

InterLab®

FCC Measurement Technical Report on

RFID MultiPen LF-HF-UHF Multipen APOLLO

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

Report Reference: MDE_TECTU_1701_FCCb_Rev1

Test Laboratory:

7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany



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.

7layers GmbH

Borsigstraße 11
40880 Ratingen, Germany
T +49 (0) 2102 749 0
F +49 (0) 2102 749 350

Geschäftsführer/
Managing Director:
Frank Spiller
Alexandre Norré-Oudard

Registergericht/registered:
Düsseldorf HRB 75554
USt-Id.-Nr./VAT-No. DE203159652
Steuer-Nr./TAX-No. 147/5869/0385

a Bureau Veritas
Group Company

www.7layers.com

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0 Summary

0.1 Technical Report Summary

Type of Authorization

Certification for an intentional radiator operating at 13.56 MHz

Applicable FCC Rules

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 (10-1-16 Edition) 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

§ 15.205 Restricted bands of operation

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.215 Additional provisions to the general radiated emission limitations

§ 15.225 Operation within the band 13.110-14.010 MHz

ANSI C63.10-2013 is applied

Summary Test Results:

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

0.2 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 §15.209

Radiated Emissions

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Port	2013 Final Result
op-mode 1	Setup_01 and 02	Enclosure	passed

FCC Part 15, Subpart J § 2.1049

Occupied Bandwidth

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Port	2013 Final Result
op-mode 1	Setup_01 and 02	Enclosure	passed

FCC Part 15, Subpart C § 15.225

Spectrum Mask

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Port	2013 Final Result
op-mode 1	Setup_01 and 02	Enclosure	passed

FCC Part 15, Subpart J § 2.1055

Frequency Tolerance

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Port	2013 Final Result
op-mode 2	Setup_03	Enclosure	passed

N/A not applicable (the EUT is battery powered and when the battery is charging the device cannot operate).

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:



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:	NFC Tag reader
Voltage Type:	DC - Ni-MH batteries
Voltage level:	2.6 V nominal and tested voltages: 2.25 to 3.0 V

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 object of this report is the NFC Tag reader.

Specific product description for the EUT:

The NFC Tag reader is working at 13.56 MHz.

The EUT provides the following ports:

Ports

Enclosure
DC and USB Type B interface connector

The main components of the EUT are listed and described in Chapter 2.2.

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: DE1311000ac01)	Multipen	APOLLO	201810022	REV.B	1v3-Test
EUT B (Code: DE1311000ad01)	Multipen	APOLLO	201810023	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	FCC ID
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, CI1/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	Equipment under Test	Type Designation	Serial no.	HW Status	SW Status	FCC ID
-	-	-	-	-	-	-

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 2	Setup for measuring Spectrum mask, Occupied BW and Radiated emissions
Setup_02	EUT A + ANC 3	Setup for measuring Spectrum mask, Occupied BW and Radiated emissions
Setup_03	EUT B	Setup for measuring frequency tolerance

2.6 Operating Modes

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

Op. Mode	Description of Operating Modes	Remarks
op-mode 1	modulated carrier signal	EUT is transmitting a periodic modulated signal.
op-mode 2	CW carrier signal	EUT is transmitting a non-modulated signal

2.7 Special software used for testing

Loaded in the EUT by the customer before the tests begin.

2.8 Product labelling

2.8.1 FCC ID label

2APYJ-MULTIPEN3

2.8.2 Location of the label on the EUT

Please refer to the documentation of the applicant.

3 Test Results

3.1 Spurious radiated emissions

Standard FCC Part 15, 10-1-16 Edition Subpart C

The test was performed according to: ANSI C63.10-2013

3.1.1 Test Description

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 EMC test software from R&S. Exploratory tests are performed at 3 orthogonal axes to determine the worst-case orientation of a body-worn or handheld EUT. The final test on all kind of EUTs is performed at 2 axes. A pre-check is also performed while the EUT is powered from DC (battery) power in order to find the worst-case operating condition.

1. Measurement up to 30 MHz

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 and 0.15 – 30 MHz
- Frequency steps: 0.1 kHz and 5 kHz
- IF-Bandwidth: 0.2 kHz and 10 kHz
- Measuring time / Frequency step: 100 ms

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: 200 Hz – 10 kHz
- Measuring time / Frequency step: 100 ms

2. Measurement above 30 MHz and up to 1 GHz

Step 1: Preliminary scan

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

Settings for step 1:

- Antenna distance: 3 m
- Detector: Peak-Maxhold
- Frequency range: 30 – 1000 MHz
- Frequency steps: 60 kHz
- IF-Bandwidth: 120 kHz
- Measuring time / Frequency step: 100 μ s
- Turntable angle range: -180° to 180°
- 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: second 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 out the approximate turntable angle and antenna height for each frequency.

- Detector: Peak – Maxhold
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 100 ms
- Turntable angle range: -180° to 180°
- Turntable step size: 45°
- Height variation range: 1 – 4 m
- Height variation step size: 0.5 m
- Polarisation: horizontal + vertical

After this step the EMI test system has determined the following values for each frequency (of step 1):

- Frequency
- Azimuth value (of turntable)
- Antenna height

The last two values have now the following accuracy:

- Azimuth value (of turntable): 45°
- Antenna height: 0.5 m

Step 3: final 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 be slowly varied by $\pm 22.5^{\circ}$ 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 is also slowly varied by ± 25 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: -22.5° to $+22.5^{\circ}$ around the determined value
- Height variation range: -0.25 m to $+0.25$ m around the determined value

Step 4: 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:

The Equipment Under Test (EUT) was set up on a non-conductive support at 1.4 m height in the fully-anechoic chamber. The measurement distance was reduced to 1 m. The results were extrapolated by the extrapolation factor of 20 dB/decade (inverse linear distance for field strength measurements, inverse linear-distance squared for the power reference level measurements). Due to the fact that in this frequency range a double ridged wave guided horn antenna (up to 18 GHz) and a horn antenna (18-25 GHz) are used, the steps 2-4 are omitted. Step 1 was performed with one height of the receiving antenna only.

EMI receiver settings:

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

3.1.2 Test Requirements / Limits

FCC Part 15, Subpart C, §15.247 (d)

... In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

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

Frequency in MHz	Limit (μV/m)	Measurement distance (m)	Calculate Limit (dBμV/m @10m)	Limit (dBμV/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 (μV/m)	Measurement distance (m)	Limit (dBμV/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: $\text{Limit (dB}\mu\text{V/m)} = 20 \log (\text{Limit (}\mu\text{V/m)}/1\mu\text{V/m)}$

3.1.3 Test Protocol

Temperature: 26 °C
Air Pressure: 1008 hPa
Humidity: 42 %

3.1.3.1 Measurement up to 30 MHz

Op. Mode	Setup	Port
op-mode 1	Setup_01 and 02	Enclosure

Frequency MHz	Corrected value dBμV/m			Limit dBμV/ m	Limit dBμV/ m	Limit dBμV/ m	Delta to limit dB	Delta to limit dB
	QP	Peak	AV	QP	Peak	AV	QP/Peak	AV
-	-	-	-	-	-	-	-	-

Remark: No (further) spurious emissions in the range 20 dB below the limit found therefore step 2 was not performed. Please refer to the plot in the annex.
The peak found at 13.56 MHz is the wanted signal of the EUT.

3.1.3.2 Measurement above 30 MHz

Op. Mode	Setup	Port
op-mode 1	Setup_01 and 02	Enclosure

Polarisation	Frequency MHz	Corrected value dBμV/m			Limit dBμV/ m	Limit dBμV/ m	Limit dBμV/ m	Delta to limit dB	Delta to limit dB
		QP	Peak	AV	QP	Peak	AV	QP/Peak	AV
Vertical	40.68	33.49	-	-	40.0	-	-	6.51	-

Remark: No (further) spurious emissions in the range 20 dB below the limit found.

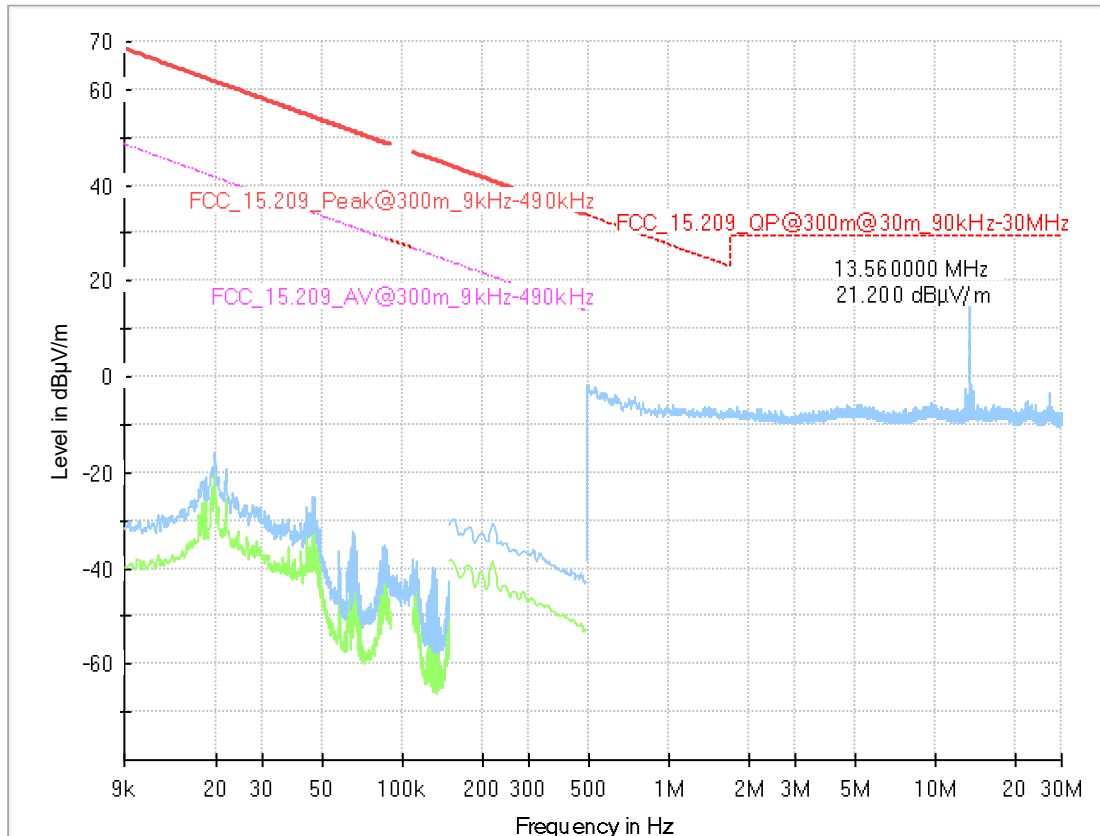
3.1.4 Test result: Spurious radiated emissions

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

3.1.5 Measurement plots

3.1.5.1 Radiated emissions ($f < 30$ MHz)

0 ° and 90° antenna polarisation

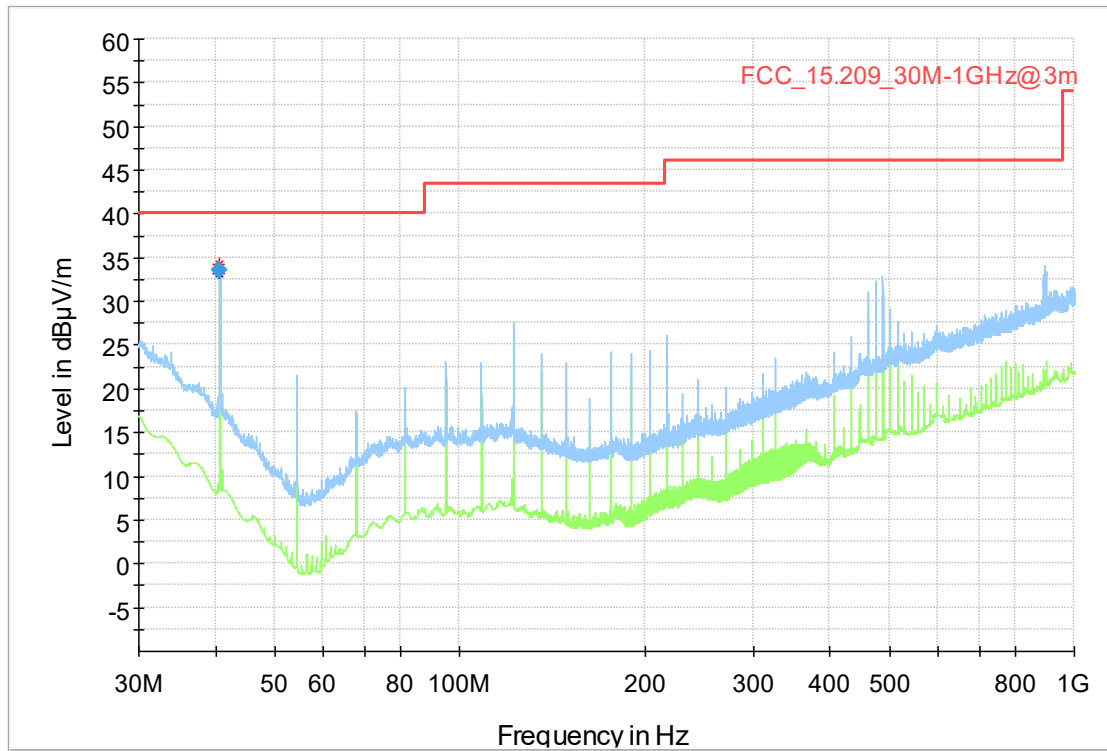


Final Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
---	---	---	---	---	---	---	---	---	---

3.1.5.2 Radiated emissions (f > 30 MHz)

0 ° and 90° antenna polarisation



Final Result

Frequency (MHz)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB)
40.680000	33.49	40.00	6.51	1000.0	120.000	100.0	V	-80.0	13.3

3.2 Occupied bandwidth

Standard FCC Part 15, 10-1-16 Edition Subpart C

The test was performed according to: FCC §2.1049

3.2.1 Test Description

The Equipment Under Test (EUT) was setup in a shielded room to perform the occupied bandwidth measurements.

The reference level is the level of the highest amplitude signal observed from the transmitter at either the fundamental frequency or first-order modulation products in all typical modes of operation, including the unmodulated carrier, even if atypical.

The results recorded were measured with the modulation which produces the worst-case (widest) occupied bandwidth.

3.2.2 Test Requirements / Limits

FCC Part 15, Subpart C, §15.215 (c)

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

3.2.3 Test Protocol

Temperature: 23 °C
Air Pressure: 998 hPa
Humidity: 55 %

Op. Mode	Setup	Port
op-mode 1	Setup_01 and 02	Enclosure

20 dB bandwidth kHz	99% bandwidth kHz	Remarks
1.55	492.251	The 20 dB bandwidth from 13.560 MHz to 13.562 MHz is entirely within the designated frequency band 13.110 MHz to 14.010 MHz.

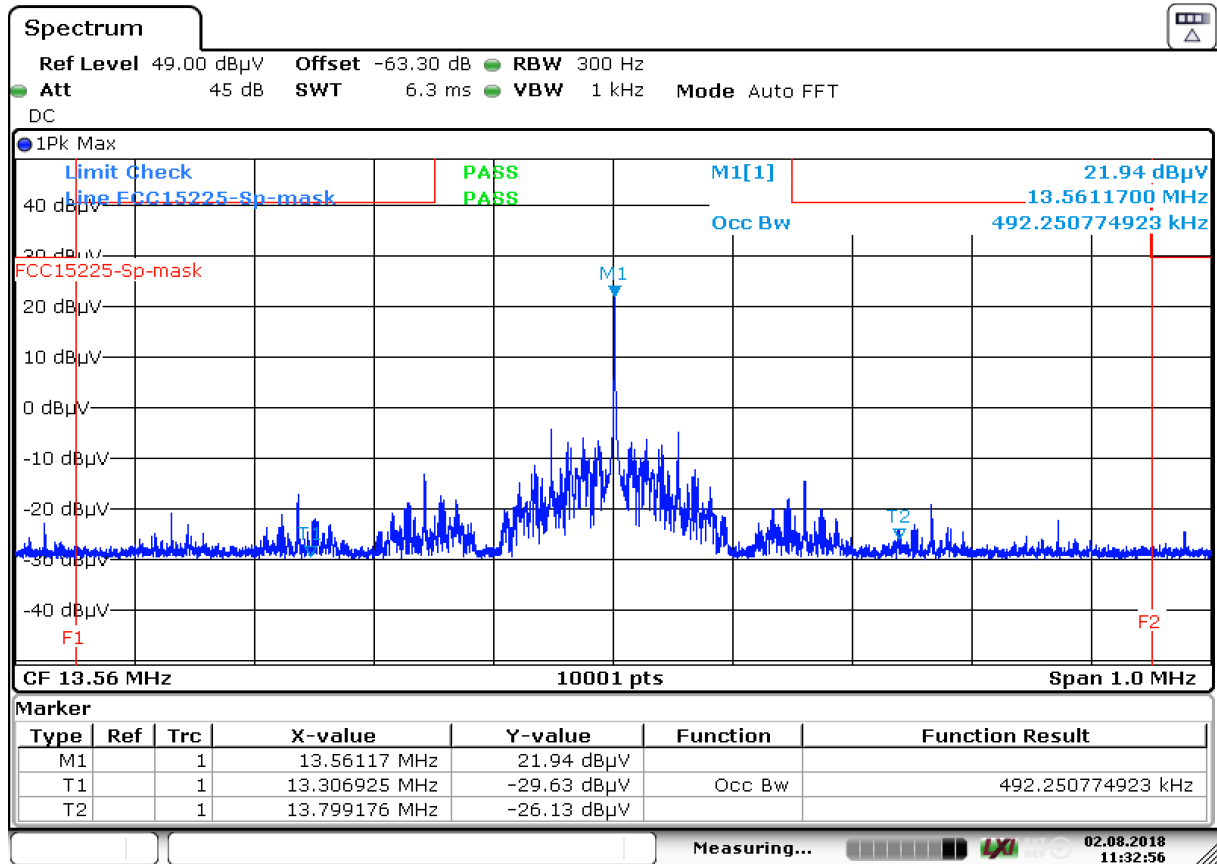
Remark: The occupied bandwidth is not dependant of the card used - ANC 2 or ANC 3.
Please see detailed plots shown in the chapter 3.3 Spectrum mask.

3.2.4 Test result: Occupied bandwidth

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

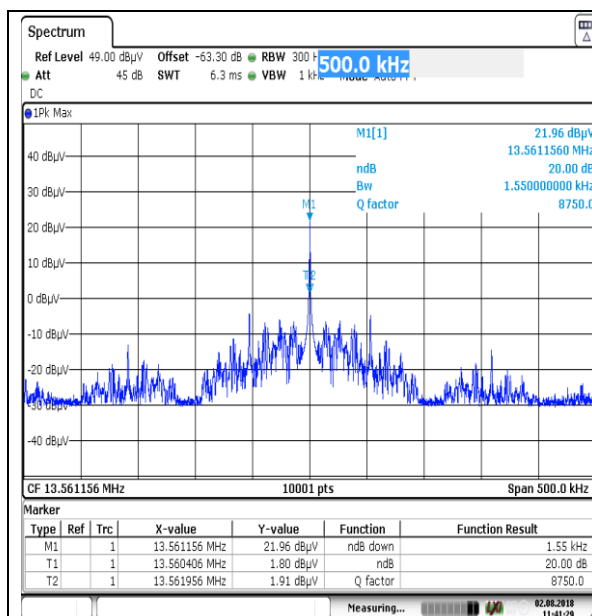
3.2.5 Measurement plots

3.2.5.1 99 % bandwidth

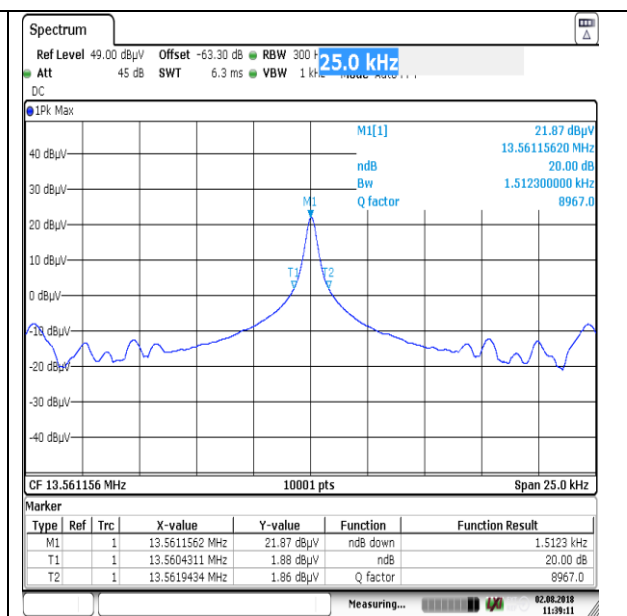


Date: 2.AUG.2018 11:32:56

3.2.5.2 20 dB bandwidth



RBW = 500 kHz



RBW = 25 kHz

3.3 Spectrum mask

Standard FCC Part 15, 10-1-16 Edition Subpart C

The test was performed according to: FCC §15.225

3.3.1 Test Description

The test set-up was made in accordance to the general provisions of ANSI C 63.10-2013. The Equipment Under Test (EUT) was set up on a non-conductive table in the anechoic chamber.

The radiated emissions measurements were made in a typical installation configuration. The measurement procedure is implemented into the EMI test software EMC32 from R&S. The Loop antenna HFH2-Z2 is used.

- Anechoic chamber
- Antenna distance: 10 m
- Detector: Peak-Maxhold
- Frequency range: 13.06 – 14.06 MHz
- Frequency steps: 5 kHz
- IF-Bandwidth: 10 kHz
- Measuring time / Frequency step: 100 ms

3.3.2 Test Limits

FCC Part 15, Subpart C, §15.225 (a-d), and §15.209, corrected by the means of the extrapolation of §15.31 due to the reduced measuring distance from 30 m to 3 m.

3.3.3 Test Protocol

Temperature: 26 °C
Air Pressure: 1008 hPa
Humidity: 42 %

Op. Mode	Setup	Port
op-mode 1	Setup_01 and 02	Enclosure

Maximum value dBµV/m	Limit dBµV/m	Remarks
21.65	84	measuring distance 3 m

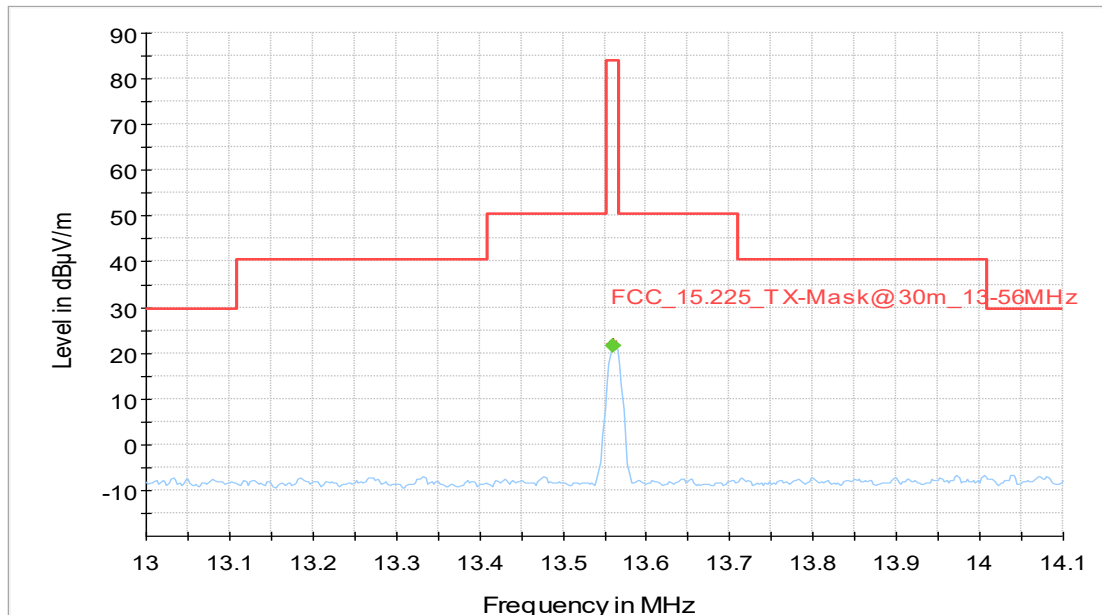
Remark: Please see annex for the measurement plot.

3.3.4 Test result: Spectrum mask

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

3.3.5 Measurement plots

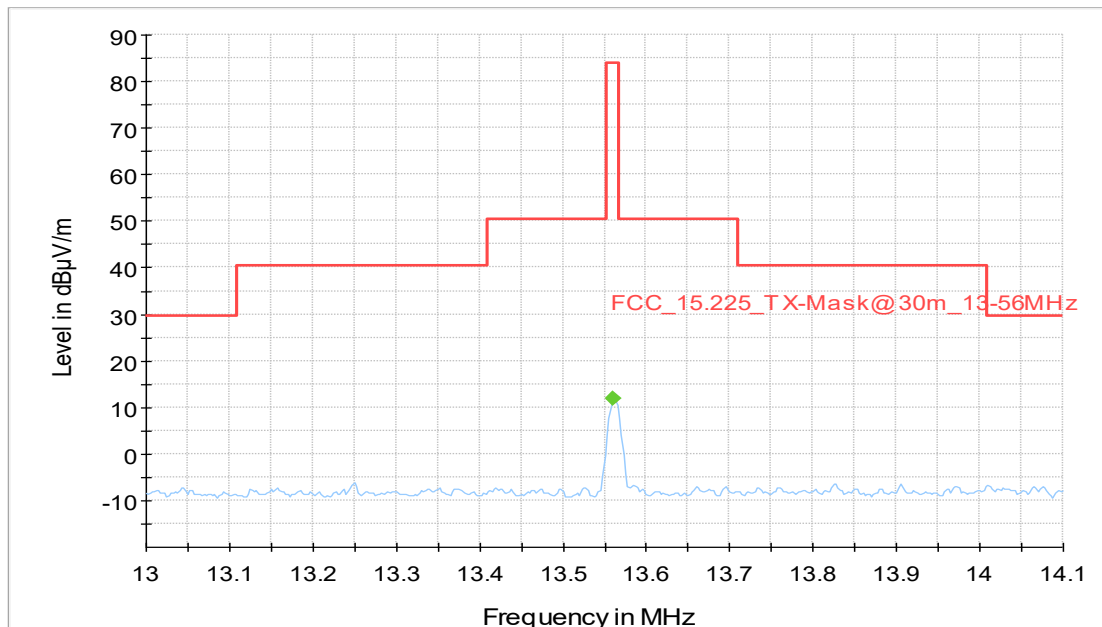
EUT in horizontal position



Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
13.560000	---	21.65	84.00	62.35	1000.0	10.000	100.0	V	0.0	-19.3

EUT in horizontal position



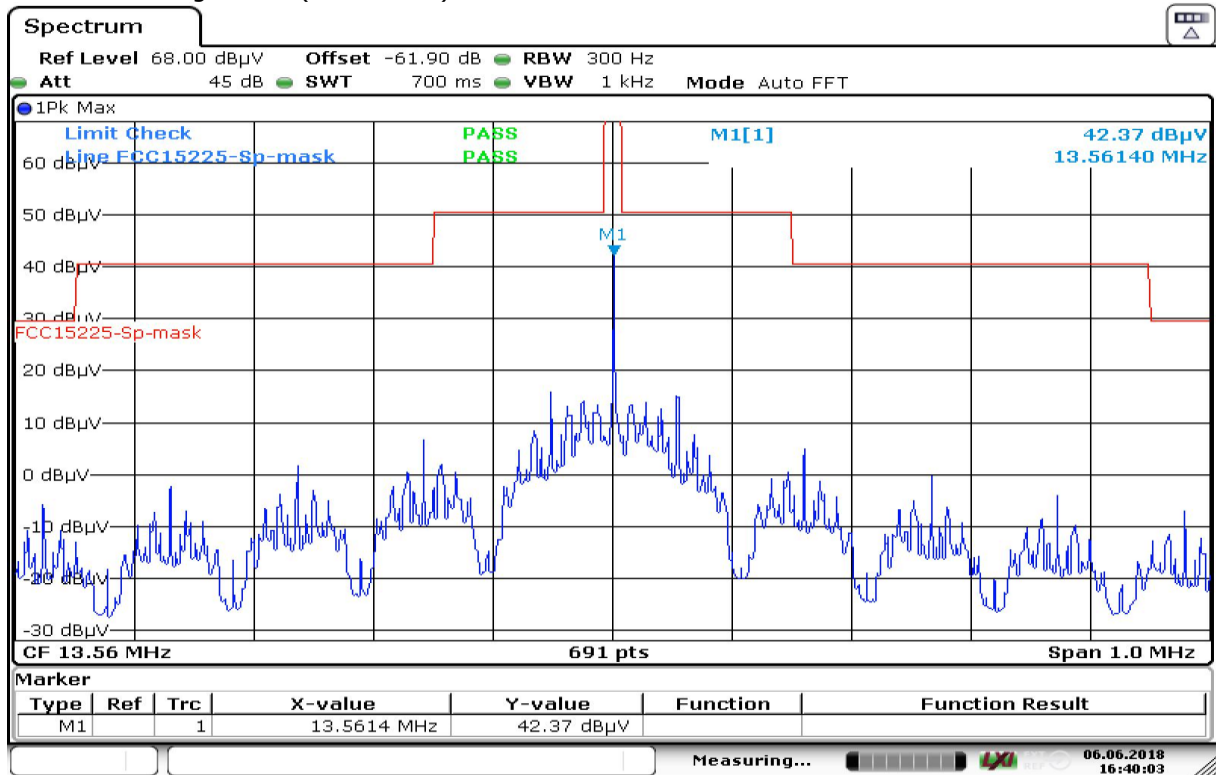
Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	QuasiPeak (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
13.560000	---	11.79	84.00	72.21	1000.0	10.000	100.0	V	-45.0	-19.3

Note: Measurements were performed by using both tags - ANC 2 and ANC 3

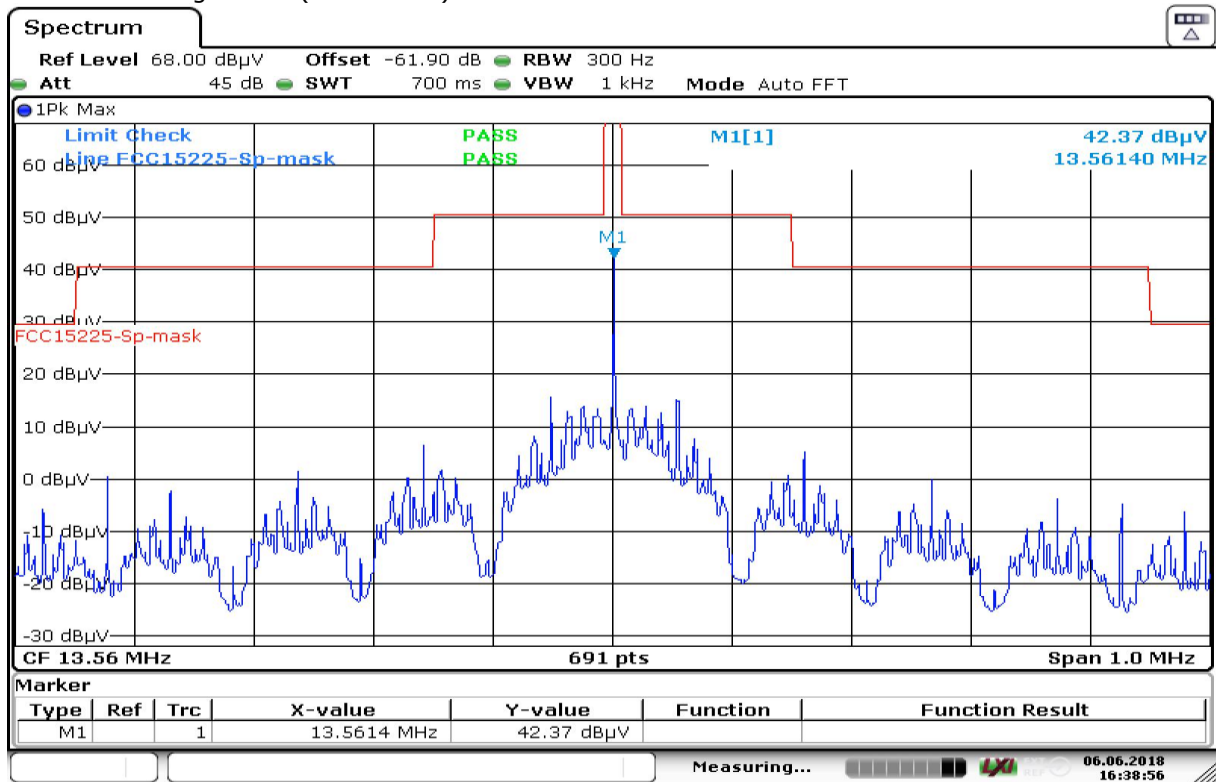
Spectrum mask details:

The EUT reading ANC 2 (ISO 14443)



Date: 6.JUN.2018 16:40:03

The EUT reading ANC 3 (ISO 15693)



Date: 6.JUN.2018 16:38:57

3.4 Frequency tolerance

Standard FCC Part 15, 10-1-16 Edition Subpart C

The test was performed according to: FCC §15.225

3.4.1 Test Description

The Equipment Under Test (EUT) is placed in a temperature chamber. The frequency drift during temperature and voltage variation is measured by the means of a spectrum analyzer with frequency counter function. The temperature was varied from -20 °C to +50 °C. At +20 °C the extreme power supply voltages of 85% and 115% are applied. After reaching each target temperature and waiting sufficient time allowing the temperature to stabilize, one measurement is performed immediately after powering on the EUT, and three further measurements are performed after 2, 5 and 10 minutes continuous operation of EUT.

3.4.2 Test Limits

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

3.4.3 Test Protocol

Temperature: -20° C to +50° C
 Air Pressure: 1009 hPa
 Humidity: 43 %

Op. Mode	Setup	Port
op-mode 2	Setup_03	Enclosure

Temperature [°C]	Voltage [V]	Time [min.]	Frequency [MHz]	Delta [Hz]
50	2.40	0	13.561183	1183
50	2.40	2	13.561257	1257
50	2.40	5	13.561286	1286
50	2.40	10	13.561301	1301
40	2.40	0	13.561173	1173
40	2.40	2	13.561195	1195
40	2.40	5	13.561215	1215
40	2.40	10	13.561224	1224
30	2.40	0	13.561184	1184
30	2.40	2	13.561193	1193
30	2.40	5	13.561179	1179
30	2.40	10	13.561190	1190
20	3.00	0	13.561174	1174
20	3.00	2	13.561172	1172
20	3.00	5	13.561174	1174
20	3.00	10	13.561173	1173
20	2.40	0	13.561223	1223
20	2.40	2	13.561173	1173
20	2.40	5	13.561179	1179
20	2.40	10	13.561173	1173
20	2.25	0	13.561181	1181
20	2.25	2	13.561173	1173
20	2.25	5	13.561173	1173
20	2.25	10	13.561173	1173
10	2.40	0	13.561247	1247
10	2.40	2	13.561186	1186
10	2.40	5	13.561179	1179
10	2.40	10	13.561175	1175
0	2.40	0	13.561230	1230
0	2.40	2	13.561197	1197
0	2.40	5	13.561192	1192
0	2.40	10	13.561189	1189
-10	2.40	0	13.561254	1254
-10	2.40	2	13.561219	1219
-10	2.40	5	13.561208	1208
-10	2.40	10	13.561204	1204
-20	2.40	0	13.561220	1220
-20	2.40	2	13.561214	1214
-20	2.40	5	13.561218	1218
-20	2.40	10	13.561220	1220

Remark: The limit is a delta of max. ± 1356 Hz (0.01 %).

The wider than $\pm 15\%$ voltage range of the declared voltage range by the applicant was used for extreme voltage testing (worst case)

Test result: Frequency tolerance

FCC Part 15, Subpart C	Op. Mode	Result
	op-mode 2	passed

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	2018-07	2019-07
1.2	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2018-07	2019-07
1.3	Opus10 TPR (8253.00)	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 m ³	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	2018-06	2021-06
1.9	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
1.10	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
1.11	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2016-12	2018-12
1.12	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronik GmbH	00083069		
1.13	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
1.14	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
1.15	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
1.16	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
1.17	TT 1.5 WI	Turn Table	Maturo GmbH	-		
1.18	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
1.19	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronik GmbH	00086675		
1.20	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008		
1.21	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2018-01	2021-01-04

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

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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	VT 4002	Climatic Chamber	Vötsch	58566002150010	2018-04	2020-04
2.6	A8455-4	4 Way Power Divider (SMA)		-		
2.7	Opus10 THI (8152.00)	ThermoHygro Datalogger 03 (Environ)	Lufft Mess- und Regeltechnik GmbH	7482	2017-03	2019-03
2.8	SMBV100A	Vector Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	259291	2016-10	2019-10
2.9	OSP120	Switching Unit with integrated power meter	Rohde & Schwarz	101158	2016-11	2018-11

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.	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

$$U_{\text{LISN}} (\text{dB } \mu\text{V}) = U (\text{dB } \mu\text{V}) + \text{Corr. (dB)}$$

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

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

U = Receiver reading

AF = Antenna factor

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

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

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)

($d_{\text{Limit}} = 3 \text{ m}$)

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

($d_{\text{Limit}} = 10 \text{ m}$)

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

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

U = Receiver reading

AF = Antenna factor

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

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

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

Tables show an extract of values.

5.4 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, atten- uator & 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, atten- uator & 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

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

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

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

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

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

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 = $-20 * \text{LOG} (d_{\text{Limit}} / d_{\text{used}})$

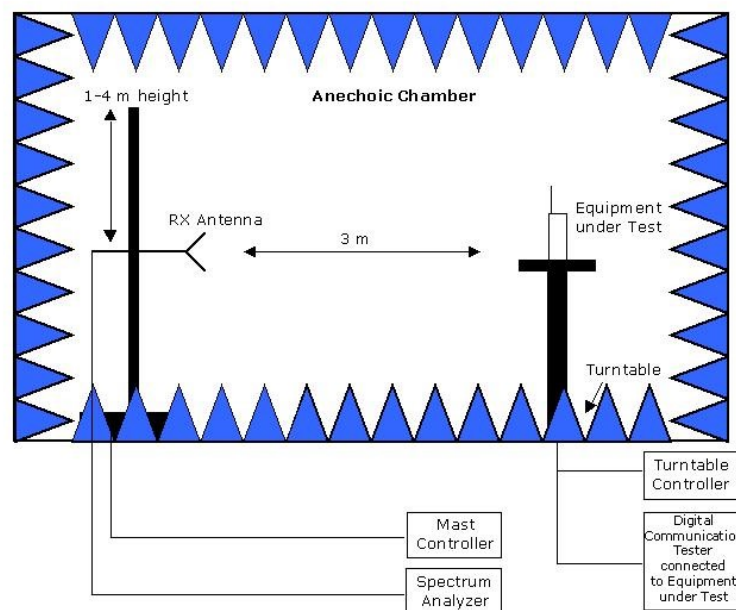
Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

6 Photo Report

Photos are included in an external report.

7 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 surfaces.

8 FCC and IC Correlation of measurement requirements

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

Radio equipment

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 5: 8.8
Out-of-band emissions	§ 15.225 (d)	RSS Gen Issue 5: 6.13/8.9/8.10; RSS-210 Issue 9: B.6
In-band emissions	§ 15.225 (a) / (b) / (c)	RSS-210 Issue 9: B.6
Frequency Stability	§ 15.225 (e)	RSS-210 Issue 9: B.6
Antenna requirement	§ 15.203 / 15.204	RSS-Gen Issue 5: 8.3
Receiver spurious emissions	–	RSS-210 Issue 9: 2.3; RSS Gen Issue 5: 5/7 *)
Handling of active and passive tag devices of RFID application	§ 15.225 (f)	RSS Gen Issue 5: 8.7

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

9 Measurement uncertainty

Test Case	Parameter	Uncertainty
Spectrum mask	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
Frequency tolerance	Frequency	± 3.4 dB