FCC Measurement/Technical Report on

RFID MultiPen LF-HF-UHF Multipen APOLLO

FCC ID: 2APYK-MULTIPEN3
IC: ---

Report Reference: MDE_TECTU_1701_FCCa_Rev1

Test Laboratory:
7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany

Deutsche Akkreditierungsstelle
D-PL-12140-01-00

Note:
The following test results relate only to the devices specified in this document. This report shall not be reproduced in parts without the written approval of the test laboratory.

Table of Contents

0 Summary 3

0.1 Technical Report Summary 3
0.2 Applicable FCC Rules 3
0.3 FCC-IC Correlation Table 4
0.4 Measurement Summary / Signatures 5

1 Administrative Data 6

1.1 Testing Laboratory 6
1.2 Project Data 6
1.3 Applicant Data 6
1.4 Manufacturer Data 6

2 Test object Data 7

2.1 General EUT Description 7
2.2 EUT Main components 8
2.3 Ancillary Equipment 8
2.4 Auxiliary Equipment 9
2.5 EUT Setups 9
2.6 Operating Modes 9
2.7 Special software used for testing 9
2.8 Product labelling 9

3 Test Results 10

3.1 Spurious radiated emissions 10
3.2 Peak power output 15
3.3 Occupied bandwidth 17

4 Test equipment 20

5 Antenna Factors, Cable Loss and Sample Calculations 22

5.1 LISN R&S ESH3-Z5 (150 kHz – 30 MHz) 22
5.2 Antenna R&S HFH2-Z2 (9 kHz – 30 MHz) 23
5.3 Antenna R&S HL562 (30 MHz – 1 GHz) 24
5.4 Antenna R&S HF907 (1 GHz – 18 GHz) 25
5.5 Antenna EMCO 3160-09 (18 GHz – 26.5 GHz) 26
5.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz) 27

6 Setup Drawings 28

7 Measurement uncertainty 28

8 Photo Report 28

0 Summary

0.1 Technical Report Summary

Type of Authorization

Certification for an intentional radiator: 125 kHz transmitter and tagging system

0.2 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 (10-1-16 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 applied.

Summary Test Results:

The EUT complied with all performed tests as listed in sub-clause 0.4 Measurement Summary / Signatures.

0.3 FCC-IC Correlation Table

General radio equipment

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 5: 8.8
Transmitter spurious radiated emissions	§ 15.209	RSS-Gen Issue 5: 6.13/8.9/8.10; RSS-210 Issue 9: 4.3/4.4
Restricted Bands	§15.205	RSS-Gen Issue 5: 8.10 RSS-210 Issue 9: 4.1
Wanted Emission (Carrier)	§ 15.209	RSS-210 Issue 9: 4.4 RSS-Gen Issue 5: 6.12, 8.9
Other requirements, e.g. Transmitter frequency stability	–	RSS-Gen Issue 5: 6.11/8.11
Receiver spurious emissions	–	RSS-Gen Issue 5: 5/7
Occupied bandwidth	§2.1049	RSS-Gen Issue 5: 6.6

Note: This EUT is subject to RSS-210, 4.4.

0.4 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
CW	Setup_01	Enclosure	passed
CW	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
CM	Setup_01	Enclosure	passed
CM	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
CM	Setup_01	Enclosure	performed
CM	Setup_02	Enclosure	performed

Notes:

N/A = Not applicable

(1) The EUT is battery powered and when the battery is charging the device cannot operate.

performed = no limit is applicable to the test result.

Revision History

Report version control			
Version	**Release date**	**Change Description**	**Version validity**
initial	2018-08-01	--	invalid
Rev1	2018-11-19	FCC ID Changed	valid

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

Responsible for Accreditation Scope: M. Pullich

Responsible for Test Report:

1 Administrative Data

1.1 Testing Laboratory

Company Name:	7layers GmbH
Address:	Borsigstr. 11 40880 Ratingen Germany

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

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

Laboratory accreditation no:	DAkkS D-PL-12140-01-01
FCC Designation Number:	DE0015
FCC Test Firm Registration:	929146
Responsible for accreditation scope:	Dipl.-Ing. Marco Kullik
Report Template Version:	2018-01-22

1.2 Project Data

Responsible for testing and report:	Dipl.-Ing. Dobrin Dobrinov
Employees who performed the tests:	documented internally at 7Layers
Date of Report:	2018-11-19
Testing Period:	2018-06-06 to 2018-07-02

1.3 Applicant Data

Company Name:	TECTUS Transponder Technology GmbH
Address:	Eurotec-Ring 39 47445 Moers Germany
Contact Person:	Mr. Frank Scheuermann

1.4 Manufacturer Data

Company Name:	please see at Applicant Data
Address:	
Contact Person:	

2 Test object Data

2.1 General EUT Description

Equipment under Test	RFID MultiPen LF-HF-UHF
Product Name	Multipen
Type Designation:	APOLLO
Kind of Device:	125 kHz, 134 kHz Transmitters and Tagging System
Voltage Type:	DC - Ni-MH batteries
Voltage level:	2.6 V nominal and tested voltage; 2.25 to 3.0 V

2.1.1 General product description:

The RFID handheld device MultiPen enables reading of UIDs of passive RFID transponders in Frequency ranges UHF (902…928MHz), RF / NFC (13,56 MHz) and LF (125/134 kHz FDX-B/HDX).

The objects of this report are LF transmitters at 125kHz and 134 kHz operating frequencies.

2.1.2 Specific product description for the EUT:

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

2.1.3 The EUT provides the following ports:

- Enclosure
- DC combined

Note: DC combined is a USB Type B connector installed on the EUT body and served as a battery charging input, and EUT factory configuration.

2.2 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: DE1311000aa01)	Multipen	APOLLO	201810020	REV.B	1v3-Test
EUT B (Code: DE1311000ab01)	Multipen	APOLLO	201810021	REV.B	1v3-Test

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

2.3 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
ANC 1	LF-Tag	Münze 30mm, gelb, HiTAG1	637B4665	–	–
ANC 2	HF-Tag	Karte "Elektor", ISO 14443	049B99EA972880	–	–
ANC 3	HF-Tag	Karte "ST", ISO 15693	E002207201D98836		
ANC 4	UHF-Tag	gelb, länglich, Cl1/Gen2	E20030351315025714 507FD1		

2.4 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
–	–	–	–	–	–

2.5 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 + ANC 1	EUT is consequently set on 125 kHz and 135 kHz modes. EUT read ancillary, radiating continuously modulated signal. Representative setup for radiated emissions.
Setup_02	EUT B	EUT is consequently set on 125 kHz and 135 kHz modes. EUT radiated continuous wave signal (not modulated carrier) Representative setup for Output Power test.

2.6 Operating Modes

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

Op. Mode	Description of Operating Modes	Remarks
CM	continuously modulated	EUT is transmitting a continuously modulated signal
CW	continuous wave (sinusoidal signal)	EUT is transmitting a continuously not modulated signal

2.7 Special software used for testing

The applicant provides the test software.

2.8 Product labelling

Please refer to the documentation of the applicant.

3 Test Results

3.1 Spurious radiated emissions

Standard FCC Part 15, Subpart C

The test was performed according to: ANSI C63.10

3.1.1 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
- 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.

3.1.2 Test Requirements / Limits

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
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)

3.1.3 Test Protocol

Temperature: 23-24 °C
Air Pressure: 990-1006 hPa
Humidity: 37-40 %

3.1.3.1 Measurement up to 30 MHz

Op. Mode	Setup	Port
CM	Setup_01_125_kHz	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
–	–	–	–	–	–	–	–	–	–	–

Op. Mode	Setup	Port
CM	Setup_01_134kHz	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: No relevant spurious emissions are found in the range 20 dB below the limit.

3.1.3.2 Measurement above 30 MHz

Op. Mode	Setup	Port
CM	Setup_01_125_kHz	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
–	–	–	–	–	–	–	–	–	–	–

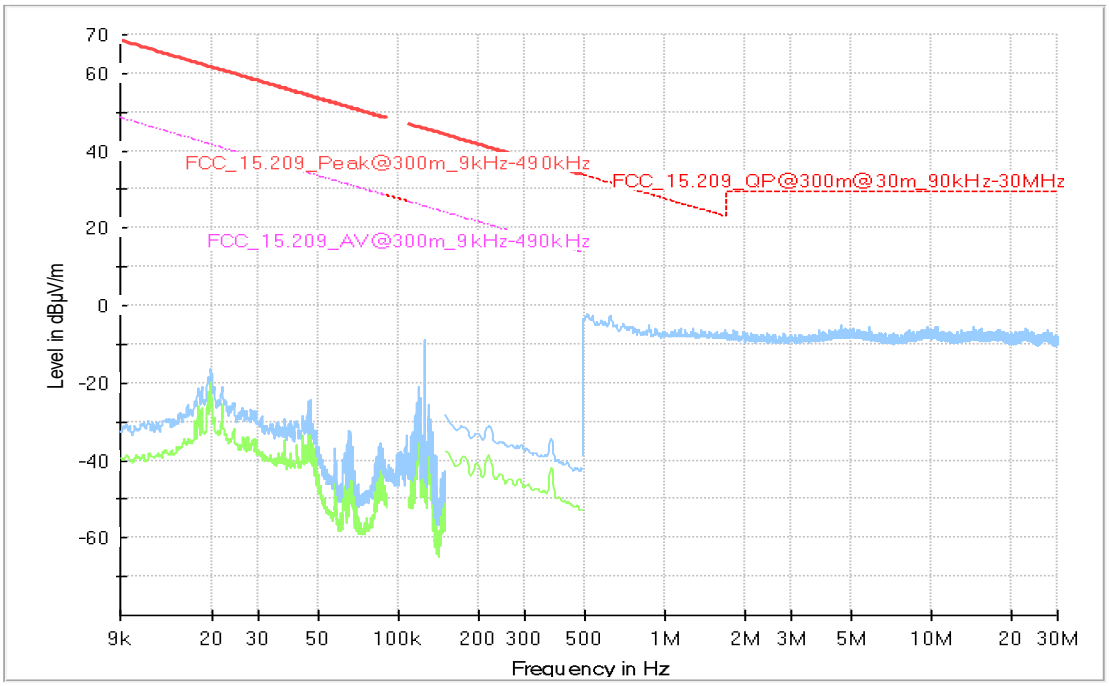
Op. Mode	Setup	Port
CM	Setup_01_134kHz	Enclosure

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
–	–	–	–	–	–	–	–	–	–	–

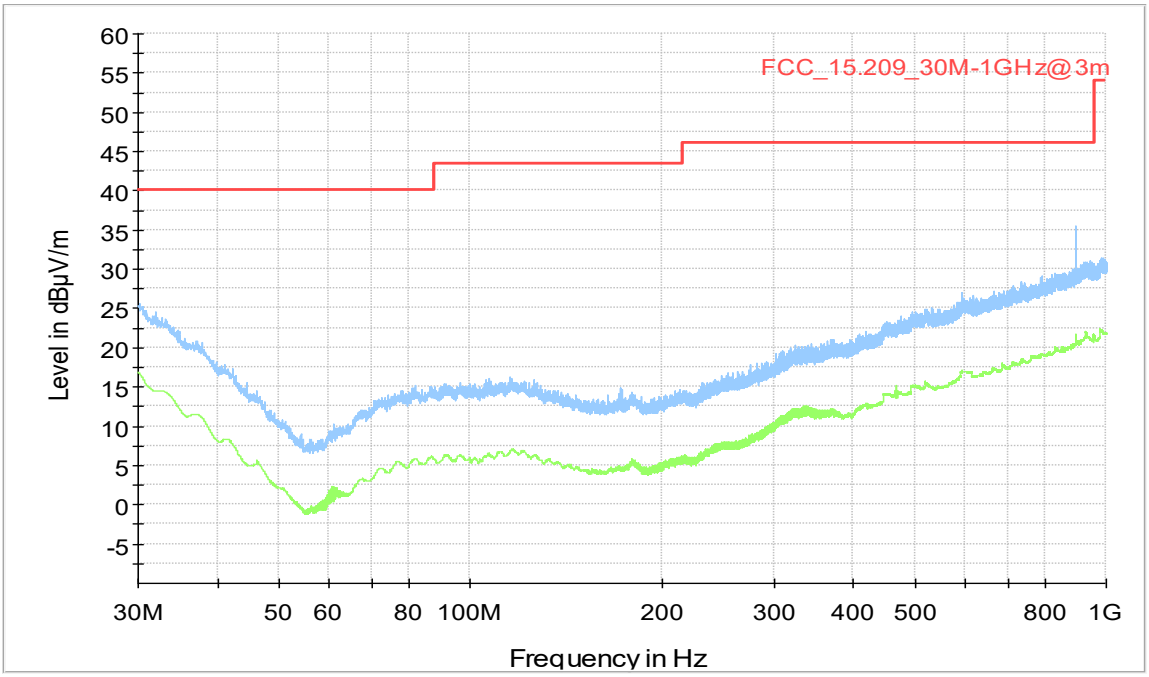
Remark: No relevant spurious emissions are found in the range 20 dB below the limit.

3.1.4 Measurement Plots (worst case)

3.1.4.1 Below 30 MHz



3.1.4.2 Above 30 MHz



3.1.5 Test Equipment used

- Radiated Emissions

3.2 Peak power output

Standard FCC Part 15, Subpart C

The test was performed according to: ANSI C63.10

3.2.1 Test Description

Please refer to sub-clause 3.1.1.

3.2.2 Test Limits

Please refer to sub-clause 3.1.2.

3.2.3 Test Protocol

Temperature: 24 °C
Air Pressure: 992 hPa
Humidity: 37 %

Op. Mode	Setup	Port
CW	Setup_01_125_kHz	Enclosure

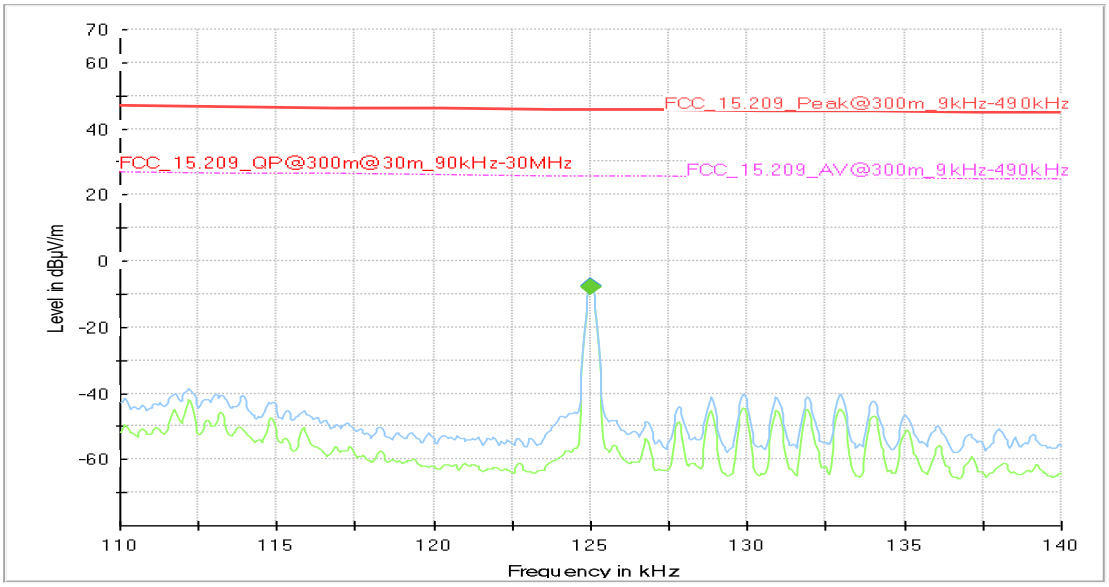
Antenna orien-tation	EUT orien-tation	Frequency kHz	Maximum radiated field strength at fundamental frequency (corrected) dBµV/m	Limit dBµV/m	Margin dB
			AV = PK	AV	AV
0°	Hor.	125.00	-7.75	25.69	33.43

Op. Mode	Setup	Port
CW	Setup_01_134_kHz	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
0°	Hor.	133.350	-7.86	25.13	32.98

3.2.4 Measurement Plot (worst case)

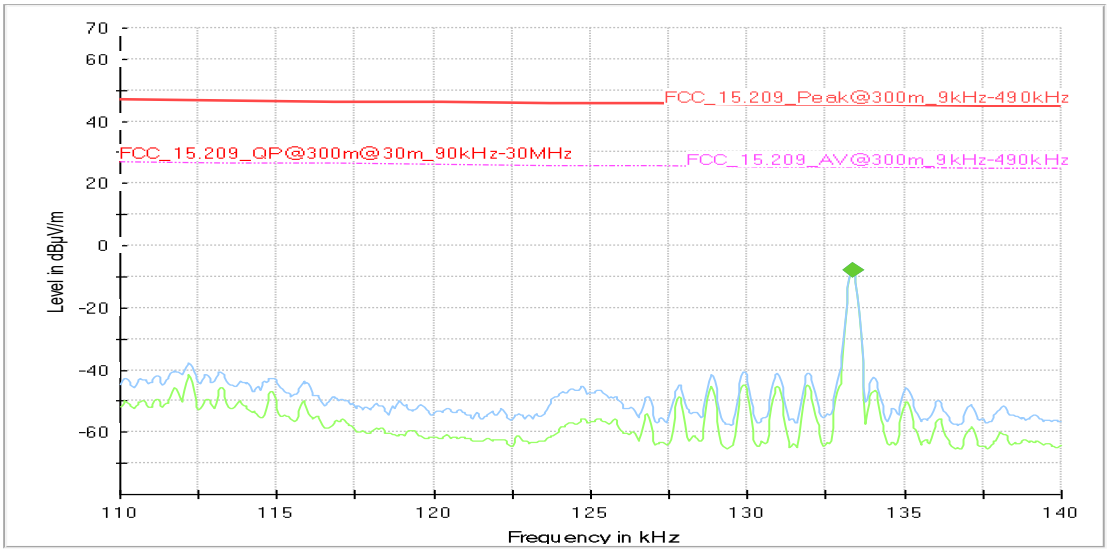
TX on at 125kHz, EUT Horizontal, CW mode



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)
0.125000	---	-7.75	25.69	33.43	1000.0	0.200	100.0	V	-2.0
0.125000	-7.67	---	45.69	53.36	1000.0	0.200	100.0	V	-2.0

TX on at 134 kHz, EUT Horizontal, CW mode



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)
0.133350	---	-7.86	25.13	32.98	1000.0	0.200	100.0	V	-3.0
0.133350	-7.82	---	45.13	52.95	1000.0	0.200	100.0	V	-3.0

3.2.5 Test Equipment used

- Radiated Emissions

3.3 Occupied bandwidth

Standard FCC Part 2, Subpart J, §2.1049

The test was performed according to: ANSI C63.10

3.3.1 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.

3.3.2 Test Requirements / Limits

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

3.3.3 Test Protocol

Temperature: 25-26 °C
Air Pressure: 1003-1004 hPa
Humidity: 33-34 %

Op. Mode	Setup	Port
CM	Setup_01_125_kHz	Enclosure

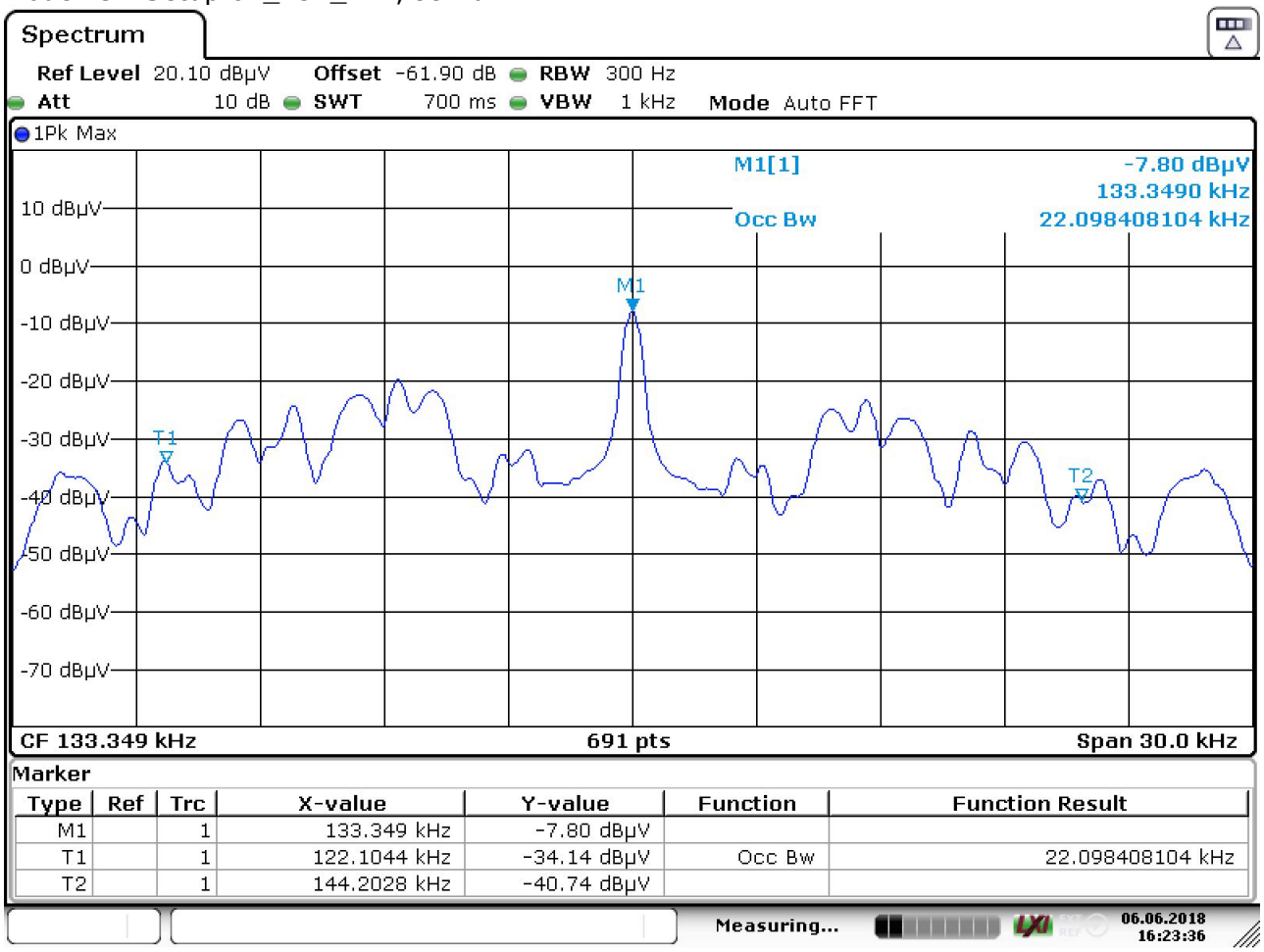
20 dBc bandwidth	99% occupied bandwidth
15.673 kHz	20.796 kHz

Op. Mode	Setup	Port
CM	Setup_01_134_kHz	Enclosure

20 dBc bandwidth	99% occupied bandwidth
18.06 kHz	22.098 kHz

3.3.4 Measurement Plots (worst case)

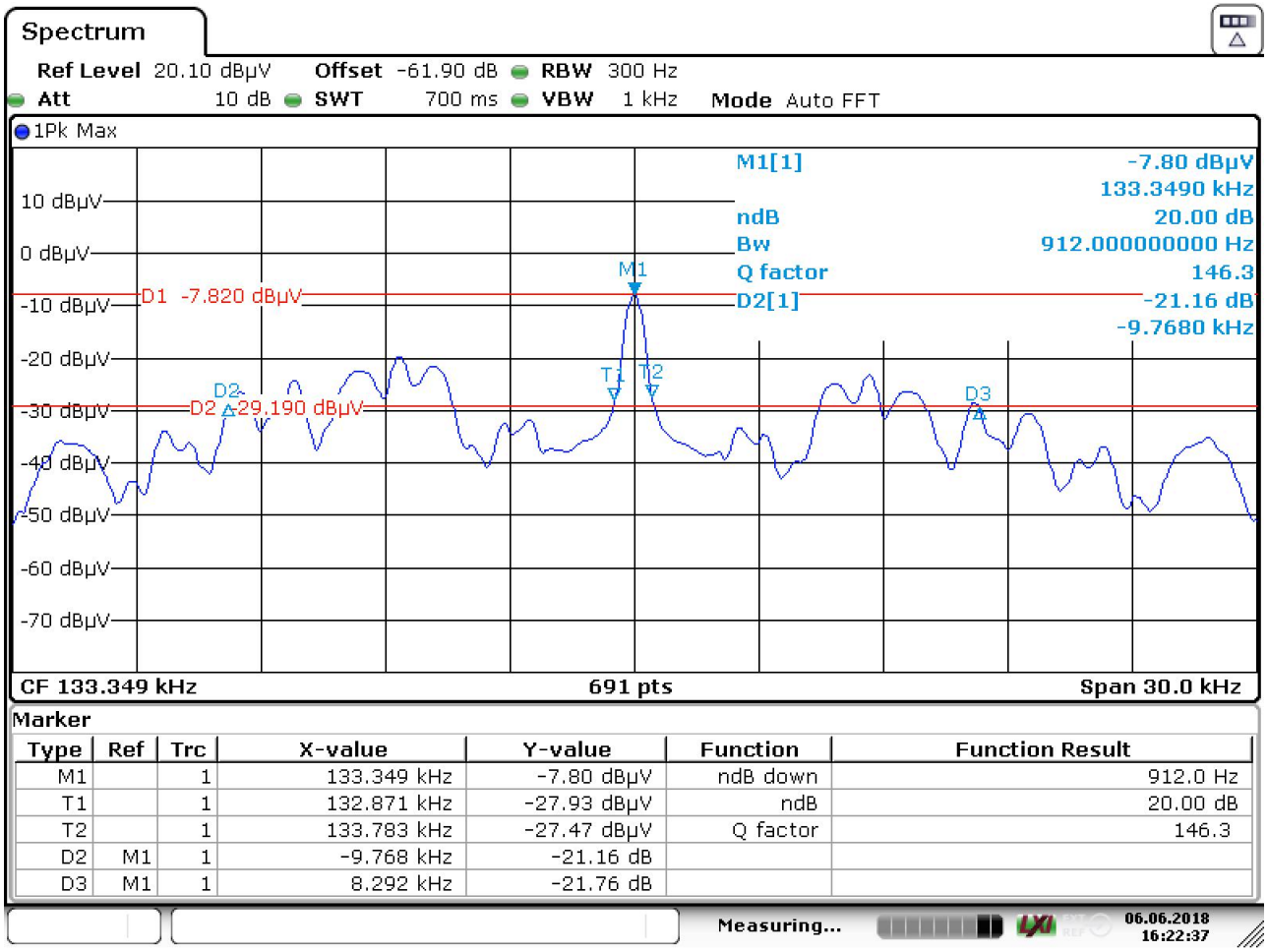
Mode: CM Setup 01_134_kHz, 99 % BW



Date: 6.JUN.2018 16:23:37

Note:
According to ANSI C63.10: Span = 1.5 to 5 times OccBW. Hence, the minimal Span is 33.15 kHz. The laboratory's choise 30 kHz is very near to the Standard requirement, but it gives a better view and more accuracy in measurement of the bandwidth.

Mode: CM Setup 01_134_kHz, 20 dBc BW



Date: 6.JUN.2018 16:22:38

3.3.5 Test Equipment used

- Radio Lab

4 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	827753/005	2017-11	2018-11
1.2	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2017-10	2018-10
1.3	Opus10 THI (8252.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
1.4	Anechoic Chamber	10.58 x 6.38 x 6.00 m³	Frankonia	none	2016-05	2019-05
1.5	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2016-04	2019-04
1.6	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
1.7	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
1.8	Fully Anechoic Room	8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	2015-06 2018-06	2018-06 2020-06
1.9	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
1.10	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2016-12	2018-12
1.11	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronic GmbH	00083069		
1.12	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
1.13	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
1.14	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
1.15	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
1.16	TT 1.5 WI	Turn Table	Maturo GmbH	-		
1.17	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
1.18	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronic GmbH	00086675		
1.19	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008		
1.20	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2018-01	2021-01

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.21	Opus10 THI (8152.00)	ThermoHygro Datalogger 12 (Environ)	Lufft Mess- und Regeltechnik GmbH	12482	2017-03	2019-03
1.22	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2016-11	2018-11
1.23	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
1.24	AS 620 P	Antenna mast	HD GmbH	620/37		
1.25	Tilt device Maturo (Rohacell)	Antrieb TD1.5-10kg	Maturo GmbH	TD1.5-10kg/024/3790709		
1.26	ESIB 26	Spectrum Analyzer	Rohde & Schwarz	830482/004	2018-01	2020-01
1.27	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
1.28	AM 4.0	Antenna mast	Maturo GmbH	AM4.0/180/11920513		

2 Radio Lab
Lab to perform bandwidth test

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	FSIQ26	Spectrum Analyzer	Rohde & Schwarz	840061/005	2017-05	2019-05
2.2	Opus10 THI (8152.00)	ThermoHygro Datalogger 03	Lufft Mess- und Regeltechnik GmbH	7482	2017-03	2019-03

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

5 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.

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

Frequency		Corr.
MHz		dB
0,15		10,1
5		10,3
7		10,5
10		10,5
12		10,7
14		10,7
16		10,8
18		10,9
20		10,9
22		11,1
24		11,1
26		11,2
28		11,2
30		11,3

LISN insertion loss ESH3-Z5	cable loss (incl. 10 dB atten-uator)
dB	dB
0,1	10,0
0,1	10,2
0,2	10,3
0,2	10,3
0,3	10,4
0,3	10,4
0,4	10,4
0,4	10,5
0,4	10,5
0,5	10,6
0,5	10,6
0,5	10,7
0,5	10,7
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.

5.2 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

5.3 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.

5.4 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.

5.5 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.

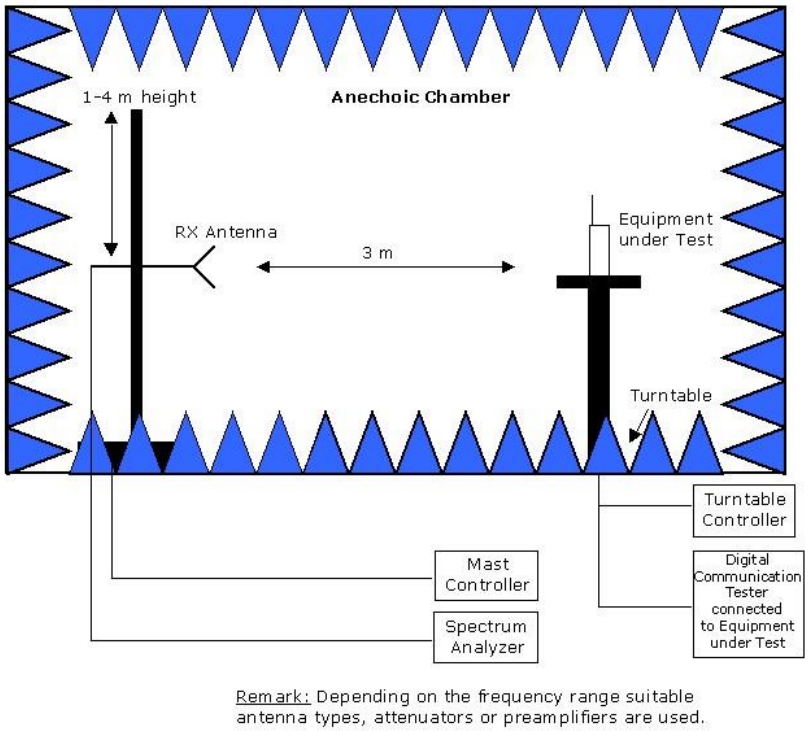
5.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)

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				-15,6	3	0,5
27,0	43,4	-11,2	4,4				-15,6	3	0,5
28,0	43,4	-11,1	4,5				-15,6	3	0,5
29,0	43,5	-11,0	4,6				-15,6	3	0,5
30,0	43,5	-10,9	4,7				-15,6	3	0,5
31,0	43,5	-10,8	4,7				-15,6	3	0,5
32,0	43,5	-10,7	4,8				-15,6	3	0,5
33,0	43,6	-10,7	4,9				-15,6	3	0,5
34,0	43,6	-10,6	5,0				-15,6	3	0,5
35,0	43,6	-10,5	5,1				-15,6	3	0,5
36,0	43,6	-10,4	5,1				-15,6	3	0,5
37,0	43,7	-10,3	5,2				-15,6	3	0,5
38,0	43,7	-10,2	5,3				-15,6	3	0,5
39,0	43,7	-10,2	5,4				-15,6	3	0,5
40,0	43,8	-10,1	5,5				-15,6	3	0,5

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.

6 Setup Drawings



Drawing 1: Setup in the Anechoic chamber. For measurements below 1 GHz the ground was replaced by a conducting ground plane.

7 Measurement uncertainty

Test Case	Parameter	Uncertainty
Peak power output	Field strength	± 5.5 dB
Occupied bandwidth	Power Frequency:	± 2.9 dB ± 0.125 kHz
Spurious radiated emissions	Field strength Frequency:	± 5.5 dB ± 11.2 kHz
AC Power Line	Power	± 3.4 dB

8 Photo Report

Photos are included in an external report.