HERMON LABORATORIES

ELECTRICAL TESTING
0839.01

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# TEST REPORT

**ACCORDING TO:**

**FCC 47CFR part 15 subpart C § 15.247 (Hybrid) and subpart B, Class B**

**FOR:**

## Hoopo Systems Ltd.

## hoopoSense

## Model: 502B1000-1A

## FCC ID: 2AVS8-S01

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# 1 Applicant information

| | |
|---|---|
| **Client name:** | Hoopo Systems Ltd. |
| **Address:** | 5 Ayalon St., Ramat Hasharon, 4700225 Israel |
| **Telephone:** | 052-5192244 |
| **E-mail:** | menachem@hoopo.tech |
| **Contact name:** | Mr. Menachem Tipris |

# 2 Equipment under test attributes

| | |
|---|---|
| **Product name:** | hoopoSense |
| **Product type:** | IoT Sensor |
| **Model(s):** | 502B1000-1A |
| **Serial number:** | 24 |
| **Hardware version:** | 0.0 |
| **Software release:** | 1.3 |
| **Receipt date** | 22-Nov-19 |

# 3 Manufacturer information

| | |
|---|---|
| **Manufacturer name:** | Hoopo Systems Ltd. |
| **Address:** | 5 Ayalon St., Ramat Hasharon, 4700225 Israel |
| **Telephone:** | 052-5192244 |
| **E-Mail:** | menachem@hoopo.tech |
| **Contact name:** | Mr. Menachem Tipris |

# 4 Test details

| | |
|---|---|
| **Project ID:** | 35117 |
| **Location:** | Primary: Hermon Laboratories Ltd. P.O. Box 23, Binyamina 3055001, Israel<br>Satellite: Hermon Laboratories Ltd. Hefetz-Haim 10, Tel Aviv 6744124, Israel |
| **Test started:** | 17-Dec-19 |
| **Test completed:** | 11-Feb-20 |
| **Test specification(s):** | FCC 47CFR part 15 subpart C § 15.247 (Hybrid) and subpart B, Class B |

# 5 Tests summary

| Test | Status |
|---|---|
| **Transmitter characteristics** | |
| Section 15.247(a)1, 20 dB bandwidth | Pass |
| Section 15.247(a)1, Frequency separation | Pass |
| Section 15.247(a)1, Number of hopping frequencies | Pass |
| Section 15.247(a)1, Average time of occupancy | Pass |
| Section 15.247(b), Peak output power | Pass |
| Section 15.247(e), Peak spectral density | Pass |
| Section 15.247(d), Radiated spurious emissions | Pass |
| Section 15.247(i), RF exposure | Pass* |
| Section 15.247(d), Emissions at band edges | Pass |
| Section 15.207(a), Conducted emission | Not required |
| Section 15.203, Antenna requirements | Pass |
| **Unintentional emissions** | |
| Section 15.107, Class B, Conducted emission at AC power port | Not required |
| Section 15.109, Class B, Radiated emission | Pass |

* - Pass, the exhibit to the application of certification is provided.

Testing was completed against all relevant requirements of the test standard. The results obtained indicate that the product under test complies in full with the requirements tested.
The test results relate only to the items tested. Pass/ fail decision was based on nominal values.

| | Name and Title | Date | Signature |
|---|---|---|---|
| **Tested by:** | Mr. I. Zilberstein, test engineer,<br>EMC & Radio<br>Mrs. E. Pitt, test engineer,<br>EMC & Radio | 17-Dec-19 – 11-Feb-20 | |
| **Reviewed by:** | Mrs. S. Peysahov Sheynin, test engineer,<br>EMC & Radio | 03-May-20 | |
| **Approved by:** | Mr. S. Samokha, technical manager,<br>EMC & Radio | 14-June-20 | |

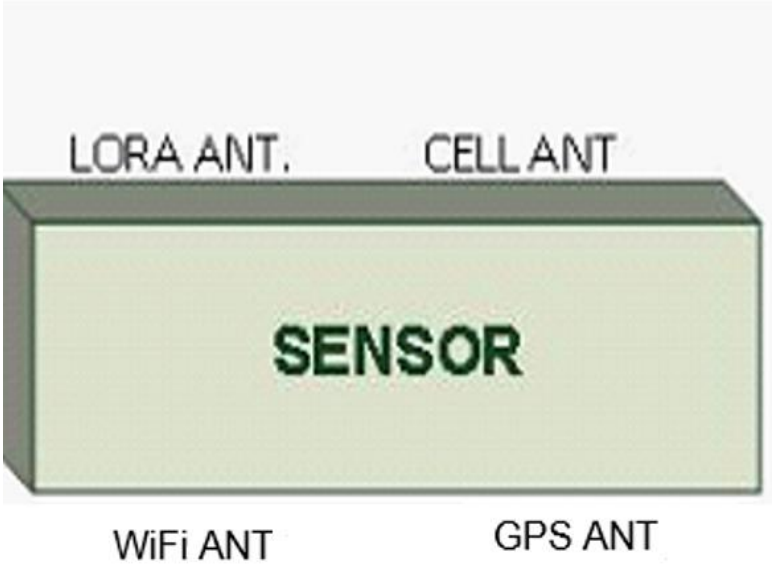
# 6 EUT description

Note: The following data in this clause is provided by the customer and represents his sole responsibility

## 6.1 General information

The EUT, a hoopoSense, is a low power device powered by four AA prime batteries. The device is equiped with a LoRa transceiver, an optional cellular modem, a WiFi receiver and a GPS device.

## 6.2 Test configuration




## 6.3 Changes made in EUT

No changes were implemented in the EUT during the testing.

## 6.4 Transmitter characteristics

| **Type of equipment** | |
|---|---|
| X | Stand-alone (Equipment with or without its own control provisions) |
| | Combined equipment (Equipment where the radio part is fully integrated within another type of equipment) |
| | Plug-in card (Equipment intended for a variety of host systems) |

| **Intended use** | | **Condition of use** |
|---|---|---|
| | fixed | Always at a distance more than 2 m from all people |
| X | mobile | Always at a distance more than 20 cm from all people |
| | portable | May operate at a distance closer than 20 cm to human body |

| | |
|---|---|
| **Assigned frequency ranges** | 902 – 928 MHz |
| **Operating frequencies** | 902.5 – 927.5 MHz |

| | | |
|---|---|---|
| **Maximum rated output power** | At transmitter 50 Ω RF output connector | |
| | Peak output power | 8.20 dBm |

| | | | | | |
|---|---|---|---|---|---|
| **Is transmitter output power variable?** | | No | | | |
| | X | Yes | | continuous variable | |
| | | | X | stepped variable with stepsize | 1 dB |
| | | | minimum RF power | | -1.8dBm |
| | | | maximum RF power | | +8.2 dBm |

| **Antenna connection** | | | | |
|---|---|---|---|---|
| unique coupling | standard connector | X | integral | with temporary RF connector |
| | | | | X without temporary RF connector |

| **Antenna/s technical characteristics** | | | |
|---|---|---|---|
| Type | Manufacturer | Model number | Gain |
| Internal | Hoopo systems | part of PCB | 2 dBi |

| | |
|---|---|
| **Transmitter aggregate data rate/s** | 980 bps/5470 bps |
| **Type of modulation** | LoRa |
| **Modulating test signal (baseband)** | PRBS |

| **Transmitter power source** | | | | | |
|---|---|---|---|---|---|
| X | Battery | **Nominal rated voltage** | 3 VDC | Battery type | L91 or L6 |
| | DC | **Nominal rated voltage** | | | |
| | AC mains | **Nominal rated voltage** | | Frequency | |

| | | |
|---|---|---|
| **Common power source for transmitter and receiver** | X yes | no |

| | | |
|---|---|---|
| **Spread spectrum technique used** | | Frequency hopping (FHSS) |
| | | Digital transmission system (DTS) |
| | X | Hybrid |

| **Spread spectrum parameters for transmitters tested per FCC 15.247 only** | | |
|---|---|---|
| **FHSS** | Total number of hops | 16 |
| | Bandwidth per hop | 166.456 kHz |
| | Max. separation of hops | 200 kHz |

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, 20 dB bandwidth** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.7 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

# 7 Transmitter tests according to 47CFR part 15 subpart C requirements

## 7.1 20 dB bandwidth

### 7.1.1 General

This test was performed to measure 20 dB bandwidth of the transmitter hopping channel. Specification test limits are given in Table 7.1.1.

**Table 7.1.1 The 20 dB bandwidth limits**

| Assigned frequency, MHz | Maximum bandwidth, kHz | Modulation envelope reference points*, dBc |
|---|---|---|
| 902.0 – 928.0 | 250 | 20 |

* - Modulation envelope reference points provided in terms of attenuation below the peak of modulated carrier.

### 7.1.2 Test procedure

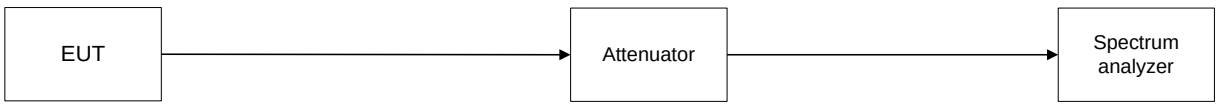
**7.1.2.1** The EUT was set up as shown in Figure 7.1.1, energized and its proper operation was checked.

**7.1.2.2** The EUT was set to transmit modulated carrier at maximum data rate.

**7.1.2.3** The transmitter bandwidth was measured with spectrum analyzer as frequency delta between reference points on modulation envelope and provided in Table 7.1.2 and associated plot.

**7.1.2.4** The test was repeated for each data rate and each modulation format.

**Figure 7.1.1 The 20 dB bandwidth test setup**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, 20 dB bandwidth** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.7 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.1.2 The 20 dB bandwidth test results**

| | |
|---|---|
| ASSIGNED FREQUENCY BAND: | 902-928 MHz |
| DETECTOR USED: | Peak |
| SWEEP TIME: | Auto |
| VIDEO BANDWIDTH: | ≥ RBW |
| MODULATION ENVELOPE REFERENCE POINTS: | 20.0 dBc |
| MODULATING SIGNAL: | PRBS |
| FREQUENCY HOPPING: | Disabled |

| Carrier frequency, MHz | Type of modulation | Data rate, bps | Symbol rate, Msymbols/s | 20 dB bandwidth, kHz | Limit, kHz | Margin, kHz | Verdict |
|---|---|---|---|---|---|---|---|
| 902.5 | LoRa | 980 | NA | 166.456 | 250 | -83.544 | Pass |
| | | 5470 | | 162.128 | 250 | -87.872 | Pass |
| 915.0 | LoRa | 980 | NA | 165.023 | 250 | -84.977 | Pass |
| | | 5470 | | 161.883 | 250 | -88.117 | Pass |
| 927.5 | LoRa | 980 | NA | 164.969 | 250 | -85.031 | Pass |
| | | 5470 | | 162.154 | 250 | -87.846 | Pass |

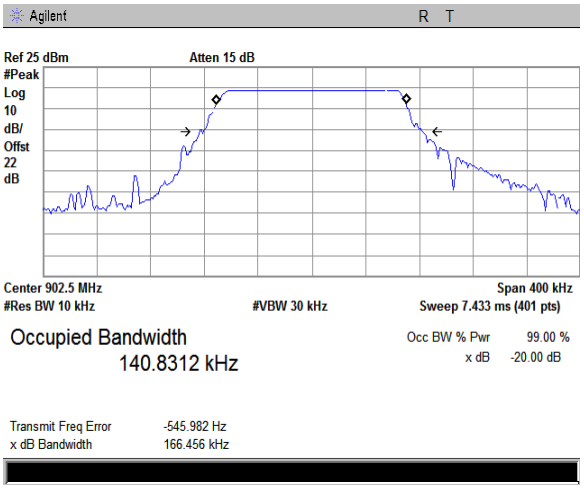
**Reference numbers of test equipment used**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| HL 2909 | HL 5111 | HL 5612 | HL 5606 | | | | | |

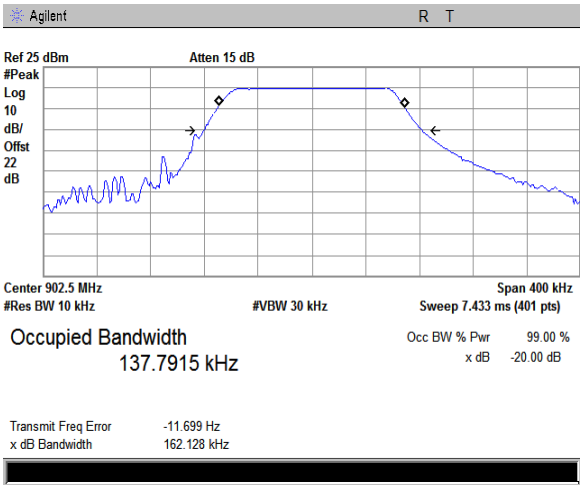
Full description is given in Appendix A.

| **Test specification:** | **Section 15.247(a)1, 20 dB bandwidth** | | |
|---|---|---|---|
| **Test procedure:** | ANSI C63.10, section 7.8.7 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.1.1 The 20 dB bandwidth test result at low frequency**

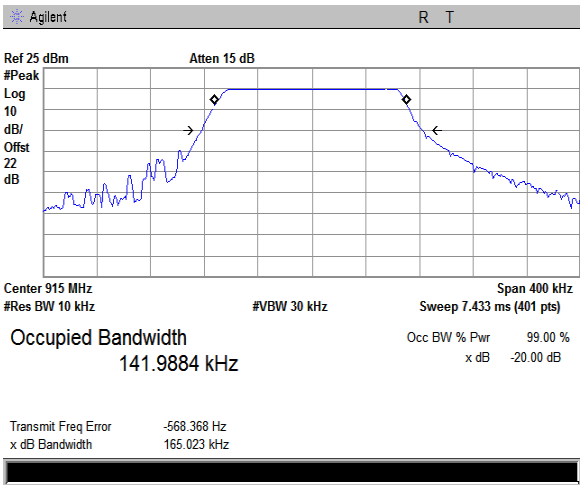



Data rate: 980 bps

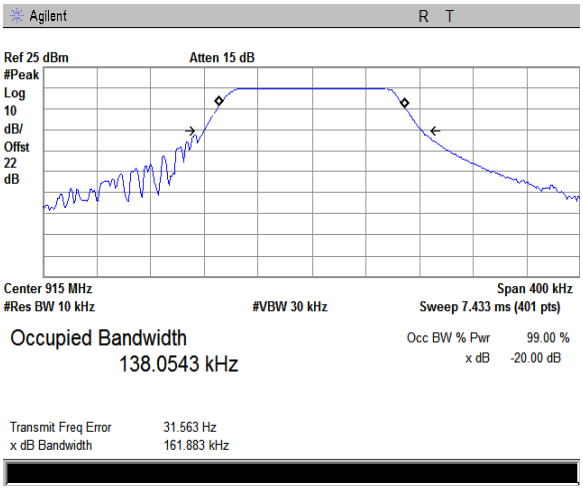



Data rate: 5470 bps

**Plot 7.1.2 The 20 dB bandwidth test result at mid frequency**



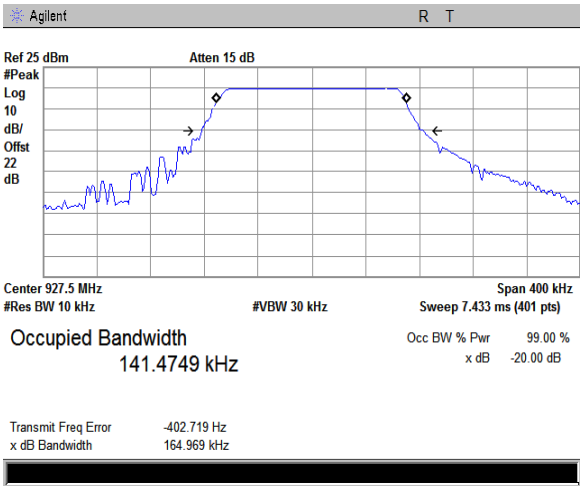

Data rate: 980 bps



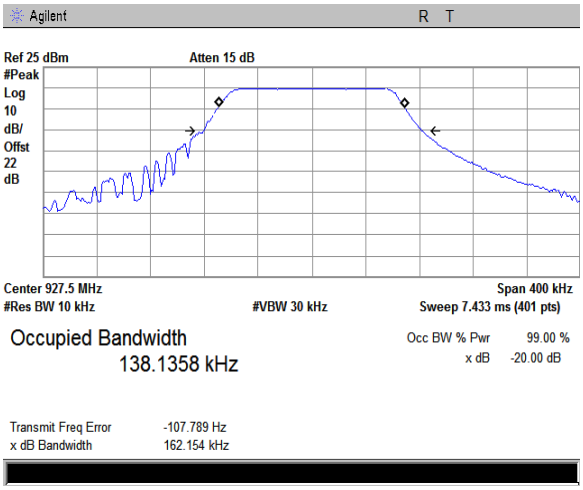

Data rate: 5470 bps

| **Test specification:** | **Section 15.247(a)1, 20 dB bandwidth** | | |
|---|---|---|---|
| **Test procedure:** | ANSI C63.10, section 7.8.7 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.1.3 The 20 dB bandwidth test result at high frequency**




Data rate: 980 bps




Data rate: 5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Frequency separation** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.2 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3.2 VDC |
| **Remarks:** | | | |

## 7.2 Carrier frequency separation

### 7.2.1 General

This test was performed to measure frequency separation between the peaks of adjacent channels. Specification test limits are given in Table 7.2.1.

**Table 7.2.1 Carrier frequency separation limits**

| Assigned frequency range, MHz | Carrier frequency separation |
|---|---|
| 902.0 – 928.0 | 25 kHz or 20 dB bandwidth of the hopping channel, whichever is greater |

### 7.2.2 Test procedure

**7.2.2.1** The EUT was set up as shown in Figure 7.2.1, energized with frequency hopping function enabled and its proper operation was checked.

**7.2.2.2** The spectrum analyzer span was set to capture the carrier frequency and both of adjacent channels, the lower and the higher. The resolution bandwidth was set wider than 1 % of the frequency span.

**7.2.2.3** The spectrum analyzer was set in max hold mode and allowed trace to stabilize.

**7.2.2.4** The frequency separation between the peaks of adjacent channels was measured as provided in Table 7.2.2 and associated plots.

**Figure 7.2.1 Carrier frequency separation test setup**

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Frequency separation** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.2 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3.2 VDC |
| **Remarks:** | | | |

**Table 7.2.2 Carrier frequency separation test results**

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: ≥ 1% of the span
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled
20 dB BANDWIDTH: 166.456 kHz

| Carrier frequency separation, kHz | Limit, kHz | Margin* | Verdict |
|---|---|---|---|
| 200.0 | 166.456 | 33.544 | Pass |

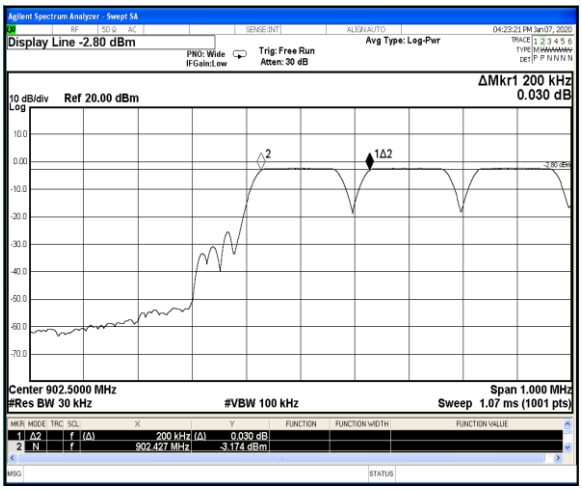
* - Margin = Carrier frequency separation – specification limit.

**Reference numbers of test equipment used**

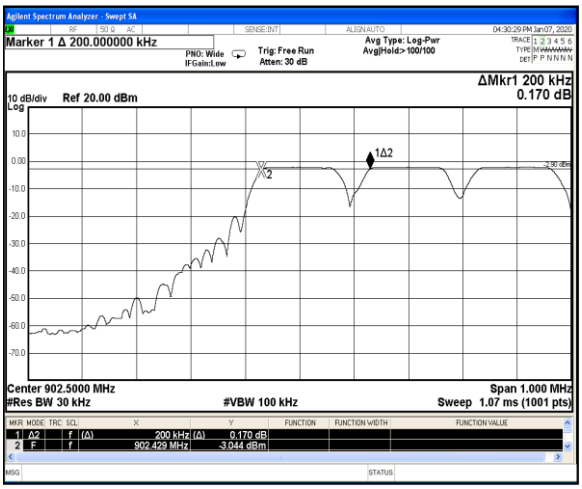
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 2909 | HL 5111 | HL 5612 | HL 5606 | | | | |

Full description is given in Appendix A.

**Plot 7.2.1 Carrier frequency separation**




980 bps




5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Number of hopping frequencies** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.3 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3.2 VDC |
| **Remarks:** | | | |

## 7.3 Number of hopping frequencies

### 7.3.1 General

This test was performed to calculate the number of hopping frequencies used by the EUT. Specification test limits are given in Table 7.3.1.

**Table 7.3.1 Minimum number of hopping frequencies**

| Assigned frequency range, MHz | Number of hopping frequencies |
|---|---|
| 902.0 – 928.0 | 50 (if the 20 dB bandwidth is less than 250 kHz) |

### 7.3.2 Test procedure

**7.3.2.1** The EUT was set up as shown in Figure 7.3.1, energized with frequency hopping function enabled and its proper operation was checked.

**7.3.2.2** Initially the spectrum analyzer span was set equal to frequency band of operation and the resolution bandwidth was set wider than 1 % of the frequency span. If the separate hopping channels were not clearly resolved the frequency band of operation was broken to sections and the resolution bandwidth was set wider than 1 % of the frequency span of each section.

**7.3.2.3** The spectrum analyzer was set in max hold mode and allowed trace to stabilize.

**7.3.2.4** The number of frequency hopping channels was calculated as provided in Table 7.3.2 and associated plots.

**Figure 7.3.1 Hopping frequencies test setup**

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Number of hopping frequencies** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.3 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 19-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 38 % | **Air Pressure:** 1008 hPa | **Power:** 3.2 VDC |
| **Remarks:** | | | |

**Table 7.3.2 Hopping frequencies test results**

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
VIDEO BANDWIDTH: ≥ RBW
FREQUENCY HOPPING: Enabled

| Number of hopping frequencies | Minimum number of hopping frequencies | Margin* | Verdict |
|---|---|---|---|
| 16 | NA for hybrid mode | NA | Pass |

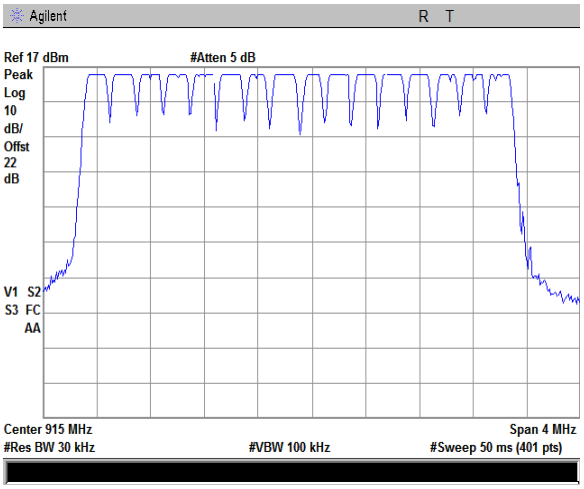
* - Margin = Number of hopping frequencies – Minimum number of hopping frequencies.

**Reference numbers of test equipment used**

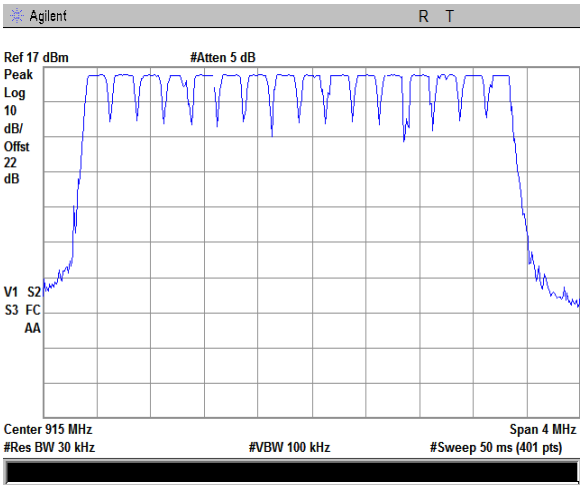
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 2909 | HL 5111 | HL 5612 | HL 5606 | | | | |

Full description is given in Appendix A.

**Plot 7.3.1 Number of hopping frequencies**




980 bps




5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Average time of occupancy** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1009 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.4 Average time of occupancy

### 7.4.1 General

This test was performed to calculate the average time of occupancy (dwell time) on any frequency channel of the EUT. Specification test limits are given in Table 7.4.1.

**Table 7.4.1 Average time of occupancy limits**

| Assigned frequency range, MHz | Maximum average time of occupancy, s | Investigated period, s | Number of hopping frequencies |
|---|---|---|---|
| 902.0 – 928.0 | 0.4 | 20.0 | ≥ 50 |
| 902.0 – 928.0 | 0.4 | 10.0 | < 50 |
| **902.0 – 928.0** | **0.4** | **0.4 × N** | **N = 16** |

### 7.4.2 Test procedure

**7.4.2.1** The EUT was set up as shown in Figure 7.4.1, energized with frequency hopping function enabled and its proper operation was checked.

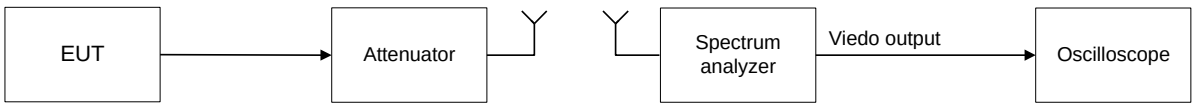
**7.4.2.2** The spectrum analyzer span was set to zero centered on a hopping channel.

**7.4.2.3** The single transmission duration and period were measured with oscilloscope.

**7.4.2.4** The average time of occupancy was calculated as the single transmission time multiplied by the investigated period and divided by the single transmission period.

**7.4.2.5** The test was repeated at each data rate and modulation type as provided in Table 7.4.2 and associated plots.

**Figure 7.4.1 Average time of occupancy test setup**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Average time of occupancy** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1009 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.4.2 Average time of occupancy test results**

ASSIGNED FREQUENCY: 902-928 MHz
MODULATION: LoRa
DETECTOR USED: Peak
NUMBER OF HOPPING FREQUENCIES: 16
INVESTIGATED PERIOD: 6.4 s
FREQUENCY HOPPING: Enabled

| Carrier frequency, MHz | Single transmission duration, ms | Single transmission period, s | Average time of occupancy*, s | Bit rate, bps | Symbol rate, Msymbol/s | Limit, s | Margin, s** | Verdict |
|---|---|---|---|---|---|---|---|---|
| 915 | 327 | > 6.4 | 0.3270 | 980 | NA | 0.4 | 0.0730 | Pass |
| 915 | 51.25 | > 6.4 | 0.0513 | 5470 | NA | 0.4 | 0.3487 | Pass |

* - Average time of occupancy = the transmit time per hop × the number of hops in the investigated period.

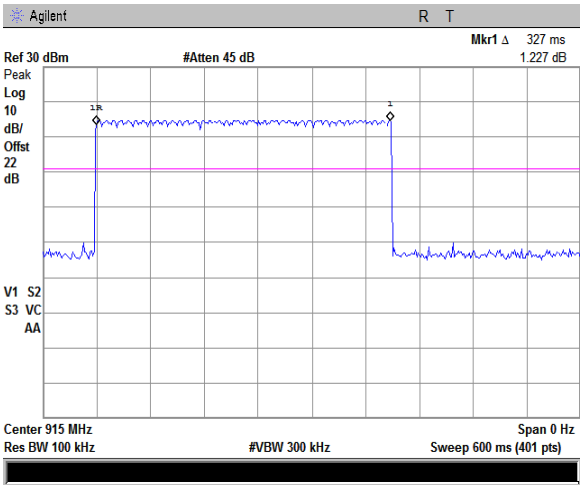
**Reference numbers of test equipment used**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 2909 | HL | HL | | | | | |

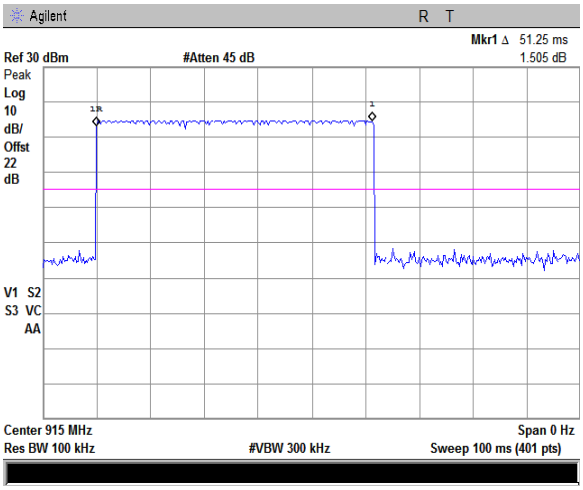
Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(a)1, Average time of occupancy** | | |
| **Test procedure:** | ANSI C63.10, section 7.8.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1009 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.4.1 Single transmission duration at mid frequency**

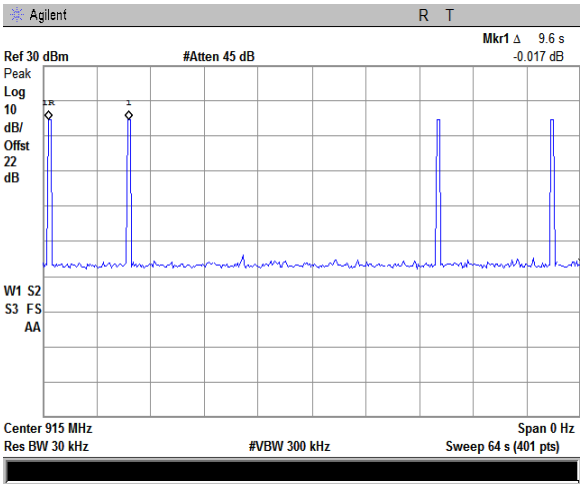



980 bps

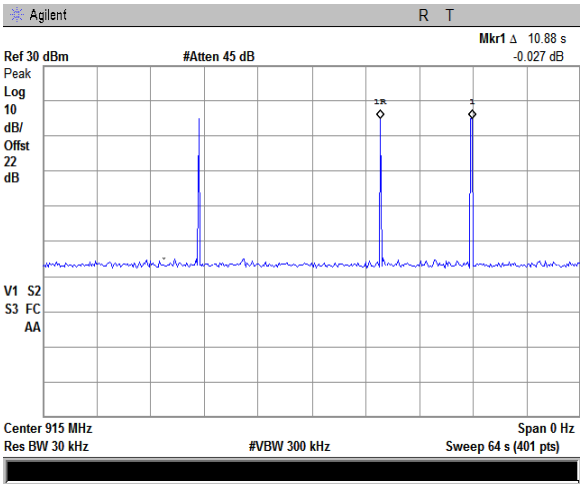



5470 bps

**Plot 7.4.2 Single transmission period**




980 bps




5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.5 Peak output power

### 7.5.1 General

This test was performed to measure the maximum peak output power radiated by transmitter. Specification test limits are given in Table 7.5.1.

**Table 7.5.1 Peak output power limits**

| Assigned frequency range, MHz | Peak output power* | | Equivalent field strength limit @ 3m, dB(µV/m)* | Maximum antenna gain, dBi |
|---|---|---|---|---|
| | W | dBm | | |
| 902.0 – 928.0 | 0.25 (<50 hopping channels) | 24.0(<50 hopping channels) | 125.2 (<50 hopping channels) | 6.0* |

*- Equivalent field strength limit was calculated from the peak output power as follows: E=sqrt(30×P×G)/r, where P is peak output power in Watts, r is antenna to EUT distance in meters and G is transmitter antenna gain in dBi.
**- The limit is provided in terms of conducted RF power at the antenna connector. If transmitting antennas of directional gain greater than 6 dBi are used, the peak output power limit shall be reduced below the stated value as follows:

- by 1 dB for every 3 dB that the directional gain of antenna exceeds 6 dBi for fixed point-to-point transmitters operate in 2400-2483.5 MHz band;
- without any corresponding reduction for fixed point-to-point transmitters operate in 5725-5850 MHz band;
- by the amount in dB that the directional gain of antenna exceeds 6 dBi for the rest of transmitters.

### 7.5.2 Test procedure

**7.5.2.1** The EUT was set up as shown in Figure 7.5.1, energized and its proper operation was checked.

**7.5.2.2** The EUT was adjusted to produce maximum available to end user RF output power.

**7.5.2.3** The frequency span of spectrum analyzer was set approximately 5 times wider than 20 dB bandwidth of the EUT and the resolution bandwidth was set wider than 20 dB bandwidth of the EUT. To find maximum radiation the turntable was rotated $360^0$ and the measuring antenna height was swept in both vertical and horizontal polarizations.

**7.5.2.4** The maximum field strength of the EUT carrier frequency was measured as provided in Table 7.5.2 and associated plots.

**7.5.2.5** The maximum peak output power was calculated from the field strength of carrier as follows:

$$P = (E \times d)^2 / (30 \times G),$$

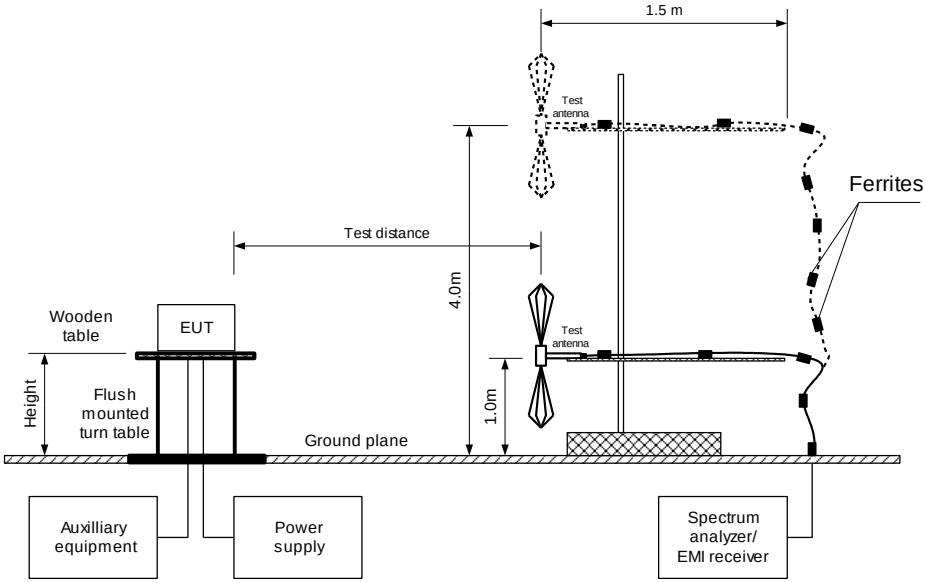
where P is the peak output power in W, E is the field strength in V/m, d is the test distance and G is the transmitter numeric antenna gain over an isotropic radiator.
The above equation was converted in logarithmic units for 3 m test distance:

Peak output power in dBm = Field strength in dB(µV/m) - Transmitter antenna gain in dBi – 95.2 dB

**7.5.2.6** The worst test results (the lowest margins) were recorded in Table 7.5.2.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Figure 7.5.1 Setup for carrier field strength measurements**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.5.2 Peak output power test results**

ASSIGNED FREQUENCY: 902.0 – 928.0 MHz
TEST DISTANCE: 3 m
TEST SITE: Semi anechoic chamber
EUT HEIGHT: 0.8 m
DETECTOR USED: Peak
TEST ANTENNA TYPE: Biconilog (30 MHz – 1000 MHz)
Double ridged guide (above 1000 MHz)
MODULATION: LoRa
MODULATING SIGNAL: PRBS

TRANSMITTER OUTPUT POWER SETTINGS: Maximum
DETECTOR USED: Peak
RESOLUTION BANDWIDTH: 1 MHz
VIDEO BANDWIDTH: 10 MHz

BIT RATE: 980 bps

| Frequency, MHz | Field strength, dB(μV/m) | Antenna polarization | Antenna height, m | Azimuth, degrees* | EUT antenna gain, dBi | Peak output power, dBm** | Limit, dBm | Margin, dB*** | Verdict |
|---|---|---|---|---|---|---|---|---|---|
| 902.5 | 105.40 | Horizontal | 1.40 | 33 | 2.0 | 8.20 | 24.0 | -15.80 | Pass |
| 915.0 | 103.15 | Horizontal | 1.40 | 42 | 2.0 | 5.95 | 24.0 | -18.05 | Pass |
| 927.5 | 99.70 | Horizontal | 1.40 | 35 | 2.0 | 2.50 | 24.0 | -21.50 | Pass |

BIT RATE: 5470 bps

| Frequency, MHz | Field strength, dB(μV/m) | Antenna polarization | Antenna height, m | Azimuth, degrees* | EUT antenna gain, dBi | Peak output power, dBm** | Limit, dBm | Margin, dB*** | Verdict |
|---|---|---|---|---|---|---|---|---|---|
| 902.5 | 105.06 | Horizontal | 1.40 | 33 | 2.0 | 7.86 | 24.0 | -16.14 | Pass |
| 915.0 | 102.22 | Horizontal | 1.40 | 42 | 2.0 | 5.02 | 24.0 | -18.98 | Pass |
| 927.5 | 98.99 | Horizontal | 1.40 | 35 | 2.0 | 1.79 | 24.0 | -22.21 | Pass |

*****- EUT front panel refer to 0 degrees position of turntable.
******- Peak output power was calculated from the field strength of carrier as follows: $P = (E \times d)^2 / (30 \times G)$,
where P is the peak output power in W, E is the field strength in V/m, d is the test distance in meters and G is the transmitter numeric antenna gain over an isotropic radiator. The above equation was converted in logarithmic units for 3 m test distance: *Peak output power in dBm = Field strength in dB(μV/m) - Transmitter antenna gain in dBi – 95.2 dB*
***- Margin = Peak output power – specification limit.
Note: Maximum peak output power was obtained at Unom (115%Unom, 85%Unom) input power voltage.

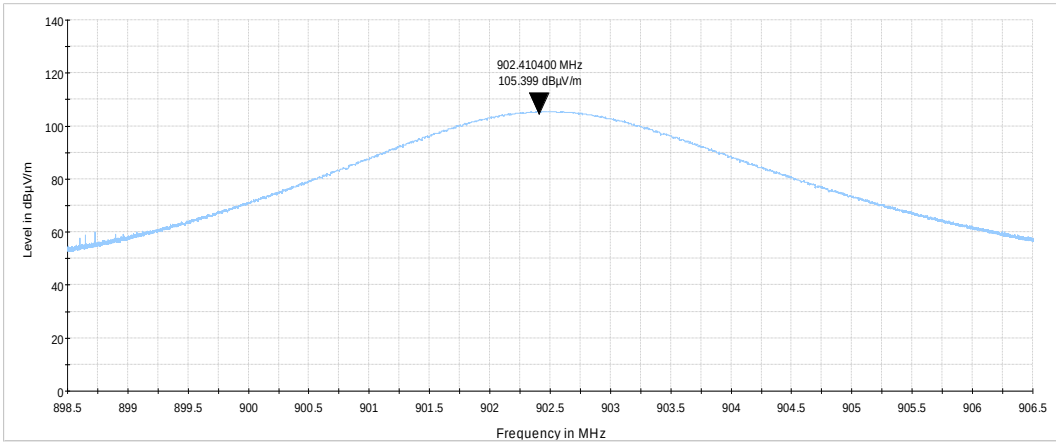
**Reference numbers of test equipment used**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 3903 | HL 4360 | HL 5288 | HL 5665 | | | | |

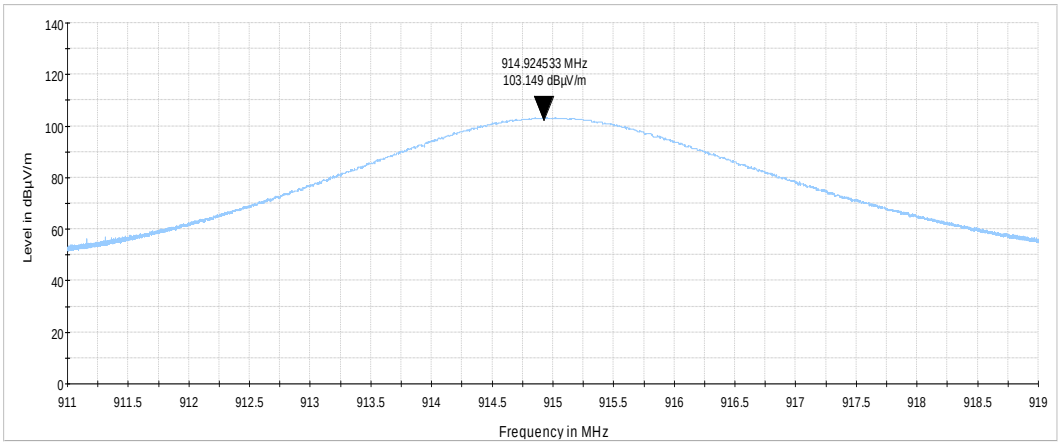
Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.5.1 Field strength of carrier at low frequency and bitrate 980 bps**

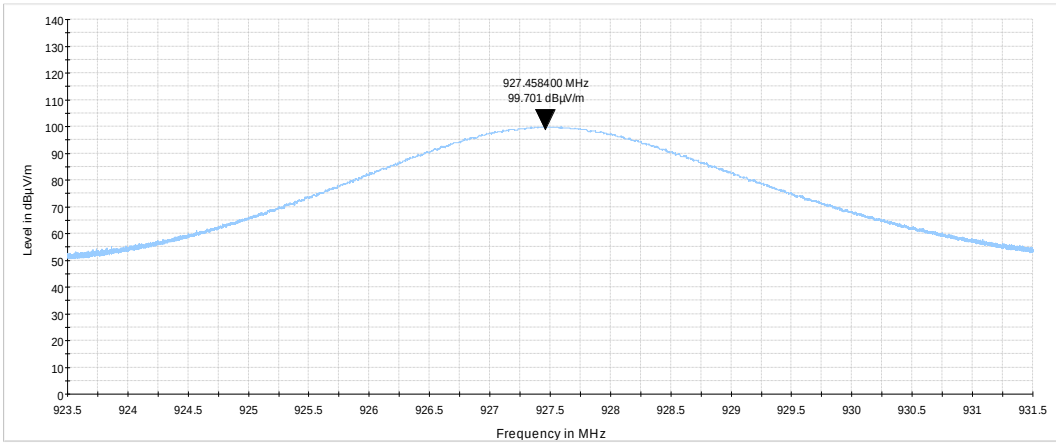



**Plot 7.5.2 Field strength of carrier at mid frequency and bitrate 980 bps**



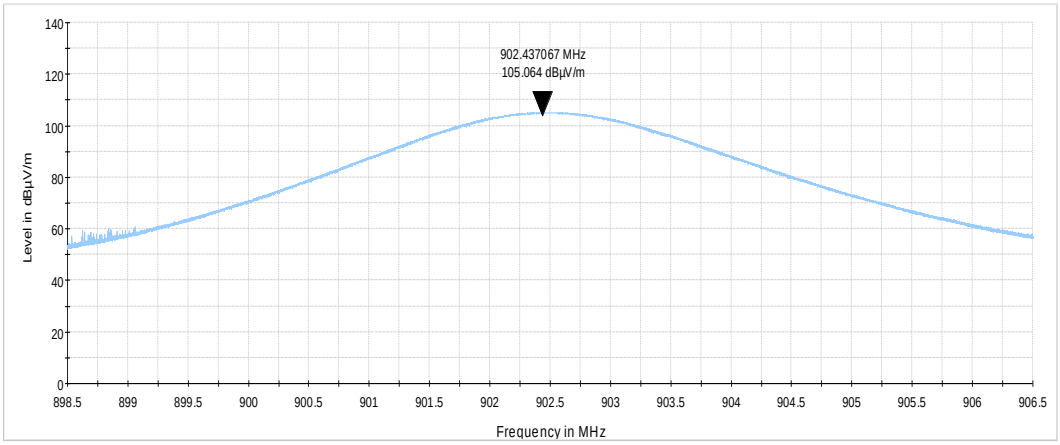
| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.5.3 Field strength of carrier at high frequency and bitrate 980 bps**

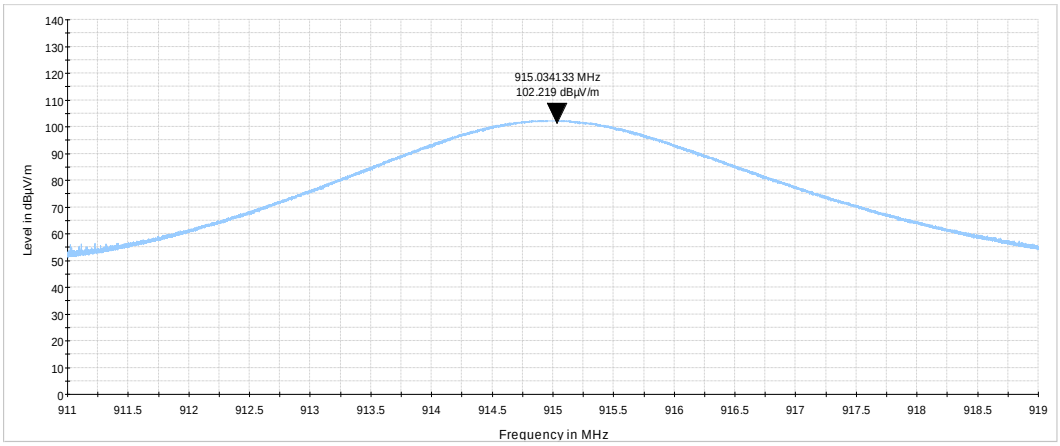


| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.5.4 Field strength of carrier at low frequency and bitrate 5470 bps**

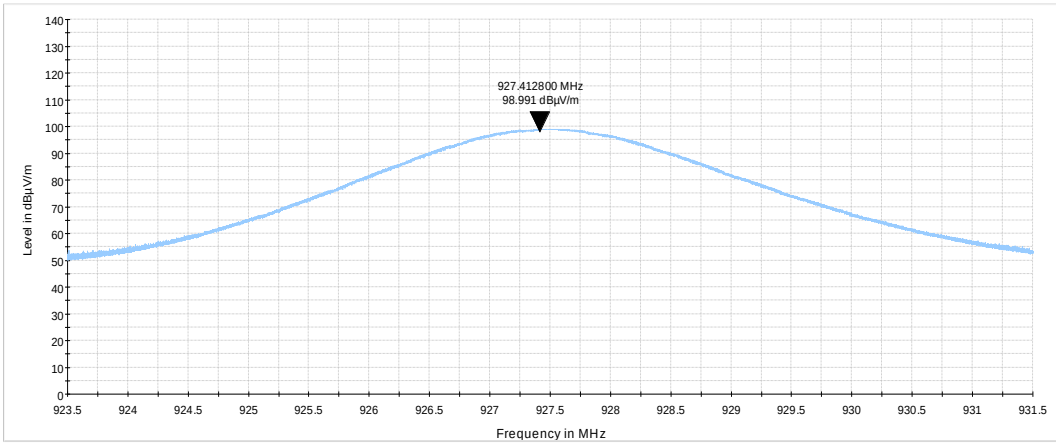



**Plot 7.5.5 Field strength of carrier at mid frequency and bitrate 5470 bps**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(b), Peak output power** | | |
| **Test procedure:** | ANSI C63.10, section 11.9.2.2.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 18-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1027 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.5.6 Field strength of carrier at high frequency and bitrate 5470 bps**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Peak power density** | | |
| **Test procedure:** | ANSI C63.10, section 11.10.5 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.6 Peak spectral power density

### 7.6.1 General

This test was performed to measure the peak spectral power density radiated by the transmitter RF antenna. Specification test limits are given in Table 7.6.1.

**Table 7.6.1 Peak spectral power density limits**

| Assigned frequency range, MHz | Measurement bandwidth, kHz | Peak spectral power density, dBm | Equivalent field strength limit @ 3m, dB(μV/m)* |
|---|---|---|---|
| 902.0 – 928.0 | 3.0 | 8.0 | 103.2 |

* - Equivalent field strength limit was calculated from the peak spectral power density as follows: E=sqrt(30×P)/r, where P is peak spectral power density and r is antenna to EUT distance in meters.

### 7.6.2 Test procedure for field strength measurements

**7.6.2.1** The EUT was set up as shown in Figure 7.6.1, energized and its proper operation was checked.

**7.6.2.2** The EUT was adjusted to produce maximum available to end user RF output power.

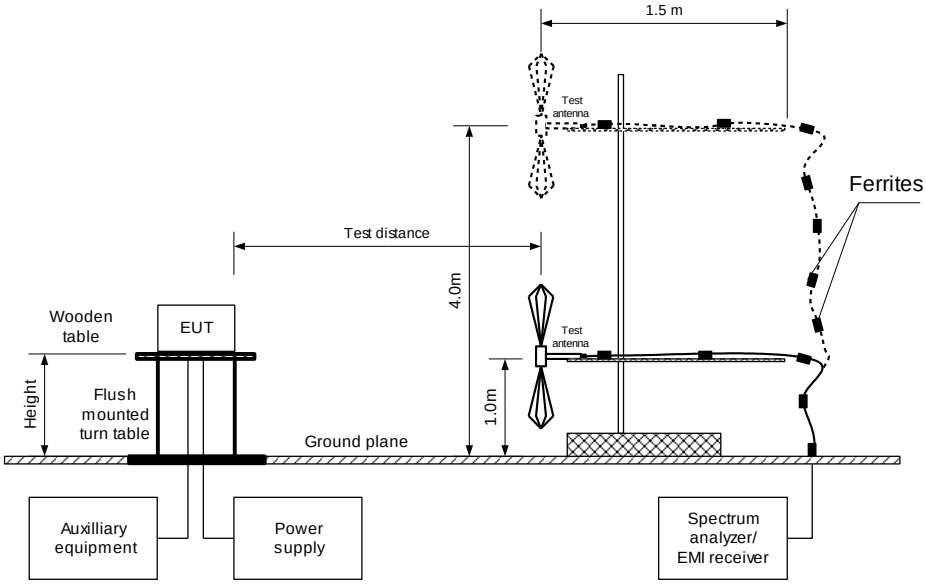
**7.6.2.3** The field strength of the EUT carrier frequency was measured with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated $360^0$ and the measuring antenna height was swept in both vertical and horizontal polarizations.

**7.6.2.4** The frequency span of spectrum analyzer was set to capture the entire 6 dB band of the transmitter, in peak hold mode with resolution bandwidth set to 3.0 kHz, video bandwidth wider than resolution bandwidth, auto sweep time and sufficient number of sweeps was allowed for trace stabilization. The spectrum lines spacing was verified to be wider than 3 kHz. Otherwise the resolution bandwidth was reduced until individual spectrum lines were resolved and the power of individual spectrum lines was integrated over 3 kHz band.

**7.6.2.5** The peak of emission was zoomed with span set just wide enough to capture the emission peak area and sweep time was set equal to span width divided by resolution bandwidth. Spectrum analyzer was set in peak hold mode, sufficient number of sweeps was allowed for trace stabilization and peak spectral power density was measured as provided in Table 7.6.2 and associated plots.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Peak power density** | | |
| **Test procedure:** | ANSI C63.10, section 11.10.5 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Figure 7.6.1 Setup for carrier field strength measurements**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Peak power density** | | |
| **Test procedure:** | ANSI C63.10, section 11.10.5 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.6.2 Field strength measurement of peak spectral power density**

| | |
|---|---|
| ASSIGNED FREQUENCY: | 902.0 – 928.0 MHz |
| TEST DISTANCE: | 3 m |
| TEST SITE: | Semi anechoic chamber |
| EUT HEIGHT: | 0.8 m |
| DETECTOR USED: | Peak |
| RESOLUTION BANDWIDTH: | 3 kHz |
| VIDEO BANDWIDTH: | 10 kHz |
| TEST ANTENNA TYPE: | Biconilog (30 MHz – 1000 MHz) |
| MODULATION: | LoRa |
| MODULATING SIGNAL: | PRBS |
| TRANSMITTER OUTPUT POWER SETTINGS: | Maximum |

BIT RATE: 980 bps

| Frequency, MHz | Field strength, dB(μV/m) | EUT antenna gain, dBi | Limit, dB(μV/m) | Margin, dB* | Antenna polarization | Antenna height, m | Turn-table position**, degrees |
|---|---|---|---|---|---|---|---|
| 902.5 | 104.53 | 2.0 | 8.0 | -0.67 | Horizontal | 1.4 | 33 |
| 915.0 | 102.31 | 2.0 | 8.0 | -2.89 | Horizontal | 1.4 | 42 |
| 927.5 | 98.63 | 2.0 | 8.0 | -6.57 | Horizontal | 1.4 | 35 |

BIT RATE: 5470 bps

| Frequency, MHz | Field strength, dB(μV/m) | EUT antenna gain, dBi | Limit, dB(μV/m) | Margin, dB* | Antenna polarization | Antenna height, m | Turn-table position**, degrees |
|---|---|---|---|---|---|---|---|
| 902.5 | 102.23 | 2.0 | 8.0 | -2.97 | Horizontal | 1.4 | 33 |
| 915.0 | 99.10 | 2.0 | 8.0 | -6.10 | Horizontal | 1.4 | 42 |
| 927.5 | 95.33 | 2.0 | 8.0 | -9.87 | Horizontal | 1.4 | 35 |

*****- Margin = Field strength - EUT antenna gain - calculated field strength limit.
******- EUT front panel refer to 0 degrees position of turntable.

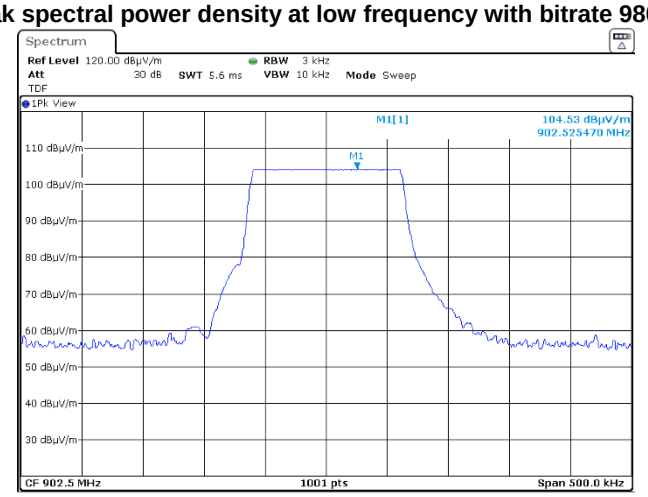
**Reference numbers of test equipment used**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 3903 | HL 4355 | HL 5288 | HL 5665 | | | | |

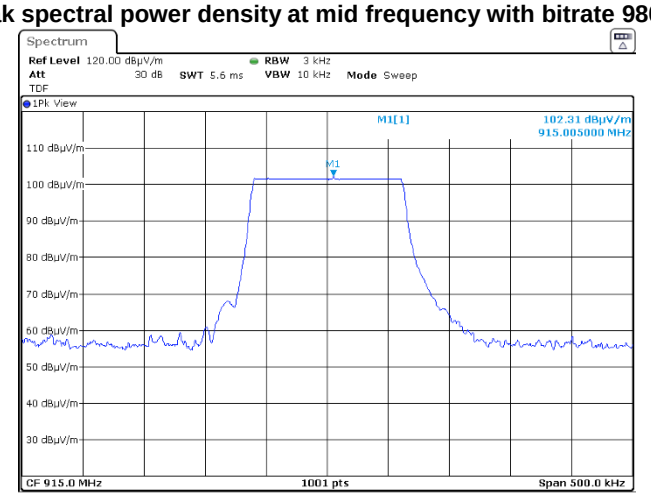
Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Peak power density** | | |
| **Test procedure:** | ANSI C63.10, section 11.10.5 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

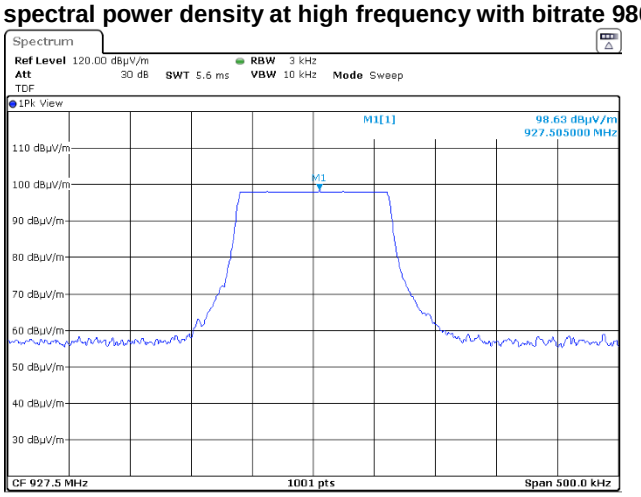
**Plot 7.6.1 Peak spectral power density at low frequency with bitrate 980 bps**




**Plot 7.6.2 Peak spectral power density at mid frequency with bitrate 980 bps**

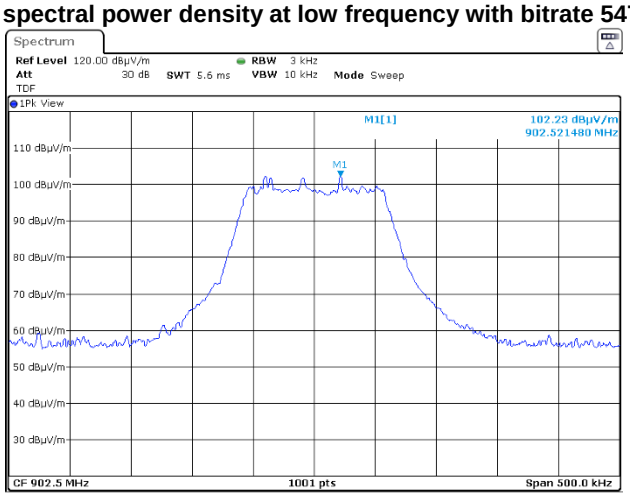



**Plot 7.6.3 Peak spectral power density at high frequency with bitrate 980 bps**

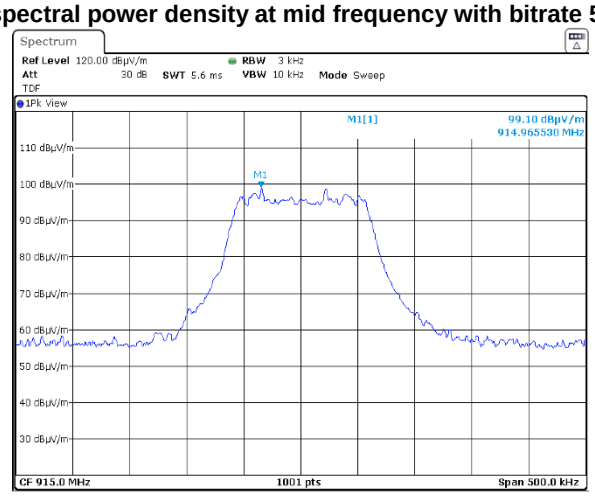


| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Peak power density** | | |
| **Test procedure:** | ANSI C63.10, section 11.10.5 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

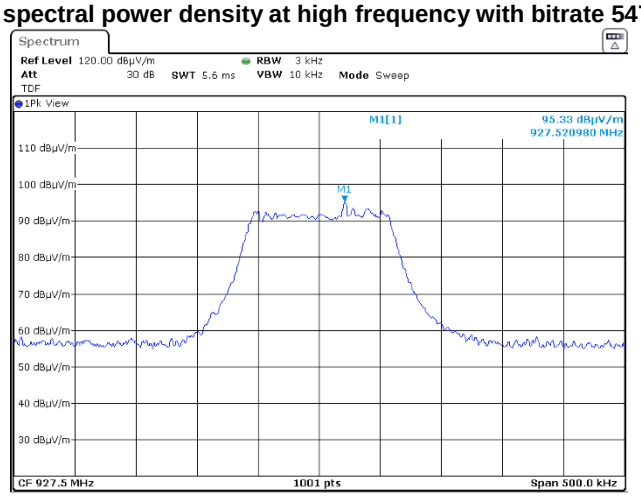
**Plot 7.6.4 Peak spectral power density at low frequency with bitrate 5470 bps**




**Plot 7.6.5 Peak spectral power density at mid frequency with bitrate 5470 bps**




**Plot 7.6.6 Peak spectral power density at high frequency with bitrate 5470 bps**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.7 Field strength of spurious emissions

### 7.7.1 General

This test was performed to measure field strength of spurious emissions from the EUT. Specification test limits are given in Table 7.7.1.

**Table 7.7.1 Radiated spurious emissions limits**

| Frequency, MHz | Field strength at 3 m within restricted bands, dB(μV/m)* | | | Attenuation of field strength of spurious versus carrier outside restricted bands, dBc*** |
|---|---|---|---|---|
| | Peak | Quasi Peak | Average | |
| 0.009 – 0.090 | 148.5 – 128.5 | NA | 128.5 – 108.5** | 20.0 |
| 0.090 – 0.110 | NA | 108.5 – 106.8** | NA | |
| 0.110 – 0.490 | 126.8 – 113.8 | NA | 106.8 – 93.8** | |
| 0.490 – 1.705 | NA | 73.8 – 63.0** | NA | |
| 1.705 – 30.0* | | 69.5 | | |
| 30 – 88 | | 40.0 | | |
| 88 – 216 | | 43.5 | | |
| 216 – 960 | | 46.0 | | |
| 960 - 1000 | | 54.0 | | |
| 1000 – 10th harmonic | 74.0 | NA | 54.0 | |

*- The limit for 3 m test distance was calculated using the inverse square distance extrapolation factor as follows:

$$Lim_{S2} = Lim_{S1} + 40 \log (S_1/S_2),$$

where $S_1$ and $S_2$ – standard defined and test distance respectively in meters.

**- The limit decreases linearly with the logarithm of frequency.

*** - The field strength limits applied from the lowest radio frequency generated in the device, without going below 9 kHz up to the tenth harmonic of the highest fundamental frequency.

### 7.7.2 Test procedure for spurious emission field strength measurements in 9 kHz to 30 MHz band

**7.7.2.1** The EUT was set up as shown in Figure 7.7.1, energized and the performance check was conducted.

**7.7.2.2** The specified frequency range was investigated with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated $360^0$ and the measuring antenna was rotated around its vertical axis.

**7.7.2.3** The worst test results (the lowest margins) were recorded and shown in the associated plots.

### 7.7.3 Test procedure for spurious emission field strength measurements above 30 MHz

The EUT was set up as shown in Figure 7.7.2, Figure 7.7.3 energized and the performance check was conducted.

**7.7.3.1** The specified frequency range was investigated with antenna connected to spectrum analyzer/ EMI receiver. To find maximum radiation the turntable was rotated $360^0$, the measuring antenna height was changed from 1 to 4 m, its polarization was switched from vertical to horizontal.

**7.7.3.2** The worst test results (the lowest margins) were recorded and shown in the associated plots.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Figure 7.7.1 Setup for spurious emission field strength measurements below 30 MHz**

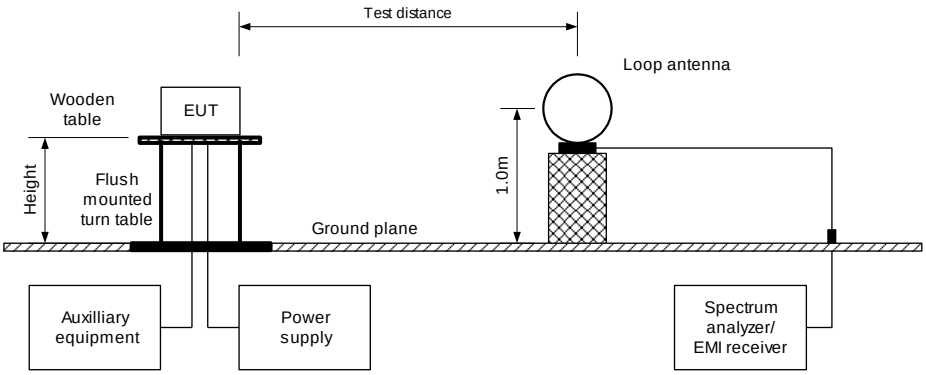
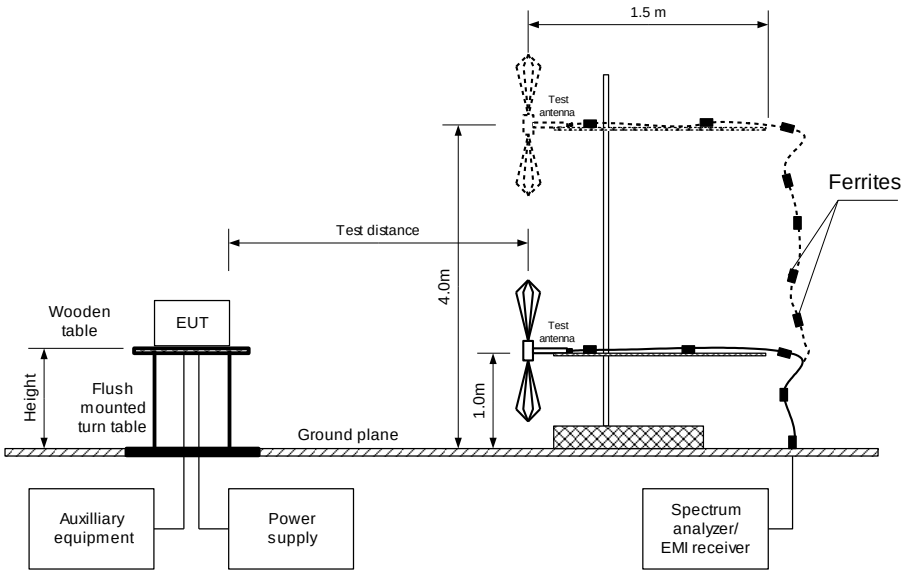
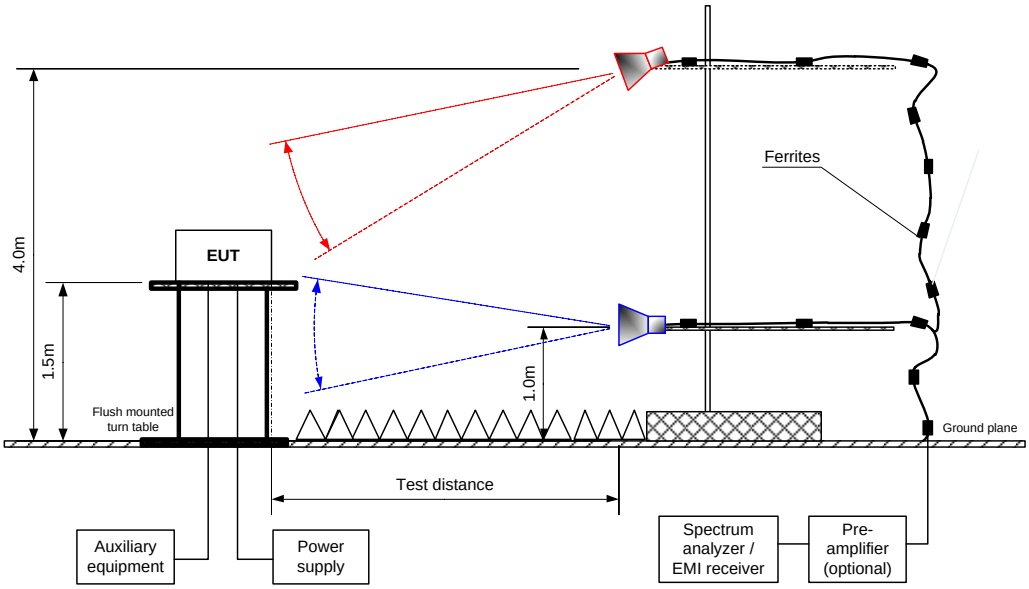



**Figure 7.7.2 Setup for spurious emission field strength measurements in 30 – 1000 MHz**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Figure 7.7.3 Setup for spurious emission field strength measurements above1000 MHz**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.7.2 Field strength of emissions outside restricted bands**

| | |
|---|---|
| ASSIGNED FREQUENCY: | 902.0 – 928.0 MHz |
| INVESTIGATED FREQUENCY RANGE: | 0.009 – 9500 MHz |
| TEST DISTANCE: | 3 m |
| MODULATION: | LoRa |
| MODULATING SIGNAL: | PRBS |
| DUTY CYCLE: | 100 % |
| TRANSMITTER OUTPUT POWER SETTINGS: | Maximum |
| DETECTOR USED: | Peak |
| RESOLUTION BANDWIDTH: | 100 kHz |
| VIDEO BANDWIDTH: | 300 kHz |
| TEST ANTENNA TYPE: | Active loop (9 kHz – 30 MHz)<br>Biconilog (30 MHz – 1000 MHz)<br>Double ridged guide (above 1000 MHz) |

| Frequency, MHz | Field strength of spurious, dB(μV/m) | Antenna polarization | Antenna height, m | Azimuth, degrees* | Field strength of carrier, dB(μV/m) | Attenuation below carrier, dBc | Limit, dBc | Margin, dB** | Verdict |
|---|---|---|---|---|---|---|---|---|---|
| **Low carrier frequency 902.5 MHz** | | | | | | | | | |
| 1805.0 | 45.6 | Horizontal | 1.7 | -130 | 104.99 | 59.39 | 20.0 | 39.39 | Pass |
| 6317.5 | 56.8 | Vertical | 1.3 | -90 | | 48.19 | | 28.19 | |
| 7220.0 | 49.2 | Vertical | 1.7 | -44 | | 55.79 | | 35.79 | |
| **Mid carrier frequency 915.0 MHz** | | | | | | | | | |
| 1830.0 | 49.5 | Horizontal | 1.8 | -132 | 102.93 | 53.43 | 20.0 | 33.43 | Pass |
| 5490.0 | 49.4 | Vertical | 1.3 | -76 | | 53.53 | | 33.53 | |
| 6405.0 | 51.2 | Vertical | 1.8 | -48 | | 51.73 | | 31.73 | |
| **High carrier frequency 927.5 MHz** | | | | | | | | | |
| 1855.0 | 55.2 | Horizontal | 1.8 | -125 | 99.52 | 44.32 | 20.0 | 24.32 | Pass |
| 5565.0 | 49.8 | Vertical | 1.3 | -95 | | 49.72 | | 29.72 | |
| 6492.5 | 52.6 | Vertical | 1.7 | -50 | | 46.92 | | 26.92 | |

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Attenuation below carrier – specification limit.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.7.3 Field strength of spurious emissions above 1 GHz within restricted bands**

| | |
|---|---|
| ASSIGNED FREQUENCY: | 902.0 – 928.0 MHz |
| INVESTIGATED FREQUENCY RANGE: | 1000 - 9500 MHz |
| TEST DISTANCE: | 3 m |
| MODULATION: | LoRa |
| MODULATING SIGNAL: | PRBS |
| DUTY CYCLE: | 100 % |
| TRANSMITTER OUTPUT POWER SETTINGS: | Maximum |
| DETECTOR USED: | Peak |
| RESOLUTION BANDWIDTH: | 1000 kHz |
| TEST ANTENNA TYPE: | Double ridged guide |

| Frequency, MHz | Antenna | | Azimuth, degrees* | Peak field strength(VBW=3 MHz) | | | Average field strength(VBW=10 Hz) | | | | Verdict |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Polarization | Height, m | | Measured, dB(μV/m) | Limit, dB(μV/m) | Margin, dB** | Measured, dB(μV/m) | Calculated, dB(μV/m) | Limit, dB(μV/m) | Margin, dB** | |
| **Low carrier frequency 902.5 MHz** | | | | | | | | | | | |
| 2707.5 | Horizontal | 1.4 | 60 | 56.9 | 74 | -17.1 | 53.2 | NA | 54 | -0.8 | Pass |
| 3610.0 | Vertical | 1.5 | 102 | 49.1 | 74 | -24.9 | 44.5 | NA | 54 | -9.5 | |
| 4512.5 | Vertical | 1.5 | -76 | 54.3 | 74 | -19.7 | 49.2 | NA | 54 | -4.8 | |
| 5415.0 | Vertical | 1.4 | -140 | 53.4 | 74 | -20.6 | 48.3 | NA | 54 | -5.7 | |
| 8122.5 | Horizontal | 1.6 | -137 | 49.4 | 74 | -24.6 | 44.1 | NA | 54 | -9.9 | |
| 9025.0 | Horizontal | 1.6 | -130 | 49.1 | 74 | -24.9 | 43.9 | NA | 54 | -10.1 | |
| **Mid carrier frequency 915.0 MHz** | | | | | | | | | | | |
| 2745.0 | Horizontal | 1.4 | 56 | 55.7 | 74 | -18.3 | 52.7 | NA | 54 | -1.3 | Pass |
| 3660.0 | Vertical | 1.5 | -100 | 46.5 | 74 | -27.5 | 41.0 | NA | 54 | -13 | |
| 4086.0 | Vertical | 1.5 | -76 | 48.7 | 74 | -25.3 | 43.5 | NA | 54 | -10.5 | |
| **High carrier frequency 927.5 MHz** | | | | | | | | | | | |
| 2782.5 | Horizontal | 1.4 | 55 | 54.8 | 74 | -19.2 | 51.2 | NA | 54 | -2.8 | Pass |
| 3710.0 | Vertical | 1.5 | -98 | 40.7 | 74 | -33.3 | 35.3 | NA | 54 | -18.7 | |
| 4637.5 | Vertical | 1.5 | -80 | 49.8 | 74 | -24.2 | 43.7 | NA | 54 | -10.3 | |

*****- EUT front panel refers to 0 degrees position of turntable.
******- Margin = Measured field strength - specification limit.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.7.4 Field strength of spurious emissions below 1 GHz within restricted bands**

| | |
|---|---|
| ASSIGNED FREQUENCY: | 902.0 MHz |
| INVESTIGATED FREQUENCY RANGE: | 0.009 – 1000 MHz |
| TEST DISTANCE: | 3 m |
| MODULATION: | LoRa |
| MODULATING SIGNAL: | PRBS |
| BIT RATE: | 3.9 kbps |
| DUTY CYCLE: | 100 % |
| TRANSMITTER OUTPUT POWER SETTINGS: | Maximum |
| RESOLUTION BANDWIDTH: | 0.2 kHz (9 kHz – 150 kHz)<br>9.0 kHz (150 kHz – 30 MHz)<br>120 kHz (30 MHz – 1000 MHz) |
| VIDEO BANDWIDTH: | > Resolution bandwidth |
| TEST ANTENNA TYPE: | Active loop (9 kHz – 30 MHz)<br>Biconilog (30 MHz – 1000 MHz) |

| Frequency, MHz | Peak emission, dB(μV/m) | Quasi-peak | | | Antenna polarization | Antenna height, m | Turn-table position**, degrees | Verdict |
|---|---|---|---|---|---|---|---|---|
| | | Measured emission, dB(μV/m) | Limit, dB(μV/m) | Margin, dB* | | | | |
| **Low carrier frequency 902.5 MHz** | | | | | | | | |
| All emissions are more than 20 dB below the limit | | | | | | | | Pass |
| **Mid carrier frequency 915.0 MHz** | | | | | | | | |
| All emissions are more than 20 dB below the limit | | | | | | | | Pass |
| **High carrier frequency 927.5 MHz** | | | | | | | | |
| All emissions are more than 20 dB below the limit limit | | | | | | | | Pass |

*****- Margin = Measured emission - specification limit.
******- EUT front panel refer to 0 degrees position of turntable.

**Table 7.7.5 Restricted bands**

| MHz | MHz | MHz | MHz | MHz | GHz |
|---|---|---|---|---|---|
| 0.09 - 0.11 | 8.37625 - 8.38675 | 73 - 74.6 | 399.9 - 410 | 2690 - 2900 | 10.6 - 12.7 |
| 0.495 - 0.505 | 8.41425 - 8.41475 | 74.8 - 75.2 | 608 - 614 | 3260 - 3267 | 13.25 - 13.4 |
| 2.1735 - 2.1905 | 12.29 - 12.293 | 108 - 121.94 | 960 - 1240 | 3332 - 3339 | 14.47 - 14.5 |
| 4.125 - 4.128 | 12.51975 - 12.52025 | 123 - 138 | 1300 - 1427 | 3345.8 - 3358 | 15.35 - 16.2 |
| 4.17725 - 4.17775 | 12.57675 - 12.57725 | 149.9 - 150.05 | 1435 - 1626.5 | 3600 - 4400 | 17.7 - 21.4 |
| 4.20725 - 4.20775 | 13.36 - 13.41 | 156.52475 - 156.52525 | 1645.5 - 1646.5 | 4500 - 5150 | 22.01 - 23.12 |
| 6.215 - 6.218 | 16.42 - 16.423 | 156.7 - 156.9 | 1660 - 1710 | 5350 – 5460 | 23.6 - 24 |
| 6.26775 - 6.26825 | 16.69475 - 16.69525 | 162.0125 - 167.17 | 1718.8 - 1722.2 | 7250 - 7750 | 31.2 - 31.8 |
| 6.31175 - 6.31225 | 16.80425 - 16.80475 | 167.72 - 173.2 | 2200 - 2300 | 8025 – 8500 | 36.43 - 36.5 |
| 8.291 - 8.294 | 25.5 - 25.67 | 240 - 285 | 2310 - 2390 | 9000 - 9200 | Above 38.6 |
| 8.362 - 8.366 | 37.5 - 38.25 | 322 - 335.4 | 2483.5 - 2500 | 9300 - 9500 | |

**Reference numbers of test equipment used**

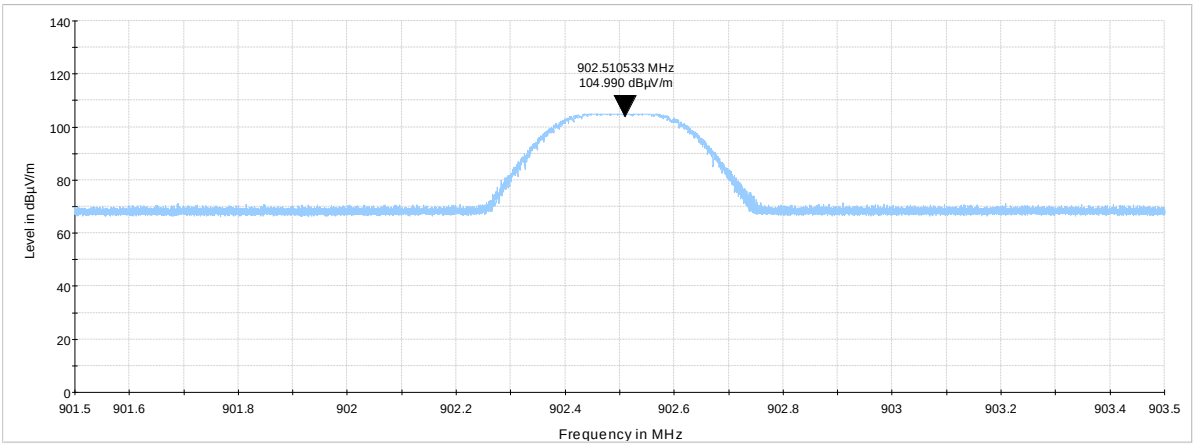
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 3903 | HL 4360 | HL 4933 | HL 5288 | HL 5665 | HL 446 | HL 5404 | HL 4338 |

Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

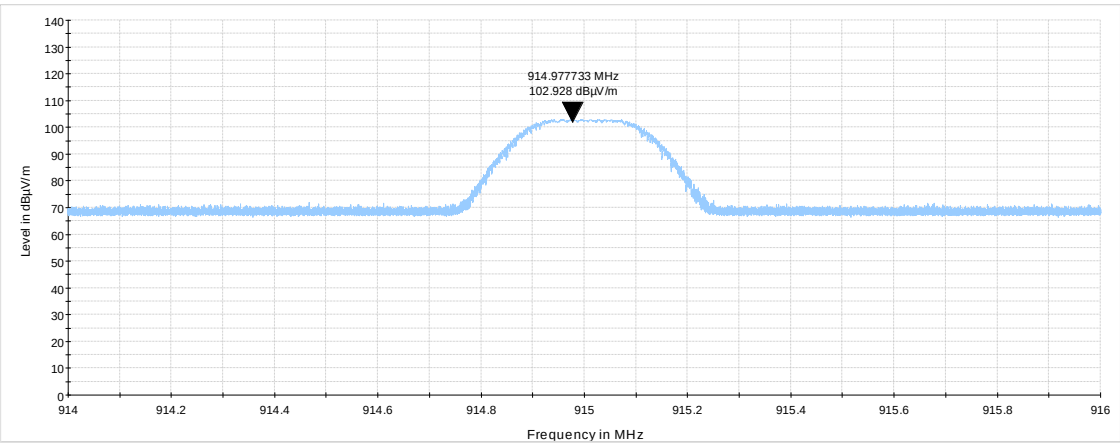
**Plot 7.7.1 Radiated emission measurements at the low carrier frequency**

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal




**Plot 7.7.2 Radiated emission measurements at the mid carrier frequency**

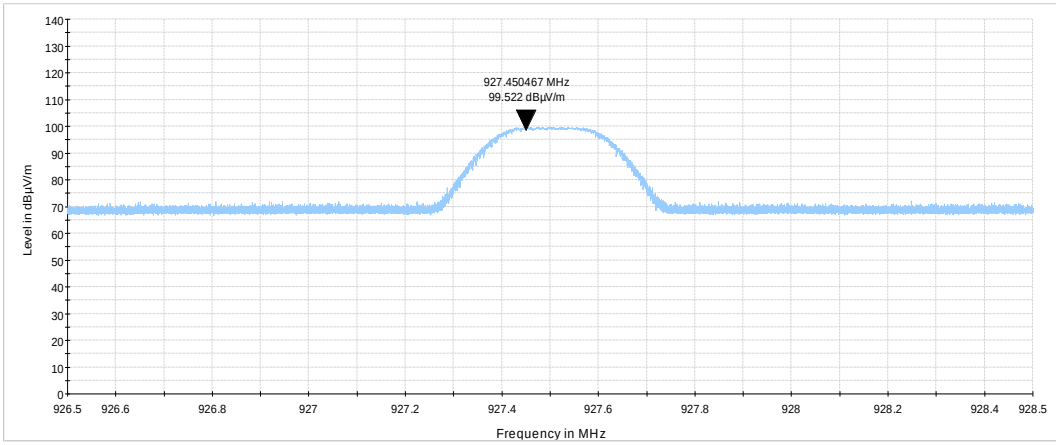
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.7.3 Radiated emission measurements at the high carrier frequency**

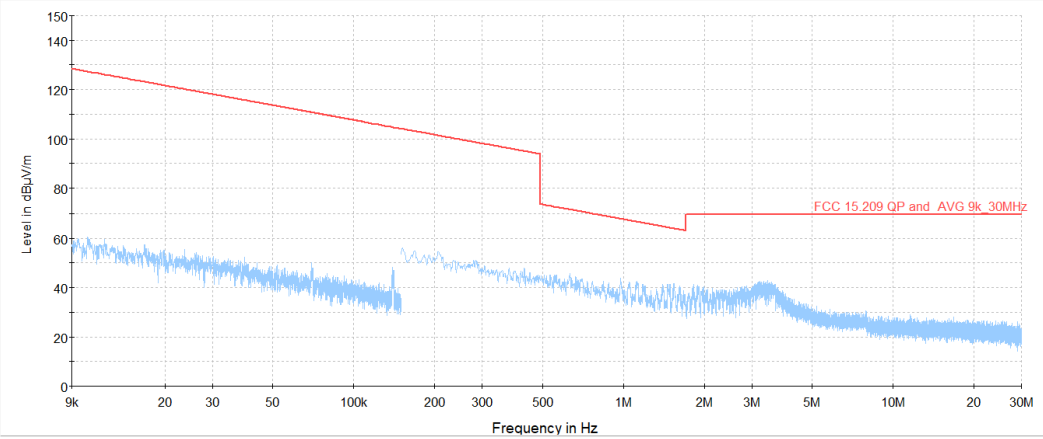
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

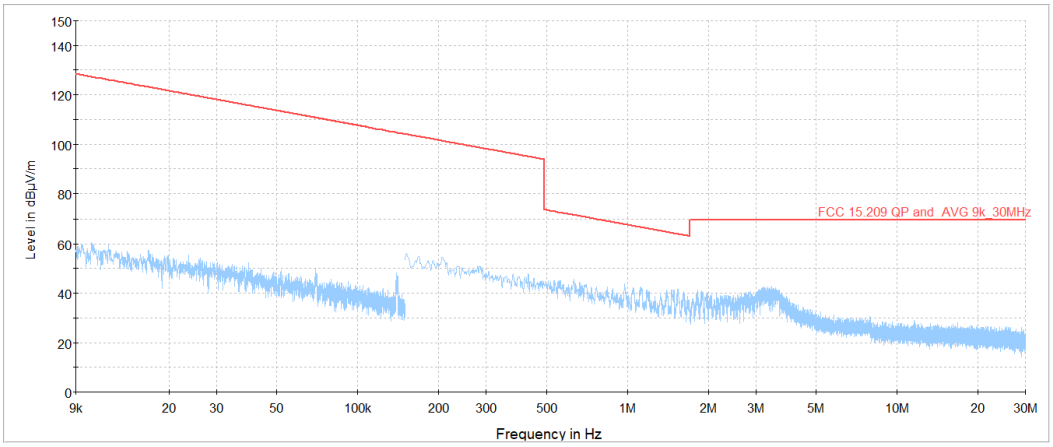
**Plot 7.7.4 Radiated emission measurements from 9 kHz to 30 MHz at the low carrier frequency**

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical




**Plot 7.7.5 Radiated emission measurements from 9 kHz to 30 MHz at the high carrier frequency**

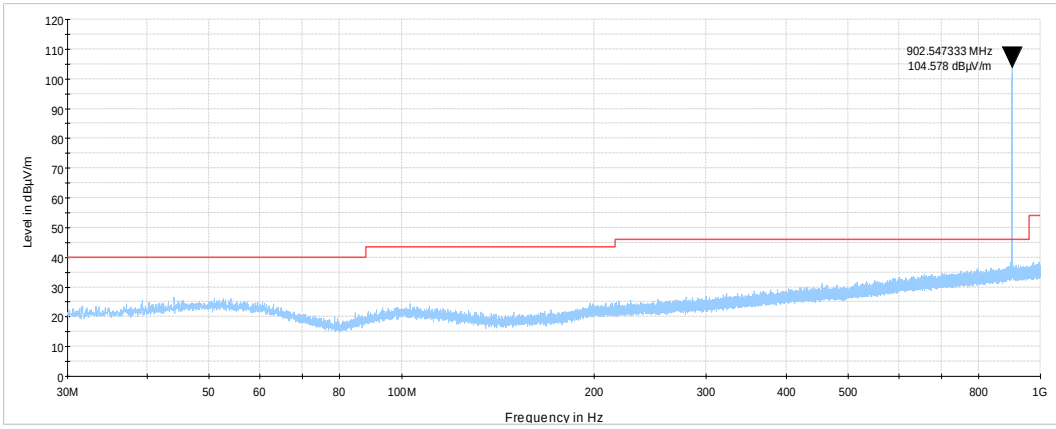
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

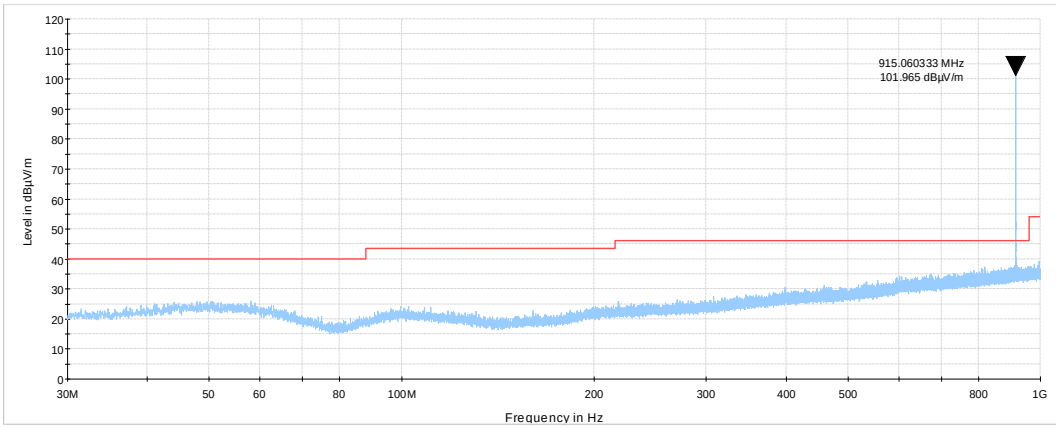
**Plot 7.7.6 Radiated emission measurements from 30 to 1000 MHz at the low carrier frequency**

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal




**Plot 7.7.7 Radiated emission measurements from 30 to 1000 MHz at the mid carrier frequency**

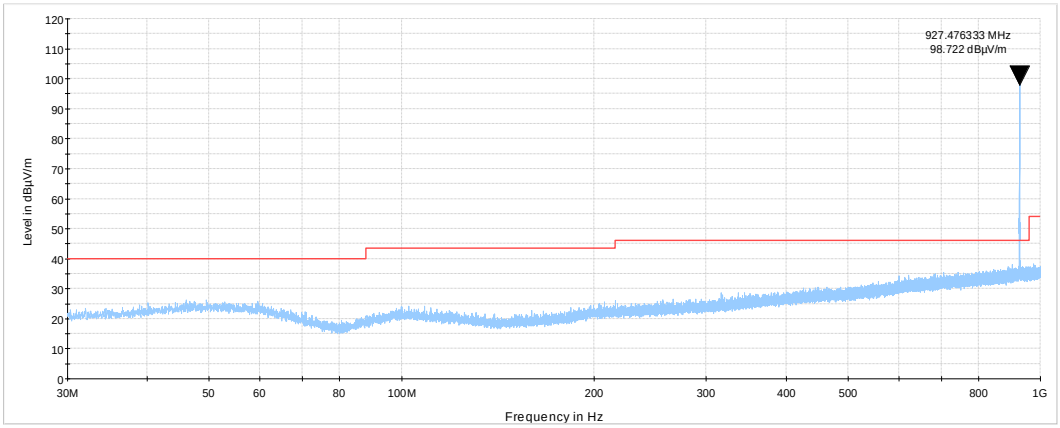
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.7.8 Radiated emission measurements from 30 to 1000 MHz at the high carrier frequency**

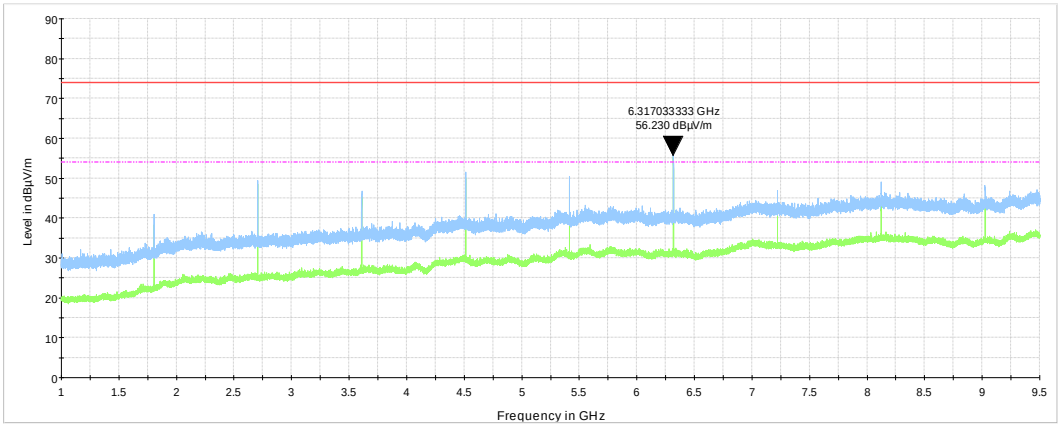
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

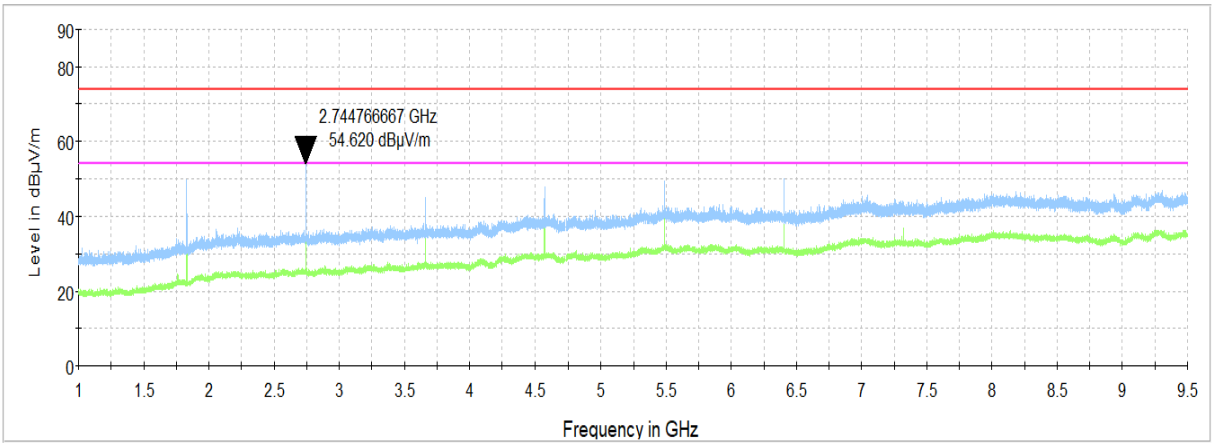
**Plot 7.7.9 Radiated emission measurements from 1000 to 9500 MHz at the low carrier frequency**

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal




**Plot 7.7.10 Radiated emission measurements from 1000 to 9500 MHz at the mid carrier frequency**

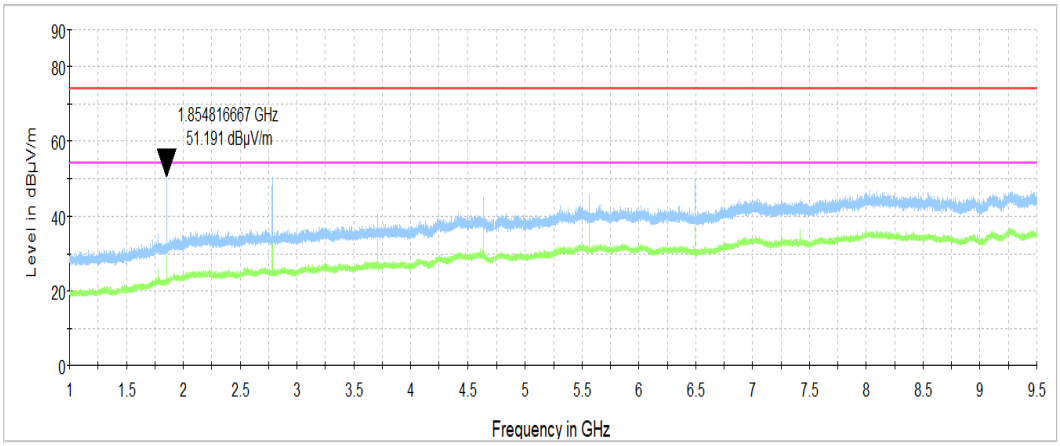
TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(c), Radiated spurious emissions** | | |
| **Test procedure:** | ANSI C63.10, sections 6.5, 6.6 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 20-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 40 % | **Air Pressure:** 1010 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.7.11 Radiated emission measurements from 1000 to 9500 MHz at the high carrier frequency**

TEST SITE: Semi anechoic chamber
TEST DISTANCE: 3 m
ANTENNA POLARIZATION: Vertical and Horizontal



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Emissions at band edges** | | |
| **Test procedure:** | ANSI C63.10, Section 6.10 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 26-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.8 Band edge radiated emissions

### 7.8.1 General

This test was performed to measure emissions, radiated from the EUT at the assigned frequency band edges. Specification test limits are given in Table 7.8.1.

**Table 7.8.1 Band edge emission limits**

| Assigned frequency, MHz | Attenuation below carrier*, dBc | Field strength at 3 m within restricted bands, dB(μV/m) | |
|---|---|---|---|
| | | Peak | Average |
| 902.0 – 928.0 | 20.0 | 74.0 | 54.0 |

* - Band edge emission limit is provided in terms of attenuation below the peak of modulated carrier measured with the same resolution bandwidth.

### 7.8.2 Test procedure

**7.8.2.1** The EUT was set up as shown in Figure 7.8.1, energized normally modulated at the maximum data rate with its hopping function disabled and its proper operation was checked.

**7.8.2.2** The EUT was adjusted to produce maximum available to end user RF output power at the lowest carrier frequency.

**7.8.2.3** The spectrum analyzer span was set to capture the carrier frequency and associated modulation products. The resolution bandwidth was set wider than 1 % of the frequency span.

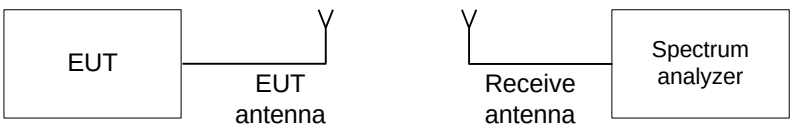
**7.8.2.4** The spectrum analyzer was set in max hold mode and allowed trace to stabilize. The highest emission level within the authorized band was measured.

**7.8.2.5** The maximum band edge emission and modulation product outside of the band were measured as provided in Table 7.8.2 and associated plots and referenced to the highest emission level measured within the authorized band.

**7.8.2.6** The above procedure was repeated with the EUT adjusted to produce maximum RF output power at the highest carrier frequency.

**7.8.2.7** The above procedure was repeated with the frequency hopping function enabled.

**Figure 7.8.1 Band edge emission test setup**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Emissions at band edges** | | |
| **Test procedure:** | ANSI C63.10, Section 6.10 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 26-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 7.8.2 Band edge emission test results**

ASSIGNED FREQUENCY RANGE: 902-928 MHz
DETECTOR USED: Peak
MODULATION: LoRa
RESOLUTION BANDWIDTH: 100 kHz
VIDEO BANDWIDTH: 300 kHz

BIT RATE: 980bps

| Frequency, MHz | Band edge emission, dBm | Emission at carrier, dBm | Attenuation below carrier, dBc | Limit, dBc | Margin, dB* | Verdict |
|---|---|---|---|---|---|---|
| **Frequency hopping disabled** | | | | | | |
| 902 | -34.00 | 14.05 | 48.05 | 20.0 | 28.05 | Pass |
| 928 | -27.41 | 13.94 | 41.38 | | 21.38 | |
| **Frequency hopping enabled** | | | | | | |
| 902 | -34.04 | 13.98 | 48.02 | 20.0 | 28.02 | Pass |
| 928 | -26.92 | 13.96 | 40.88 | | 20.88 | |

**BIT RATE: 5470 bps**

| Frequency, MHz | Band edge emission, dBm | Emission at carrier, dBm | Attenuation below carrier, dBc | Limit, dBc | Margin, dB* | Verdict |
|---|---|---|---|---|---|---|
| **Frequency hopping disabled** | | | | | | |
| 902 | -33.70 | 14.08 | 47.78 | 20.0 | 27.78 | Pass |
| 928 | -26.97 | 14.03 | 41.00 | | 21.00 | |
| **Frequency hopping enabled** | | | | | | |
| 902 | -34.86 | 13.81 | 47.87 | 20.0 | 27.87 | Pass |
| 928 | -28.63 | 13.95 | 42.58 | | 22.58 | |

*****- Margin = Attenuation below carrier – specification limit.

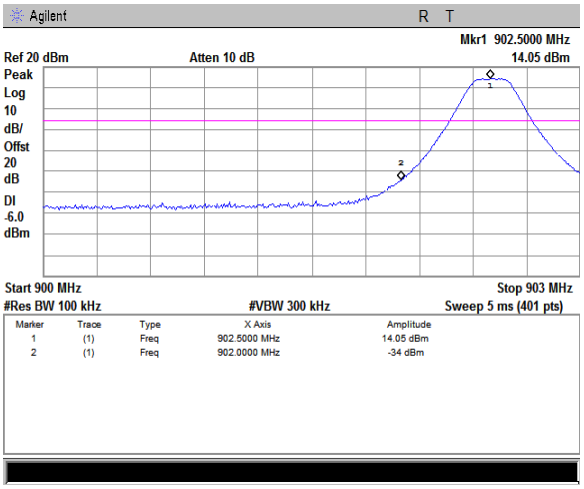
**Reference numbers of test equipment used**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 2909 | HL 5606 | HL 5612 | | | | | |

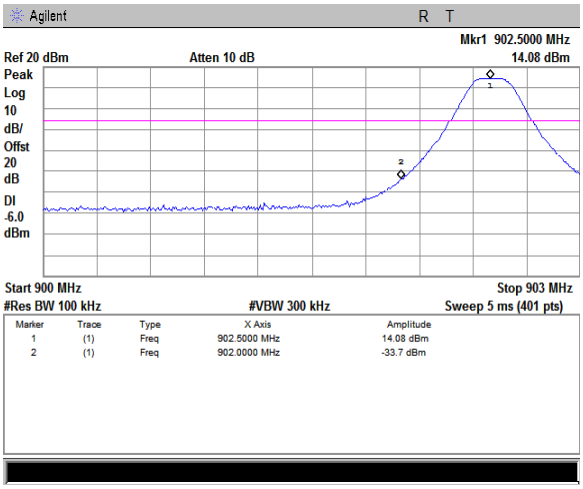
Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Emissions at band edges** | | |
| **Test procedure:** | ANSI C63.10, Section 6.10 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 26-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.8.1 The band edge emission at low carrier frequency with hopping function disabled**

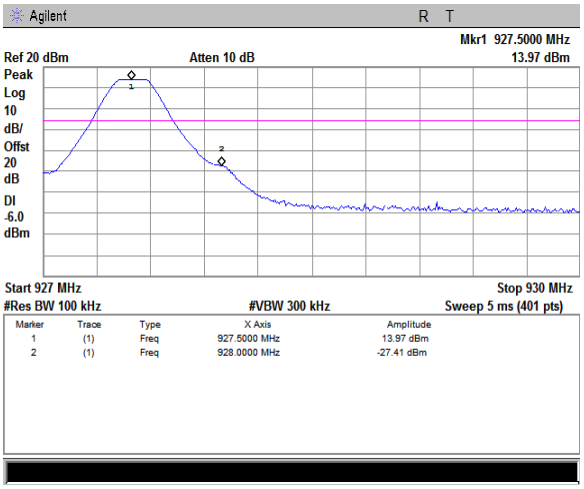



980 bps

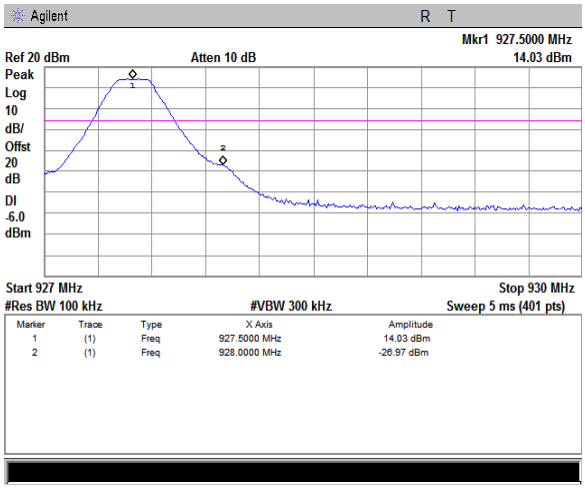



5470 bps

**Plot 7.8.2 The band edge emission at high carrier frequency with hopping function disabled**



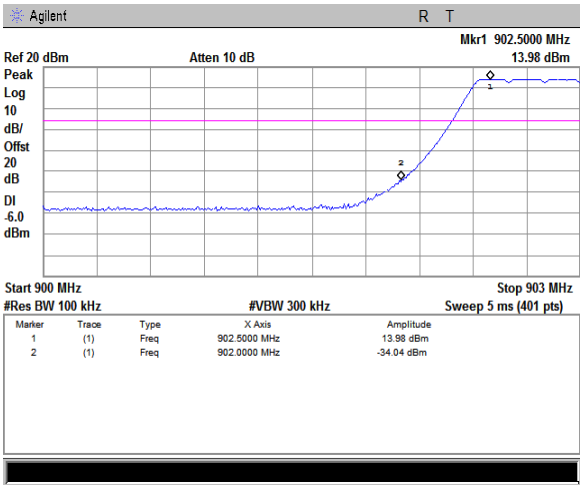

980 bps



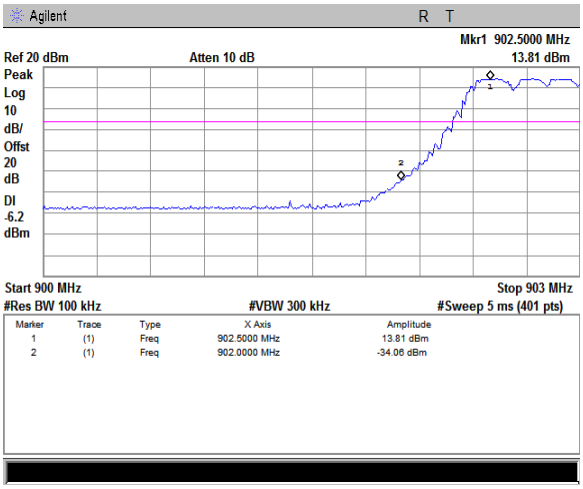

5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.247(d), Emissions at band edges** | | |
| **Test procedure:** | ANSI C63.10, Section 6.10 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 26-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Plot 7.8.3 The band edge emission at low carrier frequency with hopping function enabled**

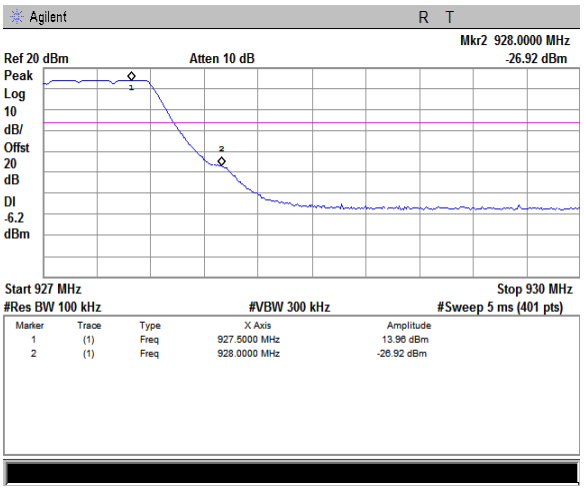



980 bps

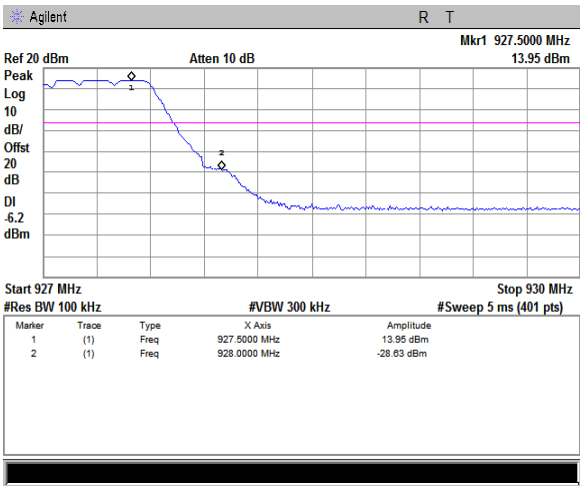



5470 bps

**Plot 7.8.4 The band edge emission at high carrier frequency with hopping function enabled**




980 bps




5470 bps

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.203, Antenna requirements** | | |
| **Test procedure:** | Visual inspection | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 26-Dec-19 | | |
| **Temperature:** 23 ºC | **Relative Humidity:** 45 % | **Air Pressure:** 1008 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

## 7.9 Antenna requirements

The EUT was verified for compliance with antenna requirements. A transmitter shall be designed to ensure that no antenna other than that furnished by the responsible party will be used with the device. It may be either permanently attached or employs a unique antenna connector for every antenna proposed for use with the EUT. This requirement does not apply to professionally installed transmitters.
The rationale for compliance with the above requirements was either visual inspection results or supplier declaration. The summary of results is provided in Table 7.9.1.

**Table 7.9.1 Antenna requirements**

| Requirement | Rationale | Verdict |
|---|---|---|
| The transmitter antenna is permanently attached | Visual inspection | Comply |
| The transmitter employs a unique antenna connector | NA | |
| The transmitter requires professional installation | NA | |

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.109, Radiated emission** | | |
| **Test procedure:** | ANSI C63.4, Sections 11.6 and 12.1.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 17-Dec-19 | | |
| **Temperature:** 22 ºC | **Relative Humidity:** 47 % | **Air Pressure:** 1020 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

# 8 Emission tests according to 47CFR part 15 subpart B requirements

## 8.1 Radiated emission measurements

### 8.1.1 General

This test was performed to measure radiated emissions from the EUT enclosure. Specification test limits are given in Table 8.1.1.

**Table 8.1.1 Radiated emission test limits**

| Frequency, MHz | Class B limit, dB(μV/m) | | Class A limit, dB(μV/m) | |
|---|---|---|---|---|
| | 10 m distance | 3 m distance | 10 m distance | 3 m distance |
| 30 - 88 | 29.5* | 40.0 | 39.0 | 49.5* |
| 88 - 216 | 33.0* | 43.5 | 43.5 | 54.0* |
| 216 - 960 | 35.5* | 46.0 | 46.4 | 56.9* |
| Above 960 | 43.5* | 54.0 | 49.5 | 60.0* |

* The limit for test distance other than specified was calculated using the inverse linear distance extrapolation factor as follows: $Lim_{S2} = Lim_{S1} + 20 \log (S_1/S_2)$,
where $S_1$ and $S_2$ – standard defined and test distance respectively in meters.

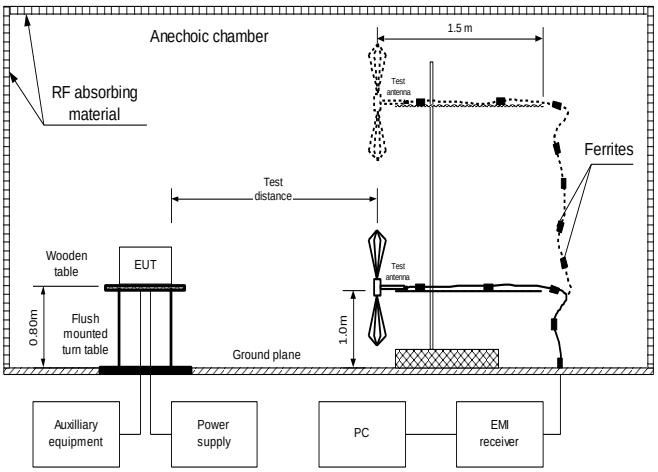
### 8.1.2 Test procedure for measurements in semi-anechoic chamber

**8.1.2.1** The EUT was set up as shown in Figure 8.1.1 and associated photograph/s, energized and the performance check was conducted.

**8.1.2.2** The specified frequency range was investigated with biconilog antenna connected to EMI receiver. To find maximum radiation the turntable was rotated $360^0$, the measuring antenna height was changed from 1 to 4 m, its polarization was switched from vertical to horizontal and the EUT cables position was varied.

**8.1.2.3** The worst test results (the lowest margins) were recorded in Table 8.1.2 and shown in the associated plots.

**Figure 8.1.1 Setup for radiated emission measurements in anechoic chamber, table-top equipment**



| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.109, Radiated emission** | | |
| **Test procedure:** | ANSI C63.4, Sections 11.6 and 12.1.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 17-Dec-19 | | |
| **Temperature:** 22 ºC | **Relative Humidity:** 47 % | **Air Pressure:** 1020 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

**Table 8.1.2 Radiated emission test results**

EUT SET UP: TABLE-TOP
LIMIT: Class B
EUT OPERATING MODE: Receive
TEST SITE: SEMI ANECHOIC CHAMBER
TEST DISTANCE: 3 m
DETECTORS USED: PEAK / QUASI-PEAK
FREQUENCY RANGE: 30 MHz – 1000 MHz
RESOLUTION BANDWIDTH: 120 kHz

| Frequency, MHz | Peak emission, dB(μV/m) | Quasi-peak | | | Antenna polarization | Antenna height, m | Turn-table position**, degrees | Verdict |
|---|---|---|---|---|---|---|---|---|
| | | Measured emission, dB(μV/m) | Limit, dB(μV/m) | Margin, dB* | | | | |
| All emissions are more than 20 dB below the limit | | | | | | | | Pass |

TEST SITE: SEMI ANECHOIC CHAMBER
TEST DISTANCE: 3 m
DETECTORS USED: PEAK / AVERAGE
FREQUENCY RANGE: 1000 MHz – 5000 MHz
RESOLUTION BANDWIDTH: 1000 kHz

| Frequency, MHz | Peak | | | Average | | | Antenna polarization | Antenna height, m | Turn-table position**, degrees | Verdict |
|---|---|---|---|---|---|---|---|---|---|---|
| | Measured emission, dB(μV/m) | Limit, dB(μV/m) | Margin, dB* | Measured emission, dB(μV/m) | Limit, dB(μV/m) | Margin, dB* | | | | |
| All emissions are more than 20 dB below the limit | | | | | | | | | | Pass |

*- Margin = Measured emission - specification limit.
**- EUT front panel refer to 0 degrees position of turntable.

**Reference numbers of test equipment used**

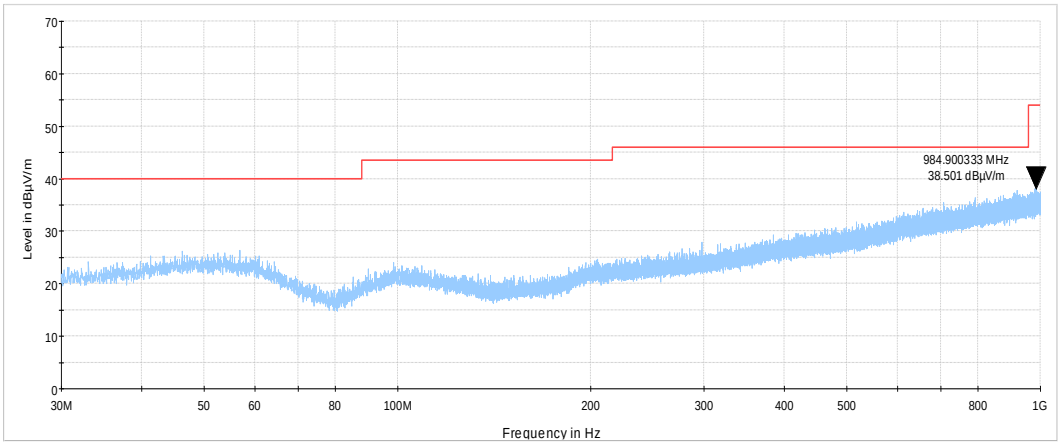
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| HL 3903 | HL 4360 | HL 4933 | HL 5288 | HL 5665 | | | |

Full description is given in Appendix A.

| | | | |
|---|---|---|---|
| **Test specification:** | **Section 15.109, Radiated emission** | | |
| **Test procedure:** | ANSI C63.4, Sections 11.6 and 12.1.4 | | |
| **Test mode:** | Compliance | **Verdict:** | PASS |
| **Date(s):** | 17-Dec-19 | | |
| **Temperature:** 22 ºC | **Relative Humidity:** 47 % | **Air Pressure:** 1020 hPa | **Power:** 3 VDC |
| **Remarks:** | | | |

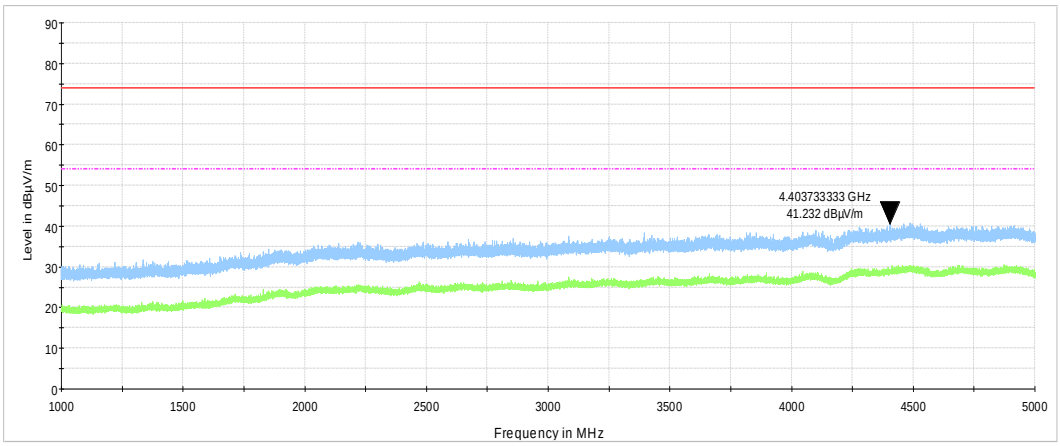
**Plot 8.1.1 Radiated emission measurements in 30 - 1000 MHz range, vertical and horizontal antenna polarization**

TEST SITE: Semi anechoic chamber
LIMIT: Class B
TEST DISTANCE: 3 m
EUT OPERATING MODE: Receive




**Plot 8.1.2 Radiated emission measurements above 1000 MHz, vertical and horizontal antenna polarization**

TEST SITE: Semi anechoic chamber
LIMIT: Class B
TEST DISTANCE: 3 m
EUT OPERATING MODE: Receive



# 9 APPENDIX A Test equipment and ancillaries used for tests

| HL No | Description | Manufacturer | Model | Ser. No. | Last Cal./ Check | Due Cal./ Check |
|---|---|---|---|---|---|---|
| 0446 | Antenna, Loop, Active, 10 (9) kHz - 30 MHz | EMCO | 6502 | 2857 | 24-Feb-20 | 24-Feb-21 |
| 2909 | Spectrum analyzer, ESA-E, 100 Hz to 26.5 GHz | Agilent Technologies | E4407B | MY41444762 | 04-Apr-19 | 04-Apr-20 |
| 3903 | Microwave Cable Assembly, 40.0 GHz, 1.5 m, SMA/SMA | Huber-Suhner | SUCOFLEX 102A | 1226/2A | 07-Apr-19 | 07-Apr-20 |
| 4338 | Reject Band Filter, 50 Ohm, 0 to 2170 and 3000 to 18000 MHz,SMA-FM / SMA-M | Micro-Tronics | BRM 50702-02 | 023 | 05-Jun-19 | 05-Jun-20 |
| 4355 | Signal and Spectrum Analyzer, 9 kHz to 7 GHz | Rohde & Schwarz | FSV 7 | 101630 | 04-Aug-19 | 04-Aug-20 |
| 4360 | EMI Test Receiver, 20 Hz to 40 GHz. | Rohde & Schwarz | ESU40 | 100322 | 20-Jan-20 | 20-Jan-21 |
| 4933 | Active Horn Antenna, 1 GHz to 18 GHz | COM-POWER CORPORATION | AHA-118 | 701046 | 06-Jan-20 | 06-Jan-21 |
| 5111 | RF cable, 40 GHz, 5.5 m, K-type | Huber-Suhner | SF102EA/11SK/11SK/5500MM | 502493/2EA | 14-Aug-19 | 14-Aug-20 |
| 5288 | Trilog Antenna, 25 MHz - 8 GHz, 100W | Frankonia | ALX-8000E | 00809 | 08-Feb-19 | 08-Feb-22 |
| 5404 | RF cable, 18 GHz, N-N, 6 m | Huber-Suhner | SF118/11N(x2) | 500024/18 | 11-Aug-19 | 11-Aug-20 |
| 5606 | Precision Fixed Attenuator, 50 Ohm, 5 W, 10 dB, DC to 18000 MHz | Mini Circuits | BW-N10W5+ | NA | 24-Sep-19 | 24-Sep-20 |
| 5612 | Precision Fixed Attenuator, 50 Ohm, 5 W, 10 dB, DC to 18 GHz | Mini Circuits | BW-S10W5+ | NA | 24-Sep-19 | 24-Sep-20 |
| 5665 | Cable SF118/11N(x2)/6M, 18 GHz, 11N/11N | Huber-Suhner | SF118 | 501644/118 | 23-Oct-19 | 23-Oct-20 |

# 10 APPENDIX B Test equipment correction factors

**HL 0446: Active Loop Antenna**
**EMCO, model: 6502, s/n 2857**

| Frequency, | Measured antenna factor, dBS/m | Measurement uncertainty, dB |
|---|---|---|
| 10 | -33.4 | ±1.0 |
| 20 | -37.8 | ±1.0 |
| 50 | -40.5 | ±1.0 |
| 75 | -41.0 | ±1.0 |
| 100 | -41.2 | ±1.0 |
| 150 | -41.2 | ±1.0 |
| 250 | -41.1 | ±1.0 |
| 500 | -41.2 | ±1.0 |
| 750 | -41.3 | ±1.0 |
| 1000 | -41.3 | ±1.0 |

| Frequency, | Measured antenna factor, dBS/m | Measurement uncertainty, dB |
|---|---|---|
| 2000 | -41.4 | ±1.0 |
| 3000 | -41.4 | ±1.0 |
| 4000 | -41.5 | ±1.0 |
| 5000 | -41.5 | ±1.0 |
| 10000 | -41.7 | ±1.0 |
| 15000 | -42.1 | ±1.0 |
| 20000 | -42.7 | ±1.0 |
| 25000 | -44.2 | ±1.0 |
| 30000 | -45.8 | ±1.0 |

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμA/m.

**HL 4933: Active Horn Antenna**
**COM-POWER CORPORATION, model: AHA-118, s/n 701046**

| Frequency, MHz | Measured antenna factor (with preamplifier), dB/m |
|---|---|
| 1000 | -16.1 |
| 1500 | -15.1 |
| 2000 | -10.9 |
| 2500 | -11.9 |
| 3000 | -11.1 |
| 3500 | -10.6 |
| 4000 | -8.6 |
| 4500 | -8.3 |
| 5000 | -5.9 |
| 5500 | -5.7 |
| 6000 | -3.3 |
| 6500 | -4.0 |
| 7000 | -2.2 |
| 7500 | -1.7 |
| 8000 | 1.1 |
| 8500 | -0.8 |
| 9000 | -1.5 |
| 9500 | -0.2 |

| Frequency, MHz | Measured antenna factor (with preamplifier), dB/m |
|---|---|
| 10000 | 1.8 |
| 10500 | 1.0 |
| 11000 | 0.3 |
| 11500 | -0.5 |
| 12000 | 3.1 |
| 12500 | 1.4 |
| 13000 | -0.3 |
| 13500 | -0.4 |
| 14000 | 2.5 |
| 14500 | 2.2 |
| 15000 | 1.9 |
| 15500 | 0.5 |
| 16000 | 2.1 |
| 16500 | 1.2 |
| 17000 | 0.6 |
| 17500 | 3.1 |
| 18000 | 4.2 |

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

**HL 5288: Trilog Antenna**
**Frankonia, model: ALX-8000E, s/n: 00809**
**30-1000 MHz**

| Frequency, MHz | Antenna factor, dB/m | Frequency, MHz | Antenna factor, dB/m |
|---|---|---|---|
| 30 | 14.96 | 160 | 12.67 |
| 35 | 15.33 | 180 | 13.34 |
| 40 | 16.37 | 200 | 15.40 |
| 45 | 17.56 | 250 | 16.42 |
| 50 | 17.95 | 300 | 17.28 |
| 60 | 16.87 | 400 | 19.98 |
| 70 | 13.22 | 500 | 21.11 |
| 80 | 10.56 | 600 | 22.90 |
| 90 | 13.61 | 700 | 24.13 |
| 100 | 15.46 | 800 | 25.25 |
| 120 | 14.03 | 900 | 26.35 |
| 140 | 12.23 | 1000 | 27.18 |

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

**above 1000 MHz**

| Frequency, MHz | Antenna factor, dB/m | Frequency, MHz | Antenna factor, dB/m |
|---|---|---|---|
| 1000 | 26.9 | 3600 | 38.9 |
| 1100 | 28.1 | 3700 | 39.4 |
| 1200 | 28.4 | 3800 | 39.4 |
| 1300 | 29.6 | 3900 | 39.6 |
| 1400 | 29.1 | 4000 | 39.7 |
| 1500 | 30.4 | 4100 | 39.8 |
| 1600 | 30.7 | 4200 | 40.5 |
| 1700 | 31.5 | 4300 | 40.9 |
| 1800 | 32.3 | 4400 | 41.1 |
| 1900 | 32.6 | 4500 | 41.4 |
| 2000 | 32.5 | 4600 | 41.3 |
| 2100 | 32.9 | 4700 | 41.6 |
| 2200 | 33.5 | 4800 | 41.9 |
| 2300 | 33.2 | 4900 | 42.3 |
| 2400 | 33.7 | 5000 | 42.7 |
| 2500 | 34.6 | 5100 | 43.0 |
| 2600 | 34.7 | 5200 | 42.9 |
| 2700 | 34.6 | 5300 | 43.5 |
| 2800 | 35.0 | 5400 | 43.6 |
| 2900 | 35.5 | 5500 | 44.3 |
| 3000 | 36.2 | 5600 | 44.7 |
| 3100 | 36.8 | 5700 | 45.0 |
| 3200 | 36.8 | 5800 | 45.0 |
| 3300 | 37.0 | 5900 | 45.3 |
| 3400 | 37.5 | 6000 | 45.9 |
| 3500 | 38.2 | | |

The antenna factor shall be added to receiver reading in dBμV to obtain field strength in dBμV/m.

**HL 5111: RF cable**

**Huber-Suhner, SF102EA/11SK/11SK/5500MM, s/n 502493/2EA**

| Set / Applied, MHz | Measured, dB | Uncertainty, dB |
|---|---|---|
| 100 | 0.70 | ±0.07 |
| 200 | 0.99 | ±0.08 |
| 300 | 1.21 | ±0.08 |
| 500 | 1.56 | ±0.08 |
| 1000 | 2.20 | ±0.08 |
| 1500 | 2.69 | ±0.08 |
| 2000 | 3.11 | ±0.08 |
| 2500 | 3.50 | ±0.10 |
| 3000 | 3.85 | ±0.10 |
| 3500 | 4.16 | ±0.10 |
| 4000 | 4.47 | ±0.10 |
| 4500 | 4.74 | ±0.10 |
| 5000 | 5.03 | ±0.10 |
| 5500 | 5.30 | ±0.10 |
| 6000 | 5.57 | ±0.10 |
| 6500 | 5.76 | ±0.10 |
| 7000 | 6.00 | ±0.10 |
| 7500 | 6.20 | ±0.10 |
| 8000 | 6.44 | ±0.10 |
| 8500 | 6.67 | ±0.10 |
| 9000 | 6.82 | ±0.10 |
| 9500 | 7.04 | ±0.10 |
| 10000 | 7.18 | ±0.10 |
| 10500 | 7.36 | ±0.10 |
| 11000 | 7.55 | ±0.10 |
| 11500 | 7.75 | ±0.10 |
| 12000 | 7.90 | ±0.10 |
| 12500 | 8.08 | ±0.13 |
| 13000 | 8.19 | ±0.13 |
| 13500 | 8.39 | ±0.13 |
| 14000 | 8.58 | ±0.13 |
| 14500 | 8.76 | ±0.18 |
| 15000 | 8.92 | ±0.18 |
| 15500 | 9.03 | ±0.18 |
| 16000 | 9.18 | ±0.18 |
| 16500 | 9.34 | ±0.18 |
| 17000 | 9.51 | ±0.18 |
| 17500 | 9.66 | ±0.18 |
| 18000 | 9.80 | ±0.18 |
| 18500 | 9.94 | ±0.23 |
| 19000 | 10.05 | ±0.23 |
| 19500 | 10.22 | ±0.23 |

| Set / Applied, MHz | Measured, dB | Uncertainty, dB |
|---|---|---|
| 20000 | 10.32 | ±0.23 |
| 20500 | 10.48 | ±0.23 |
| 21000 | 10.60 | ±0.23 |
| 21500 | 10.73 | ±0.23 |
| 22000 | 10.87 | ±0.23 |
| 22500 | 10.97 | ±0.29 |
| 23000 | 11.09 | ±0.29 |
| 23500 | 11.26 | ±0.29 |
| 24000 | 11.37 | ±0.29 |
| 24500 | 11.50 | ±0.29 |
| 25000 | 11.61 | ±0.23 |
| 25500 | 11.72 | ±0.23 |
| 26000 | 11.87 | ±0.23 |
| 26500 | 11.99 | ±0.23 |
| 27000 | 12.09 | ±0.33 |
| 27500 | 12.24 | ±0.33 |
| 28000 | 12.34 | ±0.40 |
| 28500 | 12.47 | ±0.40 |
| 29000 | 12.61 | ±0.40 |
| 29500 | 12.70 | ±0.40 |
| 30000 | 12.86 | ±0.40 |
| 30500 | 12.92 | ±0.33 |
| 31000 | 13.09 | ±0.33 |
| 31500 | 13.16 | ±0.33 |
| 32000 | 13.33 | ±0.33 |
| 32500 | 13.40 | ±0.33 |
| 33000 | 13.62 | ±0.33 |
| 33500 | 13.70 | ±0.33 |
| 34000 | 13.88 | ±0.33 |
| 34500 | 13.97 | ±0.40 |
| 35000 | 14.05 | ±0.40 |
| 35500 | 14.23 | ±0.40 |
| 36000 | 14.25 | ±0.40 |
| 36500 | 14.46 | ±0.40 |
| 37000 | 14.49 | ±0.33 |
| 37500 | 14.72 | ±0.33 |
| 38000 | 14.77 | ±0.33 |
| 38500 | 14.97 | ±0.33 |
| 39000 | 15.04 | ±0.33 |
| 39500 | 15.22 | ±0.33 |
| 40000 | 15.63 | ±0.47 |

# 11 APPENDIX C Measurement uncertainties

**Expanded uncertainty at 95% confidence in Hermon Labs EMC measurements**

| Test description | Expanded uncertainty |
|---|---|
| Conducted carrier power at RF antenna connector | Below 12.4 GHz: ± 1.7 dB<br>12.4 GHz to 40 GHz: ± 2.3 dB |
| Conducted emissions at RF antenna connector | 9 kHz to 2.9 GHz: ± 2.6 dB<br>2.9 GHz to 6.46 GHz: ± 3.5 dB<br>6.46 GHz to 13.2 GHz: ± 4.3 dB<br>13.2 GHz to 22.0 GHz: ± 5.0 dB<br>22.0 GHz to 26.8 GHz: ± 5.5 dB<br>26.8 GHz to 40.0 GHz: ± 4.8 dB |
| Occupied bandwidth | ± 8.0 % |
| Duty cycle, timing (Tx ON / OFF) and average factor measurements | ± 1.0 % |
| Conducted emissions with LISN | 9 kHz to 150 kHz: ± 3.9 dB<br>150 kHz to 30 MHz: ± 3.8 dB |
| Radiated emissions at 3 m measuring distance<br>Horizontal polarization<br><br><br><br>Vertical polarization | <br>Biconilog antenna: ± 5.3 dB<br>Biconical antenna: ± 5.0 dB<br>Log periodic antenna: ± 5.3 dB<br>Double ridged horn antenna: ± 5.3 dB<br>Biconilog antenna: ± 6.0 dB<br>Biconical antenna: ± 5.7 dB<br>Log periodic antenna: ± 6.0 dB<br>Double ridged horn antenna: ± 6.0 dB |

Hermon Laboratories is accredited by A2LA for calibration according to present requirements of ISO/IEC 17025 and NCSL Z540-1. The accreditation is granted to perform calibration of parameters that are listed in the Scope of Hermon Laboratories Accreditation.

Hermon Laboratories calibrates its reference and transfer standards by calibration laboratories accredited to ISO/IEC 17025 by a mutually recognized Accreditation Body or by a recognized national metrology institute. All reference and transfer standards used in the calibration system are traceable to national or international standards.

In-house calibration of all test and measurement equipment is performed on a regular basis according to Hermon Laboratories calibration procedures, manufacturer calibration/verification procedures or procedures defined in the relevant standards. The Hermon Laboratories test and measurement equipment is calibrated within the tolerances specified by the manufacturers and/or by the relevant standards.

# 12 APPENDIX D Test laboratory description

Tests were performed at Hermon Laboratories Ltd., which is a fully independent, private, EMC, Radio, Safety, Environmental and Telecommunication testing facility.
Hermon Laboratories is recognized and accredited by the Federal Communications Commission (USA) for 1, 2, 15, 18 parts of Code of Federal Regulations 47 (CFR 47), Test Firm Registration Number is 927748, Designation Number is IL1001; registered by Industry Canada for electromagnetic emissions, file number IC 2186A-1 for OATS, certified by VCCI, Japan (the registration numbers are R-10808 for OATS, R-1082 for anechoic chamber, G-10869 for RE measurements above 1 GHz, C-10845 for conducted emissions site and T-11606 for conducted emissions at telecommunication ports).
The laboratory is accredited by American Association for Laboratory Accreditation (USA) according to ISO/IEC 17025 for electromagnetic compatibility, product safety, telecommunications testing, environmental simulation and calibration (for exact scope please refer to Certificate No. 839.01, 839.03 and 839.04).

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# 13 APPENDIX E Specification references

| | |
|---|---|
| FCC 47CFR part 15:2019 | Radio Frequency Devices. |
| ANSI C63.4:2014 | American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz. |
| ANSI C63.10:2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |

# 14 APPENDIX F Abbreviations and acronyms

| | |
|---|---|
| A | ampere |
| AC | alternating current |
| A/m | ampere per meter |
| AM | amplitude modulation |
| AVRG | average (detector) |
| cm | centimeter |
| dB | decibel |
| dBm | decibel referred to one milliwatt |
| dB(μV) | decibel referred to one microvolt |
| dB(μV/m) | decibel referred to one microvolt per meter |
| dB(μA) | decibel referred to one microampere |
| DC | direct current |
| EIRP | equivalent isotropically radiated power |
| ERP | effective radiated power |
| EUT | equipment under test |
| F | frequency |
| GHz | gigahertz |
| GND | ground |
| H | height |
| HL | Hermon laboratories |
| Hz | hertz |
| k | kilo |
| kHz | kilohertz |
| LO | local oscillator |
| m | meter |
| MHz | megahertz |
| min | minute |
| mm | millimeter |
| ms | millisecond |
| μs | microsecond |
| NA | not applicable |
| NB | narrow band |
| OATS | open area test site |
| Ω | Ohm |
| PM | pulse modulation |
| PS | power supply |
| ppm | part per million ($10^{-6}$) |
| QP | quasi-peak |
| RE | radiated emission |
| RF | radio frequency |
| rms | root mean square |
| Rx | receive |
| s | second |
| T | temperature |
| Tx | transmit |
| V | volt |
| WB | wideband |

END OF DOCUMENT