FCC Measurement/Technical Report on

Vacuum cleaner CT

CT MINI I, CT MIDI I

FCC ID: 2AL2E-CTCOM
IC: 22501-CTCOM

Test Report Reference: MDE_FESTO_1803_FCCa_rev1

Test Laboratory:
7layers GmbH
Borsigstrasse 11
40880 Ratingen
Germany

Deutsche Akkreditierungsstelle D-PL-12140-01-00

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

Table of Contents

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 (10-1-17 Edition). The following subparts are applicable to the results in this test report.

Part 2, Subpart J - Equipment Authorization Procedures, Certification

Part 15, Subpart C – Intentional Radiators

§ 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:
The tests were selected and performed with reference to the FCC Public Notice “Guidance for Compliance Measurements on Digital Transmission System, Frequency Hopping Spread Spectrum System, and Hybrid System Devices Operating under Section 15.247 of the FCC Rules, 558074 D01 15.247 Meas Guidance v05, 2018-08-24”. 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 DTS (e.g. WLAN 2.4 GHz, BT LE) equipment from FCC and IC

DTS equipment

Measurement	FCC reference	IC reference
Conducted emissions on AC Mains	§ 15.207	RSS-Gen Issue 5: 8.8
Occupied bandwidth	§ 15.247 (a) (2)	RSS-247 Issue 2: 5.2 (a)
Peak conducted output power	§ 15.247 (b) (3), (4)	RSS-247 Issue 2: 5.4 (d)
Transmitter spurious RF conducted emissions	§ 15.247 (d)	RSS-Gen Issue 5: 6.13 / 8.9/8.10; RSS-247 Issue 2: 5.5
Transmitter spurious radiated emissions	§ 15.247 (d); § 15.209 (a)	RSS-Gen Issue 5: 6.13 / 8.9/8.10; RSS-247 Issue 2: 5.5
Band edge compliance	§ 15.247 (d)	RSS-247 Issue 2: 5.5
Power density	§ 15.247 (e)	RSS-247 Issue 2: 5.2 (b)
Antenna requirement	§ 15.203 / 15.204	RSS-Gen Issue 5: 8.3
Receiver spurious emissions	–	–

1.3 MEASUREMENT SUMMARY / SIGNATURES

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247 **§ 15.207**

Conducted Emissions at AC Mains

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Final Result FCC	IC
Operating mode, Connection to AC mains			
worst case, direct	S01_AG02	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247 **§ 15.247 (a) (2)**

Occupied Bandwidth (6 dB)

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Final Result FCC	IC
Radio Technology, Operating Frequency			
Bluetooth LE, high	S02_AF01	Passed	Passed
Bluetooth LE, low	S02_AF01	Passed	Passed
Bluetooth LE, mid	S02_AF01	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247 **-**

Occupied Bandwidth (99%)

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Final Result FCC	IC
Radio Technology, Operating Frequency			
Bluetooth LE, high	S02_AF01	N/A	Passed
Bluetooth LE, low	S02_AF01	N/A	Passed
Bluetooth LE, mid	S02_AF01	N/A	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247 **§ 15.247 (b) (3)**

Peak Power Output

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Final Result FCC	IC
Radio Technology, Operating Frequency, Measurement method			
Bluetooth LE, high, conducted	S02_AE01	Passed	Passed
Bluetooth LE, low, conducted	S02_AE01	Passed	Passed
Bluetooth LE, mid, conducted	S02_AE01	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247 **§ 15.247 (d)**

Spurious RF Conducted Emissions

The measurement was performed according to ANSI C63.10

OP-Mode	Setup	Final Result FCC	IC
Radio Technology, Operating Frequency			
Bluetooth LE, high	S02_AF01	Passed	Passed
Bluetooth LE, high	S02_AF01	Passed	Passed
Bluetooth LE, low	S02_AF01	Passed	Passed
Bluetooth LE, low	S02_AF01	Passed	Passed
Bluetooth LE, mid	S02_AF01	Passed	Passed
Bluetooth LE, mid	S02_AF01	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 LE, high, 1 GHz - 26 GHz	S01_AD01	Passed	Passed
Bluetooth LE, high, 30 MHz - 1 GHz	S01_AG02	Passed	Passed
Bluetooth LE, low, 1 GHz - 26 GHz	S01_AD01	Passed	Passed
Bluetooth LE, low, 30 MHz - 1 GHz	S01_AG02	Passed	Passed
Bluetooth LE, mid, 1 GHz - 26 GHz	S01_AD01	Passed	Passed
Bluetooth LE, mid, 30 MHz - 1 GHz	S01_AG02	Passed	Passed
Bluetooth LE, mid, 9 kHz - 30 MHz	S01_AG02	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247	§ 15.247 (d)		
Band Edge Compliance Conducted			
The measurement was performed according to ANSI C63.10		Final Result	
OP-Mode	**Setup**	**FCC**	**IC**
Radio Technology, Operating Frequency, Band Edge			
Bluetooth LE, high, high	S02_AF01	Passed	Passed
Bluetooth LE, high, high	S02_AF01	Passed	Passed
Bluetooth LE, low, low	S02_AF01	Passed	Passed
Bluetooth LE, low, low	S02_AF01	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247	§ 15.247 (d)		
Band Edge Compliance Radiated			
The measurement was performed according to ANSI C63.10		Final Result	
OP-Mode	**Setup**	**FCC**	**IC**
Radio Technology, Operating Frequency, Band Edge			
Bluetooth LE, high, high	S01_AD01	Passed	Passed

47 CFR CHAPTER I FCC PART 15 Subpart C §15.247	§ 15.247 (e)		
Power Density			
The measurement was performed according to ANSI C63.10		Final Result	
OP-Mode	**Setup**	**FCC**	**IC**
Radio Technology, Operating Frequency			
Bluetooth LE, high	S02_AF01	Passed	Passed
Bluetooth LE, low	S02_AF01	Passed	Passed
Bluetooth LE, mid	S02_AF01	Passed	Passed

N/A: Not applicable

2 REVISION HISTORY

Report version control			
Version	**Release date**	**Change Description**	**Version validity**
initial	2019-05-02	--	invalid
rev1	2019-05-29	change of the device name; plot added to show calculation of duty cycle correction factor; inclusion of conducted test results of device CT-F I/M	valid

COMMENT:

An electronic radio part is integrated into an end-product, the conducted RF tests have been carried out at the device CT-F I/M which has integrated the identical RF chip, according to the applicant.

According to the applicant:
CT MINI I, CT MIDI I, both are electrically identical.

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

(responsible for testing and report)
Dipl.-Ing. Andreas Petz

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3 ADMINISTRATIVE DATA

3.1 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
ISED CAB Identifier	DE0007; ISED#: 3699A
Responsible for accreditation scope:	Dipl.-Ing. Marco Kullik
Report Template Version:	2019-02-12

3.2 PROJECT DATA

Responsible for testing and report:	Dipl.-Ing. Andreas Petz
Employees who performed the tests:	documented internally at 7Layers
Date of Report:	2019-05-29
Testing Period:	2017-07-01 to 2017-07-06 and 2018-06-05 to 2018-09-11

3.3 APPLICANT DATA

Company Name:	Festool GmbH
Address:	Wertstrasse 20 73240 Wendlingen Germany
Contact Person:	Mr. Markus Roth

3.4 MANUFACTURER DATA

Company	please see Applicant Data

4 TEST OBJECT DATA

4.1 GENERAL EUT DESCRIPTION

Kind of Device product description	Vacuum cleaner with integrated Bluetooth® LE module
Product name	Vacuum cleaner CT
Type	CT MINI I, CT MIDI I
Declared EUT data by the supplier	
Voltage Type	AC
Voltage Level	120 V / 60 Hz
Tested Modulation Type	GFSK Modulation
General product description	Vacuum cleaner
Specific product description for the EUT	The EUT is a vacuum cleaner that is intended to operate stand-alone or in conjunction with products (tools) or remote control of the applicant. For the latter purpose, it provides a Bluetooth Low Energy radio interface to control the vacuum cleaner operation (switching on/off) in remote mode. CT MINI/MIDI I contains the BT module.
The EUT provides the following ports:	AC In (affixed cable) and AC Outlet The port AC In (affixed cable) is directly connected to the AC Outlet, this port is electrically identical and therefore it need not be tested separately.
Tested data rates	1 Mbps
Special software used for testing	InterLab Automation Explorer; for sample DE1189004af01 only: Mobile phone application to set the EUT in testmode

The main components of the EUT are listed and described in chapter 4.2 EUT Main components.

4.2 EUT MAIN COMPONENTS

Sample Name	Sample Code	Description
CT MIDI I, conducted sample #AE01 for FCC testing (PCB only)	DE1189014ae01	DTM Mode SW, Mainboard of CT MIDI I
Sample Parameter	**Value**	
Serial No.	10037618E	
HW Version	J	
SW Version	B	
Comment	-	
Integral Antenna	yes, but replaced by temporary antenna connector for the tests	

Sample Name	Sample Code	Description
CT MIDI I, radiated sample #AD01 for FCC testing	DE1189014ad01	120 V AC / 60 Hz, DTM Mode SW
Sample Parameter	**Value**	
Serial No.	10038495E	
HW Version	J	
SW Version	B	
Comment	-	
Integral Antenna	yes	

Sample Name	Sample Code	Description
CT MINI I, FCC Part 15 Subpart C, sample #AG02	DE1189014ag02	120 V AC / 60 Hz, in BT-LE test mode
Sample Parameter	**Value**	
Serial No.	10037146E	
HW Version	J (with additional ferrite)	
SW Version	B	
Comment	Sample tested with additional ferrite.	
Integral Antenna	yes	

Sample Name	Sample Code	Description
CT-F I/M (Vacuum cleaner retrofit module with Bluetooth low energy), sample #AF01	DE1189004af01	Conducted Sample, supplied by 5 V DC
Sample Parameter	**Value**	
Integral Antenna	deactivated	
Serial No.	only assembled pcb	
HW Version	10027680	
SW Version	10027683	
Comment	–	

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

4.3 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**
-	-	-

4.4 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, Type Model, HW, SW, S/N)**	**Description**
-	-	-

4.5 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**
S01_AG02	CT MINI I, FCC Part 15 Subpart C, sample #AG02	Setup #AG02, 120 V, for radiated FCC tests in test mode
S01_AD01	CT MIDI I, radiated sample #AD01 for FCC testing	Setup #AD01, for radiated FCC tests in test mode
S02_AE01	CT MIDI I, conducted sample #AE01 for FCC testing (PCB only)	Setup #AE01 for conducted FCC tests in test mode (PCB only)
S02_AF01	CT-F I/M conducted sample #AF01 for FCC testing (PCB only)	Setup #AF01 for conducted FCC tests in test mode (PCB only)

4.6 OPERATING MODES

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

4.6.1 TEST MODE

The EUT is directly controlled by an external laptop using the tool “InterLab Automation Explorer” which provides the possibility to start a continuous transmission on any channel.

4.6.2 TEST CHANNELS

	2.4 GHz ISM 2400 - 2483.5 MHz		
BT LE Test Channels:	**low**	**mid**	**high**
Channel:	0	19	39
Frequency [MHz]	2402	2440	2480

4.7 PRODUCT LABELLING

Please refer to the documentation of the applicant.

5 TEST RESULTS

5.1 CONDUCTED EMISSIONS AT AC MAINS

Standard **FCC Part 15 Subpart C**

The test was performed according to: ANSI C63.10

5.1.1 TEST DESCRIPTION

The test set-up was made in accordance to the general provisions of ANSI C 63.10.
The Equipment Under Test (EUT) was setup in a shielded room to perform the conducted emissions measurements in a typical installation configuration. The EUT was powered from 50µH || 50 Ohm Line Impedance Stabilization Network (LISN). The LISN's unused connections were terminated with 50 Ohm loads.

The measurement procedure consists of two steps. It is implemented into the EMI test software EMC-32 from R&S.

Step 1: Preliminary scan
Intention of this step is, to determine the conducted EMI-profile of the EUT.
EMI receiver settings:
- Detector: Peak – Maxhold & Average
- Frequency range: 150 kHz – 30 MHz
- Frequency steps: 2.5 kHz
- IF–Bandwidth: 9 kHz
- Measuring time / Frequency step: 100 ms (FFT-based)
- Measurement on phase + neutral lines of the power cords

On basis of this preliminary scan the highest amplitudes and the corresponding frequencies relative to the limit are identified. Emissions above the limit and emissions which are in the 10 dB range below the limit are considered.

Step 2: Final measurement
Intention of this step is, to determine the highest emissions with the settings defined in the test specification for the frequencies identified in step 1.
EMI receiver settings:
- Detector: Quasi-Peak
- IF Bandwidth: 9 kHz
- Measuring time: 1 s / frequency

At each frequency determined in step 1, four measurements are performed in the following combinations:
1) Neutral lead - reference ground (PE grounded)
2) Phase lead - reference ground (PE grounded)
3) Neutral lead - reference ground (PE floating)
4) Phase lead - reference ground (PE floating)

The highest value is reported.

5.1.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.207

Frequency (MHz)	QP Limits (dBµV)	AV Limits (dBµV)
0.15 – 0.5	66 - 56	56 - 46
0.5 - 5	56	46
5 - 30	60	50

Used conversion factor: Limit (dBµV) = 20 log (Limit (µV)/1µV).

5.1.3 TEST PROTOCOL

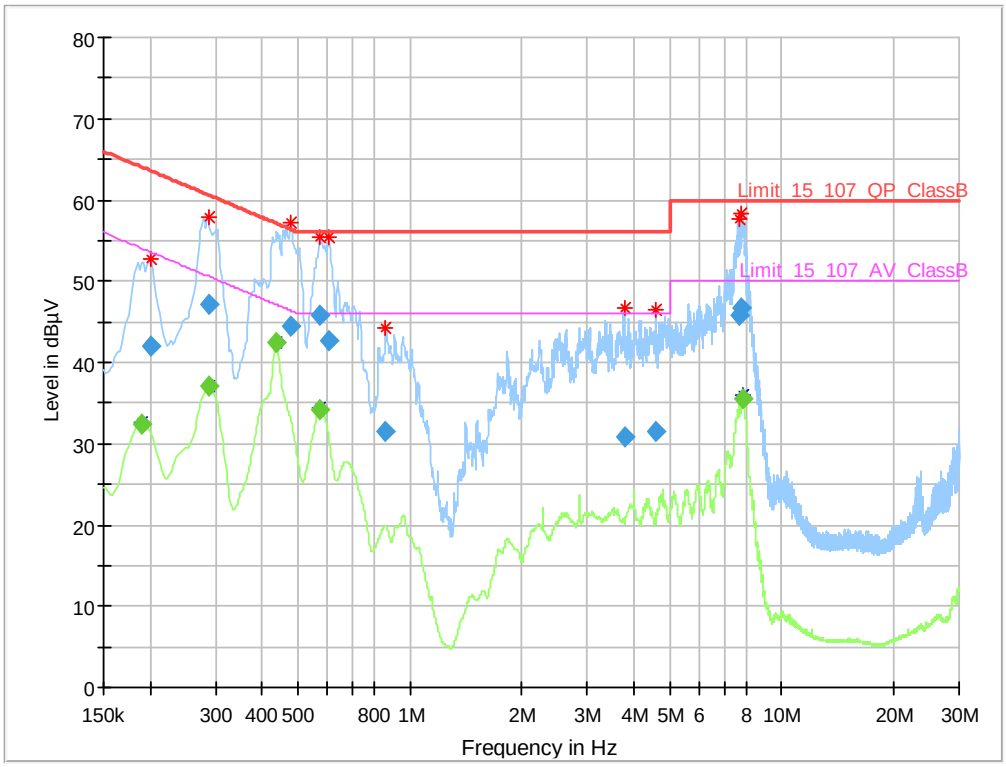
Temperature: 26 °C
Air Pressure: 1017 hPa
Humidity: 41 %

Power line	PE	Frequency [MHz]	Level [dBµV]	Detector	Limit [dBµV]	Margin [dB]
N	FLO	0.19	32.5	AV	54.0	21.5
N	GND	0.20	42.0	QP	63.5	21.6
L1	GND	0.29	47.2	QP	60.6	13.4
N	FLO	0.29	37.0	AV	50.5	13.5
L1	FLO	0.44	42.5	AV	47.1	4.6
N	GND	0.48	44.4	QP	56.4	12.0
L1	GND	0.57	45.7	QP	56.0	10.3
L1	GND	0.58	34.3	AV	46.0	11.7
N	GND	0.60	42.7	QP	56.0	13.3
N	GND	0.86	31.4	QP	56.0	24.6
L1	GND	3.77	30.8	QP	56.0	25.2
N	GND	4.57	31.5	QP	56.0	24.5
N	GND	7.65	45.9	QP	60.0	14.1
N	FLO	7.80	46.7	QP	60.0	13.3
N	GND	7.87	35.4	AV	50.0	14.6

Remark: Please see next sub-clause for the measurement plot.

5.1.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

Test Description:	Conducted Emissions
Test Standard:	FCC §15.207, ANSI C63.10
EUT / Setup Code:	DE1189014ag02
Operating Conditions:	120 V / 60 Hz; BTLE Testmode; TX = 2440 MHz (CH19)
Operator Name:	Pet
Comment:	Vacumer off
Legend:	Trace: blue = PK, green = CISPR AV; Star: red or blue = critical frequency; Rhombus: blue = final QP, green = final CISPR AV
Tested Port / used LISN:	AC mains / ESH3-Z5
Termination of other ports:	N/A



Final_Result

Frequency (MHz)	QuasiPeak (dBµV)	CAverage (dBµV)	Limit (dBµV)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Line	PE	Corr. (dB)
0.190500	---	32.50	54.02	21.52	1000.0	9.000	L1	FLO	10.1
0.201750	41.96	---	63.54	21.57	1000.0	9.000	L1	GND	10.1
0.287250	47.24	---	60.60	13.36	1000.0	9.000	N	GND	10.1
0.289500	---	37.01	50.54	13.52	1000.0	9.000	L1	FLO	10.1
0.435750	---	42.51	47.14	4.63	1000.0	9.000	N	FLO	10.1
0.478500	44.39	---	56.37	11.97	1000.0	9.000	N	GND	10.1
0.573000	45.74	---	56.00	10.26	1000.0	9.000	N	GND	10.1
0.575250	---	34.28	46.00	11.72	1000.0	9.000	N	GND	10.1
0.604500	42.69	---	56.00	13.31	1000.0	9.000	L1	GND	10.1
0.861000	31.44	---	56.00	24.56	1000.0	9.000	N	GND	10.1
3.765750	30.84	---	56.00	25.16	1000.0	9.000	N	GND	10.2
4.573500	31.48	---	56.00	24.52	1000.0	9.000	N	GND	10.3
7.649250	45.86	---	60.00	14.14	1000.0	9.000	N	GND	10.5
7.804500	46.73	---	60.00	13.27	1000.0	9.000	L1	FLO	10.5
7.872000	---	35.44	50.00	14.56	1000.0	9.000	N	GND	10.5

5.1.5 TEST EQUIPMENT USED

- Conducted Emissions FCC

5.2 OCCUPIED BANDWIDTH (6 DB)

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

5.2.1 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 results recorded were measured with the modulation which produce the worst-case (smallest) emission bandwidth.

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

Analyzer settings:

- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Span: 3 MHz
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 5 ms
- Detector: Peak

5.2.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.247 (a) (2)
Systems using digital modulation techniques may operate in the 902-928 MHz and 2400-2483.5 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

5.2.3 TEST PROTOCOL

Ambient temperature: 22 °C
Air Pressure: 1009 hPa
Humidity: 48 %

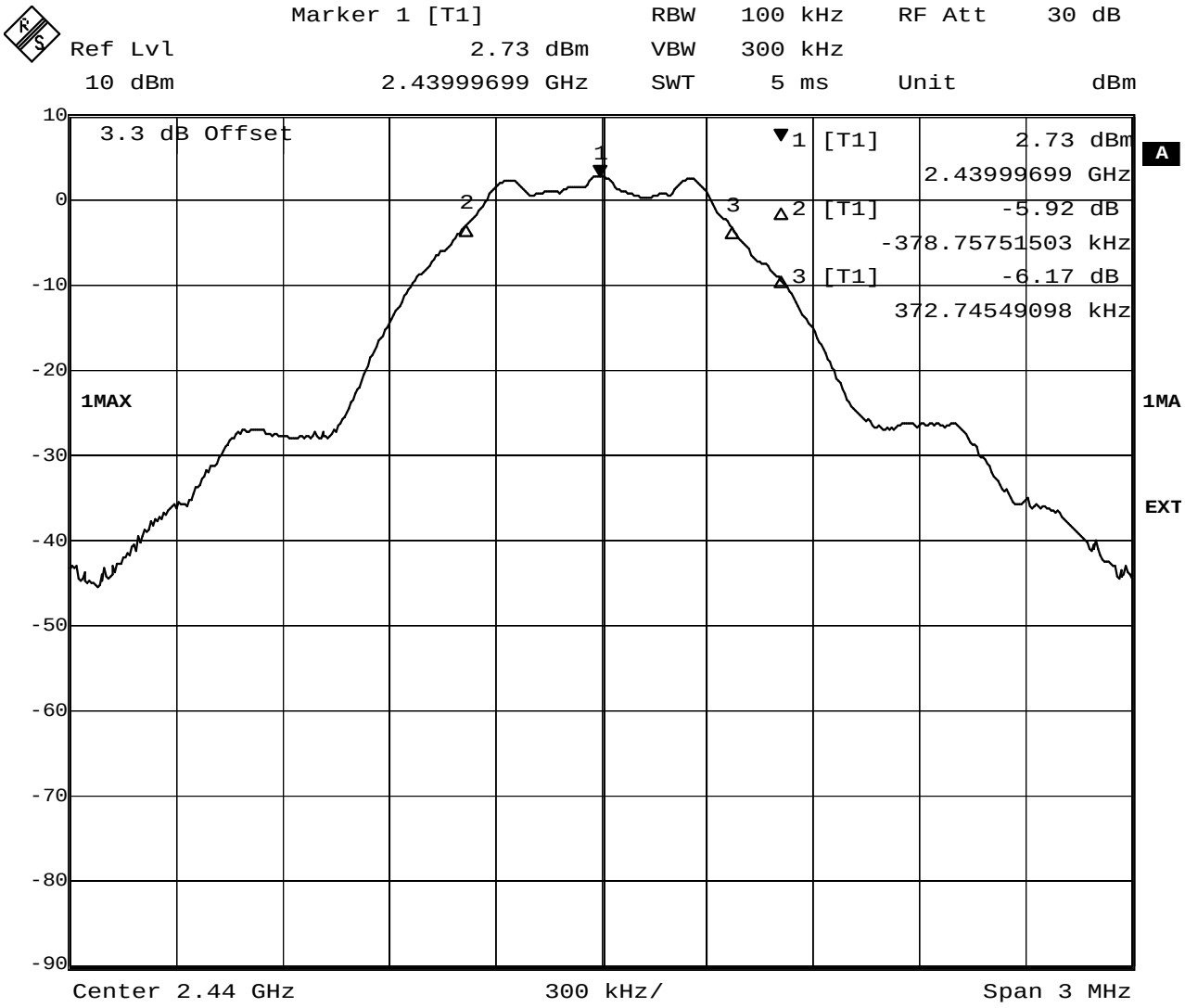
BT LE GFSK

Band	Channel No.	Frequency [MHz]	6 dB Bandwidth [MHz]	Limit [MHz]	Margin to Limit [MHz]
2.4 GHz ISM	0	2402	0.758	0.5	0.258
	19	2440	0.752	0.5	0.252
	39	2480	0.758	0.5	0.258

Remark: Please see next sub-clause for the measurement plot.

5.2.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

BTLE CH19



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5.2.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

5.3 OCCUPIED BANDWIDTH (99%)

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

5.3.1 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): 30 kHz
- Video Bandwidth (VBW): 100 kHz
- Span: 3 MHz
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 8.5 ms
- Detector: Sample

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

5.3.2 TEST REQUIREMENTS / LIMITS

No limit is applicable.

5.3.3 TEST PROTOCOL

Ambient temperature: 22 °C
Air Pressure: 1009 hPa
Humidity: 48 %

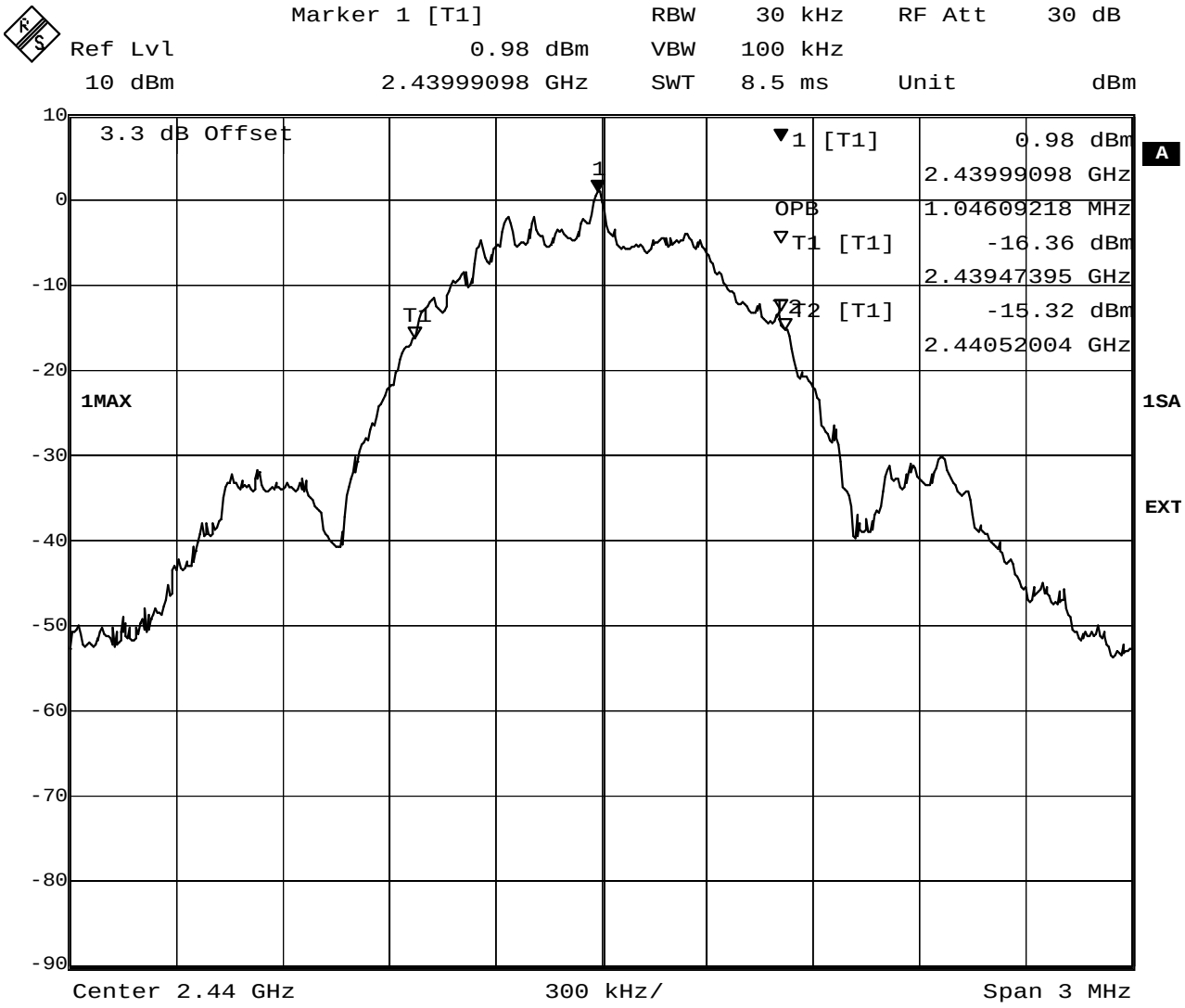
BT LE

Band	Channel No.	Frequency [MHz]	99 % Bandwidth [MHz]
2.4 GHz ISM	0	2402	1.046
	19	2440	1.046
	39	2480	1.052

Remark: Please see next sub-clause for the measurement plot.

5.3.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

BTLE CH19



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5.3.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

5.4 PEAK POWER OUTPUT

Standard **FCC Part 15 Subpart C**

The test was performed according to: ANSI C63.10

5.4.1 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): 1 MHz
- Video Bandwidth (VBW): 3 MHz
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 5 ms
- Detector: Peak

5.4.2 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.

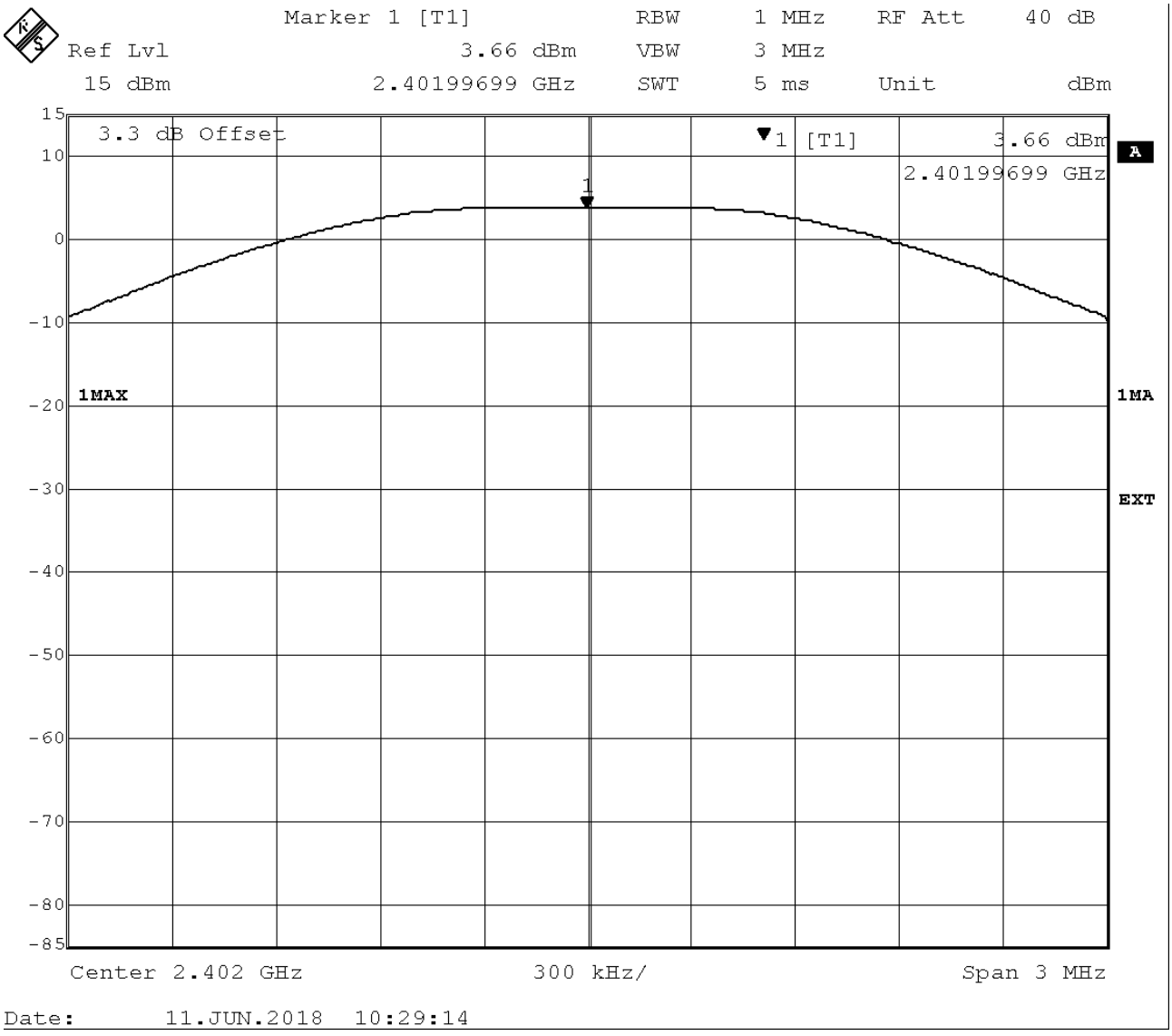
Used conversion factor: Limit (dBm) = 10 log (Limit (W)/1mW)

5.4.3 TEST PROTOCOL

Ambient temperature: 23 °C
Air Pressure: 1010 hPa
Humidity: 40 %
BT LE

Band	Channel No.	Frequency [MHz]	Peak Power [dBm]	Limit [dBm]	Margin to Limit [dB]
2.4 GHz ISM	0	2402	3.7	30.0	26.3
	19	2440	3.4	30.0	26.6
	39	2480	3.4	30.0	26.6

5.4.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)



5.4.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

5.5 SPURIOUS RF CONDUCTED EMISSIONS

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

5.5.1 TEST DESCRIPTION

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

- Frequency range: 30 – 25000 MHz
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Trace: Maxhold
- Sweeps: 2
- Sweep Time: 330 s
- Detector: Peak

The reference value for the measurement of the spurious RF conducted emissions is determined during the test “band edge compliance conducted”. This value is used to calculate the 20 dBc limit.

5.5.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.247 (c)
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

5.5.3 TEST PROTOCOL

Ambient temperature: 22 °C
Air Pressure: 1009 hPa
Humidity: 48 %

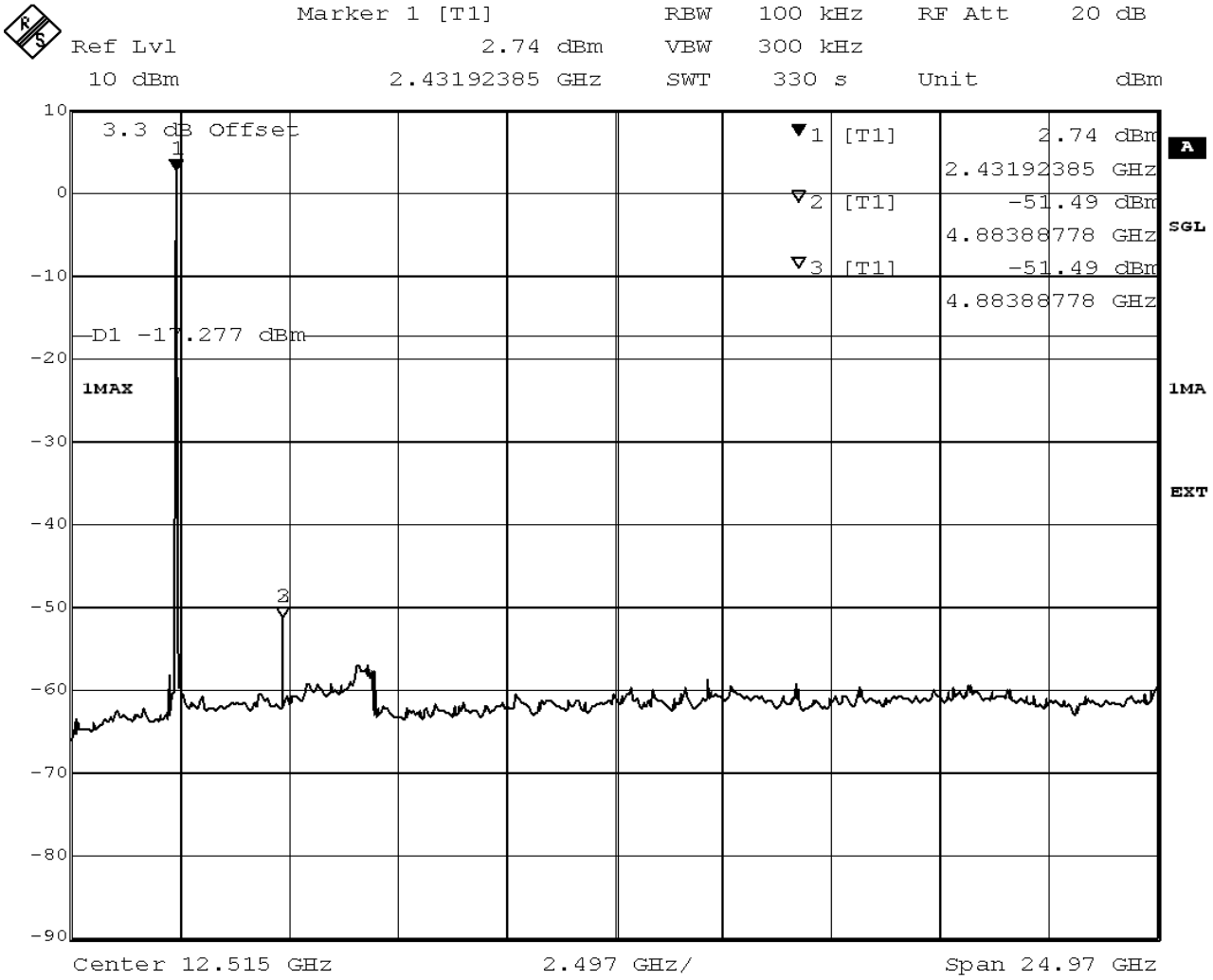
BT LE GFSK

Channel No	Channel Center Freq. [MHz]	Spurious Freq. [MHz]	Spurious Level [dBm]	Detector	RBW [kHz]	Ref. Level [dBm]	Limit [dBm]	Margin to Limit [dB]
0	2402	4783.8	-49.5	PEAK	100	3.1	-16.9	32.7
0	2402	4783.8	-49.5	PEAK	100	3.1	-16.9	32.7
19	2440	4883.8	-51.5	PEAK	100	2.7	-17.3	34.2
19	2440	4883.8	-51.5	PEAK	100	2.7	-17.3	34.2
39	2480	4993.9	-54.9	PEAK	100	3.1	-16.9	38.0
39	2480	4993.9	-54.9	PEAK	100	3.1	-16.9	38.0

Remark: Please see next sub-clause for the measurement plot.

5.5.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

BTLE CH19



Title: spurious emissions
Comment A: CH M2: 2440 MHz
Date: 6.JUL.2017 08:30:25

5.5.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

5.6 TRANSMITTER SPURIOUS RADIATED EMISSIONS

Standard **FCC Part 15 Subpart C**

The test was performed according to: ANSI C63.10

5.6.1 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 (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 ± 45° for the elevation axis is performed.

The turn table azimuth will slowly vary by ± 22.5°.

The elevation angle will slowly vary by ± 45°

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

5.6.2 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)	Limits (dBµV/m)
0.009 – 0.49	2400/F(kHz)@300m	3	(48.5 – 13.8)@300m
0.49 – 1.705	24000/F(kHz)@30m	3	(33.8 – 23.0)@30m
1.705 – 30	30@30m	3	29.5@30m

The measured values are corrected with an inverse linear distance extrapolation factor (40 dB/decade) according FCC 15.31 (2).

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limits (dBµV/m)
30 – 88	100@3m	3	40.0@3m
88 – 216	150@3m	3	43.5@3m
216 – 960	200@3m	3	46.0@3m
960 - 26000	500@3m	3	54.0@3m
26000 - 40000	500@3m	1	54.0@3m

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: Limit (dBµV/m) = 20 log (Limit (µV/m)/1µV/m)

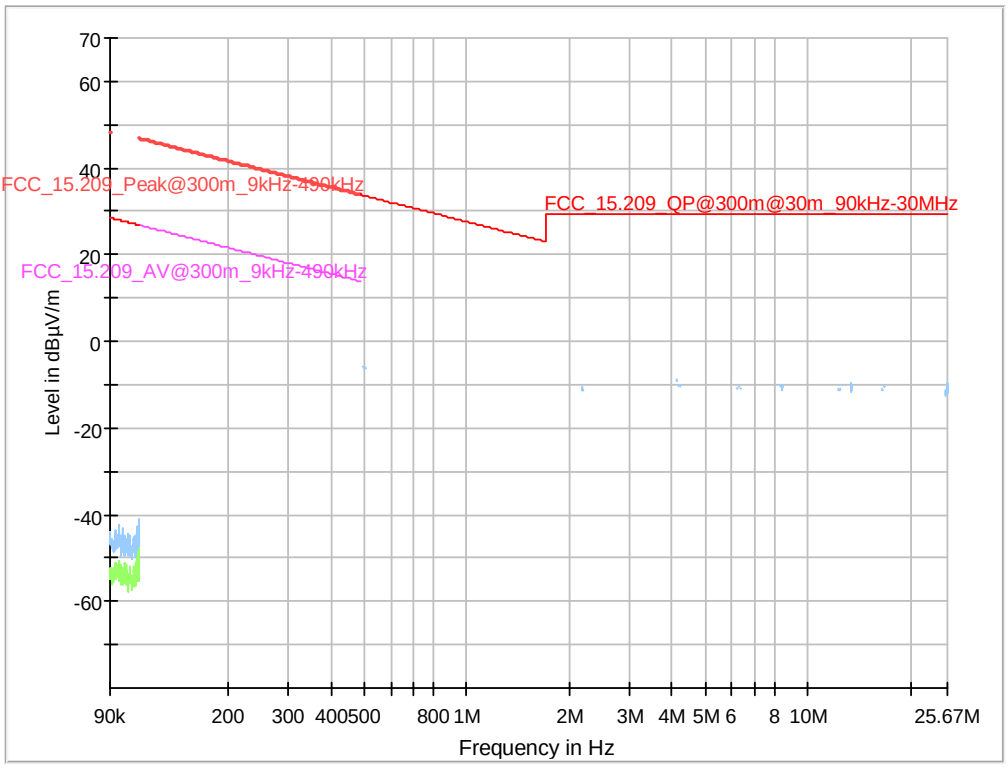
5.6.3 TEST PROTOCOL

Ambient temperature: 25 - 26 °C
Air Pressure: 1006 - 1007 hPa
Humidity: 37 - 42 %
BT low Energy
Applied duty cycle correction (AV): 16.3 dB

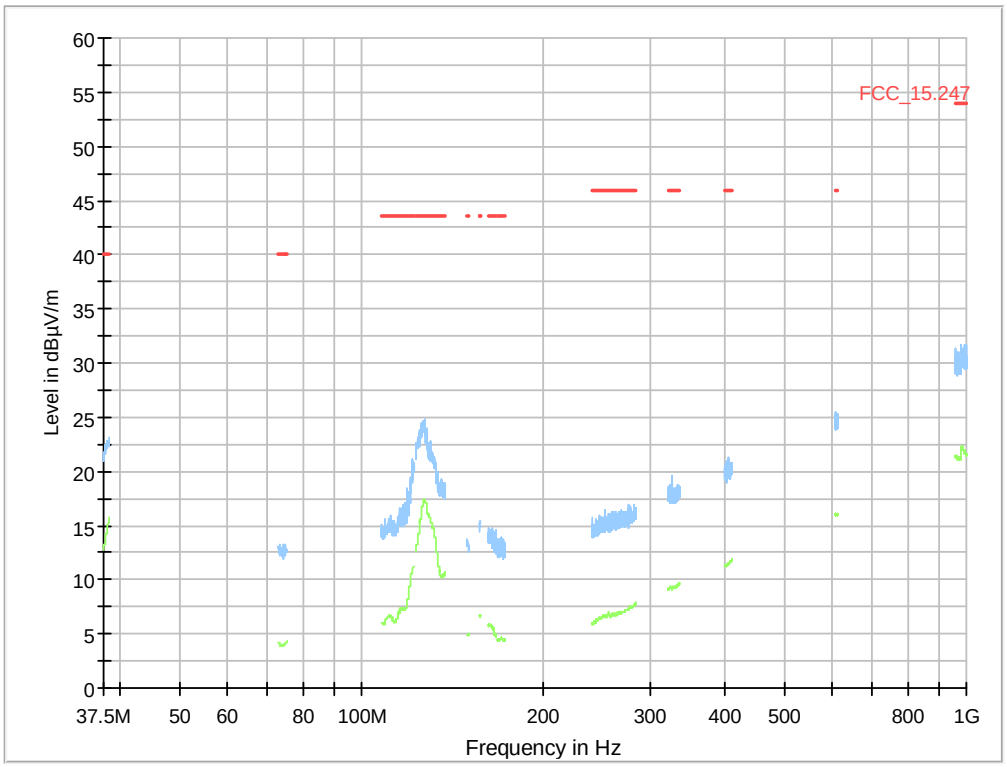
Ch. No.	Ch. Center Freq. [MHz]	Spurious Freq. [MHz]	Spurious Level [dBµV/m]	Detec-tor	RBW [kHz]	Limit [dBµV/m]	Margin to Limit [dB]	Limit Type
0	2402	- - -	- - -	- - -	- - -	- - -	- - -	- - -
19	2440	- - -	- - -	- - -	- - -	- - -	- - -	- - -
39	2480	- - -	- - -	- - -	- - -	- - -	- - -	- - -
19	2440	- - -	- - -	- - -	- - -	- - -	- - -	- - -
0	2402	- - -	- - -	- - -	- - -	- - -	- - -	- - -
19	2440	- - -	- - -	- - -	- - -	- - -	- - -	- - -
39	2480	- - -	- - -	- - -	- - -	- - -	- - -	- - -

Remark: Please see next sub-clause for the measurement plot.

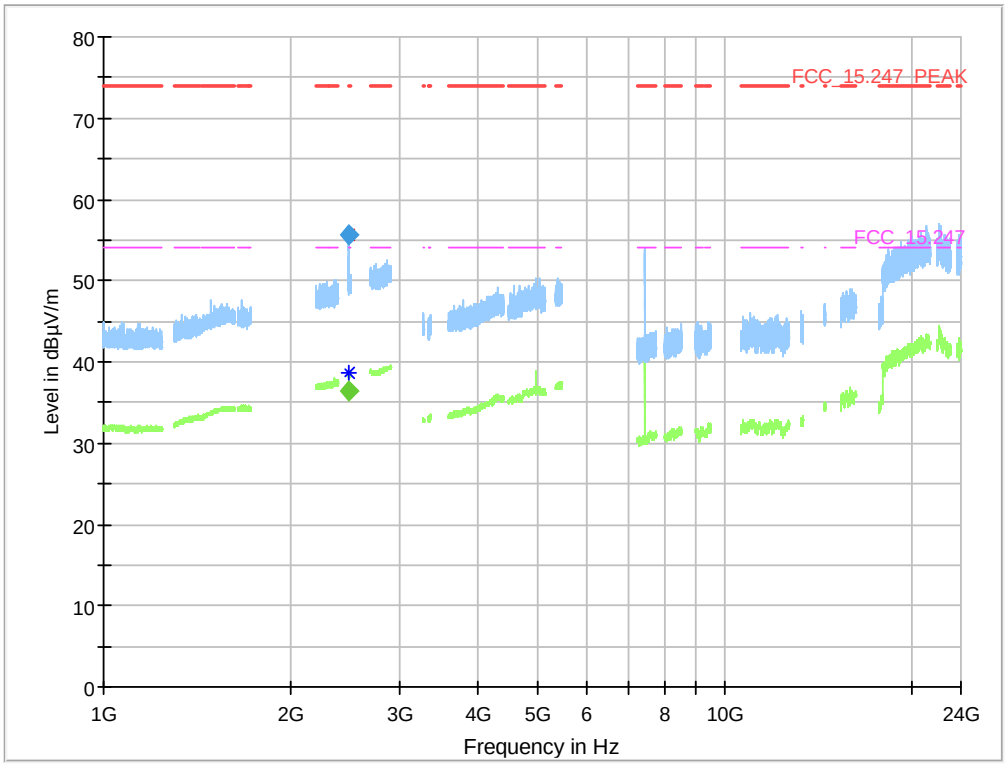
5.6.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)



Frequency range 9 kHz – 30 MHz, setup S01_AG02, mid channel



Frequency range 30 MHz – 1 GHz, setup S01_AG02, mid channel



Frequency range 1 MHz – 24 GHz, setup S01_AD01, high channel (marker = band edge)

5.6.5 TEST EQUIPMENT USED

- Radiated Emissions

5.7 BAND EDGE COMPLIANCE CONDUCTED

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

5.7.1 TEST DESCRIPTION

For the conducted measurement, the Equipment Under Test (EUT) is placed in a shielded room. The reference power was measured in the test case “Spurious RF Conducted Emissions”. The EUT was connected to the spectrum analyzer via a short coax cable with a known loss.

Analyzer settings:

- Frequency Range 2397 MHz – 2483 MHz
- Detector: Peak
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Sweeptime: 5 ms
- Sweeps: 2
- Trace: Maxhold

5.7.2 TEST REQUIREMENTS / LIMITS

FCC Part 15.247 (d)
“In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. ...
If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in Section 15.209(a) is not required. 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)).”

For the conducted measurement the RF power at the band edge shall be “at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power...”

5.7.3 TEST PROTOCOL

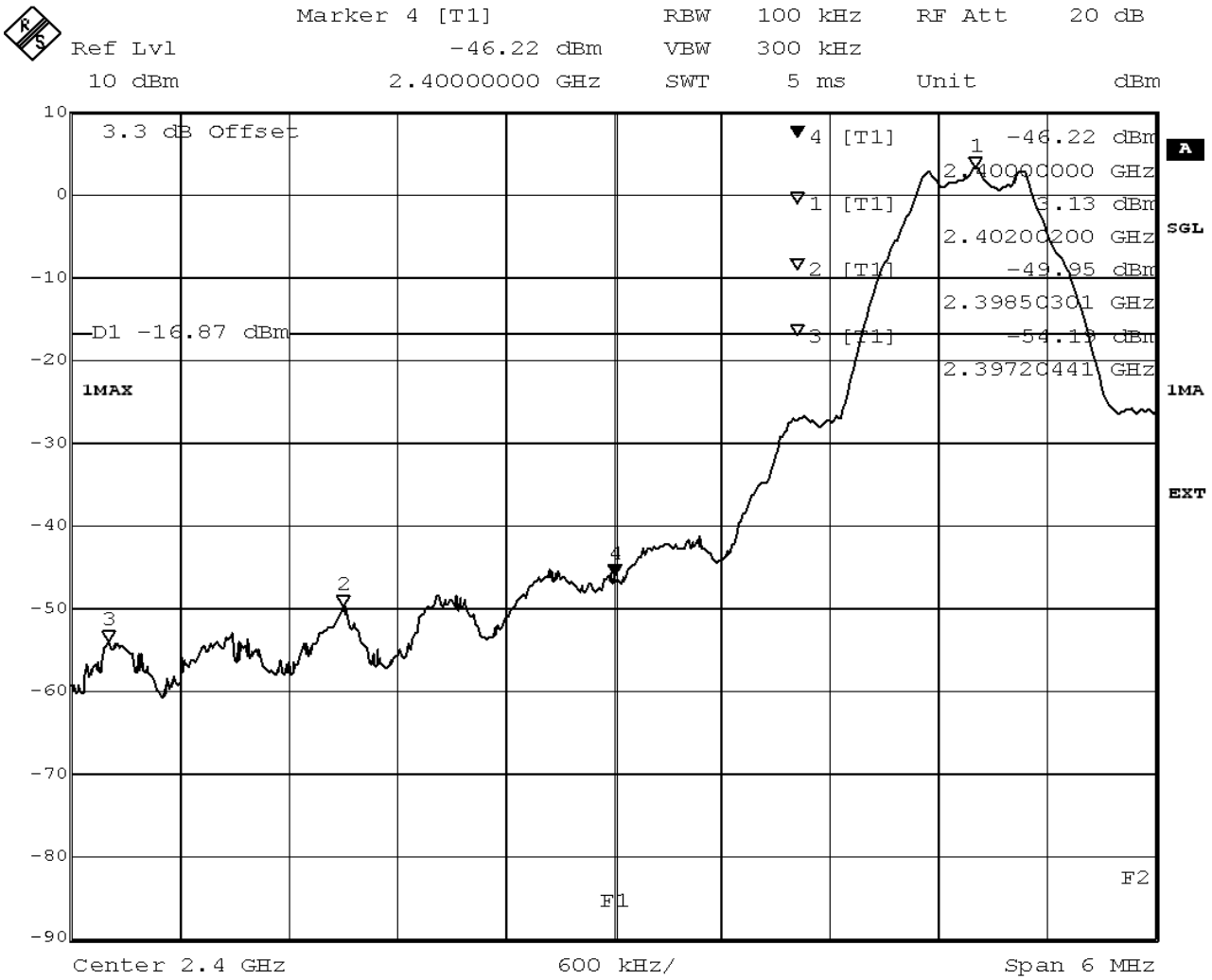
Ambient temperature: 22 °C
Air Pressure: 1009 hPa
Humidity: 48 %

BT LE GFSK

Channel No.	Channel Center Frequency [MHz]	Band Edge Freq. [MHz]	Spurious Level [dBm]	Detector	RBW [kHz]	Ref. Level [dBm]	Limit [dBm]	Margin to Limit [dB]
0	2402	2400.0	-46.2	PEAK	100	3.1	-16.9	29.4
0	2402	2400.0	-46.2	PEAK	100	3.1	-16.9	29.4
39	2480	2483.5	-49.5	PEAK	100	3.1	-16.9	32.6
39	2480	2483.5	-49.5	PEAK	100	3.1	-16.9	32.6

5.7.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

BTLE CH0



Title: Band Edge Compliance
Comment A: CH B: 2402 MHz
Date: 6.JUL.2017 08:05:17

5.7.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

5.8 BAND EDGE COMPLIANCE RADIATED

Standard **FCC Part 15 Subpart C**

The test was performed according to: ANSI C63.10

5.8.1 TEST DESCRIPTION

Please see test description for the test case “Spurious Radiated Emissions”

5.8.2 TEST REQUIREMENTS / LIMITS

For band edges connected to a restricted band, the limits are specified in Section 15.209(a)

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

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limits (dBµV/m)
0.009 – 0.49	2400/F(kHz)@300m	3	(48.5 – 13.8)@300m
0.49 – 1.705	24000/F(kHz)@30m	3	(33.8 – 23.0)@30m
1.705 – 30	30@30m	3	29.5@30m

The measured values are corrected with an inverse linear distance extrapolation factor (40 dB/decade) according FCC 15.31 (2).

Frequency in MHz	Limit (µV/m)	Measurement distance (m)	Limits (dBµV/m)
30 – 88	100@3m	3	40.0@3m
88 – 216	150@3m	3	43.5@3m
216 – 960	200@3m	3	46.0@3m
960 - 26000	500@3m	3	54.0@3m
26000 - 40000	500@3m	1	54.0@3m

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: Limit (dBµV/m) = 20 log (Limit (µV/m)/1µV/m)

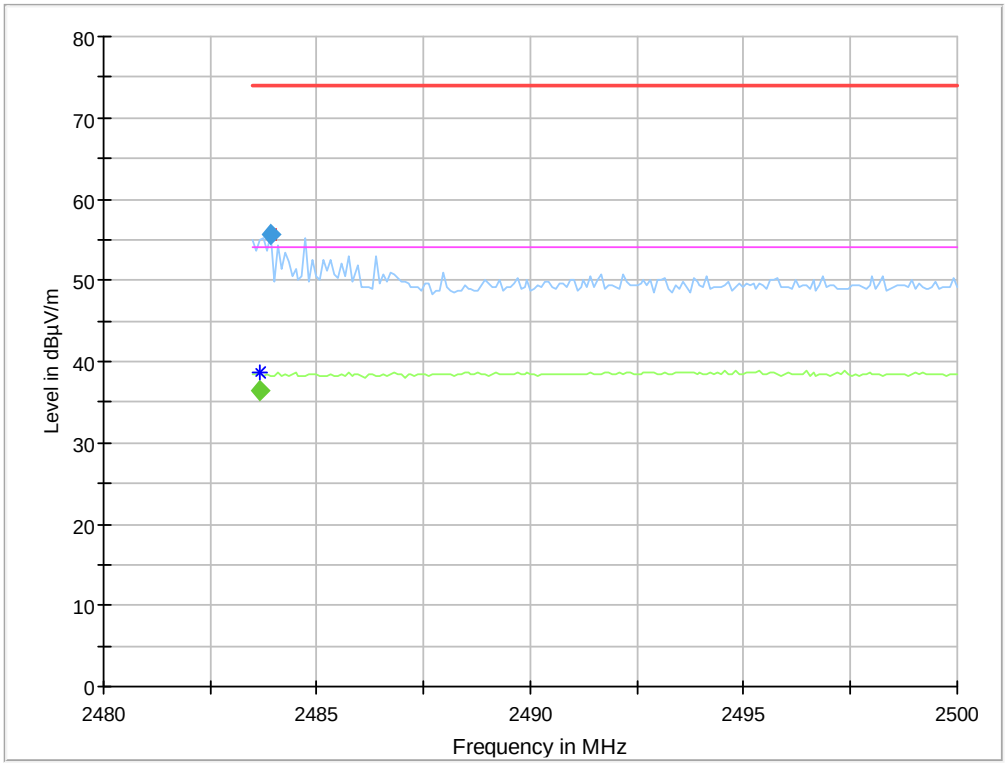
5.8.3 TEST PROTOCOL

Ambient temperature: 25 °C
Air Pressure: 1006 hPa
Humidity: 48 %
BT LE GFSK
Applied duty cycle correction (AV): 16.3 dB

Ch. No.	Ch. Center Freq. [MHz]	Band Edge Freq. [MHz]	Spurious Level [dBµV/m]	Detec-tor	RBW [kHz]	Limit [dBµV/m]	Margin to Limit [dB]	Limit Type
39	2480	2483.5	55.7	PEAK	1000	74.0	18.3	BE
39	2480	2483.5	52.8	AV	1000	54.0	1.2	BE

Remark: Please see next sub-clause for the measurement plot.

5.8.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)



Critical_Freqs

Frequency (MHz)	MaxPeak (dBµV/m)	Average (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2483.665	---	38.8	54.0	15.2	---	---	150.0	V	30.0	4.6
2483.913	55.5	---	74.0	18.5	---	---	150.0	V	30.0	4.6

Final_Result

Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
2483.665	---	36.5	54.0	17.5	1000	1000	150.0	V	30.0	4.6
2483.913	55.7	---	74.0	18.3	1000	1000	150.0	V	30.0	4.6

5.8.5 TEST EQUIPMENT USED

- Radiated Emissions

5.9 POWER DENSITY

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

5.9.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was set up in a shielded room to perform the Power Density measurements.
The results recorded were measured with the modulation which produces the worst-case (highest) power density.

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

Analyzer settings:

- Resolution Bandwidth (RBW): 3 kHz
- Video Bandwidth (VBW): 10 kHz
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 420 ms
- Detector: Peak

5.9.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.247 (e)

For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.
...
The same method of determining the conducted output power shall be used to determine the power spectral density.

5.9.3 TEST PROTOCOL

Ambient temperature: 22 °C
Air Pressure: 1009 hPa
Humidity: 48 %

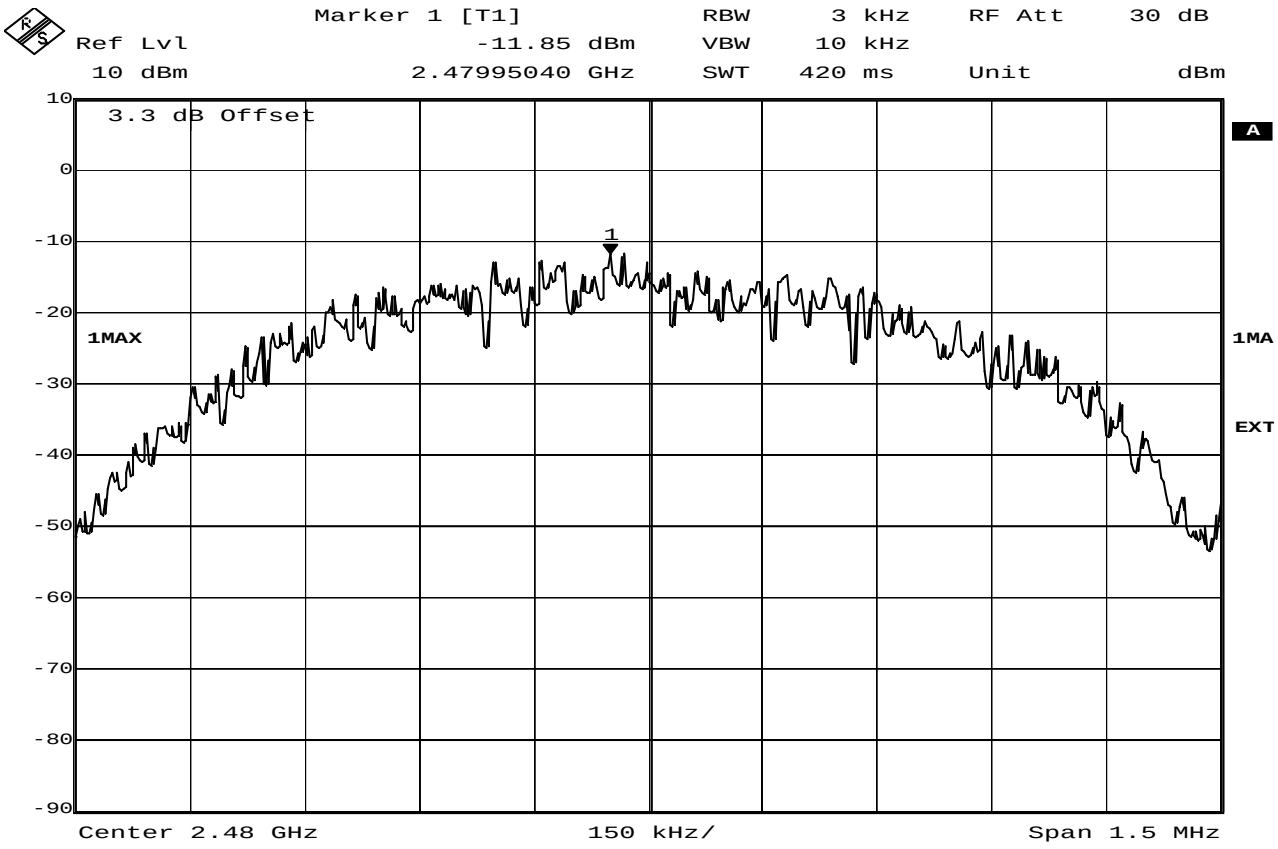
BT LE

Band	Channel No.	Frequency [MHz]	Power Density [dBm / 3kHz]	Limit [dBm / 3kHz]	Margin to Limit [dB]
2.4 GHz ISM	0	2402	-12.0	8.0	20.0
	19	2440	-12.3	8.0	20.3
	39	2480	-11.9	8.0	19.9

Remark: Please see next sub-clause for the measurement plot.

5.9.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, “WORST CASE”)

BTLE CH39



5.9.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

6 TEST EQUIPMENT

1 Conducted Emissions FCC

Conducted Emissions power line for FCC standards

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
1.2	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2018-04	2020-04
1.3	ESH3-Z5	Two-Line V-Network	Rohde & Schwarz	828304/029	2017-05	2019-05
1.4	EP 1200/B, NA/B1	Amplifier with integrated variable Oscillator	Spitzenberger & Spieß	B6278		
1.5	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
1.6	Shielded Room 02	Shielded Room for conducted testing, 12qm	Frankonia	-		
1.7	ESH3-Z5	Two-Line V-Network	Rohde & Schwarz	829996/002	2017-05	2019-05
1.8	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2016-11	2018-11
1.9	Opus10 THI (8152.00)	ThermoHygro Datalogger 02 (Environ)	Lufft Mess- und Regeltechnik GmbH	7489	2017-04	2019-04

2 Radiated Emissions

Lab to perform radiated emission tests

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	NRV-Z1	Sensor Head A	Rohde & Schwarz GmbH & Co. KG	827753/005	2017-05 2018-07	2018-05 2019-07
2.2	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2016-09 2017-10	2017-09 2018-10
2.3	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
2.4	ESW44	EMI Test Receiver	Rohde & Schwarz GmbH & Co. KG	101603	2018-05	2019-05
2.5	Anechoic Chamber	10.58 x 6.38 x 6.00 m³	Frankonia	none	2016-05 2018-06	2019-05 2020-06
2.6	FS-Z60	Harmonic Mixer 40 - 60 GHz	Rohde & Schwarz Messgerätebau GmbH	100178	2016-12	2019-12
2.7	FS-Z220	Harmonic Mixer 140 - 220 GHz	Rohde & Schwarz Messgerätebau GmbH	101005	2017-03	2020-03

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.8	SGH-05	Standard Gain / Pyramidal Horn Antenna (140 - 220 GHz)	RPG-Radiometer Physics GmbH	075		
2.9	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2015-06 2018-07	2018-06 2021-07
2.10	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
2.11	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
2.12	Fully Anechoic Room	8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	2015-07 2018-06	2018-07 2020-06
2.13	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2016-02 2018-04	2018-02 2020-04
2.14	NRVD	Power Meter	Rohde & Schwarz GmbH & Co. KG	828110/016	2016-05 2018-07	2017-07 2019-07
2.15	HF 906	Double-ridged horn	Rohde & Schwarz	357357/002	2015-06	2018-06
2.16	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
2.17	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2016-12	2018-12
2.18	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronic GmbH	00083069		
2.19	SGH-19	Standard Gain / Pyramidal Horn Antenna (40 - 60 GHz)	RPG-Radiometer Physics GmbH	093		
2.20	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
2.21	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
2.22	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
2.23	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
2.24	TT 1.5 WI	Turn Table	Maturo GmbH	-		
2.25	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
2.26	HF 906	Double-ridged horn	Rohde & Schwarz	357357/001	2018-03	2021-03
2.27	FS-Z325	Harmonic Mixer 220 - 325 GHz	Rohde & Schwarz Messgerätebau GmbH	101006	2017-03	2020-03
2.28	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronic GmbH	00086675		

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.29	SGH-08	Standard Gain / Pyramidal Horn Antenna (90 - 140 GHz)	RPG-Radiometer Physics GmbH	064		
2.30	SGH-12	Standard Gain / Pyramidal HornAntenna (60 - 90 GHz)	RPG-Radiometer Physics GmbH	326		
2.31	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008		
2.32	FS-Z140	Harmonic Mixer 90 -140 GHz	Rohde & Schwarz Messgerätebau GmbH	101007	2017-02	2020-02
2.33	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2014-11 2018-01	2017-11 2021-01
2.34	Opus10 THI (8152.00)	ThermoHygro Datalogger 12 (Environ)	Lufft Mess- und Regeltechnik GmbH	12482	2017-03	2019-03
2.35	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2016-11	2018-11
2.36	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
2.37	AS 620 P	Antenna mast	HD GmbH	620/37		
2.38	Tilt device Maturo (Rohacell)	Antrieb TD1.5-10kg	Maturo GmbH	TD1.5-10kg/024/3790709		
2.39	SGH-03	Standard Gain / Pyramidal Horn Antenna (220 - 325 GHz)	RPG-Radiometer Physics GmbH	060		
2.40	FS-Z90	Harmonic Mixer 60 - 90 GHz	Rohde & Schwarz Messgerätebau GmbH	101686	2017-03	2020-03
2.41	ESIB 26	Spectrum Analyzer	Rohde & Schwarz	830482/004	2015-12 2018-01	2017-12 2020-01
2.42	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
2.43	AFS42-00101800-25-S-42	Broadband Amplifier 25 MHz - 18 GHz	Miteq	2035324		
2.44	AM 4.0	Antenna mast	Maturo GmbH	AM4.0/180/11920513		
2.45	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2015-05 2018-07	2018-05 2021-07

3 Regulatory Bluetooth RF Test Solution
Regulatory Bluetooth RF Tests

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
3.1	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2016-09 2017-10	2017-09 2018-10
3.2	EX520	Digital Multimeter 12 (Multimeter)	Extech Instruments Corp	05157876	2016-02 2018-04	2018-02 2020-04
3.3	NRV Z1 A	Power Sensor	Rohde & Schwarz	832279/013	2016-09 2017-09	2017-09 2018-09
3.4	Opus10 THI (8152.00)	T/H Logger 15	Lufft Mess- und Regeltechnik GmbH	13985	2017-04	2019-04
3.5	TOCT Switching Unit		7layers, Inc.	040107		
3.6	ADU 200 Relay Box 7	used for automated testing (EMMI) only	Ontrak Control Systems Inc	A04380		
3.7	CBT	IL BT RF Test Solution	Rohde & Schwarz	100302	2017-02 2018-03	2018-02 2019-03
3.8	NRVD	Power Meter	Rohde & Schwarz	832025/059	2016-08 2017-09	2017-08 2018-09
3.9	FSIQ26	Signal Analyser	Rohde & Schwarz	832695/007	2016-09	2018-09
3.10	Shielded Room 07	Shielded Room 4m x 6m				
3.11	SMP02	Signal Generator SMP	Rohde & Schwarz	833286/0014	2016-05	2019-05
3.12	SMIQ 03B	Signal Generator	Rohde & Schwarz GmbH & Co. KG	832870/017	2016-06	2019-06
3.13	CBT	Bluetooth Tester "CBT-01"	Rohde & Schwarz GmbH & Co. KG	100589	2015-01 2018-05	2018-01 2021-05
3.14	NGSM 32/10	Power Supply	Rohde & Schwarz	2725	2015-06 2017-06	2017-06 2019-06
3.15	CMW500	CMW500-SUW	Rohde & Schwarz GmbH & Co. KG	156000	2017-11	2018-10

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.

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

Frequency		Corr.	LISN insertion loss ESH3-Z5	cable loss (incl. 10 dB atten-uator)
MHz		dB	dB	dB
0.15		10.1	0.1	10.0
5		10.3	0.1	10.2
7		10.5	0.2	10.3
10		10.5	0.2	10.3
12		10.7	0.3	10.4
14		10.7	0.3	10.4
16		10.8	0.4	10.4
18		10.9	0.4	10.5
20		10.9	0.4	10.5
22		11.1	0.5	10.6
24		11.1	0.5	10.6
26		11.2	0.5	10.7
28		11.2	0.5	10.7
30		11.3	0.5	10.8

Sample calculation

U_{LISN} (dB µV) = U (dB µV) + Corr. (dB)
U = Receiver reading
LISN Insertion loss = Voltage Division Factor of LISN
Corr. = sum of single correction factors of used LISN, cables, switch units (if used)
Linear interpolation will be used for frequencies in between the values in the table.

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

Frequency	AF HFH-Z2)	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-40 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
0.009	20.50	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.01	20.45	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.015	20.37	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.02	20.36	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.025	20.38	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.03	20.32	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.05	20.35	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.08	20.30	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.1	20.20	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.2	20.17	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.3	20.14	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.49	20.12	-79.6	0.1	0.1	0.1	0.1	-80	300	3
0.490001	20.12	-39.6	0.1	0.1	0.1	0.1	-40	30	3
0.5	20.11	-39.6	0.1	0.1	0.1	0.1	-40	30	3
0.8	20.10	-39.6	0.1	0.1	0.1	0.1	-40	30	3
1	20.09	-39.6	0.1	0.1	0.1	0.1	-40	30	3
2	20.08	-39.6	0.1	0.1	0.1	0.1	-40	30	3
3	20.06	-39.6	0.1	0.1	0.1	0.1	-40	30	3
4	20.05	-39.5	0.2	0.1	0.1	0.1	-40	30	3
5	20.05	-39.5	0.2	0.1	0.1	0.1	-40	30	3
6	20.02	-39.5	0.2	0.1	0.1	0.1	-40	30	3
8	19.95	-39.5	0.2	0.1	0.1	0.1	-40	30	3
10	19.83	-39.4	0.2	0.1	0.2	0.1	-40	30	3
12	19.71	-39.4	0.2	0.1	0.2	0.1	-40	30	3
14	19.54	-39.4	0.2	0.1	0.2	0.1	-40	30	3
16	19.53	-39.3	0.3	0.1	0.2	0.1	-40	30	3
18	19.50	-39.3	0.3	0.1	0.2	0.1	-40	30	3
20	19.57	-39.3	0.3	0.1	0.2	0.1	-40	30	3
22	19.61	-39.3	0.3	0.1	0.2	0.1	-40	30	3
24	19.61	-39.3	0.3	0.1	0.2	0.1	-40	30	3
26	19.54	-39.3	0.3	0.1	0.2	0.1	-40	30	3
28	19.46	-39.2	0.3	0.1	0.3	0.1	-40	30	3
30	19.73	-39.1	0.4	0.1	0.3	0.1	-40	30	3

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
distance correction = -40 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values

7.3 ANTENNA R&S HL562 (30 MHZ – 1 GHZ)

(d_{Limit} = 3 m)

Frequency	AF R&S HL562	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
30	18.6	0.6	0.29	0.04	0.23	0.02	0.0	3	3
50	6.0	0.9	0.39	0.09	0.32	0.08	0.0	3	3
100	9.7	1.2	0.56	0.14	0.47	0.08	0.0	3	3
150	7.9	1.6	0.73	0.20	0.59	0.12	0.0	3	3
200	7.6	1.9	0.84	0.21	0.70	0.11	0.0	3	3
250	9.5	2.1	0.98	0.24	0.80	0.13	0.0	3	3
300	11.0	2.3	1.04	0.26	0.89	0.15	0.0	3	3
350	12.4	2.6	1.18	0.31	0.96	0.13	0.0	3	3
400	13.6	2.9	1.28	0.35	1.03	0.19	0.0	3	3
450	14.7	3.1	1.39	0.38	1.11	0.22	0.0	3	3
500	15.6	3.2	1.44	0.39	1.20	0.19	0.0	3	3
550	16.3	3.5	1.55	0.46	1.24	0.23	0.0	3	3
600	17.2	3.5	1.59	0.43	1.29	0.23	0.0	3	3
650	18.1	3.6	1.67	0.34	1.35	0.22	0.0	3	3
700	18.5	3.6	1.67	0.42	1.41	0.15	0.0	3	3
750	19.1	4.1	1.87	0.54	1.46	0.25	0.0	3	3
800	19.6	4.1	1.90	0.46	1.51	0.25	0.0	3	3
850	20.1	4.4	1.99	0.60	1.56	0.27	0.0	3	3
900	20.8	4.7	2.14	0.60	1.63	0.29	0.0	3	3
950	21.1	4.8	2.22	0.60	1.66	0.33	0.0	3	3
1000	21.6	4.9	2.23	0.61	1.71	0.30	0.0	3	3

(d_{Limit} = 10 m)

30	18.6	-9.9	0.29	0.04	0.23	0.02	-10.5	10	3
50	6.0	-9.6	0.39	0.09	0.32	0.08	-10.5	10	3
100	9.7	-9.2	0.56	0.14	0.47	0.08	-10.5	10	3
150	7.9	-8.8	0.73	0.20	0.59	0.12	-10.5	10	3
200	7.6	-8.6	0.84	0.21	0.70	0.11	-10.5	10	3
250	9.5	-8.3	0.98	0.24	0.80	0.13	-10.5	10	3
300	11.0	-8.1	1.04	0.26	0.89	0.15	-10.5	10	3
350	12.4	-7.9	1.18	0.31	0.96	0.13	-10.5	10	3
400	13.6	-7.6	1.28	0.35	1.03	0.19	-10.5	10	3
450	14.7	-7.4	1.39	0.38	1.11	0.22	-10.5	10	3
500	15.6	-7.2	1.44	0.39	1.20	0.19	-10.5	10	3
550	16.3	-7.0	1.55	0.46	1.24	0.23	-10.5	10	3
600	17.2	-6.9	1.59	0.43	1.29	0.23	-10.5	10	3
650	18.1	-6.9	1.67	0.34	1.35	0.22	-10.5	10	3
700	18.5	-6.8	1.67	0.42	1.41	0.15	-10.5	10	3
750	19.1	-6.3	1.87	0.54	1.46	0.25	-10.5	10	3
800	19.6	-6.3	1.90	0.46	1.51	0.25	-10.5	10	3
850	20.1	-6.0	1.99	0.60	1.56	0.27	-10.5	10	3
900	20.8	-5.8	2.14	0.60	1.63	0.29	-10.5	10	3
950	21.1	-5.6	2.22	0.60	1.66	0.33	-10.5	10	3
1000	21.6	-5.6	2.23	0.61	1.71	0.30	-10.5	10	3

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
distance correction = -20 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Tables show an extract of values.

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

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay + cable inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit, atten-uator & pre-amp)	cable loss 4 (to receiver)		
MHz	dB (1/m)	dB	dB	dB	dB	dB		
1000	24.4	-19.4	0.99	0.31	-21.51	0.79		
2000	28.5	-17.4	1.44	0.44	-20.63	1.38		
3000	31.0	-16.1	1.87	0.53	-19.85	1.33		
4000	33.1	-14.7	2.41	0.67	-19.13	1.31		
5000	34.4	-13.7	2.78	0.86	-18.71	1.40		
6000	34.7	-12.7	2.74	0.90	-17.83	1.47		
7000	35.6	-11.0	2.82	0.86	-16.19	1.46		

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay inside chamber)	cable loss 2 (inside chamber)	cable loss 3 (outside chamber)	cable loss 4 (switch unit, atten-uator & pre-amp)	cable loss 5 (to receiver)	used for FCC 15.247
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	
3000	31.0	-23.4	0.47	1.87	0.53	-27.58	1.33	
4000	33.1	-23.3	0.56	2.41	0.67	-28.23	1.31	
5000	34.4	-21.7	0.61	2.78	0.86	-27.35	1.40	
6000	34.7	-21.2	0.58	2.74	0.90	-26.89	1.47	
7000	35.6	-19.8	0.66	2.82	0.86	-25.58	1.46	

Frequency	AF R&S HF907	Corr.	cable loss 1 (relay inside chamber)	cable loss 2 (High Pass)	cable loss 3 (pre-amp)	cable loss 4 (inside chamber)	cable loss 5 (outside chamber)	cable loss 6 (to receiver)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB	dB
7000	35.6	-57.3	0.56	1.28	-62.72	2.66	0.94	1.46
8000	36.3	-56.3	0.69	0.71	-61.49	2.84	1.00	1.53
9000	37.1	-55.3	0.68	0.65	-60.80	3.06	1.09	1.60
10000	37.5	-56.2	0.70	0.54	-61.91	3.28	1.20	1.67
11000	37.5	-55.3	0.80	0.61	-61.40	3.43	1.27	1.70
12000	37.6	-53.7	0.84	0.42	-59.70	3.53	1.26	1.73
13000	38.2	-53.5	0.83	0.44	-59.81	3.75	1.32	1.83
14000	39.9	-56.3	0.91	0.53	-63.03	3.91	1.40	1.77
15000	40.9	-54.1	0.98	0.54	-61.05	4.02	1.44	1.83
16000	41.3	-54.1	1.23	0.49	-61.51	4.17	1.51	1.85
17000	42.8	-54.4	1.36	0.76	-62.36	4.34	1.53	2.00
18000	44.2	-54.7	1.70	0.53	-62.88	4.41	1.55	1.91

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
Tables show an extract of values.

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

Frequency	AF EMCO 3160-09	Corr.	cable loss 1 (inside chamber)	cable loss 2 (pre-amp)	cable loss 3 (inside chamber)	cable loss 4 (switch unit)	cable loss 5 (to receiver)
MHz	dB (1/m)	dB	dB	dB	dB	dB	dB
18000	40.2	-23.5	0.72	-35.85	6.20	2.81	2.65
18500	40.2	-23.2	0.69	-35.71	6.46	2.76	2.59
19000	40.2	-22.0	0.76	-35.44	6.69	3.15	2.79
19500	40.3	-21.3	0.74	-35.07	7.04	3.11	2.91
20000	40.3	-20.3	0.72	-34.49	7.30	3.07	3.05
20500	40.3	-19.9	0.78	-34.46	7.48	3.12	3.15
21000	40.3	-19.1	0.87	-34.07	7.61	3.20	3.33
21500	40.3	-19.1	0.90	-33.96	7.47	3.28	3.19
22000	40.3	-18.7	0.89	-33.57	7.34	3.35	3.28
22500	40.4	-19.0	0.87	-33.66	7.06	3.75	2.94
23000	40.4	-19.5	0.88	-33.75	6.92	3.77	2.70
23500	40.4	-19.3	0.90	-33.35	6.99	3.52	2.66
24000	40.4	-19.8	0.88	-33.99	6.88	3.88	2.58
24500	40.4	-19.5	0.91	-33.89	7.01	3.93	2.51
25000	40.4	-19.3	0.88	-33.00	6.72	3.96	2.14
25500	40.5	-20.4	0.89	-34.07	6.90	3.66	2.22
26000	40.5	-21.3	0.86	-35.11	7.02	3.69	2.28
26500	40.5	-21.1	0.90	-35.20	7.15	3.91	2.36

Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values.

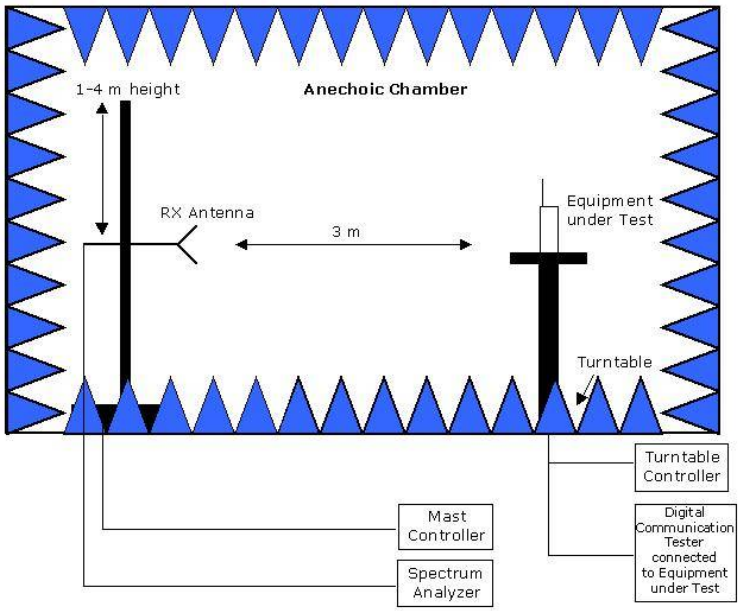
7.6 ANTENNA EMCO 3160-10 (26.5 GHZ – 40 GHZ)

Frequency	AF EMCO 3160-10	Corr.	cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d_{Limit} (meas. distance (limit)	d_{used} (meas. distance (used)
GHz	dB (1/m)	dB	dB	dB	dB	dB	dB	m	m
26.5	43.4	-11.2	4.4				-9.5	3	1.0
27.0	43.4	-11.2	4.4				-9.5	3	1.0
28.0	43.4	-11.1	4.5				-9.5	3	1.0
29.0	43.5	-11.0	4.6				-9.5	3	1.0
30.0	43.5	-10.9	4.7				-9.5	3	1.0
31.0	43.5	-10.8	4.7				-9.5	3	1.0
32.0	43.5	-10.7	4.8				-9.5	3	1.0
33.0	43.6	-10.7	4.9				-9.5	3	1.0
34.0	43.6	-10.6	5.0				-9.5	3	1.0
35.0	43.6	-10.5	5.1				-9.5	3	1.0
36.0	43.6	-10.4	5.1				-9.5	3	1.0
37.0	43.7	-10.3	5.2				-9.5	3	1.0
38.0	43.7	-10.2	5.3				-9.5	3	1.0
39.0	43.7	-10.2	5.4				-9.5	3	1.0
40.0	43.8	-10.1	5.5				-9.5	3	1.0

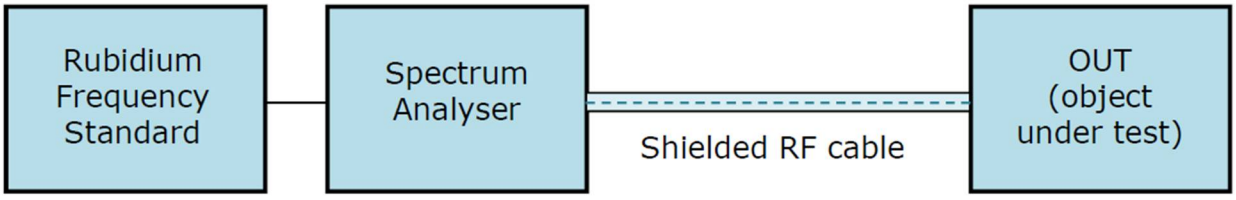
Sample calculation

E (dB µV/m) = U (dB µV) + AF (dB 1/m) + Corr. (dB)
U = Receiver reading
AF = Antenna factor
Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)
Linear interpolation will be used for frequencies in between the values in the table.
distance correction = -20 * LOG (d_{Limit}/ d_{used})
Linear interpolation will be used for frequencies in between the values in the table.
Table shows an extract of values.

8 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.

9 MEASUREMENT UNCERTAINTIES

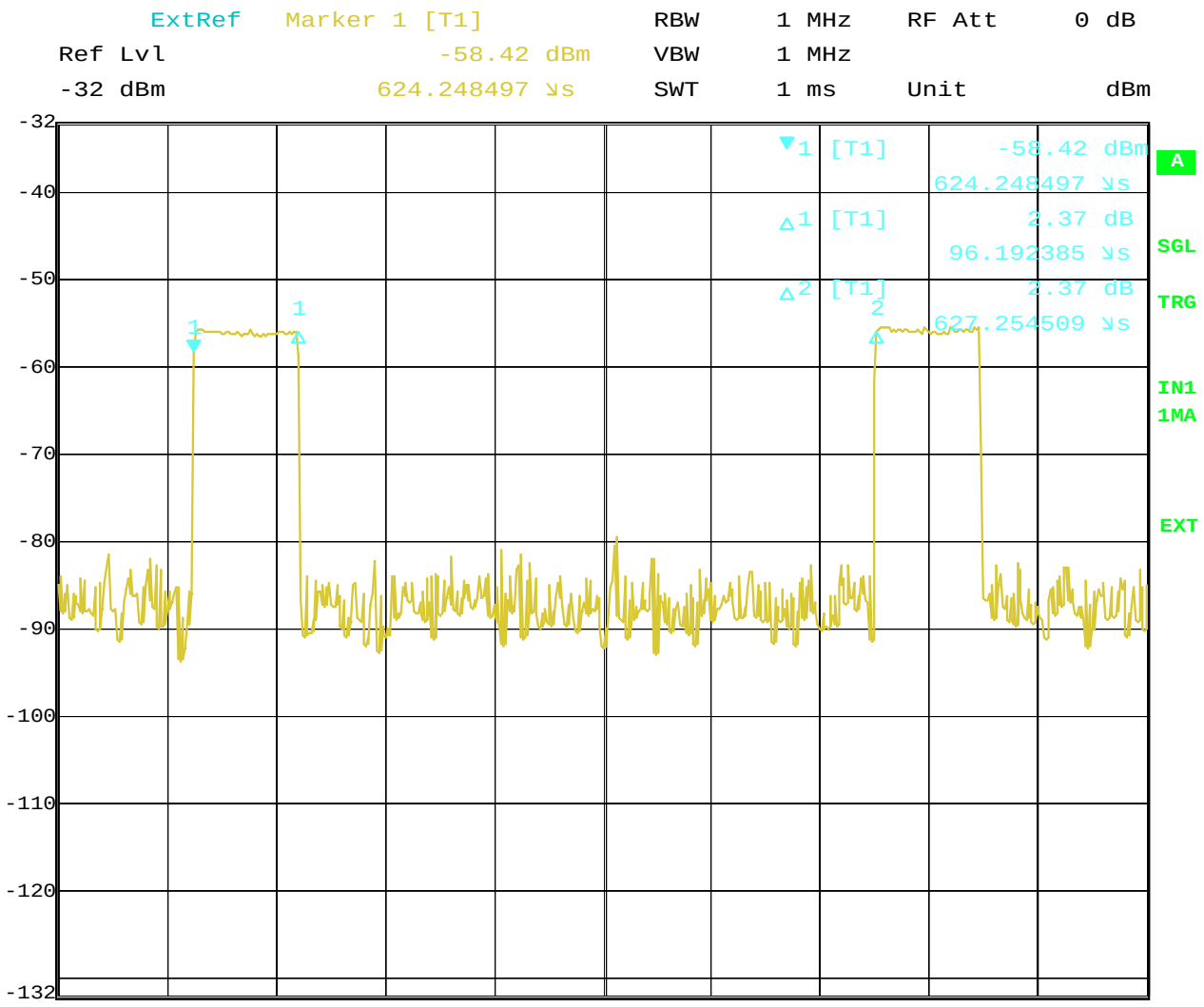
Test Case	Parameter	Uncertainty
AC Power Line	Power	± 3.4 dB
Field Strength of spurious radiation	Power	± 5.5 dB
6 dB / 26 dB / 99% Bandwidth	Power Frequency	± 2.9 dB ± 11.2 kHz
Conducted Output Power	Power	± 2.2 dB
Band Edge Compliance	Power Frequency	± 2.2 dB ± 11.2 kHz
Frequency Stability	Frequency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

10 PHOTO REPORT

Please see separate photo report.

11 ANNEX: DUTY CYCLE PLOT

Sample: DE1189014ad01



Date: 6.JUN.2018 17:22:42

Mode	t1/m(µ)s	t2/m(µ)s	(t1-t2)/t1	dB
BT LE	627.3	96.2	0.1534	16.3

The duty cycle correction factor of 16.3 dB is added to the AV values where stated because the measurements include times of blanking intervals and need to be corrected accordingly.