# FCC Measurement/Technical Report on

# Thermostat
# TH-1.1

# FCC ID: 2AO6WTH11
# IC: 23736-TH11

**Test Report Reference:** MDE_Jabil_1703_FCCa_rev1

**Test Laboratory:**
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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.

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# 1 APPLIED STANDARDS AND TEST SUMMARY

## 1.1 APPLIED STANDARDS

**Type of Authorization**
Certification for an Intentional Radiator.

**Applicable FCC Rules**

Prepared in accordance with the requirements of FCC Rules and Regulations as listed in 47 CFR Ch.1 Parts 2 and 15 (10-1-15 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.

**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 2: 5.2 (a) |
| Peak conducted output power | § 15.247 (b) (3), (4) | RSS-247 Issue 2: 5.4 (d) |
| Transmitter spurious RF conducted emissions | § 15.247 (d) | RSS-Gen Issue 4: 6.13 / 8.9/8.10;<br>RSS-247 Issue 2: 5.5 |
| Transmitter spurious radiated emissions | § 15.247 (d);<br>§ 15.209 (a) | RSS-Gen Issue 4: 6.13 / 8.9/8.10;<br>RSS-247 Issue 2: 5.5 |
| Band edge compliance | § 15.247 (d) | RSS-247 Issue 2: 5.5 |
| Power density | § 15.247 (e) | RSS-247 Issue 2: 5.2 (b) |
| Antenna requirement | § 15.203 / 15.204 | RSS-Gen Issue 4: 8.3 |
| Receiver spurious emissions | – | – |

## 1.3 MEASUREMENT SUMMARY / SIGNATURES

| **47 CFR CHAPTER I FCC PART 15 Subpart C §15.247** | **§ 15.207** | | |
|---|---|---|---|
| Conducted Emissions at AC Mains<br>The measurement was performed according to ANSI C63.10 | | **Final Result** | |
| **OP-Mode** | **Setup** | **FCC** | **IC** |
| Operating mode | | | |
| worst case | S01_AB01 | Passed | Passed |

| **47 CFR CHAPTER I FCC PART 15 Subpart C §15.247** | **§ 15.247 (a) (2)** | | |
|---|---|---|---|
| Occupied Bandwidth (6 dB)<br>The measurement was performed according to ANSI C63.10 | | **Final Result** | |
| **OP-Mode** | **Setup** | **FCC** | **IC** |
| Radio Technology, Operating Frequency | | | |
| IEEE 802.15.4, high | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, low | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, mid | S01_AC01 | Passed | Passed |

| **47 CFR CHAPTER I FCC PART 15 Subpart C §15.247** | **IC RSS-Gen & IC TRC; Ch. 6.6 & Ch. 8** | | |
|---|---|---|---|
| Occupied Bandwidth (99%)<br>The measurement was performed according to ANSI C63.10 | | **Final Result** | |
| **OP-Mode** | **Setup** | **FCC** | **IC** |
| Radio Technology, Operating Frequency | | | |
| IEEE 802.15.4, high | S01_AC01 | N/A | Passed |
| IEEE 802.15.4, low | S01_AC01 | N/A | Passed |
| IEEE 802.15.4, mid | S01_AC01 | N/A | Passed |

| **47 CFR CHAPTER I FCC PART 15 Subpart C §15.247** | **§ 15.247 (b) (3)** | | |
|---|---|---|---|
| Peak Power Output<br>The measurement was performed according to ANSI C63.10 | | **Final Result** | |
| **OP-Mode** | **Setup** | **FCC** | **IC** |
| Radio Technology, Operating Frequency, Measurement method | | | |
| IEEE 802.15.4, high, conducted | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, low, conducted | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, mid, conducted | S01_AC01 | 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** | **Setup** | **FCC** | **IC** |
|---|---|---|---|
| Radio Technology, Operating Frequency | | | |
| IEEE 802.15.4, high | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, low | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, mid | S01_AC01 | Passed | Passed |

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

Transmitter Spurious Radiated Emissions
The measurement was performed according to ANSI C63.10 **Final Result**

| **OP-Mode** | **Setup** | **FCC** | **IC** |
|---|---|---|---|
| Radio Technology, Operating Frequency, Measurement range | | | |
| IEEE 802.15.4, high, 1 GHz - 26 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, high, 30 MHz - 1 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, low, 1 GHz - 26 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, low, 30 MHz - 1 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, mid, 1 GHz - 26 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, mid, 30 MHz - 1 GHz | S01_AA01 | Passed | Passed |
| IEEE 802.15.4, mid, 9 kHz - 30 MHz | S01_AA01 | Passed | Passed |

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

Band Edge Compliance Conducted
The measurement was performed according to ANSI C63.10 **Final Result**

| **OP-Mode** | **Setup** | **FCC** | **IC** |
|---|---|---|---|
| Radio Technology, Operating Frequency, Band Edge | | | |
| IEEE 802.15.4, high, high | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, low, low | S01_AC01 | Passed | Passed |

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

Band Edge Compliance Radiated
The measurement was performed according to ANSI C63.10 **Final Result**

| **OP-Mode** | **Setup** | **FCC** | **IC** |
|---|---|---|---|
| Radio Technology, Operating Frequency, Band Edge | | | |
| IEEE 802.15.4, high, high | S01_AA01 | Passed | Passed |

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

Power Density
The measurement was performed according to ANSI C63.10

| **OP-Mode** | **Setup** | **Final Result** | |
|---|---|---|---|
| Radio Technology, Operating Frequency | | **FCC** | **IC** |
| IEEE 802.15.4, high | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, low | S01_AC01 | Passed | Passed |
| IEEE 802.15.4, mid | S01_AC01 | Passed | Passed |

N/A: Not applicable
N/P: Not performed

## Revision History

| Report version control | | | |
|---|---|---|---|
| **Version** | **Release date** | **Change Description** | **Version validity** |
| initial | 2018-04-26 | -- | invalid |
| rev1 | 2018-06-25 | Changed FCC ID | valid |

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

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# 2 ADMINISTRATIVE DATA

## 2.1 TESTING LABORATORY

| | |
|---|---|
| Company Name: | 7layers GmbH |
| Address: | Borsigstr. 11<br>40880 Ratingen<br>Germany |

This facility has been fully described in a report submitted to the ISED and accepted under the registration number: Site# 3699A-1.

The test facility is also accredited by the following accreditation organisation:

| | |
|---|---|
| Laboratory accreditation no: | DAkkS D-PL-12140-01-00 |
| FCC Designation Number: | DE0015 |
| FCC Test Firm Registration: | 929146 |
| Responsible for accreditation scope: | Dipl.-Ing. Marco Kullik |
| Report Template Version: | 2018-01-10 |

## 2.2 PROJECT DATA

| | |
|---|---|
| Responsible for testing and report: | Dipl.-Ing. Daniel Gall |
| Employees who performed the tests: | documented internally at 7Layers |
| Date of Report: | 2018-06-25 |
| Testing Period: | 2018-03-01 to 2018-04-19 |

## 2.3 APPLICANT DATA

| | |
|---|---|
| Company Name: | Busch-Jaeger Elektro GmbH |
| Address: | Freisenbergstrasse 2<br>58513 Luedenscheid<br>Germany |
| Contact Person: | Mr. Thomas Reitz |

## 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 | Thermostat with IEEE 802.15.4 functionality |
| Product name | Thermostat |
| Type | TH-1.1 |
| **Declared EUT data by the supplier** | |
| Voltage Type | AC |
| Voltage Level | 24 V 60 Hz |
| Tested Modulation Type | Offset-QPSK |
| General product description | The EUT is a thermostat with IEEE 802.15.4 and integrated switches for auxiliary equipment. |
| Specific product description for the EUT | The EUT supports IEEE 802.15.4 in the 2.4 GHz band. |
| The EUT provides the following ports: | Strip Terminal unshielded lines<br>The USB connection to the laptop is only a temporary connection, the port is covered by the housing in end user samples. |
| Tested datarates | 250 kBit/s |
| Special software used for testing | Commands send by terminal program |

**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** |
|---|---|---|
| EUT A | DE1102005aa01 | FCC Test Mode Sample Radiated |
| **Sample Parameter** | **Value** | |
| Serial No. | 2426A18060062 | |
| HW Version | DVT | |
| SW Version | 0.24 | |
| Comment | | |
| Integral Antenna | 3.7 dBi | |

| **Sample Name** | **Sample Code** | **Description** |
|---|---|---|
| EUT B | DE1102005ab01 | FCC Normal Mode Sample Radiated |
| **Sample Parameter** | **Value** | |
| Serial No. | 2426A18060015 | |
| HW Version | DVT | |
| SW Version | 0.24 | |
| Comment | | |
| Integral Antenna | 3.7 dBi | |

| Sample Name | Sample Code | Description |
|---|---|---|
| EUT C | DE1102005ac01 | FCC Test Mode Sample Conducted |
| **Sample Parameter** | **Value** | |
| Serial No. | 38018060034 | |
| HW Version | DVT | |
| SW Version | 0.24 | |
| Comment | | |
| Integral Antenna | Removed for conducted testing | |

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 |
|---|---|---|
| AUX1 | White Rodgers, -, - , - | Voltage Converter (Transformer 120 V - 24 V) |
| AUX2 | White Rodgers, -, - , - | Voltage Converter (Transformer 120 V - 24 V) |
| AUX3 | White Rodgers, -, - , - | Voltage Converter (Transformer 120 V - 24 V) |
| AUX4 | RS components, -, - , - | 6 Resistors as dummy load |
| AUX5 | Hewlett-Packard HP 630, Rev: 3674-100, Windows 7 Professional English, 5CB20221YX | Laptop used to send commands and set EUT OP modes |

## 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_AA01 | EUT A, AUX1, | Setup Radiated testing |
| S01_AC01 | EUT C, AUX3, | Setup Conducted Testing |
| S01_AB01 | EUT B, AUX2, AUX4,AUX5 | Setup for normal mode testing with exercising of switched ports |

## 3.6 OPERATING MODES

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

### 3.6.1 TEST CHANNELS

| | 2.4 GHz ISM 2400 - 2483.5 MHz | | |
|---|---|---|---|
| **IEEE 802.15.4 Channels:** | **low** | **mid** | **high** |
| **Channel:** | 11 | 18 | 26 |
| **Frequency [MHz]** | 2405 | 2440 | 2480 |

### 3.6.2 SET POWER IN TX COMMAND

| | 2.4 GHz ISM 2400 - 2483.5 MHz | | | |
|---|---|---|---|---|
| **IEEE 802.15.4 Channels:** | **low** | **mid** | **high** | |
| **Channel:** | 11 | 18 | 25 | 26 |
| **Frequency [MHz]:** | 2405 | 2440 | 2475 | 2480 |
| **Power Setting:** | 8 | 8 | 9 1) | 15 |

Note: Higher Power Setting = Lower Output Power.
1) For the radiated tests it was decided to use a higher power setting, resulting in lower output power. The conducted tests were performed with setting 8 and were not repeated with the new power setting since higher output power is worse case.

## 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 CONDUCTED EMISSIONS AT AC MAINS

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.1.1 TEST DESCRIPTION

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

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

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

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

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

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

The highest value is reported.

## 4.1.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.207

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

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

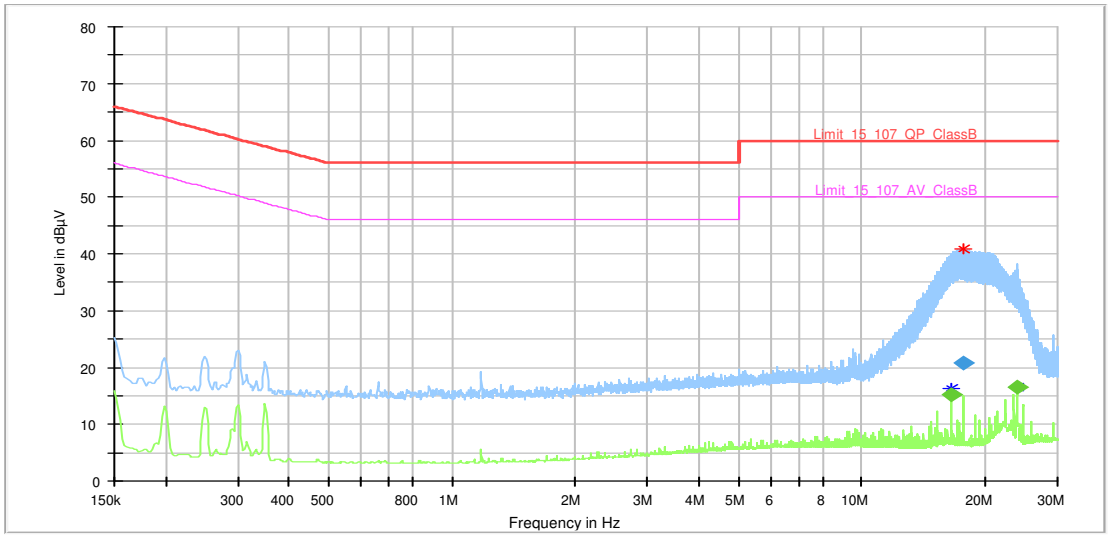
## 4.1.3 TEST PROTOCOL

Temperature: 24 °C
Air Pressure: 995 hPa
Humidity: 33 %

| **Power line** | **PE** | **Frequency [MHz]** | **Measured value QP [dBµV]** | **Measured value AV [dBµV]** | **Limit [dBµV]** | **Margin [dB]** |
|---|---|---|---|---|---|---|
| N | GND | 17.6 | 20.8 | - | 60.0 | 39.2 |

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

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




### Final_Result

| Frequency (MHz) | QuasiPeak (dBµV) | CAverage (dBµV) | Limit (dBµV) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Line | PE | Corr. (dB) | Corr. (dB) |
|---|---|---|---|---|---|---|---|---|---|---|
| 16.482750 | --- | 15.17 | 50.00 | 34.83 | 1000.0 | 9.000 | N | GND | 11 | --- |
| 17.630250 | 20.78 | --- | 60.00 | 39.22 | 1000.0 | 9.000 | N | GND | 11 | --- |
| 24.020250 | --- | 16.49 | 50.00 | 33.51 | 1000.0 | 9.000 | N | GND | 11 | --- |

## 4.1.5 TEST EQUIPMENT USED

- Conducted Emissions FCC

## 4.2 OCCUPIED BANDWIDTH (6 DB)

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 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: 30 / 50 MHz (for 20 / 40 MHz nominal bandwidth)
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 20 ms
- Detector: Peak

### 4.2.2 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.

### 4.2.3 TEST PROTOCOL

Ambient temperature: 24 °C
Air Pressure: 998 hPa
Humidity: 21 %
IEEE 802.15.4

| Band | Channel No. | Frequency [MHz] | 6 dB Bandwidth [MHz] | Limit [MHz] | Margin to Limit [MHz] |
|---|---|---|---|---|---|
| 2.4 GHz ISM | 11 | 2405 | 1.68 | 0.5 | 1.18 |
| | 18 | 2440 | 1.68 | 0.5 | 1.18 |
| | 25 | 2475 | 1.68 | 0.5 | 1.18 |
| | 26 | 2480 | 1.68 | 0.5 | 1.18 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = high (S01_AC01)

Channel 26

### 4.2.5 TEST EQUIPMENT USED

- R&S TS8997

## 4.3 OCCUPIED BANDWIDTH (99%)

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 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): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Span: 30 / 50 MHz (for 20 / 40 MHz nominal bandwidth)
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 20 ms
- Detector: Sample

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

### 4.3.2 TEST REQUIREMENTS / LIMITS

No applicable limit:

### 4.3.3 TEST PROTOCOL

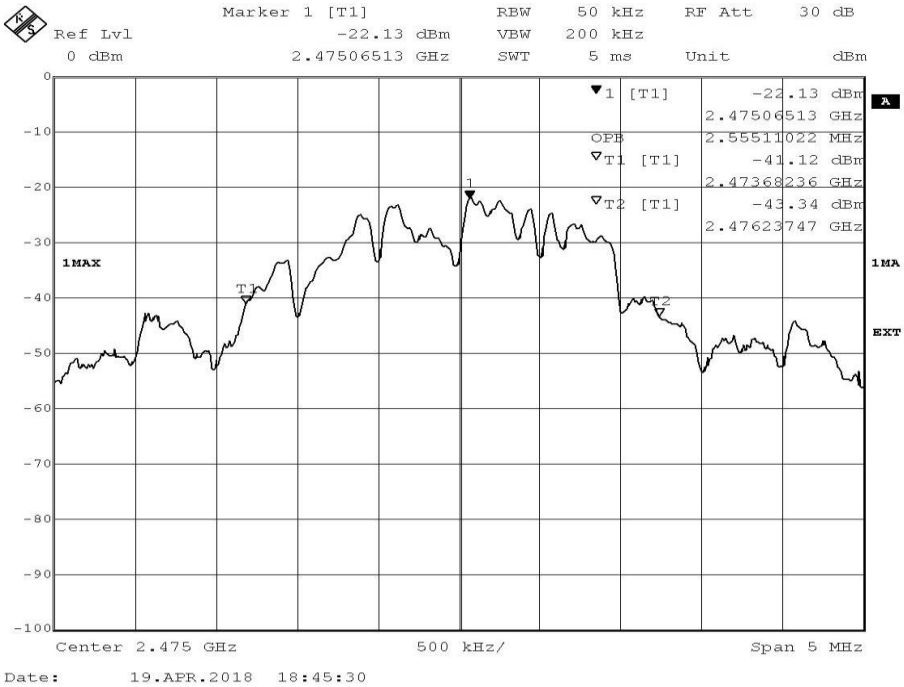
Ambient temperature: 27 °C
Air Pressure: 1019 hPa
Humidity: 30 %
IEEE 802.15.4

| Band | Channel No. | Frequency [MHz] | 99 % Bandwidth [MHz] |
|---|---|---|---|
| 2.4 GHz ISM | 11 | 2405 | 2.5 |
| | 18 | 2440 | 2.5 |
| | 25 | 2475 | 2.6 |
| | 26 | 2480 | 2.5 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = high
(S01_AC01)




Channel 25

## 4.3.5 TEST EQUIPMENT USED

- Radio Lab

## 4.4 PEAK POWER OUTPUT

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 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)

### 4.4.2 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)

## 4.4.3 TEST PROTOCOL

Ambient temperature: 24 °C
Air Pressure: 998 hPa
Humidity: 21 %
IEEE 802.15.4

| Band | Channel No. | Frequency [MHz] | Peak Power [dBm] | Limit [dBm] | Margin to Limit [dB] |
|---|---|---|---|---|---|
| 2.4 GHz ISM | 11 | 2405 | 15.4 | 30.0 | 14.6 |
| | 18 | 2440 | 14.3 | 30.0 | 15.7 |
| | 25 | 2475 | 13.2 | 30.0 | 16.8 |
| | 26 | 2480 | -1.2 | 30.0 | 31.2 |

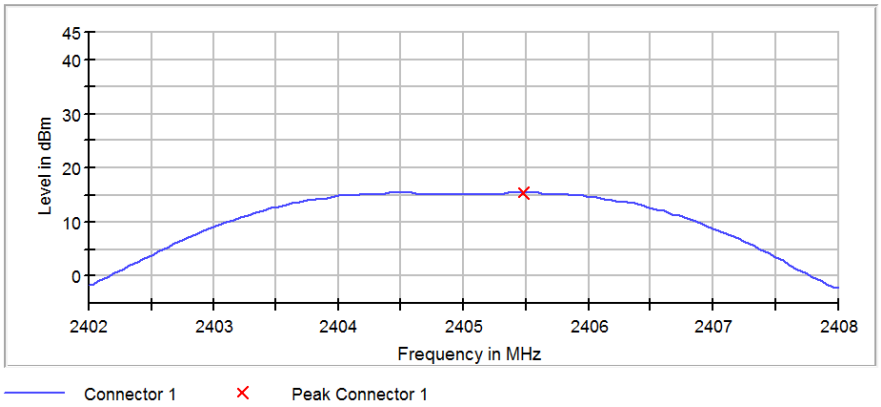
Remark: Please see next sub-clause for the measurement plot.

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

Radio Technology = IEEE 802.15.4, Operating Frequency = low, Measurement method = conducted
(S01_AC01)

**Result**

| DUT Frequency (MHz) | Peak Power (dBm) | Limit Max (dBm | Result |
|---|---|---|---|
| 2405.000000 | 15.4 | 30.0 | PASS |




**Measurement**

| Setting | Instrument Value |
|---|---|
| Start Frequency | 2.40200 GHz |
| Stop Frequency | 2.40800 GHz |
| Span | 6.000 MHz |
| RBW | 2.000 MHz |
| VBW | 10.000 MHz |
| SweepPoints | 101 |
| Sweeptime | 953.450 ns |
| Reference Level | 10.000 dBm |
| Attenuation | 30.000 dB |
| Detector | MaxPeak |
| SweepCount | 100 |
| Filter | 3 dB |
| Trace Mode | Max Hold |
| Sweeptype | FFT |
| Preamp | off |
| Stablemode | Trace |
| Stablevalue | 0.20 dB |
| Run | -1 / max. 150 |
| Stable | -1 / 3 |
| Max Stable Difference | -1.00 dB |

## 4.4.5 TEST EQUIPMENT USED

- R&S TS8997

## 4.5 SPURIOUS RF CONDUCTED EMISSIONS

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.5.1 TEST DESCRIPTION

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

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

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

### 4.5.2 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.

## 4.5.3 TEST PROTOCOL

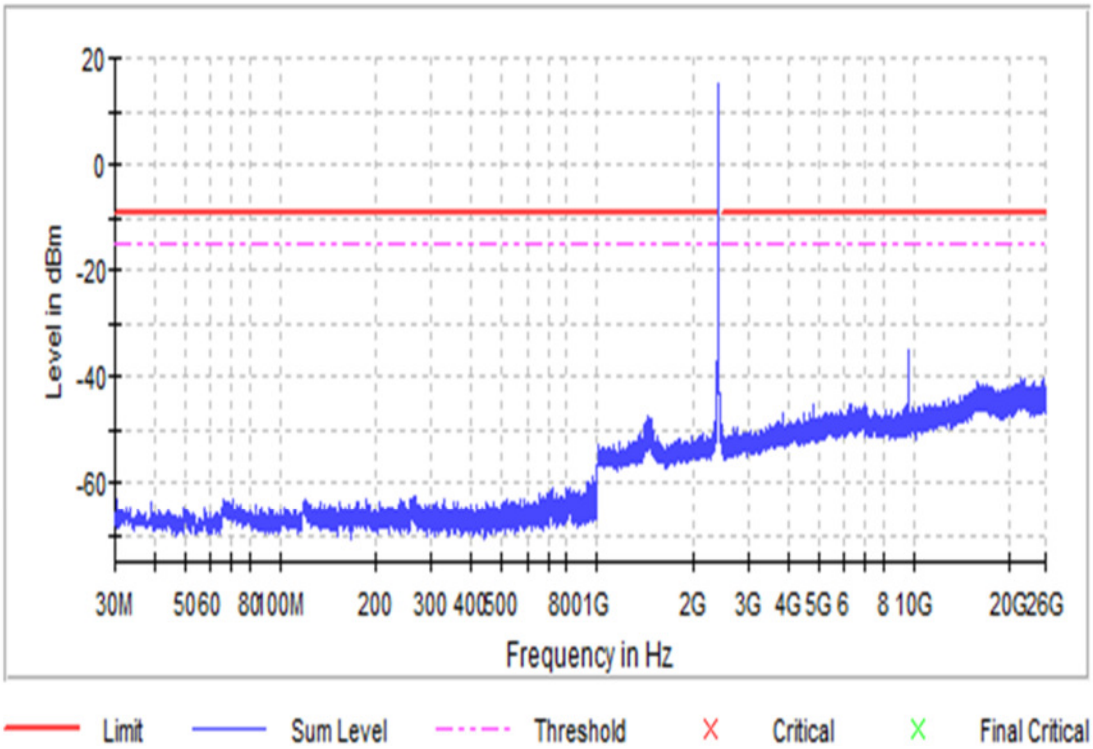
Ambient temperature: 24 °C
Air Pressure: 998 hPa
Humidity: 21 %
IEEE 802.15.4

| Channel No | Channel Center Freq. [MHz] | Spurious Freq. [MHz] | Spurious Level [dBm] | Detector | RBW [kHz] | Ref. Level [dBm] | Limit [dBm] | Margin to Limit [dB] |
|---|---|---|---|---|---|---|---|---|
| 11 | 2405 | 9618.3 | -34.8 | PEAK | 1000 | 10.9 | -9.1 | 25.7 |
| 18 | 2440 | 9758.3 | -35.9 | PEAK | 1000 | 9.7 | -10.3 | 25.6 |
| 25 | 2475 | 9902.3 | -39.1 | PEAK | 1000 | 8.3 | -11.7 | 27.4 |
| 26 | 2480 | 2483.5 | -29.8 | PEAK | 1000 | -6.4 | -26.4 | 3.4 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = low
(S01_AC01)




## 4.5.5 TEST EQUIPMENT USED

- R&S TS8997

## 4.6 TRANSMITTER SPURIOUS RADIATED EMISSIONS

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.6.1 TEST DESCRIPTION

The test set-up was made in accordance to the general provisions of ANSI C63.10 in a typical installation configuration. The Equipment Under Test (EUT) was set up on a non-conductive table 1.0 x 2.0 m² in the semi-anechoic chamber. The influence of the EUT support table that is used between 30–1000 MHz was evaluated.
The measurement procedure is implemented into the EMI test software EMC32 from R&S.
Exploratory tests are performed at 3 orthogonal axes to determine the worst-case orientation of a body-worn or handheld EUT. The final test on all kind of EUTs is also performed at 3 axes.
A pre-check is performed while the EUT is powered from a DC power source.

**1. Measurement up to 30 MHz**
The Loop antenna HFH2-Z2 is used.

**Step 1:** pre measurement
- Anechoic chamber
- Antenna distance: 3 m
- Detector: Peak-Maxhold
- Frequency range: 0.009 - 0.15 MHz and 0.15 – 30 MHz
- Frequency steps: 0.05 kHz and 2.25 kHz
- IF–Bandwidth: 0.2 kHz and 9 kHz
- Measuring time / Frequency step: 100 ms (FFT-based)

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

**Step 2:** final measurement
For the relevant emissions determined in step 1, an additional measurement with the following settings will be performed. Intention of this step is to find the maximum emission level.
- Open area test side
- Antenna distance: according to the Standard
- Detector: Quasi-Peak
- Frequency range: 0.009 – 30 MHz
- Frequency steps: measurement at frequencies detected in step 1
- IF–Bandwidth: 0.2 - 10 kHz
- Measuring time / Frequency step: 1 s

**2. Measurement above 30 MHz and up to 1 GHz**

**Step 1:** Preliminary scan
This is a preliminary test to identify the highest amplitudes relative to the limit.
Settings for step 1:
- Antenna distance: 3 m
- Detector: Peak-Maxhold / Quasipeak (FFT-based)
- Frequency range: 30 – 1000 MHz

- Frequency steps: 30 kHz
- IF–Bandwidth: 120 kHz
- Measuring time / Frequency step: 100 ms
- Turntable angle range: –180° to 90°
- Turntable step size: 90°
- Height variation range: 1 – 3 m
- Height variation step size: 2 m
- Polarisation: Horizontal + Vertical

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

**Step 2:** Adjustment measurement
In this step the accuracy of the turntable azimuth and antenna height will be improved. This is necessary to find out the maximum value of every frequency.
For each frequency, which was determined the turntable azimuth and antenna height will be adjusted. The turntable azimuth will slowly vary by ± 45° around this value. During this action, the value of emission is continuously measured. The turntable azimuth at the highest emission will be recorded and adjusted. In this position, the antenna height will also slowly vary by ± 100 cm around the antenna height determined. During this action, the value of emission is also continuously measured. The antenna height of the highest emission will also be recorded and adjusted.
- Detector: Peak – Maxhold
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 100 ms
- Turntable angle range: ± 45 ° around the determined value
- Height variation range: ± 100 cm around the determined value
- Antenna Polarisation: max. value determined in step 1

**Step 3:** Final measurement with QP detector
With the settings determined in step 3, the final measurement will be performed:
EMI receiver settings for step 4:
- Detector: Quasi-Peak (< 1 GHz)
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 120 kHz
- Measuring time: 1 s

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

**3. Measurement above 1 GHz**
The following modifications apply to the measurement procedure for the frequency range above 1 GHz:
**Step 1:**
The Equipment Under Test (EUT) was set up on a non-conductive support (tilt device) at 1.5 m height in the fully-anechoic chamber.
All steps were performed with one height (1.5 m) of the receiving antenna only.
The EUT is turned during the preliminary measurement across the elevation axis, with a step size of 90 °.
The turn table step size (azimuth angle) for the preliminary measurement is 45 °.
**Step 2:**
Due to the fact, that in this frequency range the test is performed in a fully anechoic room, the height scan of the receiving antenna instep 2 is omitted. Instead of this, a maximum search with a step size ± 45° for the elevation axis is performed.

The turn table azimuth will slowly vary by ± 22.5°.
The elevation angle will slowly vary by ± 45°
EMI receiver settings (for all steps):
- Detector: Peak, Average
- IF Bandwidth = 1 MHz

**Step 3:**
Spectrum analyser settings for step 3:
- Detector: Peak / Average
- Measured frequencies: in step 1 determined frequencies
- IF – Bandwidth: 1 MHz
- Measuring time: 1 s

### 4.6.2 TEST REQUIREMENTS / LIMITS

FCC Part 15, Subpart C, §15.247 (d)
... In addition, radiated emissions which fall in the restricted bands, as defined in Section 15.205(a), must also comply with the radiated emission limits specified in Section 15.209(a) (see Section 15.205(c)).

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

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

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

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

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

§15.35(b) ..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit....

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

## 4.6.3 TEST PROTOCOL

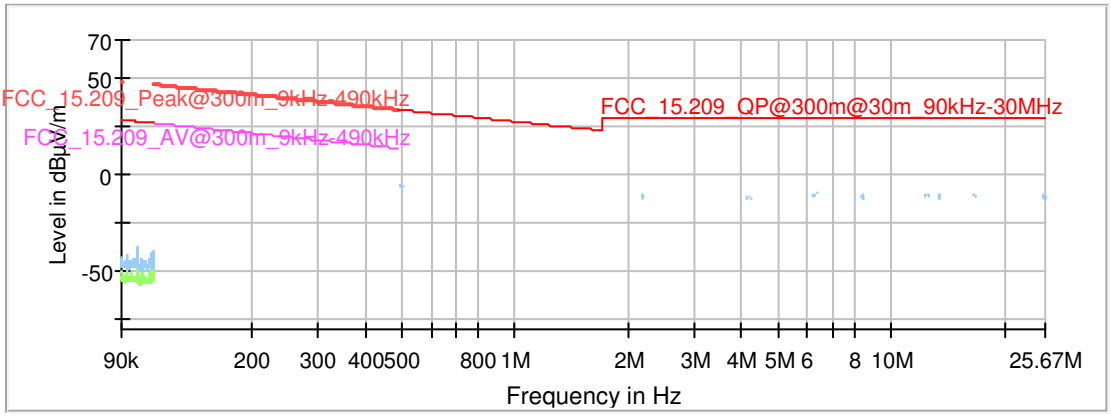
Ambient temperature: 22 °C
Air Pressure: 998 hPa
Humidity: 23 %
IEEE 802.15.4
Applied duty cycle correction (AV): 0 dB

| Ch. No. | Ch. Center Freq. [MHz] | Spurious Freq. [MHz] | Spurious Level [dBµV/m] | Detec-tor | RBW [kHz] | Limit [dBµV/m] | Margin to Limit [dB] | Limit Type |
|---|---|---|---|---|---|---|---|---|
| 11 | 2405 | 2389.6 | 56.3 | PEAK | 1000 | 74.0 | 17.7 | RB |
| 11 | 2405 | 2390.0 | 46.4 | AV | 1000 | 54.0 | 7.6 | RB |
| 11 | 2405 | 4810.9 | 54.1 | PEAK | 1000 | 74.0 | 19.9 | RB |
| 11 | 2405 | 4810.9 | 45.1 | AV | 1000 | 54.0 | 8.9 | RB |
| 18 | 2440 | --- | - | PEAK | 1000 | 74.0 | - | RB |
| 25 | 2475 | --- | - | PEAK | 1000 | 74.0 | - | RB |
| 26 | 2480 | --- | - | PEAK | 1000 | 74.0 | - | RB |

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

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

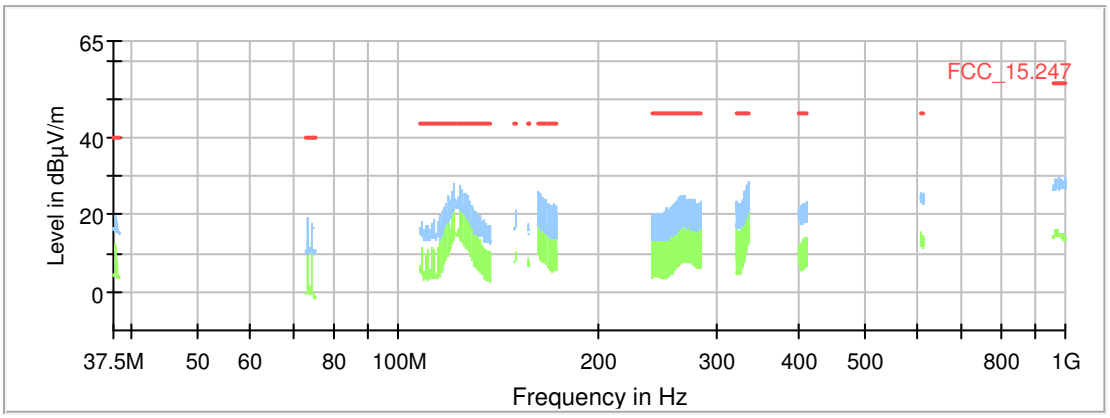
Radio Technology = IEEE 802.15.4, Operating Frequency = mid, Measurement range = 9 kHz - 30 MHz
(S01_AA01)




## Final_Result

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

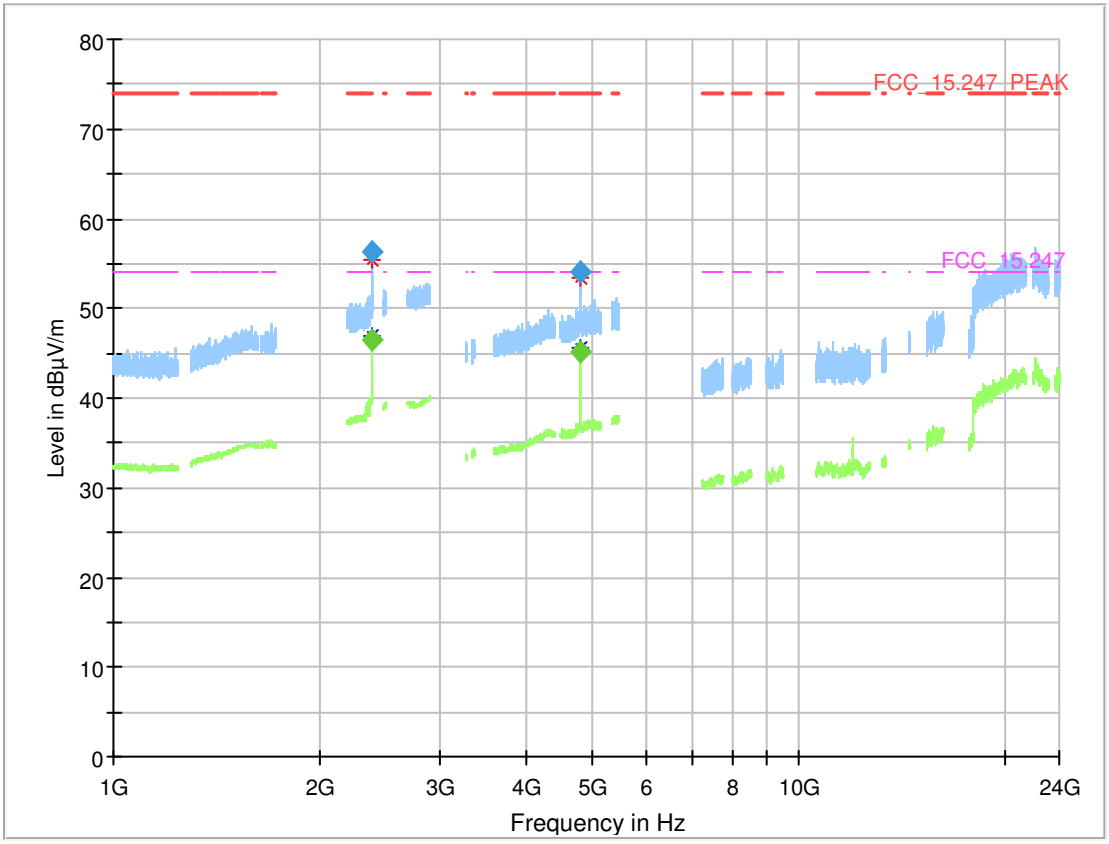
Radio Technology = IEEE 802.15.4, Operating Frequency = low, Measurement range = 30 MHz - 1 GHz
(S01_AA01)




## Final_Result

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

Radio Technology = IEEE 802.15.4, Operating Frequency = low, Measurement range = 1 GHz - 26 GHz
(S01_AA01)




## Critical_Freqs

| Frequency (MHz) | MaxPeak (dBµV/m) | Average (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2389.600000 | 55.40 | --- | 74.00 | 18.60 | --- | --- | 150.0 | H | 142.0 | 2.0 |
| 2390.000000 | --- | 46.96 | 54.00 | 7.04 | --- | --- | 150.0 | H | 142.0 | 4.0 |
| 4810.862500 | 53.47 | --- | 74.00 | 20.53 | --- | --- | 150.0 | H | 41.0 | -6.0 |
| 4810.862500 | --- | 45.65 | 54.00 | 8.35 | --- | --- | 150.0 | H | 40.0 | -12.0 |

## Final_Result

| Frequency (MHz) | MaxPeak (dBµV/m) | CAverage (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2389.600000 | 56.32 | --- | 74.00 | 17.68 | 1000.0 | 1000.000 | 150.0 | H | 142.0 | 2.0 |
| 2390.000000 | --- | 46.41 | 54.00 | 7.59 | 1000.0 | 1000.000 | 150.0 | H | 142.0 | 4.0 |
| 4810.862500 | --- | 45.07 | 54.00 | 8.93 | 1000.0 | 1000.000 | 150.0 | H | 41.0 | -12.0 |
| 4810.862500 | 54.10 | --- | 74.00 | 19.90 | 1000.0 | 1000.000 | 150.0 | H | 41.0 | -6.0 |

### 4.6.5 TEST EQUIPMENT USED

- Radiated Emissions

## 4.7 BAND EDGE COMPLIANCE CONDUCTED

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.7.1 TEST DESCRIPTION

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

Analyzer settings:

- Lower Band Edge:
  Minimum frequency: 2397.0 MHz
  Upper Band Edge
  Maximum frequency: 2485.0 MHz
- Span:
  Bluetooth: 6 MHz
  WLAN: 25 / 45 / 85 MHz [depending on channel bandwidth]
- Detector: Peak
- Resolution Bandwidth (RBW): 100 kHz
- Video Bandwidth (VBW): 300 kHz
- Sweeptime: 5 ms
- Sweeps: 2000
- Trace: Maxhold

### 4.7.2 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..."

## 4.7.3 TEST PROTOCOL

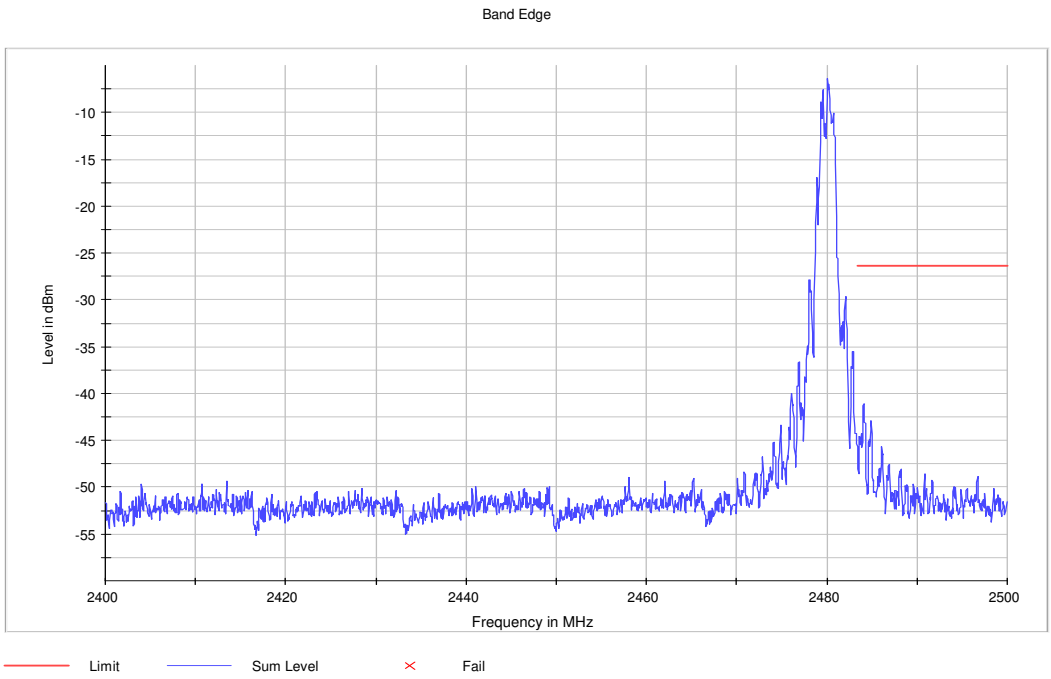
Ambient temperature: 24 °C
Air Pressure: 998 hPa
Humidity: 21 %
IEEE 802.15.4

| 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 | -29.1 | PEAK | 100 | 10.9 | -9.1 | 20.0 |
| 25 | 2475 | 2483.5 | -38.9 | PEAK | 100 | 8.3 | -11.7 | 27.2 |
| 26 | 2480 | 2483.5 | -41.1 | PEAK | 100 | -6.4 | -26.4 | 14.7 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = high, Band Edge = high (S01_AC01)




Channel 26

## 4.7.5 TEST EQUIPMENT USED

- R&S TS8997

## 4.8 BAND EDGE COMPLIANCE RADIATED

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.8.1 TEST DESCRIPTION

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

### 4.8.2 TEST REQUIREMENTS / LIMITS

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

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

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

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

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

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

§15.35(b) ..., there is also a limit on the radio frequency emissions, as measured using instrumentation with a peak detector function, corresponding to 20 dB above the maximum permitted average limit....

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

## 4.8.3 TEST PROTOCOL

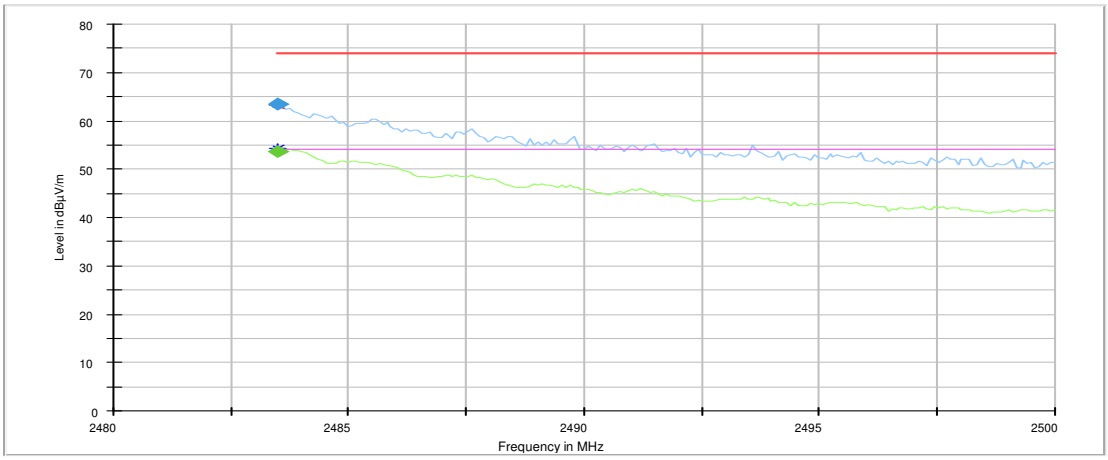
Ambient temperature: 22 °C
Air Pressure: 998 hPa
Humidity: 23 %
IEEE 802.15.4
Applied duty cycle correction (AV): 0 dB

| Ch. No. | Ch. Center Freq. [MHz] | Band Edge Freq. [MHz] | Spurious Level [dBµV/m] | Detec-tor | RBW [kHz] | Limit [dBµV/m] | Margin to Limit [dB] |
|---|---|---|---|---|---|---|---|
| 25 | 2475 | 2483.5 | 63.5 | PEAK | 1000 | 74.0 | 10.5 |
| 25 | 2475 | 2483.5 | 53.7 | AV | 1000 | 54.0 | 0.3 |
| 26 | 2480 | 2483.5 | 63.6 | PEAK | 1000 | 74.0 | 10.4 |
| 26 | 2480 | 2483.5 | 53.5 | AV | 1000 | 54.0 | 0.5 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = high, Band Edge = high (S01_AA01)
Channel 25




### Critical_Freqs

| Frequency (MHz) | MaxPeak (dBµV/m) | Average (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2483.500000 | 63.33 | --- | 74.00 | 10.67 | --- | --- | 150.0 | H | 139.0 | 6.0 |
| 2483.500000 | --- | 54.30 | 54.00 | -0.30 | --- | --- | 150.0 | H | 139.0 | 4.0 |

### Final_Result

| Frequency (MHz) | MaxPeak (dBµV/m) | CAverage (dBµV/m) | Limit (dBµV/m) | Margin (dB) | Meas. Time (ms) | Bandwidth (kHz) | Height (cm) | Pol | Azimuth (deg) | Elevation (deg) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2483.500000 | --- | 53.67 | 54.00 | 0.33 | 1000.0 | 1000.000 | 150.0 | H | 139.0 | 4.0 |
| 2483.500000 | 63.53 | --- | 74.00 | 10.47 | 1000.0 | 1000.000 | 150.0 | H | 139.0 | 6.0 |

## 4.8.5 TEST EQUIPMENT USED

- Radiated Emissions

## 4.9 POWER DENSITY

Standard **FCC Part 15 Subpart C**

**The test was performed according to:**
ANSI C63.10

### 4.9.1 TEST DESCRIPTION

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

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

Analyzer settings:

- Resolution Bandwidth (RBW): 3 kHz
- Video Bandwidth (VBW): 30 kHz
- Trace: Maxhold
- Sweeps: 2000
- Sweeptime: 5 ms
- Detector: Peak

### 4.9.2 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.

### 4.9.3 TEST PROTOCOL

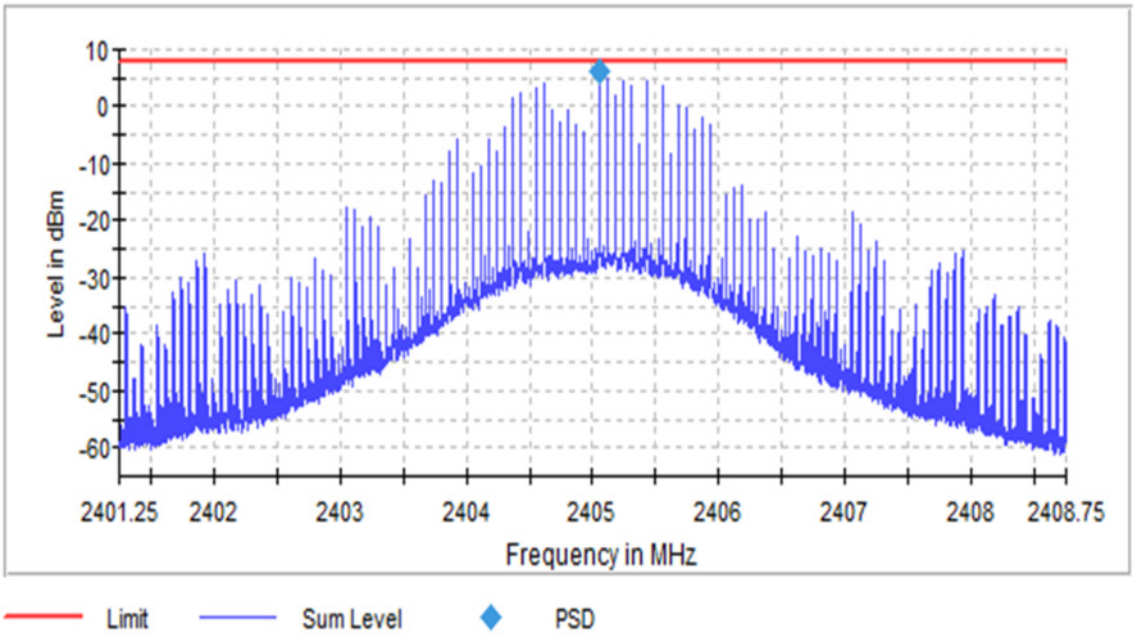
Ambient temperature: 24 °C
Air Pressure: 998 hPa
Humidity: 21 %
IEEE 802.15.4

| Band | Channel No. | Frequency [MHz] | Power Density [dBm/3kHz] | Limit [dBm/3kHz] | Margin to Limit [dB] |
|---|---|---|---|---|---|
| 2.4 GHz ISM | 11 | 2405 | 6.0 | 8.0 | 2.0 |
| | 18 | 2440 | 4.4 | 8.0 | 3.6 |
| | 25 | 2475 | 3.3 | 8.0 | 4.7 |
| | 26 | 2480 | -11.7 | 8.0 | 19.7 |

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

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

Radio Technology = IEEE 802.15.4, Operating Frequency = low
(S01_AC01)




### 4.9.5 TEST EQUIPMENT USED

- R&S TS8997

# 5 TEST EQUIPMENT

## 1 Conducted Emissions FCC

Conducted Emissions power line for FCC standards

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 1.1 | Opus10 TPR (8253.00) | ThermoAirpressure Datalogger 13 (Environ) | Lufft Mess- und Regeltechnik GmbH | 13936 | 2017-04 | 2019-04 |
| 1.2 | Fluke 177 | Digital Multimeter 03 (Multimeter) | Fluke Europe B.V. | 86670383 | 2018-04 | 2020-04 |
| 1.3 | ESH3-Z5 | Two-Line V-Network | Rohde & Schwarz | 828304/029 | 2017-05 | 2019-05 |
| 1.4 | EP 1200/B, NA/B1 | Amplifier with integrated variable Oscillator | Spitzenberger & Spieß | B6278 | 2015-07 | 2018-07 |
| 1.5 | Chroma 6404 | AC Power Source | Chroma ATE INC. | 64040001304 | | |
| 1.6 | Shielded Room 02 | Shielded Room for conducted testing, 12qm | Frankonia | - | | |
| 1.7 | ESH3-Z5 | Two-Line V-Network | Rohde & Schwarz | 829996/002 | 2017-05 | 2019-05 |
| 1.8 | ESR 7 | EMI Receiver / Spectrum Analyzer | Rohde & Schwarz | 101424 | 2016-11 | 2018-11 |
| 1.9 | Opus10 THI (8152.00) | ThermoHygro Datalogger 02 (Environ) | Lufft Mess- und Regeltechnik GmbH | 7489 | 2017-04 | 2019-04 |
| 1.10 | ESIB 26 | Spectrum Analyzer | Rohde & Schwarz | 830482/004 | 2018-01 | 2020-01 |

## 2 R&S TS8997

EN300328/301893 Test Lab

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 2.1 | SMB100A | Signal Generator 9 kHz - 6 GHz | Rohde & Schwarz | 107695 | 2017-07 | 2020-07 |
| 2.2 | MFS | Rubidium Frequency Standard | Datum-Beverly | 5489/001 | 2017-07 | 2018-07 |
| 2.3 | 1515 / 93459 | Broadband Power Divider SMA (Aux) | Weinschel Associates | LN673 | | |
| 2.4 | FSV30 | Signal Analyzer 10 Hz - 30 GHz | Rohde & Schwarz | 103005 | 2016-02 | 2018-04 |
| 2.5 | Fluke 177 | Digital Multimeter 03 (Multimeter) | Fluke Europe B.V. | 86670383 | 2018-04 | 2020-04 |
| 2.6 | A8455-4 | 4 Way Power Divider (SMA) | | - | | |

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 2.7 | Opus10 THI (8152.00) | ThermoHygro Datalogger 03 (Environ) | Lufft Mess- und Regeltechnik GmbH | 7482 | 2017-03 | 2019-03 |
| 2.8 | SMBV100A | Vector Signal Generator 9 kHz - 6 GHz | Rohde & Schwarz | 259291 | 2016-10 | 2019-10 |
| 2.9 | OSP120 | Switching Unit with integrated power meter | Rohde & Schwarz | 101158 | 2016-11 | 2018-11 |

3 Radiated Emissions
Lab to perform radiated emission tests

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 3.1 | NRV-Z1 | Sensor Head A | Rohde & Schwarz | 827753/005 | 2017-05 | 2018-05 |
| 3.2 | MFS | Rubidium Frequency Normal MFS | Datum GmbH | 002 | 2017-10 | 2018-10 |
| 3.3 | Opus10 TPR (8253.00) | ThermoAirpressure Datalogger 13 (Environ) | Lufft Mess- und Regeltechnik GmbH | 13936 | 2017-04 | 2019-04 |
| 3.4 | Anechoic Chamber | 10.58 x 6.38 x 6.00 m³ | Frankonia | none | 2016-05 | 2019-05 |
| 3.5 | FS-Z60 | Harmonic Mixer 40 - 60 GHz | Rohde & Schwarz Memmingen | 100178 | 2016-12 | 2019-12 |
| 3.6 | FS-Z220 | Harmonic Mixer 140 - 220 GHz | Rohde & Schwarz Memmingen | 101005 | 2017-03 | 2020-03 |
| 3.7 | SGH-05 | Antenna (140 - 220 GHz) | | 075 | | |
| 3.8 | HL 562 | Ultralog new biconicals | Rohde & Schwarz | 830547/003 | 2015-06 | 2018-06 |
| 3.9 | 5HC2700/12750-1.5-KK | High Pass Filter | Trilithic | 9942012 | | |
| 3.10 | ASP 1.2/1.8-10 kg | Antenna Mast | Maturo GmbH | - | | |
| 3.11 | Fully Anechoic Room | 8.80m x 4.60m x 4.05m (l x w x h) | Albatross Projects | P26971-647-001-PRB | 2015-06 | 2018-06 |
| 3.12 | Fluke 177 | Digital Multimeter 03 (Multimeter) | Fluke Europe B.V. | 86670383 | 2018-04 | 2020-04 |
| 3.13 | JS4-18002600-32-5P | Broadband Amplifier 18 GHz - 26 GHz | Miteq | 849785 | | |
| 3.14 | FSW 43 | Spectrum Analyzer | Rohde & Schwarz | 103779 | 2016-12 | 2018-12 |
| 3.15 | 3160-09 | Standard Gain / Pyramidal Horn Antenna 26.5 GHz | EMCO Elektronic GmbH | 00083069 | | |

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 3.16 | SGH-19 | Antenna (40 - 60 GHz) | | 093 | | |
| 3.17 | WHKX 7.0/18G-8SS | High Pass Filter | Wainwright | 09 | | |
| 3.18 | 4HC1600/12750-1.5-KK | High Pass Filter | Trilithic | 9942011 | | |
| 3.19 | Chroma 6404 | AC Power Source | Chroma ATE INC. | 64040001304 | | |
| 3.20 | JS4-00102600-42-5A | Broadband Amplifier 30 MHz - 26 GHz | Miteq | 619368 | | |
| 3.21 | TT 1.5 WI | Turn Table | Maturo GmbH | - | | |
| 3.22 | HL 562 Ultralog | Log.-per. Antenna | Rohde & Schwarz | 100609 | 2016-04 | 2019-04 |
| 3.23 | FS-Z325 | Harmonic Mixer 220 - 325 GHz | Rohde & Schwarz Memmingen | 101006 | 2017-03 | 2020-03 |
| 3.24 | 3160-10 | Standard Gain / Pyramidal Horn Antenna 40 GHz | EMCO Elektronic GmbH | 00086675 | | |
| 3.25 | SGH-08 | Antenna (90 - 140 GHz) | | 064 | | |
| 3.26 | SGH-12 | Antenna (60 - 90 GHz) | | 326 | | |
| 3.27 | 5HC3500/18000-1.2-KK | High Pass Filter | Trilithic | 200035008 | | |
| 3.28 | FS-Z140 | Harmonic Mixer 90 -140 GHz | Rohde & Schwarz Memmingen | 101007 | 2017-02 | 2020-02 |
| 3.29 | HFH2-Z2 | Loop Antenna | Rohde & Schwarz | 829324/006 | 2018-01 | 2021-01 |
| 3.30 | Opus10 THI (8152.00) | ThermoHygro Datalogger 12 (Environ) | Lufft Mess- und Regeltechnik GmbH | 12482 | 2017-03 | 2019-03 |
| 3.31 | ESR 7 | EMI Receiver / Spectrum Analyzer | Rohde & Schwarz | 101424 | 2016-11 | 2018-11 |
| 3.32 | JS4-00101800-35-5P | Broadband Amplifier 30 MHz - 18 GHz | Miteq | 896037 | | |
| 3.33 | AS 620 P | Antenna mast | HD GmbH | 620/37 | | |
| 3.34 | Tilt device Maturo (Rohacell) | Antrieb TD1.5-10kg | Maturo GmbH | TD1.5-10kg/024/3790709 | | |
| 3.35 | SGH-03 | Antenna (220 - 325 GHz) | | 060 | | |
| 3.36 | FS-Z90 | Harmonic Mixer 60 - 90 GHz | Rohde & Schwarz Memmingen | 101686 | 2017-03 | 2020-03 |
| 3.37 | ESIB 26 | Spectrum Analyzer | Rohde & Schwarz | 830482/004 | 2018-01 | 2020-01 |
| 3.38 | PAS 2.5 - 10 kg | Antenna Mast | Maturo GmbH | - | | |
| 3.39 | AFS42-00101800-25-S-42 | Broadband Amplifier 25 MHz - 18 GHz | Miteq | 2035324 | | |
| 3.40 | AM 4.0 | Antenna mast | Maturo GmbH | AM4.0/180/11920513 | | |

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 3.41 | HF 907 | Double-ridged horn | Rohde & Schwarz | 102444 | 2015-05 | 2018-05 |

4 Radio Lab
Conducted Radio Test Lab

| Ref.No. | Device Name | Description | Manufacturer | Serial Number | Last Calibration | Calibration Due |
|---|---|---|---|---|---|---|
| 4.1 | SMB100A | Signal Generator 9 kHz - 6 GHz | Rohde & Schwarz | 107695 | 2017-07 | 2020-07 |
| 4.2 | MFS | Rubidium Frequency Standard | Datum-Beverly | 5489/001 | 2017-07 | 2018-07 |
| 4.3 | FSV30 | Signal Analyzer 10 Hz - 30 GHz | Rohde & Schwarz | 103005 | 2016-02 | 2018-04 |
| 4.4 | Fluke 177 | Digital Multimeter 03 (Multimeter) | Fluke Europe B.V. | 86670383 | 2018-04 | 2020-04 |
| 4.5 | SMP03 | Signal Generator 2 GHz - 27 GHz | Rohde & Schwarz | 833680/003 | 2017-09 | 2020-09 |
| 4.6 | FSIQ26 | Signal Analyser | Rohde & Schwarz | 840061/005 | 2017-05 | 2019-05 |
| 4.7 | Chroma 6404 | AC Power Source | Chroma ATE INC. | 64040001304 | | |
| 4.8 | WA1515 | Broadband Power Divider SMA | Weinschel Associates | A855 | | |
| 4.9 | A8455-4 | 4 Way Power Divider (SMA) | | - | | |
| 4.10 | Opus10 THI (8152.00) | ThermoHygro Datalogger 03 (Environ) | Lufft Mess- und Regeltechnik GmbH | 7482 | 2017-03 | 2019-03 |
| 4.11 | SMBV100A | Vector Signal Generator 9 kHz - 6 GHz | Rohde & Schwarz | 259291 | 2016-10 | 2019-10 |

The calibration interval is the time interval between “Last Calibration” and “Calibration Due”

# 6 ANTENNA FACTORS, CABLE LOSS AND SAMPLE CALCULATIONS

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

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

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

**Sample calculation**

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

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

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

**Sample calculation**

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

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

**($d_{Limit}$ = 3 m)**

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

**($d_{Limit}$ = 10 m)**

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

**Sample calculation**

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

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

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

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

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

**Sample calculation**

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

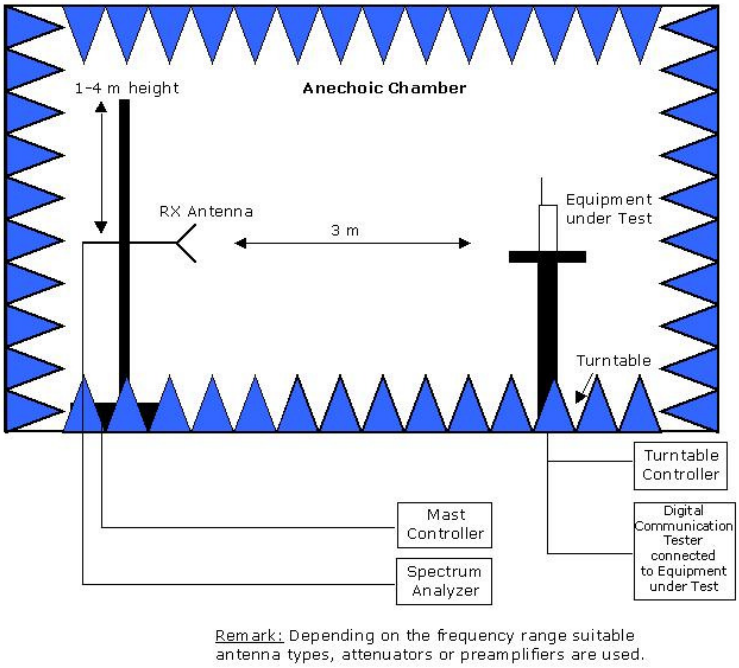
## 6.5 ANTENNA EMCO 3160-09 (18 GHZ – 26.5 GHZ)

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

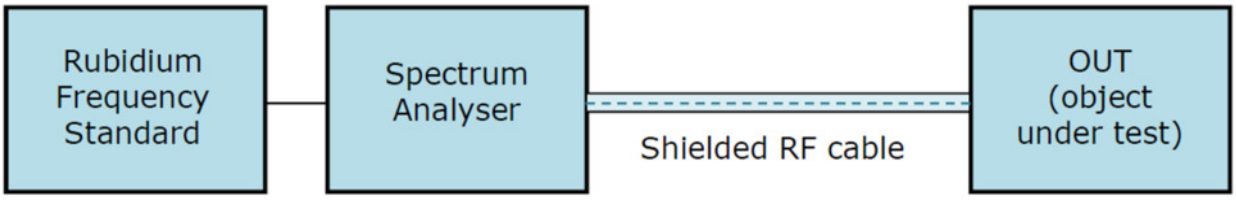
**Sample calculation**

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

# 7 SETUP DRAWINGS




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




**Drawing 2:** Setup for conducted radio tests.

# 8 MEASUREMENT UNCERTAINTIES

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

# 9 PHOTO REPORT

Please see separate photo report.