

FCC Measurement/Technical Report on

Remote control unit

CT-F I

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

Test Report Reference: MDE_FESTO_1601_FCCc

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.

7layers GmbH

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

Geschäftsführer/

Managing Directors:

Frank Spiller
Bernhard Retka
Alexandre Norré-Oudard

Registergericht/registered:

Düsseldorf HRB 75554

USt-Id.-Nr./VAT-No. DE203159652

Steuer-Nr./TAX-No. 147/5869/0385

*a Bureau Veritas
Group Company*

www.7layers.com

Table of Contents

1 Applied Standards and Test Summary	4
1.1 Applied Standards	4
1.2 FCC-IC Correlation Table	5
1.3 Measurement Summary / Signatures	5
2 Administrative Data	9
2.1 Testing Laboratory	9
2.2 Project Data	9
2.3 Applicant Data	9
2.4 Manufacturer Data	9
3 Test object Data	10
3.1 General EUT Description	10
3.2 EUT Main components	10
3.3 Ancillary Equipment	11
3.4 Auxiliary Equipment	11
3.5 EUT Setups	11
3.6 Operating Modes	11
3.7 Product labelling	12
4 Test Results	13
4.1 Occupied Bandwidth (6 dB)	13
4.2 Occupied Bandwidth (99%)	15
4.3 Peak Power Output	17
4.4 Spurious RF Conducted Emissions	19
4.5 Transmitter Spurious Radiated Emissions	21
4.6 Band Edge Compliance Conducted	26
4.7 Band Edge Compliance Radiated	28
4.8 Power Density	30
5 Test Equipment	32
6 Antenna Factors, Cable Loss and Sample Calculations	34
6.1 LISN R&S ESH3-Z5 (150 kHz – 30 MHz)	34
6.2 Antenna R&S HFH2-Z2 (9 kHz – 30 MHz)	35
6.3 Antenna R&S HL562 (30 MHz – 1 GHz)	36
6.4 Antenna R&S HF907 (1 GHz – 18 GHz)	37
6.5 Antenna EMCO 3160-09 (18 GHz – 26.5 GHz)	38
6.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)	39
7 Setup Drawings	40
8 Measurement Uncertainties	41

9 Photo Report

41

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 (10-1-15 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: (DTS Equipment)

The tests were selected and performed with reference to the FCC Public Notice "Guidance for Performing Compliance Measurements on Digital Transmission Systems (DTS) Operating Under §15.247, 558074 D01 DTS Meas Guidance v04, 2017-04-05". ANSI C63.10-2013 is applied.

Note 2: (FHSS Equipment)

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 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 4: 8.8
Occupied bandwidth	§ 15.247 (a) (2)	RSS-247 Issue 1: 5.2 (1)
Peak conducted output power	§ 15.247 (b) (3), (4)	RSS-247 Issue 1: 5.4 (4)
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
Power density	§ 15.247 (e)	RSS-247 Issue 1: 5.2 (2)
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 (a) (2)

Occupied Bandwidth (6 dB)

The measurement was performed according to ANSI C63.10

Final Result

OP-Mode

Radio Technology, Operating Frequency

Bluetooth LE, high

Bluetooth LE, low

Bluetooth LE, mid

Setup

S01_AG01

S01_AG01

S01_AG01

FCC

Passed

Passed

Passed

IC

Passed

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

Final Result

OP-Mode

Radio Technology, Operating Frequency

Bluetooth LE, high

Bluetooth LE, low

Bluetooth LE, mid

Setup

S01_AG01

S01_AG01

S01_AG01

FCC

N/A

N/A

N/A

IC

Passed

Passed

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

Final Result

OP-Mode

Radio Technology, Operating Frequency, Measurement method

Bluetooth LE, high, conducted

Bluetooth LE, low, conducted

Bluetooth LE, mid, conducted

Setup

S01_AG01

S01_AG01

S01_AG01

FCC

Passed

Passed

Passed

IC

Passed

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

Final Result

OP-Mode

Radio Technology, Operating Frequency

Bluetooth LE, high

Bluetooth LE, low

Bluetooth LE, mid

Setup

S01_AG01

S01_AG01

S01_AG01

FCC

Passed

Passed

Passed

IC

Passed

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

Radio Technology, Operating Frequency, Measurement range

Bluetooth LE, high, 1 GHz - 26 GHz

Bluetooth LE, high, 30 MHz - 1 GHz

Bluetooth LE, low, 1 GHz - 26 GHz

Bluetooth LE, low, 30 MHz - 1 GHz

Bluetooth LE, mid, 1 GHz - 26 GHz

Bluetooth LE, mid, 30 MHz - 1 GHz

Bluetooth LE, mid, 9 kHz - 30 MHz

Setup

FCC

IC

S01_AB01

Passed

Passed

S01_AB01

Passed

Passed

S01_AB01

Passed

Passed

S01_AB01

Passed

Passed

S01_AB01

Passed

Passed

S01_AB01

Passed

Passed

S01_AB01

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

Radio Technology, Operating Frequency, Band Edge

Bluetooth LE, high, high

Bluetooth LE, low, low

Setup

FCC

IC

S01_AG01

Passed

Passed

S01_AG01

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

Radio Technology, Operating Frequency, Band Edge

Bluetooth LE, high, high

Setup

FCC

IC

S01_AB01

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

Radio Technology, Operating Frequency

Bluetooth LE, high

Bluetooth LE, low

Bluetooth LE, mid

Setup

S01_AG01

S01_AG01

S01_AG01

FCC

Passed

Passed

Passed

IC

Passed

Passed

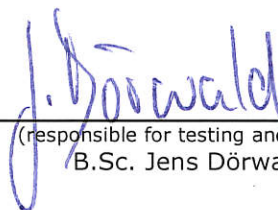
Passed

N/A: Not applicable

N/P: Not performed



(responsible for accreditation scope)
Dipl.-Ing. Bernhard Retka



(responsible for testing and report)
B.Sc. Jens Dörwald



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

2 ADMINISTRATIVE DATA

2.1 TESTING LABORATORY

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

This facility has been fully described in a report submitted to the 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. Bernhard Retka
Report Template Version: 2017-07-06

2.2 PROJECT DATA

Responsible for testing and report: B.Sc. Jens Dörwald
Employees who performed the tests: documented internally at 7Layers
Date of Report: 2017-08-17
Testing Period: 2017-07-01 to 2017-07-07

2.3 APPLICANT DATA

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

2.4 MANUFACTURER DATA

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

3 TEST OBJECT DATA

3.1 GENERAL EUT DESCRIPTION

Kind of Device product description	Remote control unit with Bluetooth low energy
Product name	CT-F I
Declared EUT data by the supplier	
Voltage Type	DC
Voltage Level	3 V
Tested Modulation Type	GFSK Modulation
General product description	Remote control unit with Bluetooth low energy to switch on or off a vacuum cleaner.
The EUT provides the following ports:	-
Tested datarates	1 Mbps
Special software used for testing	Mobile phone application ti set the EUT in testmode.

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
DE1189005	ag01	Conducted Sample
Sample Parameter	Value	
Integral Antenna	deactivated	
Serial No.	only assembled pcb	
HW Version	709368	
SW Version	709370	
Comment	-	

Sample Name	Sample Code	Description
DE1189005	ab01	Radiated Setup
Sample Parameter	Value	
Integral Antenna	2.14 dBi (omnidirectional pcb antenna)	
Serial No.	10029918	
HW Version	709368	
SW Version	709370	
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
-	-	-

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
S01_AB01	DE1189005ab01	Radiated Setup
S01_AG01	DE1189005ag01	Conducted Setup

3.6 OPERATING MODES

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

3.6.1 TEST CHANNELS

BT LE Test Channels:
Channel:
Frequency [MHz]

2.4 GHz ISM 2400 - 2483.5 MHz		
low	mid	high
0	19	39
2402	2440	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 OCCUPIED BANDWIDTH (6 DB)

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 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
- Sweep time: 5 ms
- Detector: Peak

4.1.2 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.

4.1.3 TEST PROTOCOL

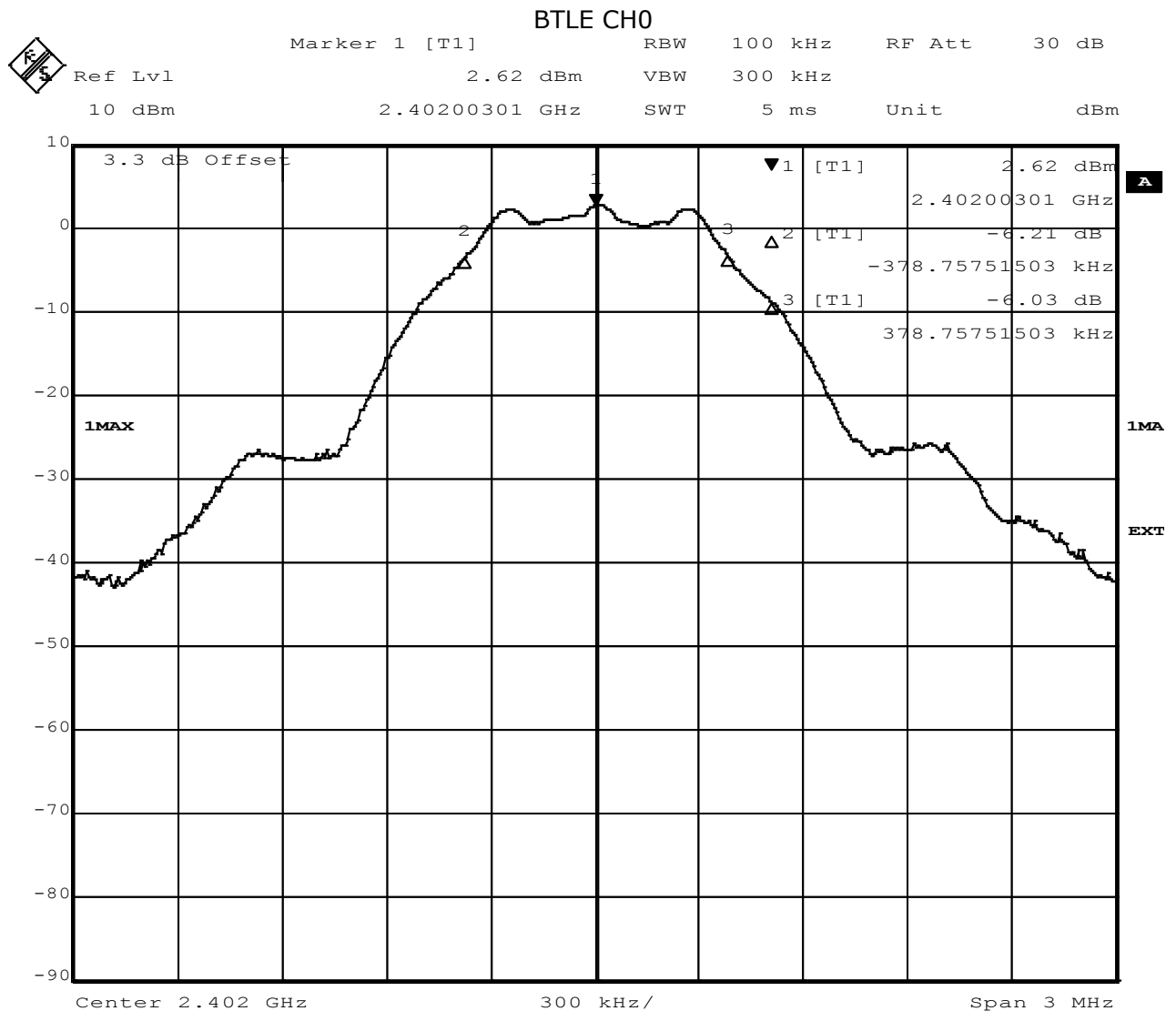
Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %

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	0.764	0.5	0.264
	39	2480	0.758	0.5	0.258

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

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



Date: 7.JUL.2017 10:21:48

4.1.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

4.2 OCCUPIED BANDWIDTH (99%)

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.2.1 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 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.

4.2.2 TEST REQUIREMENTS / LIMITS

No applicable limit:

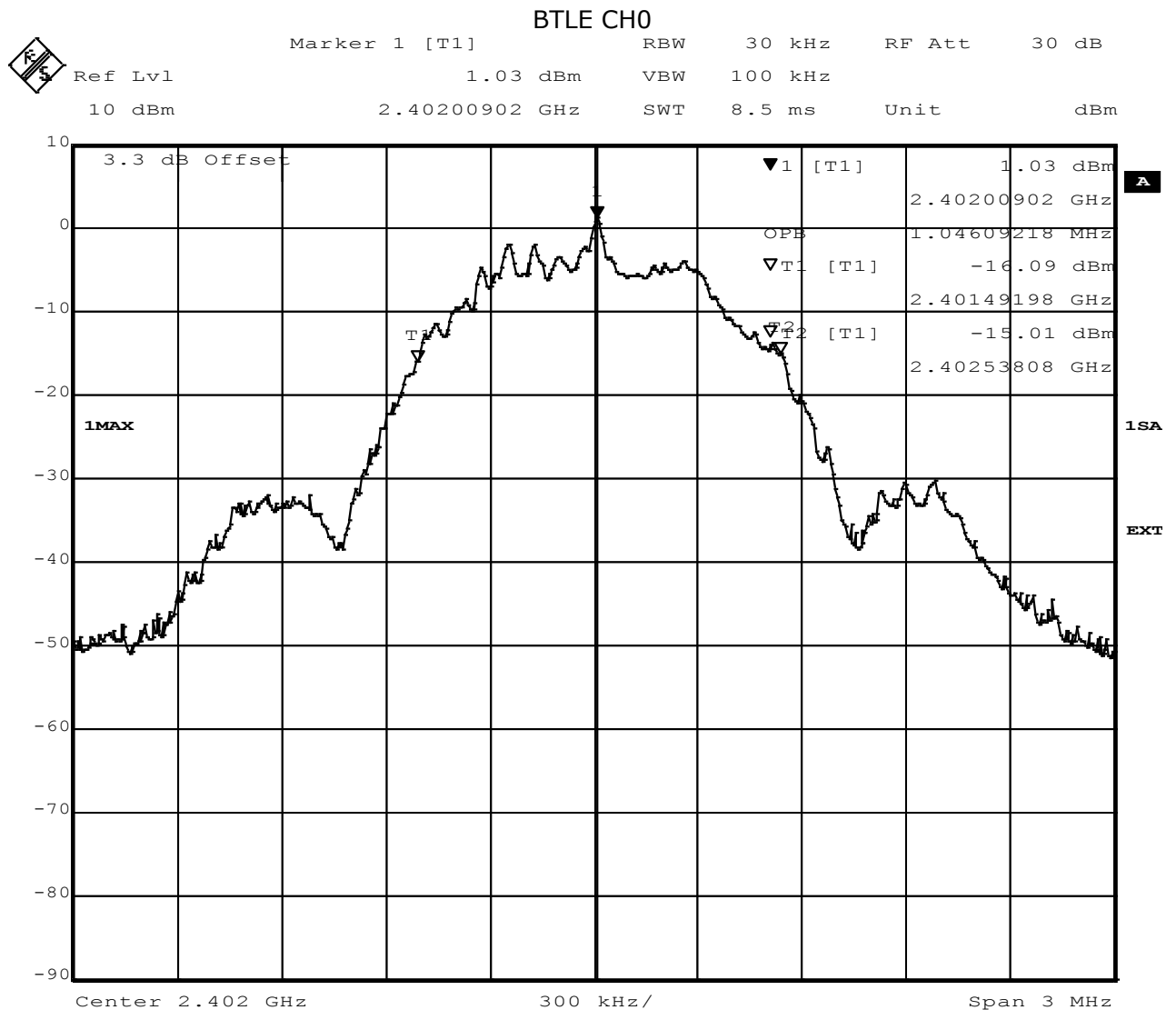
4.2.3 TEST PROTOCOL

Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %
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.

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



Date: 7.JUL.2017 10:15:35

4.2.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

4.3 PEAK POWER OUTPUT

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.3.1 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

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

4.3.2 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)

4.3.3 TEST PROTOCOL

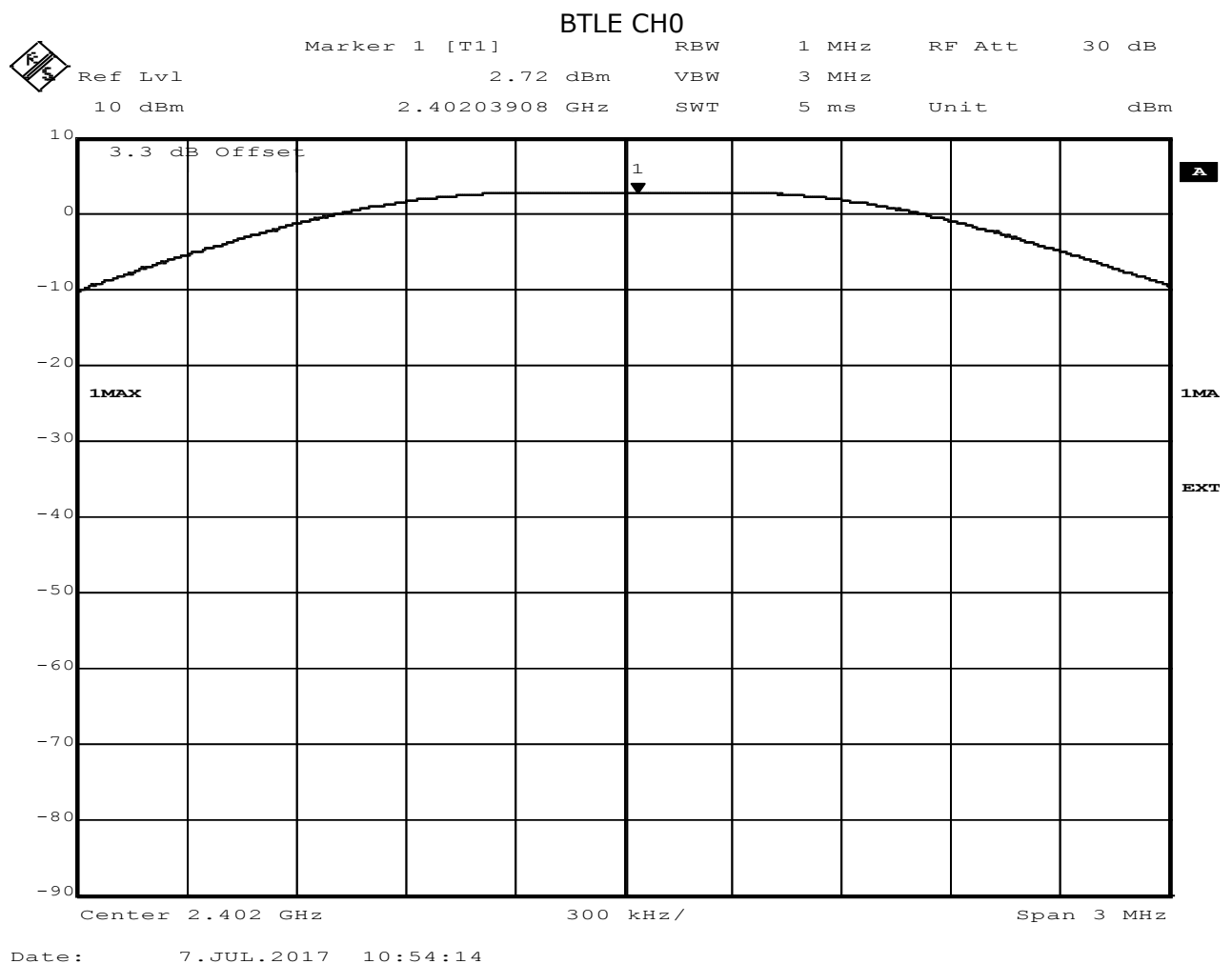
Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %

BT LE

Band	Channel No.	Frequency [MHz]	Peak Power [dBm]	Limit [dBm]	Margin to Limit [dB]
2.4 GHz ISM	0	2402	2.7	30.0	27.3
	19	2440	2.0	30.0	28.0
	39	2480	2.2	30.0	27.9

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

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



4.3.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

4.4 SPURIOUS RF CONDUCTED EMISSIONS

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.4.1 TEST DESCRIPTION

The Equipment Under Test (EUT) was set up to perform the 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.

4.4.2 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.

4.4.3 TEST PROTOCOL

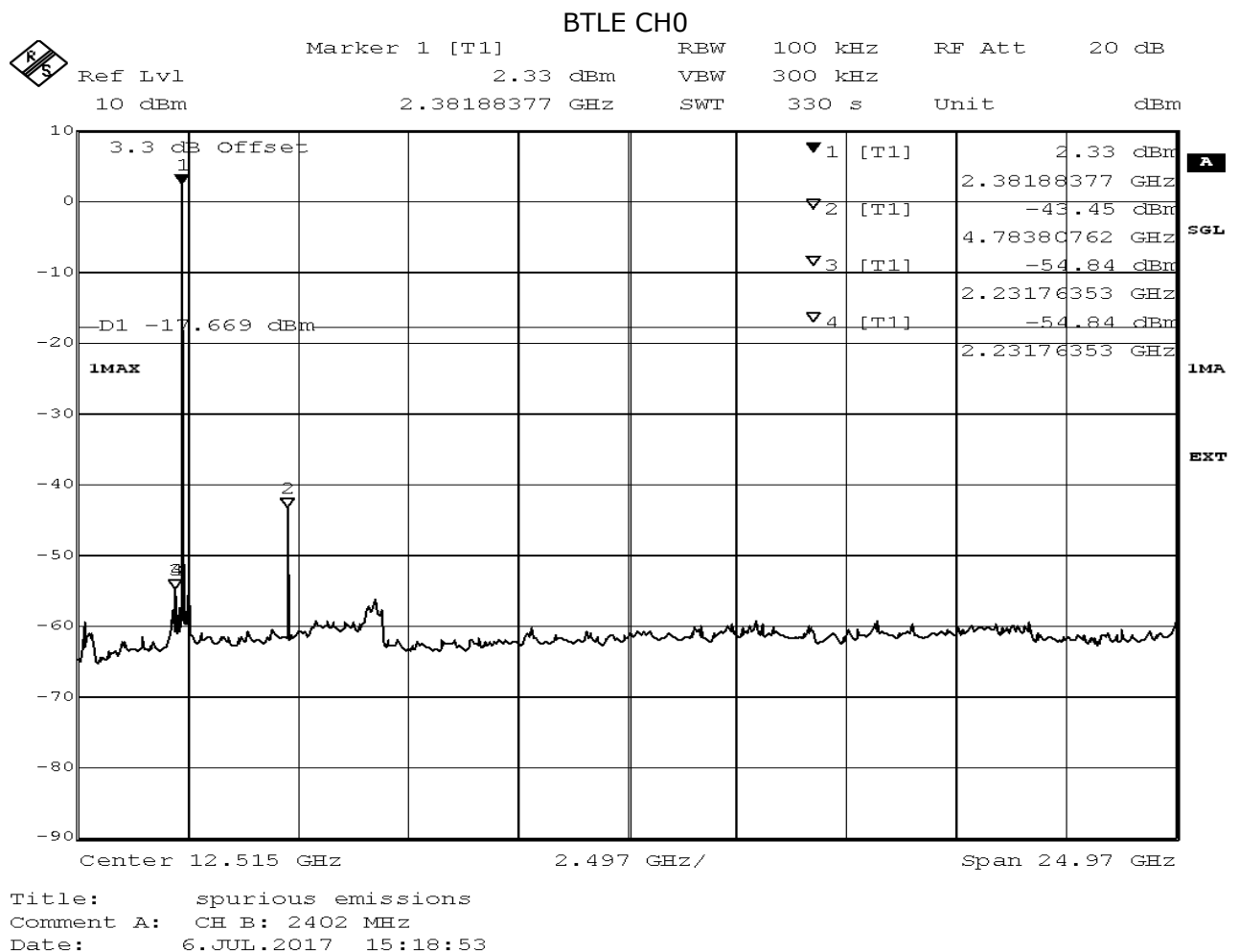
Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %

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	-43.5	PEAK	100	2.3	-17.7	25.8
19	2440	4883.8	-47.1	PEAK	100	1.8	-18.2	28.8
39	2480	4933.9	-50.7	PEAK	100	2.0	-18.0	32.7

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

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



4.4.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

4.5 TRANSMITTER SPURIOUS RADIATED EMISSIONS

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.5.1 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

4.5.2 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 ($\mu\text{V/m}$)	Measurement distance (m)	Limits ($\text{dB}\mu\text{V/m}$)
0.009 – 0.49	$2400/F(\text{kHz})@300\text{m}$	3	$(48.5 - 13.8)@300\text{m}$
0.49 – 1.705	$24000/F(\text{kHz})@30\text{m}$	3	$(33.8 - 23.0)@30\text{m}$
1.705 – 30	$30@30\text{m}$	3	$29.5@30\text{m}$

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

Frequency in MHz	Limit ($\mu\text{V/m}$)	Measurement distance (m)	Limits ($\text{dB}\mu\text{V/m}$)
30 – 88	$100@3\text{m}$	3	$40.0@3\text{m}$
88 – 216	$150@3\text{m}$	3	$43.5@3\text{m}$
216 – 960	$200@3\text{m}$	3	$46.0@3\text{m}$
960 – 26000	$500@3\text{m}$	3	$54.0@3\text{m}$
26000 – 40000	$500@3\text{m}$	1	$54.0@3\text{m}$

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

4.5.3 TEST PROTOCOL

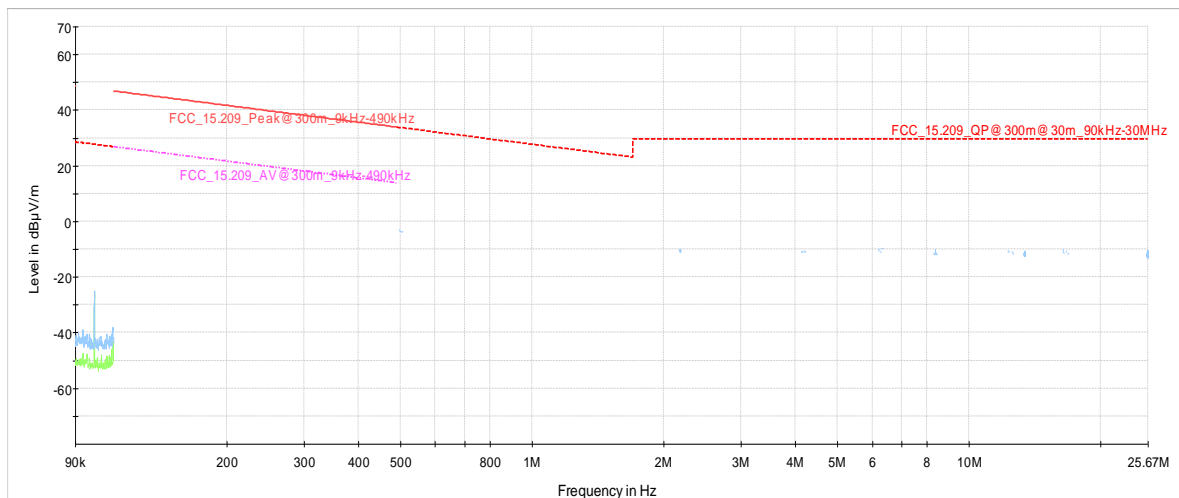
Ambient temperature: 26 °C
Air Pressure: 1003 hPa
Humidity: 43 %

BT low Energy

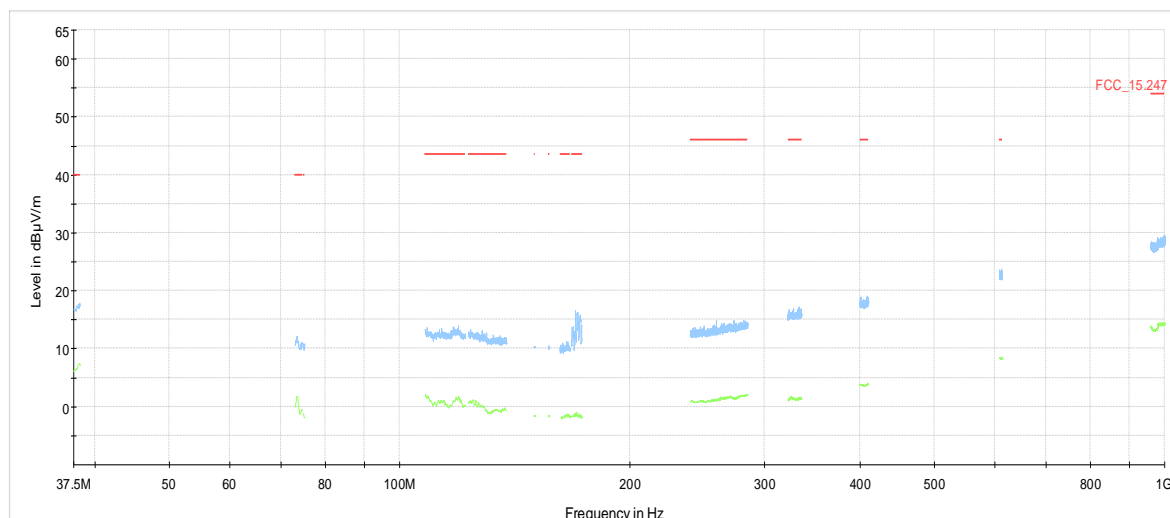
Ch. No.	Ch. Center Freq. [MHz]	Spurious Freq. [MHz]	Spurious Level [dBμV/m]	Detector	RBW [kHz]	Limit [dBμV/m]	Margin to Limit [dB]	Limit Type
0	2402	4804.0	55.3	PEAK	1000	74.0	18.7	RB
0	2402	4804.0	43.8	AV	1000	54.0	10.2	RB
19	2440	4880.0	55.5	PEAK	1000	74.0	18.5	RB
19	2440	4880.0	42.7	AV	1000	54.0	11.4	RB
39	2480	4960.0	55.5	PEAK	1000	74.0	18.5	RB
39	2480	4960.0	43.8	AV	1000	54.0	10.2	RB
39	2480	7440.0	54.8	PEAK	1000	74.0	19.2	RB
39	2480	7440.0	43.7	AV	1000	54.0	10.3	RB

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

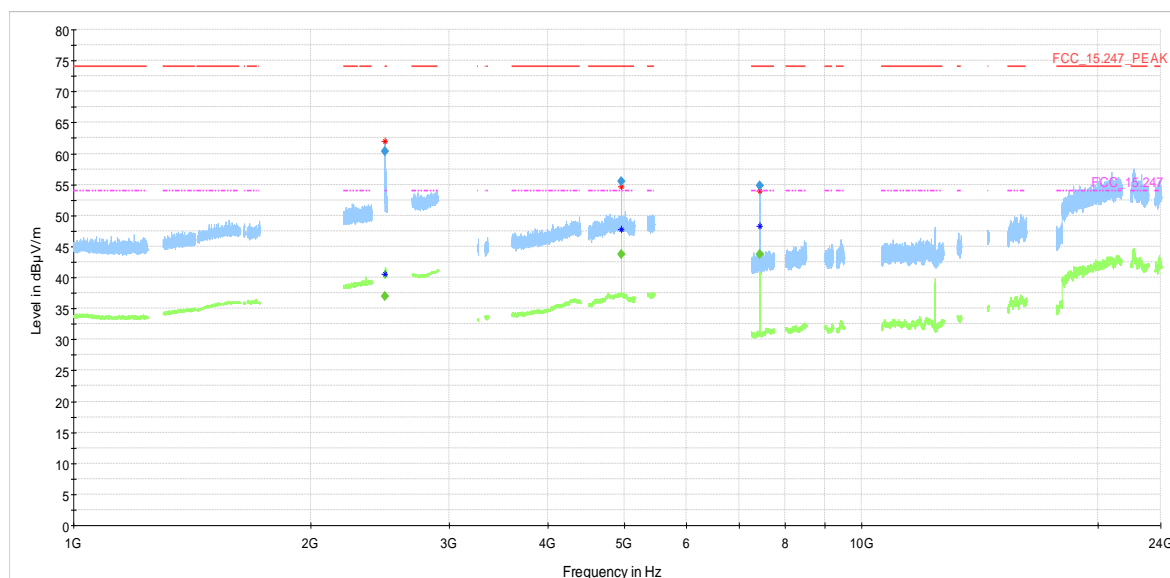
4.5.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, "WORST CASE") 9 kHz – 30 MHz: BTLE CH19



30 MHz – 1 GHz: BTLE CH 19



1 GHz – 26 GHz: BTLE CH39



Frequency (MHz)	MaxPeak (dBµV/m)	CAverage (dBµV/m)	Limit (dBµV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)
2483.582500	60.29	---	74.00	13.71	1000.0	1000.000	150.0	H	-1.0	-4.0
2484.655000	---	36.96	54.00	17.04	1000.0	1000.000	150.0	H	11.0	-12.1
4959.875000	---	43.76	54.00	10.24	1000.0	1000.000	150.0	H	-161.0	-4.2
4960.037500	55.47	---	74.00	18.53	1000.0	1000.000	150.0	H	161.0	1.9
7439.750000	---	43.73	54.00	10.27	1000.0	1000.000	150.0	H	92.0	74.9
7440.625000	54.83	---	74.00	19.17	1000.0	1000.000	150.0	H	95.0	74.8

4.5.5 TEST EQUIPMENT USED

- Radiated Emissions

4.6 BAND EDGE COMPLIANCE CONDUCTED

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.6.1 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 GHz
- Detector: Peak
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Sweptime: 5 ms
- Sweeps: 2
- Trace: Maxhold

4.6.2 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..."

4.6.3 TEST PROTOCOL

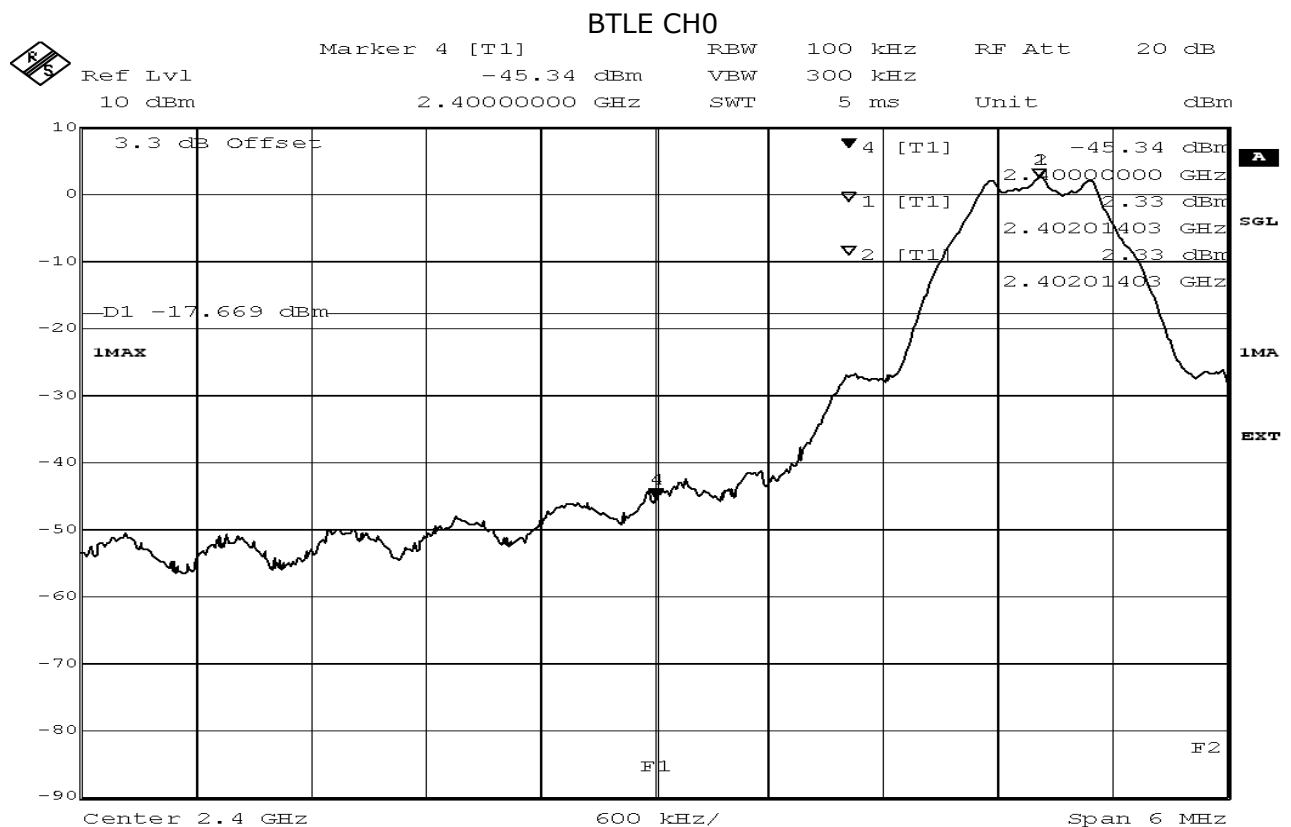
Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %

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	-45.3	PEAK	100	2.3	-17.7	27.7
39	2480	2483.5	-48.4	PEAK	100	1.9	-18.1	30.3

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

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



Title: Band Edge Compliance
Comment A: CH B: 2402 MHz
Date: 6.JUL.2017 15:06:52

4.6.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

4.7 BAND EDGE COMPLIANCE RADIATED

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.7.1 TEST DESCRIPTION

Please see test description for the test case "Spurious Radiated Emissions"

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

4.7.3 TEST PROTOCOL

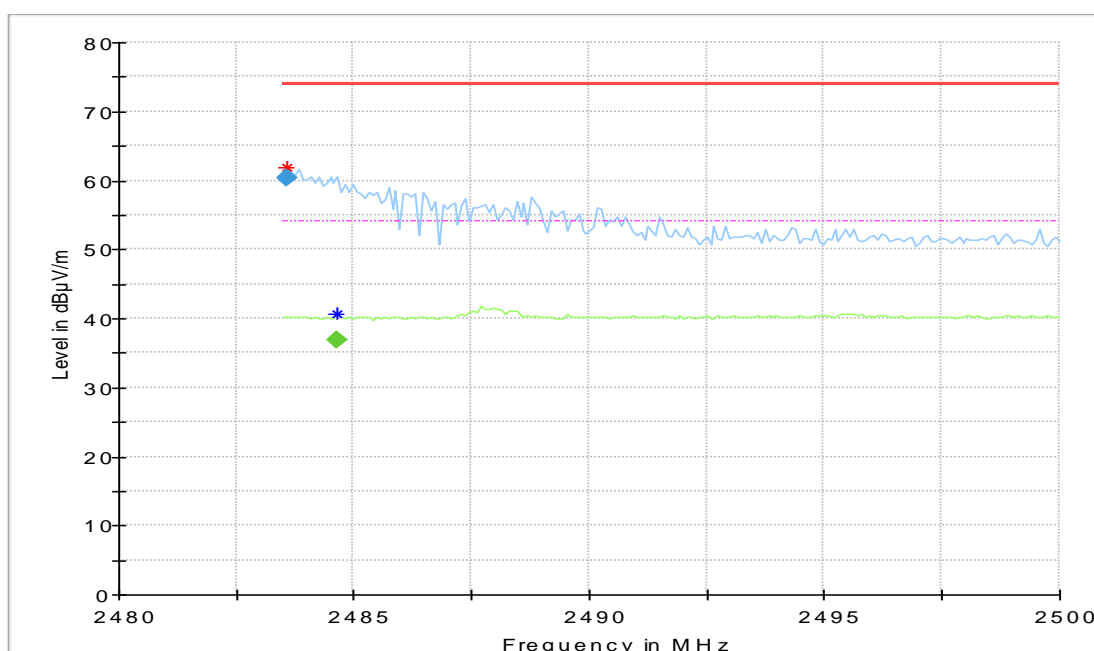
Ambient temperature: 26 °C
Air Pressure: 1003 hPa
Humidity: 43 %

BT LE GFSK

Ch. No.	Ch. Center Freq. [MHz]	Band Edge Freq. [MHz]	Spurious Level [dBμV/m]	Detector	RBW [kHz]	Limit [dBμV/m]	Margin to Limit [dB]	Limit Type
39	2480	2483.5	60.3	PEAK	1000	74.0	13.7	BE
39	2480	2483.5	37.0	AV	1000	54.0	17.0	BE

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

4.7.4 MEASUREMENT PLOT (SHOWING THE HIGHEST VALUE, "WORST CASE") BTLE CH39



Frequency (MHz)	MaxPeak (dBμV/m)	CAverage (dBμV/m)	Limit (dBμV/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)
2483.582500	60.29	---	74.00	13.71	1000.0	1000.000	150.0	H	-1.0	-4.0
2484.655000	---	36.96	54.00	17.04	1000.0	1000.000	150.0	H	11.0	-12.1

4.7.5 TEST EQUIPMENT USED

- Radiated Emissions

4.8 POWER DENSITY

Standard **FCC Part 15 Subpart C**

The test was performed according to:
ANSI C63.10

4.8.1 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

4.8.2 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.

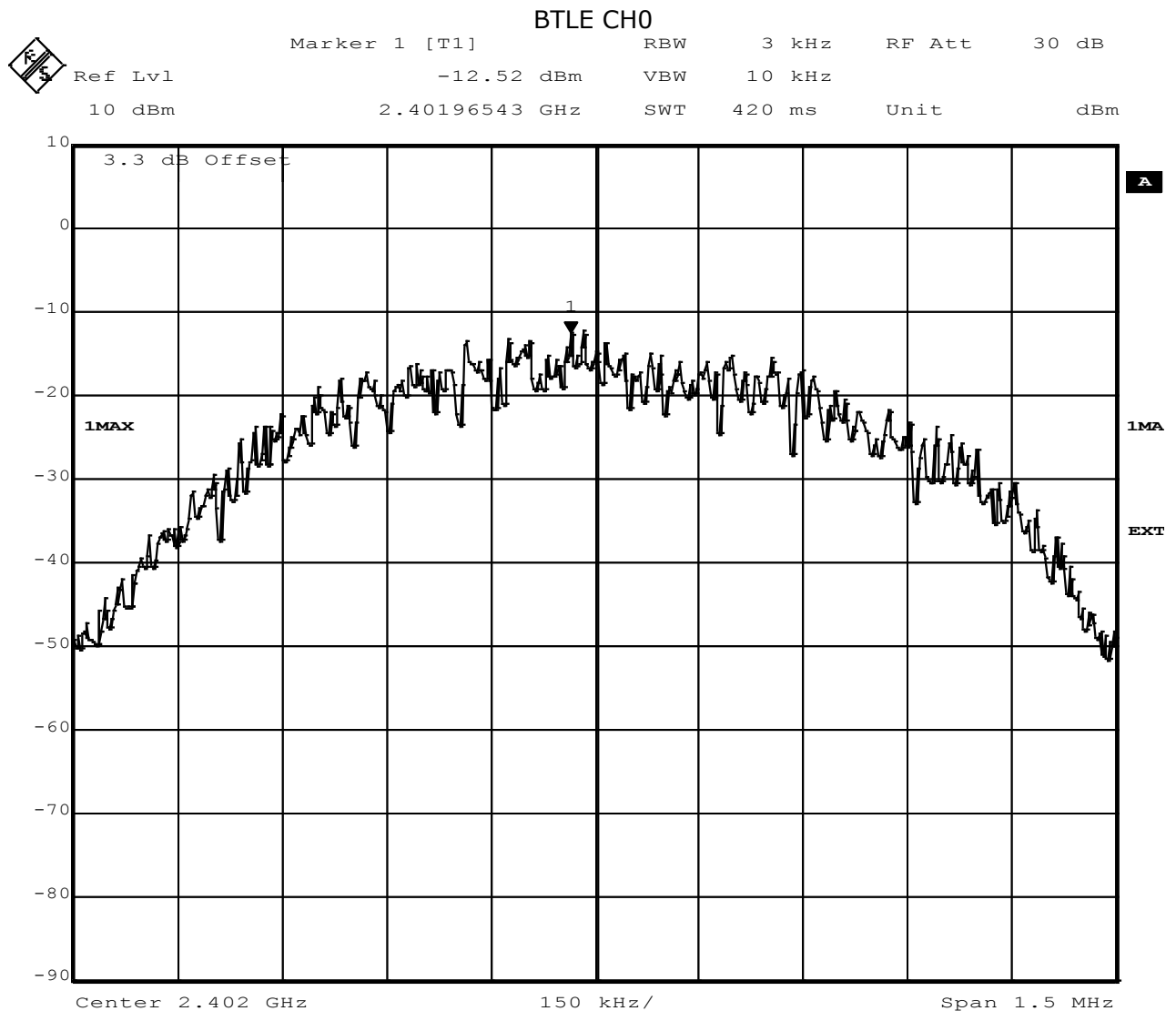
4.8.3 TEST PROTOCOL

Ambient temperature: 23 °C
Air Pressure: 1009 hPa
Humidity: 41 %
BT LE

Band	Channel No.	Frequency [MHz]	Power Density [dBm/3kHz]	Limit [dBm/3kHz]	Margin to Limit [dB]
2.4 GHz ISM	0	2402	-12.5	8.0	20.5
	19	2440	-13.0	8.0	21.0
	39	2480	-12.9	8.0	20.9

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

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



Date: 7.JUL.2017 10:55:14

4.8.5 TEST EQUIPMENT USED

- Regulatory Bluetooth RF Test Solution

Test Equipment

- 1 Radiated Emissions
Lab to perform radiated emission tests

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	NRV-Z1	Sensor Head A	Rohde & Schwarz	827753/005	2017-05	2018-05
1.2	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002		
1.3	Opus10 TPR (8253.00)	ThermoAirpressure Datalogger 13 (Environ)	Lufft Mess- und Regeltechnik GmbH	13936	2017-04	2019-04
1.4	Anechoic Chamber	10.58 x 6.38 x 6.00 m ³	Frankonia	none	2016-05	2019-05
1.5	HL 562	Ultralog new biconicals	Rohde & Schwarz	830547/003	2015-06	2018-06
1.6	5HC2700/12750-1.5-KK	High Pass Filter	Trilithic	9942012		
1.7	ASP 1.2/1.8-10 kg	Antenna Mast	Maturo GmbH	-		
1.8	Fully Anechoic Room	8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	2015-07	2018-07
1.9	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2016-02	2018-02
1.10	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785		
1.11	FSW 43	Spectrum Analyzer	Rohde & Schwarz	103779	2016-12	2018-12
1.12	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronik GmbH	00083069		
1.13	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright	09		
1.14	4HC1600/12750-1.5-KK	High Pass Filter	Trilithic	9942011		
1.15	Chroma 6404	AC Power Source	Chroma ATE INC.	64040001304		
1.16	JS4-00102600-42-5A	Broadband Amplifier 30 MHz - 26 GHz	Miteq	619368		
1.17	TT 1.5 WI	Turn Table	Maturo GmbH	-		
1.18	HL 562 Ultralog	Log.-per. Antenna	Rohde & Schwarz	100609	2016-04	2019-04
1.19	3160-10	Standard Gain / Pyramidal Horn Antenna 40 GHz	EMCO Elektronik GmbH	00086675		
1.20	5HC3500/18000-1.2-KK	High Pass Filter	Trilithic	200035008		
1.21	HFH2-Z2	Loop Antenna	Rohde & Schwarz	829324/006	2014-11	2017-11
1.22	Opus10 THI (8152.00)	ThermoHygro Datalogger 12 (Environ)	Lufft Mess- und Regeltechnik GmbH	12482	2017-03	2019-03

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.23	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2016-11	2018-11
1.24	JS4-00101800-35-5P	Broadband Amplifier 30 MHz - 18 GHz	Miteq	896037		
1.25	AS 620 P	Antenna mast	HD GmbH	620/37		
1.26	Tilt device Maturo (Rohacell)	Antrieb TD1.5-10kg	Maturo GmbH	TD1.5-10kg/024/3790709		
1.27	ESIB 26	Spectrum Analyzer	Rohde & Schwarz	830482/004	2015-12	2017-12
1.28	PAS 2.5 - 10 kg	Antenna Mast	Maturo GmbH	-		
1.29	AM 4.0	Antenna mast	Maturo GmbH	AM4.0/180/11920513		
1.30	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2015-05	2018-05

2 Regulatory Bluetooth RF Test Solution Regulatory Bluetooth RF Tests

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	MFS	Rubidium Frequency Normal MFS	Datum GmbH	002	2016-09	2017-09
2.2	EX520	Digital Multimeter 12 (Multimeter)	Extech Instruments Corp	05157876	2016-02	2018-02
2.3	NRV Z1 A	Power Sensor	Rohde & Schwarz	832279/013	2016-09	2017-09
2.4	Opus10 THI (8152.00)	T/H Logger 15	Lufft Mess- und Regeltechnik GmbH	13985	2017-04	2019-04
2.5	SMP03	Signal Generator 2 GHz - 27 GHz	Rohde & Schwarz	833680/003		
2.6	TOCT Switching Unit		7layers, Inc.	040107		
2.7	KWP 120/70	Temperature Chamber Weiss 01	Weiss	59226012190010	2016-03	2018-03
2.8	ADU 200 Relay Box 7	used for automated testing (EMMI) only	Ontrak Control Systems Inc	A04380		
2.9	CBT	IL BT RF Test Solution	Rohde & Schwarz	100302	2017-02	2018-02
2.10	NRVD	Powermeter	Rohde & Schwarz	832025/059	2016-08	2017-08
2.11	FSIQ26	Signal Analyser	Rohde & Schwarz	832695/007	2016-09	2018-09
2.12	SMP02	Signal Generator SMP	Rohde & Schwarz	833286/0014	2016-05	2019-05
2.13	SMIQ03B	Signal Generator	Rohde & Schwarz	832870/017	2016-06	2019-06
2.14	CBT	Bluetooth Tester	Rohde & Schwarz	100589	2015-01	2018-01
2.15	NGSM 32/10	Power Supply	Rohde & Schwarz	2725	2015-06	2017-06

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

5 ANTENNA FACTORS, CABLE LOSS AND SAMPLE CALCULATIONS

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

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

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

Sample calculation

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

U = Receiver reading

LISN Insertion loss = Voltage Division Factor of LISN

Corr. = sum of single correction factors of used LISN, cables, switch units (if used)

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

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

Frequency 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

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

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

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

cable loss 1 (inside chamber)	cable loss 2 (outside chamber)	cable loss 3 (switch unit)	cable loss 4 (to receiver)	distance corr. (-20 dB/ decade)	d_{Limit} (meas. distance (limit))	d_{used} (meas. distance (used))
dB	dB	dB	dB	dB	m	m
0.29	0.04	0.23	0.02	0.0	3	3
0.39	0.09	0.32	0.08	0.0	3	3
0.56	0.14	0.47	0.08	0.0	3	3
0.73	0.20	0.59	0.12	0.0	3	3
0.84	0.21	0.70	0.11	0.0	3	3
0.98	0.24	0.80	0.13	0.0	3	3
1.04	0.26	0.89	0.15	0.0	3	3
1.18	0.31	0.96	0.13	0.0	3	3
1.28	0.35	1.03	0.19	0.0	3	3
1.39	0.38	1.11	0.22	0.0	3	3
1.44	0.39	1.20	0.19	0.0	3	3
1.55	0.46	1.24	0.23	0.0	3	3
1.59	0.43	1.29	0.23	0.0	3	3
1.67	0.34	1.35	0.22	0.0	3	3
1.67	0.42	1.41	0.15	0.0	3	3
1.87	0.54	1.46	0.25	0.0	3	3
1.90	0.46	1.51	0.25	0.0	3	3
1.99	0.60	1.56	0.27	0.0	3	3
2.14	0.60	1.63	0.29	0.0	3	3
2.22	0.60	1.66	0.33	0.0	3	3
2.23	0.61	1.71	0.30	0.0	3	3

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

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

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

Sample calculation

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

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

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

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

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

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

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

cable loss 1 (relay inside chamber)	cable loss 2 (High Pass)	cable loss 3 (pre- amp)	cable loss 4 (inside chamber)	cable loss 5 (outside chamber)	cable loss 6 (to receiver)
dB	dB	dB	dB	dB	dB
0.56	1.28	-62.72	2.66	0.94	1.46
0.69	0.71	-61.49	2.84	1.00	1.53
0.68	0.65	-60.80	3.06	1.09	1.60
0.70	0.54	-61.91	3.28	1.20	1.67
0.80	0.61	-61.40	3.43	1.27	1.70
0.84	0.42	-59.70	3.53	1.26	1.73
0.83	0.44	-59.81	3.75	1.32	1.83
0.91	0.53	-63.03	3.91	1.40	1.77
0.98	0.54	-61.05	4.02	1.44	1.83
1.23	0.49	-61.51	4.17	1.51	1.85
1.36	0.76	-62.36	4.34	1.53	2.00
1.70	0.53	-62.88	4.41	1.55	1.91

Sample calculation

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

U = Receiver reading

AF = Antenna factor

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

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

Tables show an extract of values.

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

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

Sample calculation

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

U = Receiver reading

AF = Antenna factor

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

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

Table shows an extract of values.

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

Frequency GHz	AF EMCO 3160-10 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. (-20 dB/ decade) dB	d _{Limit} (meas. distance (limit) m	d _{used} (meas. distance (used) m
26.5	43.4	-11.2	4.4				-15.6	3	0.5
27.0	43.4	-11.2	4.4				-15.6	3	0.5
28.0	43.4	-11.1	4.5				-15.6	3	0.5
29.0	43.5	-11.0	4.6				-15.6	3	0.5
30.0	43.5	-10.9	4.7				-15.6	3	0.5
31.0	43.5	-10.8	4.7				-15.6	3	0.5
32.0	43.5	-10.7	4.8				-15.6	3	0.5
33.0	43.6	-10.7	4.9				-15.6	3	0.5
34.0	43.6	-10.6	5.0				-15.6	3	0.5
35.0	43.6	-10.5	5.1				-15.6	3	0.5
36.0	43.6	-10.4	5.1				-15.6	3	0.5
37.0	43.7	-10.3	5.2				-15.6	3	0.5
38.0	43.7	-10.2	5.3				-15.6	3	0.5
39.0	43.7	-10.2	5.4				-15.6	3	0.5
40.0	43.8	-10.1	5.5				-15.6	3	0.5

Sample calculation

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

U = Receiver reading

AF = Antenna factor

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

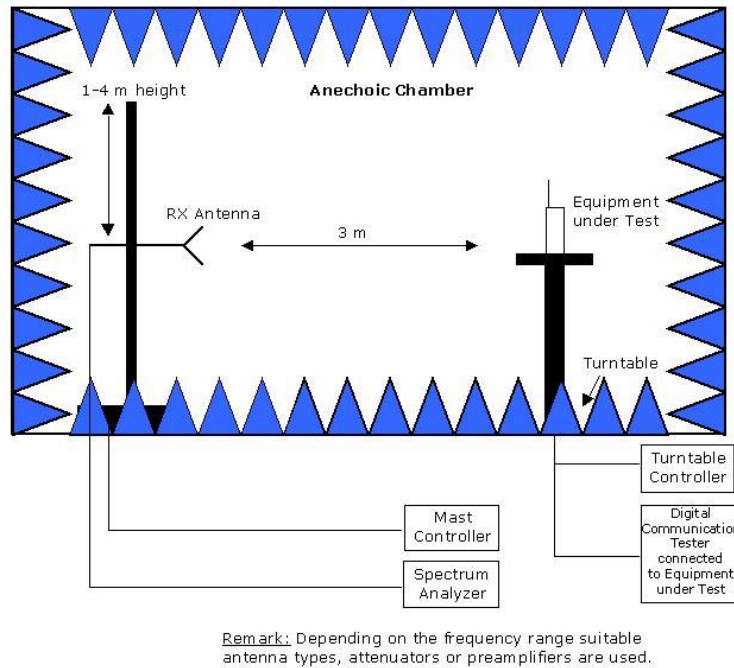
Linear interpolation will be used for frequencies in between the values in the table.

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

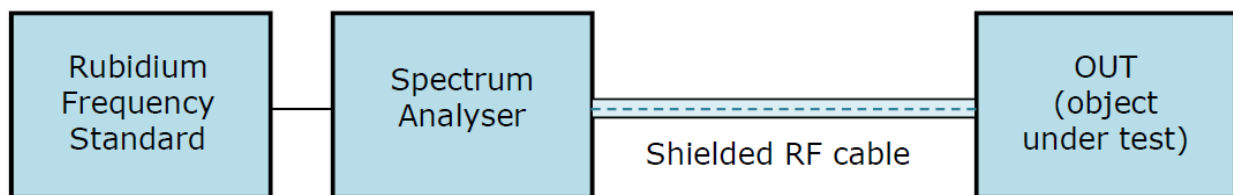
Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

6 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.

7 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

8 PHOTO REPORT

Please see separate photo report.