

FCC Measurement/Technical Report on

RFID MultiPen LF-HF-UHF

Multipen

APOLLO

FCC ID: 2APYJ-MULTIPEN3
IC: ---

Report Reference: MDE_TECTU_1701_FCCc

Test Laboratory:

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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.

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1 SUMMARY

1.1 TECHNICAL REPORT SUMMARY

Type of Authorization

Certification for an Intentional Radiator.

Applicable FCC Rules

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 (10-1-14 Edition) and 15 (10-1-14 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

§ 15.201 Equipment authorization requirement

§ 15.205 Restricted bands of operation

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.249 Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHz, and 24.0-24.25 GHz.

Note:

ANSI C63.10-2013 is applied.

Summary Test Results:

The EUT complied with all performed tests as listed in chapter 1.3 Measurement Summary.

1.2 CORRELATION OF MEASUREMENT REQUIREMENTS FOR GENERAL RADIO EQUIPMENT FROM FCC AND IC

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: 2.5
Field strength of Fundamental	§ 15.249	RSS-210 Issue 9: 2.5.1 RSS-Gen Issue 5: 6.12, 8.9
Operation within the bands 902-928 MHz, 2400-2483.5 MHz, 5725-5875 MHz, and 24.0-24.25 GHz.	§15.249	RSS-210, Issue 9: Annex B

1.3 MEASUREMENT SUMMARY

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

2013

Final Result

N/A

FCC Part 15, Subpart C

§ 15.249 (a)

Field strength of Fundamental / Radiated power output

The measurement was performed according to ANSI C63.10

OP-Mode

Setup

Port

2013

Final Result

passed

FCC Part 15, Subpart C

§ 15.249 (a), § 15.35 (b), § 15.209

Field Strength of Harmonics / Spurious radiated emissions

The measurement was performed according to ANSI C63.10

OP-Mode

Setup

Port

2013

Final Result

passed

N/A not applicable (the EUT is powered by DC)

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

This facility has been fully described in a report submitted to the ISED 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-12140-01-00

FCC Designation Number: DE0015

FCC Test Firm Registration: 929146

Responsible for accreditation scope: Dipl.-Ing. Marco Kullik

Report Template Version: 2017-07-14

2.2 PROJECT DATA

Responsible for testing and report: Dipl.-Ing. Dobrin Dobrinov

Date of Test(s): 2018-06-06 to 2018-08-16

Date of Report: 2018-11-05

2.3 APPLICANT DATA

Company Name: TECTUS Transponder Technology GmbH

Address: Eurotec-Ring 39
47445 Moers
Germany

Contact Person: Mr. Frank Scheuermann

2.4 MANUFACTURER DATA

Company Name: Please see applicant's data

Address:

Contact Person:

3 TEST OBJECT DATA

3.1 GENERAL EUT DESCRIPTION

General product description:

Kind of Device product description	125 kHz, 134 kHz, 917.5 MHz Transmitters and Tagging System
Product name	RFID MultiPen LF-HF-UHF
Type	AOLLO

Declared EUT data by the supplier

Voltage Type	DC NiMH battery
Normal Voltage	2.4 V
Low Voltage	2.25 V
High Voltage	3.0 V
Normal Temperature	23 °C
Low Temperature	-20 °C
High Temperature	+50 °C
Specific product description for the EUT	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 EUT provides the following ports:	Enclosure and DC/Configuration port USB Type B
Special software used for testing	V3-Test

Note: The subject of this report is the 917.9 MHz transmitter.

The main components of the EUT are listed and described in Chapter 3.2.

3.2 EUT MAIN COMPONENTS

Sample Name	Sample Code	Description
DE1311000 EUT A	aa01	radiated sample
Sample Parameter	Value	
Serial No.	201810020	
HW Version	REV.B	
SW Version	1v3-Test	
Comment	used for radiated measurements, continuously modulated	

Sample Name	Sample Code	Description
DE1311000 EUT B	ab02	radiated sample
Sample Parameter	Value	
Serial No.	201810021	
HW Version	REV.B	
SW Version	1v3-Test	
Comment	used for radiated measurements, continuously not modulated	

General description of ancillary equipment

Device	Details (Manufacturer, Type Model, OUT Code)	Reason for using
ANC 1	UHF-Tag, gelb, länglich, CI1/Gen2, S/N: E20030351315025714507FD1	EUT reading the Tag by radiated measurements

General description of auxiliary equipment

Device	Details (Manufacturer, HW, SW, S/N)	Description
---	---	---

3.3 EUT SETUPS

This chapter describes the combination of EUTs and ancillary equipment used for testing.

Setup No.	Combination of EUTs	Description
Setup_01	EUT A + ANC 1	Setup for radiated measurements
Setup_02	EUT B	Setup for radiated measurements

3.4 OPERATING MODES

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

Op. Mode	Description of Operating Modes	Remarks
op-mode 1	Continuous modulated	Transmitter sends continuously modulated signal
op-mode 2	Continuous wave	Transmitter sends a non-modulated carrier

Remark: In continuous modulated mode the EUT reads a Tag and transmits a modulated carrier

3.5 PRODUCT LABELLING

3.5.1 FCC ID label

2APYJ-MULTIPEN3

3.5.2 IC LABEL

3.5.3 LOCATION OF THE LABEL ON THE EUT

Please refer to the documentation of the applicant.

4 TEST RESULTS

4.1 FIELD STRENGTH OF FUNDAMENTAL / RADIATED POWER OUTPUT

Standard FCC Part 15, Subpart C

The test was performed according to ANSI C63.10

4.1.1 TEST DESCRIPTION

Please refer to the description at sub-clause 4.2.1, esp. item no. 3.

4.1.2 Test Requirements / Limits

FCC Part 15, Subpart C, §15.249

(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902-928 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
2400-2483.5 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
5725-5875 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
24.0-24.25 GHz	250 (108.0 dB μ V/m)	2500 (68.0 dB μ V/m)

Used conversion factor: Limit (dB μ V/m) = 20 log (Limit (μ V/m)/1 μ V/m)

(c) Field strength limits are specified at 3 meters.

(e) As shown in §15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.

TEST PROTOCOL

Temperature:	24 °C
Air Pressure:	1009 hPa
Humidity:	38 %

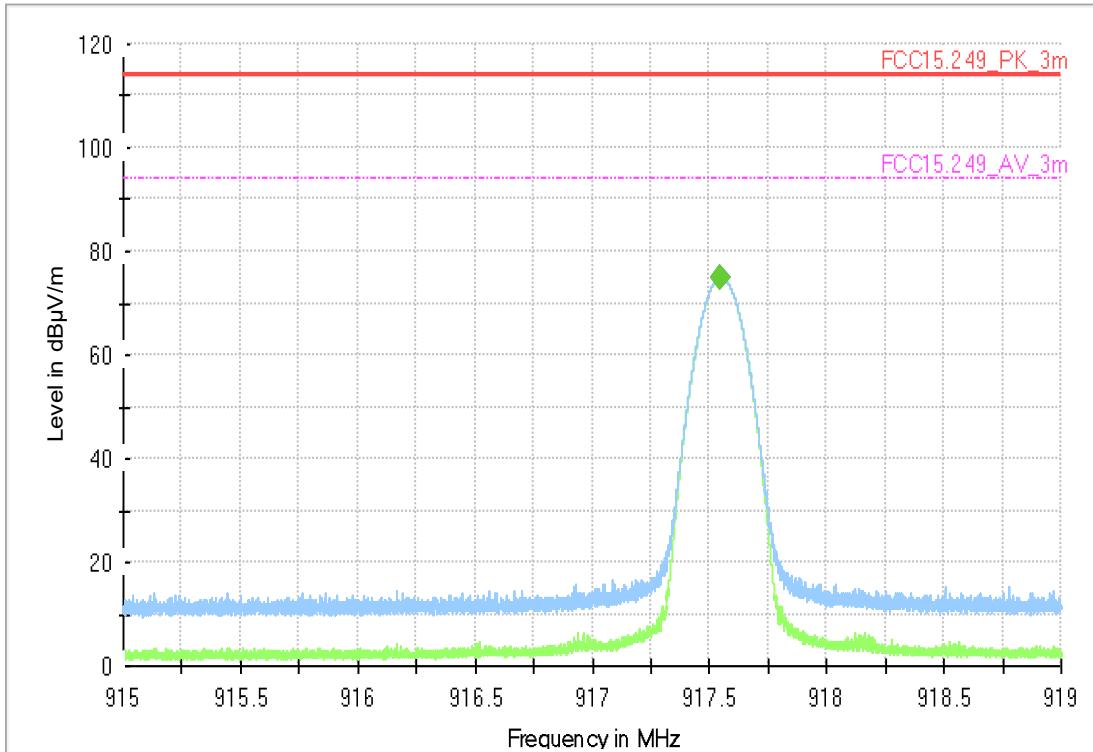
Op. Mode	Setup	Port
op-mode 1	Setup_01	Enclosure

Frequency [MHz]	Output power [dB μ V/m]	Limit [dB μ V/m]	Margin to Limit [dB]	Remarks
917.550	75.0	94.0	19	Maximum radiated field strength at fundamental frequency

Note: The EUT transmitted continuously non-modulated carrier.

TEST RESULT: Maximum radiated field strength at fundamental frequency

FCC Part 15, Subpart C	Op. Mode	Result
	op-mode 1	passed


Final Result

Frequency (MHz)	MaxPeak (dB μ V/m)	CAverage (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol
917.550	75.0	---	114	39	1000.0	100.000	150.0	H
917.550	---	74.7	94	19.3	1000.0	100.000	150.0	H

4.2 FIELD STRENGTH OF HARMONICS / SPURIOUS RADIATED EMISSIONS

Standard FCC Part 15, Subpart C

The test was performed according to ANSI C63.10

4.2.1 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 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 also performed at 3 axes. A pre-check is performed while the EUT is powered from a DC power source.

1. Measurement up to 30 MHz

The Loop antenna HFH2-Z2 is used.

Step 1: pre-measurement

- Anechoic chamber
- Antenna distance: 3 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 with the following settings will be performed. Intention of this step is to find the maximum emission level.

- Open area test side
- Antenna distance: according to the Standard
- Detector: Quasi-Peak
- Frequency range: 0.009 – 30 MHz
- Frequency steps: measurement at frequencies detected in step 1
- IF-Bandwidth: 0.2 - 10 kHz
- 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 3, the final measurement will be performed:

EMI receiver settings for step 4:

- 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 which 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. Measurement above 1 GHz

The following modifications apply to the measurement procedure for the frequency range above 1 GHz:

Step 1:

The Equipment Under Test (EUT) was set up on a non-conductive support (tilt device) at 1.5 m height in the fully-anechoic chamber.

All steps were performed with one height of the receiving antenna only.

The EUT is turned during the preliminary measurement across the elevation axis, with a step size of 90 °.

The turn table step size (azimuth angle) for the preliminary measurement is 45 °.

Step 2:

Due to the fact, that in this frequency range the test is performed in a fully anechoic room, the height scan of the receiving antenna instep 2 is omitted. Instead of this, a maximum search with a step size $\pm 45^\circ$ for the elevation axis is performed.

The turn table azimuth will slowly vary by $\pm 22.5^\circ$.

The elevation angle will slowly vary by $\pm 45^\circ$

EMI receiver settings (for all steps):

- Detector: Peak, Average
- IF Bandwidth = 1 MHz

Step 3:

Spectrum analyser settings for step 3:

- Detector: Peak / Average
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 1 MHz
- Measuring time: 1 s

4.2.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.249

(a) Except as provided in paragraph (b) of this section, the field strength of emissions from intentional radiators operated within these frequency bands shall comply with the following:

Fundamental frequency	Field strength of fundamental (millivolts/meter)	Field strength of harmonics (microvolts/meter)
902-928 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
2400-2483.5 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
5725-5875 MHz	50 (94.0 dB μ V/m)	500 (54.0 dB μ V/m)
24.0-24.25 GHz	250 (108.0 dB μ V/m)	2500 (68.0 dB μ V/m)

Used conversion factor: Limit (dB μ V/m) = 20 log (Limit (μ V/m)/1 μ V/m)

(c) Field strength limits are specified at a distance of 3 meters.

(d) Emissions radiated outside of the specified frequency bands, except for harmonics, shall be attenuated by at least 50 dB below the level of the fundamental or to the general radiated emission limits in §15.209, whichever is the lesser attenuation.

(e) As shown in §15.35(b), for frequencies above 1000 MHz, the field strength limits in paragraphs (a) and (b) of this section are based on average limits. However, the peak field strength of any emission shall not exceed the maximum permitted average limits specified above by more than 20 dB under any condition of modulation.

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

Frequency (MHz)	Limit (μ V/m)	Measurement distance (m)	Calculate Limit (dB μ V/m @10m)	Limit (dB μ V/m) @10m
0.009 – 0.49	2400/F (kHz)	300	(48.5 – 13.8) + 59.1 dB	107.6 – 72.9
0.49 – 1.705	24000/F (kHz)	30	(33.8 – 23.0) + 19.1 dB	52.9 – 42.1
1.705 – 30	30	30	29.5 + 19.1 dB	39.5

Frequency in MHz	Limit (μ V/m)	Measurement distance (m)	Limit (dB μ V/m)
30 – 88	100	3	40.0
88 – 216	150	3	43.5
216 – 960	200	3	46.0
above 960	500	3	54.0

§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 (dB μ V/m) = 20 log (Limit (μ V/m)/1 μ V/m)

§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 (dB μ V/m) = 20 log (Limit (μ V/m)/1 μ V/m)

§15.35(c):

[...] when the radiated emission limits are expressed in terms of the average value of the emission, and pulsed operation is employed, the measurement field strength shall be determined by averaging over one complete pulse train, including blanking intervals, as long as the pulse train does not exceed 0.1 seconds.

As an alternative (provided the transmitter operates for longer than 0.1 seconds) or in cases where the pulse train exceeds 0.1 seconds, the measured field strength shall be determined from the average absolute voltage during a 0.1 second interval during which the field strength is at its maximum value. The exact method of calculating the average field strength shall be submitted [...].

§15.231(b)(3)

The limits on the field strength of the spurious emissions in the above table are based on the fundamental frequency of the intentional radiator.

Spurious emissions shall be attenuated to the average (or, alternatively, CISPR quasi-peak) limits shown in this table or to the general limits shown in §15.209, whichever limit permits a higher field strength.

Interpretation of the test laboratory:

The last subordinate clause of §15.231(b)(3) is overruled by §15.205/209, therefore within the restricted bands the limits defined at §15.205/209 and outside the restricted bands the limits defined at §15.231(b) resp. §15.231(e) are applied.

TEST PROTOCOL

Temperature: 24 °C
 Air Pressure: 1009 hPa
 Humidity: 35 %

MEASUREMENT UP TO 30 MHz

Op. Mode		Setup			Port					
op-mode 1		Setup_01			Enclosure					
Measuring Antenna Polarisation	Spurious Emission Frequency [MHz]	Corrected value [dB μ V/m]			Limit [dB μ V/m]	Limit [dB μ V/m]	Limit [dB μ V/m]	Margin to limit [dB]	Margin to limit [dB]	
		QP	Peak	AV		QP	Peak	AV	QP/Peak	AV
0°	---	---	---	---	---	---	---	---	---	---
90°	---	---	---	---	---	---	---	---	---	---

Remark: In step 1 no spurious emissions in the range below the limit were found, using a peak detector, therefore step 2 (using a QP-detector) was not performed. For this test the EUT was sending a continuously modulated signal.
 Please see the measurement plots.

MEASUREMENT ABOVE 30 MHZ TO 1 GHz

Op. Mode		Setup			Port					
op-mode 1		Setup_01			Enclosure					
Polarisation of the antenna and the EUT	Spurious Emission Frequency [MHz]	Corrected value [dB μ V/m]			Limit [dB μ V/m]	Limit [dB μ V/m]	Limit [dB μ V/m]	Margin to limit [dB]	Margin to limit [dB]	
		QP	Peak	AV		QP	Peak	AV	QP/Peak	AV
---	---	---	---	---	---	---	---	---	---	---
90°	---	---	---	---	---	---	---	---	---	---

Remark: - No more spurious emissions in the range 15 dB below the limit were found.

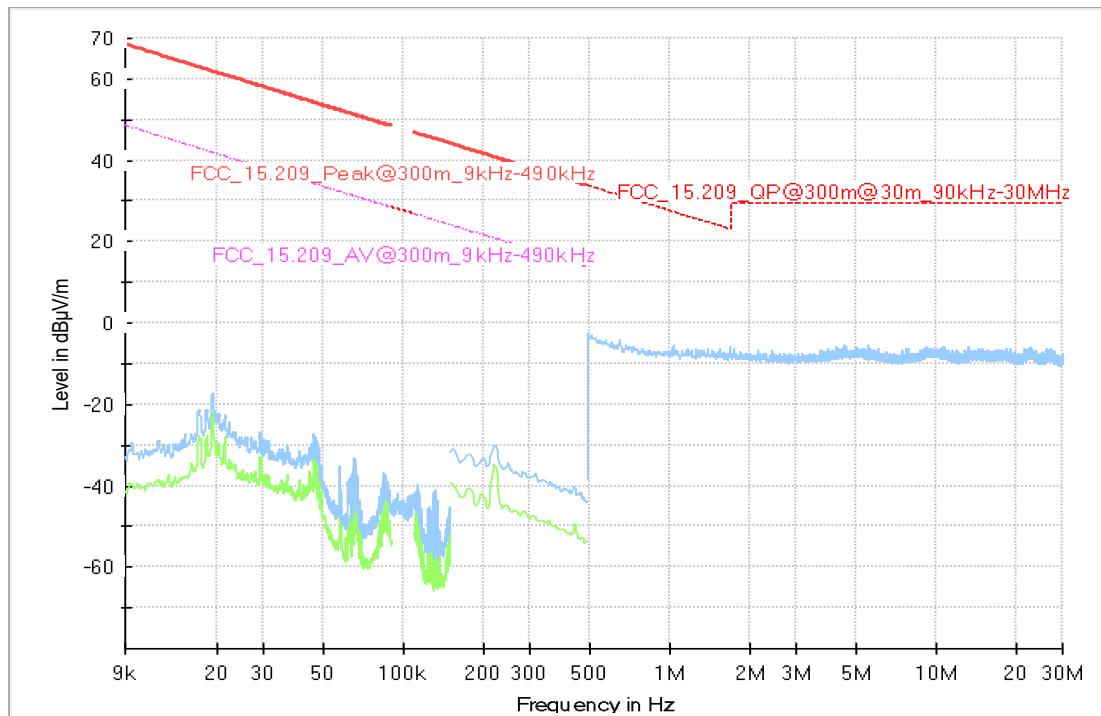
MEASUREMENT ABOVE 1 GHz

Op. Mode		Setup			Port					
op-mode 1		Setup_01			Enclosure					
Polarisation of the antenna and the EUT	Spurious Emission Frequency [MHz]	Corrected value [dB μ V/m]			Limit [dB μ V/m]	Limit [dB μ V/m]	Limit [dB μ V/m]	Margin to limit [dB]	Margin to limit [dB]	
		QP	Peak	AV		QP	Peak	AV	QP/Peak	AV
horizontal	1835.060			50.2				53.98		3.79
horizontal	2752.760	---	---	52.2	---	---	53.98	---	1.75	
horizontal	3670.000	---	---	49.1	---	---	53.98	---	4.90	

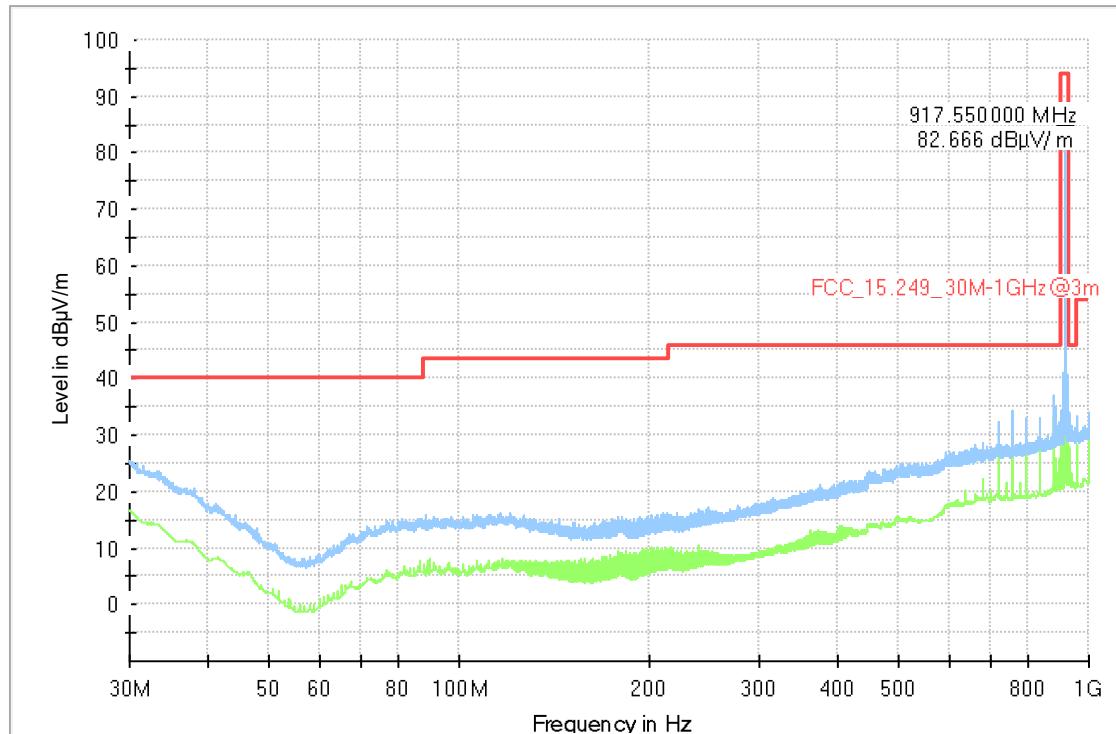
Remarks: - No more spurious emissions in the range 15 dB below the limit were found.
 - The test was performed in the frequency range from 1 GHz to 10 GHz.
 - For this test the EUT was sending a continuously modulated signal.
 - Please see the measurement plot.
 - The EUT is tested in horizontal position.

4.3 MEASUREMENT PLOTS

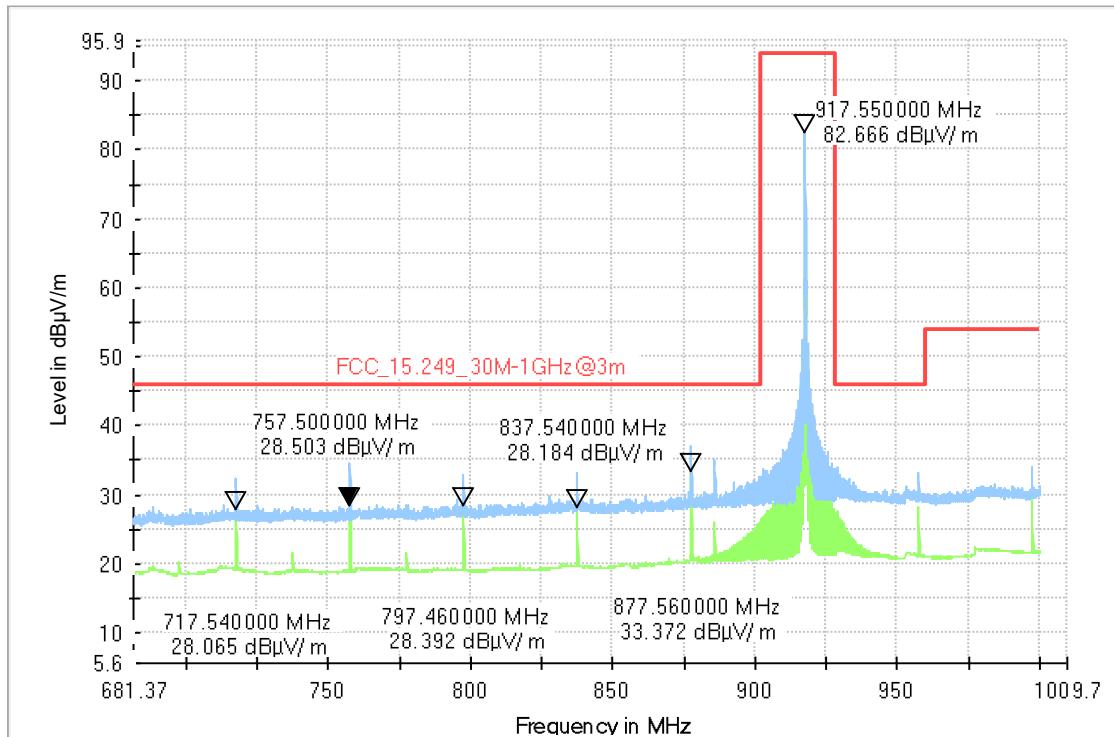
RADIATED EMISSIONS (f < 30 MHz)



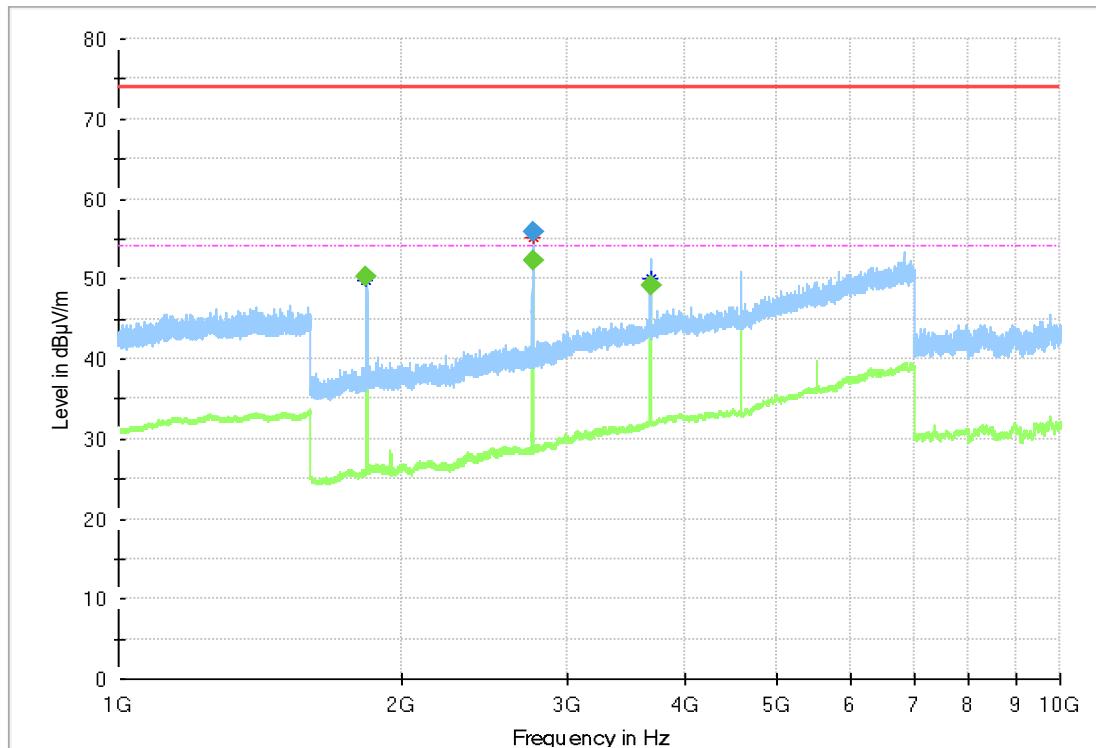
RADIATED EMISSIONS (30 MHz < f < 1 GHz)



RADIATED EMISSIONS (30 MHz < f < 1 GHz) zoom at picks



RADIATED EMISSIONS (1 GHz < f < 10 GHz)


Critical_Freqs

Frequency (MHz)	MaxPeak (dB μ V/m)	Average (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)
1835.060	---	49.8	53.98	4.15	---	--	150.0	H	-57.0	105.0
2752.760	---	52.5	53.98	1.48	---	--	150.0	H	58.0	101.0
3670.000	---	50.1	53.98	3.86	---	--	150.0	H	-4.0	75.0

Final_Result

Frequency (MHz)	MaxPeak (dB μ V/m)	CAverage (dB μ V/m)	Limit (dB μ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)
1835.060	---	50.2	53.98	3.79	1000.0	1000.000	150.0	H	-57.0	105.0
2752.760	---	52.2	53.98	1.75	1000.0	1000.000	150.0	H	58.0	101.0
3670.000	---	49.1	53.98	4.90	1000.0	1000.000	150.0	H	-4.0	75.0

4.4 OCCUPIED BANDWIDTH

Standard **FCC Part 15 Subpart C**

The test was performed according to ANSI C63.10

4.4.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was set up 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 EUT was connected to spectrum analyzer via a short coax cable with a known loss.
 Analyzer settings:

- Resolution Bandwidth (RBW): 1 kHz
- Video Bandwidth (VBW): 10 kHz
- Span: 250 kHz
- Trace: Maxhold
- Sweptime: 700 ms
- Detector: Max Peak

The 99 % measurement function of the spectrum analyser function was used to determine the 99 % bandwidth.

4.4.2 TEST REQUIREMENTS / LIMITS

No applicable limit.

TEST PROTOCOL

Temperature: 23 °C
 Air Pressure: 1009 hPa
 Humidity: 42 %

Op. Mode	Setup	Port
op-mode 1	Setup_02	Enclosure

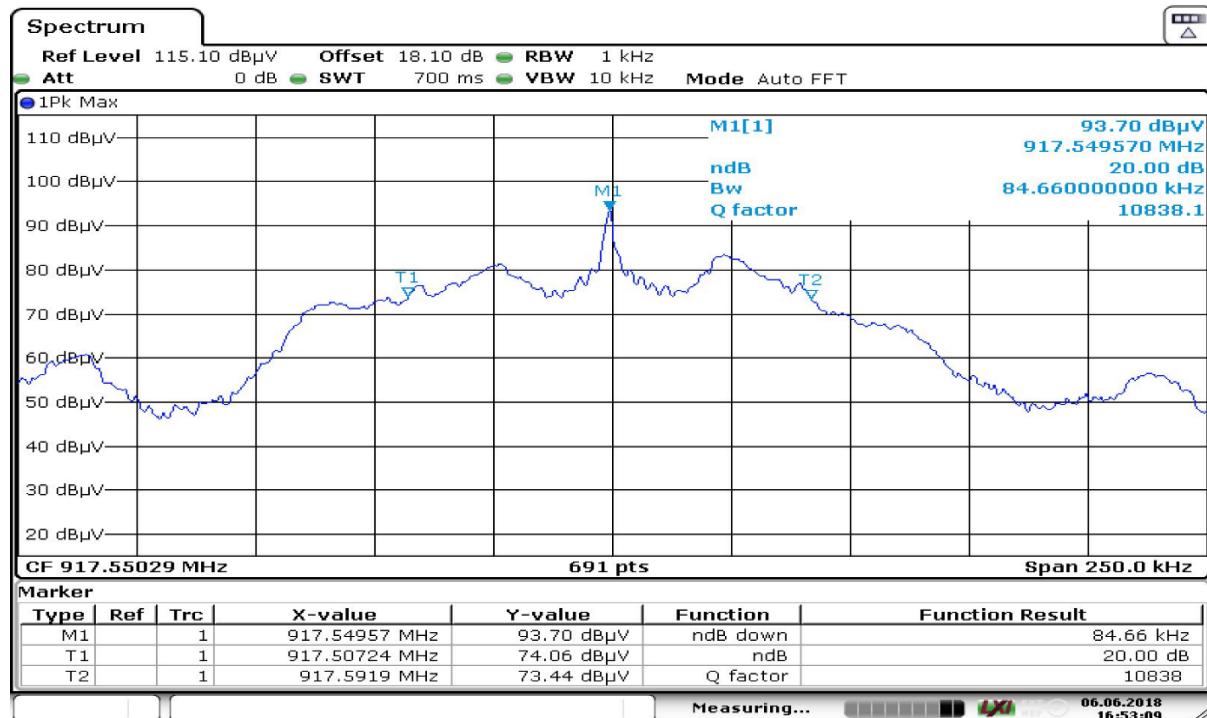
Channel Frequency [MHz]	20 dB bandwidth [kHz]	99% bandwidth [kHz]
917.5	84.66	121.56

4.4.3 TEST RESULT: OCCUPIED BANDWIDTH

FCC Part 15, Subpart C	Op. Mode	Result
	op-mode 1	performed

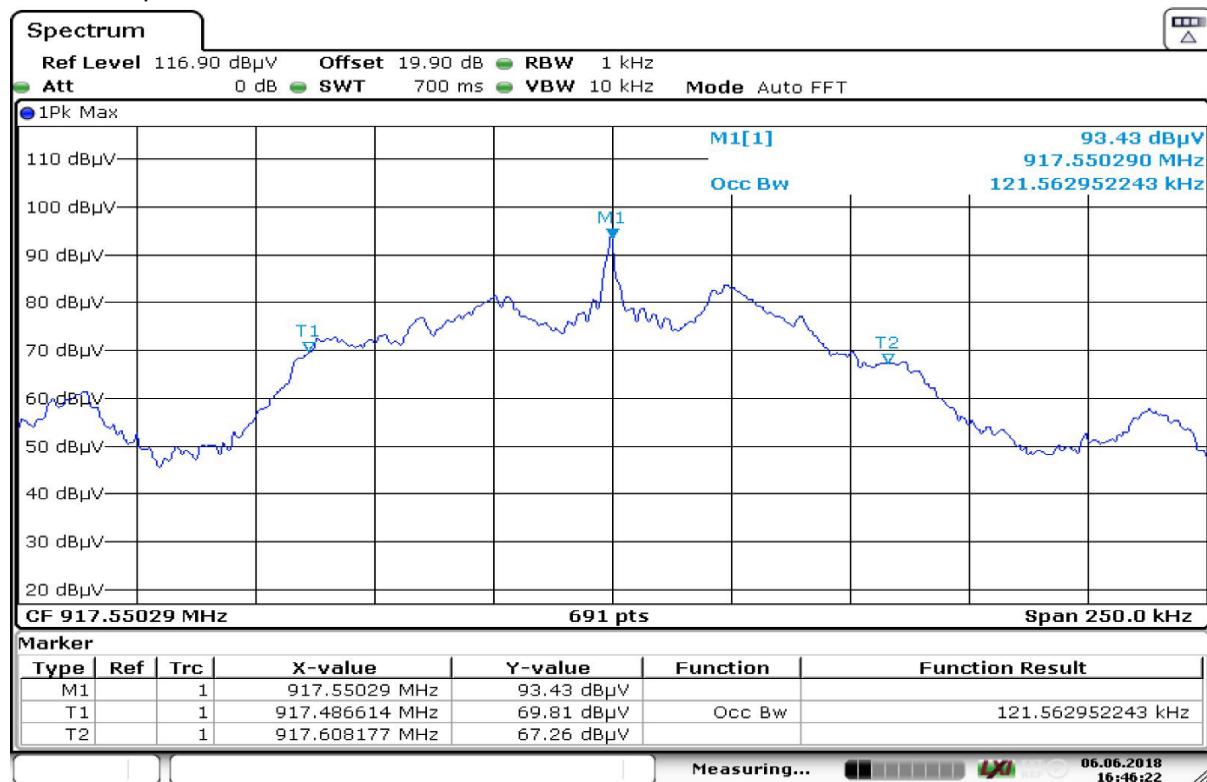
MEASUREMENT PLOTS OCCUPIED BANDWIDTH

20 dB occupied bandwidth



Date: 6.JUN.2018 16:53:09

99% occupied bandwidth between T2 and T1 = 23.83 kHz



Date: 6.JUN.2018 16:46:23

5 MEASUREMENT UNCERTAINTIES

Parameter	Uncertainty
Radio frequency	± 0.5 ppm
RF power, conducted	± 1.0 dB
Conducted spurious emission of transmitter, valid up to 6 GHz	± 2.0 dB
Conducted emission of receivers	± 2.0 dB
Radiated emission of transmitter, valid up to 6 GHz	± 4.5 dB
Radiated emission of receiver, valid up to 6 GHz	± 4.5 dB
RF level uncertainty for a given BER	± 1.5 dB
Occupied Bandwidth	± 4.5%
Temperature	± 0.3 °C
Humidity	± 3%

6 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	NRVD	Power Meter	Rohde & Schwarz GmbH & Co. KG	828110/016	2018-07	2019-07
1.3	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2017-10	2018-10
1.4	Opus10 TPR (8253.00)	ThermoAirpress ure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
1.5	ESW44	EMI Test Receiver	Rohde & Schwarz GmbH & Co. KG	101603	2018-05	2019-05
1.6	Anechoic Chamber	10.58 x 6.38 x 6.00 m ³	Frankonia	none	2018-06	2020-06
1.7	FS-Z60	Harmonic Mixer 40 - 60 GHz	Rohde & Schwarz Messgerätebau GmbH	100178	2016-12	2019-12
1.8	FS-Z220	Harmonic Mixer 140 - 220 GHz	Rohde & Schwarz Messgerätebau GmbH	101005	2017-03	2020-03
1.9	SGH-05	Standard Gain / Pyramidal Horn Antenna (140 - 220 GHz)		075		
1.10	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2018-07	2021-07
1.11	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
1.12	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
1.13	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
1.14	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
1.15	HF 906	Double-ridged horn	Rohde & Schwarz	357357/002		
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		
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	2016-11	2018-11
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		
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	-		

Ref. No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
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 Radio Lab

Lab to perform conducted tests

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	FSV30	Signal Analyzer 10 Hz - 30 GHz	Rohde & Schwarz	103005	2018-04	2020-04
2.4	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
2.5	SMP03	Signal Generator 2 GHz - 27 GHz	Rohde & Schwarz	833680/003	2017-09	2020-09
2.6	FSIQ26	Signal Analyser	Rohde & Schwarz	840061/005	2017-05	2019-05
2.7	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
2.8	VT 4002	Temperature Chamber	Vötsch	5856600215001 0	2018-04	2020-04
2.9	WA1515	Broadband Power Divider SMA	Weinschel Associates	A855		
2.10	A8455-4	4 Way Power Divider (SMA)		-		
2.11	Opus10 THI (8152.00)	ThermoHygro Datalogger 03 (Environ)	Lufft Mess- und Regeltechnik GmbH	7482	2017-03	2019-03
2.12	SMBV100A	Vector Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	259291	2016-10	2019-10

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

7 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.

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

$$E (\text{dB } \mu\text{V/m}) = U (\text{dB } \mu\text{V}) + AF (\text{dB } 1/\text{m}) + \text{Corr. (dB)}$$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

distance correction = $-40 * \text{LOG}(\frac{d_{\text{limit}}}{d_{\text{used}}})$

Linear interpolation will be used for frequencies in between the values in the table.

Linear interpolation will be used
Table shows an extract of values

ANTENNA R&S HL562 (30 MHZ – 1 GHZ)

 (d_{limit} = 3 m)

Frequency	AF R&S HL562	Corr.
MHz	dB (1/m)	dB
30	18.6	0.6
50	6.0	0.9
100	9.7	1.2
150	7.9	1.6
200	7.6	1.9
250	9.5	2.1
300	11.0	2.3
350	12.4	2.6
400	13.6	2.9
450	14.7	3.1
500	15.6	3.2
550	16.3	3.5
600	17.2	3.5
650	18.1	3.6
700	18.5	3.6
750	19.1	4.1
800	19.6	4.1
850	20.1	4.4
900	20.8	4.7
950	21.1	4.8
1000	21.6	4.9

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))
dB	dB	dB	dB	dB	m	m
0.29	0.04	0.23	0.02	0.0	3	3
0.39	0.09	0.32	0.08	0.0	3	3
0.56	0.14	0.47	0.08	0.0	3	3
0.73	0.20	0.59	0.12	0.0	3	3
0.84	0.21	0.70	0.11	0.0	3	3
0.98	0.24	0.80	0.13	0.0	3	3
1.04	0.26	0.89	0.15	0.0	3	3
1.18	0.31	0.96	0.13	0.0	3	3
1.28	0.35	1.03	0.19	0.0	3	3
1.39	0.38	1.11	0.22	0.0	3	3
1.44	0.39	1.20	0.19	0.0	3	3
1.55	0.46	1.24	0.23	0.0	3	3
1.59	0.43	1.29	0.23	0.0	3	3
1.67	0.34	1.35	0.22	0.0	3	3
1.67	0.42	1.41	0.15	0.0	3	3
1.87	0.54	1.46	0.25	0.0	3	3
1.90	0.46	1.51	0.25	0.0	3	3
1.99	0.60	1.56	0.27	0.0	3	3
2.14	0.60	1.63	0.29	0.0	3	3
2.22	0.60	1.66	0.33	0.0	3	3
2.23	0.61	1.71	0.30	0.0	3	3

 (d_{limit} = 10 m)

30	18.6	-9.9
50	6.0	-9.6
100	9.7	-9.2
150	7.9	-8.8
200	7.6	-8.6
250	9.5	-8.3
300	11.0	-8.1
350	12.4	-7.9
400	13.6	-7.6
450	14.7	-7.4
500	15.6	-7.2
550	16.3	-7.0
600	17.2	-6.9
650	18.1	-6.9
700	18.5	-6.8
750	19.1	-6.3
800	19.6	-6.3
850	20.1	-6.0
900	20.8	-5.8
950	21.1	-5.6
1000	21.6	-5.6

0.29	0.04	0.23	0.02	-10.5	10	3
0.39	0.09	0.32	0.08	-10.5	10	3
0.56	0.14	0.47	0.08	-10.5	10	3
0.73	0.20	0.59	0.12	-10.5	10	3
0.84	0.21	0.70	0.11	-10.5	10	3
0.98	0.24	0.80	0.13	-10.5	10	3
1.04	0.26	0.89	0.15	-10.5	10	3
1.18	0.31	0.96	0.13	-10.5	10	3
1.28	0.35	1.03	0.19	-10.5	10	3
1.39	0.38	1.11	0.22	-10.5	10	3
1.44	0.39	1.20	0.19	-10.5	10	3
1.55	0.46	1.24	0.23	-10.5	10	3
1.59	0.43	1.29	0.23	-10.5	10	3
1.67	0.34	1.35	0.22	-10.5	10	3
1.67	0.42	1.41	0.15	-10.5	10	3
1.87	0.54	1.46	0.25	-10.5	10	3
1.90	0.46	1.51	0.25	-10.5	10	3
1.99	0.60	1.56	0.27	-10.5	10	3
2.14	0.60	1.63	0.29	-10.5	10	3
2.22	0.60	1.66	0.33	-10.5	10	3
2.23	0.61	1.71	0.30	-10.5	10	3

Sample calculation

$$E (\text{dB } \mu\text{V/m}) = U (\text{dB } \mu\text{V}) + AF (\text{dB } 1/\text{m}) + \text{Corr. (dB)}$$

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)

$$\text{distance correction} = -20 * \text{LOG} (d_{\text{limit}} / d_{\text{used}})$$

Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

ANTENNA R&S HF907 (1 GHZ – 18 GHZ)

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
1000	24.4	-19.4
2000	28.5	-17.4
3000	31.0	-16.1
4000	33.1	-14.7
5000	34.4	-13.7
6000	34.7	-12.7
7000	35.6	-11.0

cable loss 1 (relay + cable inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit, attenu- ator & pre-amp)	cable loss 4 (to receiver)		
dB	dB	dB	dB		
0.99	0.31	-21.51	0.79		
1.44	0.44	-20.63	1.38		
1.87	0.53	-19.85	1.33		
2.41	0.67	-19.13	1.31		
2.78	0.86	-18.71	1.40		
2.74	0.90	-17.83	1.47		
2.82	0.86	-16.19	1.46		

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
3000	31.0	-23.4
4000	33.1	-23.3
5000	34.4	-21.7
6000	34.7	-21.2
7000	35.6	-19.8

cable loss 1 (relay inside chamber)	cable loss 2 (inside chamber)	cable loss 3 (outside chamber)	cable loss 4 (switch unit, attenu- ator & pre-amp)	cable loss 5 (to receiver)	used for FCC 15.247
dB	dB	dB	dB	dB	
0.47	1.87	0.53	-27.58	1.33	
0.56	2.41	0.67	-28.23	1.31	
0.61	2.78	0.86	-27.35	1.40	
0.58	2.74	0.90	-26.89	1.47	
0.66	2.82	0.86	-25.58	1.46	

Frequency	AF R&S HF907	Corr.
MHz	dB (1/m)	dB
7000	35.6	-57.3
8000	36.3	-56.3
9000	37.1	-55.3
10000	37.5	-56.2
11000	37.5	-55.3
12000	37.6	-53.7
13000	38.2	-53.5
14000	39.9	-56.3
15000	40.9	-54.1
16000	41.3	-54.1
17000	42.8	-54.4
18000	44.2	-54.7

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)
dB	dB	dB	dB	dB	dB
0.56	1.28	-62.72	2.66	0.94	1.46
0.69	0.71	-61.49	2.84	1.00	1.53
0.68	0.65	-60.80	3.06	1.09	1.60
0.70	0.54	-61.91	3.28	1.20	1.67
0.80	0.61	-61.40	3.43	1.27	1.70
0.84	0.42	-59.70	3.53	1.26	1.73
0.83	0.44	-59.81	3.75	1.32	1.83
0.91	0.53	-63.03	3.91	1.40	1.77
0.98	0.54	-61.05	4.02	1.44	1.83
1.23	0.49	-61.51	4.17	1.51	1.85
1.36	0.76	-62.36	4.34	1.53	2.00
1.70	0.53	-62.88	4.41	1.55	1.91

Sample calculation

$$E (\text{dB } \mu\text{V}/\text{m}) = U (\text{dB } \mu\text{V}) + AF (\text{dB } 1/\text{m}) + \text{Corr. (dB)}$$

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.

ANTENNA EMCO 3160-09 (18 GHZ – 26.5 GHZ)

Frequency	AF EMCO 3160-09	Corr.
MHz	dB (1/m)	dB
18000	40.2	-23.5
18500	40.2	-23.2
19000	40.2	-22.0
19500	40.3	-21.3
20000	40.3	-20.3
20500	40.3	-19.9
21000	40.3	-19.1
21500	40.3	-19.1
22000	40.3	-18.7
22500	40.4	-19.0
23000	40.4	-19.5
23500	40.4	-19.3
24000	40.4	-19.8
24500	40.4	-19.5
25000	40.4	-19.3
25500	40.5	-20.4
26000	40.5	-21.3
26500	40.5	-21.1

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)
dB	dB	dB	dB	dB
0.72	-35.85	6.20	2.81	2.65
0.69	-35.71	6.46	2.76	2.59
0.76	-35.44	6.69	3.15	2.79
0.74	-35.07	7.04	3.11	2.91
0.72	-34.49	7.30	3.07	3.05
0.78	-34.46	7.48	3.12	3.15
0.87	-34.07	7.61	3.20	3.33
0.90	-33.96	7.47	3.28	3.19
0.89	-33.57	7.34	3.35	3.28
0.87	-33.66	7.06	3.75	2.94
0.88	-33.75	6.92	3.77	2.70
0.90	-33.35	6.99	3.52	2.66
0.88	-33.99	6.88	3.88	2.58
0.91	-33.89	7.01	3.93	2.51
0.88	-33.00	6.72	3.96	2.14
0.89	-34.07	6.90	3.66	2.22
0.86	-35.11	7.02	3.69	2.28
0.90	-35.20	7.15	3.91	2.36

Sample calculation

$$E (\text{dB } \mu\text{V/m}) = U (\text{dB } \mu\text{V}) + AF (\text{dB } 1/\text{m}) + \text{Corr. (dB)}$$

U = Receiver reading

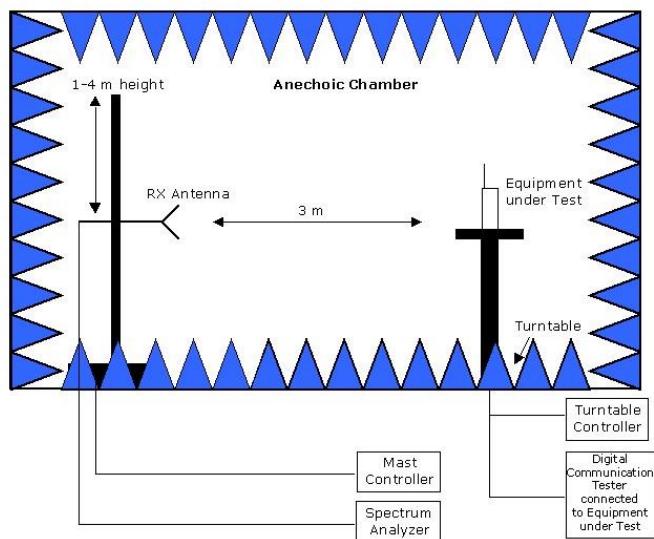
AF = Antenna factor

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.

8 SETUP DRAWINGS



Remark: Depending on the frequency range suitable antenna types, attenuators or preamplifiers are used.

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 surface

9 PHOTO REPORT

Photos are included in an external report.