InterLab

FCC Measurement/Technical Report on

111 kHz Transceiver Wireless Power Transfer

WCH-193c, 9J1.035.504.A

FCC ID: RK7193-00
IC: 4774A-19300

Report Reference: MDE_LAIRD_1812_FCCa_rev1

Test Laboratory:
7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany

Deutsche Akkreditierungsstelle D-PL-12140-01-00

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1 Summary

1.1 Technical Report Summary

Type of Authorization

Certification for an intentional radiator: 111 kHz transmitter and load modulation system

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 (10-1-17 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

§ 2.1049 Occupied bandwidth

§ 15.205 Restricted bands of operation

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

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

WPT Devices

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-216 Issue 2: 6.2.2.1 ICES-001 Issue 4: 4, 5, 7.1.1 CAN/CSA-CEI/IEC CISPR 11:04
Transmitter spurious radiated emissions	§ 15.209	RSS-216 Issue 2: 6.2.2.2 ICES-001 Issue 4: 4, 5, 7.1.1 CAN/CSA-CEI/IEC CISPR 11:04
Restricted Bands	§ 15.205	RSS-Gen Issue 5: 8.10 RSS-216 Issue 2: 6.2.3
Wanted Emission (Carrier)	§ 15.209	RSS-216 Issue 2: 6.2.2.2 ICES-001 Issue 4: 4, 5, 7.1.1 CAN/CSA-CEI/IEC CISPR 11:04
Other requirements, e.g. Transmitter frequency stability	–	RSS-Gen Issue 5: 6.11/8.11
Receiver spurious emissions	–	RSS-216 Issue 2: 6.2.2.1 ICES-001 Issue 4: 4, 5, 7.1.1 CAN/CSA-CEI/IEC CISPR 11:04
Occupied bandwidth	§ 2.1049	RSS-Gen Issue 5: 6.7

Notes:
This EUT is classified as WPT Transmitter Type 1.
Precise / exhaustive versions of the Standards:
ICES-001: ICES-001, Issue 4, June 2006, updated November 2014
CISPR 11: CAN/CSA-CEI/IEC CISPR 11:04 (R2013): “This National Standard of Canada is equivalent to International Standard CEI/IEC CISPR 11:2003.”
Publish date: 2004-06-01, Reaffirmed: 2013-09-11
Applied Standard: IEC CISPR 11:2003 + A1:2004, Edition 4.1, 2004-06

1.3 Measurement Summary / Signatures

47 CFR Chapter I FCC Part 15, Subpart C	§15.209		
Radiated Emissions			
The measurement was performed according to ANSI C63.10			
OP-Mode	**Setup**	**Port**	**Final Result**
WPT_act	Setup_02	Enclosure	passed

47 CFR Chapter I FCC Part 15, Subpart C	§15.209		
Peak Output Power			
The measurement was performed according to ANSI C63.10			
OP-Mode	**Setup**	**Port**	**Final Result**
WPT_act	Setup_02	Enclosure	passed

47 CFR Chapter I FCC Part 15, Subpart C	§15.207		
Conducted Emissions AC Power line			
The measurement shall be performed according to ANSI C63.10			
OP-Mode	**Setup**	**Port**	**Final Result**
–	–	–	N/A (1)

47 CFR Chapter I FCC Part 2, Subpart J	§2.1049		
Occupied Bandwidth			
The measurement was performed according to ANSI C63.10			
OP-Mode	**Setup**	**Port**	**Final Result**
WPT_act	Setup_02	Enclosure	performed

RSS-Gen	6.11/8.11		
Frequency Stability			
The measurement shall be performed according to ANSI C63.10			
OP-Mode	**Setup**	**Port**	**Final Result**
–	–	–	N/A (2)

Notes:

N/A = Not applicable
(*) Tested in the frequency range 9 kHz to 30 MHz.
(1) The EUT is DC powered. It is only intendent for the use in vehicles.
(2) Not required per 8.11.
performed = no limit is applicable to the test result.

1.4 Revision History

Version	Release date	Change Description	Version validity
initial	2019-02-15	--	invalid
rev1	2019-04-25	• Note added to the EUT setups explaining the usage of a "spacer" to represent possible worst-case conditions. • Removal of ping mode and all related items, as requested by the TCB, i.e.: Removal of Setup_01, EUT A and the related results. • Change of WPT Transmitter Type from 3 to 1, as declared by ISED answer on 2016-04-13 to an inquiry to "ConsultationRadioStandards-ConsultationNormesRadio (IC)". • Adding ISED CAB Identifier at Administrative Data	valid

Responsible for Accreditation Scope: D. Gelle

Responsible for Test Report: A. Pet

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

This facility has been fully described in a report submitted to the FCC and accepted under the registration number 96716 and IC(ISED) under the registration number: Site# 3699A-1

The test facility is also accredited by the following accreditation organisation:

Laboratory accreditation no:	DAkkS D-PL-12140-01-00
FCC Designation Number:	DE0015
FCC Test Firm Registration:	929146
ISED CAB Identifier	DE0007
Responsible for accreditation scope:	Dipl.-Ing. Daniel Gall
Report Template Version:	2019-01-22

2.2 Project Data

Responsible for testing and report:	Dipl.-Ing. Andreas Petz
Employees who performed the tests:	documented internally at 7Layers
Date of Report:	2019-04-25
Testing Period:	2019-01-04 to 2019-02-11

2.3 Applicant Data

Company Name:	Laird Dabendorf GmbH
Address:	Märkische Strasse 72 15806 Zossen Germany
Contact Person:	Mr. Heiko Dörschel

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	Wireless Power Transfer System, Power Transmitter
Product Name	Wireless Charger WCH-193c, 9J1.035.504.A
Type Designation:	WCH-193
Kind of Device:	111 kHz Transceiver Wireless Power Transfer
Voltage Type:	DC
Voltage level:	12 V nominal and tested voltage

3.1.1. General product description:

The EUT is a wireless power transmitter operating as transceiver according to the Qi-Standard on 111 kHz. It will be integrated by professionals in vehicles in vertical position.

According to applicant's information:

WCH-193c is a Wireless Charging Unit (WCU), i.e. a phone cradle which provides wireless charging technology in accordance with the WPC Qi 1.3 standard and antenna coupling to a mobile phone. The charging function is started after the WCU has obtained a successful response from the receiver towards a ping cycle initiated by the WCU. A ping cycle can be started immediately from the WCU due to object changing detected by a proximity sensor (CAP sensor) or after a certain, defined time (1 minute), depending on the state of the WCU. After a successful response the mobile phone has communicated to the WCU that it is chargeable according to the Qi wireless charging standard.

3.1.2. Specific product description for the EUT:

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

3.1.3. The EUT provides the following ports:

- Enclosure
- DC connector
- CAN bus
- FAKRA output from passive antenna coupler
- KESSY signal

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 B (Code: DE1340001ad01)	Wireless Charger WCH-193c, 9J1.035.504.A	WCH-193	000002B70018	H03	0002

Note: The short description is used to simplify the identification of the EUT in this test report.

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	WPT Test Receiver with 5 W artificial load	Novero, EMC WCH testreceiver DAB15131E	SN 0003	V.3.4	–
AUX 2	Bias-Tee incl. loads: 50 ohm at RF & 10 kohm at DC	Mini-Circuits ZFBT-6G+	R UU34901805	–	–

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_02	EUT B + AUX 1 + AUX 2	EUT B has a special firmware variant providing "charging" mode for the test purpose (the power receiver does not contain any kind of battery, charging current is constant); AUX 2 terminates the port "FAKRA"

Note:
The tests have been carried out using an additional "spacer" between the EUT and AUX1: Close contact to power transmitter, central position, separated by dedicated plastic support and for test purpose additional 6 mm spacer (pressboard).
This setup has been chosen in order to represent the "worst-case" positioning (max. distance between EUT and AUX1) that generates the highest, "worst-case" emissions, simulating if a smartphone is used together with a customer-added protective bag (pouch, case, sleeve, flip case, cover, outdoor bumper), which has not been excluded by the applicant.
The same "worst-case" set-up is used as requested by ETSI EN 303 417 V1.1.1 (2017-09).

3.6 Operating Modes

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

Op. Mode	Description of Operating Modes	Remarks
WPT_act	Maximum power is transferred from the EUT to AUX 1	EUT is transmitting continuously at 111 kHz and information between the AUX 1 and the EUT is exchanged by load modulation

3.7 Special software used for testing

Variants of the normal firmware are used to provide the desired operating modes without the necessity of maintaining a CAN bus connection.

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 EMI test software EMC32 from R&S. (Exploratory) Tests are performed at 2 orthogonal EUT orientations (vertical and horizontal) to determine the worst-case EUT orientation. In combination with the turntable rotation, emissions of at least 3 orthogonal axes are detected.

1. Measurement up to 30 MHz
The Loop antenna HFH2-Z2 is used.

Step 1: pre measurement
- Anechoic chamber
- Antenna distance: 3 m
- Antenna height: 1 m (lowest part to ground)
- Detector: Peak-Maxhold
- Frequency range: 0.009 - 0.15 MHz and 0.15 – 30 MHz
- Frequency steps: 0.05 kHz and 2.25 kHz
- IF–Bandwidth: 0.2 kHz and 9 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 will be performed with the following changed settings. 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

Step 1: Preliminary scan
This is a 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 – 3 m
- Height variation step size: 2 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 by ± 45° around this value. 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 by ± 100 cm around the antenna height determined. 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: ± 45 ° around the determined value
- Height variation range: ± 100 cm around the determined value
- 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

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

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limit (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)	Limit (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
26000 - 40000	500@3m	1	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)

2) RSS-216, 6.2.2.2, Radiated Emission Limits

The raw values obtained at the measurement distance are extrapolated to the FCC's definition distance. The limits defined in RSS-216 are calculated for these FCC's distances in order to include the limits directly in one measurement plot and to demonstrate if compliance is achieved. The verdict related to RSS-216 is basing on the margin which is constant for different distances and i.e. is not altered by these linear transformations.

Limits CISPR 11, table 3b for induction cooking (group 2) equipment:

Frequency in MHz	Limit (RSS-216) (dBµA/m) @3m	Measurement distance (m)	Limit (dBµV/m) @ FCC distance	Frequency in MHz
0.009 – 0.070	69	3	(40.5)@300m	0.009 – 0.070
0.070 – 0.1485	69 – 39 *)	3	(40.5 – 10.5)@300m	0.070 – 0.1485
0.1485 – 4.0	39 – 3 *)	3	(10.5 – -2.5)@300m	0.1485 – 0.49
			(37.5 – 14.5)@30m	0.49 – 4.0
4.0 – 30.0	3	3	(14.5)@30m	4.0 – 30.0

*) Decreasing linearly with logarithm of frequency

The alternate 60 cm loop test method and corresponding limits for small residential WPT devices is used for the tests in the frequency range 9 kHz – 30 MHz.

The measured field strength is extrapolated to the distance specified using the formula indicating that the field strength varies as the inverse distance square (40 dB per decade of distance), according to RSS-Gen, 6.5.
For fractal values of definition and reference distance the factor of $40*LOG_{10}(d_{ref}/d_{def})$ applies.
Relation between electrical and magnetic field strength: dBµV = dBµA + 51.5 dB.

Limits CISPR 11, table 4 for group 2 class B equipment (quasi-peak limits):

Frequency in MHz	Limit (RSS-216) (dBµV/m) @10m	Measurement distance (m)	Limit (dBµV/m) @ FCC distance
30 – 80.872	30	3	40.5@3m
80.872 – 81.848	50	3	60.5@3m
81.848 – 134.786	30	3	40.5@3m
134.786 – 136.414	50	3	60.5@3m
136.414 – 230	30	3	40.5@3m
230 – 1000	37	3	47.5@3m

Transformation of the limit at 10 m to the distance of 3 m: $20*LOG_{10}(10m/3m) = 10.5$ dB

4.1.3. Test Protocol

Temperature: 23 °C
Air Pressure: 1030 hPa
Humidity: 41 %

Measurement up to 30 MHz

Op. Mode	Setup	Port
WPT_act	Setup_02	Enclosure

Antenna orien-tation	EUT orien-tation	Fre-quency 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
–	–	–	–	–	–	–	–	–	–	–

Remark: The margin is related to the FCC limits. Margin related to RSS-216 limits is given in sub-clause 4.1.4.

Measurement above 30 MHz

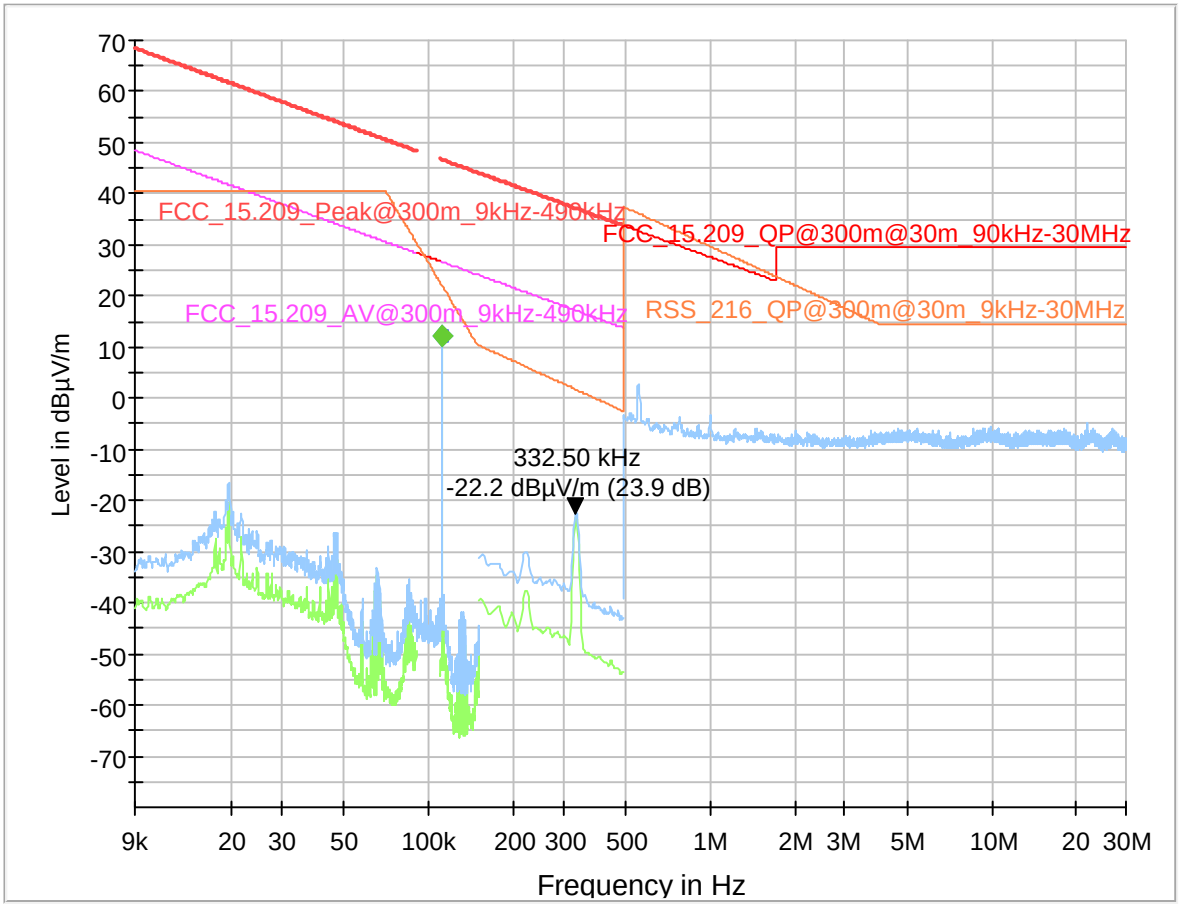
Op. Mode	Setup	Port
WPT_act	Setup_02	Enclosure

Antenna orien-tation	EUT orien-tation	Fre-quency 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
–	–	–	–	–	–	–	–	–	–	–

Remark: None.

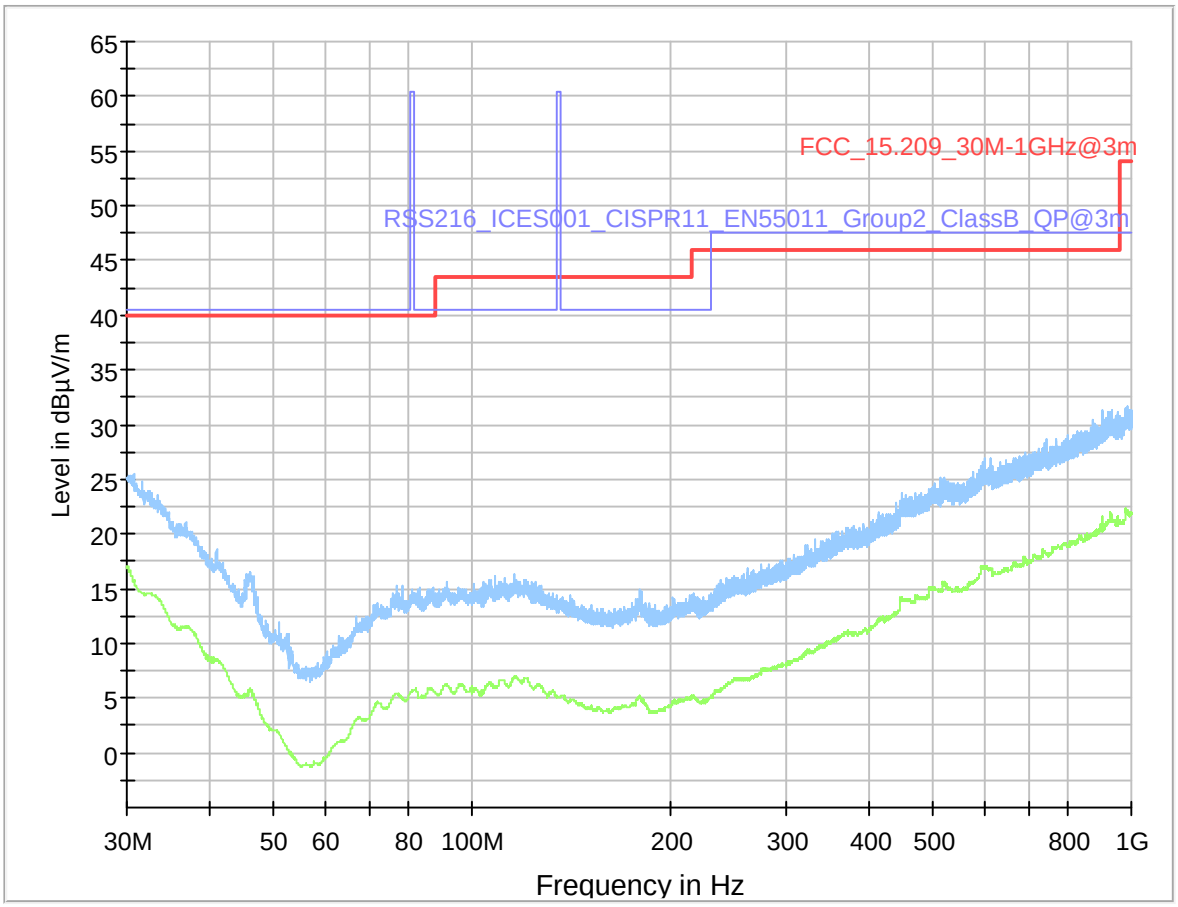
4.1.4. Measurement Plots (worst case)

Below 30 MHz, Setup_02



Note: The marker shows the margin to the RSS-216 limit (in brackets).

Above 30 MHz, Setup_02



4.1.5. Test Equipment used

- Radiated Emissions

4.2 Peak power output

Standard FCC Part 15, Subpart C

The test was performed according to: ANSI C63.10

4.2.1. Test Description

Please refer to sub-clause 4.1.1.

4.2.2. Test Limits

Please refer to sub-clause 4.1.2.

4.2.3. Test Protocol

Temperature: 23 °C
Air Pressure: 1030 hPa
Humidity: 41 %

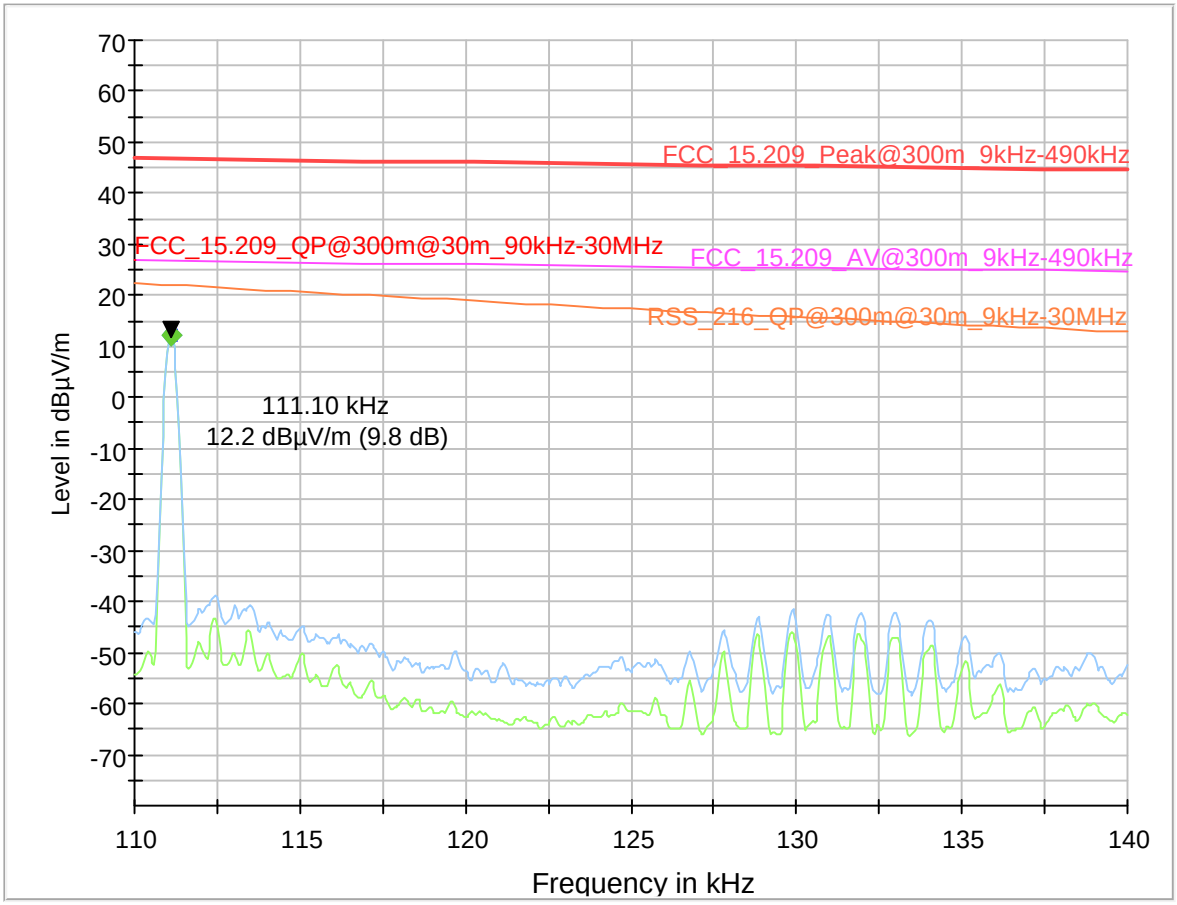
Op. Mode	Setup	Port
WPT_act	Setup_02	Enclosure

Antenna orien-tation	EUT orien-tation	Frequency kHz	Maximum radiated field strength at fundamental frequency (corrected) dBµV/m	Limit dBµV/m	Margin dB
			AV = PK	AV	AV
Parallel	Vertical	111.10	12.2	26.7	14.5

Remark: The margin is related to the FCC limits. Margin related to RSS-216 limits is given in sub-clause 4.2.4.

4.2.4. Measurement Plot (worst case)

Setup_02



Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
0.111100	---	12.22	26.71	14.49	1000.0	0.200	100.0	V	-187.0	-59.6
0.111100	12.23	---	46.71	34.48	1000.0	0.200	100.0	V	-187.0	-59.6

Note: The marker shows the margin to the RSS-216 limit (in brackets).

4.2.5. Test Equipment used

- Radiated Emissions

4.3 Occupied bandwidth

Standard FCC Part 2, Subpart J, §2.1049

The test was performed according to: ANSI C63.10

4.3.1. Test Description

The Equipment Under Test (EUT) was setup in a shielded room to perform the occupied bandwidth measurements.
The results recorded were measured with the modulation which produces the worst-case (widest) occupied bandwidth.

4.3.2. Test Requirements / Limits

FCC Part 15, Subpart C, §15.209 does not contain any requirement related to the bandwidth.

4.3.3. Test Protocol

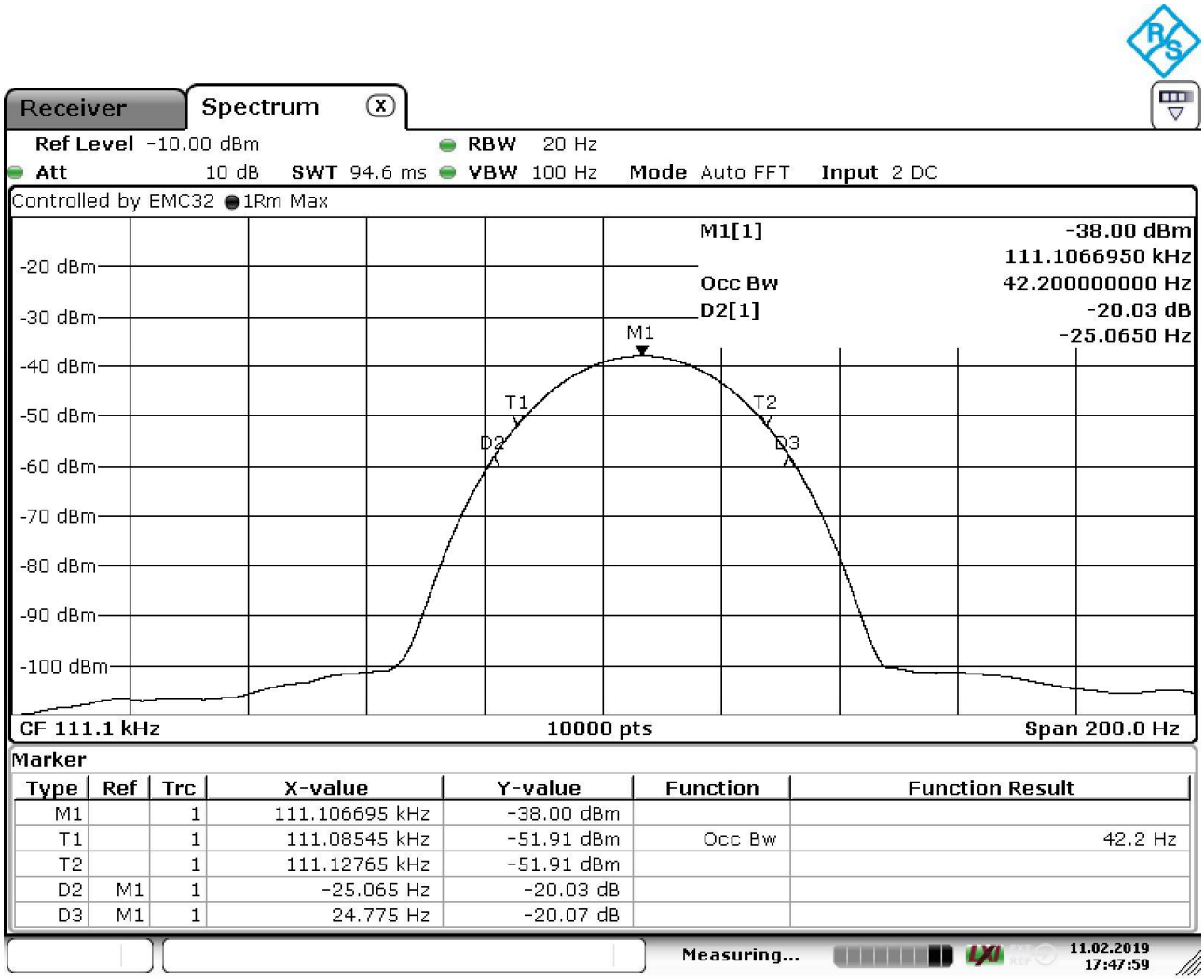
Temperature: 24 °C
Air Pressure: 1018 hPa
Humidity: 34 %

Op. Mode	Setup	Port
WPT_act	Setup_02	Enclosure

20 dBc bandwidth	99% occupied bandwidth
0.05 kHz	0.04 kHz

4.3.4. Measurement Plot (worst case)

20 dBc Bandwidth and 99% Occupied Bandwidth, Setup_02



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4.3.5. Test Equipment used

- Radiated Emissions

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	NRV-Z1	Sensor Head A	Rohde & Schwarz GmbH & Co. KG	827753/005	2018-07	2019-07
1.2	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2018-10	2019-10
1.3	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
1.4	ESW44	EMI Test Receiver	Rohde & Schwarz GmbH & Co. KG	101603	2018-05	2019-05
1.5	Anechoic Chamber	10.58 x 6.38 x 6.00 m³	Frankonia	none	2018-06	2020-06
1.6	FS-Z60	Harmonic Mixer 40 - 60 GHz	Rohde & Schwarz Messgerätebau GmbH	100178	2016-12	2019-12
1.7	FS-Z220	Harmonic Mixer 140 - 220 GHz	Rohde & Schwarz Messgerätebau GmbH	101005	2017-03	2020-03
1.8	SGH-05	Standard Gain / Pyramidal Horn Antenna (140 - 220 GHz)		075		
1.9	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2018-07	2021-07
1.10	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
1.11	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
1.12	Fully Anechoic Room	8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	2018-06	2020-06
1.13	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
1.14	NRVD	Power Meter	Rohde & Schwarz GmbH & Co. KG	828110/016	2018-07	2019-07
1.15	HF 906	Double-ridged horn	Rohde & Schwarz	357357/002	2018-09	2021-09
1.16	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
1.17	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2016-12	2018-12
1.18	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronic GmbH	00083069		

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.19	SGH-19	Standard Gain / Pyramidal Horn Antenna (40 - 60 GHz)		093		
1.20	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
1.21	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
1.22	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
1.23	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
1.24	TT 1.5 WI	Turn Table	Maturo GmbH	-		
1.25	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
1.26	HF 906	Double-ridged horn	Rohde & Schwarz	357357/001	2018-03	2021-03
1.27	FS-Z325	Harmonic Mixer 220 - 325 GHz	Rohde & Schwarz Messgerätebau GmbH	101006	2017-03	2020-03
1.28	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronic GmbH	00086675		
1.29	SGH-08	Standard Gain / Pyramidal Horn Antenna (90 - 140 GHz)		064		
1.30	SGH-12	Standard Gain / Pyramidal HornAntenna (60 - 90 GHz)		326		
1.31	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008		
1.32	FS-Z140	Harmonic Mixer 90 -140 GHz	Rohde & Schwarz Messgerätebau GmbH	101007	2017-02	2020-02
1.33	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2018-01	2021-01
1.34	Opus10 THI (8152.00)	ThermoHygro Datalogger 12 (Environ)	Lufft Mess- und Regeltechnik GmbH	12482	2017-03	2019-03
1.35	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2019-01	2020-01
1.36	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
1.37	AS 620 P	Antenna mast	HD GmbH	620/37		
1.38	Tilt device Maturo (Rohacell)	Antrieb TD1.5-10kg	Maturo GmbH	TD1.5-10kg/024/3790709		
1.39	SGH-03	Standard Gain / Pyramidal Horn Antenna (220 - 325 GHz)		060		

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.40	FS-Z90	Harmonic Mixer 60 - 90 GHz	Rohde & Schwarz Messgerätebau GmbH	101686	2017-03	2020-03
1.41	ESIB 26	Spectrum Analyzer	Rohde & Schwarz	830482/004	2018-01	2020-01
1.42	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
1.43	AFS42-00101800-25-S-42	Broadband Amplifier 25 MHz - 18 GHz	Miteq	2035324		
1.44	AM 4.0	Antenna mast	Maturo GmbH	AM4.0/180/1192 0513		
1.45	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2018-07	2021-07

2 R&S TS8997
Lab to perform bandwidth test

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	SMB100A	Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	107695	2017-07	2020-07
2.2	MFS	Rubidium Frequency Standard	Datum-Beverly	5489/001	2018-07	2019-07
2.3	1515 / 93459	Broadband Power Divider SMA (Aux)	Weinschel Associates	LN673		
2.4	FSV30	Signal Analyzer 10 Hz - 30 GHz	Rohde & Schwarz	103005	2018-04	2020-04
2.5	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
2.6	VT 4002	Temperature Chamber	Vötsch	58566002150010	2018-04	2020-04
2.7	A8455-4	4 Way Power Divider (SMA)		-		
2.8	Opus10 THI (8152.00)	ThermoHygro Datalogger 03 (Environ)	Lufft Mess- und Regeltechnik GmbH	7482	2017-03	2019-03
2.9	SMBV100A	Vector Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	259291	2016-10	2019-10
2.10	OSP120	Switching Unit with integrated power meter	Rohde & Schwarz	101158	2018-05	2021-05

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.

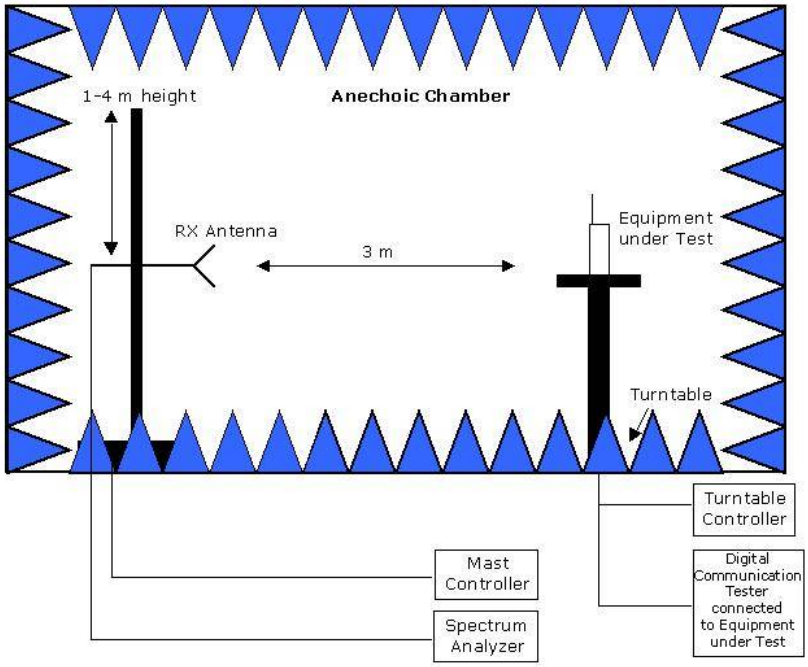
6.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)

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 Setup Drawings



Drawing 1: Setup in the Anechoic chamber:
Measurements below 1 GHz: Semi-anechoic, conducting ground plane.
Measurements above 1 GHz: Fully-anechoic, absorbers on all surfaces.

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

9 Photo Report

Photos are included in an external report.