

FCC Measurement/Technical Report on

BE L014

FCC ID: 2ACRLBEL005

IC: -

Test Report Reference: MDE_HARMAN_1505_FCCb

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 APPLIED STANDARDS AND TEST SUMMARY

1.1 APPLIED STANDARDS

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 and 15 (10-1-13 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

§ 15.207 Conducted limits

§ 15.209 Radiated emission limits; general requirements

§ 15.247 Operation within the bands 902-928 MHz, 2400-2483.5 MHz

Note 1:

The tests were selected and performed with reference to the FCC Public Notice DA 00-705, released March 30, 2000. Instead of applying ANSI C63.4-1992 which is referenced in the FCC Public Note, the newer ANSI C63.10-2013 is applied.

Summary Test Results:

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

1.2 FCC-IC CORRELATION TABLE

**Correlation of measurement requirements for
FHSS (e.g. Bluetooth®) equipment
from
FCC and IC**

FHSS equipment

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 4: 8.8
Occupied bandwidth	§ 15.247 (a) (1)	RSS-247 Issue 1: 5.1 (2)
Peak conducted output power	§ 15.247 (b) (1), (4)	RSS-247 Issue 1: 5.4 (2)
Transmitter spurious RF conducted emissions	§ 15.247 (d)	RSS-Gen Issue 4: 6.13/8.9/8.10; RSS-247 Issue 1: 5.5
Transmitter spurious radiated emissions	§ 15.247 (d); § 15.209 (a)	RSS-Gen Issue 4: 6.13 / 8.9/8.10; RSS-247 Issue 1: 5.5
Band edge compliance	§ 15.247 (d)	RSS-247 Issue 1: 5.5
Dwell time	§ 15.247 (a) (1) (iii)	RSS-247 Issue 1: 5.1 (4)
Channel separation	§ 15.247 (a) (1)	RSS-247 Issue 1: 5.1 (2)
No. of hopping frequencies	§ 15.247 (a) (1) (iii)	RSS-247 Issue 1: 5.1 (4)
Hybrid systems (only)	§ 15.247 (f); § 15.247 (e)	RSS-247 Issue 1: 5.3
Antenna requirement	§ 15.203 / 15.204	RSS-Gen Issue 4: 8.3
Receiver spurious emissions	-	-

1.3 MEASUREMENT SUMMARY / SIGNATURES

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247

§ 15.247 (b) (1)

Peak Power Output

The measurement was performed according to ANSI C63.10

Final Result

OP-Mode	Setup	FCC	IC
Radio Technology, Operating Frequency, Measurement method			
Bluetooth BDR, high, conducted	Cond_L014	Passed	Passed
Bluetooth BDR, low, conducted	Cond_L014	Passed	Passed
Bluetooth BDR, mid, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 2, high, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 2, low, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 2, mid, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 3, high, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 3, low, conducted	Cond_L014	Passed	Passed
Bluetooth EDR 3, mid, conducted	Cond_L014	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247

§ 15.247 (d)

Transmitter Spurious Radiated Emissions

The measurement was performed according to ANSI C63.10

Final Result

OP-Mode	Setup	FCC	IC
Radio Technology, Operating Frequency, Measurement range			
Bluetooth BDR, mid, 1 GHz - 26 GHz	Rad_L014	Passed	Passed
Bluetooth BDR, mid, 30 MHz - 1 GHz	Rad_L014	Passed	Passed
Bluetooth BDR, mid, 9 kHz - 30 MHz	Rad_L014	Passed	Passed

N/A: Not applicable

N/P: Not performed

This is a delta test report, based on a product modification.

The test case selection was done on applicant's demand to apply for a FCC class 2 permissive change.

Reference former test report: MDE_HARMAN_1303_FCCe_LevelC

(responsible for accreditation scope)
Dipl.-Ing. Marco Kullik

(responsible for testing and report)
Dipl.-Ing. Daniel Gall

2 ADMINISTRATIVE DATA

2.1 TESTING LABORATORY

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

This facility has been fully described in a report submitted to the FCC and accepted under the registration number 96716.

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-12140-01-00
Responsible for accreditation scope: Dipl.-Ing. Marco Kullik
Report Template Version: 2016-09-16

2.2 PROJECT DATA

Responsible for testing and report: Dipl.-Ing. Daniel Gall
Employees who performed the tests: documented internally at 7Layers
Date of Report: 2016-11-18
Testing Period: 2016-05-25 to 2016-06-23

2.3 APPLICANT DATA

Company Name: Harman Automotive Electronic Systems (Suzhou) Co., Ltd.
Address: No.125, Fangzhou Road
SIP Su Zhou, Jiang Su Province
China
Contact Person: Mrs. Danie Hong

2.4 MANUFACTURER DATA

Company Name: Please see at applicant
Address:
Contact Person:

3 TEST OBJECT DATA

3.1 GENERAL EUT DESCRIPTION

Kind of Device product description	Headunit
Product name	BE L014
Declared EUT data by the supplier	
Voltage Type	DC
Voltage Level	12
Production Tolerance Output Power	±2 dB
Tested Modulation Type	GFSK Modulation, DHx packets π/4 DQPSK Modulation, 2-DHx packets 8-DPSK Modulation, 3-DHx packets
General product description	Vehicular Infotainment System with Bluetooth
Specific product description for the EUT	BT Transceiver operating in the 2.4 GHz ISM band using Frequency Hopping Spread Spectrum (FHSS) Modulation supporting Classic Bluetooth
The EUT provides the following ports (- used cable types):	Enclosure GPS antenna (Fakra) - shielded cable >1m USB (Fakra) - shielded cable >1m Cable Harness including DC - unshielded >1m FM (Fakra) - shielded cable >1m FM Diversity (Fakra) - shielded cable >1m Camera (Fakra) - shielded cable >1m Front Screen (Fakra) - shielded cable >1m DAB (Fakra) - shielded cable >1m
Tested datarates	1 Mbps (DHx packets) 2 Mbps (2-DHx packets) 3 Mbps (3-DHx packets)

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

3.2 EUT MAIN COMPONENTS

Sample Name	Sample Code	Description
DE1022006aa01	aa01	conducted sample
Sample Parameter	Value	
HW Version	D Sample	
Integral Antenna	-5.0 dBi	
SW Version	2.5R09	
Serial No.		
Comment		

Sample Name	Sample Code	Description
DE1022006ad01	ad01	radiated sample
Sample Parameter	Value	
HW Version	D Sample	
Integral Antenna	-5.0 dBi	
SW Version	2.5R09	
Serial No.	0347441	
Comment		

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

3.3 ANCILLARY EQUIPMENT

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

Device	Details (Manufacturer, Type Model, OUT Code)	Description
-	-	-

3.4 AUXILIARY EQUIPMENT

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

Device	Details (Manufacturer, HW, SW, S/N)	Description
Display (8SV)	, -, -,	Connect by LVDS cable to HU

Device	Details (Manufacturer, HW, SW, S/N)	Description
USB adapter	, -, -,	Used to connect HU PCB and PC for RF conduct test
Camera Cable & Camera	, -, -,	Connect HU, for camera
CAN Box	, -, -,	High Speed CAN Box
Display Cable	, -, -,	Used to connect HU and display
FM Antenna cable	, -, -,	
GPS Antenna	, -, -,	
Load box	, -, -,	Connect to main cable
Main Cable	, -, -,	Used to connect HU, HU power, CAN box, CAN Box power, Load box (12-14V DC)
USB fakra cable	, -, -,	BE L014

3.5 EUT SETUPS

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

Setup	Combination of EUTs	Description and Rationale
Rad_L014	DE1022006ad01, Main Cable , CAN Box, Display Cable, FM Antenna cable, Camera Cable & Camera, Display (8SV), Load box, USB fakra cable , GPS Antenna,	Radiated setup
Cond_L014	DE1022006aa01, Main Cable , USB adapter,	Conducted setup

3.6 OPERATING MODES

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

3.6.1 TEST CHANNELS

BT Test Channels:
Channel:
Frequency [MHz]

2.4 GHz ISM 2400 - 2483.5 MHz		
low	mid	high
0	39	78
2402	2441	2480

3.7 PRODUCT LABELLING

3.7.1 FCC ID LABEL

Please refer to the documentation of the applicant.

3.7.2 LOCATION OF THE LABEL ON THE EUT

Please refer to the documentation of the applicant.

4 TEST RESULTS

4.1 PEAK POWER OUTPUT

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.1.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was set up to perform the output power measurements. The results recorded were measured with the modulation which produces the worst-case (highest) output power. The reference level of the spectrum analyzer was set higher than the output power of the EUT.

The EUT was connected to the spectrum analyzer via a short coax cable with a known loss.

Analyzer settings:

- Resolution Bandwidth (RBW): 3 MHz
- Video Bandwidth (VBW): 3 MHz
- Trace: Maxhold
- Sweeps: 3000
- Sweptime: 5 ms
- Detector: Peak

The channel power function of the spectrum analyser was used (Used channel bandwidth = DTS bandwidth)

4.1.2 TEST REQUIREMENTS / LIMITS

DTS devices:

FCC Part 15, Subpart C, §15.247 (b) (3)

For systems using digital modulation techniques in the 902-928 MHz, 2400-2483.5 MHz and 5725-5850 MHz bands: 1 watt.

==> Maximum conducted peak output power: 30 dBm (excluding antenna gain, if antennas with directional gains that do not exceed 6 dBi are used).

Frequency Hopping Systems:

FCC Part 15, Subpart C, §15.247 (b) (1)

For frequency hopping systems operating in the 2400-2483.5 MHz band employing at least 75 non-overlapping hopping channels, and all frequency hopping systems in the 5725-5850 MHz band: 1 watt. For all other frequency hopping systems in the 2400-2483.5 MHz band: 0.125 watts.

FCC Part 15, Subpart C, §15.247 (b) (2)

For frequency hopping systems operating in the 902-928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

Used conversion factor: Limit (dBm) = 10 log (Limit (W)/1mW)

4.1.3 TEST PROTOCOL

Ambient temperature: 23 °C
 Air Pressure: 1008 hPa
 Humidity: 38 %
 BT GFSK (1-DH1)

Band	Channel No.	Frequency [MHz]	Peak Power [dBm]	Limit [dBm]	Margin to Limit [dB]
2.4 GHz ISM	0	2402.0	-2.8	21.0	23.8
	39	2441.0	-3.6	21.0	24.6
	78	2480.0	-3.9	21.0	24.9

BT n/4 DQPSK (2-DH1)

Band	Channel No.	Frequency [MHz]	Peak Power [dBm]	Limit [dBm]	Margin to Limit [dB]
2.4 GHz ISM	0	2402.0	-1.6	21.0	22.6
	39	2441.0	-2.4	21.0	23.4
	78	2480.0	-2.4	21.0	23.4

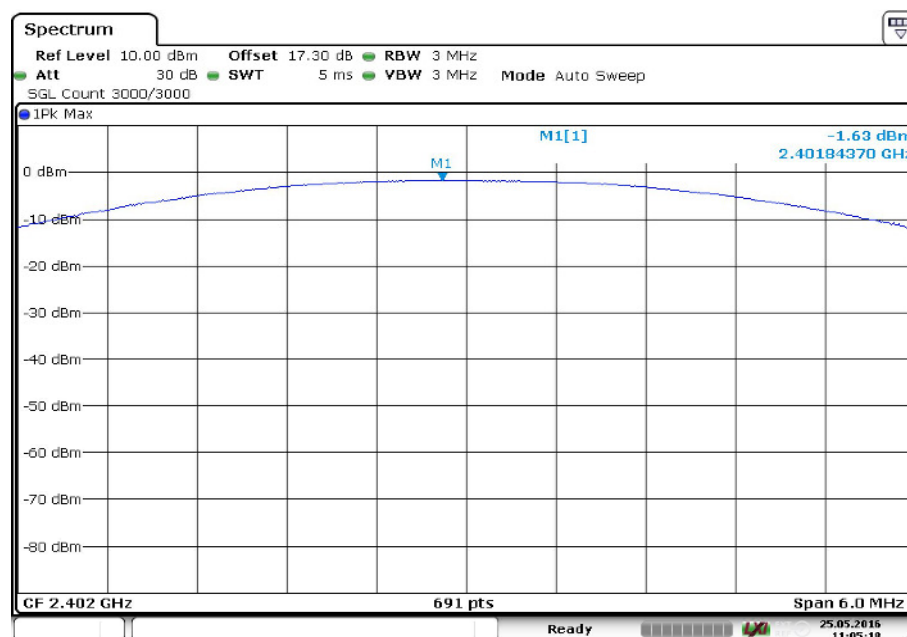
BT 8-DPSK (3-DH1)

Band	Channel No.	Frequency [MHz]	Peak Power [dBm]	Limit [dBm]	Margin to Limit [dB]
2.4 GHz ISM	0	2402.0	-1.7	21.0	22.7
	39	2441.0	-2.3	21.0	23.3
	78	2480.0	-2.5	21.0	23.5

Remark: None.

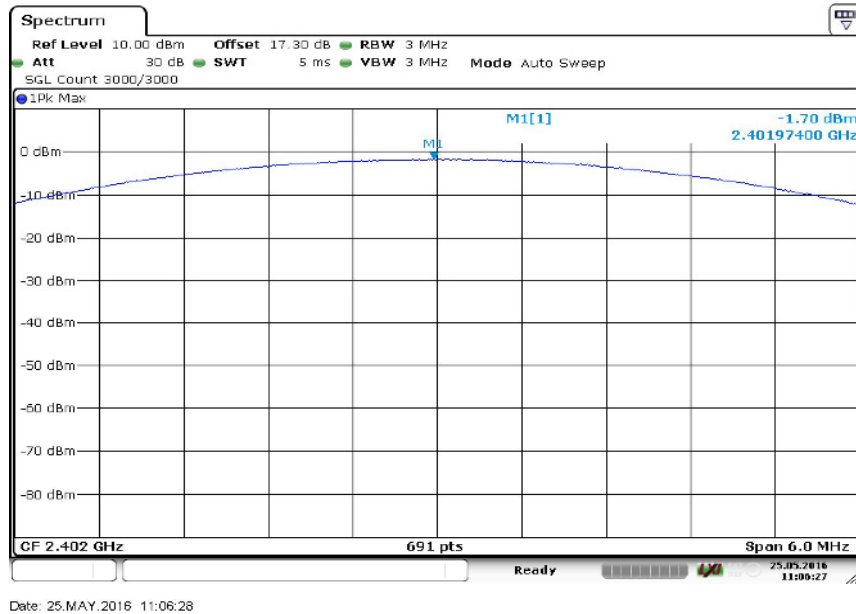
4.1.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, "WORST CASE")

Radio Technology = Bluetooth EDR 2, Operating Frequency = low, Measurement method = conducted

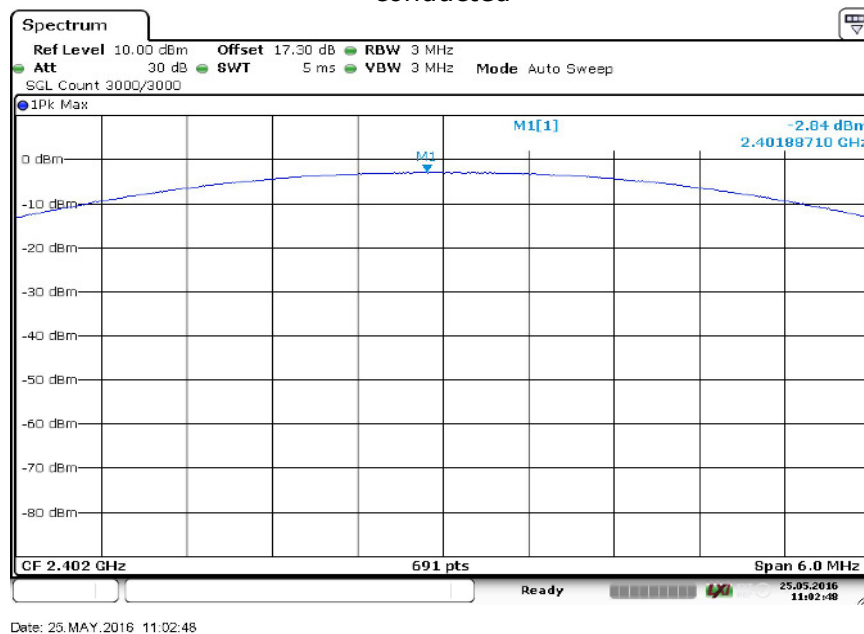


Date: 25.MAY.2016 11:05:19

Radio Technology = Bluetooth EDR 3, Operating Frequency = low, Measurement method = conducted



Radio Technology = Bluetooth BDR, Operating Frequency = low, Measurement method = conducted



4.1.5 TEST EQUIPMENT USED

R&S TS8997

4.2 TRANSMITTER 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 $\pm 45^{\circ}$ 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 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: $\pm 45^{\circ}$ 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 (1.5 m) 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, §15.247 (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 ($\mu\text{V}/\text{m}$)	Measurement distance (m)	Limits ($\text{dB}\mu\text{V}/\text{m}$)
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 ($\mu\text{V}/\text{m}$)	Measurement distance (m)	Limits ($\text{dB}\mu\text{V}/\text{m}$)
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

The measured values above 26 GHz are corrected with an inverse linear distance extrapolation factor (20 dB/decade).

§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: $\text{Limit (dB}\mu\text{V}/\text{m)} = 20 \log (\text{Limit } (\mu\text{V}/\text{m})/1\mu\text{V}/\text{m})$

4.2.3 TEST PROTOCOL

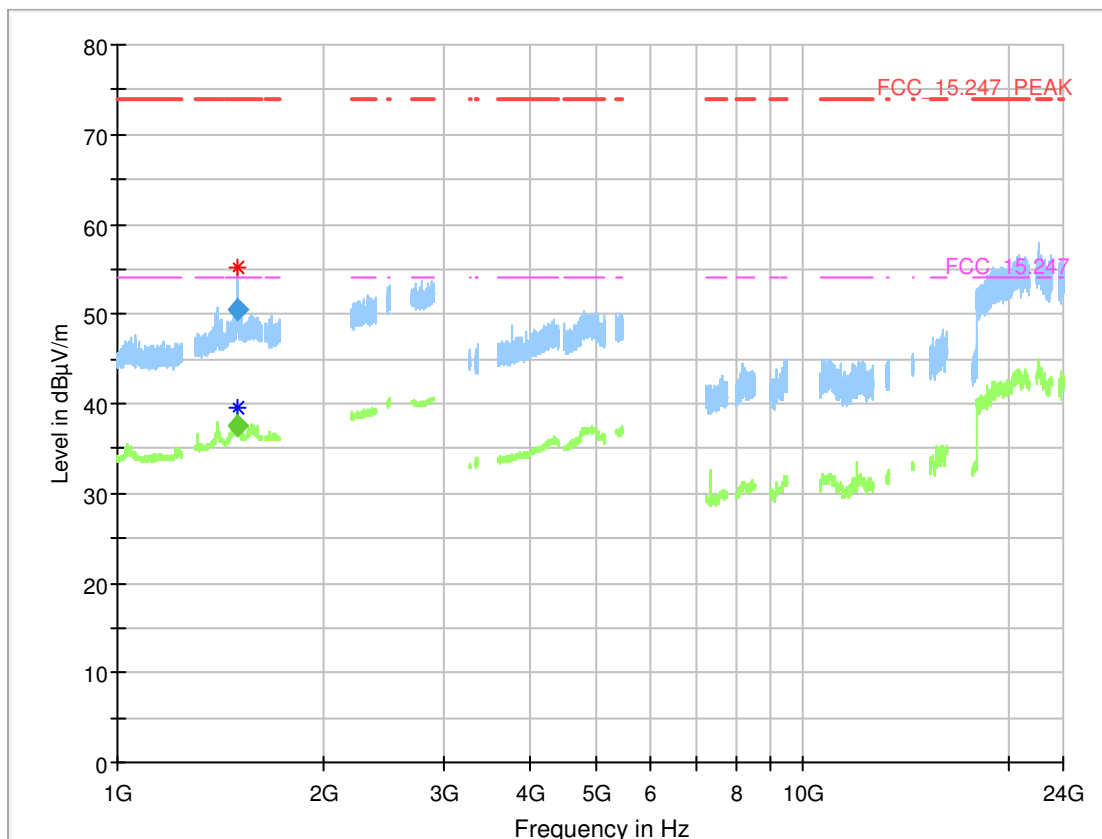
Ambient temperature: 25 °C
 Air Pressure: 1007-1015 hPa
 Humidity: 45 %
 BT GFSK (1-DH1)

Ch. No.	Ch. Center Freq. [MHz]	Spurious Freq. [MHz]	Spurious Level [dB μ V/m]	Detector	RBW [kHz]	Limit [dB μ V/m]	Margin to Limit [dB]	Limit Type
39	2441.0	1499.5	50.4	PEAK	1000.0	74.0	23.6	RB
39	2441.0	1500.5	47.8	AV	1000.0	54.0	6.3	RB

Remark: None.

4.2.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, "WORST CASE")

Radio Technology = Bluetooth BDR, Operating Frequency = mid, Measurement range = 1 GHz - 26 GHz



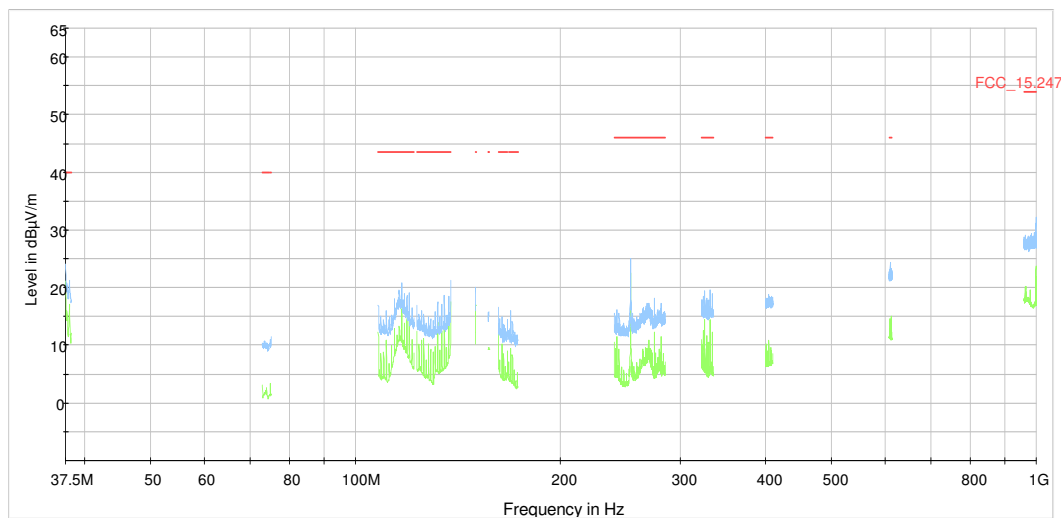
Critical Freqs

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)
1499.53550	55.15	---	74.00	18.85	---	---	150.0	H	-181.0	78.4
1500.49300	---	39.53	54.00	14.47	---	---	150.0	H	115.0	105.2

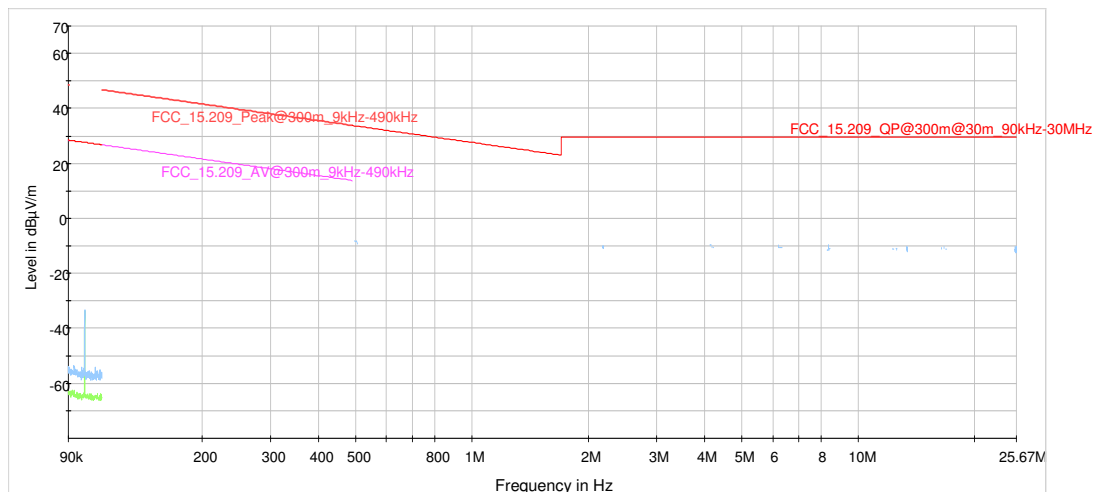
Final Result

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)
1499.53550	50.39	---	74.00	23.61	1000.0	1000.000	150.0	H	-181.0	77.8
1500.49300	---	37.65	54.00	16.35	1000.0	1000.000	150.0	H	115.0	105.2

Radio Technology = Bluetooth BDR, Operating Frequency = mid, Measurement range = 30 MHz - 1 GHz



Radio Technology = Bluetooth BDR, Operating Frequency = mid, Measurement range = 9 kHz - 30 MHz



4.2.5 TEST EQUIPMENT USED

Radiated Emissions

5 TEST EQUIPMENT

1 R&S TS8997
EN300328/301893 Test Lab

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	OSP120	Switching Unit with integrated power meter	Rohde & Schwarz	101158	2015-08	2016-08
1.2	A8455-4	4 Way Power Divider (SMA)		-		
1.3	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2016-02	2018-02
1.4	Opus10 THI (8152.00)	ThermoHygro Datalogger 03 (Environ)	Lufft Mess- und Regeltechnik GmbH	7482	2015-02	2017-02
1.5	SMB100A	Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	107695	2014-06	2017-06
1.6	VT 4002	Climatic Chamber	Vötsch	58566002150010	2016-03	2018-03
1.7	FSV30	Signal Analyzer 10 Hz - 30 GHz	Rohde & Schwarz	103005	2016-02	2018-02
1.8	SMBV100A	Vector Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	259291	2016-10	2019-10
1.9	1515 / 93459	Broadband Power Divider SMA (Aux)	Weinschel Associates	LN673		
1.10	Datum, Model: MFS	Rubidium Frequency Standard	Datum-Beverly	5489/001	2016-06	2017-06

2 Radiated Emissions
Lab to perform radiated emission tests

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronik GmbH	00083069		
2.2	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
2.3	5HC3500/1800 0-1.2-KK	High Pass Filter	Trilithic	200035008		
2.4	Datum MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2016-09	2017-09

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.5	Fully Anechoic Room	8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB		
2.6	AM 4.0	Antenna mast	Maturo GmbH	AM4.0/180/11920513		
2.7	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2014-11	2016-11
2.8	TT 1.5 WI	Turn Table	Maturo GmbH	-		
2.9	Anechoic Chamber	10.58 x 6.38 x 6.00 m ³	Frankonia	none	2014-01	2017-01
2.10	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2016-02	2018-02
2.11	ESIB 26	Spectrum Analyzer	Rohde & Schwarz	830482/004	2015-12	2017-12
2.12	Tilt device Maturo (Rohacell)	Antrieb TD1.5-10kg	Maturo GmbH	TD1.5-10kg/024/3790709		
2.13	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
2.14	AS 620 P	Antenna mast	HD GmbH	620/37		
2.15	NRV-Z1	Sensor Head A	Rohde & Schwarz	827753/005	2016-05	2017-05
2.16	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
2.17	ASP 1.2/1.8-10kg	Antenna Mast	Maturo GmbH	-		
2.18	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
2.19	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
2.20	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2015-06	2018-06
2.21	Opus10 THI (8152.00)	ThermoHygro Datalogger 12 (Environ)	Lufft Mess- und Regeltechnik GmbH	12482	2015-03	2017-03
2.22	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
2.23	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2014-11	2017-11

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.24	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2014-11	2016-11
2.25	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2015-02	2017-02
2.26	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
2.27	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronik GmbH	00086675		
2.28	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
2.29	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
2.30	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2015-05	2018-05

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

6 ANTENNA FACTORS, CABLE LOSS AND SAMPLE CALCULATIONS

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

6.1 LISN R&S ESH3-Z5 (150 KHZ – 30 MHZ)

Frequency MHz	Corr. dB	LISN insertion loss ESH3- Z5 dB	cable loss (incl. 10 dB atten- uator) 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.

6.2 ANTENNA R&S HFH2-Z2 (9 KHZ – 30 MHZ)

Frequency MHz	AF HFH-Z2) dB (1/m)	Corr. dB	cable loss 1 (inside chamber) dB	cable loss 2 (outside chamber) dB	cable loss 3 (switch unit) dB	cable loss 4 (to receiver) dB	distance corr. (-40 dB/ decade) dB	d _{Limit} (meas. distance (limit) m	d _{used} (meas. distance (used) 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

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

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

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

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

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

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

Tables show an extract of values.

6.4 ANTENNA R&S HF907 (1 GHZ – 18 GHZ)

Frequency	AF R&S HF907	Corr.
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, attenuator & 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, attenuator & 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

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

U = Receiver reading

AF = Antenna factor

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

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

Tables show an extract of values.

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

Frequency MHz	AF EMCO 3160-09 dB (1/m)	Corr. dB	cable loss 1 (inside chamber) dB	cable loss 2 (pre- amp) dB	cable loss 3 (inside chamber) dB	cable loss 4 (switch unit) dB	cable loss 5 (to receiver) 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

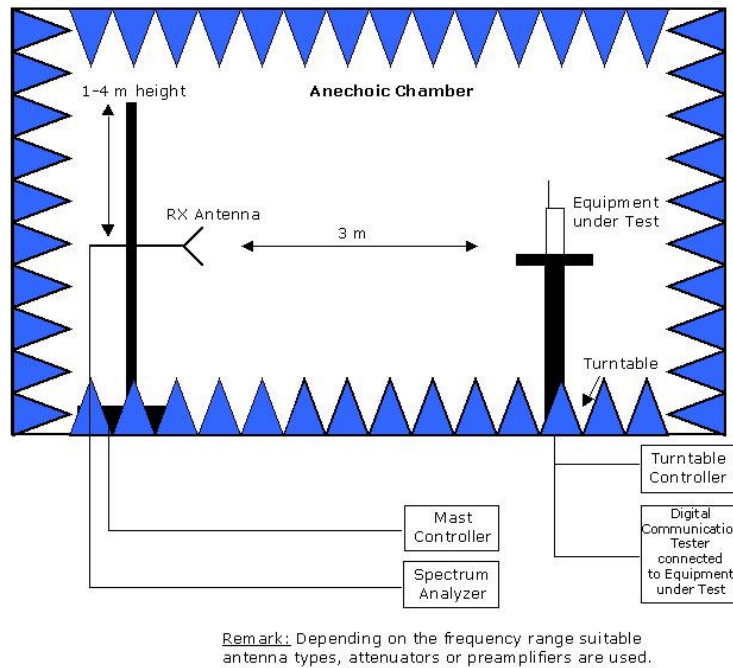
AF = Antenna factor

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

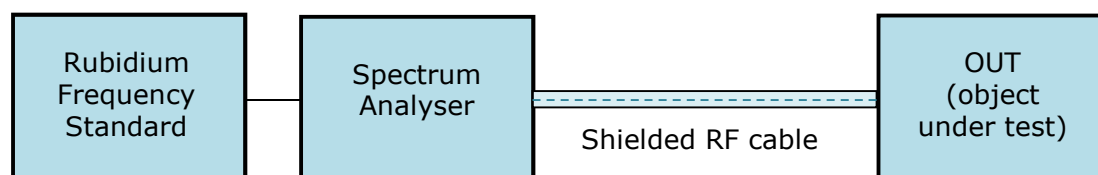
Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

7 SETUP DRAWINGS



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



Drawing 2: Setup for conducted radio tests.

8 MEASUREMENT UNCERTAINTIES

Test Case	Parameter	Uncertainty
AC Power Line	Power	± 3.4 dB
Field Strength of spurious radiation	Power	± 5.5 dB
6 dB / 26 dB / 99% Bandwidth	Power Frequency	± 2.9 dB ± 11.2 kHz
Conducted Output Power	Power	± 2.2 dB
Band Edge Compliance	Power Frequency	± 2.2 dB ± 11.2 kHz
Frequency Stability	Frequency	± 25 Hz
Power Spectral Density	Power	± 2.2 dB

9 PHOTO REPORT

Please see separate photo report.