



# FCC Measurement/Technical Report on

## SPB611 module

FCC ID: XO2-SPB611  
IC: 8713A-SPB611

**Test Report Reference:** MDE\_HDW\_2303\_FCC\_03

**Test Laboratory:**

7layers GmbH  
Borsigstrasse 11  
40880 Ratingen  
Germany



**Note:**

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

**7layers GmbH**  
Borsigstraße 11  
40880 Ratingen, Germany  
T +49 (0) 2102 749 0  
F +49 (0) 2102 749 350

Geschäftsführer/  
Managing Directors:  
Sebastian Doose  
Stefan Kischka  
Bernhard Retka

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](http://www.7layers.com)

## Table of Contents

<b>1 Applied Standards and Test Summary</b>	<b>3</b>
1.1 Applied Standards	3
1.2 FCC-IC Correlation Table	4
1.3 Measurement Summary	4
<b>2 Revision History / Signatures</b>	<b>8</b>
<b>3 Administrative Data</b>	<b>9</b>
3.1 Testing Laboratory	9
3.2 Project Data	9
3.3 Applicant Data	9
3.4 Manufacturer Data	10
<b>4 Test object Data</b>	<b>11</b>
4.1 General EUT Description	11
4.2 EUT Main components	11
4.3 Ancillary Equipment	12
4.4 Auxiliary Equipment	12
4.5 EUT Setups	12
4.6 Operating Modes / Test Channels	13
4.7 Product labelling	13
<b>5 Test Results</b>	<b>14</b>
5.1 Occupied Bandwidth (6 dB)	17
5.2 Occupied Bandwidth (99%)	21
5.3 Peak Power Output	25
5.4 Transmitter Spurious Radiated Emissions	36
5.5 Band Edge Compliance Conducted	48
5.6 Band Edge Compliance Radiated	52
5.7 Power Density	56
<b>6 Test Equipment</b>	<b>62</b>
6.1 Test Equipment Hardware	62
6.2 Test Equipment Software	64
<b>7 Antenna Factors, Cable Loss and Sample Calculations</b>	<b>66</b>
7.1 LISN R&S ESH3-Z5 (150 kHz – 30 MHz)	66
7.2 Antenna R&S HFH2-Z2 (9 kHz – 30 MHz)	67
7.3 Antenna R&S HL562 (30 MHz – 1 GHz)	68
7.4 Antenna R&S HF907 (1 GHz – 18 GHz)	69
7.5 Antenna EMCO 3160-09 (18 GHz – 26.5 GHz)	70
7.6 Antenna EMCO 3160-10 (26.5 GHz – 40 GHz)	71
<b>8 Measurement Uncertainties</b>	<b>72</b>
<b>9 Photo Report</b>	<b>73</b>



## 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 (10-1-22 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 v05r02, 2019-04-02".

ANSI C63.10-2013 is applied.

## 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 & AMD 1 & AMD 2: 8.8
Occupied bandwidth	§ 15.247 (a) (2)	RSS-247 Issue 3: 5.2 (a)
Peak conducted output power	§ 15.247 (b) (3), (4)	RSS-247 Issue 3: 5.4 (d)
Transmitter spurious RF conducted emissions	§ 15.247 (d)	RSS-Gen Issue 5 & AMD 1 & AMD 2: 6.13 / 8.9/8.10; RSS-247 Issue 3: 5.5
Transmitter spurious radiated emissions	§ 15.247 (d); § 15.209 (a)	RSS-Gen Issue 5 & AMD 1 & AMD 2: 6.13 / 8.9/8.10; RSS-247 Issue 3: 5.5
Band edge compliance	§ 15.247 (d)	RSS-247 Issue 3: 5.5
Power density	§ 15.247 (e)	RSS-247 Issue 3: 5.2 (b)
Antenna requirement	§ 15.203 / 15.204	RSS-Gen Issue 5 & AMD 1 & AMD 2: 8.3
Receiver spurious emissions	-	-

## 1.3 MEASUREMENT SUMMARY

### 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, chapter 6.2

**Final Result**

#### OP-Mode

Operating mode, Connection to AC mains  
worst case, via ancillary/auxiliary equipment

#### Setup

#### Date

#### FCC

#### IC

S04\_AD01

2024-01-04

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, chapter 11.8.1

**Final Result**

#### OP-Mode

Radio Technology, Operating Frequency  
Thread, high  
Thread, low  
Thread, mid

#### Setup

#### Date

#### FCC

#### IC

S01\_AD01

2023-11-16

Passed

Passed

S01\_AD01

2023-11-16

Passed

Passed

S01\_AD01

2023-11-16

Passed

Passed

### 47 CFR CHAPTER I FCC PART 15 Subpart C §15.247

### IC RSS-Gen & IC TRC-43; Ch. 6.7 & Ch. 8

Occupied Bandwidth (99%)

The measurement was performed according to ANSI C63.10, chapter 6.9.3

**Final Result**

#### OP-Mode

Radio Technology, Operating Frequency  
Thread, high  
Thread, low  
Thread, mid

#### Setup

#### Date

#### FCC

#### IC

S01\_AD01

2023-11-16

N/A

Performed

S01\_AD01

2023-11-16

N/A

Performed

S01\_AD01

2023-11-16

N/A

Performed

### 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, chapter 11.9.1.3

**Final Result**

#### OP-Mode

Radio Technology, Operating Frequency,  
Measurement method  
Thread, high, conducted  
Thread, low, conducted  
Thread, mid, conducted

#### Setup

#### Date

#### FCC

#### IC

S01\_AD01

2023-11-16

Passed

Passed

S01\_AD01

2023-11-16

Passed

Passed

S01\_AD01

2023-11-16

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, chapter 6.4, 6.5, 6.6.5

**Final Result**

<b>OP-Mode</b>	<b>Setup</b>	<b>Date</b>	<b>FCC</b>	<b>IC</b>
Radio Technology, Operating Frequency, Measurement range				
Thread, high, 1 GHz - 26 GHz	S02_AD01	2023-11-27	Passed	Passed
Thread, low, 1 GHz - 26 GHz	S02_AD01	2023-11-26	Passed	Passed
Thread, mid, 1 GHz - 26 GHz	S02_AD01	2023-11-27	Passed	Passed

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

Spurious RF Conducted Emissions

The measurement was performed according to ANSI C63.10, chapter 11.11

**Final Result**

<b>OP-Mode</b>	<b>Setup</b>	<b>Date</b>	<b>FCC</b>	<b>IC</b>
Radio Technology, Operating Frequency				
Thread, high	S01_AD01	2024-02-13	Passed	Passed
Thread, low	S01_AD01	2024-02-13	Passed	Passed
Thread, mid	S01_AD01	2024-02-13	Passed	Passed

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

Band Edge Compliance Conducted

The measurement was performed according to ANSI C63.10, chapter 11.11

**Final Result**

<b>OP-Mode</b>	<b>Setup</b>	<b>Date</b>	<b>FCC</b>	<b>IC</b>
Radio Technology, Operating Frequency, Band Edge				
Thread, high, high	S01_AD01	2023-11-16	Passed	Passed
Thread, low, low	S01_AD01	2023-11-16	Passed	Passed

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

Band Edge Compliance Radiated

The measurement was performed according to ANSI C63.10, chapter 6.6.5

**Final Result**

<b>OP-Mode</b>	<b>Setup</b>	<b>Date</b>	<b>FCC</b>	<b>IC</b>
Radio Technology, Operating Frequency, Band Edge				
Thread, high, high	S02_AD01	2023-11-27	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, chapter 11.10.2

**Final Result**

<b>OP-Mode</b>	<b>Setup</b>	<b>Date</b>	<b>FCC</b>	<b>IC</b>
Radio Technology, Operating Frequency				
Thread, high	S01_AD01	2023-11-16	Passed	Passed
Thread, low	S01_AD01	2023-11-16	Passed	Passed
Thread, mid	S01_AD01	2023-11-16	Passed	Passed

N/A: Not applicable

N/P: Not performed

## 2 REVISION HISTORY / SIGNATURES

Report version control			
Version	Release date	Change Description	Version validity
initial	2024-02-19	--	valid
--	--	--	--

COMMENT: -



(responsible for accreditation scope)  
Daniel Gall



(responsible for testing and report)  
Mohamed Fraitat



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

### 3 ADMINISTRATIVE DATA

#### 3.1 TESTING LABORATORY

Company Name: 7layers GmbH

Address: Borsigstr. 11  
40880 Ratingen  
Germany

The test facility is accredited by the following accreditation organisation:

Laboratory accreditation no: DAkkS D-PL-12140-01-01 | -02 | -03

FCC Designation Number: DE0015

FCC Test Firm Registration: 929146

ISED CAB Identifier DE0007; ISED#: 3699A

Responsible for accreditation scope: Daniel Gall

Report Template Version: 2023-09-29

#### 3.2 PROJECT DATA

Responsible for testing and report: Mohamed Fraitat

Employees who performed the tests: documented internally at 7Layers

Date of Report: 2024-02-19

Testing Period: 2023-11-16 to 2024-02-13

#### 3.3 APPLICANT DATA

Company Name: H&D Wireless AB

Address: Färögatan 33, Kista Science Tower  
164 51 Kista  
Sweden

Contact Person: Mikael Olsson



### 3.4 MANUFACTURER DATA

Company Name: please see Applicant Data

Address:

Contact Person:

## 4 TEST OBJECT DATA

### 4.1 GENERAL EUT DESCRIPTION

Kind of Device product description	The EUT is a Bluetooth, Thread and WLAN module.
Product name	SPB611 module
Type	SPB611

#### Declared EUT data by the supplier

Voltage Type	DC
Voltage Level	3.3 V
Antenna / Gain	External / Primary antenna (Taoglas): 3.8 dBi (in the 2.4 GHz ISM Band)
Tested Modulation Type	GFSK
Specific product description for the EUT	The EUT is a Bluetooth, Thread and WLAN module. In the 2.4 GHz band the EUT supports following technologies: Bluetooth Classic, Bluetooth Low Energy and WLAN SISO b, g, n, ax 20 and 40 MHz bandwidth.
EUT ports (connected cables during testing):	- DC: cable length appr. 0.5m - Antenna: cable length 0m
Tested datarates	250 kbps
Special software used for testing	Labtool on computer board provided by applicant.

### 4.2 EUT MAIN COMPONENTS

Sample Name	Sample Code	Description
EUT AD01	DE1495001ad01	Radiated and conducted sample
Sample Parameter	Value	
Serial No.	0016	
HW Version	SPB611 R2A	
SW Version	linux-611-sdio-uart-v2.1	
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
AUX1	H&D Wireless, SPB437, -, -, -,	Evaluation Board for module providing ports
AUX2	Raspberry, Model 4, -, -, -,	Raspberry Pi 4 Test Jig
AUX3	Taoglas, GW.71.5153, -, -,	Dipole Antenna primary
AUX7	PeakTech, 6005D (30 V / 5 A), -, -, 81062045	Lab Power Supply (provided by 7Layers).

#### 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_AD01	EUT AD01, AUX 2,	Setup for conducted measurement
S02_AD01	EUT AD01, AUX 2, AUX3	Setup for radiated measurement
S04_AD01	EUT AD01, AUX 2, AUX3, AUX7	Setup for AC conducted emissions

## 4.6 OPERATING MODES / TEST CHANNELS

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

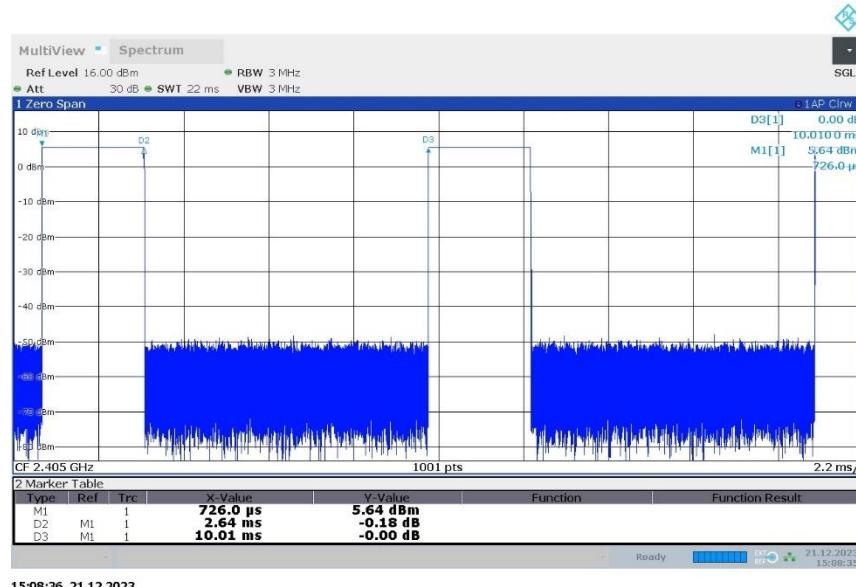
**Thread Channels:**  
**Channel:**  
**Frequency [MHz]**

2.4 GHz ISM 2400 - 2483.5 MHz		
low	mid	high
11	18	26
2405	2440	2480

## 4.7 DUTY CYCLE

Test Mode	T <sub>on+off</sub> (ms)	T <sub>on</sub> (ms)	Duty cycle (%)
Thread	10	2.7	27 %

Thread



## 4.8 PRODUCT LABELLING

### 4.8.1 FCC ID LABEL

Please refer to the documentation of the applicant.

### 4.8.2 LOCATION OF THE LABEL ON THE EUT

Please refer to the documentation of the applicant.

## 5 TEST RESULTS

### 5.1 CONDUCTED EMISSIONS AT AC MAINS

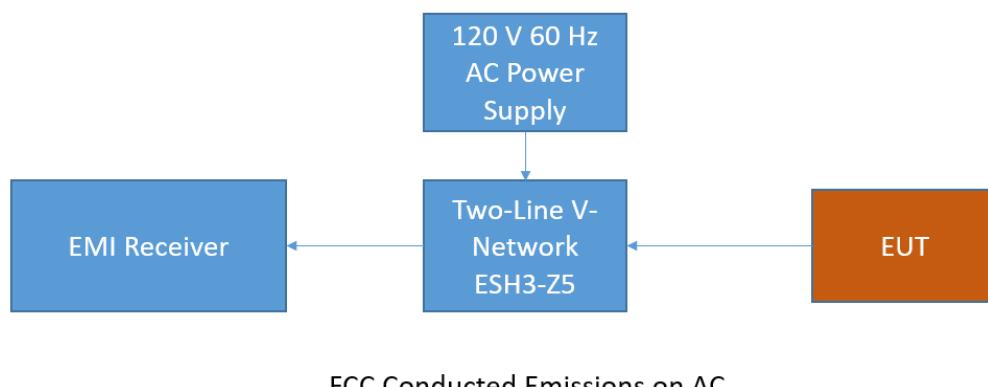
Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 6.2

#### 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 50 $\mu$ H || 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 & (CISPR) Average

- 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 (dB $\mu$ V)	AV Limits (dB $\mu$ V)
0.15 - 0.5	66 - 56	56 - 46
0.5 - 5	56	46
5 - 30	60	50

Used conversion factor: Limit (dB $\mu$ V) = 20 log (Limit ( $\mu$ V)/1 $\mu$ V).

### 5.1.3 TEST PROTOCOL

Temperature: 27 °C  
 Air Pressure: 1010 hPa  
 Humidity: 38 %

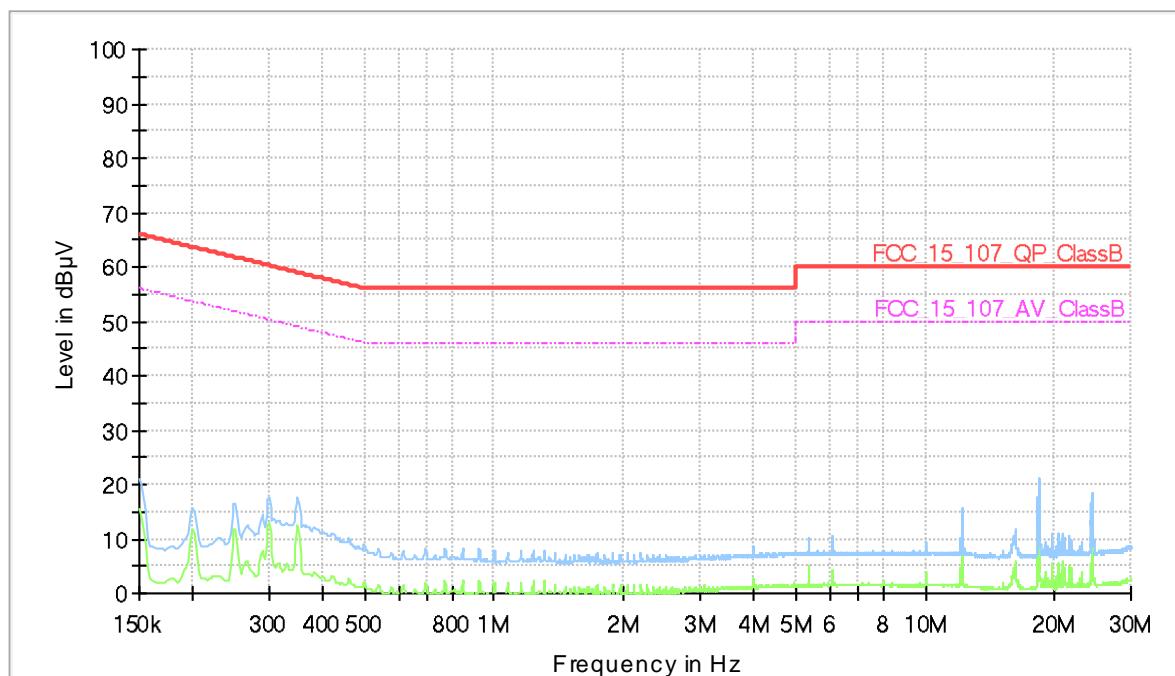
Power line	PE	Frequency [MHz]	Measured value QP [dB $\mu$ V]	Measured value AV [dB $\mu$ V]	Limit [dB $\mu$ V]	Margin [dB]
N	GND	-	-	-	-	< 6 dB
N	FLO	-	-	-	-	< 6 dB

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

#### 5.1.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

##### Common Information

Test Description: Conducted Emissions  
 Test Standard: FCC §15.207, ANSI C63.10  
 EUT / Setup Code: DE1495001ad01  
 Operating Conditions: 120 V 60 Hz, Thread CH18 TX on 2440 MHz  
 Comment: AC mains connection via AUX7  
 Legend: Trace: blue = QP, green = CISPR AV; Star: red or blue = critical frequency; Rhombus: blue = final QP, green = final CISPR AV  
 Tested Port / used LISN: AC mains => 1st LISN ESH3-Z5  
 Termination of other ports: N/A,



#### 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, chapter 11.8.1

### 5.2.1 TEST DESCRIPTION

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

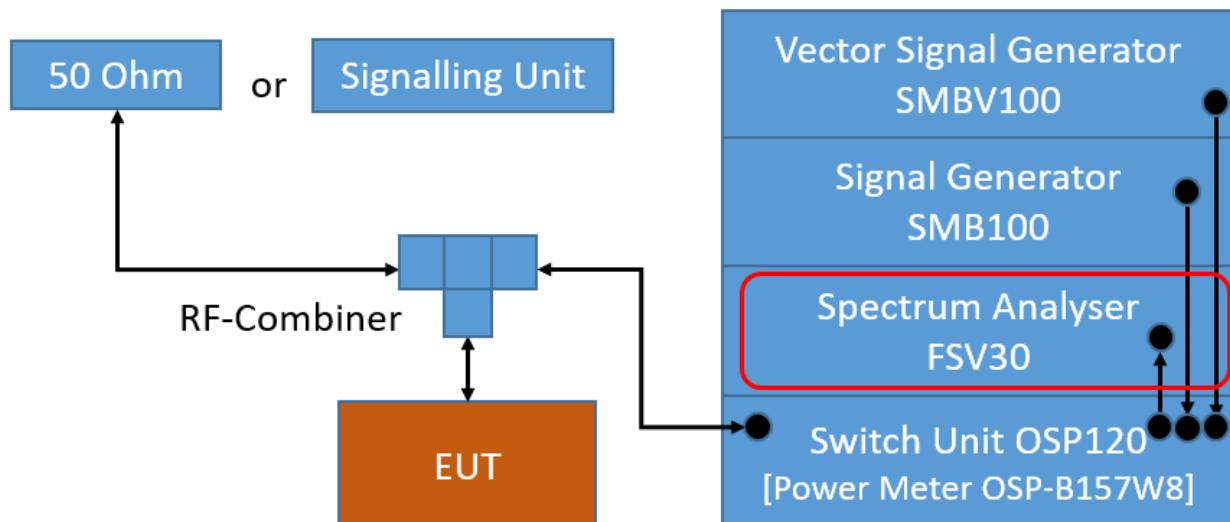
The reference level is the level of the highest amplitude signal observed from the transmitter at either the fundamental frequency or first-order modulation products in all typical modes of operation, including the unmodulated carrier, even if atypical.

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

The EUT was connected to the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

Analyser settings:

- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Span: Two times nominal bandwidth
- Trace: Maxhold
- Sweeps: Till stable (min. 500, max. 15000)
- Sweptime: Auto
- Detector: Peak



TS8997; Channel Bandwidth

## 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: 23-26 °C

Air Pressure: 990-1010hPa

Humidity: 30-40 %

### THREAD

<b>Band</b>	<b>Channel No.</b>	<b>Frequency [MHz]</b>	<b>6 dB Bandwidth [MHz]</b>	<b>Limit [MHz]</b>	<b>Margin to Limit [MHz]</b>
2.4 GHz ISM	11	2405	1.6	0.5	1.1
	18	2440	1.6	0.5	1.1
	26	2480	1.7	0.5	1.2

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

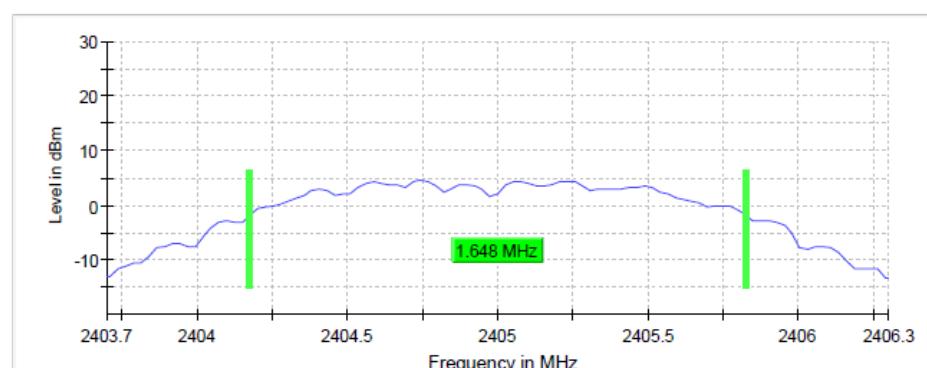
### 5.2.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Technology = Thread, Operating Frequency = low

#### 6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2405.000000	1.647524	0.500000	---	2404.176238	2405.823762

6 dB Bandwidth



#### Measurement

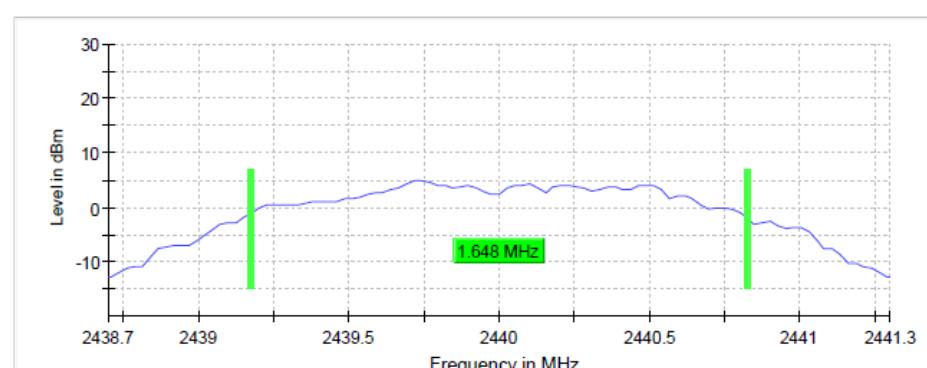
Setting	Instrument Value
Start Frequency	2.40370 GHz
Stop Frequency	2.40630 GHz
Span	2.600 MHz
RBW	100,000 kHz
VBW	300,000 kHz
SweepPoints	101
Sweptime	41.890 µs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	14 / max. 150
Stable	5 / 5
Max Stable Difference	0.43 dB

Technology = Thread, Operating Frequency = mid

#### 6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	1.647524	0.500000	---	2439.176238	2440.823762

6 dB Bandwidth



#### Measurement

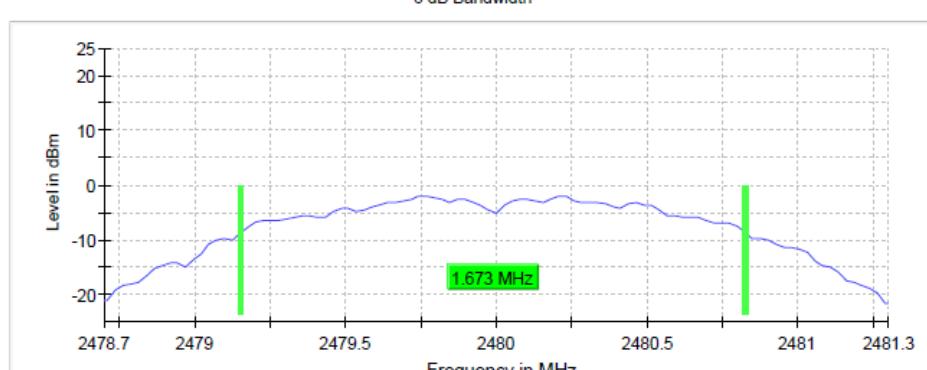
Setting	Instrument Value
Start Frequency	2.43870 GHz
Stop Frequency	2.44130 GHz
Span	2.600 MHz
RBW	100,000 kHz
VBW	300,000 kHz
SweepPoints	101
Sweptime	41.890 µs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	20 / max. 150
Stable	5 / 5
Max Stable Difference	0.00 dB

Technology = Thread, Operating Frequency = high

#### 6 dB Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	1.673267	0.500000	---	2479.150495	2480.823762

6 dB Bandwidth



#### Measurement

Setting	Instrument Value
Start Frequency	2.47870 GHz
Stop Frequency	2.48130 GHz
Span	2.600 MHz
RBW	100,000 kHz
VBW	300,000 kHz
SweepPoints	101
Sweptime	41.890 µs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	16 / max. 150
Stable	5 / 5
Max Stable Difference	0.08 dB



### 5.2.5 TEST EQUIPMENT USED

- R&S TS8997

## 5.3 OCCUPIED BANDWIDTH (99%)

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 6.9.3

### 5.3.1 TEST DESCRIPTION

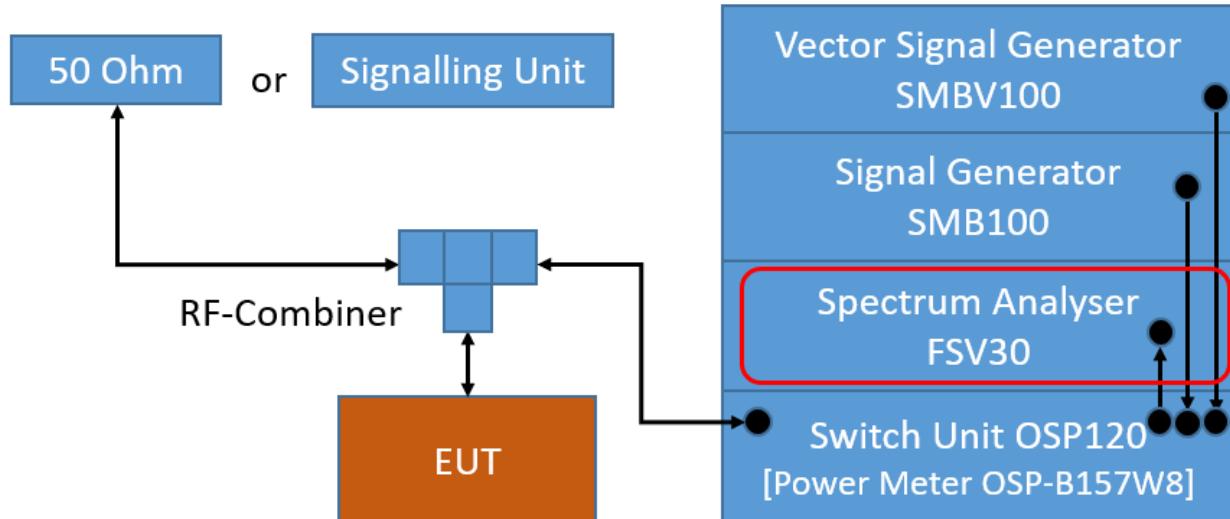
The Equipment Under Test (EUT) was set up to perform the occupied bandwidth measurements.

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 the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

Analyser settings:

- Resolution Bandwidth (RBW): 1 to 5 % of the OBW
- Video Bandwidth (VBW):  $\geq 3$  times the RBW
- Span: 1.5 to 5 times the OBW
- Trace: Maxhold
- Sweeps: Till stable (min. 500, max. 75000)
- Sweptime: Auto
- Detector: Peak



TS8997; Channel Bandwidth

### 5.3.2 TEST REQUIREMENTS / LIMITS

No applicable limit:

### 5.3.3 TEST PROTOCOL

Ambient temperature: 23-26 °C  
Air Pressure: 990-1010hPa  
Humidity: 30-40 %

#### THREAD

<b>Band</b>	<b>Channel No.</b>	<b>Frequency [MHz]</b>	<b>99% Bandwidth [MHz]</b>
2.4 GHz ISM	11	2405	2.3
	18	2440	2.3
	26	2480	2.3

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

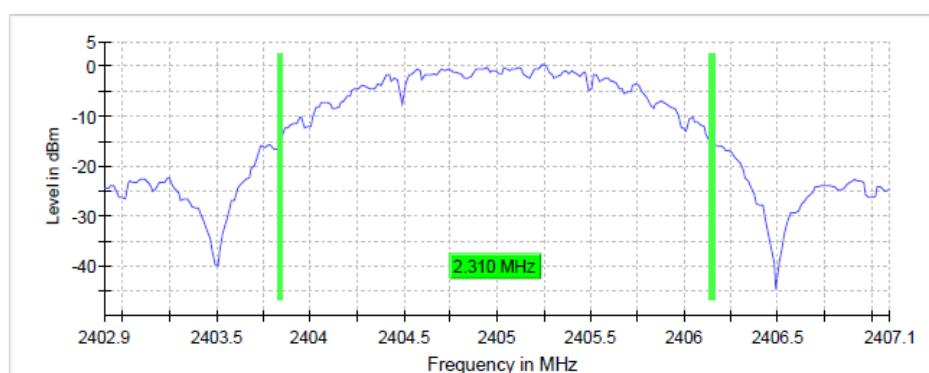
### 5.3.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Technology = Thread, Operating Frequency = low

#### 99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2405.000000	2.310000	---	---	2403.837500	2406.147500

99 % Bandwidth



#### Measurement

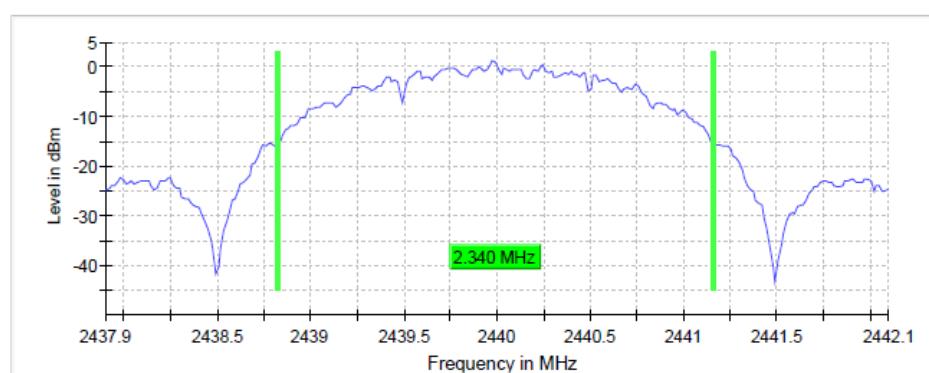
Setting	Instrument Value
Start Frequency	2.40290 GHz
Stop Frequency	2.40710 GHz
Span	4.200 MHz
RBW	30.000 kHz
VBW	100.000 kHz
SweepPoints	280
Sweeptime	140.000 μs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.30 dB
Run	13 / max. 150
Stable	3 / 3
Max Stable Difference	0.17 dB

Technology = Thread, Operating Frequency = mid

#### 99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2440.000000	2.340000	---	---	2438.822500	2441.162500

99 % Bandwidth



#### Measurement

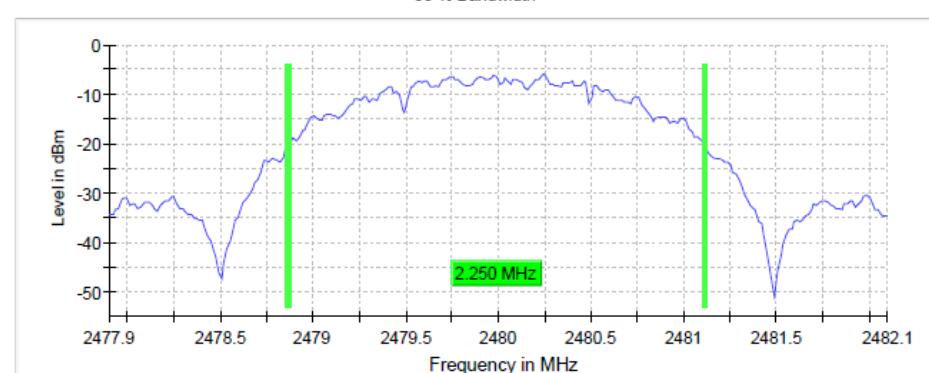
Setting	Instrument Value
Start Frequency	2.43790 GHz
Stop Frequency	2.44210 GHz
Span	4.200 MHz
RBW	30.000 kHz
VBW	100.000 kHz
SweepPoints	280
Sweeptime	140.000 μs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.30 dB
Run	28 / max. 150
Stable	3 / 3
Max Stable Difference	0.12 dB

Technology = Thread, Operating Frequency = high

#### 99 % Bandwidth

DUT Frequency (MHz)	Bandwidth (MHz)	Limit Min (MHz)	Limit Max (MHz)	Band Edge Left (MHz)	Band Edge Right (MHz)
2480.000000	2.250000	---	---	2478.867500	2481.117500

99 % Bandwidth



#### Measurement

Setting	Instrument Value
Start Frequency	2.47790 GHz
Stop Frequency	2.48210 GHz
Span	4.200 MHz
RBW	30.000 kHz
VBW	100.000 kHz
SweepPoints	280
Sweeptime	140.000 μs
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	FFT
Preamp	off
Stablemode	Trace
Stablevalue	0.30 dB
Run	21 / max. 150
Stable	3 / 3
Max Stable Difference	0.02 dB



### 5.3.5 TEST EQUIPMENT USED

- R&S TS8997

## 5.4 PEAK POWER OUTPUT

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 11.9.1.3

### 5.4.1 TEST DESCRIPTION

#### DTS EQUIPMENT:

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.

Maximum peak conducted output power (e.g. Bluetooth Low Energy):

The EUT was connected to the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

The reference level of the spectrum analyser was set higher than the output power of the EUT.

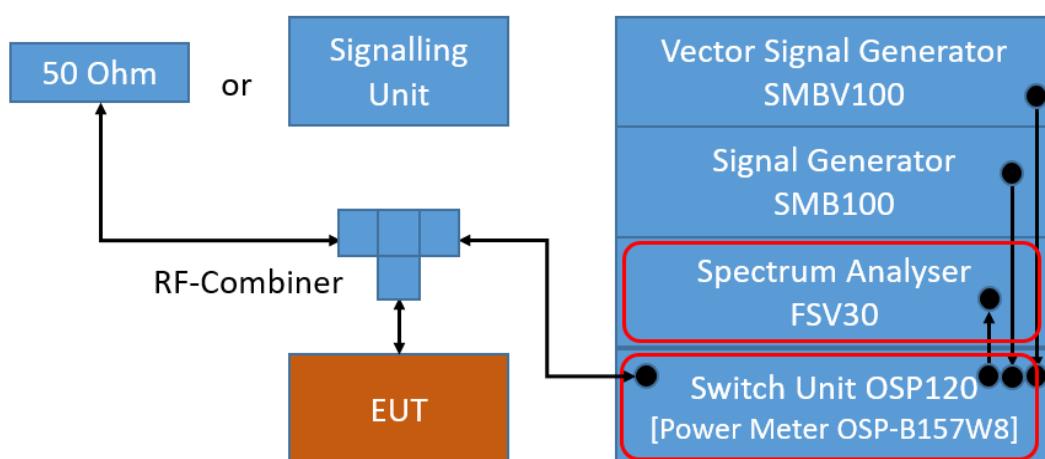
Analyser settings:

- Resolution Bandwidth (RBW):  $\geq$  DTS bandwidth
- Video Bandwidth (VBW):  $\geq$  3 times RBW or maximum of analyzer
- Span:  $\geq$  3 times RBW
- Trace: Maxhold
- Sweeps: Till stable (min. 300, max. 15000)
- Sweptime: Auto
- Detector: Peak

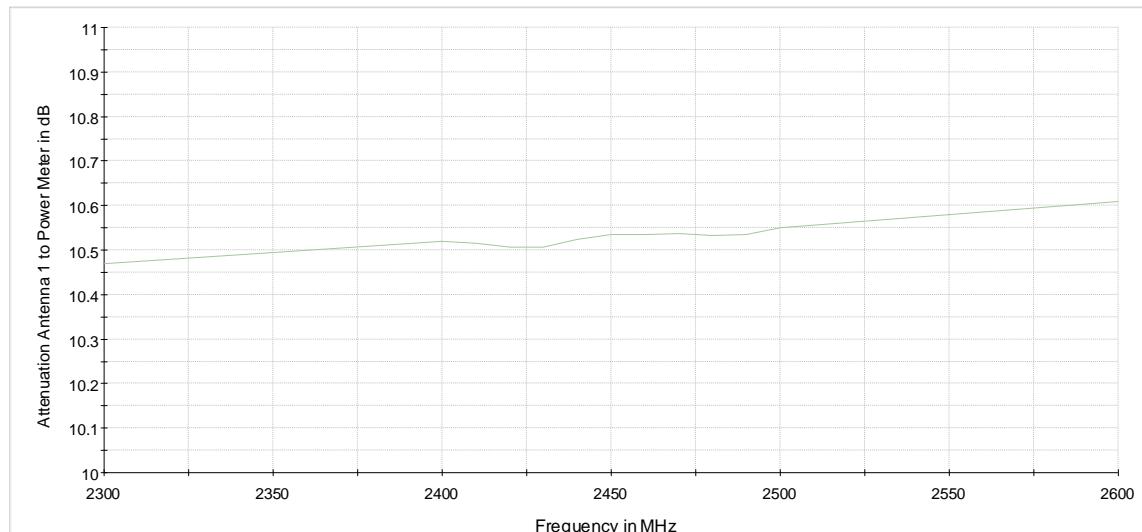
Maximum conducted average output power (e.g. WLAN):

The EUT was connected to the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

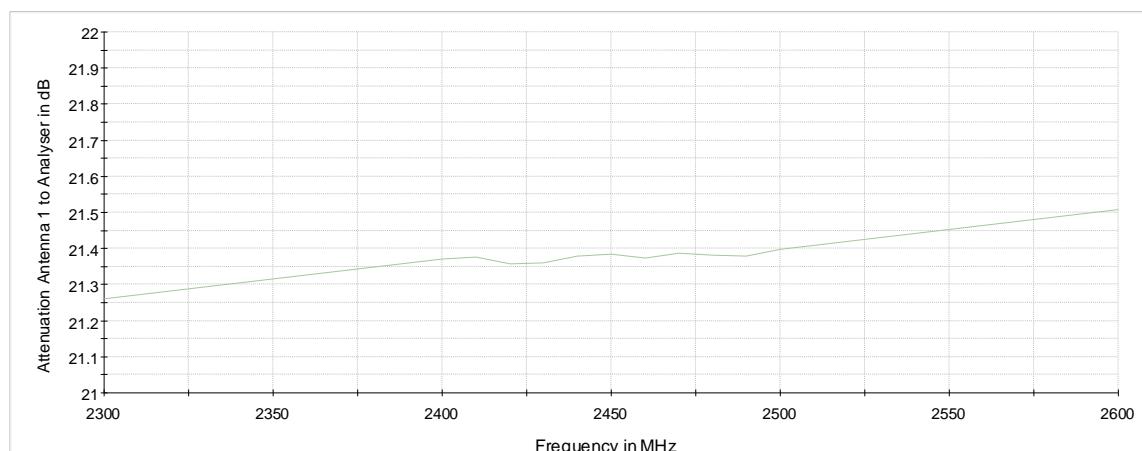
Measurement is performed using the gated RF average power meter integrated in the OSP 120 module OSP-B157W8 with signal bandwidth  $>300$  MHz.



TS8997; Output Power



Attenuation of the measurement path to Power Meter



Attenuation of the measurement path to Analyser

#### 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: 23-26 °C  
 Air Pressure: 990-1010hPa  
 Humidity: 30-40 %  
 THREAD

<b>Band</b>	<b>Channel No.</b>	<b>Frequency [MHz]</b>	<b>Peak Power [dBm]</b>	<b>Limit [dBm]</b>	<b>Margin to Limit [dB]</b>	<b>E.I.R.P [dBm]</b>
2.4 GHz ISM	11	2405	8.9	30.0	21.1	12.2
	18	2440	8.8	30.0	21.2	12.1
	26	2480	2.2	30.0	27.8	5.5

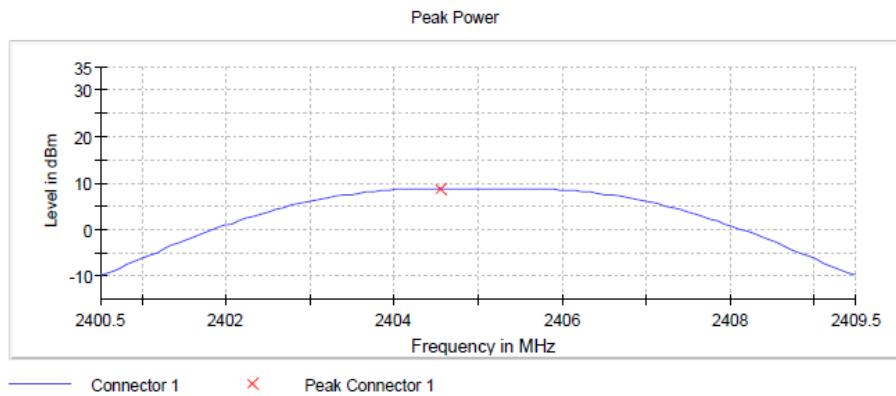
Remark: Please see next sub-clause for the measurement plot.

#### 5.4.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Technology = Thread, Operating Frequency = low

##### Result

DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2405.000000	8.9	30.0	PASS



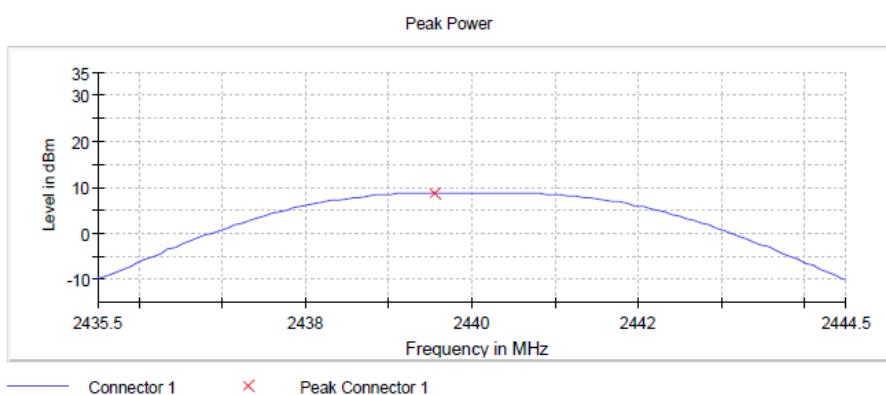
##### Measurement

Setting	Instrument Value
Start Frequency	2.40050 GHz
Stop Frequency	2.40950 GHz
Span	9.000 MHz
RBW	3.000 MHz
VBW	10.000 MHz
SweepPoints	101
Sweeptime	1.000 ms
Reference Level	10.000 dBm
Attenuation	20.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	4 / max. 150
Stable	3 / 3
Max Stable Difference	0.03 dB

Technology = Thread, Operating Frequency = mid

##### Result

DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2440.000000	8.8	30.0	PASS



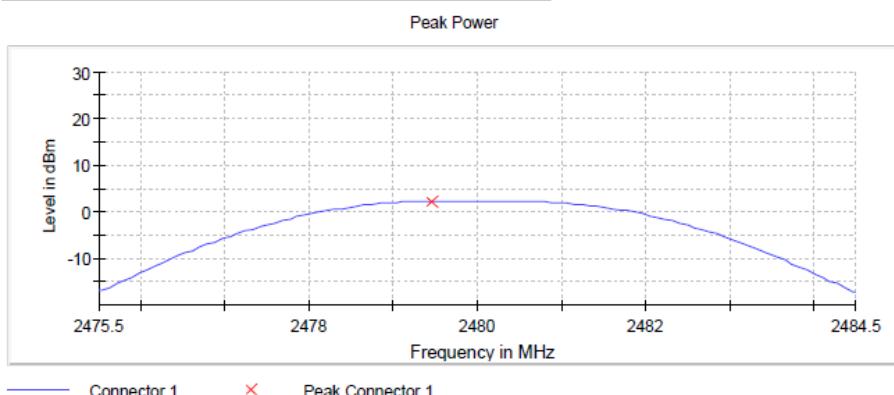
##### Measurement

Setting	Instrument Value
Start Frequency	2.43550 GHz
Stop Frequency	2.44450 GHz
Span	9.000 MHz
RBW	3.000 MHz
VBW	10.000 MHz
SweepPoints	101
Sweeptime	1.000 ms
Reference Level	10.000 dBm
Attenuation	20.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	4 / max. 150
Stable	3 / 3
Max Stable Difference	0.03 dB

Technology = Thread, Operating Frequency = high

##### Result

DUT Frequency (MHz)	Peak Power (dBm)	Limit Max (dBm)	Result
2480.000000	2.2	30.0	PASS



##### Measurement

Setting	Instrument Value
Start Frequency	2.47550 GHz
Stop Frequency	2.48450 GHz
Span	9.000 MHz
RBW	3.000 MHz
VBW	10.000 MHz
SweepPoints	101
Sweeptime	1.000 ms
Reference Level	10.000 dBm
Attenuation	20.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	4 / max. 150
Stable	3 / 3
Max Stable Difference	0.07 dB



#### 5.4.5 TEST EQUIPMENT USED

- R&S TS8997

## 5.5 SPURIOUS RF CONDUCTED EMISSIONS

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 11.11

### 5.5.1 TEST DESCRIPTION

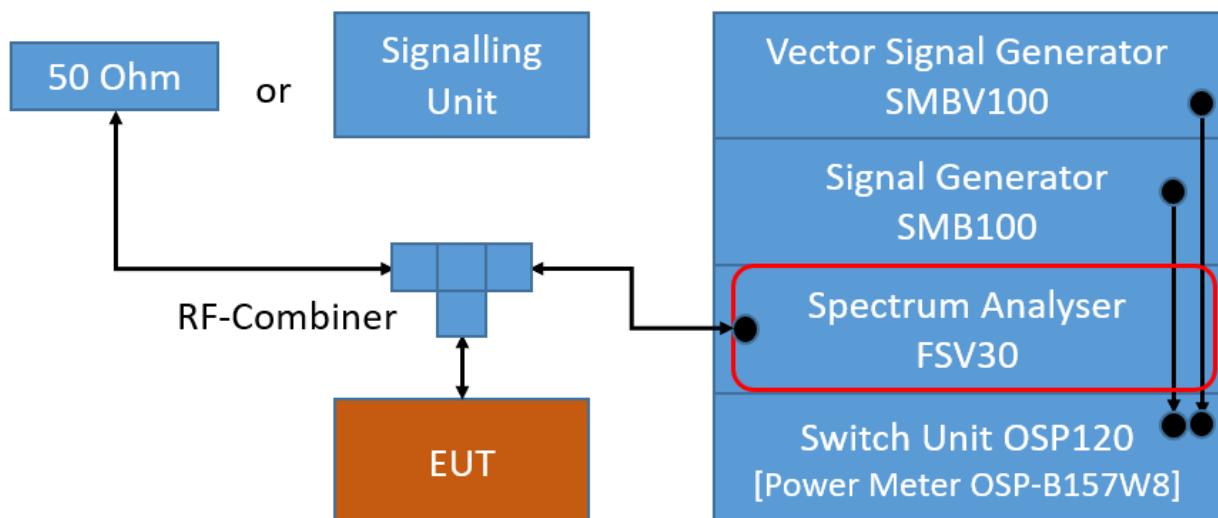
The Equipment Under Test (EUT) was set up to perform the spurious emissions measurements.

The EUT was connected to the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

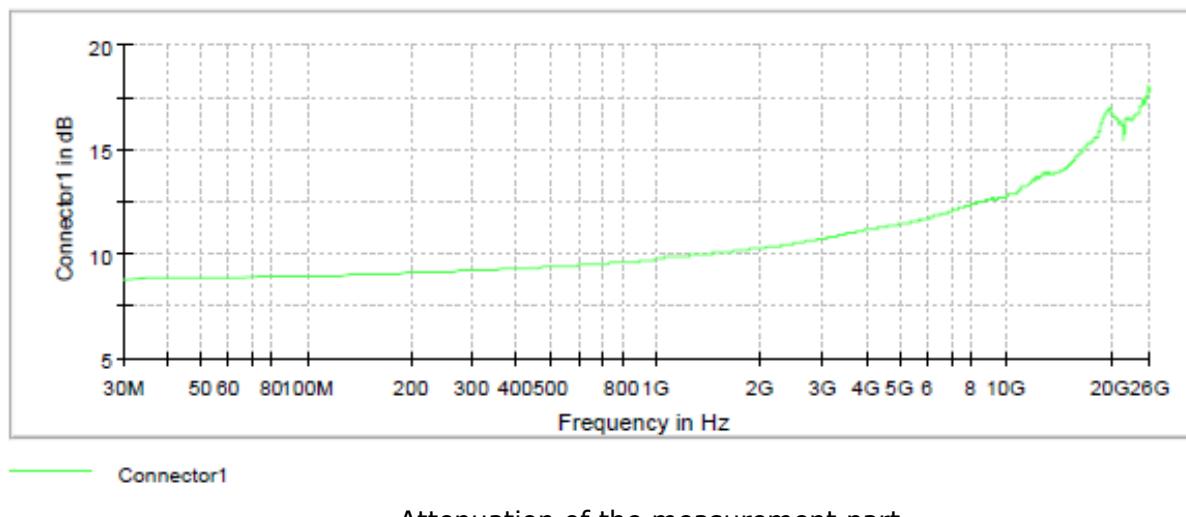
Analyser settings:

- Frequency range: 30 – 26000 MHz
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Trace: Maxhold
- Sweeps: Till Stable (max. 120)
- Sweep Time: Auto
- 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 or 30 dBc limit.



TS8997; Spurious RF Conducted Emissions



### 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

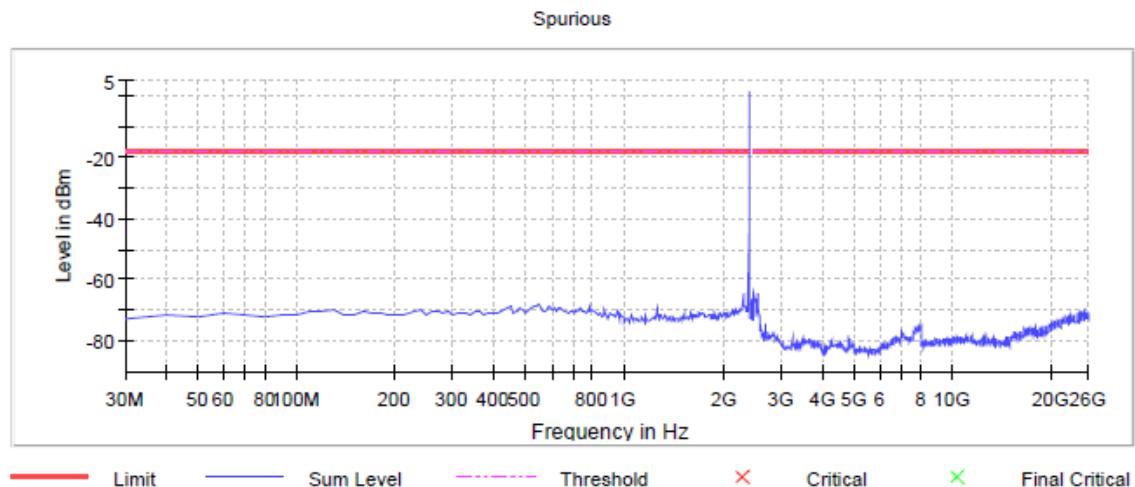
Ambient temperature: 23-26 °C  
 Air Pressure: 990-1010 hPa  
 Humidity: 30-40 %

Thread

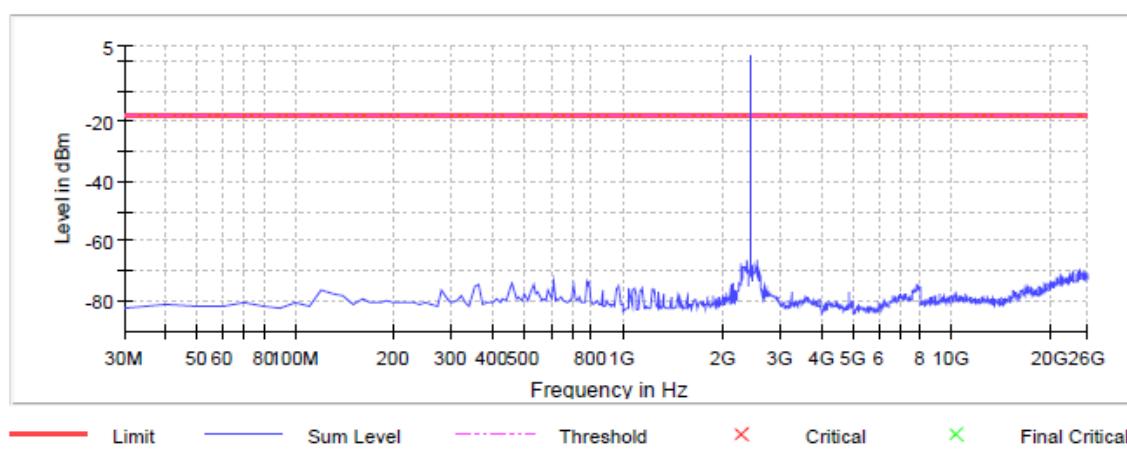
<b>Channel No</b>	<b>Channel Center Freq. [MHz]</b>	<b>Spurious Freq. [MHz]</b>	<b>Spurious Level [dBm]</b>	<b>Detector</b>	<b>RBW [kHz]</b>	<b>Ref. Level [dBm]</b>	<b>Limit [dBm]</b>	<b>Margin to Limit [dB]</b>
11	2405	2300.0	-64.2	PEAK	100	1.6	-18.4	45.8
18	2440	2543.5	-66.2	PEAK	100	2.0	-18.0	48.2
26	2480	24770.2	-70.2	PEAK	100	-5.5	-25.5	44.7

#### 5.5.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

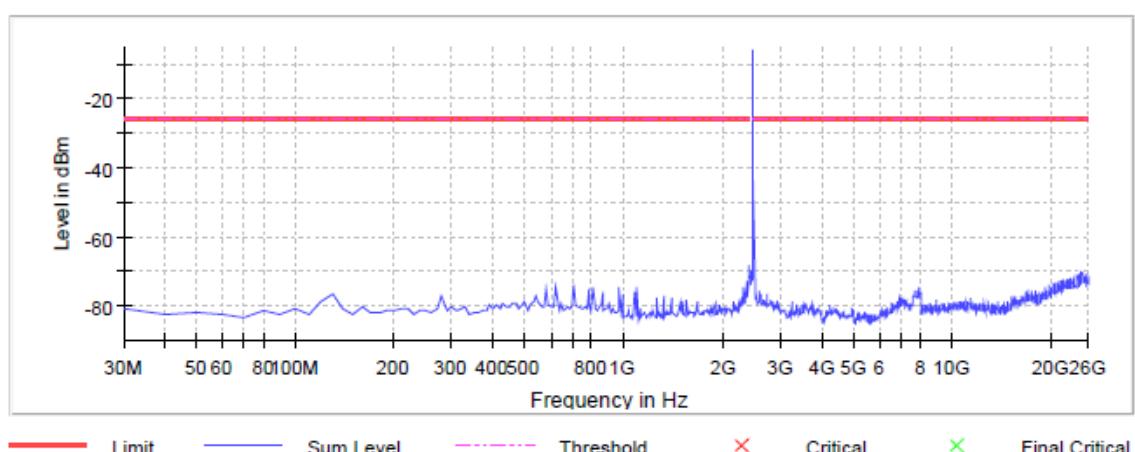
Technology = Thread, Operating Frequency = low



Technology = Thread, Operating Frequency = mid  
Spurious



Technology = Thread, Operating Frequency = high  
Spurious





### 5.5.5 TEST EQUIPMENT USED

- R&S TS8997

## 5.6 TRANSMITTER SPURIOUS RADIATED EMISSIONS

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 6.4, 6.5, 6.6.5

### 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 measurements were performed according the following sub-chapters of ANSI C63.10:

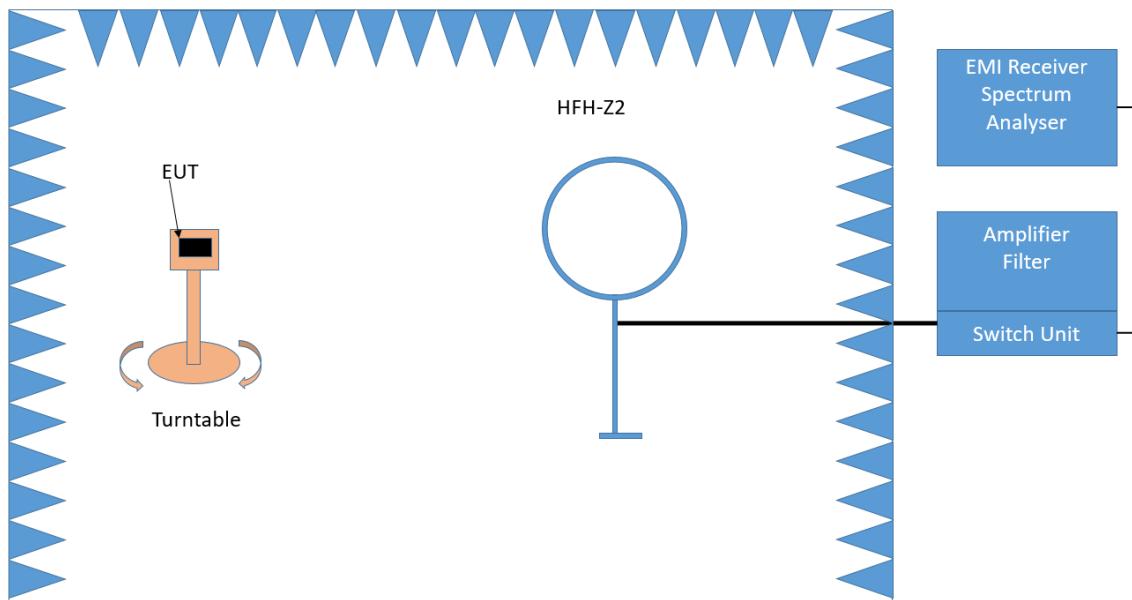
- < 30 MHz: Chapter 6.4
- 30 MHz – 1 GHz: Chapter 6.5
- > 1 GHz: Chapter 6.6 (procedure according 6.6.5 used)

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.

**Below 1 GHz:**

The Equipment Under Test (EUT) was set up on a non-conductive table in the semi-anechoic chamber. The influence of the EUT support table that is used between 30–1000 MHz was evaluated.

#### 1. Measurement up to 30 MHz



Test Setup; Spurious Emission Radiated (SAC), 9 kHz – 30 MHz

The Loop antenna HFH2-Z2 is used.

**Step 1:** pre measurement

- Anechoic chamber
- Antenna distance: 3 m
- Antenna height: 1 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)

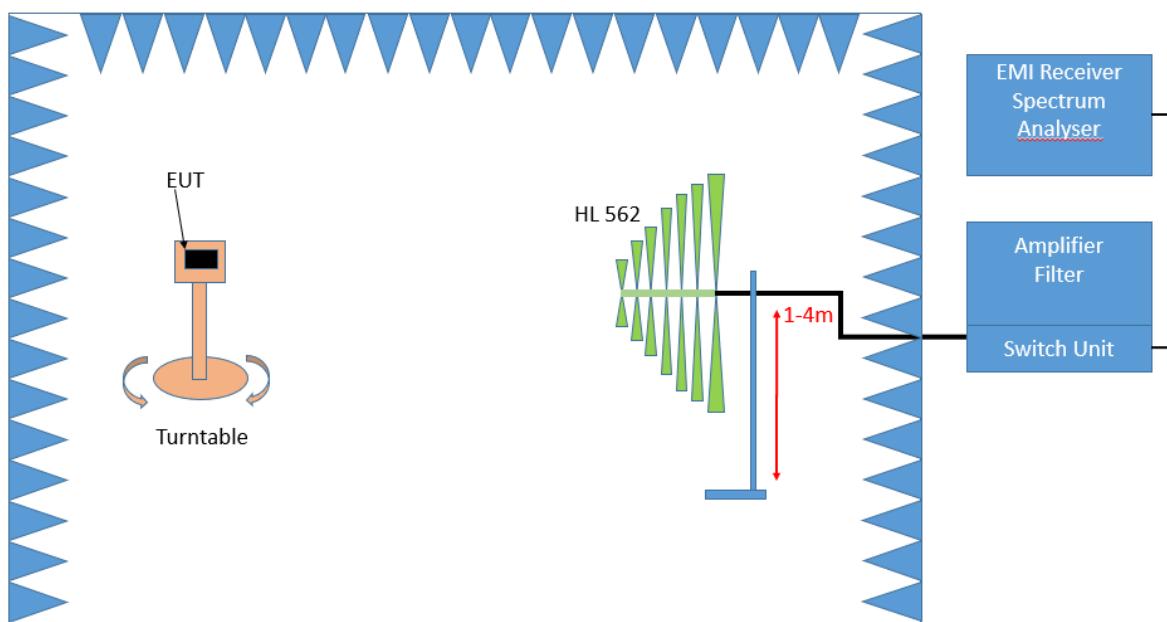
Intention of this step is, to determine the radiated EMI-profile of the EUT. Afterwards the relevant emissions for the final measurement are identified.

### 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.

- Detector: Quasi-Peak (9 kHz - 150 kHz, Peak / Average 150 kHz- 30 MHz)
- 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



Test Setup; Spurious Emission Radiated (SAC), 30 MHz- 1GHz

### 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 – 4 m
- Height variation step size: 1.5 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 360°. 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 between 1 – 4 meter. 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: 360 °
- Height variation range: 1 – 4 m
- Antenna Polarisation: max. value determined in step 1

**Step 3:** Final measurement with QP detector

With the settings determined in step 2, the final measurement will be performed:

EMI receiver settings for step 3:

- Detector: Quasi-Peak (< 1 GHz)
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 1 s

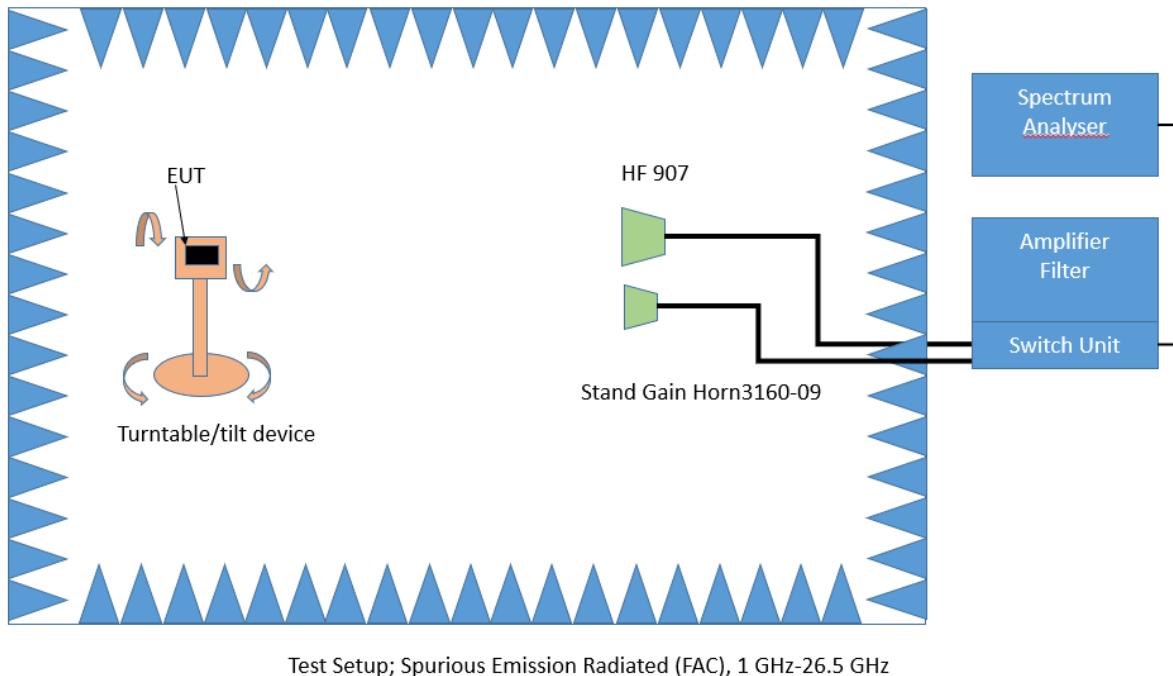
After the measurement a plot will be generated which contains a diagram with the results of the preliminary scan and a chart with the frequencies and values of the results of the final measurement.

**Above 1 GHz:**

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.

**3. Measurement above 1 GHz**



**Step 1:**

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 °.

Spectrum analyser settings:

- Detector: Peak, Average
- RBW = 1 MHz
- VBW = 3 MHz

**Step 2:**

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

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

Spectrum analyser settings:

- Detector: Peak

**Step 3:**

Spectrum analyser settings for step 3:

- Detector: Peak / CISPR Average
- Measured frequencies: in step 1 determined frequencies
- RBW = 1 MHz
- VBW = 3 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 ( $\mu$ V/m)	Measurement distance (m)	Limits (dB $\mu$ V/m)
0.009 – 0.49	2400/F(kHz)@300m	3	(48.5 – 13.8)@300m
0.49 – 1.705	24000/F(kHz)@30m	3	(33.8 – 23.0)@30m
1.705 – 30	30@30m	3	29.5@30m

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

Frequency in MHz	Limit ( $\mu$ V/m)	Measurement distance (m)	Limits (dB $\mu$ V/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 (dB $\mu$ V/m) = 20 log (Limit ( $\mu$ V/m)/1 $\mu$ V/m)

### 5.6.3 TEST PROTOCOL

Ambient temperature: 24-27 °C  
 Air Pressure: 1000-1009 hPa  
 Humidity: 40-49 %  
 THREAD

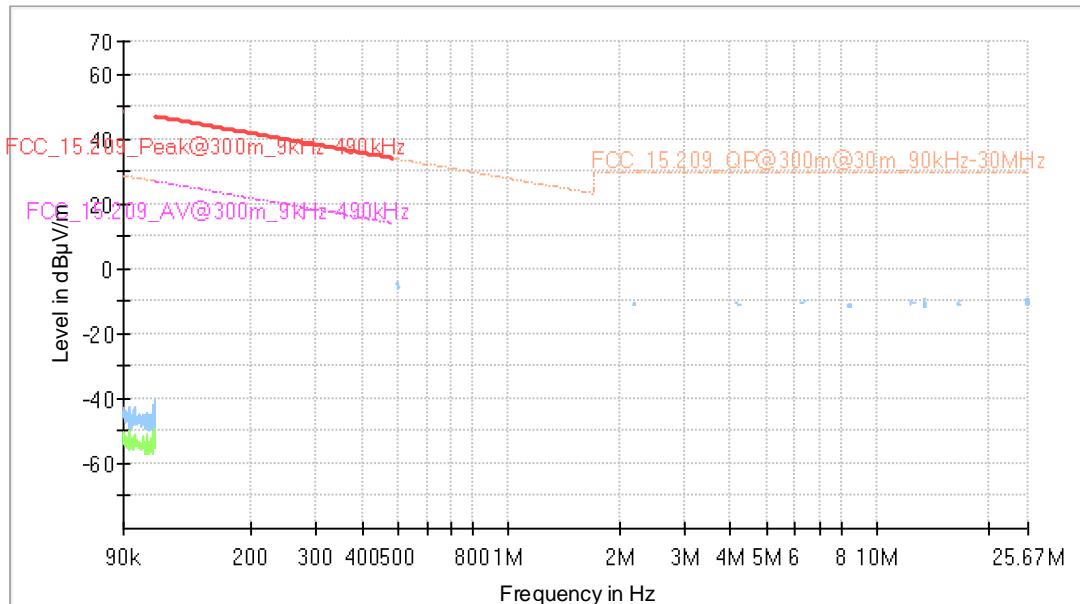
Applied duty cycle correction (AV): 0 dB

Ch. No.	Ch. Center Freq. [MHz]	Spurious Freq. [MHz]	Spurious Level [dB $\mu$ V/m]	Detector	RBW [kHz]	Limit [dB $\mu$ V/m]	Margin to Limit [dB]	Limit Type
11	2405	15602.9	43.2	AV	1000	54.0	10.8	RB
11	2405	15602.9	56.1	PEAK	1000	74.0	17.9	RB
11	2405	15609.1	43.4	AV	1000	54.0	10.6	RB
11	2405	15609.1	56.6	PEAK	1000	74.0	17.4	RB
18	2440	15601.2	42.7	AV	1000	54.0	11.3	RB
18	2440	15601.2	55.7	PEAK	1000	74.0	18.3	RB
18	2440	15621.7	42.7	AV	1000	54.0	11.3	RB
18	2440	15621.7	55.2	PEAK	1000	74.0	18.8	RB
18	2440	17792.9	46.6	AV	1000	54.0	7.4	RB
18	2440	17792.9	59.6	PEAK	1000	74.0	14.4	RB
26	2480	2483.5	41.9	AV	1000	54.0	12.1	RB
26	2480	2483.5	58.2	PEAK	1000	74.0	15.8	RB
26	2480	2486.6	37.8	AV	1000	54.0	16.2	RB
26	2480	2486.6	57.5	PEAK	1000	74.0	16.5	RB

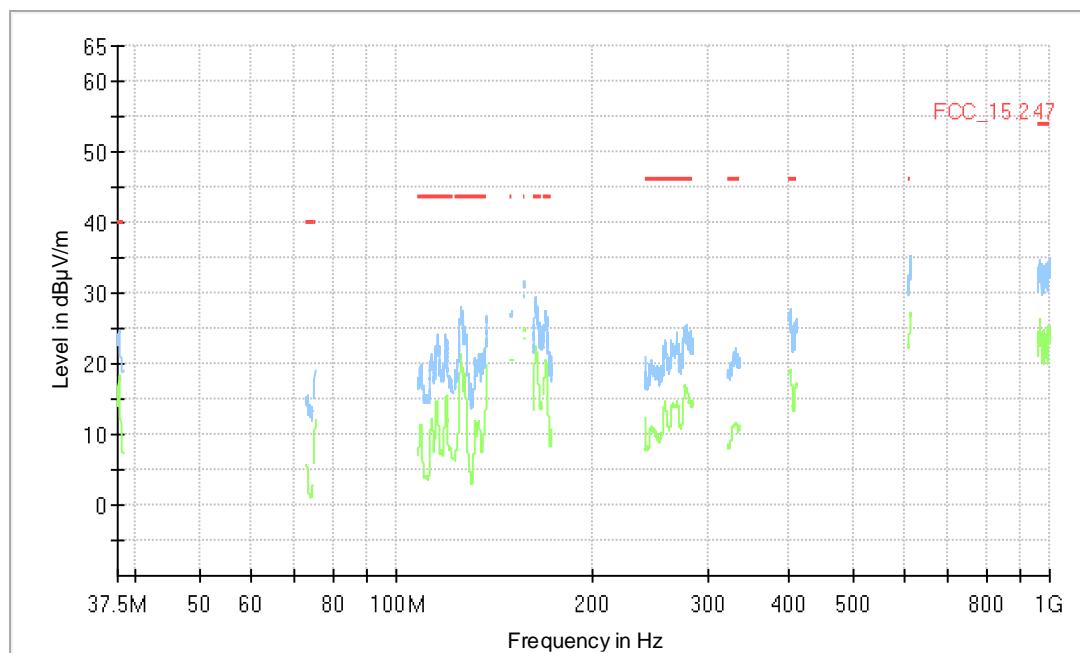
Remark: Please see next sub-clause for the measurement plot.

#### 5.6.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

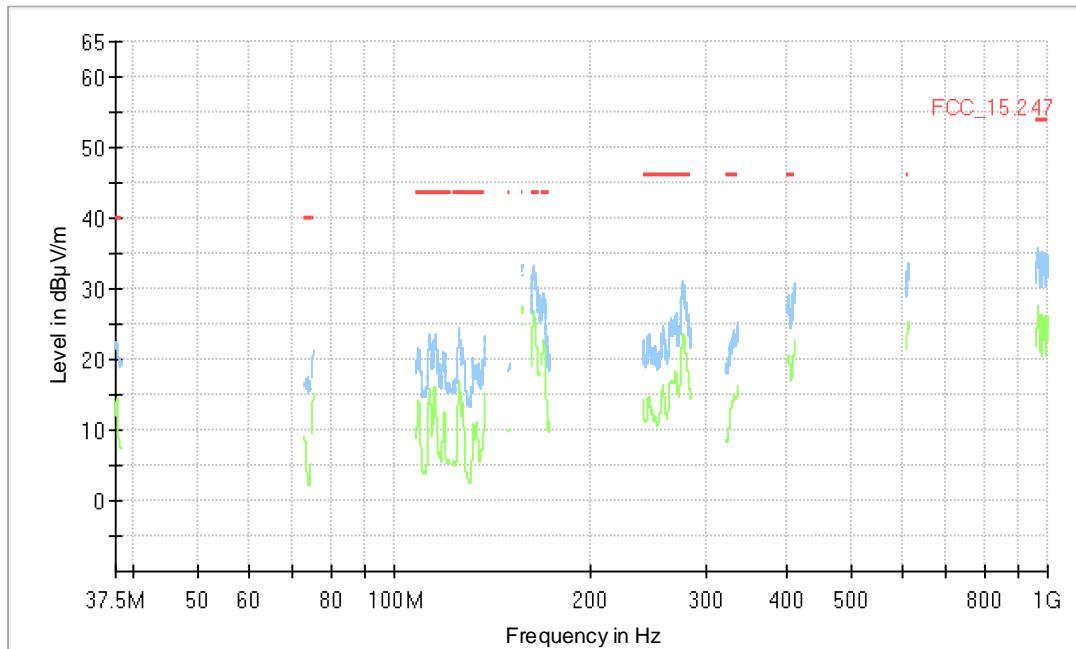
Radio Technology = Thread, Operating Frequency = low  
Measurement range = 9 kHz – 30 MHz



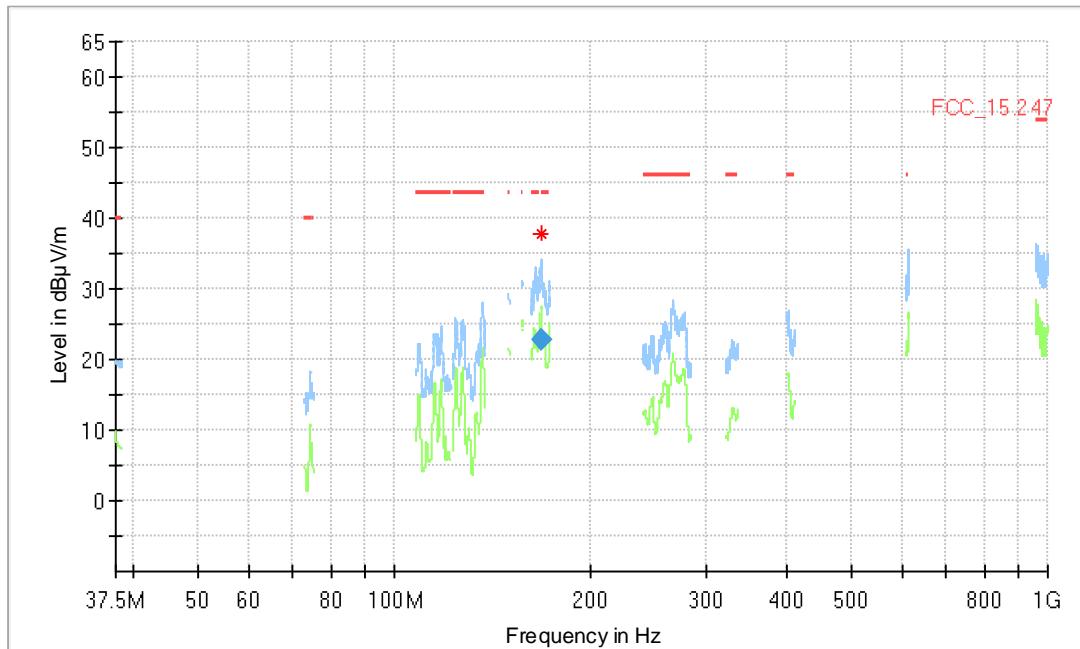
Radio Technology = Thread, Operating Frequency = low  
Measurement range = 30 MHz – 1 GHz



Radio Technology = Thread, Operating Frequency = mid  
Measurement range = 30 MHz – 1 GHz



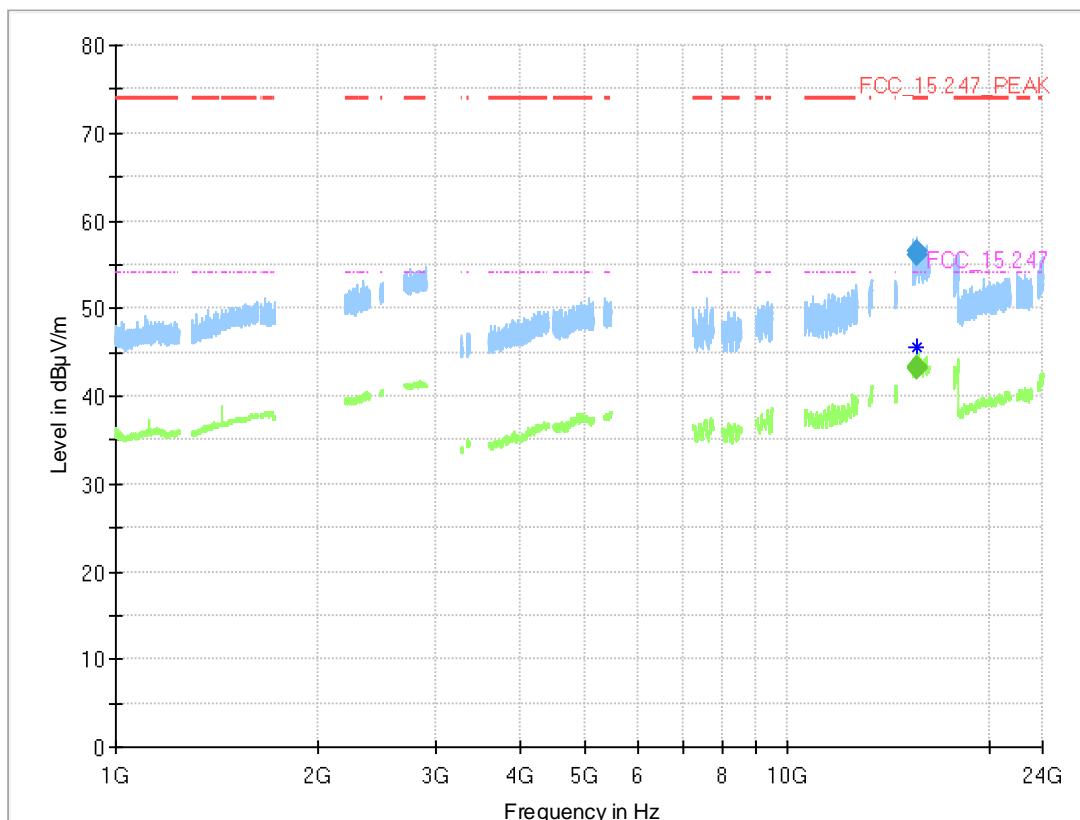
Radio Technology = Thread, Operating Frequency = high  
Measurement range = 30 MHz – 1 GHz



### Final\_Result

Frequency (MHz)	QuasiPeak (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Corr. (dB/m)
167.81000	22.74	43.50	20.76	1000.0	120.000	106.0	V	18.0	9.3

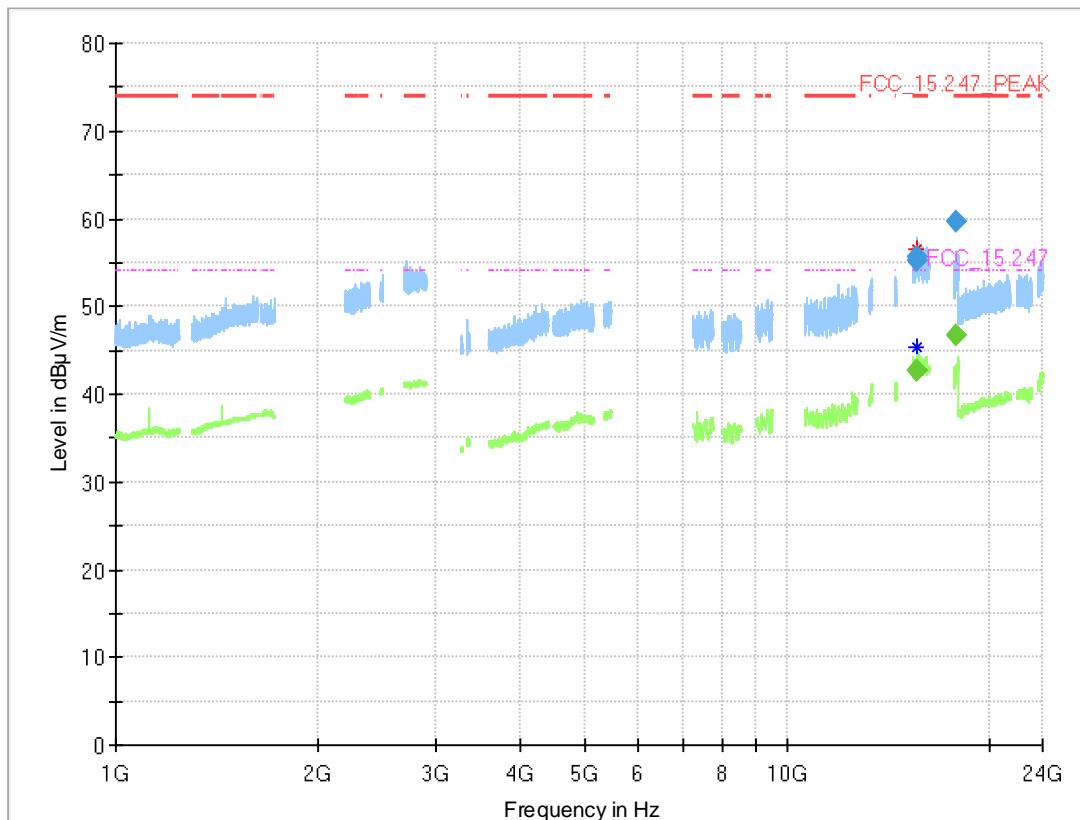
Radio Technology = Thread, Operating Frequency = low  
Measurement range = 1 GHz – 26 GHz



### Final Result

Frequency (MHz)	MaxPeak (dB $\mu$ V/m)	CAverage (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
15602.875	--	43.2	54.00	10.79	1000.0	1000.000	150.0	H	161.0	82.0	0.4
15602.875	56.1	---	74.00	17.87	1000.0	1000.000	150.0	H	161.0	82.0	0.4
15609.108	--	43.4	54.00	10.64	1000.0	1000.000	150.0	H	-79.0	78.0	0.4
15609.108	56.6	---	74.00	17.41	1000.0	1000.000	150.0	H	-79.0	78.0	0.4

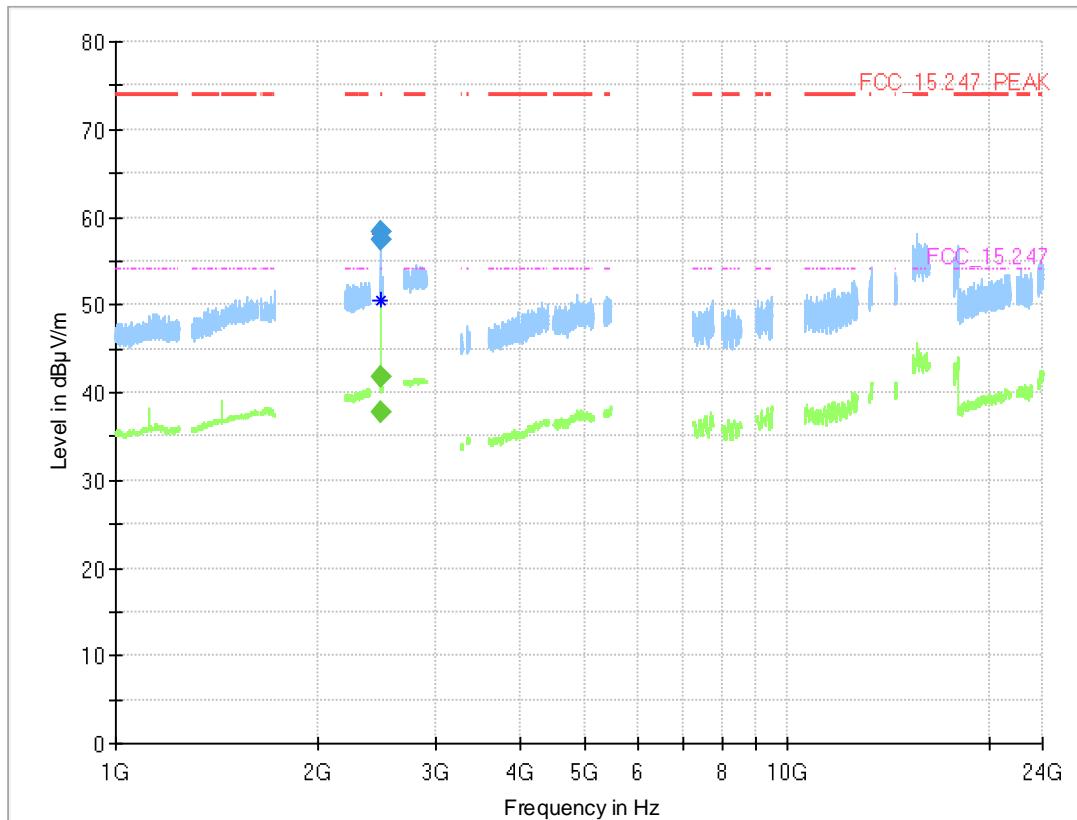
Radio Technology = Thread, Operating Frequency = mid  
Measurement range = 1 GHz – 26 GHz



### Final Result

Frequency (MHz)	MaxPeak (dB $\mu$ V/m)	CAverage (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
15601.175	---	42.7	54.00	11.26	1000.0	1000.000	150.0	H	-1.0	-2.0	0.4
15601.175	55.7	---	74.00	18.28	1000.0	1000.000	150.0	H	-1.0	-2.0	0.4
15621.717	---	42.7	54.00	11.33	1000.0	1000.000	150.0	H	-9.0	13.0	-0.1
15621.717	55.2	---	74.00	18.82	1000.0	1000.000	150.0	H	-9.0	13.0	-0.1
17792.850	---	46.6	54.00	7.40	1000.0	1000.000	150.0	V	125.0	84.0	2.4
17792.850	59.6	---	74.00	14.44	1000.0	1000.000	150.0	V	125.0	84.0	2.4

Radio Technology = Thread, Operating Frequency = high  
Measurement range = 1 GHz - 26 GHz



### Final Result

Frequency (MHz)	MaxPeak (dB $\mu$ V/m)	CAverage (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2483.500	--	41.9	54.00	12.11	1000.0	1000.000	150.0	V	-120.0	-9.0	7.8
2483.500	58.2	---	74.00	15.76	1000.0	1000.000	150.0	V	-120.0	-9.0	7.8
2486.635	--	37.8	54.00	16.23	1000.0	1000.000	150.0	V	38.0	15.0	7.9
2486.635	57.5	---	74.00	16.52	1000.0	1000.000	150.0	V	38.0	15.0	7.9

### 5.6.5 TEST EQUIPMENT USED

- Radiated Emissions FAR 2.4 GHz FCC

## 5.7 BAND EDGE COMPLIANCE CONDUCTED

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 11.11

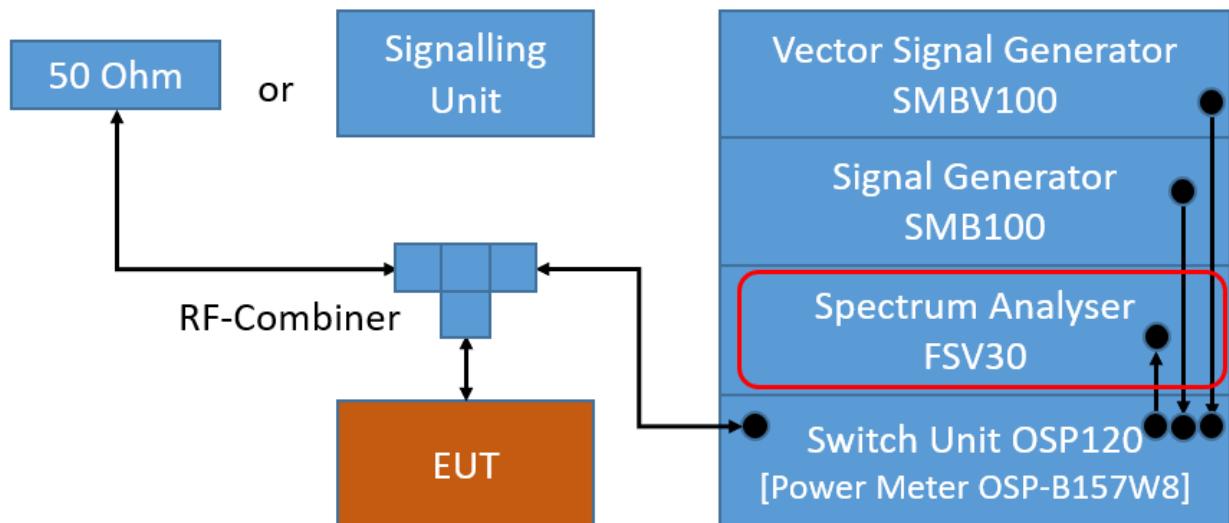
### 5.7.1 TEST DESCRIPTION

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".

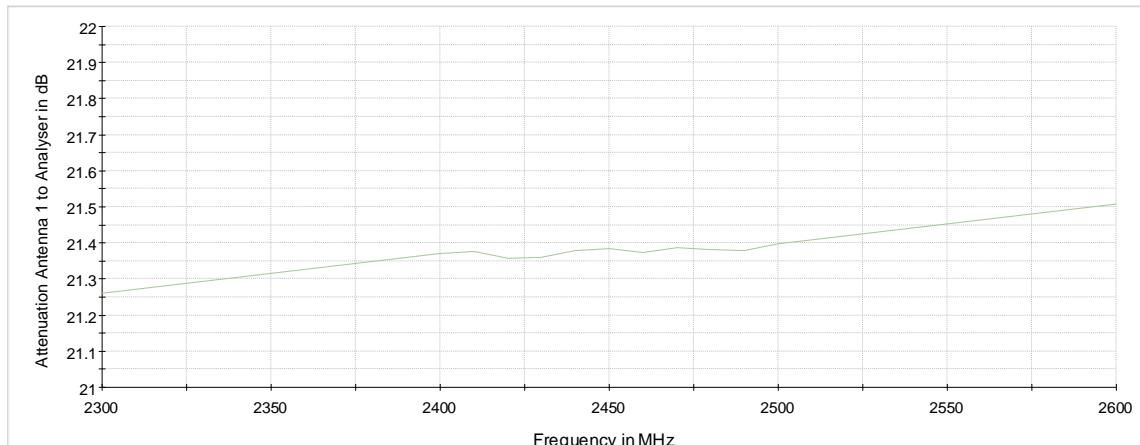
The EUT was connected to the test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

Analyser settings:

- Lower Band Edge:  
Measured range: 2310.0 MHz to 2483.5 MHz
- Upper Band Edge  
Measured range: 2400.0 MHz to 2500 MHz
- Detector: Peak
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Sweptime: Auto
- Sweeps: Till stable (min. 300, max. 15000)
- Trace: Maxhold



TS8997; Band Edge Conducted



Attenuation of the measurement path

### 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: 23-26 °C  
 Air Pressure: 990-1010hPa  
 Humidity: 30-40 %

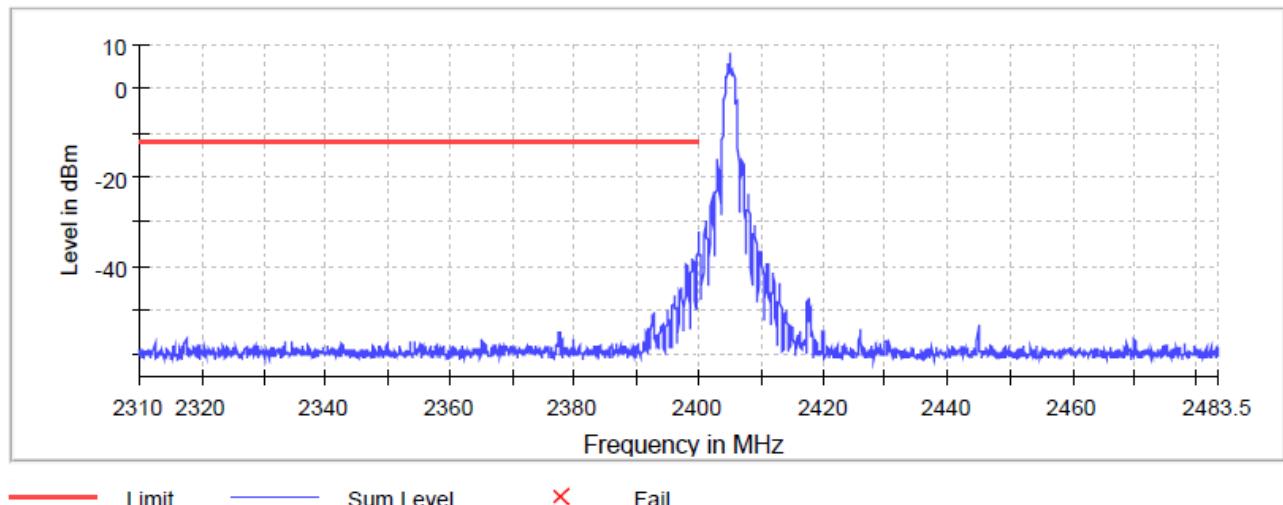
THREAD

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]
11	2405	2400.0	-32.1	PEAK	100	8.0	-12.0	20.1
26	2480	2483.5	-48.1	PEAK	100	1.6	-18.4	29.7

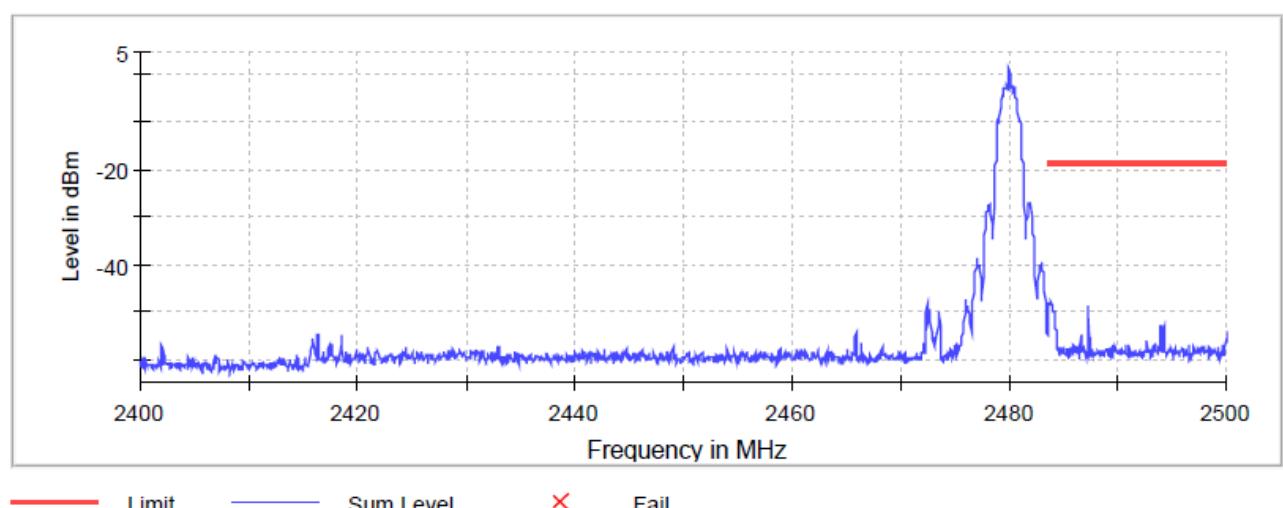
Remark: Please see next sub-clause for the measurement plot.

#### 5.7.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Radio Technology = Thread, Operating Frequency = low Band Edge



Radio Technology = Thread, Operating Frequency = high Band Edge



#### 5.7.5 TEST EQUIPMENT USED

- R&S TS8997

## 5.8 BAND EDGE COMPLIANCE RADIATED

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 6.6.5

### 5.8.1 TEST DESCRIPTION

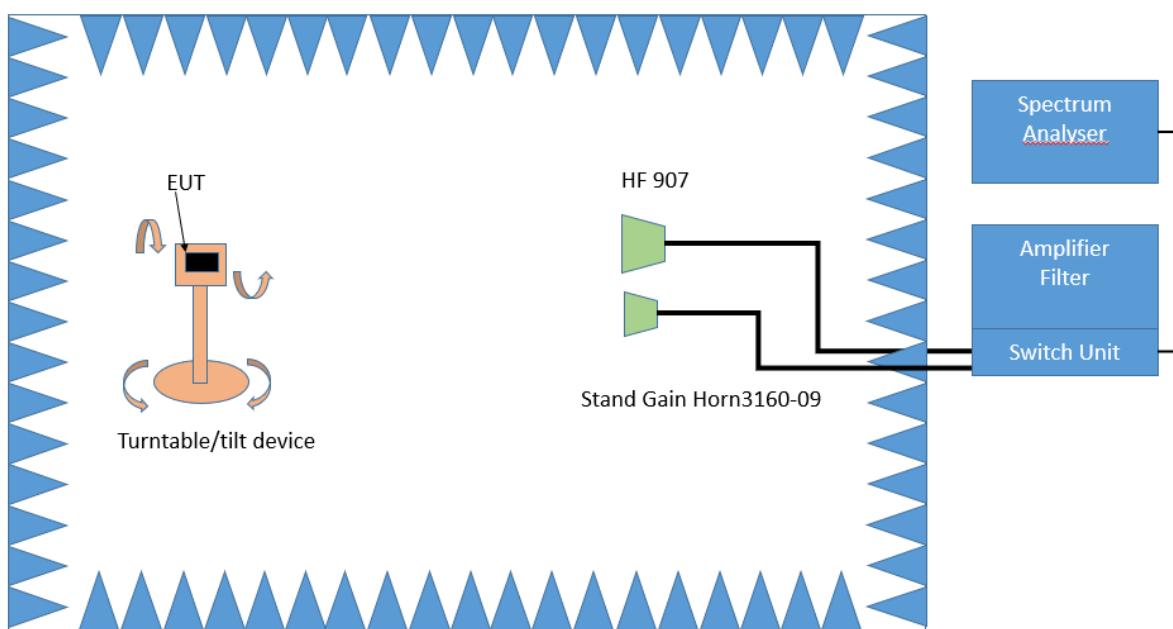
The test set-up was made in accordance to the general provisions of ANSI C63.10 in a typical installation configuration. The measurements were performed according the following sub-chapter of ANSI C63.10:

- Chapter 6.10.5

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 (procedure according ANSI C63.10, chapter 6.6.5).

### 3. Measurement above 1 GHz



Test Setup; Spurious Emission Radiated (FAC), 1 GHz-26.5 GHz

#### Step 1:

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 °.

Spectrum analyser settings:

- Detector: Peak, Average
- RBW = 1 MHz
- VBW = 3 MHz

#### Step 2:

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

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

Spectrum analyser settings:

- Detector: Peak

**Step 3:**

Spectrum analyser settings for step 3:

- Detector: Peak / CISPR Average
- Measured frequencies: in step 1 determined frequencies
- RBW = 1 MHz
- VBW = 3 MHz
- Measuring time: 1 s

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

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

Frequency in MHz	Limit ( $\mu$ V/m)	Measurement distance (m)	Limits (dB $\mu$ V/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 (dB $\mu$ V/m) = 20 log (Limit ( $\mu$ V/m)/1 $\mu$ V/m)

### 5.8.3 TEST PROTOCOL

Ambient temperature: 24-27 °C  
 Air Pressure: 1000-1009 hPa  
 Humidity: 40-49 %

#### THREAD

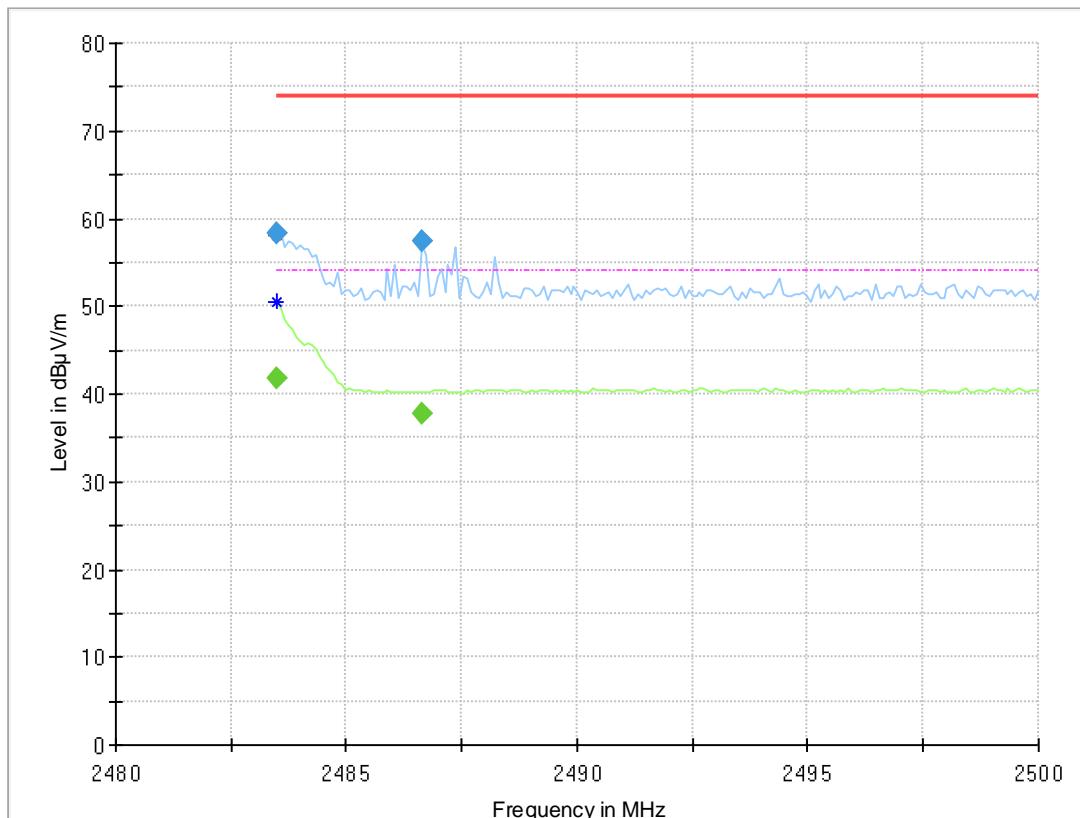
Applied duty cycle correction (AV): 0 dB

<b>Ch. No.</b>	<b>Ch. Center Freq. [MHz]</b>	<b>Band Edge Freq. [MHz]</b>	<b>Spurious Level [dB<math>\mu</math>V/m]</b>	<b>Detec- tor</b>	<b>RBW [kHz]</b>	<b>Limit [dB<math>\mu</math>V/m]</b>	<b>Margin to Limit [dB]</b>
26	2480	2483.5	58.2	PEAK	1000	74.0	15.8
26	2480	2483.5	41.9	AV	1000	54.0	12.1

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

#### 5.8.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Radio Technology = Thread, Operating Frequency = high



#### Final Result

Frequency (MHz)	MaxPeak (dB $\mu$ V/m)	CAverage (dB $\mu$ V/m)	Limit (dB $\mu$ V/m)	Margin (dB)	Meas. Time (ms)	Bandwidth (kHz)	Height (cm)	Pol	Azimuth (deg)	Elevation (deg)	Corr. (dB/m)
2483.500	---	41.9	54.00	12.11	1000.0	1000.000	150.0	V	-120.0	-9.0	7.8
2483.500	58.2	---	74.00	15.76	1000.0	1000.000	150.0	V	-120.0	-9.0	7.8
2486.635	---	37.8	54.00	16.23	1000.0	1000.000	150.0	V	38.0	15.0	7.9
2486.635	57.5	---	74.00	16.52	1000.0	1000.000	150.0	V	38.0	15.0	7.9

#### 5.8.5 TEST EQUIPMENT USED

- Radiated Emissions FAR 2.4 GHz FCC

## 5.9 POWER DENSITY

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**

ANSI C63.10, chapter 11.10.2

### 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 test system as described in the block diagram below. The complete attenuation of the measurement path is known and considered.

Maximum Peak Power Spectral Density (e.g. Bluetooth low energy):

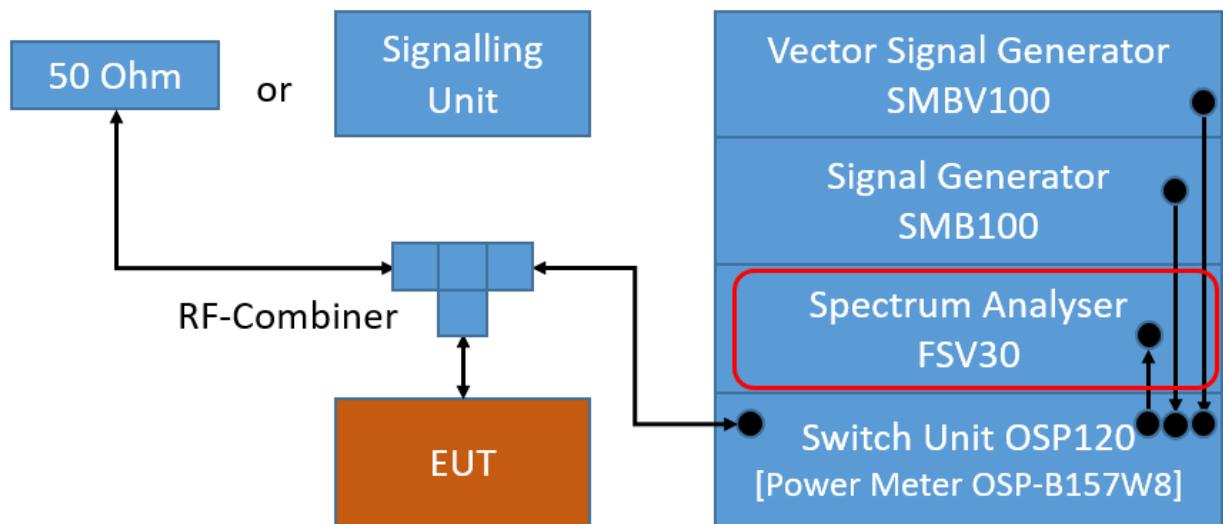
Analyser settings:

- Resolution Bandwidth (RBW): 100 kHz, 10 kHz or 3 kHz
- Video Bandwidth (VBW):  $\geq 3$  times RBW
- Trace: Maxhold
- Sweeps: Till stable (min. 200, max. 15000)
- Sweeptime: Auto
- Detector: Peak

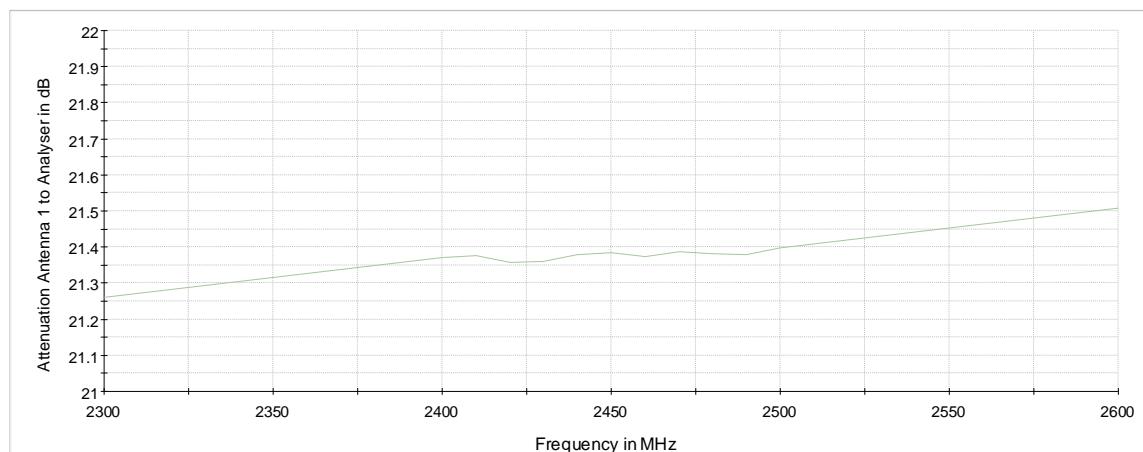
Maximum Average Power Spectral Density (e.g. WLAN):

Analyser settings:

- Resolution Bandwidth (RBW): 100 kHz, 10 kHz or 3 kHz
- Video Bandwidth (VBW):  $\geq 3$  times RBW
- Sweep Points:  $\geq 2$  times span / RBW
- Trace: Maxhold
- Sweeps: Till stable (max. 150)
- Sweeptime:  $\leq$  Number of Sweep Points x minimum transmission duration
- Detector: RMS



TS8997; Power Spectral Density



Attenuation of the measurement path



## 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.

FCC Part 15, Subpart C, §15.247 (f)

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques.

...  
The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission

### 5.9.3 TEST PROTOCOL

Ambient temperature: 23-26 °C  
 Air Pressure: 990-1010 hPa  
 Humidity: 30-40 %

#### THREAD

<b>Band</b>	<b>Channel No.</b>	<b>Frequency [MHz]</b>	<b>Power Density [dBm / RBW]</b>	<b>RBW [kHz]</b>	<b>Limit [dBm/3kHz]</b>	<b>Margin to Limit [dB]</b>
2.4 GHz ISM	11	2405	-1.3	10.0	8.0	9.3
	18	2440	-1.5	10.0	8.0	9.5
	26	2480	-7.9	10.0	8.0	15.9

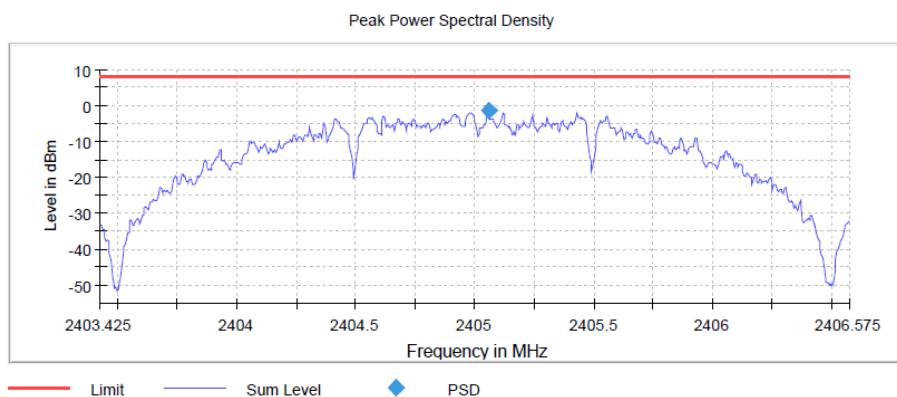
Remark: Please see next sub-clause for the measurement plot.

### 5.9.4 MEASUREMENT PLOT (EXAMPLE PLOT, SHOWING WORST CASE, IF APPLICABLE)

Technology = Thread, Operating Frequency = low

#### Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2405.000000	2405.057500	-1.342	8.0	PASS



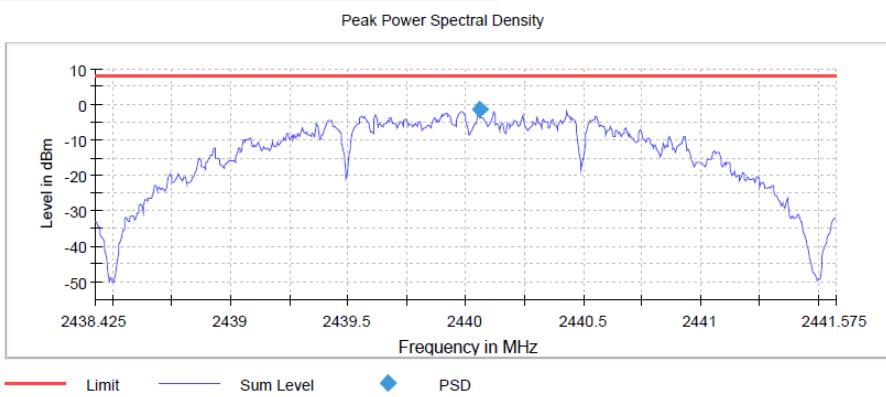
#### Measurement

Setting	Instrument Value
Start Frequency	2.40343 GHz
Stop Frequency	2.40658 GHz
Span	3.150 MHz
RBW	10.000 kHz
VBW	30.000 kHz
SweepPoints	630
Sweptime	3.150 ms
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	17 / max. 150
Stable	2 / 2
Max Stable Difference	0.48 dB

Technology = Thread, Operating Frequency = mid

#### Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2440.000000	2440.057500	-1.479	8.0	PASS



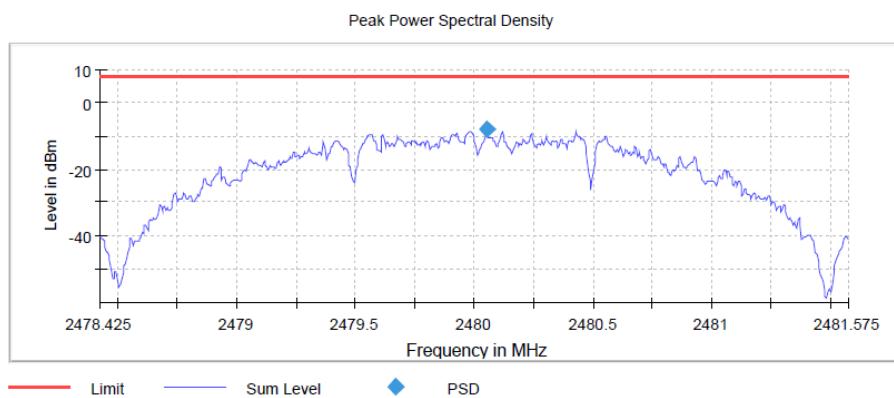
#### Measurement

Setting	Instrument Value
Start Frequency	2.43843 GHz
Stop Frequency	2.44158 GHz
Span	3.150 MHz
RBW	10.000 kHz
VBW	30.000 kHz
SweepPoints	630
Sweptime	3.150 ms
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	18 / max. 150
Stable	2 / 2
Max Stable Difference	0.39 dB

Technology = Thread, Operating Frequency = high

#### Result

DUT Frequency (MHz)	Frequency (MHz)	PSD (dBm)	Limit Max (dBm)	Result
2480.000000	2480.052500	-7.910	8.0	PASS



#### Measurement

Setting	Instrument Value
Start Frequency	2.47843 GHz
Stop Frequency	2.48158 GHz
Span	3.150 MHz
RBW	10.000 kHz
VBW	30.000 kHz
SweepPoints	630
Sweptime	3.150 ms
Reference Level	0.000 dBm
Attenuation	10.000 dB
Detector	MaxPeak
SweepCount	100
Filter	3 dB
Trace Mode	Max Hold
Sweeptype	Sweep
Preamp	off
Stablemode	Trace
Stablevalue	0.50 dB
Run	12 / max. 150
Stable	2 / 2
Max Stable Difference	0.29 dB



### 5.9.5 TEST EQUIPMENT USED

- R&S TS8997

## 6 TEST EQUIPMENT

### 6.1 TEST EQUIPMENT HARDWARE

1      Conducted Emissions FCC  
       Conducted Emissions AC Mains for FCC standards

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2023-12	2025-12
1.2	SMBV100A	Vector Signal Generator 9 kHz - 3.2 GHz (GNSS / Broadcast Signalling Unit)	Rohde & Schwarz GmbH & Co. KG	260001	2023-08	2026-08
1.3	ESH3-Z5	Two-Line V-Network (AUX)	Rohde & Schwarz GmbH & Co. KG	828304/029	2023-09	2025-09
1.4	EP 1200/B, NA/B1	AC Source, Amplifier with integrated variable Oscillator	Spitzenberger & Spies GmbH & Co. KG	B6278	N/A	N/A
1.5	Shielded Room 02	Shielded Room 4m x 3m	Frankonia Germany EMC Solution GmbH	-	N/A	N/A
1.6	CMW500	Callbox OIL-RE, SUA-160 MHz	Rohde & Schwarz GmbH & Co. KG	168927-cv	2023-08	2026-08
1.7	ESH3-Z5	Two-Line V-Network (EUT)	Rohde & Schwarz GmbH & Co. KG	829996/002	2023-09	2025-09
1.8	ESR 7	EMI Receiver / Spectrum Analyzer	Rohde & Schwarz	101424	2023-01	2025-01
1.9	CMW500	Callbox OIL-RE, SUA-160 MHz	Rohde & Schwarz GmbH & Co. KG	167766-By	2022-05	2025-05
1.10	Opus10 THI (8152.00)	T/H Logger 02	Lufft Mess- und Regeltechnik GmbH	7489	2023-12	2025-12
1.11	CS-RUB6	Rubidium Frequency Standard	Rohde & Schwarz GmbH & Co. KG	100321	2023-10	2024-10

1 R&S TS8997  
2.4 and 5 GHz Bands Conducted Test Lab

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
1.1	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2021-10	2023-12
1.2	SMB100A	Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	107695	2021-06	2024-06
1.3	EX520	Digital Multimeter 12	Extech Instruments Corp	05157876	2022-06	2024-06
1.4	FSV30	Signal Analyzer 10 Hz - 30 GHz	Rohde & Schwarz	103005	2023-08	2025-08
1.5	NGSM 32/10	Power Supply	Rohde & Schwarz GmbH & Co. KG	3456	2022-01	2024-01
1.6	Temperature Chamber VT 4002	Temperature Chamber Vötsch 03	Vötsch	58566002150010	2022-05	2024-05
1.7	FSW43	Signal Analyser	Rohde & Schwarz GmbH & Co. KG	102013	2023-07	2025-07
1.8	Opus10 THI (8152.00)	T/H Logger 14	Lufft Mess- und Regeltechnik GmbH	13993	2021-08	2023-12
1.9	SMBV100A	Vector Signal Generator 9 kHz - 6 GHz	Rohde & Schwarz	259291	2023-01	2026-01
1.10	OSP120	Contains Power Meter and Switching Unit OSP-B157W8 PLUS	Rohde & Schwarz	101158	2021-08	2024-08
1.11	CS-RUB6	Rubidium Frequency Standard	Rohde & Schwarz GmbH & Co. KG	100321	2023-10	2024-10

2 Radiated Emissions FAR 2.4 GHz FCC  
Radiated emission tests for 2.4 GHz ISM devices in a fully anechoic room

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.1	Opus10 TPR (8253.00)	T/P Logger 13	Lufft Mess- und Regeltechnik GmbH	13936	2021-10	2023-12
2.2	Innco Systems CO3000	Controller for bore sight mast FAC		CO3000/1460/54 740522/P	N/A	N/A
2.3	AMF-7D00101800-30-10P-R	Broadband Amplifier 100 MHz - 18 GHz	Miteq		N/A	N/A
2.4	Anechoic Chamber 03	FAR, 8.80m x 4.60m x 4.05m (l x w x h)	Albatross Projects	P26971-647-001-PRB	N/A	N/A
2.5	Fluke 177	Digital Multimeter 03 (Multimeter)	Fluke Europe B.V.	86670383	2023-08	2025-08
2.6	JS4-18002600-32-5P	Broadband Amplifier 18 GHz - 26 GHz	Miteq	849785	N/A	N/A

Ref.No.	Device Name	Description	Manufacturer	Serial Number	Last Calibration	Calibration Due
2.7	FSW43	Spectrum Analyzer	Rohde & Schwarz GmbH & Co. KG	103779	2023-04	2025-04
2.8	EP 1200/B, NA/B1	AC Source, Amplifier with integrated variable Oscillator	Spitzenberger & Spies GmbH & Co. KG	B6278	N/A	N/A
2.9	3160-09	Standard Gain / Pyramidal Horn Antenna 26.5 GHz	EMCO Elektronik GmbH	00083069	N/A	N/A
2.10	WHKX 7.0/18G-8SS	High Pass Filter	Wainwright Instruments GmbH	09	N/A	N/A
2.11	MA3000/0800-XP-ET-compact	Bore Sight Antenna Mast			N/A	N/A
2.12	TT 1.5 WI	Turn Table	Maturo GmbH	-	N/A	N/A
2.13	5HC3500/18000 -1.2-KK	High Pass Filter	Trilithic	200035008	N/A	N/A
2.14	Opus 20 THI (8120.00)	ThermoHygro Datalogger	Lufft Mess- und Regeltechnik GmbH	115.0318.0802.033	2023-08	2025-08
2.15	TD1.5-10kg	EUT Tilt Device (Rohacell)	Maturo GmbH	TD1.5-10kg/024/3790709	N/A	N/A
2.16	AFS42-00101800-25-S-42	Broadband Amplifier 25 MHz - 18 GHz	Miteq	2035324	N/A	N/A
2.17	HF 907	Double-ridged horn	Rohde & Schwarz	102444	2021-09	2024-09

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

## 6.2 TEST EQUIPMENT SOFTWARE

<b>Semi-Anechoic Chamber:</b>	
Software	Version
EMC32 Measurement Software	10.60.10
INNCO Mast Controller	1.02.62
MATURO Mast Controller	12.19
MATURO Turn-Table Controller	30.10
<b>Fully-Anechoic Chamber:</b>	
Software	Version
EMC32 Measurement Software	10.60.10
MATURO Turn-Unit Controller	11.10
MATURO Mast Controller	12.10
MATURO Turntable Controller	12.11
INNCO Mast Controller	1.02.62
<b>TS 8997</b>	



WMC32 Measurement Software	11.40.00
<b>Conducted AC Emissions:</b>	
Software	Version
EMC32 Measurement Software	10.60.20

## 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 attenuator)
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.

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

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

### Sample calculation

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

U = Receiver reading

AF = Antenna factor

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

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

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

Table shows an extract of values

### 7.3 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)	$d_{\text{Limit}}$ (meas. distance (limit))	$d_{\text{used}}$ (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

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

U = Receiver reading

AF = Antenna factor

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

## 7.4 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

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

U = Receiver reading

AF = Antenna factor

Corr. = sum of single correction factors of used cables, switch unit, distance correction, amplifier (if applicable)  
Linear interpolation will be used for frequencies in between the values in the table.

Tables show an extract of values.

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

Frequency	AF EMCO 3160-09	Corr.	cable	cable	cable	cable	cable
			loss 1 (inside chamber)	loss 2 (pre- amp)	loss 3 (inside chamber)	loss 4 (switch unit)	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

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

U = Receiver reading

AF = Antenna factor

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

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

Table shows an extract of values.

## 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)	$d_{\text{Limit}}$ (meas. distance (limit))	$d_{\text{used}}$ (meas. distance (used))
			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

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

U = Receiver reading

AF = Antenna factor

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

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

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

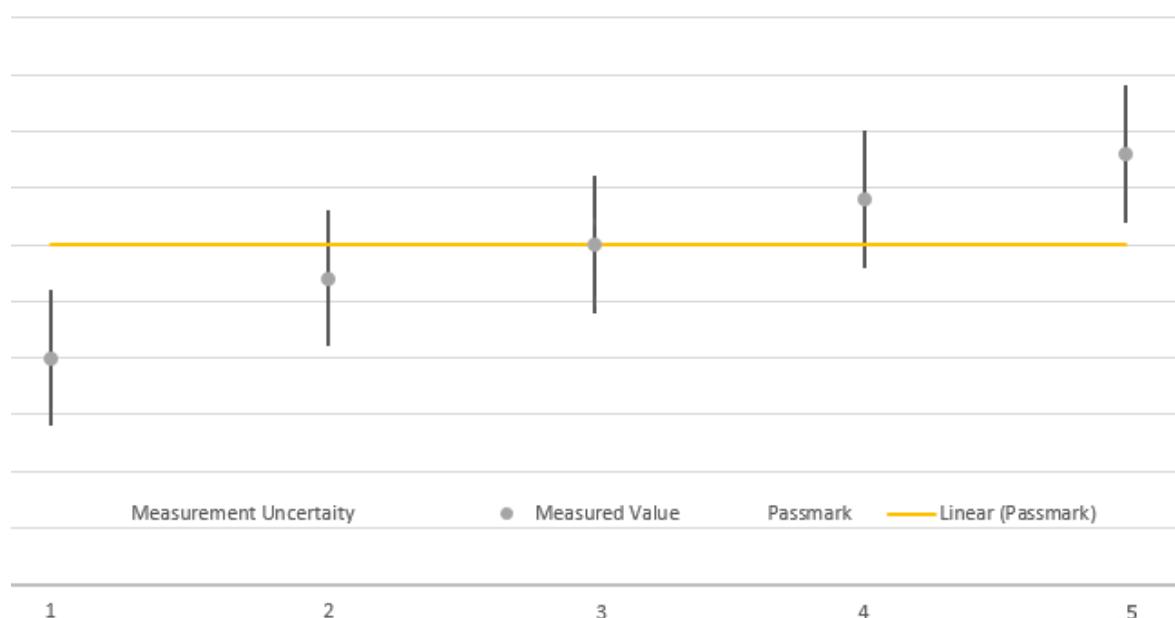
Linear interpolation will be used for frequencies in between the values in the table.

Table shows an extract of values.

## 8 MEASUREMENT UNCERTAINTIES

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

The measurement uncertainties for all parameters are calculated with an expansion factor (coverage factor)  $k = 1.96$ . This means, that the true value is in the corresponding interval with a probability of 95 %.



The verdicts in this test report are given according the above diagram:

Case	Measured Value	Uncertainty Range	Verdict
1	below pass mark	below pass mark	Passed
2	below pass mark	within pass mark	Passed
3	on pass mark	within pass mark	Passed
4	above pass mark	within pass mark	Failed
5	above pass mark	above pass mark	Failed

That means, the laboratory applies, as decision rule (see ISO/IEC 17025:2017), the so-called shared risk principle.



## 9 PHOTO REPORT

Please see separate photo report.

\*\*\*\*\*END OF TEST REPORT\*\*\*\*\*