipment

[4] RSS-Gen, Issue 5 Amendment 2 (2021-02)
General Requirements for Compliance of Radio Apparatus

Test Result

The requirements of the tests performed as shown in the overview (clause 4) were fulfilled by the equipment under test. The complete test results are presented in the following.
“Passed” indicates that the equipment under test conforms with the relevant limits of the testing standard without taking any measurement uncertainty into account as stated in clause 1.3 of ANSI C63.10 (2013). However, the measurement uncertainty is calculated and shown in this test report.

Tested and written by:		Thomas Kühn 04.08.2023
	Signature	
Reviewed and approved by:		Paul NEUFELD 04.08.2023
	Signature	

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

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1 Identification

1.1 Applicant

Name:	Marquardt GmbH
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Country:	Germany
Name for contact purposes:	Mr. Gerd SIEGEL
Phone:	+49 74 24 99-15 89
eMail address:	gerd.siegel@marquardt.de
Applicant represented during the test by the following person:	

1.2 Manufacturer

Name:	Marquardt GmbH
Address:	Schloßstraße 16 78604 Rietheim-Weilheim
Country:	Germany
Name for contact purposes:	Mr. Gerd SIEGEL
Phone:	+49 74 24 99-15 89
eMail address:	gerd.siegel@marquardt.de
Manufacturer represented during the test by the following person:	

1.3 Test Laboratory

The tests were carried out by: **PHOENIX TESTLAB GmbH**
Königswinkel 10
32825 Blomberg
Germany

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

1.4 EUT (Equipment under Test)

Test object: *	Passive entry car key
Model name: *	MS6
Serial number: *	Test mode: #12 Normal mode: #13
PCB identifier: *	243.677.011
Hardware version: *	23/19/00
Software version: *	23/19.00
FCC ID: *	IYZMS6
IC certification number: *	2701A-MS6
PMN: *	MS6
HVIN: *	MS6
FVIN: *	N/A

* Declared by the applicant

	EUT number	
	1 (Test mode)	2 (Normal mode)
Serial number: *	#12	#13
PCB identifier: *	243.677.011	243.677.011
Hardware version: *	23/19/00	23/19/00
Software version: *	23/19.00	23/19.00

Two EUTs were used for the tests. In the overview (chapter 4) is shown which EUT was used for each test case.

1.5 Technical Data of Equipment

General			
Power supply EUT: *	Lithium battery CR2032		
Supply voltage EUT: *	U_{nom} = 3.0 V_{DC}	U_{min} = 2.4 V_{DC}	U_{max} = 3.3 V_{DC}
Temperature range: *	-20 °C to +65 °C		
Lowest / highest internal frequency: *	21.845 kHz / 434.37 MHz		

* Declared by the applicant

RF part:	
Duty cycle class:*	Manual triggered device
Channel spacing: *	450 kHz (three channel operation)
Operating Frequencies: *	433.47 MHz / 433.92 MHz / 434.37 MHz
Transmitter power: *	-16 dBm
Modulation: *	BFSK
Frequency deviation: *	± 10 kHz
Data rate: *	10kBit/s
Antenna: *	Integrated PCB-Loop antenna
LF receiver	
Operating frequency: *	21.85 kHz
Number of channels: *	1
Type of modulation: *	BPSK
Data rate: *	5.4 kBit/s
Antenna type: *	3D-Axis-Coil, Rx at all axis

* Declared by the applicant

Ports / Connectors				
Identification	Connector		Length during test	Shielding (Yes / No)
	EUT	Ancillary		
-	-	-	-	-
-	No lines connectable to the EUT		-	-
-	-	-	-	-

1.6 Dates

Date of receipt of test sample:	23.06.2023
Start of test:	27.06.2023
End of test:	04.07.2023

2 Operational States

The MS6 is a passive entry car key and is part of a driving authorisation system for a car. The complete driver authorisation system consists of the MS6, the BODY CONTROL UNIT and an external antenna module. The BODY CONTROL UNIT sends an LF signal to the MS6 to wake it up. The MS6 responds using the RF part. The components exchange encrypted data for car access, to start the engine and to locate the key.

Optional the car can be accessed without handling the key. In this case RF signals are exchanged bidirectional when touching the door handle.

In case the battery is low, car access is possible by means of an integrated mechanic emergency key. The MS6 is then to be placed into a dedicated slot inside the vehicles centre console to be powered wireless by means of a magnetic field.

Because the EUT is a handheld device, the radiated emission measurements were carried out in three orthogonal directions. The positions were defined as follows:
Position 1: EUT lying on the table, buttons showing upwards.
Position 2: EUT standing on its long housing side, buttons showing right hand side.
Position 3: EUT standing on its short housing side, buttons showing right hand side.
For details of the three positions, refer also the photographs in annex A of this test report.

All measurements were carried out by using new batteries.

Test modes:

In test mode the EUT #12 is transmitting or receiving continuously with a duty cycle of 100%.

Button pressed	Button 1 Open	Button 2 Close	Button 3 Trunk
Shortly	Continuous receiving at 433.47 MHz (operation mode 4)	Continuous receiving at 434.37 MHz (operation mode 5)	Continuous receiving at 433.92 MHz (operation mode 6)
Long	Continuous transmitting at 433.47 MHz (operation mode 1)	Continuous transmitting at 434.37 MHz (operation mode 2)	Continuous transmitting at 433.92 MHz (operation mode 3)

3 Additional Information

The EUT was not labeled.

The results of the measurements of the receiver part of the EUT are documented in PHOENIX TESTLAB GmbH test report reference F222097E4.

Because the housing of the EUT is friction welded, the internal photographs are supplied by the applicant to keep the tested sample operational.

4 Overview

Application	Frequency range [MHz]	FCC 47 CFR Part 15 section [2]	RSS-Gen, Issue 5 [4] and RSS-210, Issue 10 [3]	Tested EUT	Status
Conducted emissions on supply line	0.15 – 30	15.207 (a)	8.8 [4]	-	Not applicable *
Occupied bandwidth	433.47 to 434.37	15.231 (c)	A1.3 [3] and 6.7 [4]	#12	Passed
Transmission time control	433.47 to 434.37	15.231 (a) (1)	A1.1 [3]	#13	Passed
Radiated emissions	0.009 to 5000 **	15.205 (a) 15.209 (a)	A1.2 [3], 6.13 [4] and 8.9 [4]	#12	Passed
Antenna requirement	-	15.203 [2]	6.8 [4]	-	Passed ***

*: Not applicable, because the EUT is only supplied with a non-rechargeable battery.
**: As declared by the applicant the highest radio clock frequency is 434.37 MHz.
Therefore the radiated emission measurement must be carried out up to 10th of the highest radio clock frequency, in this case 4.34 GHz. Measurements were carried out up to 5 GHz.
***: Integrated antenna only, requirement fulfilled.

5 Results

5.1 Test setups

5.1.1 Radiated: 9 kHz to 30 MHz

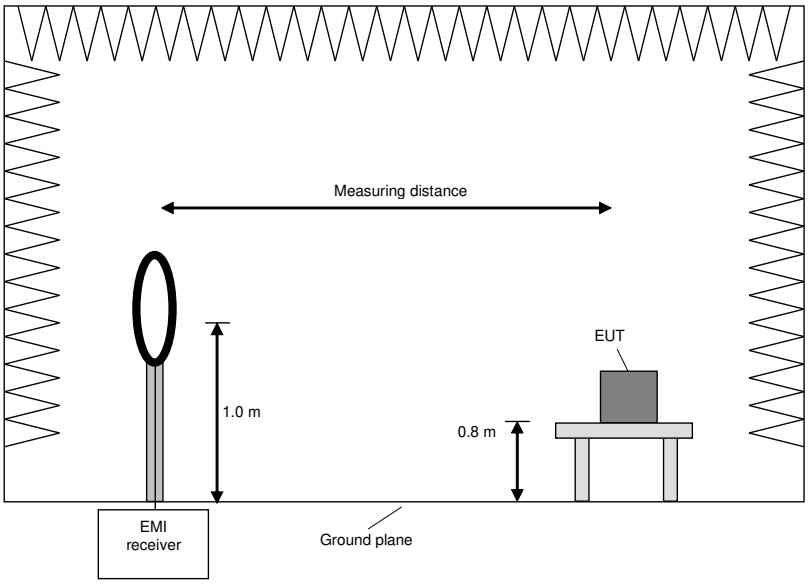
5.1.1.1 Preliminary measurement 9 kHz to 30 MHz

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	9 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.

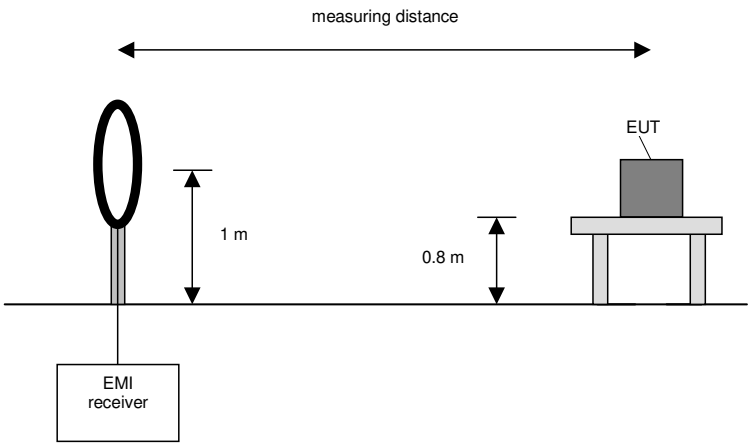
5.1.1.2 Final measurement 9 kHz to 30 MHz

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 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

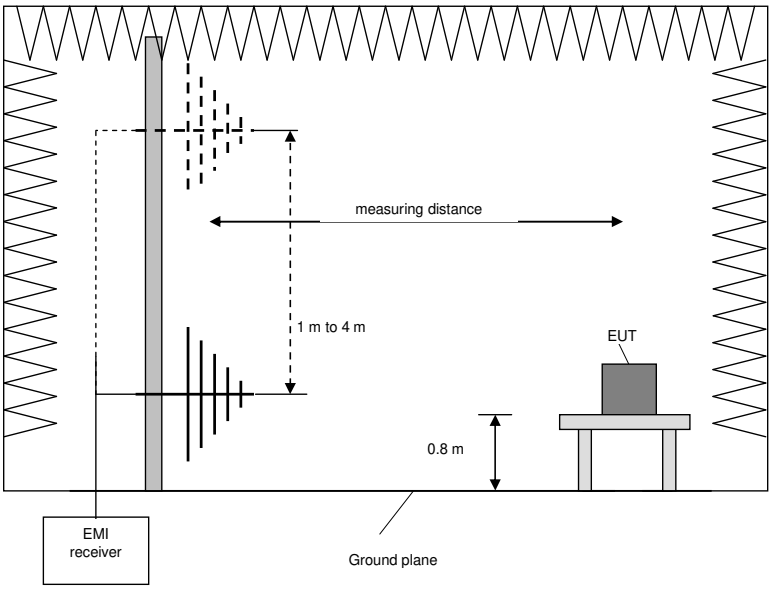
5.1.2.1 Preliminary and final measurement 30 MHz to 1 GHz

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 1 GHz	-	120 kHz	1 s	QuasiPeak



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

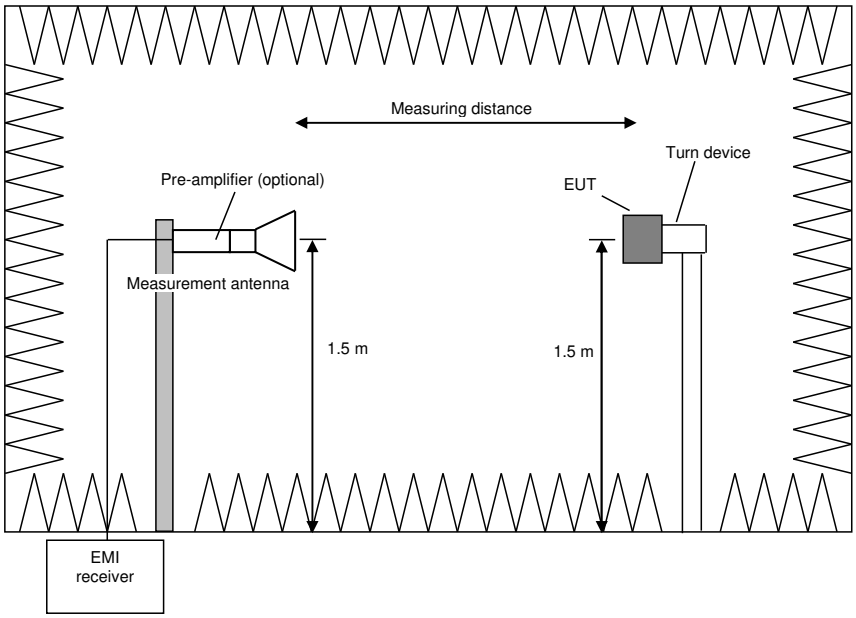
5.1.3.1 Preliminary and final measurement 1 to 40 GHz

The preliminary and final measurements are performed in a fully anechoic chamber at a measuring distance of 3 meters. 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 - 40 GHz	250 kHz	1 MHz	-	Peak Average
Final measurement	1 - 40 GHz	-	1 MHz	100 ms	Peak 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:

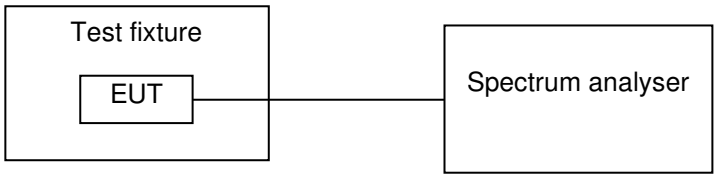
The following procedure is used:

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 Operating bandwidth

The test is carried out in a shielded chamber. Table-top devices are set up on a table and the spectrum analyser is connected to a test fixture / loop antenna, which is placed around / on top of the EUT.

Test set-up:



5.1.4.1 20 dB bandwidth

The calibration of the spectrum analyser has to be checked with the help of a known signal from a signal generator. The EUT has to be connected to the spectrum analyser via a low loss cable. If the EUT is not equipped with an antenna connector, a temporary antenna connector has to be installed or a test fixture has to be used. The EUT has to be switched on; the transmitter shall work with its maximum data rate.

The following spectrum analyser settings shall be used:

- Span: App. 2 to 3 times the 20 dB bandwidth, centred on the actual channel.
- Resolution bandwidth: Between 1 % to 5 % of the required bandwidth, if no requirements were made, the following minimum values shall be used:
  From 9 kHz to 30 MHz: RBW_{min} = 1 kHz;
  from 30 MHz to 1000: MHz RBW_{min} = 10 kHz;
  and from 1000 MHz to 40 GHz: RBW_{min} = 100 kHz.
- Video bandwidth: ≥ the resolution bandwidth.
- Sweep: Auto.
- Detector function: peak.
- Trace mode: Max hold.

After trace stabilisation the marker shall be set on the signal peak. The first display line has to be set on this value. The second display line has to be set 20 dB below the first line (or the peak marker). The frequency lines shall be set on the intersection points between the second display line and the measured curve.

5.1.4.2 99 % bandwidth

- The transmitter shall be operated at its maximum carrier power measured under normal test conditions.
- The span of the analyzer shall be set to capture all products of the modulation process, including the emission skirts.
- The resolution bandwidth (RBW) shall be in the range of 1 % to 5 % of the occupied bandwidth (OBW) and video bandwidth (VBW) shall be approximately 3x RBW.

Note: Video averaging is not permitted.

A peak, or peak hold, may be used in place of the sampling detector as this may produce a wider bandwidth than the actual bandwidth (worst-case measurement). Use of a peak hold may be necessary to determine the occupied bandwidth if the device is not transmitting continuously.

The trace data points are recovered and are directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5 % of the total is reached and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency).
This frequency is then recorded.

The difference between the two recorded frequencies is the 99 % occupied bandwidth.

5.1.1 Transmission time control

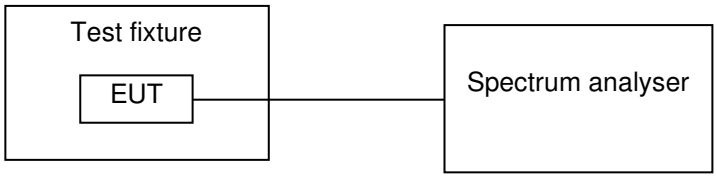
1. The calibration of the spectrum analyser has to be checked with the help of a known signal from a signal generator. The EUT has to be connected to the spectrum analyser via a low loss cable. If the EUT is not equipped with an antenna connector, a temporary antenna connector has to be installed or a test fixture has to be used. The EUT has to be switched on, the transmitter shall work with its maximum data rate.

The following spectrum analyser settings shall be used:

- Span: = 0 Hz.
- Resolution bandwidth: 1 MHz.
- Video bandwidth: ≥ the resolution bandwidth.
- Sweep: Single sweep with at least 5 seconds.
- Detector function: peak.
- Trace mode: Max hold.

The frequency line shall be set a point, were the transmitter will be released. The sweep shall start, when the transmitter started to operate, The transmitter shall released when the trace crosses the frequency line. One marker shall be set to the point of the frequency line, a delta marker to the time, were the transmitter stopped transmission.
-

Test set-up:



5.2 Operating bandwidth

5.2.1 Test setup (operating bandwidth)

Test setup (99 % bandwidth)			
Used	Setup	See sub-clause	Comment
☒	Radiated: Test fixture	5.1.4.1 and 5.1.4.2	-
☐	Test setup (antenna port conducted)	-	-

5.2.2 Test method (20 dB bandwidth)

Test method (20 dB bandwidth)				
Used	Sub-Clause	Name of method	Applicability	Comment
☒	6.9.2 [1], A1.3 [3]	Evaluation of -20 dB bandwidth	-	-

5.2.3 Test method (99 % bandwidth)

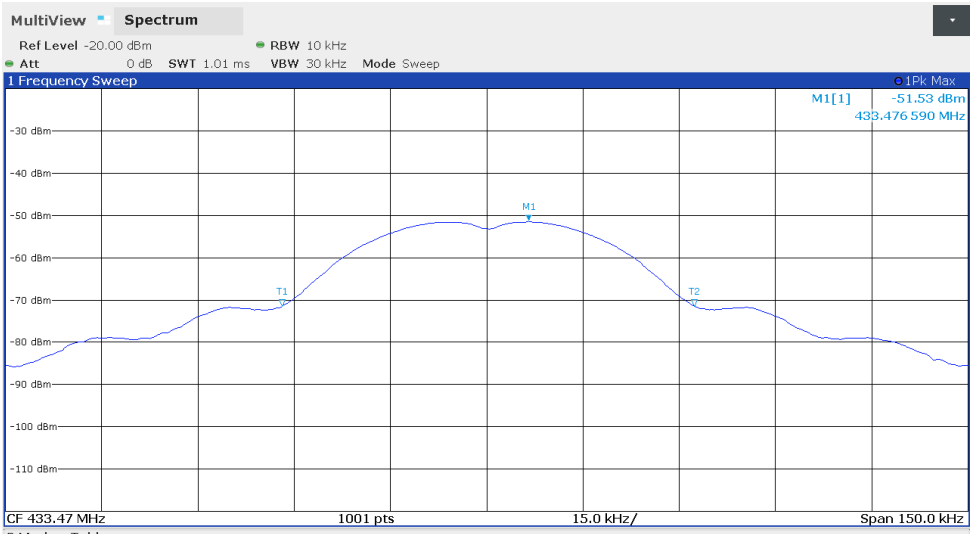
Test method (99 % bandwidth)				
Used	Sub-Clause	Name of method	Applicability	Comment
☒	6.9.3 [1], 6.7 [4]	99 % emission bandwidth	-	-

5.2.4 Test results (20 dB bandwidth)

Ambient temperature:	21 °C
Relative humidity:	55 %

Date:	04.07.2023
Tested by:	Th. KÜHN

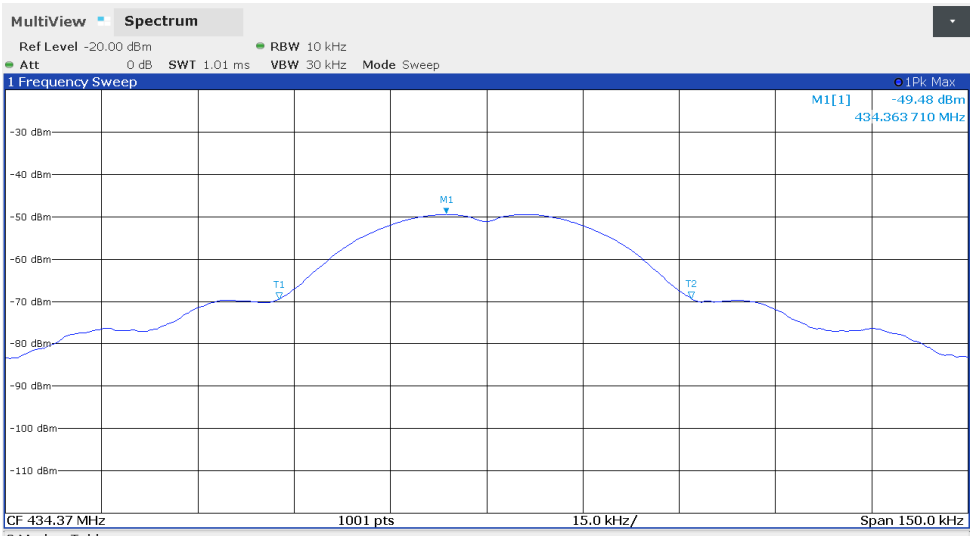
222097_102.png: 20 dB bandwidth on lower channel (operation mode 1)



2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**433.476 59 MHz**	**-51.53 dBm**	ndB	20.0 dB
T1		1	433.438 08 MHz	-71.51 dBm	ndB down BW	**64.29 kHz**
T2		1	433.502 37 MHz	-71.53 dBm	Q Factor	6 743.0

222097_103.png: 20 dB bandwidth on upper channel (operation mode 2)



2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**434.363 71 MHz**	**-49.48 dBm**	ndB	20.0 dB
T1		1	434.337 63 MHz	-69.57 dBm	ndB down BW	**64.29 kHz**
T2		1	434.401 92 MHz	-69.44 dBm	Q Factor	6 756.8

Operation mode	F_L	F_U	BW (F_U - F_L)
1	433.438080 MHz	433.502370 MHz	64.290 kHz
2	434.337630 MHz	434.401920 MHz	64.290 kHz

Test result: Passed

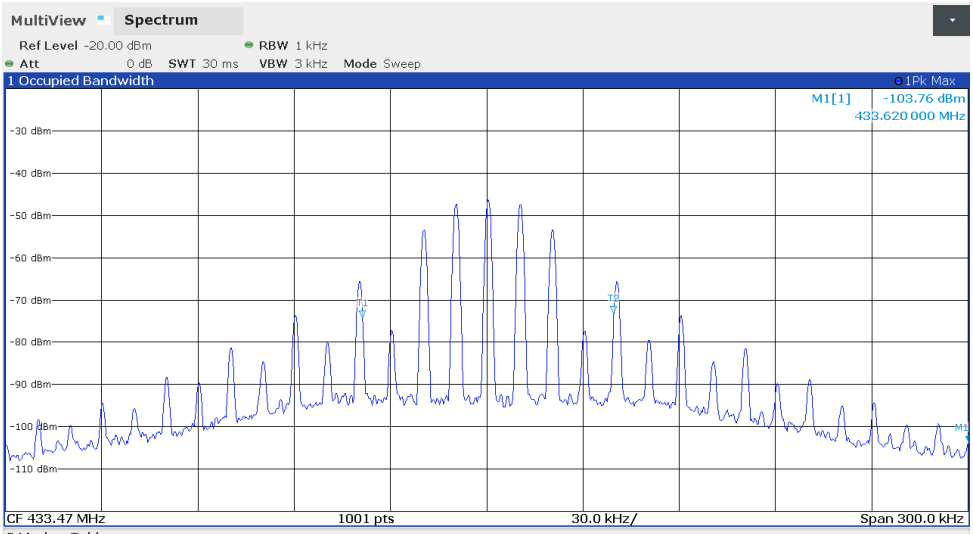
Test equipment (please refer to chapter 7 for details)
1, 2

5.2.5 Test results (99 % bandwidth)

Ambient temperature:	21 °C
Relative humidity:	55 %

Date:	04.07.2023
Tested by:	Th. KÜHN

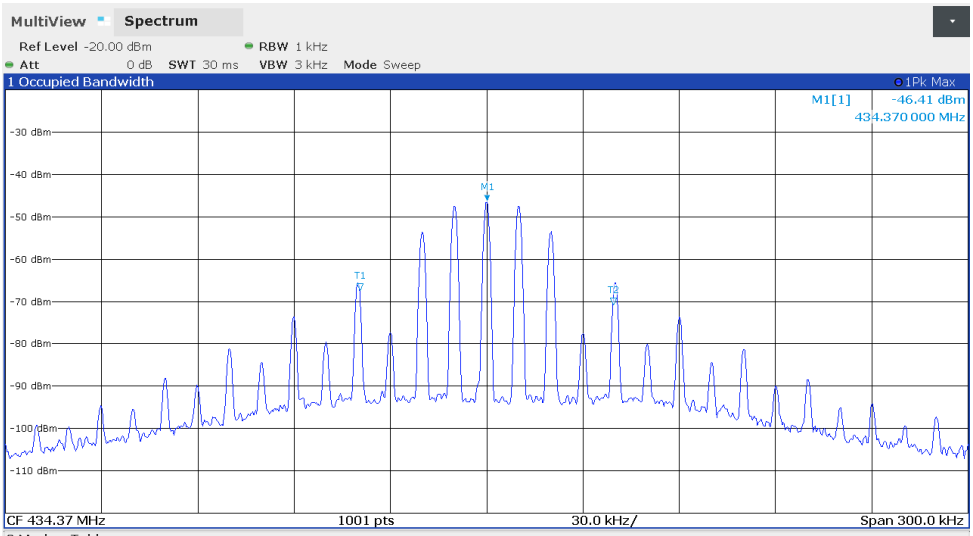
22097_104.png: 99 % bandwidth on lower channel (operation mode 1)



2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**433.62 MHz**	**-103.76 dBm**	Occ Bw	**78.264 559 218 kHz**
T1		1	433.431 258 MHz	-74.25 dBm	Occ Bw Centroid	433.470 390 507 MHz
T2		1	433.509 523 MHz	-73.07 dBm	Occ Bw Freq Offset	390.506 869 078 Hz

222097_105.png: 99 % bandwidth on upper channel (operation mode 2)



2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**434.37 MHz**	**-46.41 dBm**	Occ Bw	**78.813 780 939 kHz**
T1		1	434.330 545 MHz	-67.35 dBm	Occ Bw Centroid	434.369 952 324 MHz
T2		1	434.409 359 MHz	-70.77 dBm	Occ Bw Freq Offset	-47.675 944 269 Hz

Operation mode	F_L	F_U	BW (F_U - F_L)
1	433.431258 MHz	433.509523 MHz	78.265 kHz
2	434.330545 MHz	434.409359 MHz	78.814 kHz

Test result: Passed

Test equipment (please refer to chapter 7 for details)
1, 2

5.3 Transmission time control

5.3.1 Test setup (transmission time control)

Test setup (transmission time control)			
Used	Setup	See sub-clause	Comment
☒	Radiated: Test fixture	5.1.5	-
☐	Test setup (antenna port conducted)	-	-

5.3.2 Test method (transmission time control)

Test method (transmission time control)				
Used	Sub-Clause	Name of method	Applicability	Comment
☒	5.1.5	Transmission time control (transmitter release time)	-	-

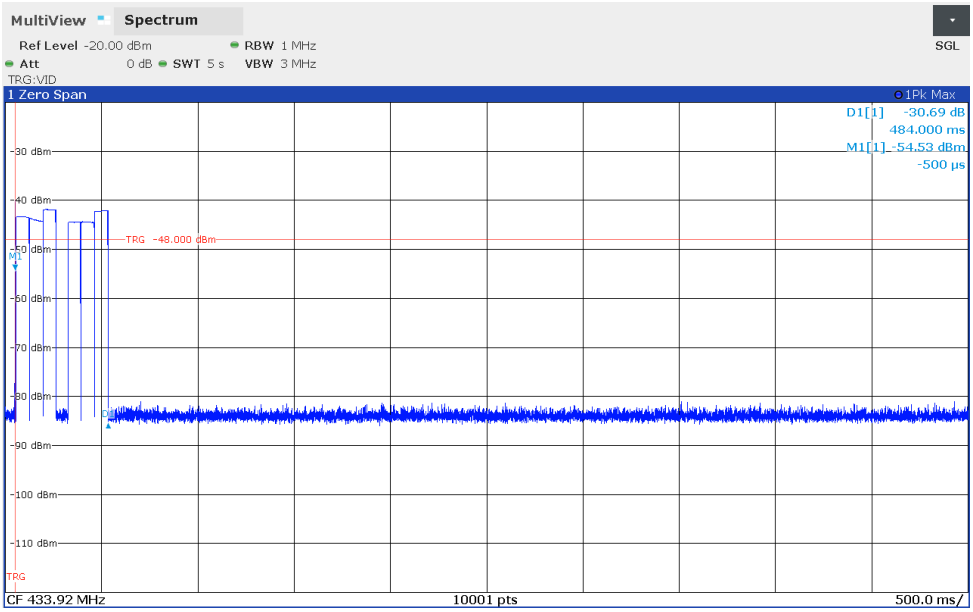
5.3.3 Test results (transmission time control)

Ambient temperature:	21 °C
Relative humidity:	55 %

Date:	04.07.2023
Tested by:	Th. KÜHN

The EUT starts transmitting as soon as a button is pressed.
The duration of transmission is independent from the moment when the key is released.
Therefore, the worst case for the transmitter release time is releasing the button immediately after pressing the button.

222097_101.png: Transmitter release time:



Transmitter release time	Limit
484 ms	5 s
Measurement uncertainty	$<10^{-7}$

Test result: Passed

Test equipment (please refer to chapter 7 for details)
1, 2

5.4 Test setup (Maximum unwanted emissions)

Test setup (Maximum unwanted emissions)			
Used	Setup	See sub-clause	Comment
☒	Radiated: 9 kHz to 30 MHz / 30 MHz to 1 GHz / 1 GHz to 40 GHz	5.1.2 / 5.1.3 / 5.1.4	-

5.4.1 Test method (Maximum unwanted emissions)

Used	Sub-Clause	Name of method	Applicability	Comment
☒	6.3 [1] 8.9 [4]	Unwanted radiated emissions	No limitations	-

5.4.2 Test results (Maximum unwanted emissions)

5.4.2.1 Test results preliminary measurement 9 kHz to 30 MHz

Ambient temperature:	21 °C
Relative humidity:	45 %

Date:	03.07.2023
Tested by:	Thomas KÜHN

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

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

Test record: The measurement value was already corrected by 40 dB/decade as described in 47 CFR 15.31(f)(2) regarding to the measurement distance as requested in 47 CFR 15.209(a)

Remark: All 3 orthogonal planes were tested separately

Calculations:

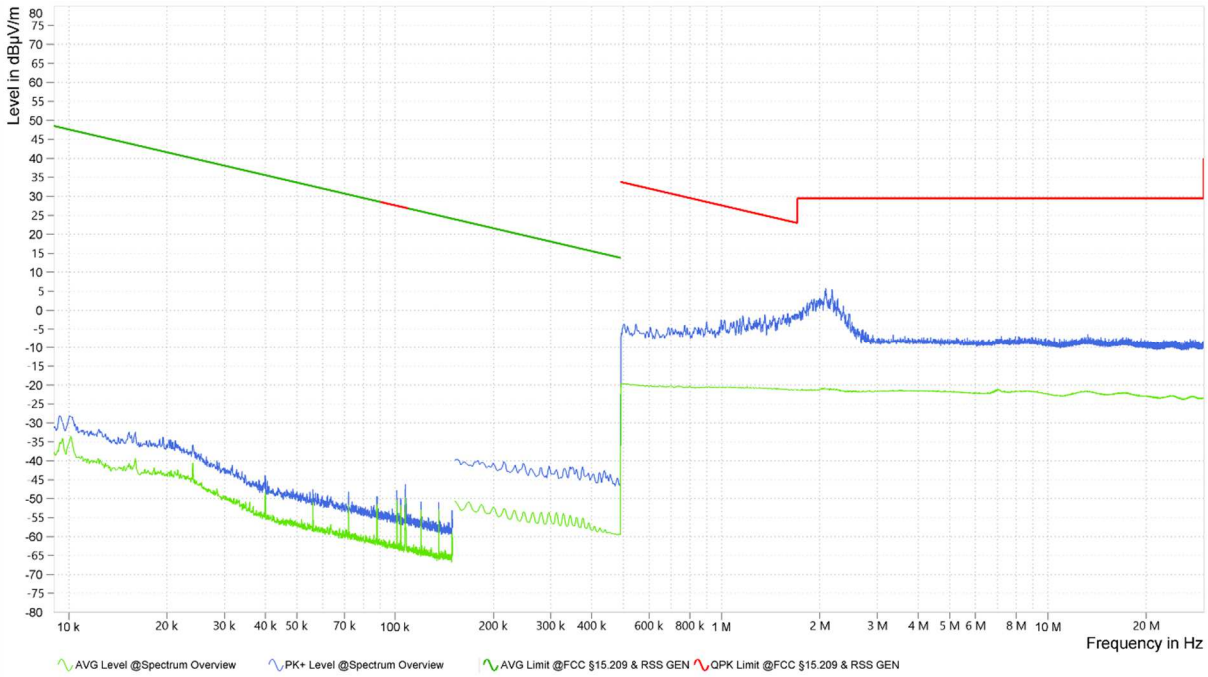
Result @ norm. dist. [dBµV/m] = Reading [dBµV] + AF [dB/m] + Distance corr. fact. [dBµV/m]

Result @ norm. dist. [dBµA/m] = Result @ norm. dist. [dBµV/m] – 20 x $\log_{10}$ (377 Ω)

Margin [dB] = Limit [dB(µV|µA)/m] - Result [dB(µV|µA)/m]

Worst case plot:

Spurious emissions from 9 kHz to 30 MHz (operation mode 2 – position 1):



Frequency range	Frequencies for final measurement
9 kHz to 150 kHz	No significant frequencies above the noise floor of the system (-28.0 dBµV/m or -79.5 dBµA/m (peak) in 300 m distance, measured at 3 m and converted with 40 dB / decade correction factor) were found during the preliminary radiated emission test, so no measurements were carried out on the outdoor test site.
150 kHz to 30 MHz	No significant frequencies above the noise floor of the system (5.8 dBµV/m or -45.7 dBµA/m (peak) in 30 m distance, measured at 3 m and converted with 40 dB / decade correction factor) were found during the preliminary radiated emission test, so no measurements were carried out on the outdoor test site.

Test result: Passed

Test equipment (please refer to chapter 7 for details)
5 – 12

5.4.2.2 Test results (30 MHz – 1 GHz)

Ambient temperature:	22 °C
Relative humidity:	62 %

Date:	29.06.2023
Tested by:	Thomas KÜHN

Position of EUT: For tests for f between 30 MHz to 1 GHz, the EUT was set-up on a table with a height of 80 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: All 3 orthogonal planes were tested separately

Calculations:

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

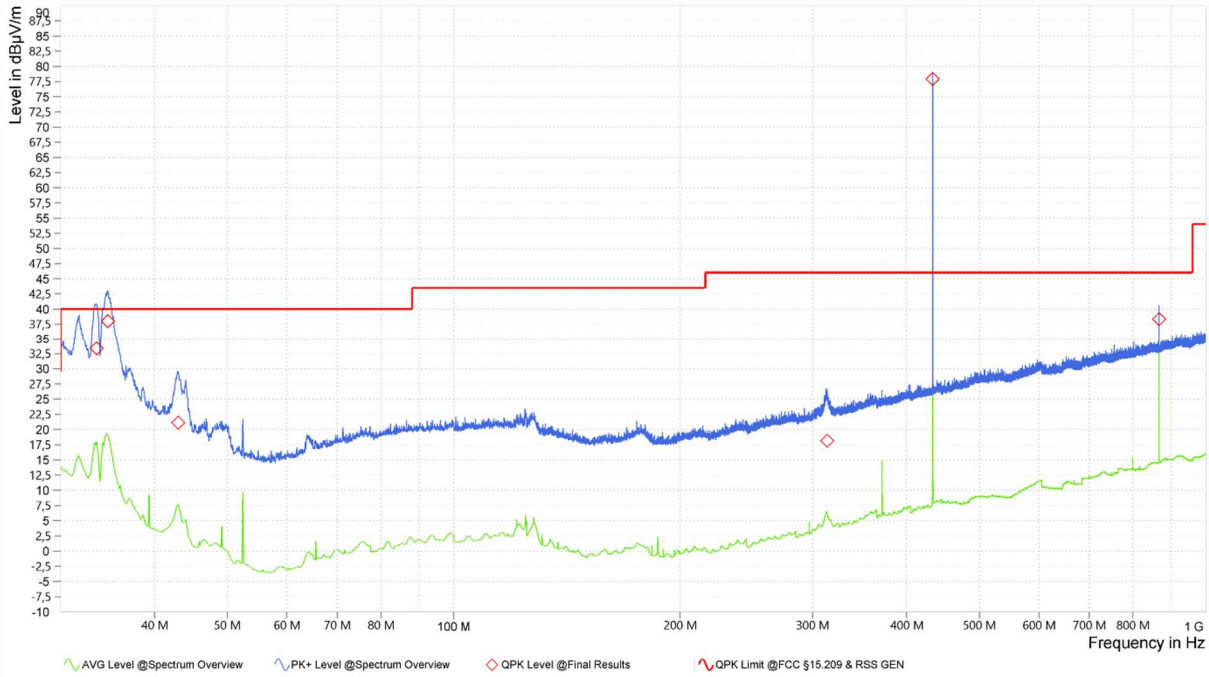
Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]

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

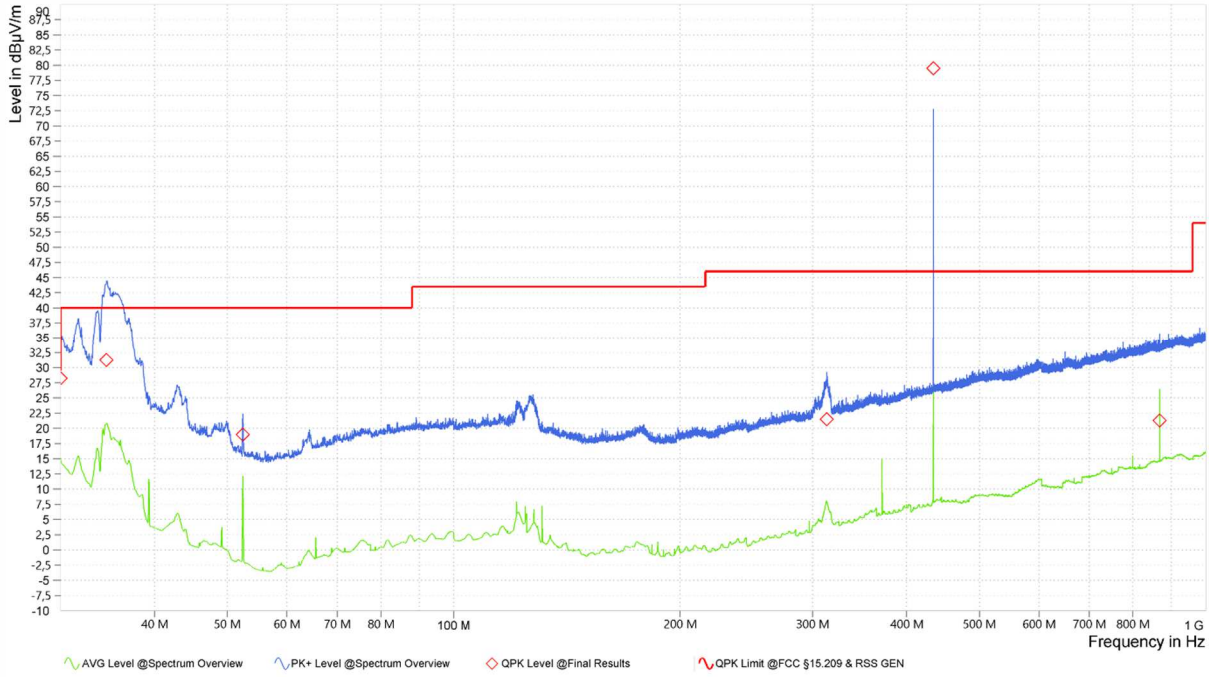
The measured points and the limit line in the following diagram refer to the standard measurement of the emitted interference in compliance with the above-mentioned standard. The measured points marked with "◆" are the measured results of the standard subsequent measurement in a semi-anechoic chamber.

Worst case plots:

Spurious emissions from 30 MHz to 1 GHz (operation mode 1 – position 2):



Spurious emissions from 30 MHz to 1 GHz (operation mode 2 – position 3):



Final results (operation mode 1)										
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas.Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Pos.
31.660	33.1	40.0	6.9	1000	120	375	Vert.	109	25.0	2
33.500	33.4	40.0	6.6	1000	120	115	Vert.	169	23.9	1
35.030	39.7	40.0	0.3	1000	120	100	Vert.	129	23.0	2
37.030	31.7	40.0	8.3	1000	120	125	Vert.	212	21.9	3
42.970	23.6	40.0	16.4	1000	120	390	Vert.	186	18.2	2
52.420	21.1	40.0	18.9	1000	120	347	Vert.	214	12.8	3
127.810	13.0	43.5	30.5	1000	120	375	Vert.	171	17.0	2
313.360	21.4	46.0	24.6	1000	120	383	Vert.	32	19.5	2
371.260	14.7	46.0	31.3	1000	120	225	Vert.	112	21.2	2
433.480	77.9	80.8 *	2.9	1000	120	100	Hor.	62	22.6	1
866.920	38.3	46.0	7.7	1000	120	100	Hor.	47	29.4	1

*: Limit calculated according to [2] Part 15.231 (b)

Final results (operation mode 2)										
Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas.Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)	Pos.
30.000	28.3	29.5	1.2	1000	120	354	V	109	26.0	3
34.730	39.5	40.0	0.5	1000	120	108	V	35	23.2	2
36.460	33.9	40.0	6.1	1000	120	161	V	64	22.2	2
43.030	15.9	40.0	24.1	1000	120	100	V	212	18.2	2
52.420	19.0	40.0	21.0	1000	120	340	V	122	12.8	3
313.450	21.5	46.0	24.5	1000	120	347	V	66	19.5	3
371.260	19.1	46.0	26.9	1000	120	227	V	186	21.2	2
434.380	79.5	80.8	1.3	1000	120	122	V	3	22.7	3
868.720	34.9	46.0	11.1	1000	120	100	H	51	29.4	1

*: Limit calculated according to [2] Part 15.231 (b)

Test result: Passed

Test equipment (please refer to chapter 7 for details)
3, 4, 6 – 12

5.4.2.3 Test results (radiated 1 to 5 GHz)

Ambient temperature:	21 °C
Relative humidity:	54 %

Date:	27.06.2023
Tested by:	Thomas KÜHN

Position of EUT: For tests for f between 1 GHz and the 10th harmonic, the EUT was set-up on a positioner device with a height of 150 cm. The distance between EUT and antenna was 3 m.

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

Test record: Plots for each frequency range are submitted below.

Remark: -

Calculation:

Max Peak [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]

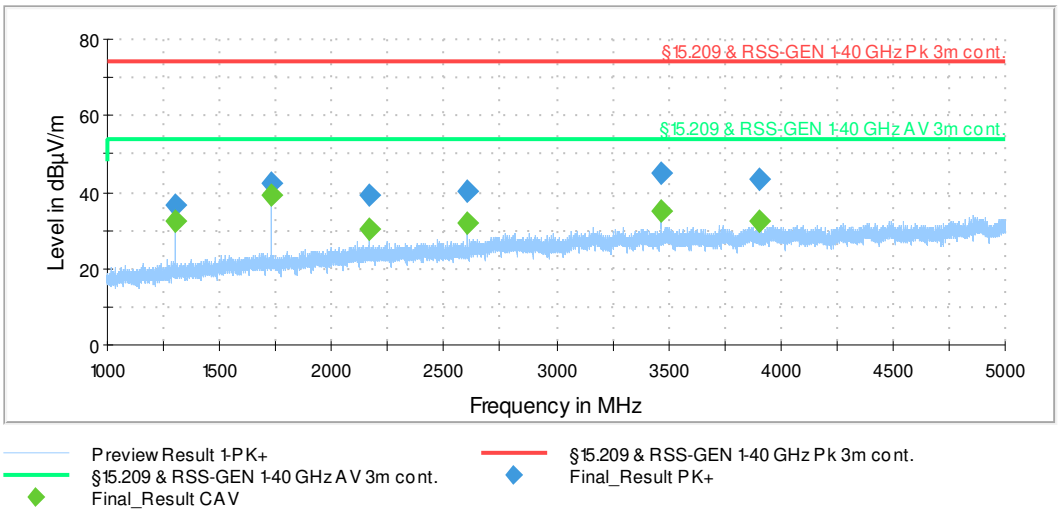
Average [dBµV/m] = Reading [dBµV] + Correction [dBµV/m]

Correction [dBµV/m] = AF [dB/m] + Cable attenuation [dB] + optional preamp gain [dB]+DCCF* [dB]
* (if applicable – only for Average values, that are fundamental related)

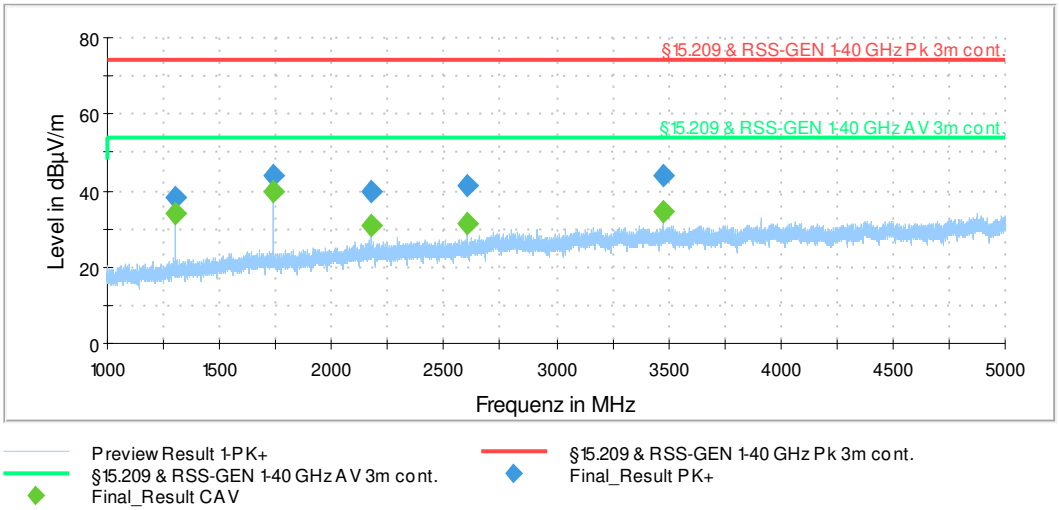
Margin [dB] = Limit [dBµV/m] – Max Peak | Average [dBµV/m]

The curves in the diagram only represent the maximum measured value for each frequency point of all preliminary measurements, which were carried out with various EUT and antenna positions.
The top measured curve represents the peak measurement. The measured points marked with "◆" are frequency points for the final peak detector measurement. These values are indicated in the following table. The bottom measured curve represents the average measurement. The measured points marked with "◆" are frequency points for the final average detector measurement.

Spurious emissions from 1 GHz to 5 GHz (operation mode 1):



Spurious emissions from 1 GHz to 5 GHz (operation mode 2):



Test results operation mode 1								
Frequency [MHz]	MaxPeak [dB(µV/m)]	Average [dB(µV/m)]	Limit [dB(µV/m)]	Margin [dB(µV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
1300.266	---	32.7	54.0	21.4	Hor.	1	30	-15.6
	36.6	---	74.0	37.4				
1733.845	---	39.4	54.0	14.6	Vert.	207	90	-13.0
	42.6	---	74.0	31.4				
2167.288	39.1	---	74.0	34.9	Vert.	8	90	-10.6
	---	30.5	54.0	23.5				
2600.666	40.1	---	74.0	33.9	Hor	208	90	-9.3
	---	31.7	54.0	22.3				
3467.574	---	35.0	54.0	19.0	Hor	221	90	-5.8
	44.7	---	74.0	29.3				
3901.197	---	32.5	54.0	21.5	Hor	251	90	-4.9
	43.5	---	74.0	30.5				
Test results operation mode 2								
Frequency [MHz]	MaxPeak [dB(µV/m)]	Average [dB(µV/m)]	Limit [dB(µV/m)]	Margin [dB(µV/m)]	Pol [H/V]	Azimuth [deg]	Elevation [deg]	Corr. [dB]
1302.975	38.4	---	74.0	35.6	Hor.	346	90	-15.5
	---	33.9	54.0	20.1				
1737.318	44.0	---	74.0	30.0	Vert.	185	90	-13.0
	---	39.8	54.0	14.2				
2171.706	39.6	---	74.0	34.4	Vert.	0	90	-10.6
	---	31.1	54.0	22.9				
2606.059	---	31.2	54.0	22.8	Hor.	201	90	-9.2
	41.1	---	74.0	32.9				
3474.749	44.0	---	74.0	30.0	Hor.	220	90	-5.8
	---	34.7	54.0	19.3				

Test result: Passed

Test equipment (please refer to chapter 7 for details)
13 – 23

6 Measurement Uncertainties

Radiated measurements		
Frequency error		
(Semi-) Anechoic chamber	ETSI TR 100 028	4.5×10^{-8}
OATS	ETSI TR 100 028	4.5×10^{-8}
Test fixture	ETSI TR 100 028	4.5×10^{-8}
Bandwidth measurements		
(Semi-) Anechoic chamber	-	9.0×10^{-8}
OATS	-	9.0×10^{-8}
Test fixture	-	9.1×10^{-8}
Radiated field strength M20		
CBL6112B @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	5.3 dB
R&S HL050 @ 3 m		
1 – 6 GHz	CISPR 16-4-2	5.1 dB
6 – 18 GHz	CISPR 16-4-2	5.4 dB
Flann Standard Gain Horns 18 – 40 GHz	-	5.9 dB
Radiated field strength M276		
R&S HL562E @ 3 m 30 MHz – 1 GHz	CISPR 16-4-2	4.8 dB
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
OATS		
Field strength measurements below 30 MHz on OATS without ground plane	-	4.4 dB

7 Test Equipment used for Tests

No.	Test equipment	Type	Manufacturer	Serial No.	PM. No.	Cal. Date	Cal Due
1	Test fixture	Für Funk 50 Ohm-System	PHOENIX TESTLAB GmbH	-	410160	Calibration not necessary	
2	Signal & spectrum analyser	FSW43	Rohde & Schwarz	100586 & 100926	481720	19.11.2021	11.2023
3	Attenuator 6 dB	WA2-6	Weinschel	-	482793	Calibration not necessary	
4	Ultralog antenna	HL562E	Rohde & Schwarz	101079	482978	18.03.2021	03.2024
5	Loop antenna	HFH2-Z2	Rohde & Schwarz	832609/014	480059	22.02.2022	02.2024
6	RF switch matrix	OSP220	Rohde & Schwarz	-	482976	Calibration not necessary	
7	Turntable	TT3.0-3t	Maturo	825/2612/.01	483224	Calibration not necessary	
8	Antenna support	BAM 4.5-P-10kg	Maturo	222/2612.01	483225	Calibration not necessary	
9	Controller	NCD	Maturo	474/2612.01	483226	Calibration not necessary	
10	Semi anechoic chamber M276	SAC5-2	Albatross Projects	C62128-A540-A138-10-0006	483227	Calibration not necessary	
11	Test-software M276	EMC32 V11.30	Rohde & Schwarz	100970	482972	Calibration not necessary	
12	EMI test-receiver	ESW44	Rohde & Schwarz	101828	482979	08.12.2021	12.2023
13	Fully anechoic chamber M20	B83117-E2439-T232	Albatross Projects	103	480303	Calibration not necessary	
14	Turntable	DS420 HE	Deisel	420/620/00	480315	Calibration not necessary	
15	Antenna support	AS620P	Deisel	620/375	480325	Calibration not necessary	
13	Multiple control unit	MCU	Maturo GmbH	MCU/043/971107	480832	Calibration not necessary	
17	Antenna (Log.Per.)	HL050	Rohde & Schwarz	100438	481170	Calibration not necessary	
18	Software	EMC32 V10.60.20	Rohde & Schwarz	-	483261	Calibration not necessary	
19	Preamplifier 100 MHz - 16 GHz	AFS6-00101600-23-10P-6-R	Narda MITEQ	2011215	482333	17.02.2022	02.2024
20	High pass filter 1 GHz	WHKX12-935-1000-15000-40ST	Wainwright Instruments GmbH	27	483809	Calibration not necessary	
21	RF-cable No.38	Sucoflex 106B	Suhner	0709/6B / Kabel 38	481328	Calibration not necessary	
22	Positioner	TDF 1.5- 10Kg	Maturo	15920215	482034	Calibration not necessary	
23	EMI test receiver	ESW44	Rohde & Schwarz	101635	482467	22.02.2022	02.2024

8 Test site Verification

Test equipment	PM. No.	Frequency range	Type of validation	According to	Val. Date	Val Due
Semi anechoic chamber M276	483227	30 – 1000 MHz	NSA/RSM	CISPR 16-1-4 + Cor1:2010 + A1:2012 +A2:2017	01.03.2023	28.02.2026
Fully anechoic chamber M20	480303	1 -18 GHz	SVSWR	CISPR 16-1-4 Amd. 1	17.08.2022	16.08.2024

9 Report History

Report Number	Date	Comment
F222097E2	02.08.2023	Initial Test Report
-	-	-
-	-	-

10 List of Annexes

Annex A Test Setup Photos 11 pages