FCC Measurement/Technical Report on

NFC transceiver

NFC 3.0

FCC ID: KR5NFC30
IC: 7812D–NFC30

Report Reference: MDE_CONTI_2031_FCC_03

Test Laboratory:
7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany

Deutsche
Akkreditierungsstelle
D-PL-12140-01-01
D-PL-12140-01-02
D-PL-12140-01-03

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1 Summary

1.1 Technical Report Summary

Type of Authorization
Certification for an intentional radiator operating at 13.56 MHz

Applicable FCC Rules

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 and 15 (10-1-19 Edition). The following subparts are applicable to the results in this test report.

Part 2, Subpart J - Equipment Authorization Procedures, Certification

Part 15, Subpart C – Intentional Radiators

§ 15.205 Restricted bands of operation

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.215 Additional provisions to the general radiated emission limitations

§ 15.225 Operation within the band 13.110-14.010 MHz

Note:
ANSI C63.10-2013 is applied

Summary Test Results:

The EUT complied with all performed tests as listed in sub-clause 1.3 Measurement Summary / Signatures.

1.2 FCC-IC Correlation Table

The following tables show the correlation of measurement requirements Radio equipment operating in the Band 13.110-14.010 MHz from FCC and IC.

Radio equipment

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 5 & Amdt. 1 2019: 8.8
Out-of-band emissions	§ 15.225 (d)	RSS Gen Issue 5 & Amdt. 1 2019: 6.13/8.9/8.10; RSS-210 Issue 10 & Amdt. 2020: B.6
In-band emissions	§ 15.225 (a) / (b) / (c)	RSS-210 Issue 10 & Amdt. 2020: B.6
Frequency Stability	§ 15.225 (e)	RSS-210 Issue 10 & Amdt. 2020: B.6
Antenna requirement	§ 15.203 / 15.204	RSS-Gen Issue 5 & Amdt. 1 2019: 8.3
Receiver spurious emissions	–	RSS-210 Issue 10 & Amdt. 2020: 2.3; RSS Gen Issue 5 & Amdt. 1 2019: 5/7 *)
Handling of active and passive tag devices of RFID application	§ 15.225 (f)	RSS Gen Issue 5 & Amdt. 1 2019: 8.7

*) Receivers are exempted from certification besides if operating in stand-alone mode in the frequency range 30–960 MHz or if these are scanner receivers.

1.3 Measurement Summary / Signatures

FCC Part 15, Subpart C	**§ 15.207**			
Conducted Emissions AC Power line				
The measurement was performed according to ANSI C63.10				
OP-Mode	**Setup**	**Port**	**Final Result**	**Date**
–	–	–	N/A	–

FCC Part 15, Subpart C	**§15.209**			
Radiated Emissions				
The measurement was performed according to ANSI C63.10				
OP-Mode	**Setup**	**Port**	**Final Result**	**Date**
NFC reading	Setup_02	Enclosure	passed	2020-12-03/10

FCC Part 15, Subpart C	**§ 15.215**			
Occupied Bandwidth				
The measurement was performed according to FCC § 2.1049				
OP-Mode	**Setup**	**Port**	**Final Result**	**Date**
NFC reading	Setup_02	Enclosure	passed	2020-11-27
NFC polling	Setup_01	Enclosure	passed	2020-11-27

FCC Part 15, Subpart C	**§ 15.225**			
Spectrum Mask				
The measurement was performed according to ANSI C63.10				
OP-Mode	**Setup**	**Port**	**Final Result**	**Date**
NFC reading	Setup_02	Enclosure	passed	2020-12-03
NFC polling	Setup_01	Enclosure	passed	2020-12-03

FCC Part 15, Subpart C	**§ 15.225**			
Frequency Tolerance				
The measurement was performed according to FCC § 2.1055				
OP-Mode	**Setup**	**Port**	**Final Result**	**Date**
NFC reading	Setup_02	Enclosure	passed	2020-12-03

N/A not applicable (the EUT is powered by DC and only intendent for the use in vehicles)

1.4 Revision History

Version	Release date	Change Description	Version validity
initial	2020-12-16	--	valid

Responsible for Accreditation Scope: _____

Responsible for Test Report: _____

7 layers GmbH, Borsigstr. 11
40880 Ratingen, Germany
Phone +49 (0)2102 749 0

2 Administrative Data

2.1 Testing Laboratory

Company Name:	7layers GmbH
Address	Borsigstr. 11 40880 Ratingen Germany
Laboratory accreditation no:	DAkkS D-PL-12140-01-01 | -02 | -03
ISED CAB Identifier	DE0007; ISED#: 3699A
FCC Designation Number:	DE0015
FCC Test Firm Registration:	929146
Responsible for Accreditation Scope:	Dipl.-Ing. Marco Kullik
Report Template Version:	2020-11-23

2.2 Project Data

Responsible for testing and report:	Dipl.-Ing. Andreas Petz
Date of Report:	2020-12-16
Testing Period:	2020-11-27 to 2020-12-10

2.3 Applicant Data

Company Name:	Continental Automotive GmbH
Address:	Siemensstrasse 12 93055 Regensburg Germany
Contact Person:	Mrs. Lavinia-Carolina Grecu

2.4 Manufacturer Data

Company Name:	please see applicant data
Address:	
Contact Person:	

3 Test object Data

3.1 General EUT Description

Equipment under Test	NFC 3.0
Product Name	–
Kind of Device:	13.56 MHz NFC Transceiver
Voltage Type:	DC
Voltage level:	12 V nominal and tested voltage

3.1.1 General product description:

The EUT is a Near Field Communication reader with NFC communication, which will be integrated into cars.

Implemented radio technology:
NFC transceiver is operating at 13.56 MHz nominal frequency:
One out of three antennas is be used at the same time. Simultaneous transmission of more than one antenna is not supported.
The central antenna provides the signal with the highest output power and is deemed as worst-case.

The test setups incl. the auxiliaries are furnished by the applicant.
The tests have been carried out using an additional "spacer" between the EUT and AUX 1 providing a short gab between the devices. The spacer is made of acrylic glass.
For the test purpose, test cables have been used representing the cable harness that will be assembled later in the car with a length of approx. 1 m.

The auxiliaries are not subject of this test report but may impact test results.

The device is intended for professional installation only.

3.1.2 Specific product description for the EUT:

For a detailed description please refer to the documentation provided by the applicant.

The EUT provides the following ports:

Ports
Enclosure
DC connector
CAN
Detection front/rear version

Tested cable length: 1.0 m (assembled by the applicant)

Note: The three latter ports are combined in one connector.

3.2 EUT Main components

Type, S/N, Short Descriptions etc. used in this Test Report

Short Description	Equipment under Test	Type Designation	Serial No.	HW Status	SW Status
EUT A (Code: DE1439002aa01)	NFC Transceiver (in polling mode)	NFC 3.0	–	C2	009_001_103
EUT B (Code: DE1439002ad01)	NFC Transceiver (in reading mode)	NFC 3.0	–	C2	009_001_100

NOTE: The short description is used to simplify the identification of the EUT in this test report. Pre-tests have been carried out using two other samples enabling two different antenna positions ("top" and "bottom"). The found emissions are lower than of the tested sample DE1439002ad01 enabling central antenna.

3.3 Ancillary Equipment

For the purposes of this test report, ancillary equipment is defined as equipment which is used in conjunction with the EUT to provide operational and control features to the EUT. It is necessary to configure the system in a typical fashion, as a customer would normally use it. But nevertheless Ancillary Equipment can influence the test results.

Short Description	Equipment under Test	Type Designation	Serial No.	HW Status	SW Status
–	–	–	–	–	–

3.4 Auxiliary Equipment

For the purposes of this test report, auxiliary equipment is defined as equipment which is used temporarily to enable operational and control features especially used for the tests of the EUT which is not used during normal operation or equipment that is used during the tests in combination with the EUT but is not subject of this test report. It is necessary to configure the system in a typical fashion, as a customer would normally use it.
But nevertheless Auxiliary Equipment can influence the test results.

Short Description	Device	Type Designation	Serial No.	HW Status	SW Status
AUX 1	NFC Tag	NXP MIFARE DESFire EV2	04:1C:32:62:D9:5B:80	Rev. 2.0	–

3.5 EUT Setups

This chapter describes the combination of EUTs and equipment used for testing. The rationale for selecting the EUTs, ancillary and auxiliary equipment and interconnecting cables, is to test a representative configuration meeting the requirements of the referenced standards.

Setup No.	Combination of EUTs	Description and Rationale
Setup_01	EUT A	EUT A in polling mode
Setup_02	EUT B + AUX 1	EUT B and one NFC tag in reading mode,

3.6 Operating Modes

This chapter describes the operating modes of the EUTs used for testing.

Op. Mode	Description of Operating Modes	Remarks
NFC polling	NFC signal transmitted via central antenna	EUT is transmitting pulsed signal, radiated by the integral antenna, low duty cycle: period: 300 ms, duration: 400 µs (nominal merits)
NFC reading	NFC signal transmitted via central antenna, reading a tag	EUT is transmitting a continuously ASK modulated signal, radiated by the integral central antenna

3.7 Special software used for testing

Samples with different parameters set in production firmware, provided by the applicant.

3.8 Product labelling

Please refer to the documentation of the applicant.

4 Test Results

4.1 Spurious radiated emissions

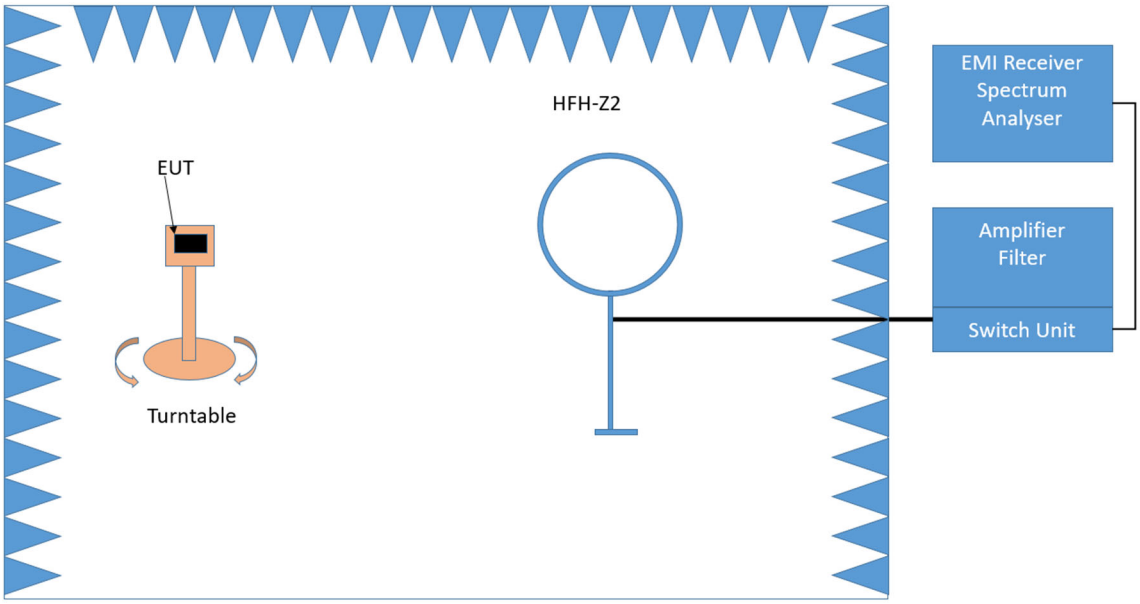
Standard FCC Part 15, Subpart C

The test was performed according to: ANSI C63.10

4.1.1 Test Description

The test set-up was made in accordance to the general provisions of ANSI C63.10 in a typical installation configuration. The Equipment Under Test (EUT) was set up on a non-conductive table 1.0 x 2.0 m² in the semi-anechoic chamber. The influence of the EUT support table that is used between 30–1000 MHz was evaluated.
The measurement procedure is implemented into the EMC32 test software from R&S. (Exploratory) Tests are performed at 3 orthogonal axes to determine the worst-case orientation of a body-worn or handheld EUT. The final test on all kind of EUTs is performed at 2 axes. A pre-check is also performed while the EUT is powered from DC (battery) power in order to find the worst-case operating condition.

1. Measurement up to 30 MHz



Test Setup; Spurious Emission Radiated (SAC), 9 kHz – 30 MHz

The Loop antenna HFH2-Z2 (shielded magnetic loop antenna) is used.

Step 1: pre measurement
- Anechoic chamber
- Antenna distance: 3 m
- Antenna height: 1 m (lowest part to ground)
- Antenna polarisation: 3 axis
- Detector: Peak-Maxhold
- Frequency range: 0.009 – 0.15 and 0.15 – 30 MHz
- Frequency steps: 0.1 kHz and 5 kHz

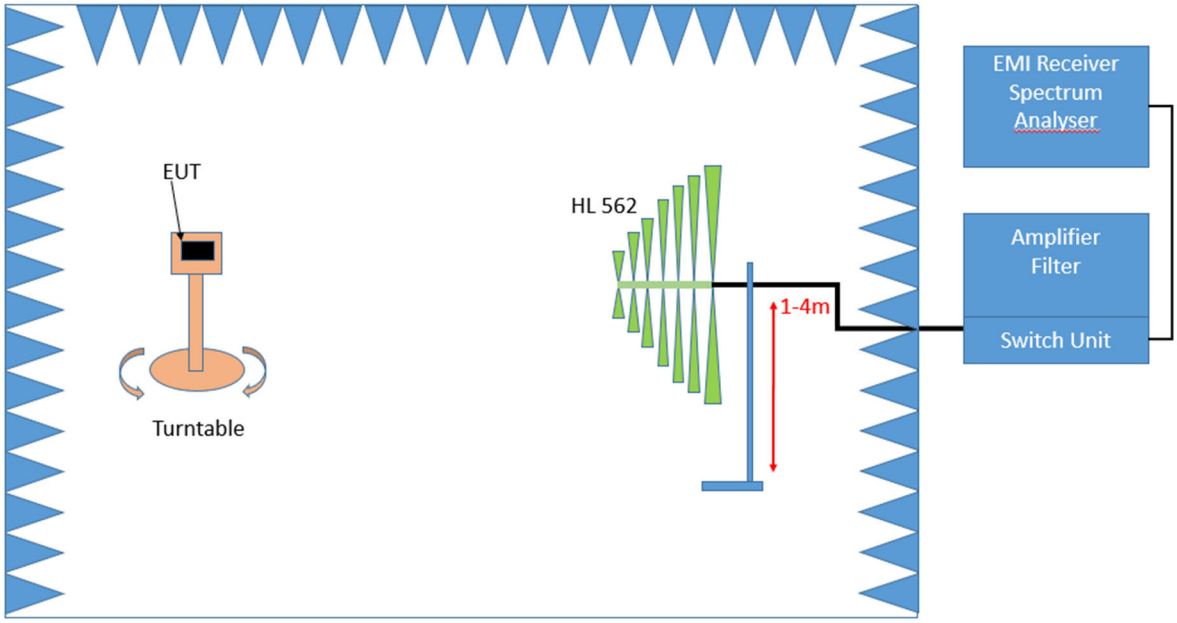
- IF–Bandwidth: 0.2 kHz and 10 kHz
- Measuring time / Frequency step: 100 ms (FFT-based)

Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

Step 2: final measurement

For the relevant emissions determined in step 1, an additional measurement with the following settings will be performed. Intention of this step is to find the maximum emission level.
- Detector: Quasi-Peak besides 9–90 kHz and 110–490 kHz: Average and Peak
- Measuring time / Frequency step: 1 s

2. Measurement above 30 MHz and up to 1 GHz



Test Setup; Spurious Emission Radiated (SAC), 30 MHz- 1GHz

Step 1: Preliminary scan

Preliminary test to identify the highest amplitudes relative to the limit.

Settings for step 1:
- Antenna distance: 3 m
- Detector: Peak-Maxhold / Quasipeak (FFT-based)
- Frequency range: 30 – 1000 MHz
- Frequency steps: 30 kHz
- IF–Bandwidth: 120 kHz
- Measuring time / Frequency step: 100 ms
- Turntable angle range: –180° to 90°
- Turntable step size: 90°
- Height variation range: 1 – 4 m
- Height variation step size: 1.5 m
- Polarisation: Horizontal + Vertical

Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

Step 2: Adjustment measurement
In this step the accuracy of the turntable azimuth and antenna height will be improved. This is necessary to find out the maximum value of every frequency.
For each frequency, which was determined the turntable azimuth and antenna height will be adjusted. The turntable azimuth will slowly vary. During this action, the value of emission is continuously measured. The turntable azimuth at the highest emission will be recorded and adjusted. In this position, the antenna height will also slowly vary. During this action, the value of emission is also continuously measured. The antenna height of the highest emission will also be recorded and adjusted.
- Detector: Peak – Maxhold
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 100 ms
- Turntable angle range: 360°
- Height variation range: 1 – 4 m
- Antenna Polarisation: max. value determined in step 1

Step 3: Final measurement with QP detector
With the settings determined in step 2, the final measurement will be performed:
EMI receiver settings for step 3:
- Detector: Quasi-Peak (< 1 GHz)
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 1 s

After the measurement a plot will be generated. It contains a diagram with the results of the preliminary scan and a chart with the frequencies and values of the results of the final measurement.

4.1.2 Test Requirements / Limits

FCC Part 15, Subpart C, §15.225 (d)
The field strength of any emissions appearing outside of the 13.110–14.010 MHz band shall not exceed the general radiated emission limits in § 15.209.

FCC Part 15, Subpart C, §15.209, Radiated Emission Limits

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limits (dBµV/m)
0.009 – 0.49	2400/F(kHz)@300m	3	(48.5 – 13.8)@300m
0.49 – 1.705	24000/F(kHz)@30m	3	(33.8 – 23.0)@30m
1.705 – 30	30@30m	3	29.5@30m

The measured values are corrected with an inverse linear distance extrapolation factor (40 dB/decade) according FCC §15.31 (2).

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limits (dBµV/m)
30 – 88	100@3m	3	40.0@3m
88 – 216	150@3m	3	43.5@3m
216 – 960	200@3m	3	46.0@3m
960 - 26000	500@3m	3	54.0@3m

§15.35(b)
..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit....

Used conversion factor: Limit (dBµV/m) = 20 log (Limit (µV/m)/1µV/m)

4.1.3 Test Protocol

Temperature: 21 - 22°C
Air Pressure: 994 - 1000 hPa
Humidity: 34 - 35 %

4.1.3.1 Measurement up to 30 MHz

Op. Mode	Setup	Port
NFC reading	Setup_02	Enclosure

Antenna orientation	EUT orientation	Frequency MHz	Corrected value dBµV/m			Limit dBµV/m	Limit dBµV/m	Limit dBµV/m	Margin dB	Margin dB
			QP	Peak	AV	QP	Peak	AV	QP/Peak	AV
Vert.&Hor.	Vertical	13.56	32.4	–	–	–	–	–	–	–

Remark: No (further) spurious emissions in the range 20 dB below the limit were found therefore step 2 was not performed.
13.56 MHz is the wanted signal of the EUT.
During pre-tests the worst-case (highest emission level) is determined as combination of EUT position, mode and antenna (central, top, bottom). This combination is tested: EUT vertical, central antenna, reading mode.

4.1.3.2 Measurement above 30 MHz

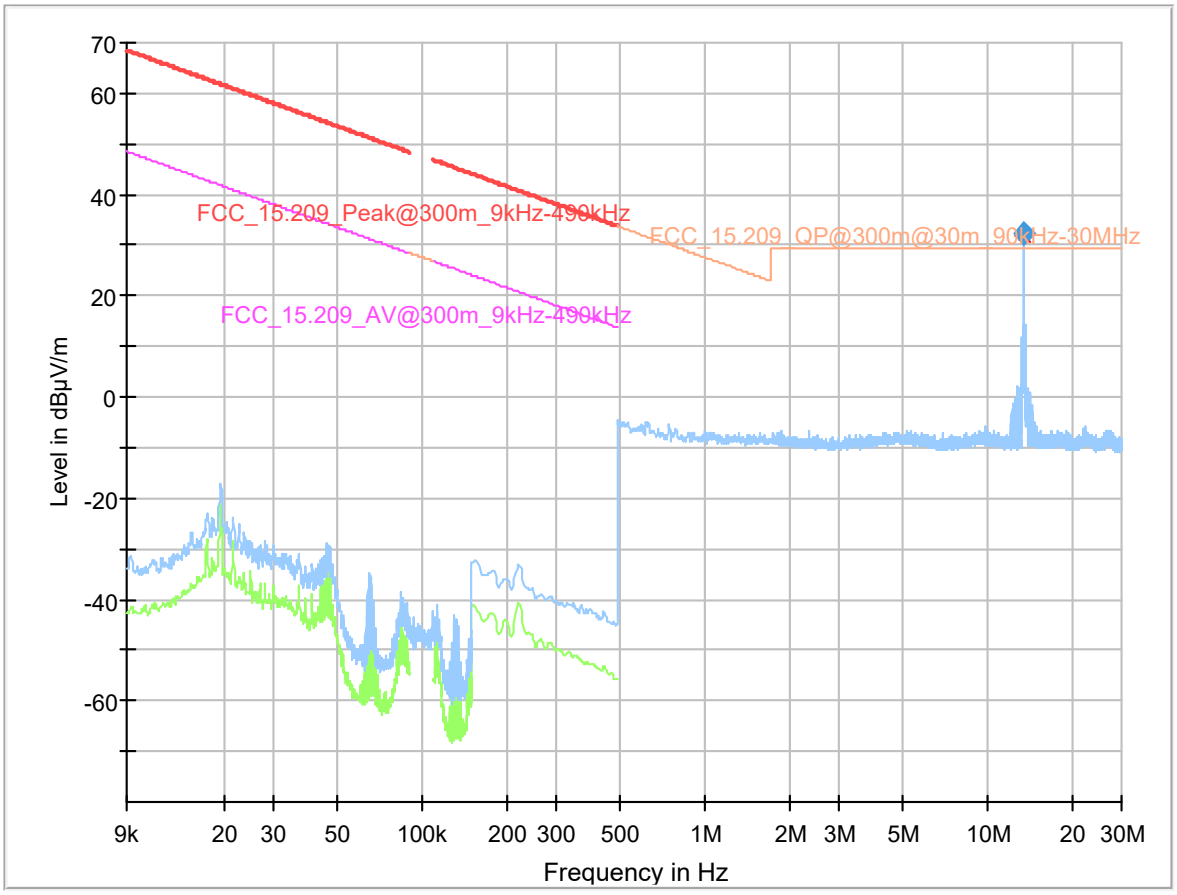
Op. Mode	Setup	Port
NFC reading	Setup_02	Enclosure

Antenna orientation	EUT orientation	Frequency MHz	Corrected value dBµV/m			Limit dBµV/m	Limit dBµV/m	Limit dBµV/m	Margin dB	Margin dB
			QP	Peak	AV	QP	Peak	AV	QP/Peak	AV
Vertical	Vertical	40.68	37.0	–	–	40.0	–	–	3.0	–

Remark: No (further) spurious emissions in the range 20 dB below the limit found.
Tested in worst-case combination (see above).

4.1.4 Measurement Plots (worst case)

4.1.4.1 Below 30 MHz

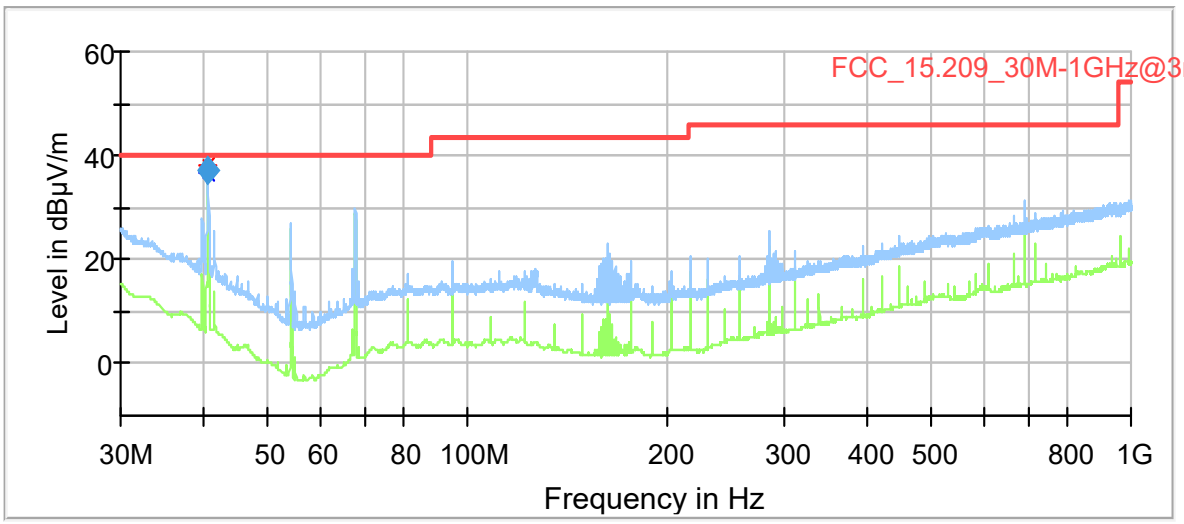


Legend: Trace: blue = Peak; green = AV, Star: = critical frequency; Rhombus: blue = final QP

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Antenna polarisation	Azimuth (deg)	Corr. (dB/m)
13.560000	32.4	---	---	1000	10	x-Orientation: loop plane vertical, vector parallel to measurement axis	450.0	-19.3

4.1.4.2 Above 30 MHz



Legend: Trace: blue = Peak; green = AV, Star: = critical frequency; Rhombus: blue = final QP

Final_Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m
40.6800	37.0	40.0	3.0	1000	120	103.0	V	-158.0	13.2

4.1.5 Test Equipment used

- Radiated Emissions

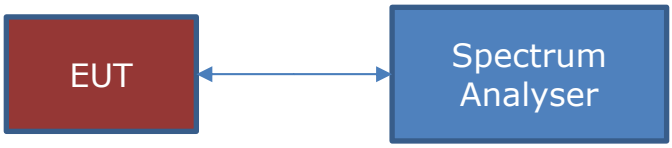
4.2 Occupied bandwidth

Standard FCC Part 15, Subpart C

The test was performed according to: FCC §15.31

4.2.1 Test Description

The Equipment Under Test (EUT) was setup in a shielded room to perform the occupied bandwidth measurements.
The reference level is the level of the highest amplitude signal observed from the transmitter at either the fundamental frequency or first-order modulation products in all typical modes of operation, including the unmodulated carrier, even if atypical.
The results recorded were measured with the modulation which produces the worst-case (widest) occupied bandwidth.



Test Setup for conducted tests

4.2.2 Test Requirements / Limits

FCC Part 15, Subpart C, §15.215 (c)
Intentional radiators operating under the alternative provisions to the general emission limits, as contained in §§ 15.217 through 15.257 and in Subpart E of this part, must be designed to ensure that the 20 dB bandwidth of the emission, or whatever bandwidth may otherwise be specified in the specific rule section under which the equipment operates, is contained within the frequency band designated in the rule section under which the equipment is operated. …

4.2.3 Test Protocol

Temperature: 23 °C
Air Pressure: 1012 hPa
Humidity: 34 %

Op. Mode	Setup	Port
NFC reading	Setup_02	Enclosure

20 dB bandwidth kHz	99% bandwidth kHz	Remarks
0.50	0.44	The 20 dB bandwidth from 13.560184 MHz to 13.560686 MHz is contained within the designated frequency band 13.110 MHz to 14.010 MHz.

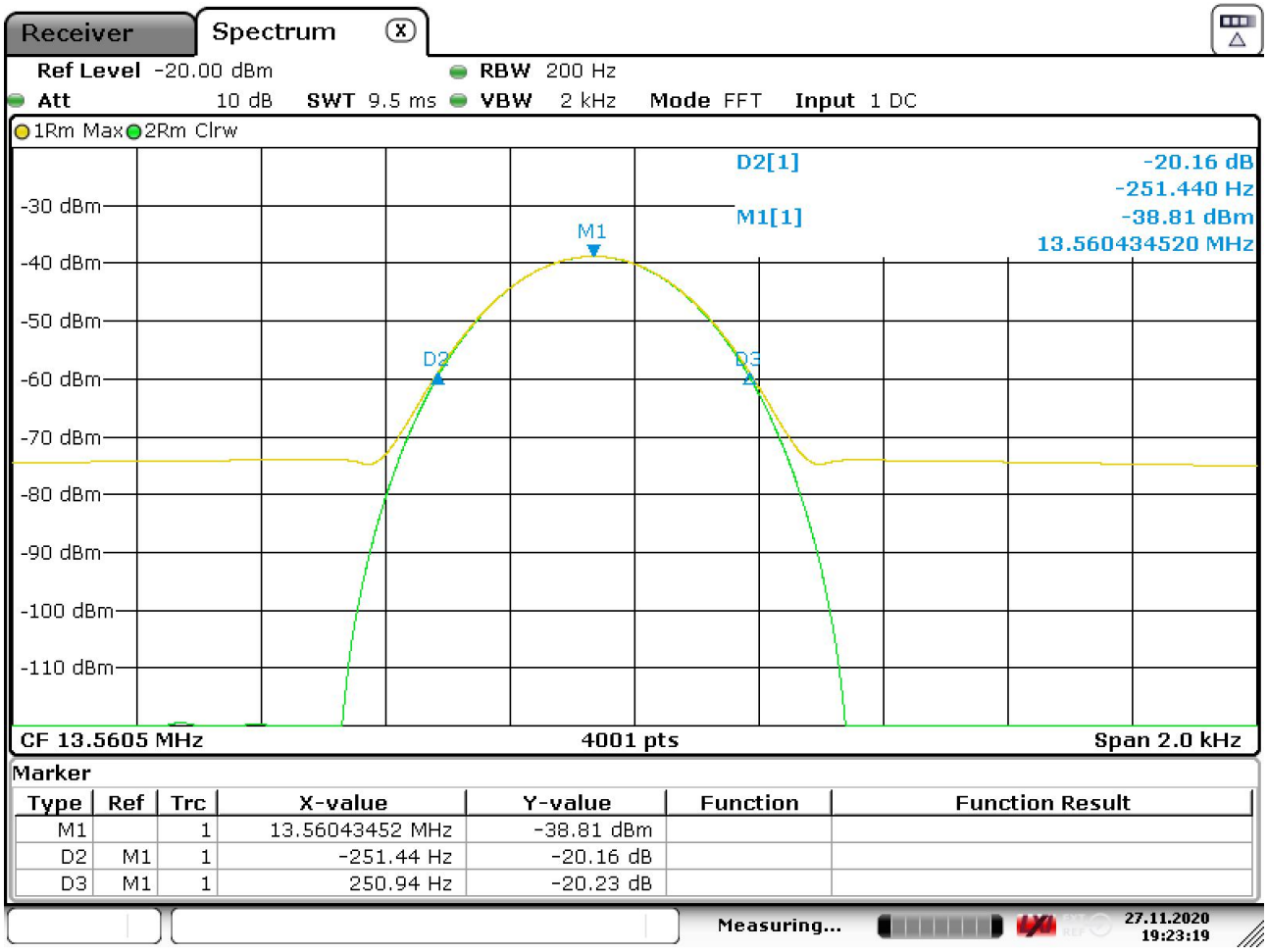
Op. Mode	Setup	Port
NFC polling	Setup_01	Enclosure

20 dB bandwidth kHz	99% bandwidth kHz	Remarks
13.585	27.097	The 20 dB bandwidth from 13.5537 MHz to 13.5673 MHz is contained within the designated frequency band 13.110 MHz to 14.010 MHz.

Remark: None

4.2.4 Measurement Plots (worst case)

4.2.4.1 20 dB bandwidth, NFC reading



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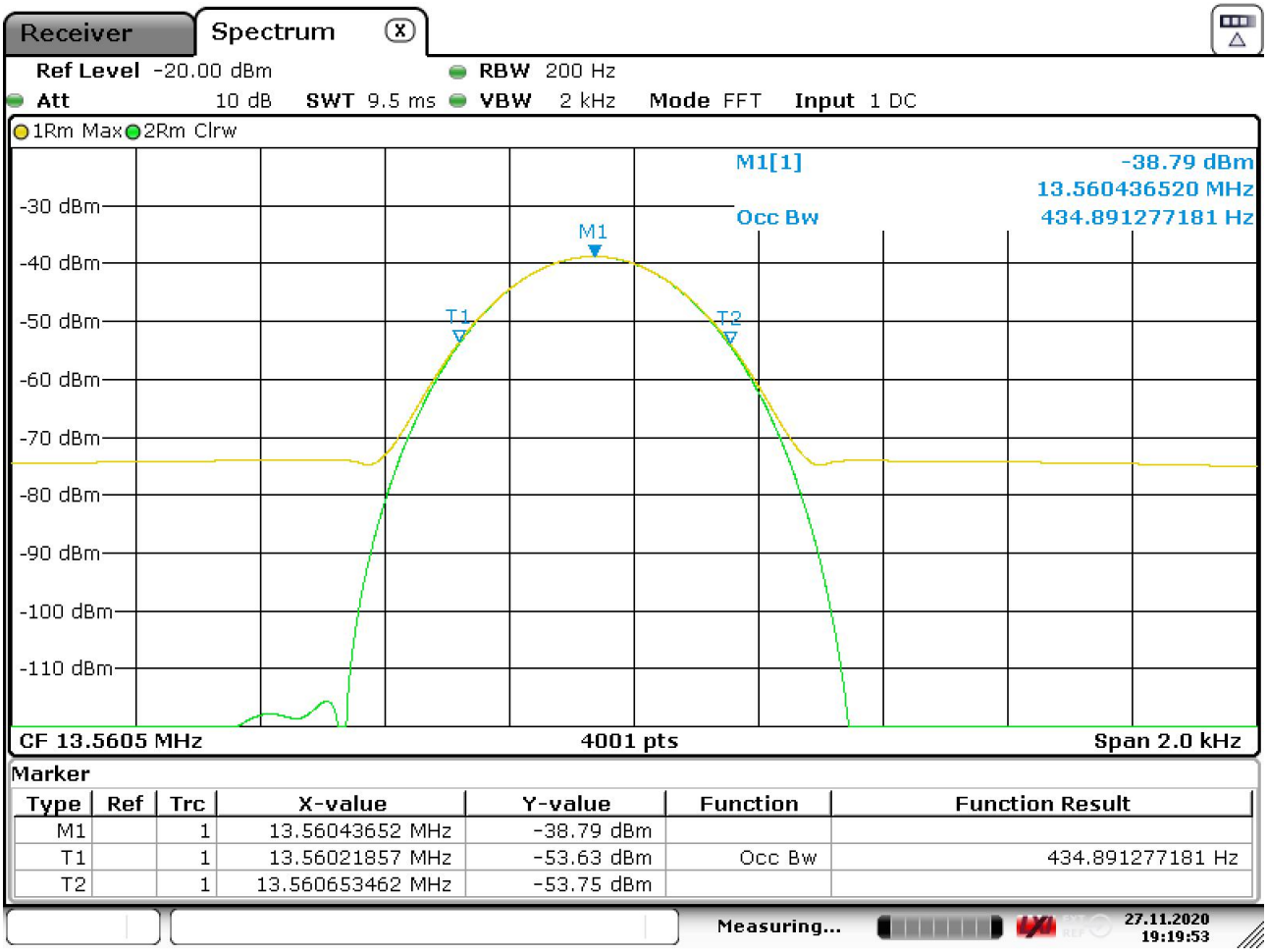
4.2.4.2 99% bandwidth, NFC reading



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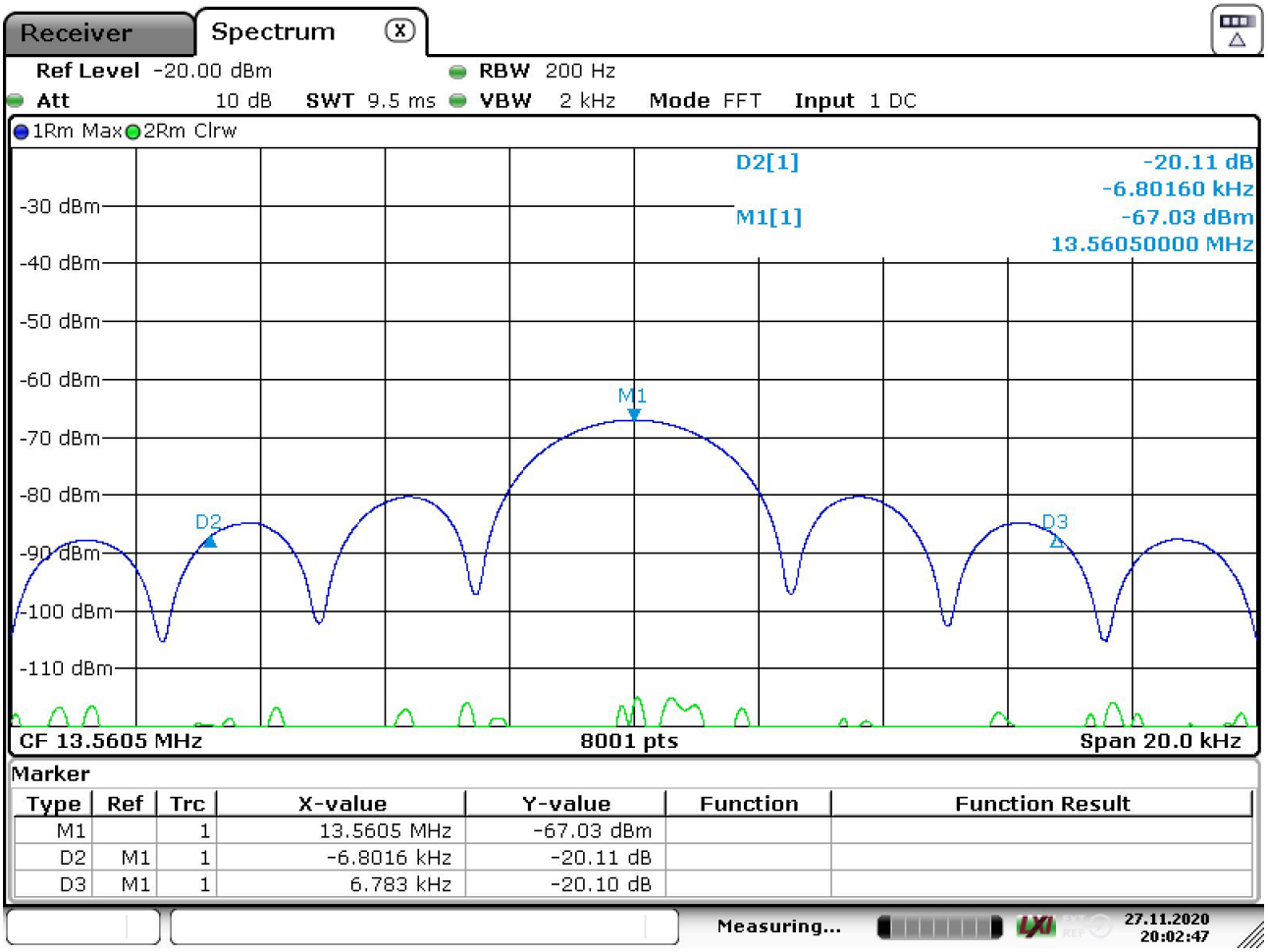
4.2.4.3 20 dB bandwidth, NFC polling



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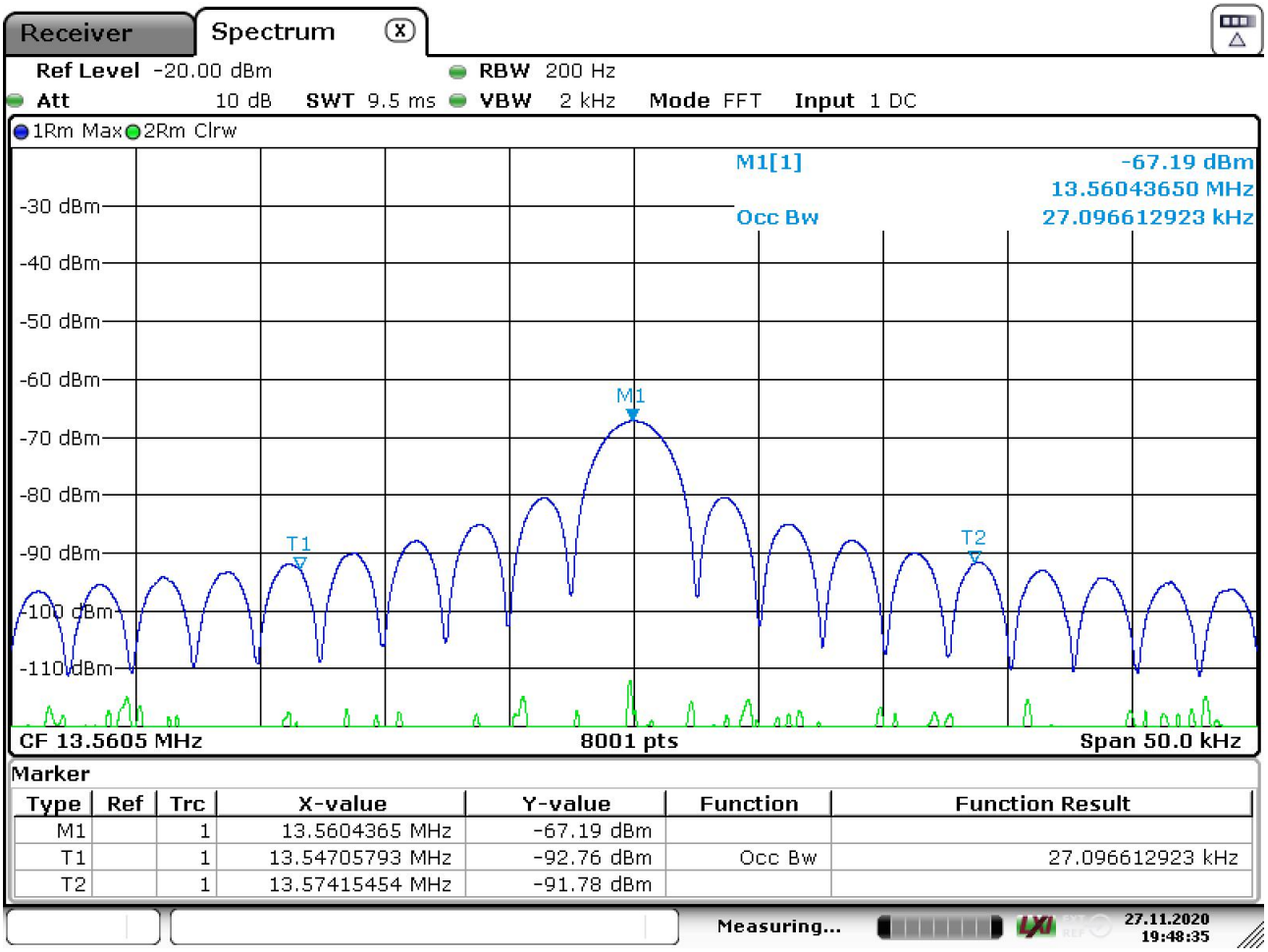
4.2.4.4 99% bandwidth, NFC polling



Date: 27.NOV.2020 19:48:35

4.2.5 Test Equipment used

- Radio Lab

4.3 Spectrum mask

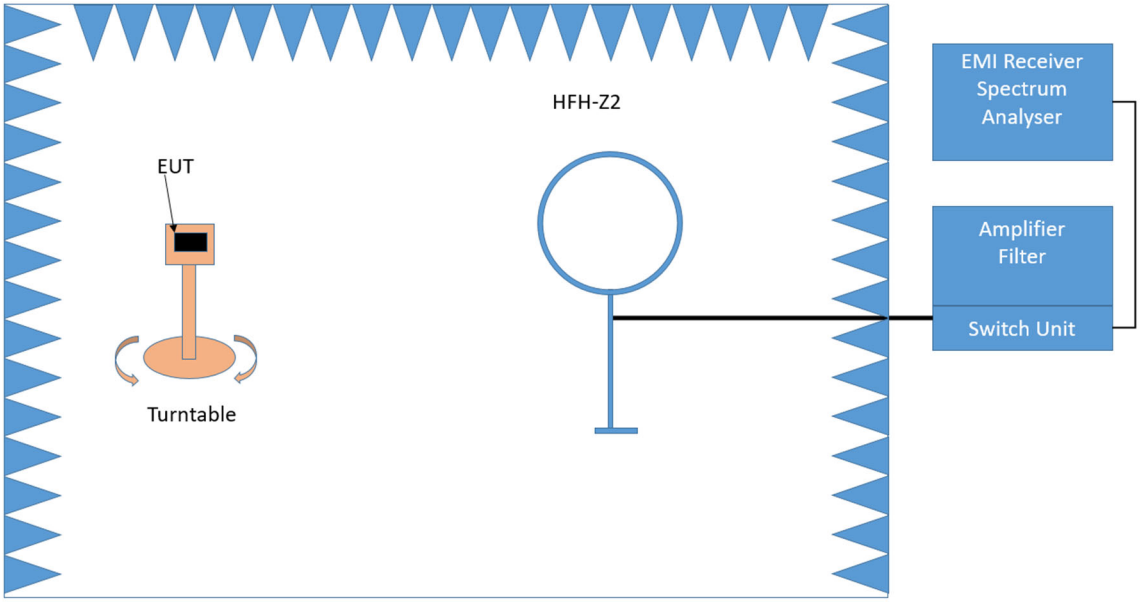
Standard FCC Part 15, Subpart C

The test was performed according to: FCC §15.225

4.3.1 Test Description

The test set-up was made in accordance to the general provisions of ANSI C 63.10.
The Equipment Under Test (EUT) was set up on a non-conductive table in the anechoic chamber.
The radiated emissions measurements were made in a typical installation configuration.
The measurement procedure is implemented into the EMI test software EMC32 from R&S.
The Loop antenna HFH2-Z2 is used.

- Semi-anechoic chamber
- Antenna distance: 3 m
- Detector: Quasi-Peak
- Frequency range: 13.06 – 14.06 MHz
- Frequency steps: 5 kHz
- IF–Bandwidth:10 kHz
- Measuring time / Frequency step: 1 s



Test Setup; Spurious Emission Radiated (SAC), 9 kHz – 30 MHz

4.3.2 Test Limits

FCC Part 15, Subpart C, §15.225 (a-d), and §15.209, corrected by the means of the extrapolation of §15.31 due to the reduced measuring distance from 30 m to 3 m.
The merits of the maximum value as well as the limit are referencing to a distance of 30 m.

4.3.3 Test Protocol

Temperature: 21 °C
Air Pressure: 994 hPa
Humidity: 34 %

Op. Mode	Setup	Port
NFC reading	Setup_02	Enclosure

Maximum value dBµV/m	Limit dBµV/m	Margin dB	Remarks
17.9	84.0	66.1	EUT horizontal, central antenna
18.1	84.0	65.9	EUT horizontal, top antenna
21.1	84.0	62.9	EUT horizontal, bottom antenna
32.2	84.0	51.8	EUT vertical, central antenna
21.0	84.0	63.0	EUT vertical, top antenna
21.0	84.0	63.0	EUT vertical, bottom antenna

Remark: The EUT is tested in vertical and horizontal position for each of the three antennas (main, top, bottom).

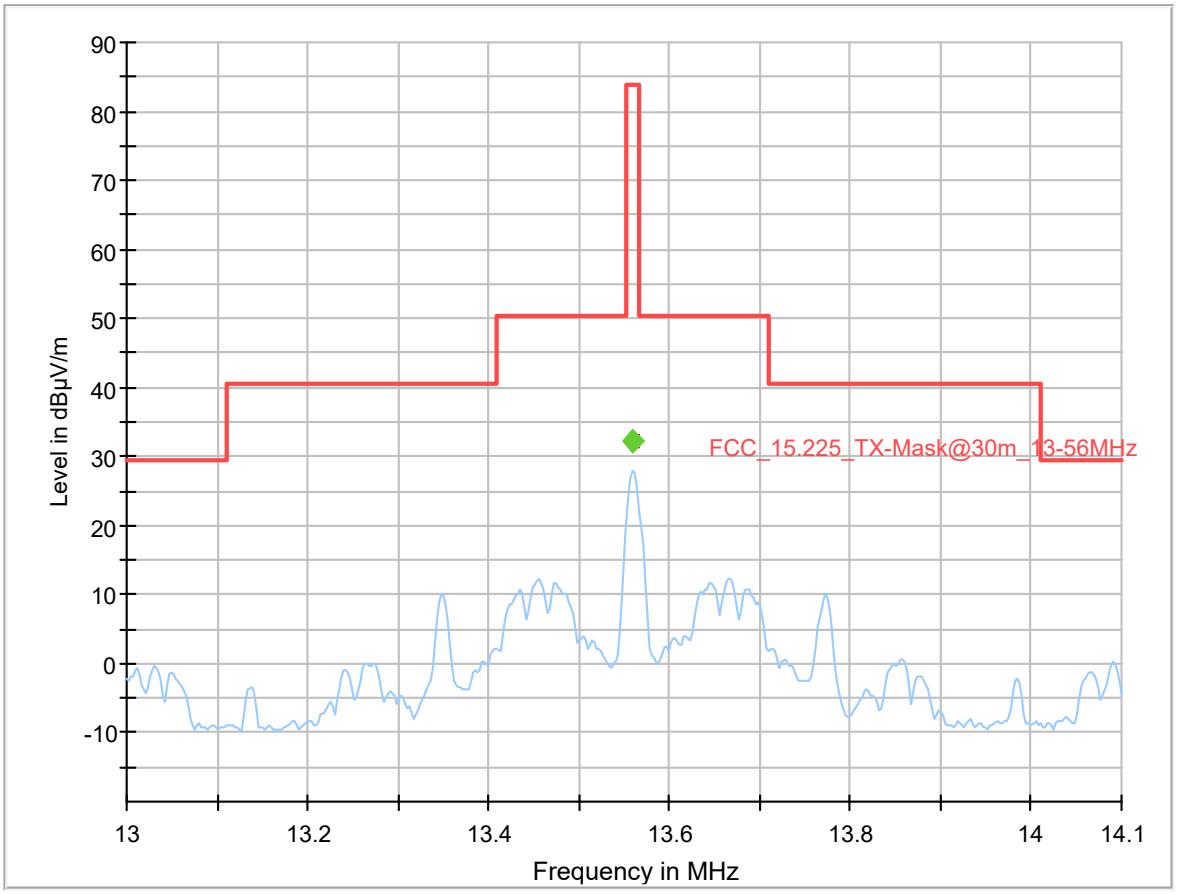
Op. Mode	Setup	Port
NFC polling	Setup_01	Enclosure

Maximum value dBµV/m	Limit dBµV/m	Margin dB	Remarks
19.0	84.0	66.0	EUT vertical, central antenna

Remark: The EUT is tested in the worst-case combination which is determined above.

4.3.4 Measurement Plots (worst case)

4.3.4.1 Setup_02, Mode NFC reading



Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)
13.560000	---	32.21	84.00	51.79	1000.0	9.000	100.0	H	51.0

4.3.5 Test Equipment used

- Radiated Emissions

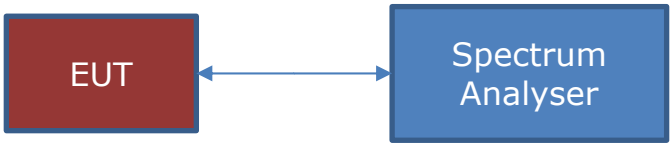
4.4 Frequency tolerance

Standard FCC Part 15, Subpart C

The test was performed according to: FCC §15.225

4.4.1 Test Description

The Equipment Under Test (EUT) is placed in a temperature chamber.
The frequency drift during temperature and voltage variation is measured by the means of a spectrum analyser with frequency counter function.
The temperature was varied from –20 °C to +50 °C. At +20 °C the wider extreme power supply voltages of 8.0 and 16.0 V (instead of 85% and 115%) are applied. After reaching each target temperature and waiting sufficient time allowing the temperature to stabilize, one measurement is performed immediately after powering on the EUT, and two further measurements are performed after 5 and 10 minutes continuous operation of the EUT.



Test Setup for conducted tests

4.4.2 Test Limits

FCC Part 15, Subpart C, §15.225 (e): The frequency tolerance of the carrier signal shall be maintained within ±0.01% of the operating frequency over a temperature variation of -20 degrees to +50 degrees C at normal supply voltage, and for a variation in the primary supply voltage from 85% to 115% of the rated supply voltage at a temperature of 20 degrees C.

4.4.3 Test Protocol

Temperature: 25 °C
Air Pressure: 986 hPa
Humidity: 33 %

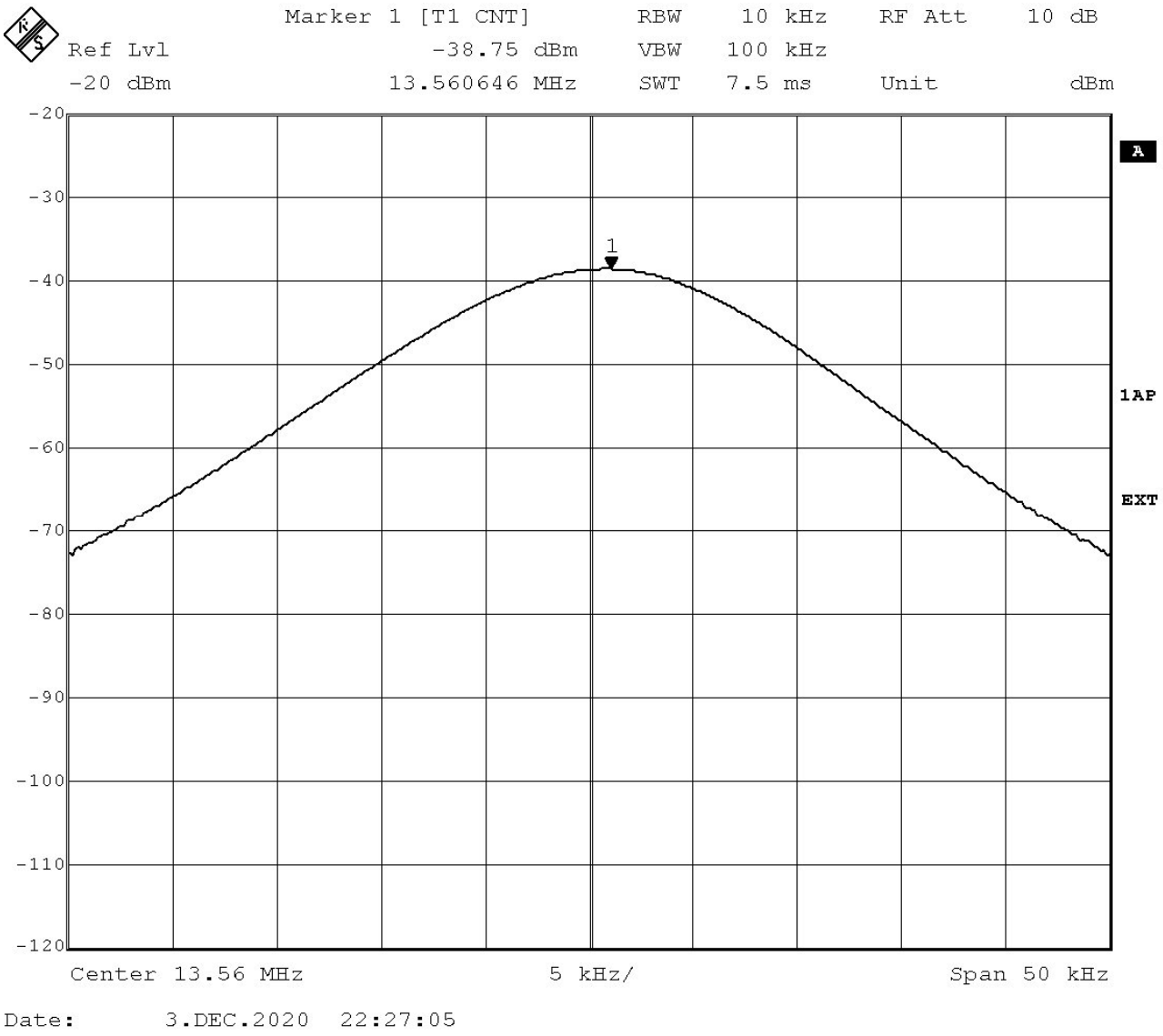
Op. Mode	Setup	Port
NFC reading	Setup_02	Enclosure

Temperature / °C	Voltage / V	Time / min.	Frequency / MHz	Delta / Hz
50	12.0	0	13.560565	565
50	12.0	5	13.560565	565
50	12.0	10	13.560565	565
40	12.0	0	13.560569	569
40	12.0	5	13.560568	568
40	12.0	10	13.560566	566
30	12.0	0	13.560595	595
30	12.0	5	13.560573	573
30	12.0	10	13.560570	570
20	8.0	0	13.560595	595
20	8.0	5	13.560595	595
20	8.0	10	13.560595	595
20	12.0	0	13.560584	584
20	12.0	5	13.560583	583
20	12.0	10	13.560583	583
20	16.0	0	13.560581	581
20	16.0	5	13.560577	577
20	16.0	10	13.560577	577
10	12.0	0	13.560642	642
10	12.0	5	13.560609	609
10	12.0	10	13.560608	608
0	12.0	0	13.560631	631
0	12.0	5	13.560630	630
0	12.0	10	13.560630	630
-10	12.0	0	13.560641	641
-10	12.0	5	13.560646	**646**
-10	12.0	10	13.560646	**646**
-20	12.0	0	13.560644	644
-20	12.0	5	13.560646	**646**
-20	12.0	10	13.560646	**646**

Remark: The limit is a delta of max. ±1356 Hz (0.01 %).
Extreme voltage values greater than ±15 % chosen within the EUT is specified to operate.

Maximum deviation from nominal frequency: 646 Hz

4.4.4 Measurement Plots (worst case)



4.4.5 Test Equipment used

- Radio Lab

5 Test Equipment

1 Radiated Emissions
Lab to perform radiated emission tests

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2020-11	2022-11
1.2	N5000/NP	Filter for EUT, 2 Lines, 250 V, 16 A	ETS-LINDGREN	241515		
1.3	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13	Lufft Mess- und Regeltechnik GmbH	ID 13936	2019-05	2021-05
1.4	ESW44	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz GmbH & Co. KG	101603	2019-12	2021-12
1.5	Anechoic Chamber 01	SAC/FAR, 10.58 m x 6.38 m x 6.00 m	Frankonia	none	2018-06	2021-06
1.6	Anechoic Chamber 03	FAR, 8.80m x 4.60m x 4.05m	Albatross Projects	P26971-647-001-PRB	2018-06	2021-06
1.7	HL 562 ULTRALOG	Biconical-log-per antenna (30 MHz - 3 GHz) with HL 562E biconicals	Rohde & Schwarz GmbH & Co. KG	830547/003	2018-07	2021-07
1.8	AMF-7D00101800-30-10P-R	Broadband Amplifier 100 MHz - 18 GHz	Miteq			
1.9	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
1.10	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2020-04	2021-04
1.11	NRVD	Power Meter	Rohde & Schwarz GmbH & Co. KG	828110/016	2020-08	2021-08
1.12	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2019-02	2021-02
1.13	DS 420S	Turn Table 2 m diameter	HD GmbH	420/573/99		
1.14	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
1.15	TT 1.5 WI	Turn Table	Maturo GmbH	-		
1.16	HL 562 ULTRALOG	Biconical-log-per Antenna (30 MHz - 3 GHz)	Rohde & Schwarz GmbH & Co. KG	100609	2019-05	2022-05
1.17	Air compressor	Anechoic Chamber; 8.8m x 4.6 m x 4.05 m	JUN-AIR Deutschland GmbH	612582		
1.18	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2018-01	2021-01

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.19	Opus10 THI (8152.00)	ThermoHygro Datalogger 12	Lufft Mess- und Regeltechnik GmbH	ID 12482	2019-06	2021-06
1.20	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
1.21	AS 620 P	Antenna Mast (pneumatic polarisation)	HD GmbH	620/37		
1.22	TD1.5-10kg	EUT Tilt Device (Rohacell)	Maturo GmbH	TD1.5-10kg/024/3790709		
1.23	NRV-Z1	Sensor Head B	Rohde & Schwarz GmbH & Co. KG	827753/006	2020-08	2021-08
1.24	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
1.25	AFS42-00101800-25-S-42	Broadband Amplifier 25 MHz - 18 GHz	Miteq	2035324		
1.26	AM 4.0	Antenna Mast 4 m	Maturo GmbH	AM4.0/180/11920513		

2 Radio Lab
Lab to perform conducted tests

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	MFS	Rubidium Frequency Standard	Datum-Beverly	5489/001	2020-09	2021-09
2.2	ESR 7	EMI Receiver / Spectrum Analyzer 10 Hz - 7 GHz	Rohde & Schwarz	101424	2019-01	2021-01
2.3	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2020-04	2021-04
2.4	KWP 120/70	Temperature Chamber	Weiss	5922601219001 0	2020-05	2022-05
2.5	A8455-4	4 Way Power Divider (SMA)		-		
2.6	Opus10 THI (8152.00)	ThermoHygro Datalogger 03 (Environ)	Lufft Mess- und Regeltechnik GmbH	7482	2019-06	2021-06

The calibration interval is the time interval between “Last Calibration” and “Calibration Due”.

6 Antenna Factors, Cable Loss and Sample Calculations

This chapter contains the antenna factors with their corresponding path loss of the used measurement path for all antennas as well as the insertion loss of the LISN.

6.1 LISN R&S ESH3-Z5 (150 kHz – 30 MHz)

Frequency		Corr.	LISN insertion loss ESH3-Z5	cable loss (incl. 10 dB atten-uator)
MHz		dB	dB	dB
0,15		10,1	0,1	10,0
5		10,3	0,1	10,2
7		10,5	0,2	10,3
10		10,5	0,2	10,3
12		10,7	0,3	10,4
14		10,7	0,3	10,4
16		10,8	0,4	10,4
18		10,9	0,4	10,5
20		10,9	0,4	10,5
22		11,1	0,5	10,6
24		11,1	0,5	10,6
26		11,2	0,5	10,7
28		11,2	0,5	10,7
30		11,3	0,5	10,8

Sample calculation

U_{LISN} (dB µV) = U (dB µV) + Corr. (dB)
U = Receiver reading
LISN Insertion loss = Voltage Division Factor of LISN
Corr. = sum of single correction factors of used LISN, cables, switch units (if used)
Linear interpolation will be used for frequencies in between the values in the table.

6.2 Antenna R&S HFH2-Z2 (9 kHz – 30 MHz)

Frequency	AF HFH-Z2)	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-40 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
0,009	20,50	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,01	20,45	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,015	20,37	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,02	20,36	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,025	20,38	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,03	20,32	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,05	20,35	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,08	20,30	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,1	20,20	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,2	20,17	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,3	20,14	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,49	20,12	-79,6	0,1	0,1	0,1	0,1	-80	300	3
0,490001	20,12	-39,6	0,1	0,1	0,1	0,1	-40	30	3
0,5	20,11	-39,6	0,1	0,1	0,1	0,1	-40	30	3
0,8	20,10	-39,6	0,1	0,1	0,1	0,1	-40	30	3
1	20,09	-39,6	0,1	0,1	0,1	0,1	-40	30	3
2	20,08	-39,6	0,1	0,1	0,1	0,1	-40	30	3
3	20,06	-39,6	0,1	0,1	0,1	0,1	-40	30	3
4	20,05	-39,5	0,2	0,1	0,1	0,1	-40	30	3
5	20,05	-39,5	0,2	0,1	0,1	0,1	-40	30	3
6	20,02	-39,5	0,2	0,1	0,1	0,1	-40	30	3
8	19,95	-39,5	0,2	0,1	0,1	0,1	-40	30	3
10	19,83	-39,4	0,2	0,1	0,2	0,1	-40	30	3
12	19,71	-39,4	0,2	0,1	0,2	0,1	-40	30	3
14	19,54	-39,4	0,2	0,1	0,2	0,1	-40	30	3
16	19,53	-39,3	0,3	0,1	0,2	0,1	-40	30	3
18	19,50	-39,3	0,3	0,1	0,2	0,1	-40	30	3
20	19,57	-39,3	0,3	0,1	0,2	0,1	-40	30	3
22	19,61	-39,3	0,3	0,1	0,2	0,1	-40	30	3
24	19,61	-39,3	0,3	0,1	0,2	0,1	-40	30	3
26	19,54	-39,3	0,3	0,1	0,2	0,1	-40	30	3
28	19,46	-39,2	0,3	0,1	0,3	0,1	-40	30	3
30	19,73	-39,1	0,4	0,1	0,3	0,1	-40	30	3

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
distance correction = -40 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values

6.3 Antenna R&S HL562 (30 MHz – 1 GHz)

(d_{Limit} = 3 m)

Frequency	AF R&S HL562	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
30	18,6	0,6	0,29	0,04	0,23	0,02	0,0	3	3
50	6,0	0,9	0,39	0,09	0,32	0,08	0,0	3	3
100	9,7	1,2	0,56	0,14	0,47	0,08	0,0	3	3
150	7,9	1,6	0,73	0,20	0,59	0,12	0,0	3	3
200	7,6	1,9	0,84	0,21	0,70	0,11	0,0	3	3
250	9,5	2,1	0,98	0,24	0,80	0,13	0,0	3	3
300	11,0	2,3	1,04	0,26	0,89	0,15	0,0	3	3
350	12,4	2,6	1,18	0,31	0,96	0,13	0,0	3	3
400	13,6	2,9	1,28	0,35	1,03	0,19	0,0	3	3
450	14,7	3,1	1,39	0,38	1,11	0,22	0,0	3	3
500	15,6	3,2	1,44	0,39	1,20	0,19	0,0	3	3
550	16,3	3,5	1,55	0,46	1,24	0,23	0,0	3	3
600	17,2	3,5	1,59	0,43	1,29	0,23	0,0	3	3
650	18,1	3,6	1,67	0,34	1,35	0,22	0,0	3	3
700	18,5	3,6	1,67	0,42	1,41	0,15	0,0	3	3
750	19,1	4,1	1,87	0,54	1,46	0,25	0,0	3	3
800	19,6	4,1	1,90	0,46	1,51	0,25	0,0	3	3
850	20,1	4,4	1,99	0,60	1,56	0,27	0,0	3	3
900	20,8	4,7	2,14	0,60	1,63	0,29	0,0	3	3
950	21,1	4,8	2,22	0,60	1,66	0,33	0,0	3	3
1000	21,6	4,9	2,23	0,61	1,71	0,30	0,0	3	3

(d_{Limit} = 10 m)

30	18,6	-9,9	0,29	0,04	0,23	0,02	-10,5	10	3
50	6,0	-9,6	0,39	0,09	0,32	0,08	-10,5	10	3
100	9,7	-9,2	0,56	0,14	0,47	0,08	-10,5	10	3
150	7,9	-8,8	0,73	0,20	0,59	0,12	-10,5	10	3
200	7,6	-8,6	0,84	0,21	0,70	0,11	-10,5	10	3
250	9,5	-8,3	0,98	0,24	0,80	0,13	-10,5	10	3
300	11,0	-8,1	1,04	0,26	0,89	0,15	-10,5	10	3
350	12,4	-7,9	1,18	0,31	0,96	0,13	-10,5	10	3
400	13,6	-7,6	1,28	0,35	1,03	0,19	-10,5	10	3
450	14,7	-7,4	1,39	0,38	1,11	0,22	-10,5	10	3
500	15,6	-7,2	1,44	0,39	1,20	0,19	-10,5	10	3
550	16,3	-7,0	1,55	0,46	1,24	0,23	-10,5	10	3
600	17,2	-6,9	1,59	0,43	1,29	0,23	-10,5	10	3
650	18,1	-6,9	1,67	0,34	1,35	0,22	-10,5	10	3
700	18,5	-6,8	1,67	0,42	1,41	0,15	-10,5	10	3
750	19,1	-6,3	1,87	0,54	1,46	0,25	-10,5	10	3
800	19,6	-6,3	1,90	0,46	1,51	0,25	-10,5	10	3
850	20,1	-6,0	1,99	0,60	1,56	0,27	-10,5	10	3
900	20,8	-5,8	2,14	0,60	1,63	0,29	-10,5	10	3
950	21,1	-5,6	2,22	0,60	1,66	0,33	-10,5	10	3
1000	21,6	-5,6	2,23	0,61	1,71	0,30	-10,5	10	3

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
distance correction = -20 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Tables show an extract of values.

6.4 Antenna R&S HF907 (1 GHz – 18 GHz)

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay + cable inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit, atten-uator & pre-amp)	cable loss 4 (to receiver)		
MHz	dB (1/m)	dB	dB	dB	dB	dB		
1000	24,4	-19,4	0,99	0,31	-21,51	0,79		
2000	28,5	-17,4	1,44	0,44	-20,63	1,38		
3000	31,0	-16,1	1,87	0,53	-19,85	1,33		
4000	33,1	-14,7	2,41	0,67	-19,13	1,31		
5000	34,4	-13,7	2,78	0,86	-18,71	1,40		
6000	34,7	-12,7	2,74	0,90	-17,83	1,47		
7000	35,6	-11,0	2,82	0,86	-16,19	1,46		

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay inside chamber)	cable loss 2 (inside chamber)	cable loss 3 (outside chamber)	cable loss 4 (switch unit, atten-uator & pre-amp)	cable loss 5 (to receiver)	used for FCC 15.247
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	
3000	31,0	-23,4	0,47	1,87	0,53	-27,58	1,33	
4000	33,1	-23,3	0,56	2,41	0,67	-28,23	1,31	
5000	34,4	-21,7	0,61	2,78	0,86	-27,35	1,40	
6000	34,7	-21,2	0,58	2,74	0,90	-26,89	1,47	
7000	35,6	-19,8	0,66	2,82	0,86	-25,58	1,46	

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay inside chamber)	cable loss 2 (High Pass)	cable loss 3 (pre-amp)	cable loss 4 (inside chamber)	cable loss 5 (outside chamber)	cable loss 6 (to receiver)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	dB
7000	35,6	-57,3	0,56	1,28	-62,72	2,66	0,94	1,46
8000	36,3	-56,3	0,69	0,71	-61,49	2,84	1,00	1,53
9000	37,1	-55,3	0,68	0,65	-60,80	3,06	1,09	1,60
10000	37,5	-56,2	0,70	0,54	-61,91	3,28	1,20	1,67
11000	37,5	-55,3	0,80	0,61	-61,40	3,43	1,27	1,70
12000	37,6	-53,7	0,84	0,42	-59,70	3,53	1,26	1,73
13000	38,2	-53,5	0,83	0,44	-59,81	3,75	1,32	1,83
14000	39,9	-56,3	0,91	0,53	-63,03	3,91	1,40	1,77
15000	40,9	-54,1	0,98	0,54	-61,05	4,02	1,44	1,83
16000	41,3	-54,1	1,23	0,49	-61,51	4,17	1,51	1,85
17000	42,8	-54,4	1,36	0,76	-62,36	4,34	1,53	2,00
18000	44,2	-54,7	1,70	0,53	-62,88	4,41	1,55	1,91

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
Tables show an extract of values.

6.5 Antenna EMCO 3160-09 (18 GHz – 26.5 GHz)

Frequency	AF EMCO 3160-09	Corr.	cable loss 1 (inside chamber)	cable loss 2 (pre-amp)	cable loss 3 (inside chamber)	cable loss 4 (switch unit)	cable loss 5 (to receiver)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB
18000	40,2	-23,5	0,72	-35,85	6,20	2,81	2,65
18500	40,2	-23,2	0,69	-35,71	6,46	2,76	2,59
19000	40,2	-22,0	0,76	-35,44	6,69	3,15	2,79
19500	40,3	-21,3	0,74	-35,07	7,04	3,11	2,91
20000	40,3	-20,3	0,72	-34,49	7,30	3,07	3,05
20500	40,3	-19,9	0,78	-34,46	7,48	3,12	3,15
21000	40,3	-19,1	0,87	-34,07	7,61	3,20	3,33
21500	40,3	-19,1	0,90	-33,96	7,47	3,28	3,19
22000	40,3	-18,7	0,89	-33,57	7,34	3,35	3,28
22500	40,4	-19,0	0,87	-33,66	7,06	3,75	2,94
23000	40,4	-19,5	0,88	-33,75	6,92	3,77	2,70
23500	40,4	-19,3	0,90	-33,35	6,99	3,52	2,66
24000	40,4	-19,8	0,88	-33,99	6,88	3,88	2,58
24500	40,4	-19,5	0,91	-33,89	7,01	3,93	2,51
25000	40,4	-19,3	0,88	-33,00	6,72	3,96	2,14
25500	40,5	-20,4	0,89	-34,07	6,90	3,66	2,22
26000	40,5	-21,3	0,86	-35,11	7,02	3,69	2,28
26500	40,5	-21,1	0,90	-35,20	7,15	3,91	2,36

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values.

6.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)

Frequency	AF EMCO 3160-10	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
GHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
26,5	43,4	-11,2	4,4				-9.5	3	1
27,0	43,4	-11,2	4,4				-9.5	3	1
28,0	43,4	-11,1	4,5				-9.5	3	1
29,0	43,5	-11,0	4,6				-9.5	3	1
30,0	43,5	-10,9	4,7				-9.5	3	1
31,0	43,5	-10,8	4,7				-9.5	3	1
32,0	43,5	-10,7	4,8				-9.5	3	1
33,0	43,6	-10,7	4,9				-9.5	3	1
34,0	43,6	-10,6	5,0				-9.5	3	1
35,0	43,6	-10,5	5,1				-9.5	3	1
36,0	43,6	-10,4	5,1				-9.5	3	1
37,0	43,7	-10,3	5,2				-9.5	3	1
38,0	43,7	-10,2	5,3				-9.5	3	1
39,0	43,7	-10,2	5,4				-9.5	3	1
40,0	43,8	-10,1	5,5				-9.5	3	1

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
distance correction = -20 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values.

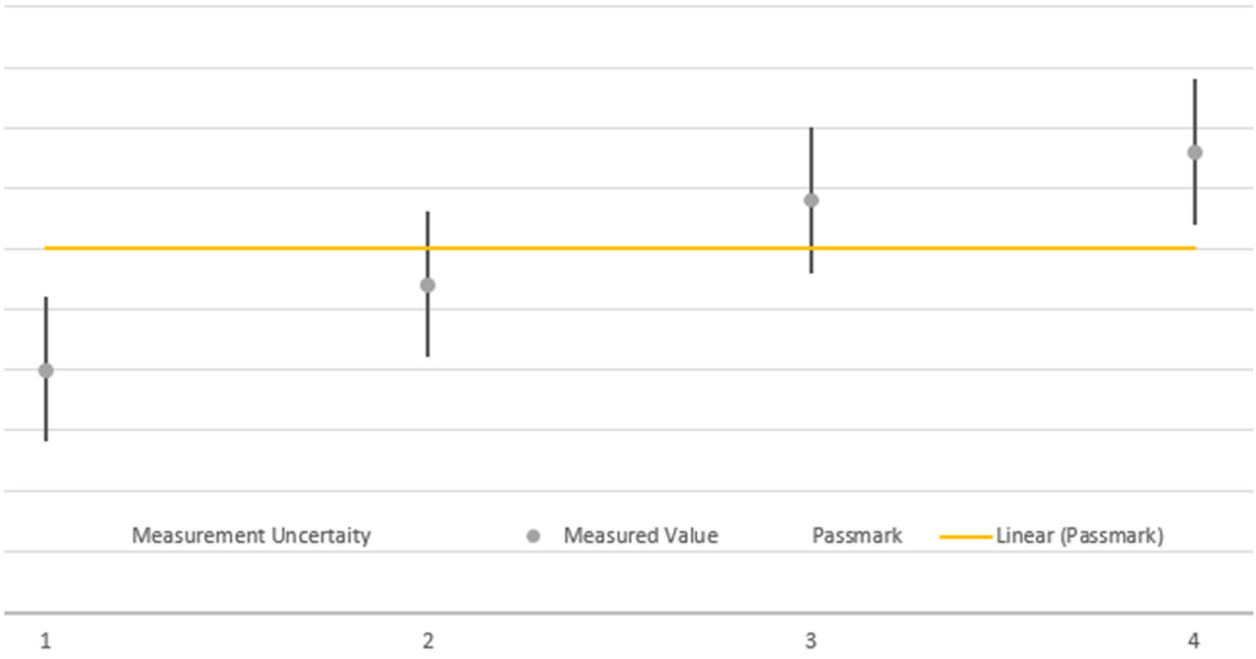
7 Photo Report

Photos are included in an external report.

8 Measurement uncertainty

Test Case	Parameter	Uncertainty
Peak power output	Fieldstrength	± 5.5 dB
Occupied bandwidth	Power Frequency:	± 2.9 dB ± 0.125 kHz
Spurious radiated emissions	Fieldstrength Frequency:	± 5.5 dB ± 11.2 kHz
AC Power Line	Power	± 3.4 dB
Frequency tolerance (frequency counter)	Frequency	± 2 Hz

The measurement uncertainties for all parameters are calculated with an expansion factor (coverage factor) k = 1.96. This means, that the true value is in the corresponding interval with a probability of 95 %.



The verdicts in this test report are given according the above diagram:

Case	Measured Value	Uncertainty Range	Verdict
1	below pass mark	below pass mark	Passed
2	below pass mark	within pass mark	Passed
3	above pass mark	within pass mark	Failed
4	above pass mark	above pass mark	Failed

That means, the laboratory applies, as decision rule (see ISO/IEC 17025:2017), the so called shared risk principle.