Choose Scandinavian trust

# Wireless test report – 404987-1R1TRFWL

Applicant:

Eleven-X Inc.

Product type:

Parking Stall Sensor

Model:

PRK001001

FCC ID:

2A0X5PRK001001

IC Registration number:

22369-PRK001001

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247

  Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz

- RSS-247, Issue 2, Feb 2017, Section 5

  Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices

  5) Standard specifications for frequency hopping systems and digital transmission systems operating in the bands 902–928 MHz, 2400–2483.5 MHz and 5725–5850 MHz

Date of issue: November 24, 2020

| | |
|---|---|
| Mark Libbrecht, EMC Specialist | Mark Libbrecht |
| Tested by | Signature |
| Fahar A Sukkoor, EMC/Wireless Specialist | A. Fahar |
| Reviewed by | Signature |



Nemko Canada Inc., a testing laboratory, is accredited by the Standards Council of Canada. The tests included in this report are within the scope of this accreditation

## Test location(s)

| | |
|---|---|
| Company name | Nemko Canada Inc. |
| Site name | Cambridge |
| Address | 130 Saltsman Drive, Unit #1 |
| City | Cambridge |
| Province | Ontario |
| Postal code | N3E 0B2 |
| Country | Canada |
| Telephone | Tel: +1 519 680 4811 |
| Website | www.nemko.com |
| Site number (3 m SAC) | FCC/IC: CA0101 |

## Limits of responsibility

Note that the results contained in this report relate only to the items tested and were obtained in the period between the date of initial receipt of samples and the date of issue of the report.
This test report has been completed in accordance with the requirements of ISO/IEC 17025. All results contain in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

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# Section 1. Report summary

## 1.1 Applicant and manufacturer

| | |
|---|---|
| Company name | Eleven-X Inc. |
| Address | 375 Hagey Blvd., Suite 311 |
| City | Waterloo |
| Province/State | Ontario |
| Postal/Zip code | N2L 6R5 |
| Country | Canada |

## 1.2 Test specifications

| | |
|---|---|
| FCC 47 CFR Part 15, Subpart C, Clause 15.247 | Operation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–585 MHz |
| RSS-247, Issue 2, Feb 2017, Section 5 | Digital Transmission Systems (DTSs), Frequency Hopping Systems (FHSs) and Licence-Exempt Local Area Network (LE-LAN) Devices |

## 1.3 Test methods

| | |
|---|---|
| 558074 D01 15.247 Meas Guidance v05r02 (April 2, 2019) | Guidance for compliance measurements on digital transmission system, frequency hopping spread spectrum system, and hybrid system devices operating under section 15.247 of the FCC rules. |
| DA 00-705, Released March 30, 2000 | Filing and Measurement Guidelines for Frequency Hopping Spread Spectrum Systems |
| ANSI C63.10 v2013 | American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices |
| RSS-Gen, Issue 5 Amendment 1, March 2019 | General Requirements for Compliance of Radio Apparatus |

## 1.4 Statement of compliance

In the configuration tested, the EUT was found compliant.

Testing was performed against all relevant requirements of the test standard except as noted in section 1.5 below. Results obtained indicate that the product under test complies in full with the requirements tested. The test results relate only to the items tested.

*See "Summary of test results" for full details.*

## 1.5 Exclusions

None

## 1.6 Test report revision history

| Revision # | Date of issue | Details of changes made to test report |
|---|---|---|
| TRF | November 12, 2020 | Original report issued |
| R1TRF | November 24, 2020 | Update HVIN |

# Section 2. Summary of test results

## 2.1 FCC Part 15 Subpart C, general requirements test results

***Table 2.1-1:*** *FCC general requirements results*

| Part | Test description | Verdict |
|---|---|---|
| §15.207(a) | Conducted limits | Not applicable |
| §15.31(e) | Variation of power source | Pass |
| §15.31(m) | Number of tested frequencies | Pass |
| §15.203 | Antenna requirement | Pass |

Notes: EUT is a battery-operated device, the testing was performed using fresh batteries.

## 2.2 FCC Part 15 Subpart C, intentional radiators test results for frequency hopping spread spectrum systems

***Table 2.2-1:*** *FCC 15.247 results for FHSS*

| Part | Test description | Verdict |
|---|---|---|
| §15.247(a)(1)(i) | Requirements for operation in the 902–928 MHz band | Pass |
| §15.247(a)(1)(ii) | Requirements for operation in the 5725–5850 MHz band | Not applicable |
| §15.247(a)(1)(iii) | Requirements for operation in the 2400–2483.5 MHz band | Not applicable |
| §15.247(b)(1) | Maximum peak output power in the 2400–2483.5 MHz band and 5725–5850 MHz band | Not applicable |
| §15.247(b)(2) | Maximum peak output power in the 902–928 MHz band | Pass |
| §15.247(c)(1) | Fixed point-to-point operation with directional antenna gains greater than 6 dBi | Not applicable |
| §15.247(c)(2) | Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams | Not applicable |
| §15.247(d) | Spurious emissions | Pass |
| §15.247(f) | Time of occupancy for hybrid systems | Pass |

## 2.3 FCC Part 15 Subpart C, intentional radiators test results for digital transmission systems (DTS)

***Table 2.3-1:*** *FCC 15.247 results for DTS*

| Part | Test description | Verdict |
|---|---|---|
| §15.247(a)(2) | Minimum 6 dB bandwidth | Pass |
| §15.247(b)(3) | Maximum peak output power in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands | Pass |
| §15.247(c)(1) | Fixed point-to-point operation with directional antenna gains greater than 6 dBi | Not applicable |
| §15.247(c)(2) | Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams | Not applicable |
| §15.247(d) | Spurious emissions | Pass |
| §15.247(e) | Power spectral density | Pass |
| §15.247(f) | Time of occupancy for hybrid systems | Pass |

## 2.4 ISED RSS-Gen, Issue 5, test results

***Table 2.4-1:*** *RSS-Gen results*

| Part | Test description | Verdict |
|---|---|---|
| 7.3 | Receiver radiated emission limits | Not applicable |
| 7.4 | Receiver conducted emission limits | Not applicable |
| 6.9 | Operating bands and selection of test frequencies | Pass |
| 8.8 | AC power-line conducted emissions limits | Not applicable |

Notes: [1] According to sections 5.2 and 5.3 of RSS-Gen, Issue 5 the EUT does not have a stand-alone receiver neither scanner receiver, therefore exempt from receiver requirements.
EUT is a battery operated device, the testing was performed using fresh batteries.

## 2.5 ISED RSS-247, Issue 2, test results for frequency hopping spread spectrum systems (FHSS)

***Table 2.5-1:*** *RSS-247 results for FHSS*

| Part | Test description | Verdict |
|---|---|---|
| 5.1 (a) | Bandwidth of a frequency hopping channel | Pass |
| 5.1 (b) | Minimum channel spacing | Pass |
| 5.1 (c) | Systems operating in the 902–928 MHz band | Pass |
| 5.1 (d) | Systems operating in the 2400–2483.5 MHz band | Not applicable |
| 5.1 (e) | Systems operating in the 5725–5850 MHz band | Not applicable |
| 5.3 | Hybrid Systems | |
| 5.3 (a) | Digital modulation turned off | Pass |
| 5.3 (b) | Frequency hopping turned off | Pass |
| 5.4 | Transmitter output power and e.i.r.p. requirements | |
| 5.4 (a) | Systems operating in the 902–928 MHz band | Pass |
| 5.4 (b) | Systems operating in the 2400–2483.5 MHz band | Not applicable |
| 5.4 (c) | Systems operating in the 5725–5850 MHz | Not applicable |
| 5.4 (e) | Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band | Not applicable |
| 5.4 (f) | Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams | Not applicable |
| 5.5 | Unwanted emissions | Pass |

Notes: None

## 2.6 ISED RSS-247, Issue 2, test results for digital transmission systems (DTS)

***Table 2.6-1:*** *RSS-247 results for DTS*

| Part | Test description | Verdict |
|---|---|---|
| 5.2 (a) | Minimum 6 dB bandwidth | Pass |
| 5.2 (b) | Maximum power spectral density | Pass |
| 5.3 | Hybrid Systems | |
| 5.3 (a) | Digital modulation turned off | Pass |
| 5.3 (b) | Frequency hopping turned off | Pass |
| 5.4 | Transmitter output power and e.i.r.p. requirements | |
| 5.4 (d) | Systems employing digital modulation techniques | Pass |
| 5.4 (e) | Point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band | Not applicable |
| 5.4 (f) | Transmitters which operate in the 2400–2483.5 MHz band with multiple directional beams | Not applicable |
| 5.5 | Unwanted emissions | Pass |

Notes: None

# Section 3. Equipment under test (EUT) details

## 3.1 Sample information

| | |
|---|---|
| Receipt date | October 9, 2020 |
| Nemko sample ID number | 1 |

## 3.2 EUT information

| | |
|---|---|
| Product type | Parking Stall Sensor |
| Model | PRK001001 |
| Software Version | 0.11.2 |
| Model variant | 1.0 |
| Serial number | 70B3B514900E0152 |

## 3.3 Technical information

| | |
|---|---|
| Applicant IC company number | 22369 |
| IC UPN number | 22369-PRK001001 |
| All used IC test site(s) Reg. number | 24676 |
| RSS number and Issue number | RSS-247 Issue 2, Feb 2017 |
| Frequency band | 902-928 MHz |
| Frequency Min (MHz) | 902.3 (FHSS)<br>903 (DTS) |
| Frequency Max (MHz) | 914.9 (FHSS)<br>914.2 (DTS) |
| RF power Max (W), Conducted | 0.204 (23.1 dBm) FHSS @ 902.3 MHz<br>0.195 (22.9 dBm) DTS @ 903 MHz |
| Field strength, dBµV/m @ 3 m | N/A |
| Measured BW (kHz), 99% OBW | 146.3 kHz (FHSS) @ 902.3 MHz<br>503.9 kHz (DTS) @ 914.2 MHz |
| Type of modulation | LoRa |
| Emission classification (F1D, G1D, D1D) | X1D |
| Transmitter spurious, dBµV/m @ 3 m | 55.4 (Peak), 53.7 (Average) @ 3634.7 MHz |
| Power requirements | Battery: 3.6V non-rechargeable Lithium Thionyl Chloride D-Cell |
| Antenna information | Peak gain = -1 dBi |

## 3.4 Product description and theory of operation

The eleven smart parking sensor is an innovative patent-pending LoRaWAN®-based device that utilizes multiple technologies including magnetic sensing, Radar, and Bluetooth: The sensor sends parking events over LoRaWAN to the eleven-x SPS analytics platform where the data provides key analytics and insight to help parking manager understand the usage of the parking assets.

## 3.5 EUT exercise details

EUT was set to transmit continuously at 100% duty cycle.

## 3.6 EUT setup diagram

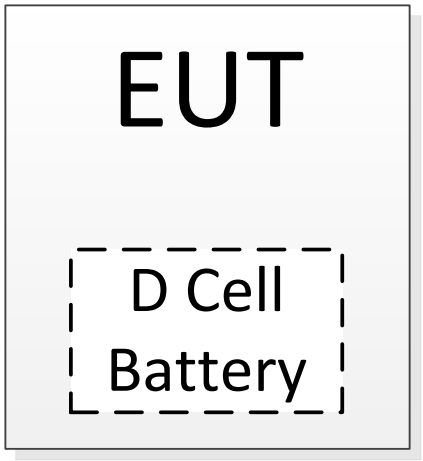



***Figure 3.6-1:*** *Setup diagram*

## 3.7 EUT sub assemblies

***Table 3.7-1:*** *EUT sub assemblies*

| Description | Brand name | Model/Part number | Serial number |
|---|---|---|---|
| 3.6 $V_{DC}$ D Cell Battery | Tadiran | TL-4930 | None |

# **Section 4.** Engineering considerations

## 4.1 Modifications incorporated in the EUT

There were no modifications performed to the EUT during this assessment.

## 4.2 Technical judgment

None

## 4.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

# **Section 5.** Test conditions

## 5.1 Atmospheric conditions

| | |
|---|---|
| Temperature | 15–30 °C |
| Relative humidity | 20–75 % |
| Air pressure | 860–1060 mbar |

When it is impracticable to carry out tests under these conditions, a note to this effect stating the ambient temperature and relative humidity during the tests shall be recorded and stated.

## 5.2 Power supply range

The normal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. For the purpose of the present document, the nominal voltage shall be the declared voltage, or any of the declared voltages ±5 %, for which the equipment was designed.

# Section 6. Measurement uncertainty

## 6.1 Uncertainty of measurement

UKAS Lab 34 and TIA-603-B have been used as guidance for measurement uncertainty reasonable estimations with regards to previous experience and validation of data. Nemko Canada, Inc. follows these test methods in order to satisfy ISO/IEC 17025 requirements for estimation of uncertainty of measurement for wireless products.

Measurement uncertainty budgets for the tests are detailed below. Measurement uncertainty calculations assume a coverage factor of K = 2 with 95% certainty.

***Table 6.1-1:*** *Measurement uncertainty*

| Test name | Measurement uncertainty, dB |
|---|---|
| All antenna port measurements | 0.55 |
| Conducted spurious emissions | 1.13 |
| Radiated spurious emissions | 3.78 |
| AC power line conducted emissions | 3.55 |

# Section 7. Test equipment

## 7.1 Test equipment list

***Table 7.1-1:*** *Equipment list*

| Equipment | Manufacturer | Model no. | Asset no. | Cal cycle | Next cal. |
|---|---|---|---|---|---|
| 3 m EMI test chamber | TDK | SAC-3 | FA003012 | 1 year | Oct. 10/21 |
| Flush mount turntable | SUNAR | FM2022 | FA003006 | — | NCR |
| Controller | SUNAR | SC110V | FA002976 | — | NCR |
| Antenna mast | SUNAR | TLT2 | FA003007 | — | NCR |
| Receiver/spectrum analyzer | Rohde & Schwarz | ESR26 | FA002969 | 1 year | Dec. 4/20 |
| Spectrum analyzer | Rohde & Schwarz | FSW43 | FA002971 | 1 year | June 21/21 |
| Horn antenna (1–18 GHz) | ETS Lindgren | 3117 | FA002911 | 1 year | Sept. 11/21 |
| Preamp (1–18 GHz) | ETS Lindgren | 124334 | FA002956 | 1 year | Mar. 18/21 |
| Bilog antenna (30–2000 MHz) | SUNAR | JB1 | FA003010 | 1 year | Sept. 17/21 |
| 50 Ω coax cable | Huber + Suhner | None | FA003047 | 1 year | Sept. 30/21 |
| 50 Ω coax cable | Huber + Suhner | None | FA003044 | 1 year | Oct. 7/21 |
| Notch filter 1.2 – 12 Ghz Highpass filter | Microwave circuits | H1G212G1 | FA003031 | 1 year | Oct. 9/21 |

Note: NCR - no calibration required

# Section 8. Testing data

## 8.1 FCC 15.31(e) Variation of power source

### 8.1.1 Definitions and limits

For intentional radiators, measurements of the variation of the input power or the radiated signal level of the fundamental frequency component of the emission, as appropriate, shall be performed with the supply voltage varied between 85% and 115% of the nominal rated supply voltage. For battery operated equipment, the equipment tests shall be performed using a new battery.

### 8.1.2 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

### 8.1.3 Observations, settings and special notes

The testing was performed as per ANSI C63.10 Section 5.13.

a) Where the device is intended to be powered from an external power adapter, the voltage variations shall be applied to the input of the adapter provided with the device at the time of sale. If the device is not marketed or sold with a specific adapter, then a typical power adapter shall be used.
b) For devices where operating at a supply voltage deviating ±15% from the nominal rated value may cause damages or loss of intended function, test to minimum and maximum allowable voltage per manufacturer's specification and document in the report.
c) For devices with wide range of rated supply voltage, test at 15% below the lowest and 15% above the highest declared nominal rated supply voltage.
d) For devices obtaining power from an input/output (I/O) port (USB, firewire, etc.), a test jig is necessary to apply voltage variation to the device from a support power supply, while maintaining the functionalities of the device.

For battery-operated equipment, the equipment tests shall be performed using a variable power supply.

### 8.1.4 Test data

| | | | |
|---|---|---|---|
| EUT Power requirements: | ☐ AC | ☐ DC | ☒ Battery |
| If EUT is an AC or a DC powered, was the noticeable output power variation observed? | ☐ YES | ☐ NO | ☒ N/A |
| If EUT is battery operated, was the testing performed using fresh batteries? | ☒ YES | ☐ NO | ☐ N/A |
| If EUT is rechargeable battery operated, was the testing performed using fully charged batteries? | ☐ YES | ☐ NO | ☒ N/A |

## 8.2 FCC 15.31(m) and RSS-Gen 6.9 Number of frequencies

### 8.2.1 Definitions and limits

**FCC:**
Measurements on intentional radiators or receivers shall be performed and, if required, reported for each band in which the device can be operated with the device operating at the number of frequencies in each band specified in the following table.

**ISED:**
Except where otherwise specified, measurements shall be performed for each frequency band of operation for which the radio apparatus is to be certified, with the device operating at the frequencies in each band of operation shown in table below. The frequencies selected for measurements shall be reported in the test report.

***Table 8.2-1:*** *Frequency Range of Operation*

| Frequency range over which the device operates (in each band) | Number of test frequencies required | Location of measurement frequency inside the operating frequency range |
|---|---|---|
| 1 MHz or less | 1 | Center (middle of the band) |
| 1–10 MHz | 2 | 1 near high end, 1 near low end |
| Greater than 10 MHz | 3 | 1 near high end, 1 near center and 1 near low end |

Note: “near” means as close as possible to or at the centre / low end / high end of the frequency range over which the device operates.

### 8.2.2 Test date

| | |
|---|---|
| Start date | October 9, 2020 |

### 8.2.3 Observations, settings and special notes

Per ANSI C63.10 Subclause 5.6.2.1:
The number of channels tested can be reduced by measuring the center channel bandwidth first and then applying the following relaxations as appropriate:

a) For each operating mode, if the measured channel bandwidth on the middle channel is at least 150% of the minimum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.
b) For multiple-input multiple-output (MIMO) systems, if the measured channel bandwidth on testing the middle channel exceeds the minimum permitted bandwidth by more than 50% on one transmit chain, then it is not necessary to repeat testing on the other chains.
c) If the measured channel bandwidth on the middle channel is less than 50% of the maximum permitted bandwidth, then it is not necessary to measure the bandwidth on the high and low channels.

Per ANSI C63.10 Subclause 5.6.2.2:
For devices with multiple operating modes, measurements on the middle channel can be used to determine the worst-case mode(s). The worst-case modes are as follows:

a) Band edge requirements—Measurements on the mode with the widest bandwidth can be used to cover the same channel (center frequency) on modes with narrower bandwidth that have the same or lower output power for each modulation family (e.g., OFDM and direct sequence spread spectrum).
b) Spurious emissions—Measure the mode with the highest output power and the mode with the highest output power spectral density for each modulation family (e.g., OFDM and direct sequence spread spectrum).
c) In-band PSD—Measurements on the mode with the narrowest bandwidth can be used to cover all modes within the same modulation family of an equal or lower output power provided the result is less than 50% of the limit.

### 8.2.4 Test data

***Table 8.2-2:*** *Test channels selection, 125 kHz FHSS*

| Start of Frequency range, MHz | End of Frequency range, MHz | Frequency range bandwidth, MHz | Low channel, MHz | Mid channel, MHz | High channel, MHz |
|---|---|---|---|---|---|
| 902 | 928 | 26 | 902.3 | 908.7 | 914.9 |

***Table 8.2-3:*** *Test channels selection, 500 kHz DTS*

| Start of Frequency range, MHz | End of Frequency range, MHz | Frequency range bandwidth, MHz | Low channel, MHz | Mid channel, MHz | High channel, MHz |
|---|---|---|---|---|---|
| 902 | 928 | 26 | 903 | 907.8 | 914.2 |

## 8.3 FCC 15.203 and RSS-Gen, section 6.8 Antenna requirement

### 8.3.1 Definitions and limits

**FCC:**
An intentional radiator shall be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device. The use of a permanently attached antenna or of an antenna that uses a unique coupling to the intentional radiator shall be considered sufficient to comply with the provisions of this section. The manufacturer may design the unit so that a broken antenna can be replaced by the user, but the use of a standard antenna jack or electrical connector is prohibited. This requirement does not apply to intentional radiators that must be professionally installed, such as perimeter protection systems and some field disturbance sensors, or to other intentional radiators which, in accordance with §15.31(d), must be measured at the installation site. However, the installer shall be responsible for ensuring that the proper antenna is employed so that the limits in this part are not exceeded.

**ISED:**
The applicant for equipment certification shall provide a list of all antenna types that may be used with the transmitter, where applicable (i.e. for transmitters with detachable antenna), indicating the maximum permissible antenna gain (in dBi) and the required impedance for each antenna. The test report shall demonstrate the compliance of the transmitter with the limit for maximum equivalent isotropically radiated power (e.i.r.p.) specified in the applicable RSS, when the transmitter is equipped with any antenna type, selected from this list.

For expediting the testing, measurements may be performed using only the antenna with highest gain of each combination of transmitter and antenna type, with the transmitter output power set at the maximum level. However, the transmitter shall comply with the applicable requirements under all operational conditions and when in combination with any type of antenna from the list provided in the test report.

### 8.3.2 Test date

| | |
|---|---|
| Start date | October 9, 2020 |

### 8.3.3 Observations, settings and special notes

None

### 8.3.4 Test data

| | | | |
|---|---|---|---|
| Must the EUT be professionally installed? | ☐ YES | ☒ NO | |
| Does the EUT have detachable antenna(s)? | ☐ YES | ☒ NO | |
| If detachable, is the antenna connector(s) non-standard? | ☐ YES | ☐ NO | ☒ N/A |

## 8.4 FCC 15.247(a)(1) and RSS-247 5.1 Frequency Hopping Systems requirements, 900 MHz operation

### 8.4.1 Definitions and limits

**FCC:**

(1) Frequency hopping systems shall have hopping channel carrier frequencies separated by a minimum of 25 kHz or the 20 dB bandwidth of the hopping channel, whichever is greater. Alternatively, frequency hopping systems operating in the 2400–2483.5 MHz band may have hopping channel carrier frequencies that are separated by 25 kHz or two-thirds of the 20 dB bandwidth of the hopping channel, whichever is greater, provided the systems operate with an output power no greater than 125 mW. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. Each frequency must be used equally on the average by each transmitter. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

(i) For frequency hopping systems operating in the 902–928 MHz band: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 20 second period; if the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping frequencies and the average time of occupancy on any frequency shall not be greater than 0.4 seconds within a 10 second period. The maximum allowed 20 dB bandwidth of the hopping channel is 500 kHz.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

**ISED:**

a) The bandwidth of a frequency hopping channel is the 20 dB emission bandwidth, measured with the hopping stopped. The system's radio frequency (RF) bandwidth is equal to the channel bandwidth multiplied by the number of channels in the hopset. The system shall hop to channel frequencies that are selected at the system hopping rate from a pseudo randomly ordered list of hopping frequencies. The system receivers shall have input bandwidths that match the hopping channel bandwidths of their corresponding transmitters and shall shift frequencies in synchronization with the transmitted signals.

c) For FHSs in the band 902–928 MHz: if the 20 dB bandwidth of the hopping channel is less than 250 kHz, the system shall use at least 50 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 20-second period. If the 20 dB bandwidth of the hopping channel is 250 kHz or greater, the system shall use at least 25 hopping channels and the average time of occupancy on any channel shall not be greater than 0.4 seconds within a 10‑second period. The maximum 20 dB bandwidth of the hopping channel shall be 500 kHz.

5.3 Hybrid systems

Hybrid systems employ a combination of both frequency hopping and digital transmission techniques and shall comply with the following:

a With the digital transmission operation of the hybrid system turned off, the frequency hopping operation shall have an average time of occupancy on any frequency not exceeding 0.4 seconds within a duration in seconds equal to the number of hopping frequencies multiplied by 0.4.

### 8.4.2 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

### 8.4.3 Observations, settings and special notes

Carrier frequency separation was tested per ANSI C63.10 subclause 7.8.2. Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | Start with the RBW set to approximately 30% of the channel spacing; adjust as necessary to best identify the center of each individual channel. |
| Video bandwidth | ≥ RBW |
| Frequency span | Wide enough to capture the peaks of two adjacent channels |
| Detector mode | Peak |
| Trace mode | Max Hold |

Number of hopping frequencies was tested per ANSI C63.10 subclause 7.8.3. Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | To identify clearly the individual channels, set the RBW to less than 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller. |
| Video bandwidth | ≥ RBW |
| Frequency span | The frequency band of operation. Depending on the number of channels the device supports, it may be necessary to divide the frequency range of operation across multiple spans, to allow the individual channels to be clearly seen. |
| Detector mode | Peak |
| Trace mode | Max Hold |

Time of occupancy (dwell time) was tested per ANSI C63.10 subclause 7.8.4. Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | shall be ≤ channel spacing and where possible RBW should be set >> 1 / T, where T is the expected dwell time per channel. |
| Video bandwidth | ≥ RBW |
| Frequency span | Zero span, centered on a hopping channel. |
| Detector mode | Peak |
| Trace mode | Max Hold |

20 dB bandwidth was tested per ANSI C63.10 subclause 6.9.2. Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | ≥ 1–5% of the 20 dB bandwidth |
| Video bandwidth | ≥ RBW |
| Frequency span | approximately 2 to 5 times the 20 dB bandwidth, centered on a hopping channel |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.4.4 Test data

***Table 8.4-1:*** *20 dB bandwidth results*

| Frequency, MHz | 20 dB bandwidth, kHz |
|---|---|
| 902.3 | 150.3 |
| 908.7 | 149.8 |
| 914.9 | 149.6 |

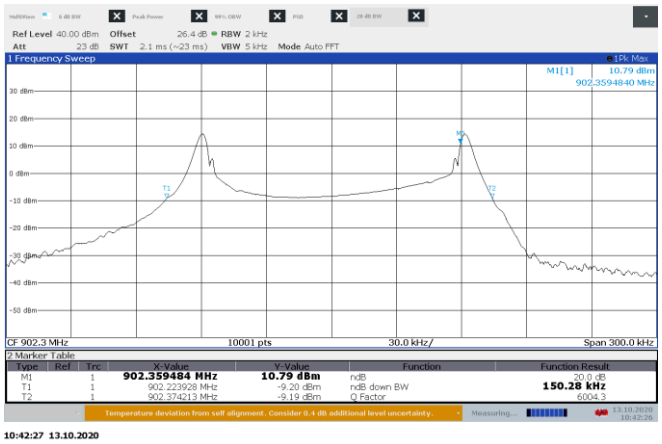



***Figure 8.4-1:*** *20 dB bandwidth on low channel, 125 kHz BW*

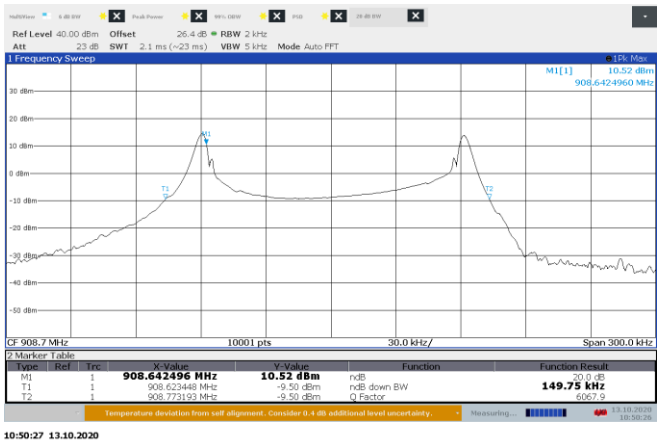



***Figure 8.4-2:*** *20 dB bandwidth on mid channel, 125 kHz BW*

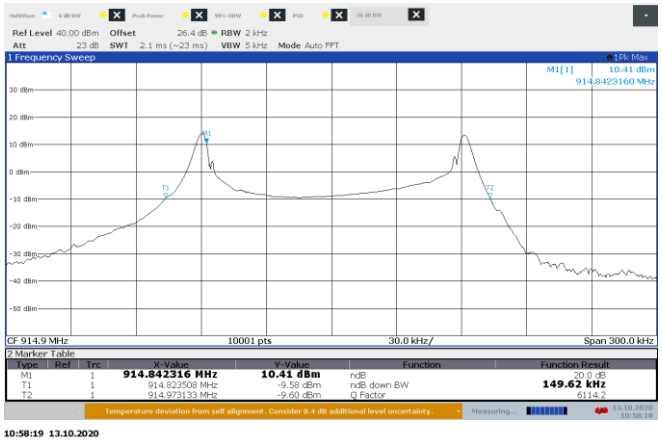



***Figure 8.4-3:*** *20 dB bandwidth on high channel, 125 kHz BW*

## 8.4.5 Test data, continued

***Table 8.4-2:*** *99% occupied bandwidth results*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 902.3 | 146.3 |
| 908.5 | 145.3 |
| 914.9 | 145.2 |

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

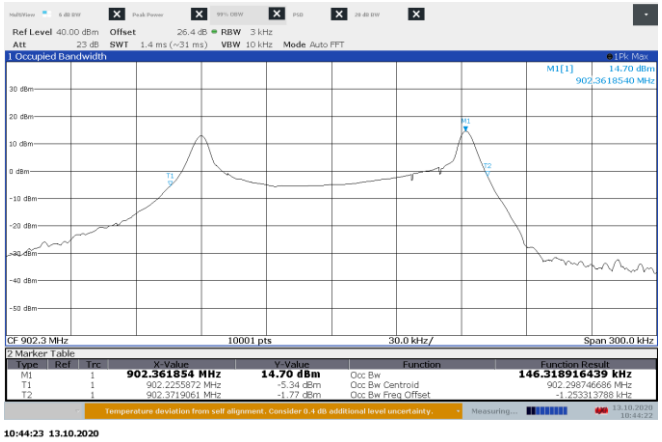



***Figure 8.4-4:*** *99% OBW on low channel, 125 kHz BW*

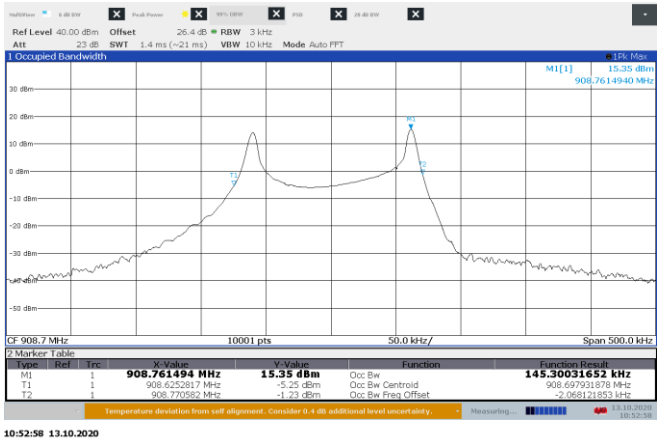



***Figure 8.4-5:*** *99% OBW on mid channel, 125 kHz BW*

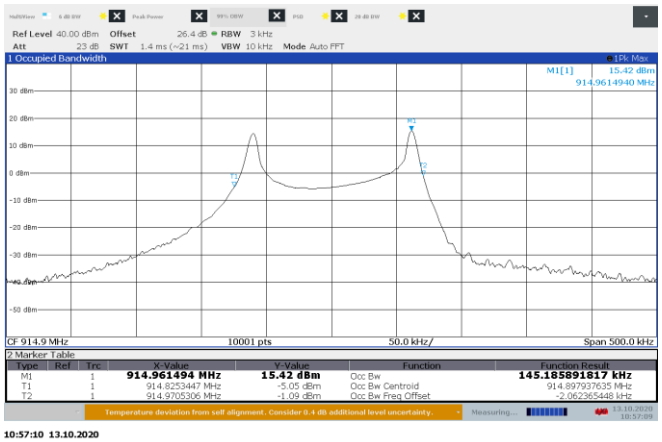



***Figure 8.4-6:*** *99% OBW bandwidth on high channel, 125 kHz BW*

## 8.4.6 Test data, continued

***Table 8.4-3:*** *Carrier frequency separation results*

| Carrier frequency separation, kHz | Minimum limit, kHz | Margin, kHz |
|---|---|---|
| 200 | 130 | 70 |

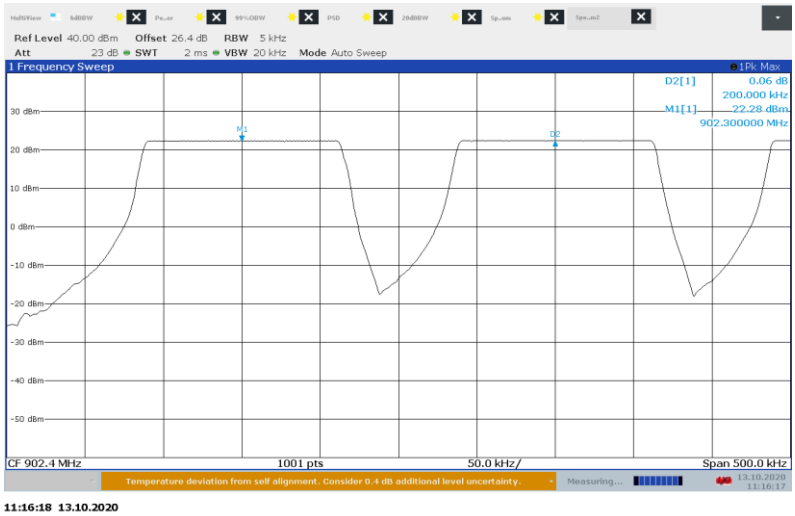



***Figure 8.4-7:*** *Carrier frequency separation*

***Table 8.4-4:*** *Number of hopping frequencies results*

| Number of hopping frequencies | Minimum limit | Margin |
|---|---|---|
| 64 | 50 | 14 |

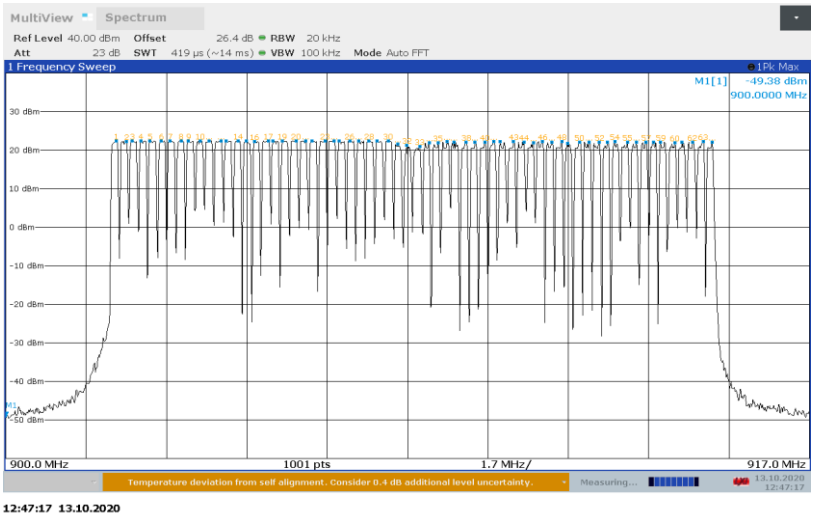



***Figure 8.4-8:*** *Number of hopping channels = 64*

### 8.4.7 Test data, continued

***Table 8.4-5:*** *Average time of occupancy results, Hybrid Mode*

| Dwell time of each pulse, ms | Number of pulses within period | Total dwell time within period, ms | Limit, ms | Margin, ms |
|---|---|---|---|---|
| 358 | 1 | 358 | 400 | 42 |

Measurement Period = 0.4 × 64 channels = 25.6 s

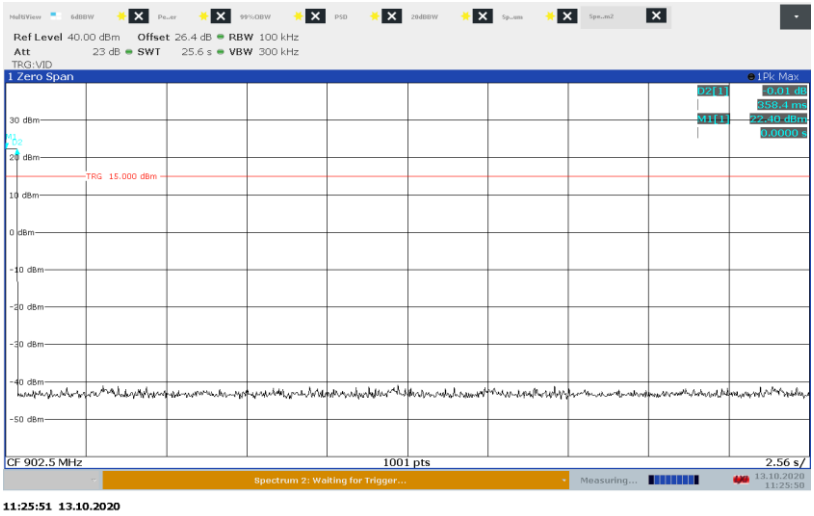



***Figure 8.4-9:*** *Dwell time*

## 8.5 FCC 15.247(a)(2) and RSS-247 5.2(a) Minimum 6 dB bandwidth for DTS systems

### 8.5.1 Definitions and limits

**FCC:**
Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

**ISED:**
The minimum 6 dB bandwidth shall be 500 kHz.

### 8.5.1 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

### 8.5.2 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.2 with reference to ANSI C63.10 subclause 11.8.
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | 100 kHz |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 2 MHz |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.5.3 Test data

***Table 8.5-1:*** *6 dB bandwidth results*

| Frequency, MHz | 6 dB bandwidth, kHz | Minimum limit, MHz | Margin, kHz |
|---|---|---|---|
| 903.0 | 618.5 | 0.50 | 118.5 |
| 907.8 | 623.5 | 0.50 | 123.5 |
| 914.2 | 617.5 | 0.50 | 117.5 |

***Table 8.5-2:*** *99% occupied bandwidth results*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 903.0 | 498.9 |
| 907.8 | 503.3 |
| 914.2 | 503.9 |

Note: there is no 99% occupied bandwidth limit in the standard's requirements, the measurement results provided for information purposes only.

## 8.5.4 Test data, continued

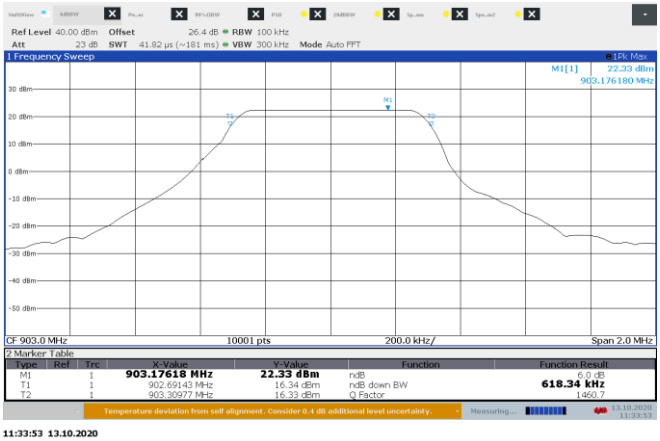



***Figure 8.5-1:*** *6 dB bandwidth on low channel, 500 kHz BW*

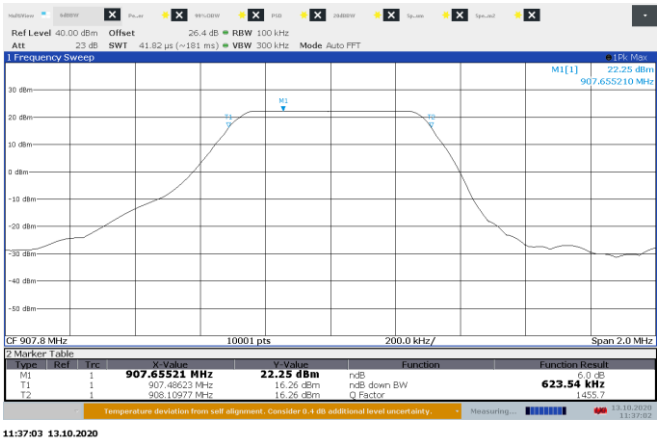



***Figure 8.5-2:*** *6 dB bandwidth on mid channel, 500 kHz BW*

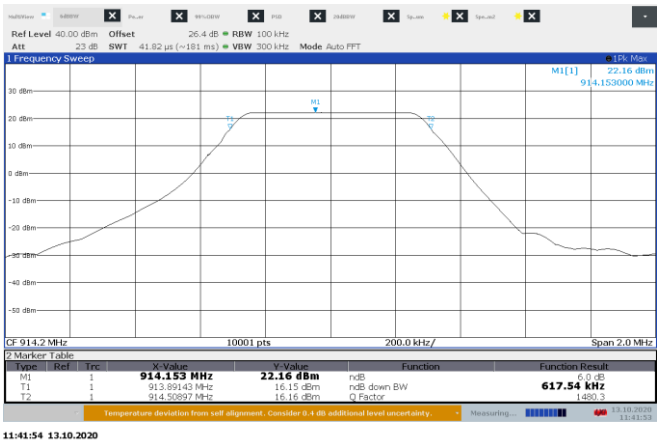



***Figure 8.5-3:*** *6 dB bandwidth on high channel, 500 kHz BW*

## 8.5.5 Test data, continued

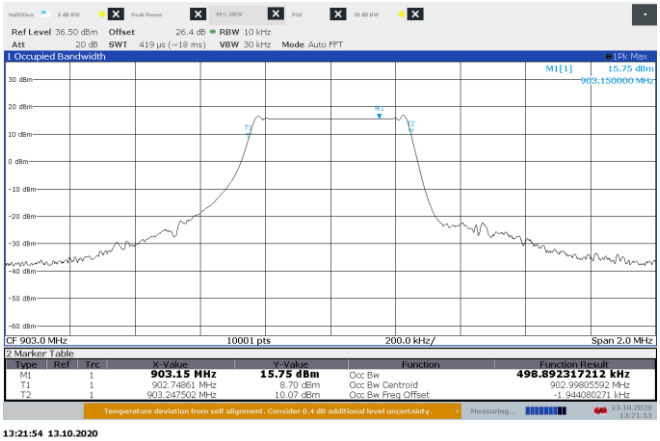



***Figure 8.5-4:*** *99% OBW on low channel, 500 kHz BW*

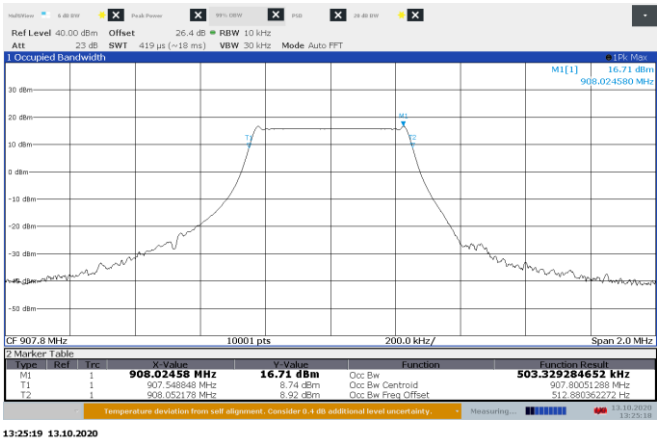



***Figure 8.5-5:*** *99% OBW on mid channel, 500 kHz BW*

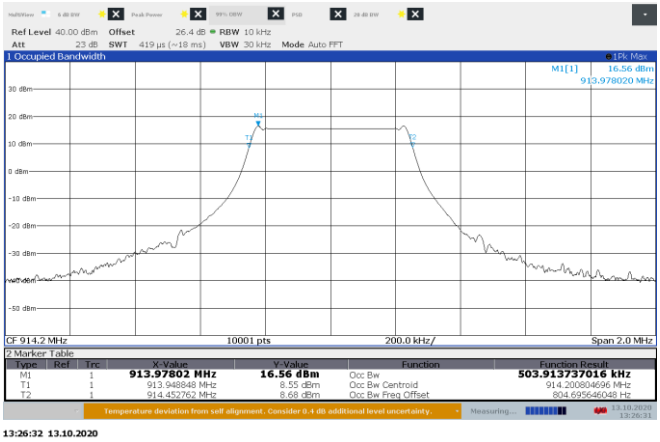



***Figure 8.5-6:*** *99% OBW on high channel, 500 kHz BW*

## 8.6 FCC 15.247(b) and RSS-247 5.4(d) Transmitter output power and e.i.r.p. requirements for DTS in 900 MHz

### 8.6.1 Definitions and limits

**FCC:**

(b) The maximum peak conducted output power of the intentional radiator shall not exceed the following:

(3) For systems using digital modulation in the 902–928 MHz band: 1 W (30 dBm). As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.

(4) The conducted output power limit specified in paragraph (b) of this section is based on the use of antennas with directional gains that do not exceed 6 dBi. Except as shown in paragraph (c) of this section, if transmitting antennas of directional gain greater than 6 dBi are used, the conducted output power from the intentional radiator shall be reduced below the stated values in paragraphs (b)(1), (b)(2), and (b)(3) of this section, as appropriate, by the amount in dB that the directional gain of the antenna exceeds 6 dBi.

(c) Operation with directional antenna gains greater than 6 dBi.
(1) Fixed point-to-point operation:
(iii) Fixed, point-to-point operation, as used in paragraphs (c)(1)(i) and (c)(1)(ii) of this section, excludes the use of point-to-multipoint systems, omnidirectional applications, and multiple co-located intentional radiators transmitting the same information. The operator of the spread spectrum or digitally modulated intentional radiator or, if the equipment is professionally installed, the installer is responsible for ensuring that the system is used exclusively for fixed, point-to-point operations. The instruction manual furnished with the intentional radiator shall contain language in the installation instructions informing the operator and the installer of this responsibility.

**ISED:**

d. For DTSs employing digital modulation techniques operating in the 902–928 MHz band, the maximum peak conducted output power shall not exceed 1 W. The e.i.r.p. shall not exceed 4 W, except as provided in section 5.4(e).

As an alternative to a peak power measurement, compliance can be based on a measurement of the maximum conducted output power. The maximum conducted output power is the total transmit power delivered to all antennas and antenna elements, averaged across all symbols in the signalling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or transmitting at a reduced power level. If multiple modes of operation are implemented, the maximum conducted output power is the highest total transmit power occurring in any mode.

### 8.6.2 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

### 8.6.3 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.3 with reference to ANSI C63.10 subclause 11.9.2.2 (average power)
Reported EUT antenna peak gain = -1 dBi. Per ANSI 63.10 (2013) clause 11.12.2.6 , 2 dBi gain used for all power calculations
The test was performed using method AVGSA-2 (trace averaging across on- and off-times of the EUT transmissions, followed by duty cycle correction).
Trace counts increased to 1000 to stabilize trace.
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | 1-5 % OBW |
| Video bandwidth | ≥3 × RBW |
| Frequency span | ≥1.5 × OBW |
| Detector mode | RMS |
| Trace mode | Average |
| Trace count | > 100 |
| Integration Bandwidth | > OBW |

### 8.6.4 Test data

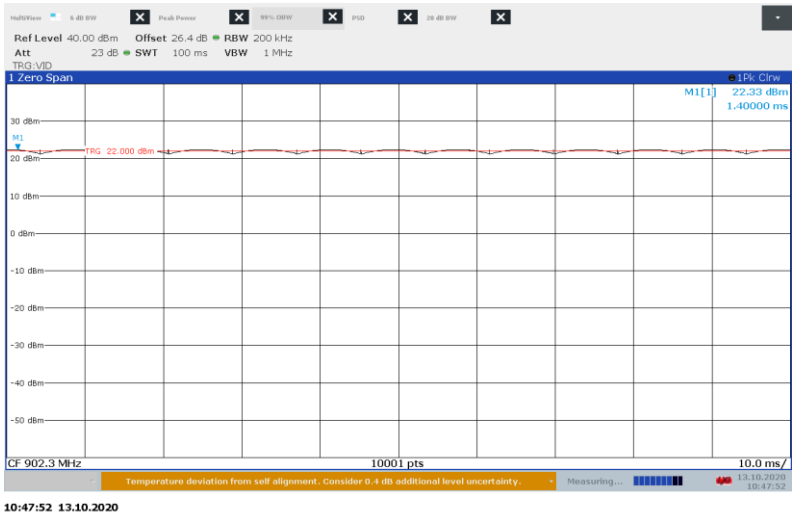



***Figure 8.6-1:*** *Duty cycle on low channel, 125 kHz BW*

| Frequency (MHz) | Bandwidth, kHz | ON Time, ms | Observation Time, ms | Duty Cycle | Duty Cycle Correction Factor (dB) |
|---|---|---|---|---|---|
| 902.3 | 125 | 100 | 100 | 1.0 | 0.0 |

Notes: Duty cycle = On Time/Time, Duty cycle correction = 10 log(1/duty cycle)

## 8.6.5 Test data, continued

***Table 8.6-1:*** *Output power measurements results, 125 kHz BW*

| Frequency (MHz) | Conducted Output Power, dBm | Conducted Output limit, dBm | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 902.3 | 23.1 | 30.0 | 6.9 | 2.0 | 25.1 | 36.0 | 10.9 |
| 908.7 | 22.9 | 30.0 | 7.1 | 2.0 | 24.9 | 36.0 | 11.1 |
| 914.9 | 22.7 | 30.0 | 7.3 | 2.0 | 24.7 | 36.0 | 11.3 |

Notes: EIRP = Output power + Antenna gain, Additional 0.5 dBm added to output power measurement to compensate for UFL to SMA connector

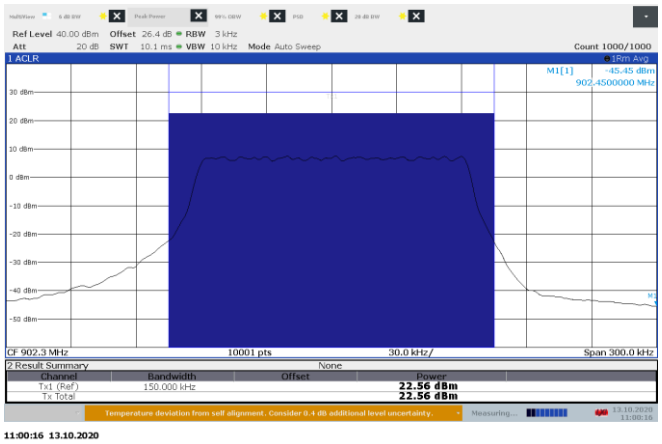



***Figure 8.6-2:*** *Output power on low channel, 125 kHz BW*

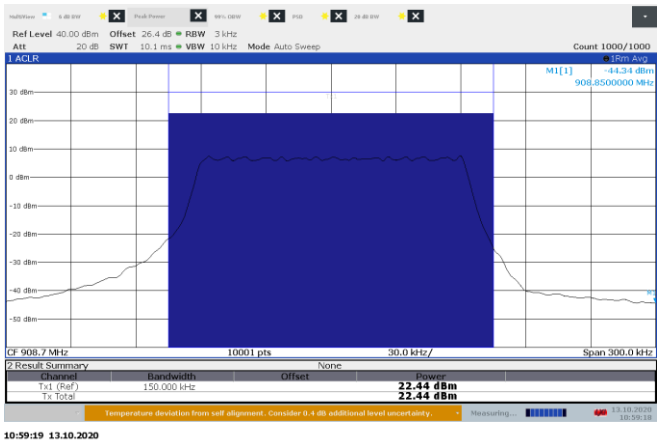



***Figure 8.6-3:*** *Output power on mid channel, 125 kHz BW*

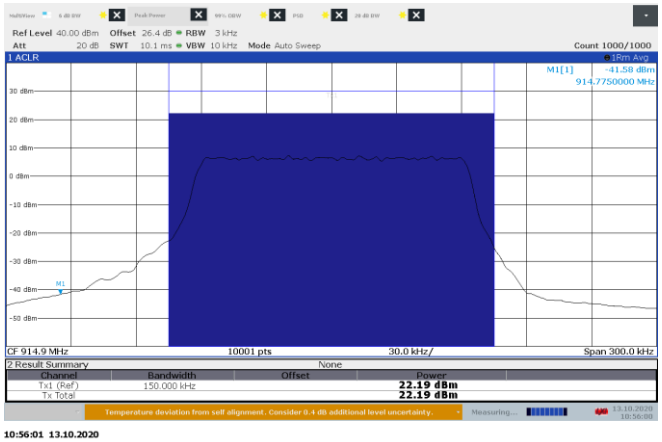



***Figure 8.6-4:*** *Output power on high channel, 125 kHz BW*

### 8.6.1 Test data, continued

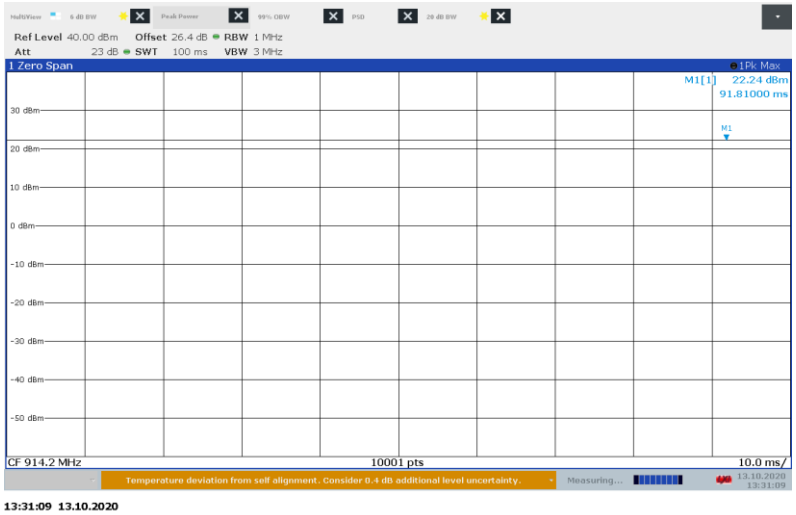



***Figure 8.6-5:*** *Duty cycle on low channel, 500 kHz BW*

| Frequency (MHz) | Bandwidth, kHz | ON Time, ms | Observation Time, ms | Duty Cycle | Duty Cycle Correction Factor (dB) |
|---|---|---|---|---|---|
| 914.2 | 500 | 100 | 100 | 1.0 | 0.0 |

Notes: Duty cycle = On Time/Time, Duty cycle correction = 10 log(1/duty cycle)

## 8.6.2 Test data, continued

***Table 8.6-2:*** *Output power measurements results, 500 kHz BW*

| Frequency (MHz) | Conducted Output Power, dBm | Conducted Output limit, dBm | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 903.0 | 22.9 | 30.0 | 7.1 | 2.0 | 24.9 | 36.0 | 11.1 |
| 907.8 | 22.8 | 30.0 | 7.2 | 2.0 | 24.8 | 36.0 | 11.2 |
| 914.2 | 22.7 | 30.0 | 7.3 | 2.0 | 24.7 | 36.0 | 11.3 |

Notes: EIRP = Output power + Antenna gain, Additional 0.5 dBm added to output power measurement to compensate for UFL to SMA connector

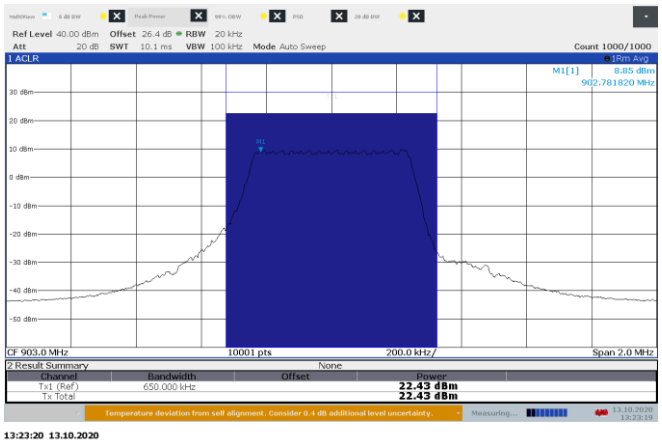



***Figure 8.6-6:*** *Output power on low channel, 500 kHz BW*

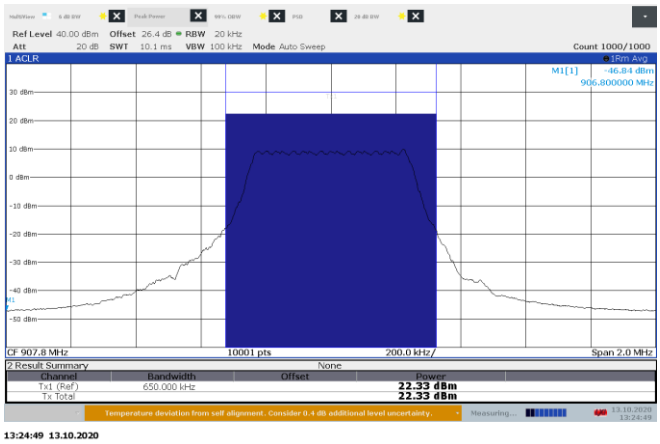



***Figure 8.6-7:*** *Output power on mid channel, 500 kHz BW*

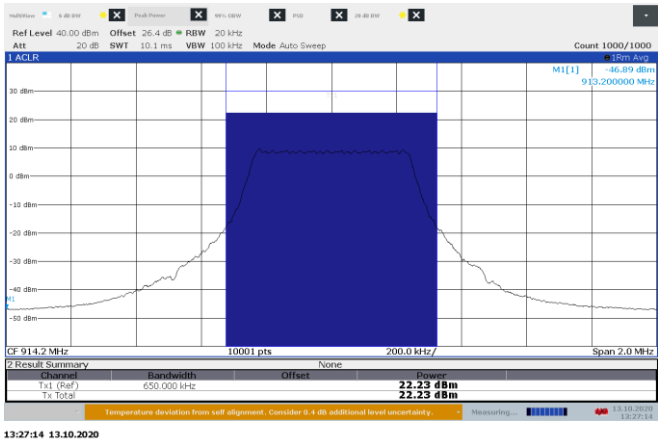



***Figure 8.6-8:*** *Output power on high channel, 500 kHz BW*

## 8.7 FCC 15.247(d) and RSS-247 5.5 Spurious (out-of-band) unwanted emissions

### 8.7.1 Definitions and limits

**FCC:**
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 §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

**ISED:**
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated device is operating, the RF power that is produced 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 that the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of root-mean-square averaging over a time interval, as permitted under section 5.4(d), the attenuation required shall be 30 dB instead of 20 dB. Attenuation below the general field strength limits specified in RSS-Gen is not required.

***Table 8.7-1:*** *FCC §15.209 and RSS-Gen – Radiated emission limits*

| Frequency, MHz | Field strength of emissions | | Measurement distance, m |
|---|---|---|---|
| | µV/m | dBµV/m | |
| 0.009–0.490 | 2400/F | $67.6 – 20 \times \log_{10}(F)$ | 300 |
| 0.490–1.705 | 24000/F | $87.6 – 20 \times \log_{10}(F)$ | 30 |
| 1.705–30.0 | 30 | 29.5 | 30 |
| 30–88 | 100 | 40.0 | 3 |
| 88–216 | 150 | 43.5 | 3 |
| 216–960 | 200 | 46.0 | 3 |
| above 960 | 500 | 54.0 | 3 |

Notes: In the emission table above, the tighter limit applies at the band edges.
For frequencies above 1 GHz the limit on peak RF emissions is 20 dB above the maximum permitted average emission limit applicable to the equipment under test

***Table 8.7-2:*** *ISED restricted frequency bands*

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 12.57675–12.57725 | 399.9–410 | 7.25–7.75 |
| 0.495–0.505 | 13.36–13.41 | 608–614 | 8.025–8.5 |
| 2.1735–2.1905 | 16.42–16.423 | 960–1427 | 9.0–9.2 |
| 3.020–3.026 | 16.69475–16.69525 | 1435–1626.5 | 9.3–9.5 |
| 4.125–4.128 | 16.80425–16.80475 | 1645.5–1646.5 | 10.6–12.7 |
| 4.17725–4.17775 | 25.5–25.67 | 1660–1710 | 13.25–13.4 |
| 4.20725–4.20775 | 37.5–38.25 | 1718.8–1722.2 | 14.47–14.5 |
| 5.677–5.683 | 73–74.6 | 2200–2300 | 15.35–16.2 |
| 6.215–6.218 | 74.8–75.2 | 2310–2390 | 17.7–21.4 |
| 6.26775–6.26825 | 108–138 | 2483.5–2500 | 22.01–23.12 |
| 6.31175–6.31225 | 149.9–150.05 | 2655–2900 | 23.6–24.0 |
| 8.291–8.294 | 156.52475–156.52525 | 3260–3267 | 31.2–31.8 |
| 8.362–8.366 | 156.7–156.9 | 3332–3339 | 36.43–36.5 |
| 8.37625–8.38675 | 162.0125–167.17 | 3345.8–3358 | Above 38.6 |
| 8.41425–8.41475 | 167.72–173.2 | 3500–4400 | |
| 12.29–12.293 | 240–285 | 4500–5150 | |
| 12.51975–12.52025 | 322–335.4 | 5350–5460 | |

Note: Certain frequency bands listed in Table 8.7-2 and above 38.6 GHz are designated for licence-exempt applications. These frequency bands and the requirements that apply to related devices are set out in the 200 and 300 series of RSSs.

***Table 8.7-3:*** *FCC restricted frequency bands*

| MHz | MHz | MHz | GHz |
|---|---|---|---|
| 0.090–0.110 | 16.42–16.423 | 399.9–410 | 4.5–5.15 |
| 0.495–0.505 | 16.69475–16.69525 | 608–614 | 5.35–5.46 |
| 2.1735–2.1905 | 16.80425–16.80475 | 960–1240 | 7.25–7.75 |
| 4.125–4.128 | 25.5–25.67 | 1300–1427 | 8.025–8.5 |
| 4.17725–4.17775 | 37.5–38.25 | 1435–1626.5 | 9.0–9.2 |
| 4.20725–4.20775 | 73–74.6 | 1645.5–1646.5 | 9.3–9.5 |
| 6.215–6.218 | 74.8–75.2 | 1660–1710 | 10.6–12.7 |
| 6.26775–6.26825 | 108–121.94 | 1718.8–1722.2 | 13.25–13.4 |
| 6.31175–6.31225 | 123–138 | 2200–2300 | 14.47–14.5 |
| 8.291–8.294 | 149.9–150.05 | 2310–2390 | 15.35–16.2 |
| 8.362–8.366 | 156.52475–156.52525 | 2483.5–2500 | 17.7–21.4 |
| 8.37625–8.38675 | 156.7–156.9 | 2690–2900 | 22.01–23.12 |
| 8.41425–8.41475 | 162.0125–167.17 | 3260–3267 | 23.6–24.0 |
| 12.29–12.293 | 167.72–173.2 | 3332–3339 | 31.2–31.8 |
| 12.51975–12.52025 | 240–285 | 3345.8–3358 | 36.43–36.5 |
| 12.57675–12.57725 | 322–335.4 | 3600–4400 | Above 38.6 |
| 13.36–13.41 | | | |

## 8.7.1 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

## 8.7.2 Observations, settings and special notes

The spectrum was searched from 30 MHz to the 10th harmonic.
Radiated measurements were performed at a distance of 3 m.
DTS emissions in non-restricted frequency bands test was performed as per KDB 558074, section 8.5 with reference to ANSI C63.10 subclause 11.11.
Since fundamental power was tested using maximum conducted (average) output power procedure to demonstrate compliance, the spurious emissions limit is −30 dBc/100 kHz.
DTS emissions in restricted frequency bands test was performed as per KDB 558074, section 8.6 with reference to ANSI C63.10 subclause 11.12.
DTS band-edge emission measurements test was performed as per KDB 558074, section 8.7 with reference to ANSI C63.10 subclause 11.13.

Spectrum analyser settings for radiated measurements within restricted bands below 1 GHz:

| | |
|---|---|
| Resolution bandwidth: | 100 kHz |
| Video bandwidth: | 300 kHz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

Spectrum analyser settings for conducted spurious emissions measurements:

| | |
|---|---|
| Resolution bandwidth: | 100 kHz |
| Video bandwidth: | 300 kHz |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

### 8.7.3 Test data, Conducted Band-edge, LoRa 125 kHz BW

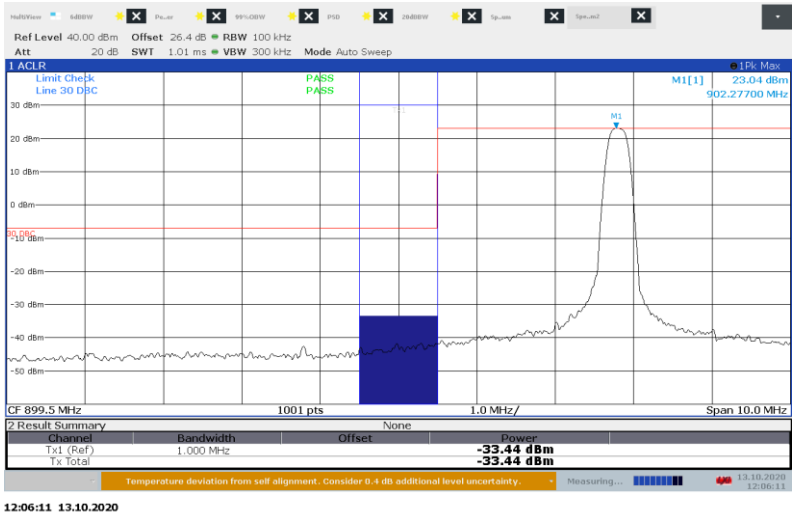



***Figure 8.7-1:*** *Conducted Band-edge low channel, 125 kHz BW*

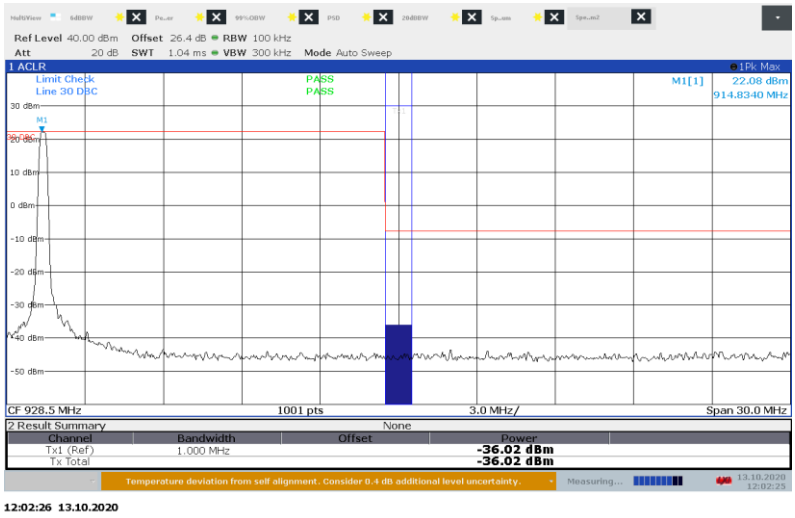



***Figure 8.7-2:*** *Conducted Band-edge high channel, 125 kHz BW*

## 8.7.4 Test data, Conducted Spurious Emissions, LoRa 125 kHz BW

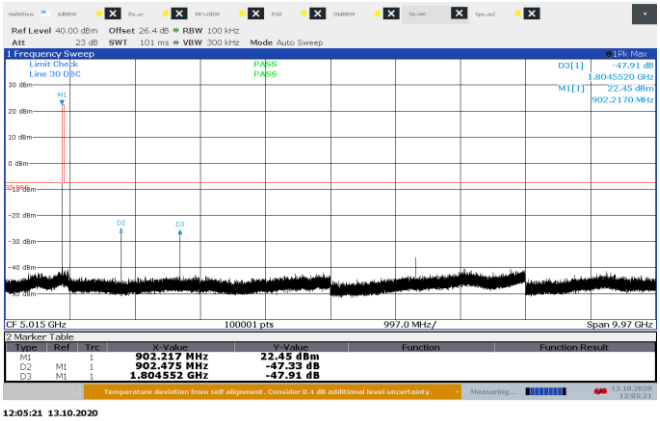



***Figure 8.7-3:*** *Conducted spurious emissions on low channel, 125 kHz BW*

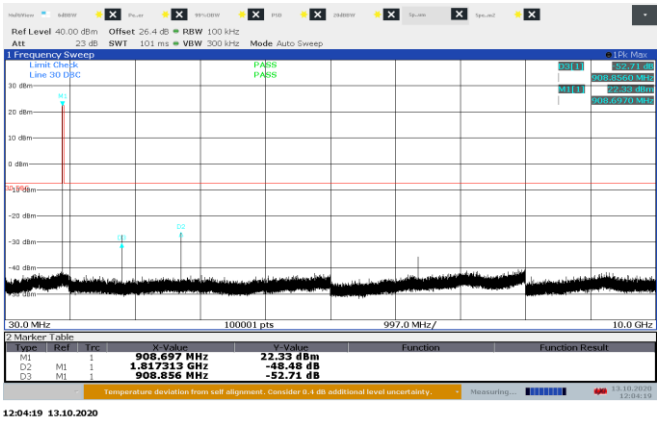



***Figure 8.7-4:*** *Conducted spurious emissions on mid channel, 125 kHz BW*

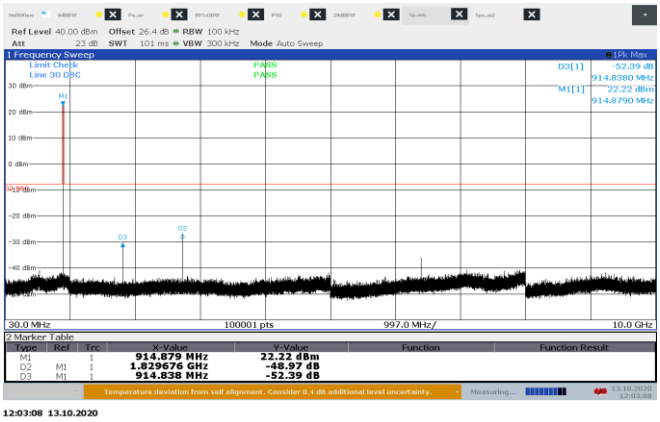



***Figure 8.7-5:*** *Conducted spurious emissions on high channel, 125 kHz BW*

### 8.7.5 Test data, Radiated spurious 30 MHz – 1 GHz, LoRa 125 kHz BW

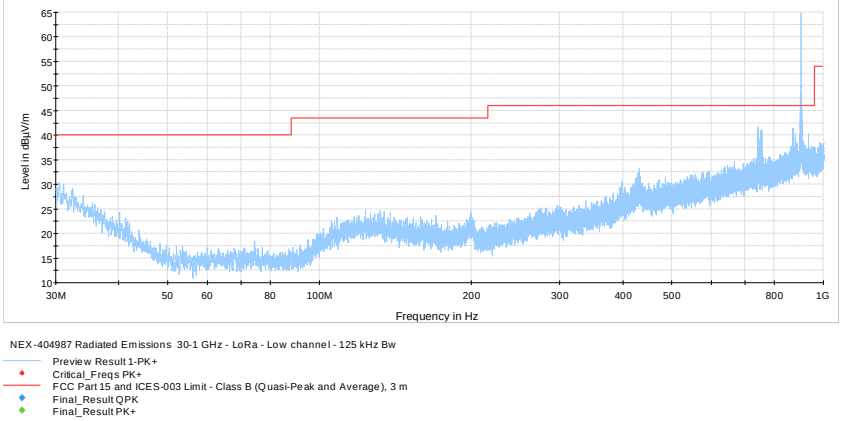



***Figure 8.7-6:*** *Radiated spurious emissions 30 MHz – 1 GHz, 902.3 MHz LORA 125 kHz BW*

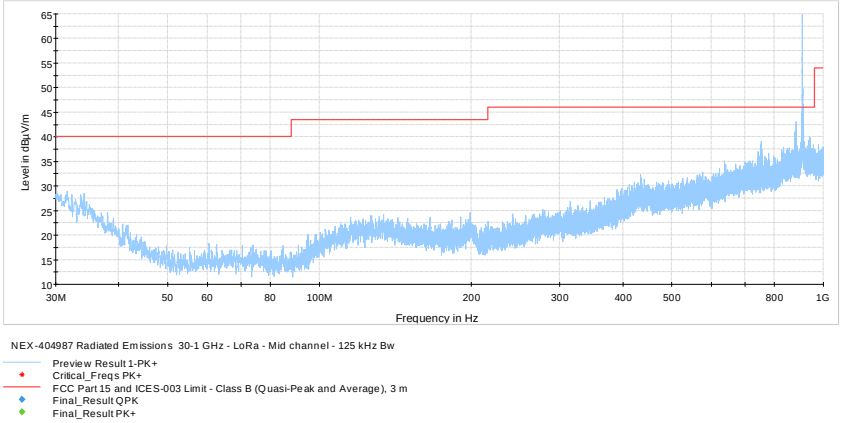



***Figure 8.7-7:*** *Radiated spurious emissions 30 MHz – 1 GHz, 908.5 MHz LoRa 125 kHz BW*

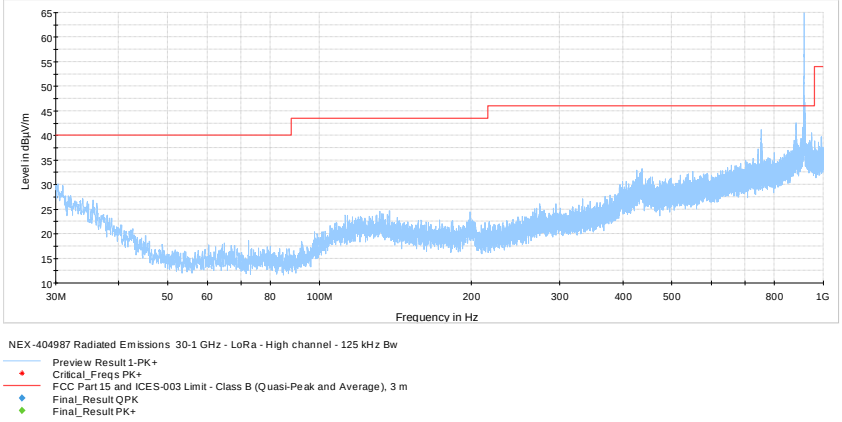



***Figure 8.7-8:*** *Radiated spurious emissions 30 MHz – 1 GHz, 914.9 MHz LoRa 125 kHz BW*

## 8.7.6 Test data, Radiated spurious 1 – 10 GHz, LoRa 125 kHz BW

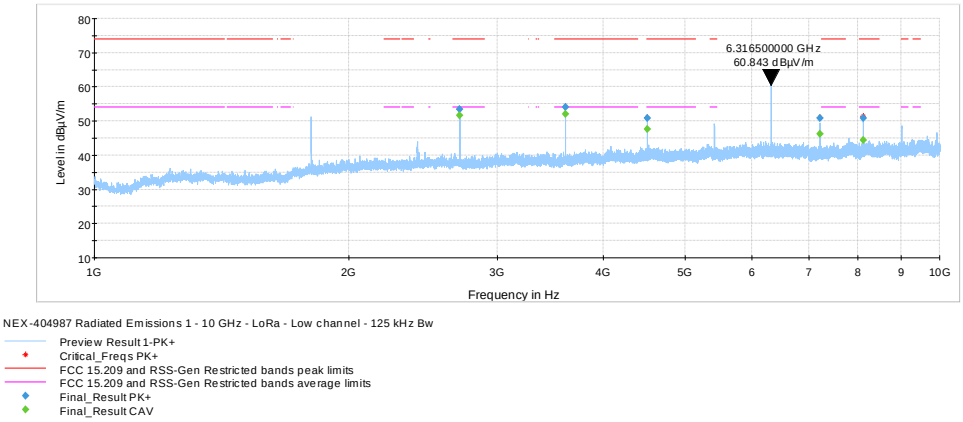



***Figure 8.7-9:*** *Radiated spurious emissions 1 - 10 GHz, 902.3 MHz LoRa 125 kHz BW*

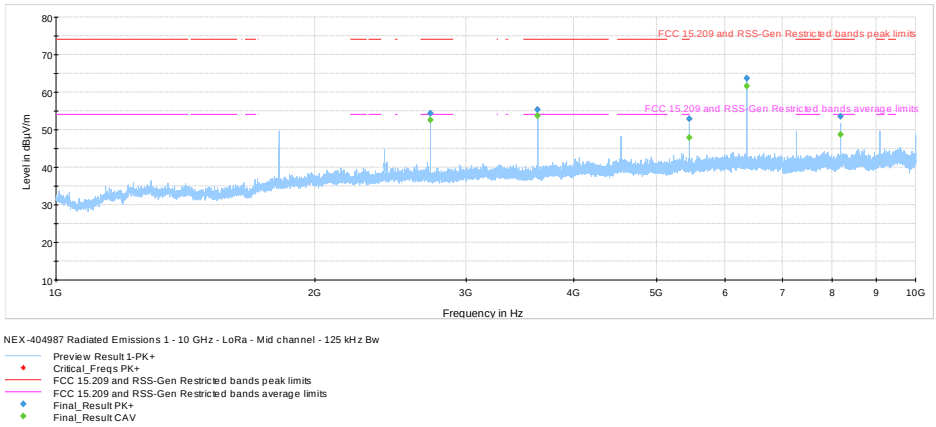



***Figure 8.7-10:*** *Radiated spurious emissions 1 - 10 GHz, 908.5 MHz LoRa 125 kHz BW*

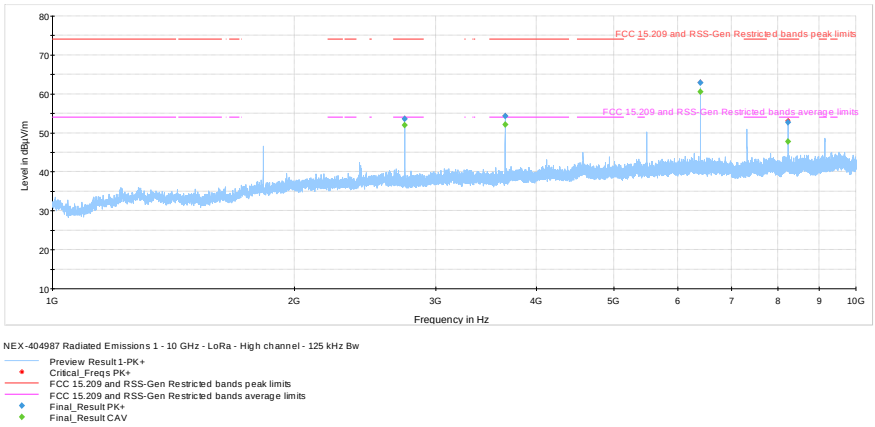



***Figure 8.7-11:*** *Radiated spurious emissions 1 - 10 GHz, 914.9 MHz LoRa 125 kHz BW*

### 8.7.7 Test data, Radiated spurious 1 – 10 GHz, LoRa 125 kHz BW results

***Table 8.7-4:*** *Radiated emissions results*

| Frequency (MHz) | CAverage field strength[1 and 3] (dBµV/m) | CAverage limit (dBµV/m) | CAverage margin (dB) | Correction factor[2] (dB) |
|---|---|---|---|---|
| **125 kHz BW Low channel: 902.3 MHz** | | | | |
| 2706.803 | 51.5 | 54.0 | 2.5 | -11.5 |
| 3609.082 | 52.0 | 54.0 | 2.0 | -9.1 |
| 4511.546 | 47.5 | 54.0 | 6.5 | -6.8 |
| 8120.993 | 44.5 | 54.0 | 9.5 | -1.1 |
| **125 kHz BW Mid channel: 908.7 MHz** | | | | |
| 2725.986 | 52.5 | 54.0 | 1.5 | -11.6 |
| 3634.736 | 53.7 | 54.0 | 0.3 | -9.1 |
| 5452.528 | 47.8 | 54.0 | 6.2 | -6.4 |
| 8178.206 | 48.8 | 54.0 | 5.2 | -0.8 |
| **125 kHz BW High channel: 914.9 MHz** | | | | |
| 2744.639 | 51.9 | 54.0 | 2.1 | -11.6 |
| 3659.748 | 52.2 | 54.0 | 1.8 | -9.0 |
| 8233.933 | 47.8 | 54.0 | 6.2 | -0.7 |

| Frequency (MHz) | Peak field strength[1 and 3] (dBµV/m) | Peak limit (dBµV/m) | Peak margin (dB) | Correction factor[2] (dB) |
|---|---|---|---|---|
| **125 kHz BW Low channel: 902.3 MHz** | | | | |
| 2706.803 | 53.5 | 74.0 | 20.5 | -11.5 |
| 3609.082 | 54.1 | 74.0 | 19.9 | -9.1 |
| 4511.546 | 50.9 | 74.0 | 23.1 | -6.8 |
| 8120.993 | 50.9 | 74.0 | 23.1 | -1.1 |
| 2706.803 | 53.5 | 74.0 | 20.5 | -11.5 |
| **125 kHz BW Mid channel: 908.7 MHz** | | | | |
| 2725.986 | 54.3 | 74.0 | 19.7 | -11.6 |
| 3634.736 | 55.4 | 74.0 | 18.6 | -9.1 |
| 5452.528 | 52.9 | 74.0 | 21.1 | -6.4 |
| 8178.206 | 53.5 | 74.0 | 20.5 | -0.8 |
| **125 kHz BW High channel: 914.9 MHz** | | | | |
| 2744.639 | 53.6 | 74.0 | 20.4 | -11.6 |
| 3659.748 | 54.3 | 74.0 | 19.7 | -9.0 |
| 8233.933 | 52.7 | 74.0 | 21.3 | -0.7 |

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) − amplifier gain (dB)
[3] Emissions that were continuously present for a minimum of 1 second and occurred more than once for every 15 seconds observation period were considered valid emissions. The maximum value of valid emissions has been recorded.

Sample calculation: 51.5 dBµV/m (field strength) = 63.0 dBµV (receiver reading) + (-11.5 dB (Correction factor))

### 8.7.8 Test data, Conducted Band-edge, LoRa 500 kHz BW

***Figure 8.7-12:*** *Conducted Band-edge low channel, 500 kHz BW*

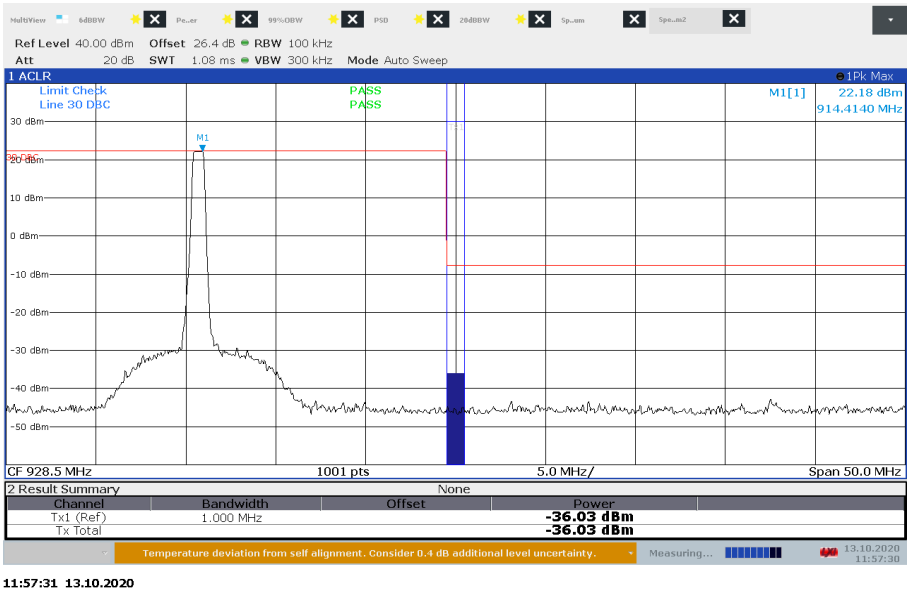



***Figure 8.7-13:*** *Conducted Band-edge high channel, 500 kHz BW*

## 8.7.9 Test data, Conducted Spurious Emissions, LoRa 500 kHz BW

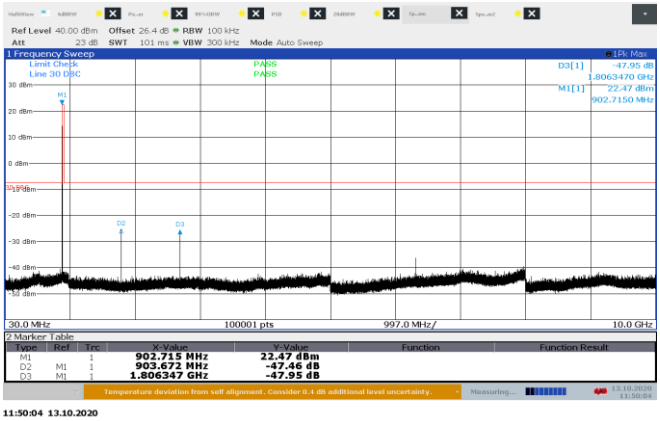



***Figure 8.7-14:*** *Conducted spurious emissions on low channel, 500 kHz BW*

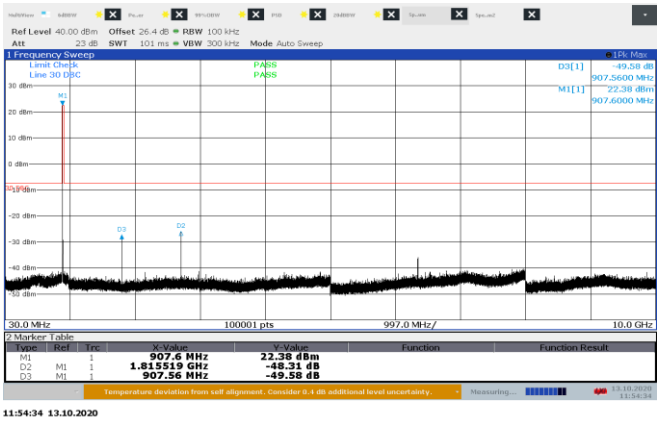



***Figure 8.7-15:*** *Conducted spurious emissions on mid channel, 500 kHz BW*

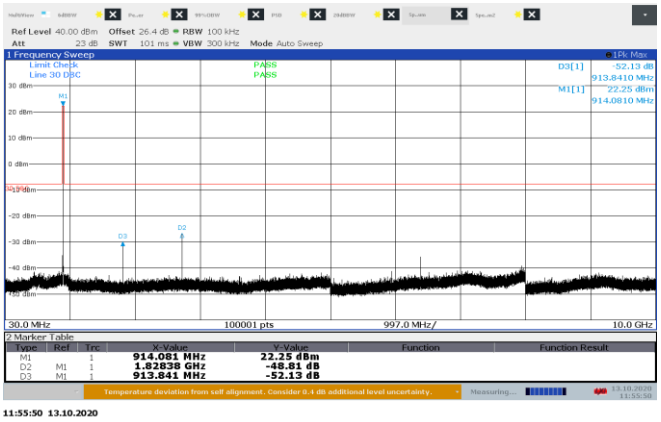



***Figure 8.7-16:*** *Conducted spurious emissions on high channel, 500 kHz BW*

### 8.7.10 Test data, Radiated spurious 30 MHz – 1 GHz, LoRa 500 kHz BW

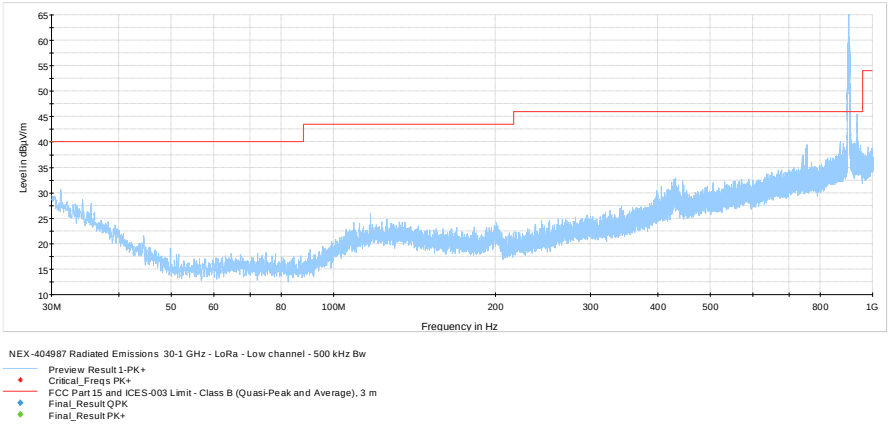



***Figure 8.7-17:*** *Radiated spurious emissions 30 MHz – 1 GHz, 903 MHz LoRa 500 kHz BW*

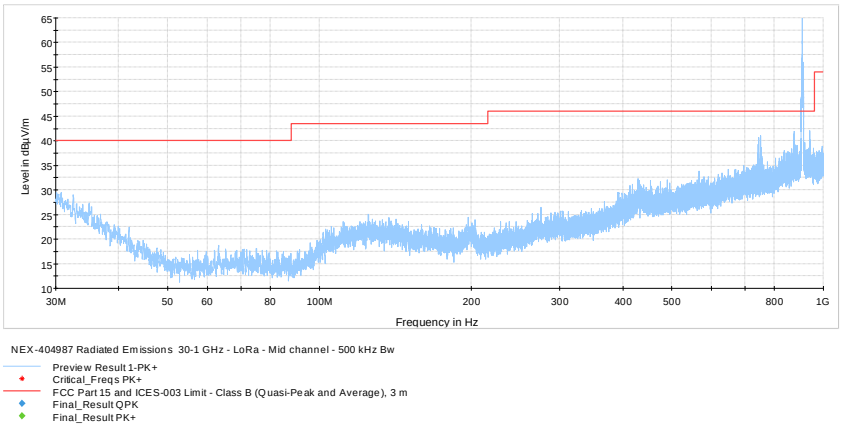



***Figure 8.7-18:*** *Radiated spurious emissions 30 MHz – 1 GHz, 907.8 MHz LoRa 500 kHz BW*

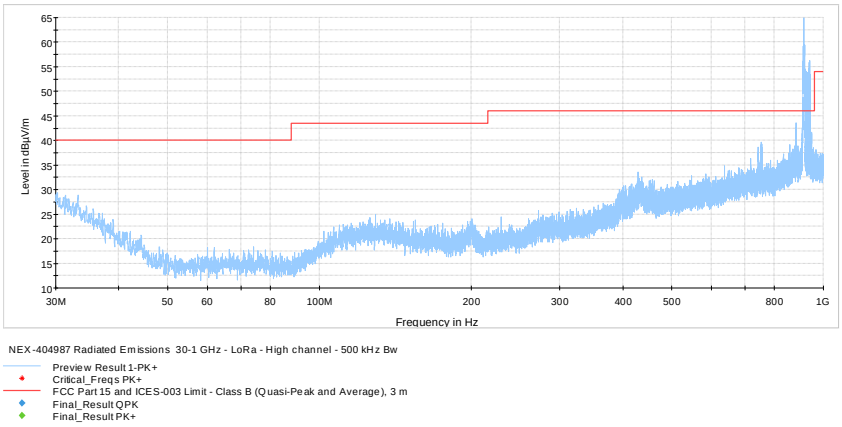



***Figure 8.7-19:*** *Radiated spurious emissions 30 MHz – 1 GHz, 914.2 MHz LoRa 500 kHz BW*

## 8.7.11 Test data, Radiated spurious 1 - 10 GHz, LoRa 500 kHz BW

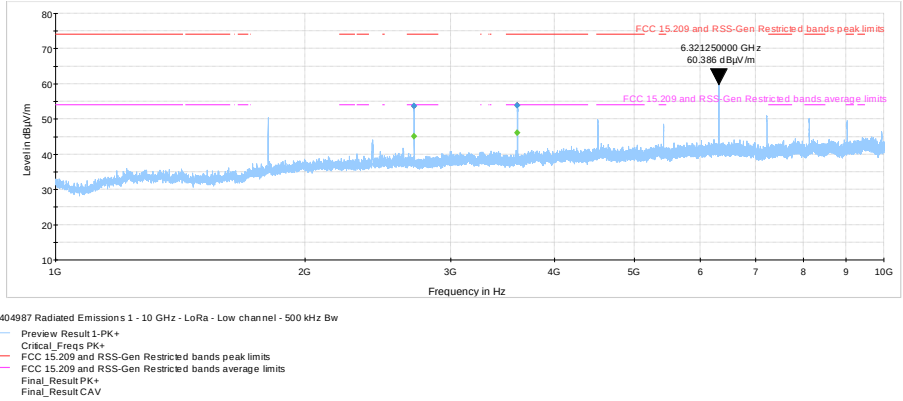



***Figure 8.7-20:*** *Radiated spurious emissions 1 - 10 GHz, 903 MHz LoRa 500 kHz BW*

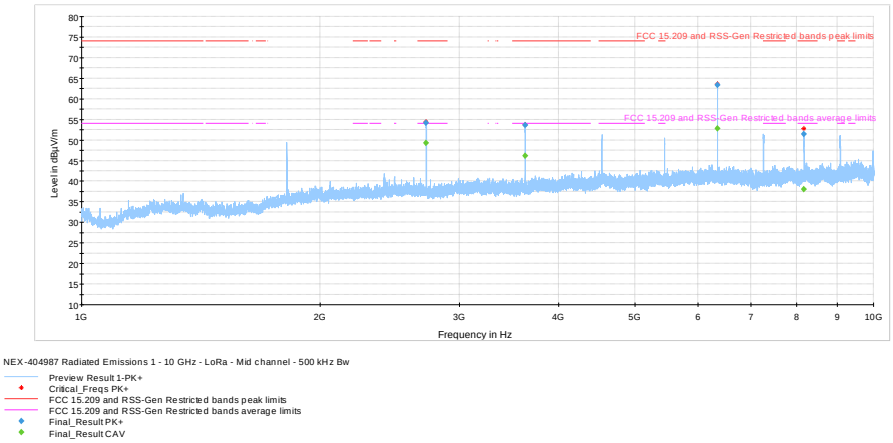



***Figure 8.7-21:*** *Radiated spurious emissions 1 - 10 GHz, 907.8 MHz LoRa 500 kHz BW*

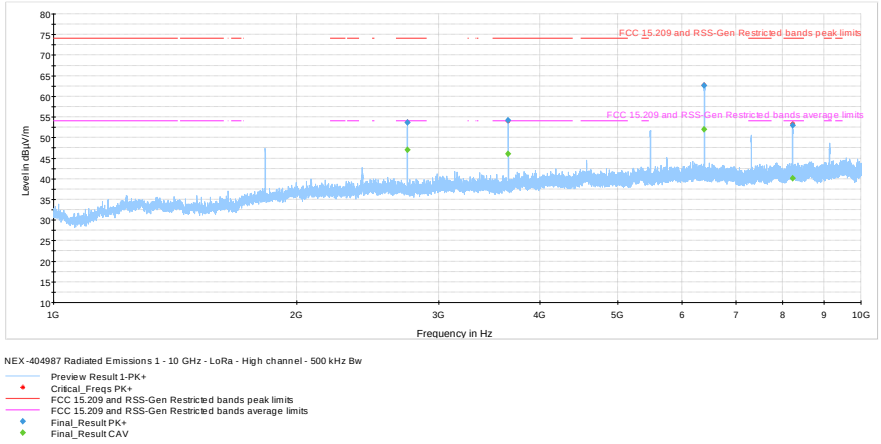



***Figure 8.7-22:*** *Radiated spurious emissions 1 - 10 GHz, 914.2 MHz LoRa 500 kHz BW*

### 8.7.1 Test data, Radiated spurious 1 – 10 GHz, LoRa 500 kHz BW results

***Table 8.7-5:*** *Radiated emissions results*

| Frequency (MHz) | CAverage field strength[1 and 3] (dBµV/m) | CAverage limit (dBµV/m) | CAverage margin (dB) | Correction factor[2] (dB) |
|---|---|---|---|---|
| **500 kHz BW Low channel: 903 MHz** | | | | |
| 2708.354 | 45.1 | 54.0 | 8.9 | -11.5 |
| 3611.505 | 46.1 | 54.0 | 7.9 | -9.1 |
| **500 kHz BW Mid channel: 907.8 MHz** | | | | |
| 2723.585 | 49.2 | 54.0 | 4.8 | -11.6 |
| 3630.776 | 46.2 | 54.0 | 7.8 | -9.1 |
| 8168.474 | 38.0 | 54.0 | 16.0 | -0.9 |
| **500 kHz BW High channel: 914.2 MHz** | | | | |
| 2742.128 | 47.0 | 54.0 | 7.0 | -11.6 |
| 3656.193 | 46.0 | 54.0 | 8.0 | -9.1 |
| 8226.978 | 40.1 | 54.0 | 13.9 | -0.7 |

| Frequency (MHz) | Peak field strength[1 and 3] (dBµV/m) | Peak limit (dBµV/m) | Peak margin (dB) | Correction factor[2] (dB) |
|---|---|---|---|---|
| **500 kHz BW Low channel: 903 MHz** | | | | |
| 2708.354 | 53.7 | 74.0 | 20.3 | -11.5 |
| 3611.505 | 53.9 | 74.0 | 20.1 | -9.1 |
| **500 kHz BW Mid channel: 907.8 MHz** | | | | |
| 2723.585 | 54.2 | 74.0 | 19.8 | -11.6 |
| 3630.776 | 53.6 | 74.0 | 20.4 | -9.1 |
| 8168.474 | 51.5 | 74.0 | 22.5 | -0.9 |
| **500 kHz BW High channel: 914.2 MHz** | | | | |
| 2742.128 | 53.7 | 74.0 | 20.3 | -11.6 |
| 3656.193 | 54.2 | 74.0 | 19.8 | -9.1 |
| 8226.978 | 53.0 | 74.0 | 21.0 | -0.7 |

Notes:
[1] Field strength (dBµV/m) = receiver/spectrum analyzer value (dBµV) + correction factor (dB)
[2] Correction factor = antenna factor ACF (dB) + cable loss (dB) − amplifier gain (dB)
[3] Emissions that were continuously present for a minimum of 1 second and occurred more than once for every 15 seconds observation period were considered valid emissions. The maximum value of valid emissions has been recorded.

Sample calculation: 45.1 dBµV/m (field strength) = 56.6 dBµV (receiver reading) + (-11.5 dB (Correction factor))

## 8.8 FCC 15.247(e) and RSS-247 5.2(b) Power spectral density for digitally modulated devices

### 8.8.1 Definitions and limits

**FCC:**
For digitally modulated systems, the 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. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

(f) For the purposes of this section, hybrid systems are those that employ a combination of both frequency hopping and digital modulation techniques. The frequency hopping operation of the hybrid system, with the direct sequence or digital modulation operation turned-off, shall have an average time of occupancy on any frequency not to exceed 0.4 seconds within a time period in seconds equal to the number of hopping frequencies employed multiplied by 0.4. The power spectral density conducted from the intentional radiator to the antenna due to the digital modulation operation of the hybrid system, with the frequency hopping operation turned off, shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission.

**ISED:**
The transmitter power spectral density conducted from the transmitter to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of section 5.4(d), (i.e. the power spectral density shall be determined using the same method as is used to determine the conducted output power).

5.3 Hybrid systems
Hybrid systems employ a combination of both frequency hopping and digital transmission techniques and shall comply with the following:

a. With the frequency hopping turned off, the digital transmission operation shall comply with the power spectral density requirements for digital modulation systems set out in of section 5.2(b) or section 6.2.4 for hybrid devices operating in the band 5725–5850 MHz.

### 8.8.1 Test date

| | |
|---|---|
| Start date | October 13, 2020 |

### 8.8.2 Observations, settings and special notes

Power spectral density test was performed as per KDB 558074, section 8.4 with reference to ANSI C63.10 subclause 11.10.
The test was performed using method AVGPSD-2 (trace averaging across on- and off-times of the EUT transmissions, followed by duty cycle correction).
Trace counts increased to 1000 to stabilize trace
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth: | 3 – 100 kHz |
| Video bandwidth: | ≥3 × RBW |
| Frequency span: | 2 times the DTS BW (Average) |
| Detector mode: | RMS |
| Trace mode: | Average |
| Trace count: | 1000 |

### 8.8.3 Test data

***Table 8.8-1:*** *PSD measurements results, 125 kHz BW*

| Frequency, MHz | PSD, dBm/10 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 902.3 | 5.0 | 8.00 | 3.0 |
| 908.5 | 5.3 | 8.00 | 2.7 |
| 914.9 | 5.6 | 8.00 | 2.4 |

Notes: Additional 0.5 dBm added to output PSD measurement to compensate for UFL to SMA connector

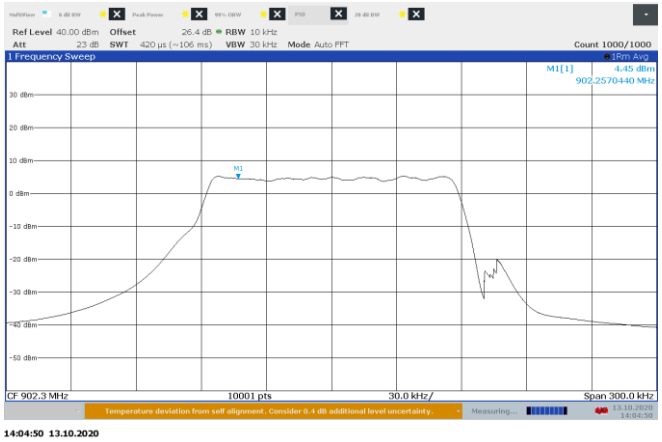



***Figure 8.8-1:*** *PSD on low channel, 125 kHz BW*

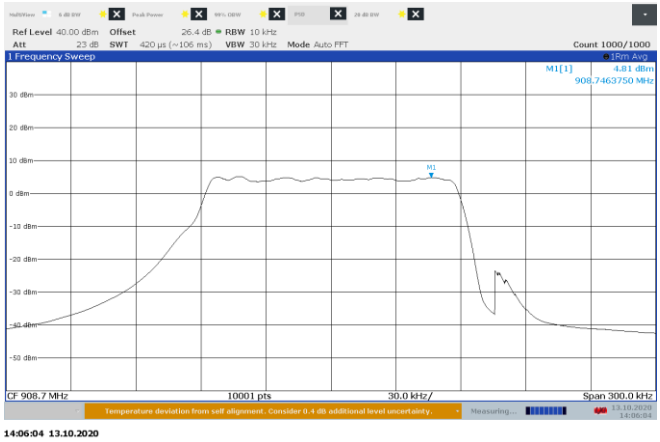



***Figure 8.8-2:*** *PSD on mid channel, 125 kHz BW*

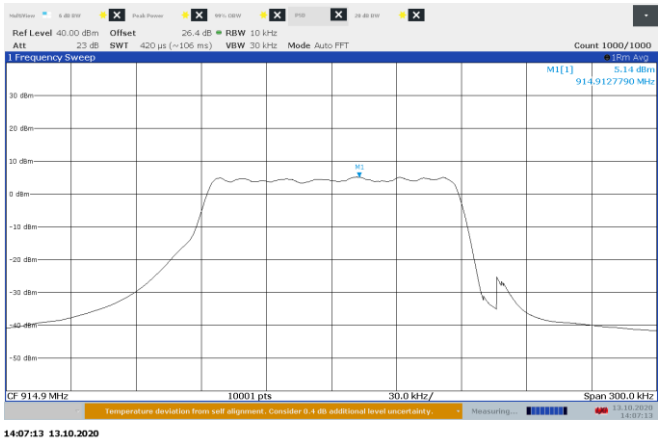



***Figure 8.8-3:*** *PSD on high channel, 125 kHz BW*

***Table 8.8-2:*** *PSD measurements results, 500 kHz BW*

| Frequency, MHz | Measured PSD, dBm/3 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 903.0 | 2.9 | 8.00 | 4.9 |
| 907.8 | 2.4 | 8.00 | 4.4 |
| 914.2 | 2.2 | 8.00 | 4.2 |

Notes: Additional 0.5 dBm added to output PSD measurement to compensate for SWG to SMA connector

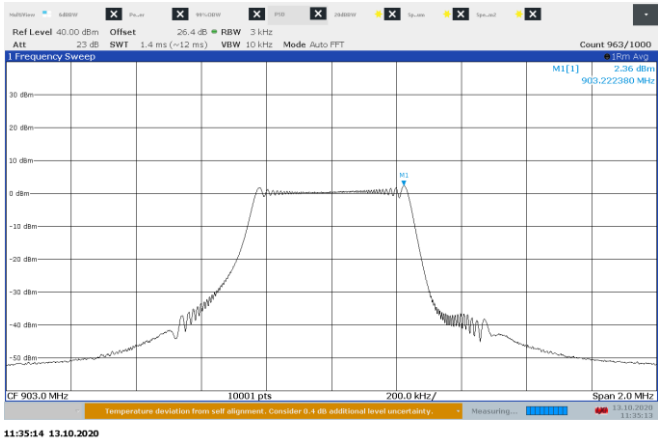



***Figure 8.8-4:*** *PSD on low channel, 500 kHz BW*

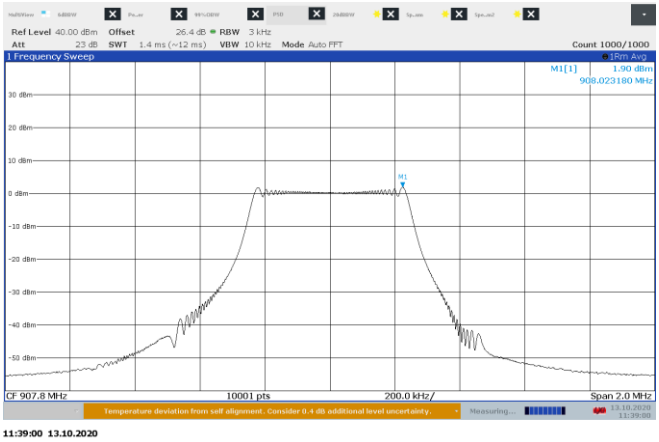



***Figure 8.8-5:*** *PSD on mid channel, 500 kHz BW*

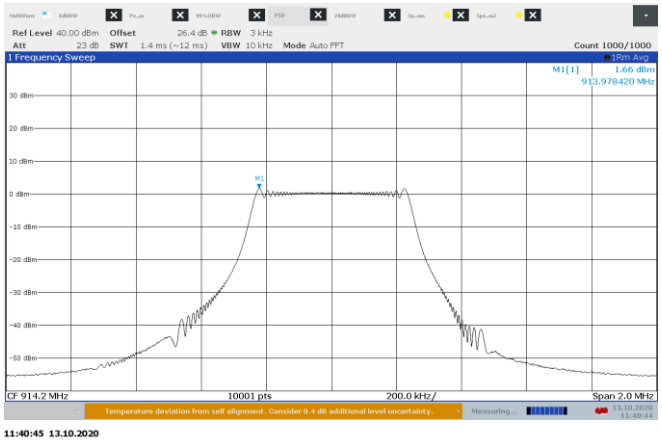
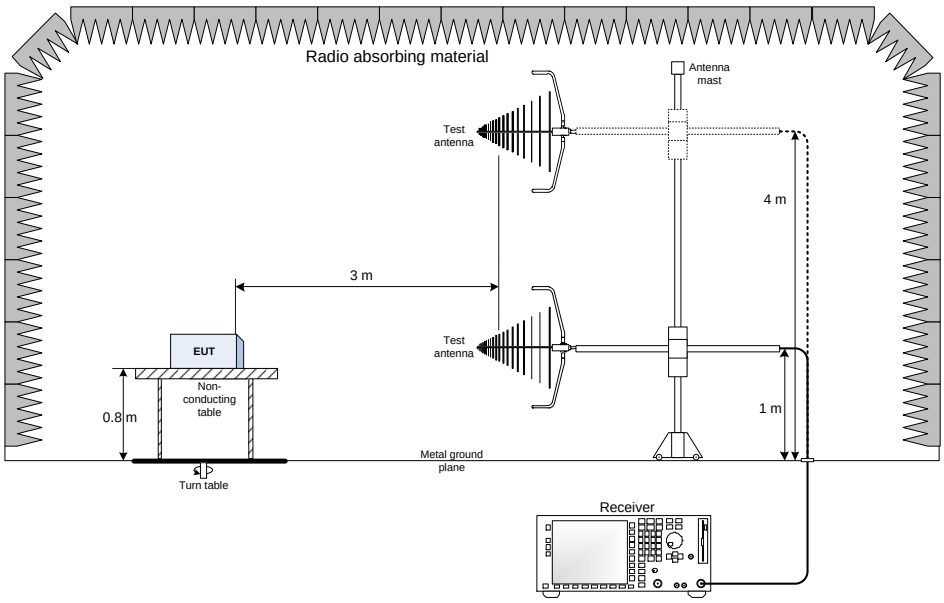


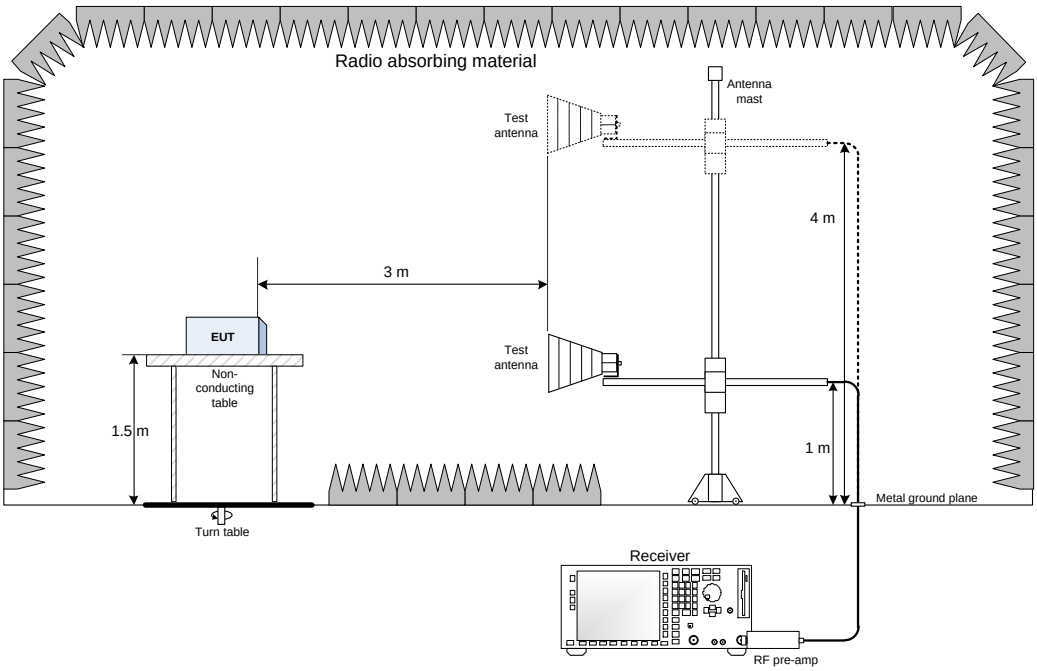
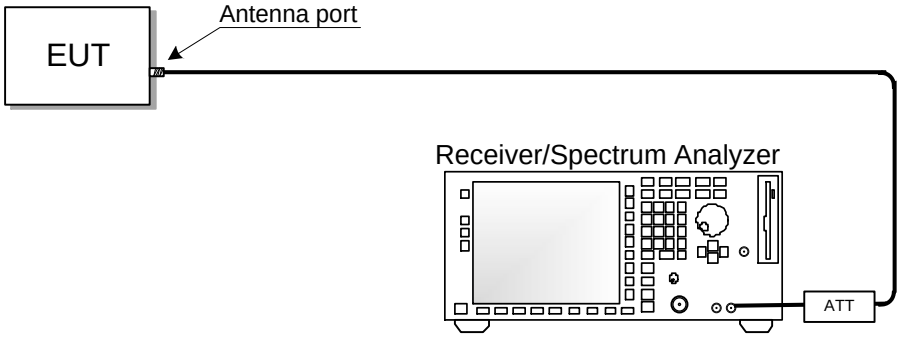

***Figure 8.8-6:*** *PSD on high channel, 500 kHz BW*

# Section 9. Block diagrams of test set-ups

## 9.1 Radiated emissions set-up for frequencies below 1 GHz




## 9.2 Radiated emissions set-up for frequencies above 1 GHz



## 9.3 Antenna port set-up