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# RADIO TEST REPORT – 403701-1TRFWL

Type of assessment:

Final product testing

Applicant:

Ring LLC

Product name (type):

Motion Detector

Model:

5AT2S9

FCC ID:

2AEUP5AT2S9

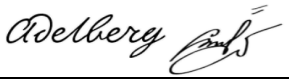
IC Registration number:

20271-5AT2S9

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247
- RSS-247, Issue 2, Feb 2017, Section 5

Date of issue: January 28, 2021

| | |
|---|---|
| Mark Libbrecht, EMC/RF Specialist |  |
| Tested by | Signature |
| Alvin Liu, EMC/RF Specialist |  |
| Tested by | Signature |
| Andrey Adelberg, Senior EMC/RF Specialist |  |
| Reviewed by | Signature |

Lab locations

| | | |
|---|---|---|
| Company name | Nemko Canada Inc. | |
| Facilities | *Cambridge site:*<br>1-130 Saltsman Drive<br>Cambridge, Ontario<br>Canada<br>N3E 0B2<br><br>Tel: +1 519 650 4811 | |
| Test site registration | **Organization** | **Recognition numbers and location** |
| | FCC/ISED | CA0101 (Cambridge) |
| Website | www.nemko.com | |

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 contained in this report are within Nemko Canada's ISO/IEC 17025 accreditation.

Copyright notification

# Table of Contents

# Section 1 Report summary

## 1.1 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 |

## 1.2 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-102, Issue 5, March 19, 2015 | Radio Frequency (RF) Exposure Compliance of Radiocommunication Apparatus (All Frequency Bands) |

## 1.3 Exclusions

None

## 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 1.3 above. 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 Test report revision history

***Table 1.5-1:*** *Test report revision history*

| Revision # | Date of issue | Details of changes made to test report |
|---|---|---|
| TRF | January 28, 2021 | Original report issued |

# Section 2 Engineering considerations

## 2.1 Modifications incorporated in the EUT for compliance

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

## 2.2 Technical judgment

Power setting = 13.0 dBm used for all measurements

## 2.3 Deviations from laboratory tests procedures

No deviations were made from laboratory procedures.

# Section 3 Test conditions

## 3.1 Atmospheric conditions

| | |
|---|---|
| Temperature | 15 °C – 35 °C |
| Relative humidity | 20 % – 75 % |
| Air pressure | 86 kPa (860 mbar) – 106 kPa (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.

## 3.2 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 4 Measurement uncertainty

## 4.1 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 4.1-1:*** *Measurement uncertainty calculations for Radio*

| Test name | Measurement uncertainty, ±dB |
|---|---|
| All antenna port measurements | 0.55 |
| Occupied bandwidth | 4.45 |
| Conducted spurious emissions | 1.13 |
| Radiated spurious emissions | 3.78 |
| AC power line conducted emissions | 3.55 |

# Section 5 Information provided by the applicant

## 5.1 Disclaimer

This section contains information provided by the applicant and has been utilized to support the test plan. Inaccurate information provided by the applicant can affect the validity of the results contained within this test report. Nemko accepts no responsibility for the information contained within this section and the impact it may have on the test plan and resulting measurements.

## 5.2 Applicant and manufacturer

| | |
|---|---|
| Applicant name | Ring LLC |
| Applicant address | 1523 26th St, Santa Monica, CA 90404, USA |
| Manufacture name | Leedarson Lighting Co.,Ltd. |
| Manufacture address | Xingtai industrial zone,Changtai, Zhangzhou Fujian. |

## 5.3 EUT information

| | |
|---|---|
| Product name | Motion Detector |
| Model | 5AT2S9 |
| Model variant(s) | None |
| Serial number | None (Radiated), None (Conducted) |
| Part number | None |
| Operating conditions | Firmware Revision V1.9 |
| Product description and theory of operation | When a person walks within the field of view of the Motion Detector, it will active the sensor and send a message to the Base Station. |

## 5.4 Technical information

| | |
|---|---|
| Applicant IC company number | 20271 |
| IC UPN number | 5AT2S9 |
| All used IC test site(s) Reg. number | 24676 |
| RSS number and Issue number | RSS-247 Issue 2, Feb 2017 |
| Category of Wideband Data Transmission equipment | ☒ Frequency Hopping Spread Spectrum (FHSS) equipment<br>☒ Other types of Wideband Data Transmission equipment (e.g. DSSS, OFDM, etc.). |
| Frequency band | 902–928 MHz |
| Frequency Min (MHz) | 902.2 (50 kbps, FHSS), 902.4 (150 kbps, FHSS), 902.5 (250 kbps, FHSS), 912 (DTS) |
| Frequency Max (MHz) | 927.8 (50 kbps, FHSS), 927.6 (150 kbps, FHSS), 927.5 (250 kbps, FHSS), 920 (DTS) |
| RF power Max (W), Conducted | 50 kbps, FHSS: 0.0174 (12.4 dBm) @ 927.8 MHz<br>150 kbps, FHSS: 0.0209 (13.2 dBm) @ 927.6 MHz<br>250 kbps, FHSS: 0.0209 (13.2 dBm) @ 927.5 MHz<br>DTS: 0.0166 (12.2 dBm) @ 920 MHz |
| Field strength, dBµV/m @ 3 m | N/A |
| Measured BW (kHz), 99% OBW | 50 kbps, FHSS: 87.3 @ 915.2 MHz<br>150 kbps, FHSS: 315.8 @ 927.6 MHz<br>250 kbps, FHSS: 380.8 @ 927.5 MHz<br>DTS: 932.1 @ 920 MHz |
| Type of modulation | Equipment class DSS: (FSK FHSS)<br>Equipment class DXX: DSSS-OQPSK |
| Emission classification | F1D, W7D |
| Transmitter spurious, dBµV/m @ 3 m | 50 kbps, FHSS: 59.2 dBµV/m (Average) @ 1.8556 GHz<br>150 kbps, FHSS: 55.4 dBµV/m (Average) @ 1.8552 GHz<br>250 kbps, FHSS: 50.9 dBµV/m (Average) @ 1.8550GHz<br>DTS: 64.9 dBµV/m (Average) @ 1.84 GHz |
| Power supply requirements | Battery: 2 × 1.5 $V_{DC}$ (AA) |
| Antenna information | Monopole Antenna<br>Peak gain = 0.26 dBi |

## 5.5 EUT setup details

### 5.5.1 EUT Exercise and monitoring

**Methods used to exercise the EUT and all relevant ports:**

- EUT set to transmit at 100% duty cycle throughout testing

**Configuration details:**

- The EUT setup in a configuration that was expected to produce the highest amplitude emissions relative to the limit and that satisfy normal operation/installation practice by the end user.
- The type and construction of cables used in the measurement set-up were consistent with normal or typical use. Cables with mitigation features (for example, screening, tighter/more twists per length, ferrite beads) have been noted below:
  - None
- The EUT was setup in a manner that was consistent with its typical arrangement and use. The measurement arrangement of the EUT, local AE and associated cabling was representative of normal practice. Any deviations from typical arrangements have been noted below:
  - None

**Monitoring details:**

- Program and monitor EUT via external laptop using Terra Terminal V4.102

## 5.6 EUT setup details, continued

### 5.5.2 EUT test configuration

***Table 5.5-1:*** *EUT sub assemblies*

| Description | Brand name | Model, Part number, Serial number, Revision level |
|---|---|---|
| 1.5 VDC Battery | Duracell | MN: LR6, SN: 1004255 |

***Table 5.5-2:*** *EUT interface ports*

| Description | Qty. |
|---|---|
| Flying leads | 4 |

***Table 5.5-3:*** *Support equipment*

| Description | Brand name | Model, Part number, Serial number, Revision level |
|---|---|---|
| Laptop | Dell Latitude | MN: E6420, SN: FA002705 |

***Table 5.5-4:*** *Inter-connection cables*

| Cable description | From | To | Length (m) |
|---|---|---|---|
| USB – flying leads | EUT | Laptop | > 1 |

## 5.6 EUT setup details, continued

### 5.5.2 EUT test configuration, continued

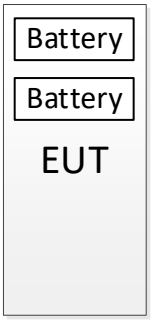



***Figure 5.5-1:*** *Radiated testing block diagram*

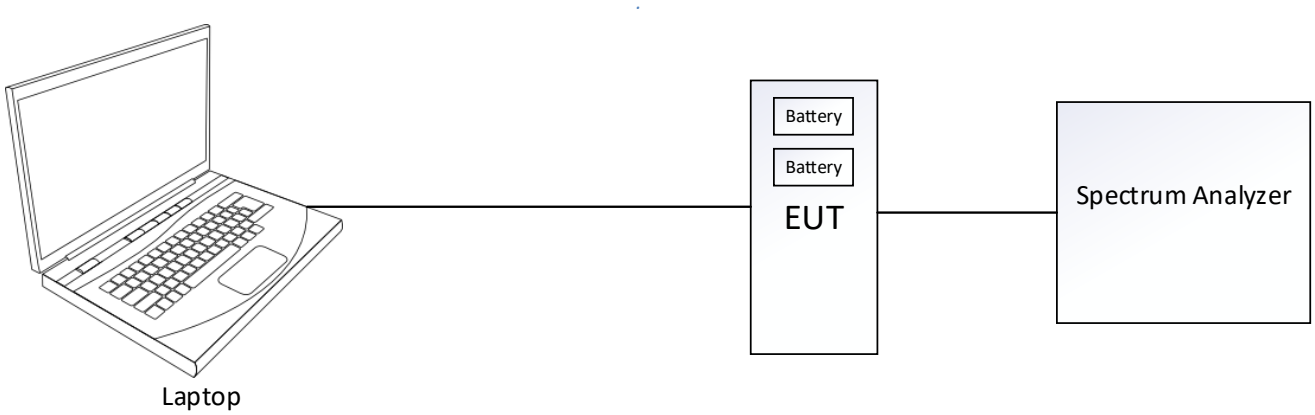



***Figure 5.5-2:*** *Antenna port testing block diagram*

# Section 6 Summary of test results

## 6.1 Testing location

| | |
|---|---|
| Test location (s) | Cambridge |

## 6.2 Testing period

| | | | |
|---|---|---|---|
| Test start date | October 7, 2020 | Test end date | January 22, 2021 |

## 6.3 Sample information

| | | | |
|---|---|---|---|
| Receipt date | October 6, 2020 | Nemko sample ID number(s) | 1,2 |

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

***Table 6.4-1:*** *FCC general requirements results*

| Part | Test description | Verdict |
|---|---|---|
| §15.207(a) | Conducted limits | Pass |
| §15.31I | Variation of power source | Pass |
| §15.31(m) | Number of tested frequencies | Pass |
| §15.203 | Antenna requirement | Pass |

Notes: EUT is an AC powered device.

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

***Table 6.5-1:*** *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 |
| §15.247I(1) | Fixed point-to-point operation with directional antenna gains greater than 6 dBi | Not applicable |
| §15.247I(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 | Not applicable |
| §15.247(i) | Radiofrequency radiation exposure evaluation | Pass |

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

***Table 6.6-1:*** *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 |
| §15.247I(1) | Fixed point-to-point operation with directional antenna gains greater than 6 dBi | Not applicable |
| §15.247I(2) | Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams | Not applicable |
| §15.247(d) | Spurious emissions | Pass |
| §15.247I | Power spectral density | Pass |
| §15.247(f) | Time of occupancy for hybrid systems | Not applicable |
| §15.247(i) | Radiofrequency radiation exposure evaluation | Not applicable |

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

***Table 6.7-1:*** *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 | Pass |
| RSS-102, 252 | Exemption Limits for Routine Evaluation — RF Exposure Evaluation | Pass |

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 an AC powered device.

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

***Table 6.8-1:*** *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 | Not applicable |
| 5.3 (b) | Frequency hopping turned off | Not applicable |
| 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 |

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

***Table 6.9-1:*** *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 | Not applicable |
| 5.3 (b) | Frequency hopping turned off | Not applicable |
| 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 |

# 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 | Apr. 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 | Nov. 12/21 |
| Spectrum analyzer | Rohde & Schwarz | FSW43 | FA002971 | 1 year | Nov. 13/21 |
| Horn antenna (1–18 GHz) | ETS Lindgren | 3117 | FA002911 | 1 year | Mar. 11/21 |
| Preamp (1–18 GHz) | ETS Lindgren | 124334 | FA002956 | 1 year | Mar. 26/21 |
| Bilog antenna (30–2000 MHz) | SUNAR | JB1 | FA003010 | 1 year | Mar. 17/21 |
| 50 Ω coax cable | Huber + Suhner | None | FA003047 | 1 year | Mar. 30/21 |
| 50 Ω coax cable | Huber + Suhner | None | FA003044 | 1 year | Apr. 7/21 |
| Notch filter 902-928 MHz | Microwave circuits | N03916M1 | FA003032 | 1 year | Apr. 9/21 |

Note: NCR - no calibration required

# Section 8 Testing data

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

### 8.1.1 References, 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 summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | October 16, 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 References, 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 summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | October 16, 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, DTS*

| Start of Frequency range, MHz | End of Frequency range, MHz | Frequency range bandwidth, MHz | Bit rate, kbps | Low channel, MHz | High channel, MHz |
|---|---|---|---|---|---|
| 902 | 928 | 26 | 100 | 912 | 920 |

Note: Long range DTS is limited to 2 channels of operation

***Table 8.2-3:*** *Test channels selection, FHSS*

| Start of Frequency range, MHz | End of Frequency range, MHz | Frequency range bandwidth, MHz | Bit Rate, kbps | Low channel, MHz | Mid channel, MHz | High channel, MHz |
|---|---|---|---|---|---|---|
| 902 | 928 | 26 | 50 | 902.2 | 915.2 | 927.8 |
| 902 | 928 | 26 | 150 | 902.4 | 914.8 | 927.6 |
| 902 | 928 | 26 | 250 | 902.5 | 915.0 | 927.5 |

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

### 8.3.1 References, 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.

**FCC 15.247(b)(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.

**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 summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | October 16, 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 |

***Table 8.3-1:*** *Antenna information*

| Antenna type | Manufacturer | Model number | Maximum gain | Connector type |
|---|---|---|---|---|
| Monopole Antenna | Jucheng | N/A | 0.26 dBi | N/A |

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

### 8.4.1 References, 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.

***Table 8.4-1:*** *Summary of the basic requirements*

| | |
|---|---|
| $P_{max\text{-}pk} \leq 1$ W | $P_{max\text{-}pk} \leq 0.25$ W |
| $N_{ch} \geq 50$ | $25 \leq N_{ch} < 50$ |
| $\Delta f \geq$ MAX { 25 kHz, $BW_{20\ dB}$ } | $\Delta f \geq$ MAX { 25 kHz, $BW_{20\ dB}$ } |
| $BW_{20\ dB} \leq 250$ kHz | 250 kHz < $BW_{20\ dB} \leq 500$ kHz |
| $t_{ch} \leq 0.4$ s for T = 20 s | $t_{ch} \leq 0.4$ s for T = 10 s |

*Note: $t_{ch}$ = average time of occupancy; T = period; $N_{ch}$ = # hopping frequencies; BW = bandwidth; $\Delta f$ = hopping channel carrier frequency separation*

**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 summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | October 9, 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, 50 kbps

***Table 8.4-2:*** *20 dB bandwidth results, 50 kbps*

| Frequency, MHz | 20 dB bandwidth, kHz | Max 20 dB bandwidth limit, kHz | Margin, kHz |
|---|---|---|---|
| 902.2 | 102.9 | 500 | 397.1 |
| 915.2 | 102.8 | 500 | 397.2 |
| 927.8 | 102.8 | 500 | 397.2 |


***Figure 8.4-1:*** *20 dB bandwidth on low channel, 50 kbps*


***Figure 8.4-2:*** *20 dB bandwidth on mid channel, 50 kbps*


***Figure 8.4-3:*** *20 dB bandwidth on high channel, 50 kbps*

Test data continued, 50 kbps

***Table 8.4-3:*** *99% occupied bandwidth results, 50 kbps*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 902.2 | 86.6 |
| 915.2 | 87.3 |
| 927.8 | 87.2 |

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

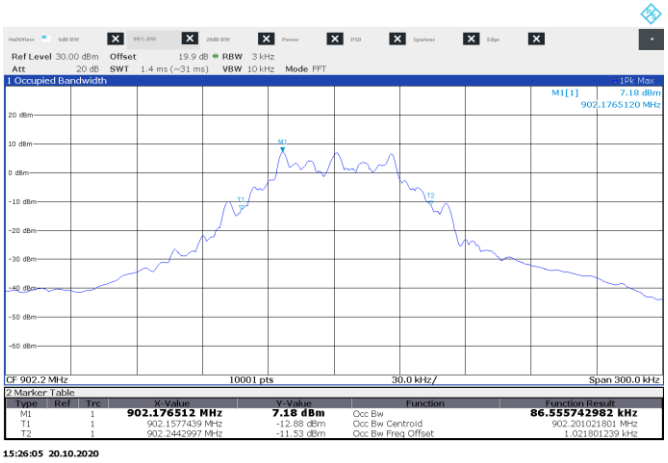



***Figure 8.4-4:*** *99% OBW on low channel, 50 kbps*


***Figure 8.4-5:*** *99% OBW on mid channel, 50 kbps*


***Figure 8.4-6:*** *99% OBW bandwidth on high channel, 50 kbps*

Test data continued, 50 kbps

***Table 8.4-4:*** *Carrier frequency separation results, 50 kbps*

| Carrier frequency separation, kHz | Minimum limit, kHz | Margin, kHz |
|---|---|---|
| 200.1 | 102.9 | 97.2 |

Note: Minimum limit = 25 kHz or the 20 dB BW whichever is greater

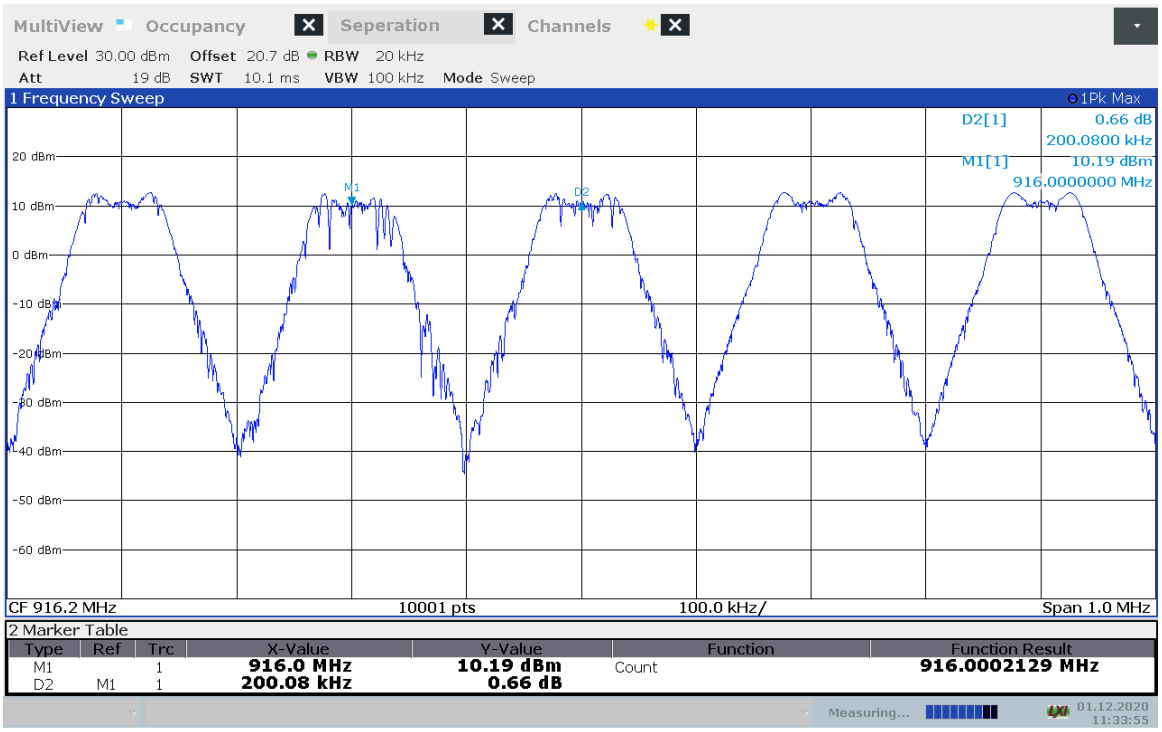



***Figure 8.4-7:*** *Carrier frequency separation*

Test data continued, 50 kbps

***Table 8.4-5:*** *Average time of occupancy results, 50 kbps*

| Dwell time of each pulse, ms | Number of pulses within period | Total dwell time within period, ms | Limit, ms | Margin, ms |
|---|---|---|---|---|
| 62 | 3 | 186 | 400 | 214 |

Note: 20 dB bandwidth < 250 kHz, therefore Measurement Period is 20 s

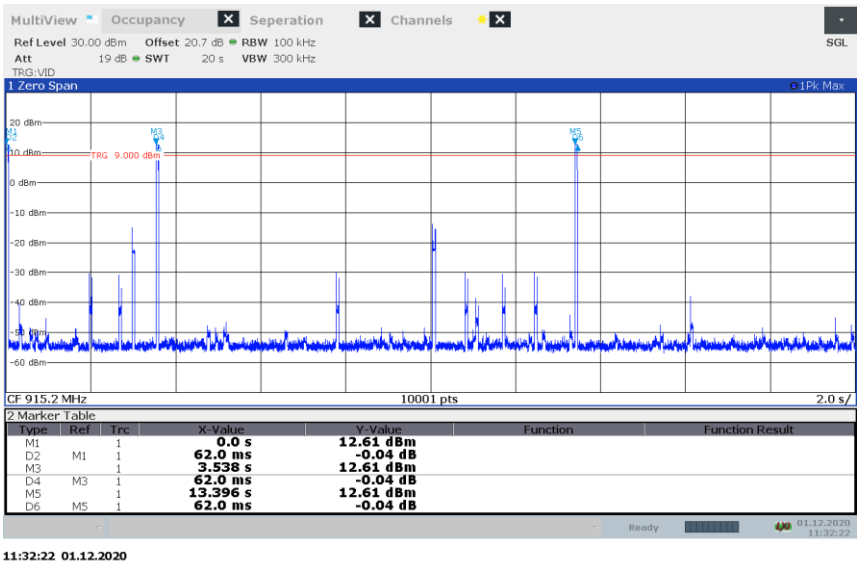



***Figure 8.4-8:*** *Dwell time*

Test data continued, 50 kbps

***Table 8.4-6:*** *Number of hopping frequencies results, 50 kbps*

| Number of hopping frequencies | Minimum limit | Margin |
|---|---|---|
| 129 | 50 | 79 |

Note: 20 dB bandwidth < 250 kHz, Minimum limit = 50 hopping frequencies

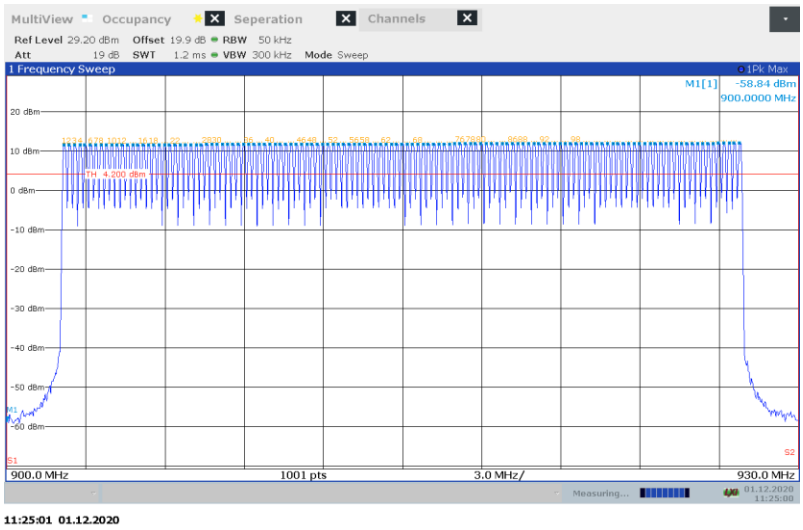



***Figure 8.4-9:*** *Number of hopping frequencies = 129*

Test data continued, 50 kbps

2 Marker Peak List

| No | X-Value | Y-Value | No | X-Value | Y-Value |
|---|---|---|---|---|---|
| 1 | 902.173000 MHz | 11.544 dBm | 66 | 915.180000 MHz | 11.790 dBm |
| 2 | 902.353000 MHz | 11.541 dBm | 67 | 915.360000 MHz | 11.791 dBm |
| 3 | 902.562000 MHz | 11.545 dBm | 68 | 915.569000 MHz | 11.794 dBm |
| 4 | 902.772000 MHz | 11.545 dBm | 69 | 915.779000 MHz | 11.797 dBm |
| 5 | 902.952000 MHz | 11.554 dBm | 70 | 915.959000 MHz | 11.795 dBm |
| 6 | 903.162000 MHz | 11.554 dBm | 71 | 916.169000 MHz | 11.798 dBm |
| 7 | 903.372000 MHz | 11.555 dBm | 72 | 916.379000 MHz | 11.796 dBm |
| 8 | 903.581000 MHz | 11.556 dBm | 73 | 916.558000 MHz | 11.802 dBm |
| 9 | 903.761000 MHz | 11.567 dBm | 74 | 916.768000 MHz | 11.801 dBm |
| 10 | 903.971000 MHz | 11.564 dBm | 75 | 916.978000 MHz | 11.830 dBm |
| 11 | 904.181000 MHz | 11.568 dBm | 76 | 917.158000 MHz | 11.831 dBm |
| 12 | 904.361000 MHz | 11.571 dBm | 77 | 917.368000 MHz | 11.833 dBm |
| 13 | 904.570000 MHz | 11.581 dBm | 78 | 917.577000 MHz | 11.831 dBm |
| 14 | 904.780000 MHz | 11.583 dBm | 79 | 917.757000 MHz | 11.830 dBm |
| 15 | 904.960000 MHz | 11.588 dBm | 80 | 917.967000 MHz | 11.833 dBm |
| 16 | 905.170000 MHz | 11.598 dBm | 81 | 918.177000 MHz | 11.833 dBm |
| 17 | 905.380000 MHz | 11.603 dBm | 82 | 918.357000 MHz | 11.831 dBm |
| 18 | 905.559000 MHz | 11.609 dBm | 83 | 918.566000 MHz | 11.835 dBm |
| 19 | 905.769000 MHz | 11.615 dBm | 84 | 918.776000 MHz | 11.837 dBm |
| 20 | 905.979000 MHz | 11.620 dBm | 85 | 918.956000 MHz | 11.843 dBm |
| 21 | 906.159000 MHz | 11.626 dBm | 86 | 919.166000 MHz | 11.842 dBm |
| 22 | 906.369000 MHz | 11.634 dBm | 87 | 919.376000 MHz | 11.844 dBm |
| 23 | 906.578000 MHz | 11.640 dBm | 88 | 919.555000 MHz | 11.849 dBm |
| 24 | 906.758000 MHz | 11.642 dBm | 89 | 919.765000 MHz | 11.854 dBm |
| 25 | 906.968000 MHz | 11.650 dBm | 90 | 919.975000 MHz | 11.859 dBm |
| 26 | 907.178000 MHz | 11.654 dBm | 91 | 920.155000 MHz | 11.864 dBm |
| 27 | 907.358000 MHz | 11.658 dBm | 92 | 920.365000 MHz | 11.872 dBm |
| 28 | 907.567000 MHz | 11.664 dBm | 93 | 920.574000 MHz | 11.875 dBm |
| 29 | 907.777000 MHz | 11.670 dBm | 94 | 920.754000 MHz | 11.884 dBm |
| 30 | 907.957000 MHz | 11.673 dBm | 95 | 920.964000 MHz | 11.886 dBm |
| 31 | 908.167000 MHz | 11.674 dBm | 96 | 921.174000 MHz | 11.898 dBm |
| 32 | 908.377000 MHz | 11.675 dBm | 97 | 921.354000 MHz | 11.902 dBm |
| 33 | 908.556000 MHz | 11.678 dBm | 98 | 921.563000 MHz | 11.906 dBm |
| 34 | 908.766000 MHz | 11.682 dBm | 99 | 921.773000 MHz | 11.909 dBm |
| 35 | 908.976000 MHz | 11.684 dBm | 100 | 921.953000 MHz | 11.917 dBm |
| 36 | 909.156000 MHz | 11.685 dBm | 101 | 922.163000 MHz | 11.922 dBm |
| 37 | 909.366000 MHz | 11.679 dBm | 102 | 922.373000 MHz | 11.923 dBm |
| 38 | 909.575000 MHz | 11.685 dBm | 103 | 922.552000 MHz | 11.929 dBm |
| 39 | 909.755000 MHz | 11.688 dBm | 104 | 922.762000 MHz | 11.934 dBm |
| 40 | 909.965000 MHz | 11.685 dBm | 105 | 922.972000 MHz | 11.937 dBm |
| 41 | 910.175000 MHz | 11.687 dBm | 106 | 923.152000 MHz | 11.937 dBm |
| 42 | 910.355000 MHz | 11.674 dBm | 107 | 923.362000 MHz | 11.937 dBm |
| 43 | 910.564000 MHz | 11.689 dBm | 108 | 923.571000 MHz | 11.937 dBm |
| 44 | 910.774000 MHz | 11.688 dBm | 109 | 923.781000 MHz | 11.944 dBm |
| 45 | 910.954000 MHz | 11.687 dBm | 110 | 923.961000 MHz | 11.943 dBm |
| 46 | 911.164000 MHz | 11.691 dBm | 111 | 924.171000 MHz | 11.944 dBm |
| 47 | 911.374000 MHz | 11.693 dBm | 112 | 924.381000 MHz | 11.945 dBm |
| 48 | 911.553000 MHz | 11.693 dBm | 113 | 924.560000 MHz | 11.945 dBm |
| 49 | 911.763000 MHz | 11.701 dBm | 114 | 924.770000 MHz | 11.950 dBm |
| 50 | 911.973000 MHz | 11.702 dBm | 115 | 924.980000 MHz | 11.949 dBm |
| 51 | 912.153000 MHz | 11.709 dBm | 116 | 925.160000 MHz | 11.948 dBm |
| 52 | 912.363000 MHz | 11.713 dBm | 117 | 925.370000 MHz | 11.952 dBm |
| 53 | 912.572000 MHz | 11.716 dBm | 118 | 925.579000 MHz | 11.952 dBm |
| 54 | 912.752000 MHz | 11.725 dBm | 119 | 925.759000 MHz | 11.952 dBm |
| 55 | 912.962000 MHz | 11.730 dBm | 120 | 925.969000 MHz | 11.958 dBm |
| 56 | 913.172000 MHz | 11.741 dBm | 121 | 926.179000 MHz | 11.958 dBm |
| 57 | 913.352000 MHz | 11.741 dBm | 122 | 926.359000 MHz | 11.966 dBm |
| 58 | 913.561000 MHz | 11.752 dBm | 123 | 926.568000 MHz | 11.968 dBm |
| 59 | 913.771000 MHz | 11.751 dBm | 124 | 926.778000 MHz | 11.973 dBm |
| 60 | 913.981000 MHz | 11.764 dBm | 125 | 926.958000 MHz | 11.979 dBm |
| 61 | 914.161000 MHz | 11.769 dBm | 126 | 927.168000 MHz | 11.983 dBm |
| 62 | 914.371000 MHz | 11.774 dBm | 127 | 927.378000 MHz | 11.990 dBm |
| 63 | 914.580000 MHz | 11.779 dBm | 128 | 927.557000 MHz | 11.992 dBm |
| 64 | 914.760000 MHz | 11.783 dBm | 129 | 927.767000 MHz | 11.994 dBm |
| 65 | 914.970000 MHz | 11.785 dBm | | | |

***Figure 8.4-10:*** *List of hopping frequencies*

### 8.4.5 Test data, 150 kbps

***Table 8.4-7:*** *20 dB bandwidth results, 150 kbps*

| Frequency, MHz | 20 dB bandwidth, kHz | Max 20 dB bandwidth limit, kHz | Margin, kHz |
|---|---|---|---|
| 902.4 | 352.7 | 500 | 147.3 |
| 914.8 | 350.5 | 500 | 149.5 |
| 927.6 | 354.4 | 500 | 145.6 |


***Figure 8.4-11:*** *20 dB bandwidth on low channel, 150 kbps*


***Figure 8.4-12:*** *20 dB bandwidth on mid channel, 150 kbps*


***Figure 8.4-13:*** *20 dB bandwidth on high channel, 150 kbps*

Test data continued, 150 kbps

***Table 8.4-8:*** *99% occupied bandwidth results, 150 kbps*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 902.4 | 315.8 |
| 914.8 | 314.6 |
| 927.6 | 315.0 |

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


***Figure 8.4-14:*** *99% OBW on low channel, 150 kbps*


***Figure 8.4-15:*** *99% OBW on mid channel, 150 kbps*

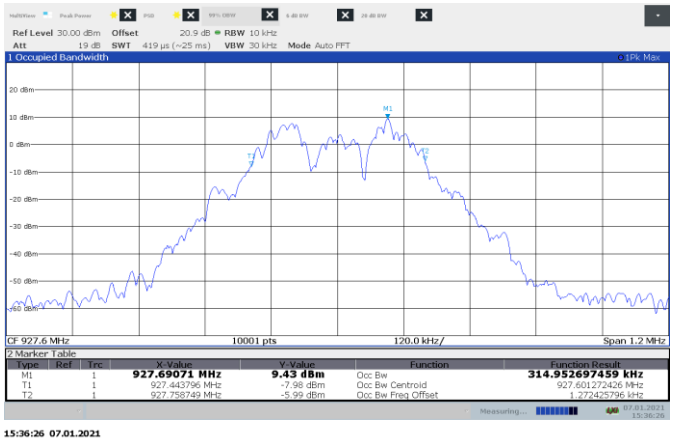



***Figure 8.4-16:*** *99% OBW bandwidth on high channel, 150 kbps*

Test data continued, 150 kbps

***Table 8.4-9:*** *Carrier frequency separation results, 150 kbps*

| Carrier frequency separation, kHz | Minimum limit, kHz | Margin, kHz |
|---|---|---|
| 405.4 | 354.4 | 51.0 |

Note: Minimum limit = 25 kHz or the 20 dB BW whichever is greater

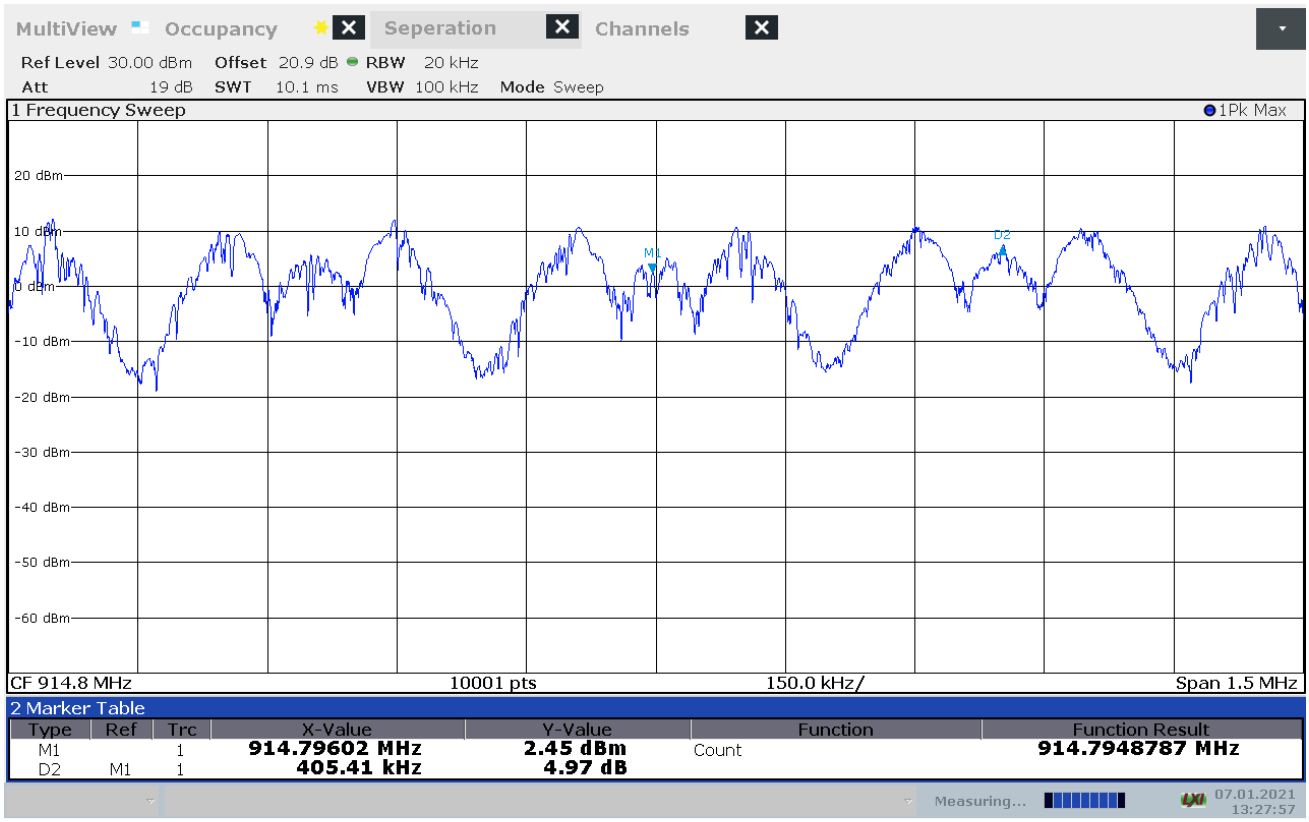



***Figure 8.4-17:*** *Carrier frequency separation*

Test data continued, 150 kbps

***Table 8.4-10:*** *Number of hopping frequencies results, 150 kbps*

| Number of hopping frequencies | Minimum limit | Margin |
|---|---|---|
| 64 | 25 | 39 |

Note: 20 dB bandwidth > 250 kHz, Minimum limit = 25 hopping frequencies

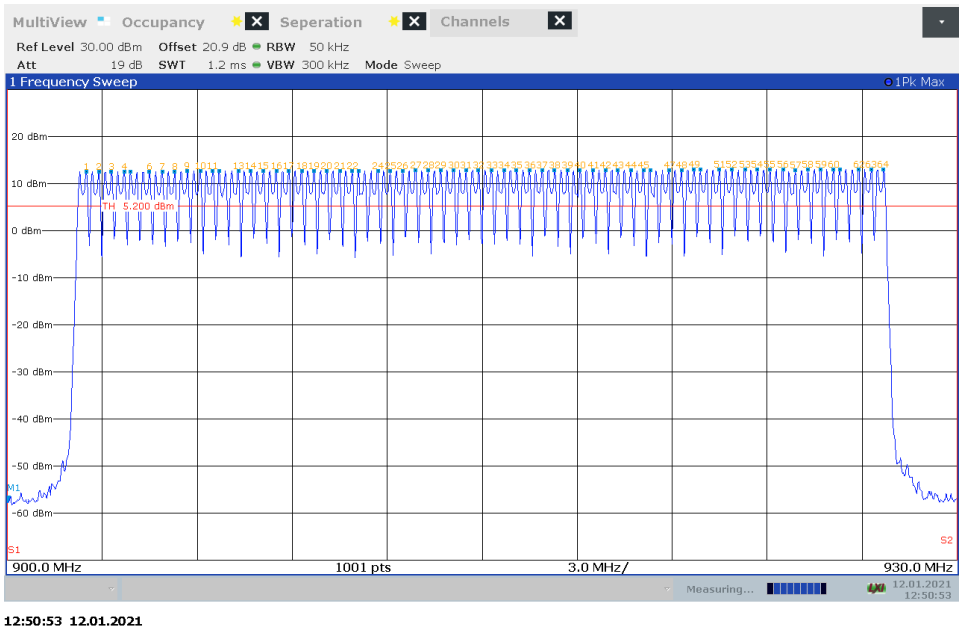
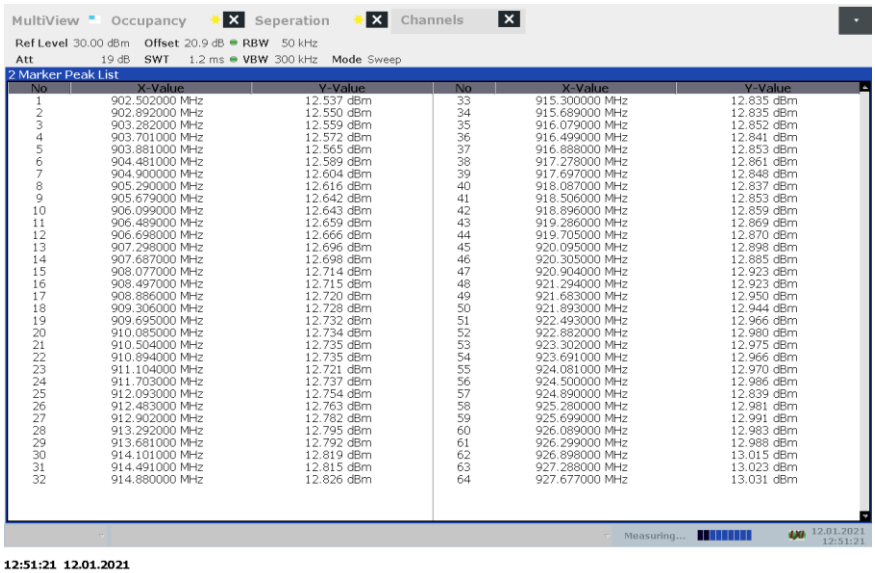



***Figure 8.4-18:*** *Number of hopping frequencies = 64*




| No | X-Value | Y-Value | No | X-Value | Y-Value |
|---|---|---|---|---|---|
| 1 | 902.502000 MHz | 12.537 dBm | 33 | 915.300000 MHz | 12.835 dBm |
| 2 | 902.892000 MHz | 12.550 dBm | 34 | 915.689000 MHz | 12.835 dBm |
| 3 | 903.282000 MHz | 12.559 dBm | 35 | 916.079000 MHz | 12.852 dBm |
| 4 | 903.701000 MHz | 12.572 dBm | 36 | 916.499000 MHz | 12.841 dBm |
| 5 | 903.881000 MHz | 12.565 dBm | 37 | 916.888000 MHz | 12.853 dBm |
| 6 | 904.481000 MHz | 12.589 dBm | 38 | 917.278000 MHz | 12.861 dBm |
| 7 | 904.900000 MHz | 12.604 dBm | 39 | 917.697000 MHz | 12.848 dBm |
| 8 | 905.290000 MHz | 12.616 dBm | 40 | 918.087000 MHz | 12.837 dBm |
| 9 | 905.679000 MHz | 12.642 dBm | 41 | 918.506000 MHz | 12.853 dBm |
| 10 | 906.099000 MHz | 12.643 dBm | 42 | 918.896000 MHz | 12.859 dBm |
| 11 | 906.489000 MHz | 12.659 dBm | 43 | 919.286000 MHz | 12.869 dBm |
| 12 | 906.698000 MHz | 12.666 dBm | 44 | 919.705000 MHz | 12.870 dBm |
| 13 | 907.298000 MHz | 12.696 dBm | 45 | 920.095000 MHz | 12.898 dBm |
| 14 | 907.687000 MHz | 12.698 dBm | 46 | 920.305000 MHz | 12.885 dBm |
| 15 | 908.077000 MHz | 12.714 dBm | 47 | 920.904000 MHz | 12.923 dBm |
| 16 | 908.497000 MHz | 12.715 dBm | 48 | 921.294000 MHz | 12.923 dBm |
| 17 | 908.886000 MHz | 12.720 dBm | 49 | 921.683000 MHz | 12.950 dBm |
| 18 | 909.306000 MHz | 12.728 dBm | 50 | 921.893000 MHz | 12.944 dBm |
| 19 | 909.695000 MHz | 12.732 dBm | 51 | 922.493000 MHz | 12.966 dBm |
| 20 | 910.085000 MHz | 12.734 dBm | 52 | 922.882000 MHz | 12.980 dBm |
| 21 | 910.504000 MHz | 12.735 dBm | 53 | 923.302000 MHz | 12.975 dBm |
| 22 | 910.894000 MHz | 12.735 dBm | 54 | 923.691000 MHz | 12.966 dBm |
| 23 | 911.104000 MHz | 12.721 dBm | 55 | 924.081000 MHz | 12.970 dBm |
| 24 | 911.703000 MHz | 12.737 dBm | 56 | 924.500000 MHz | 12.986 dBm |
| 25 | 912.093000 MHz | 12.754 dBm | 57 | 924.890000 MHz | 12.839 dBm |
| 26 | 912.483000 MHz | 12.763 dBm | 58 | 925.280000 MHz | 12.981 dBm |
| 27 | 912.902000 MHz | 12.782 dBm | 59 | 925.699000 MHz | 12.991 dBm |
| 28 | 913.292000 MHz | 12.795 dBm | 60 | 926.089000 MHz | 12.983 dBm |
| 29 | 913.681000 MHz | 12.792 dBm | 61 | 926.299000 MHz | 12.988 dBm |
| 30 | 914.101000 MHz | 12.819 dBm | 62 | 926.898000 MHz | 13.015 dBm |
| 31 | 914.491000 MHz | 12.815 dBm | 63 | 927.288000 MHz | 13.023 dBm |
| 32 | 914.880000 MHz | 12.826 dBm | 64 | 927.677000 MHz | 13.031 dBm |

***Figure 8.4-19:*** *List of hopping frequencies*

Test data continued, 150 kbps

***Table 8.4-11:*** *Average time of occupancy results, 150 kbps*

| Dwell time of each pulse, ms | Number of pulses within period | Total dwell time within period, ms | Limit, ms | Margin, ms |
|---|---|---|---|---|
| 63 | 5 | 315 | 400 | 85 |

Note: 20 dB bandwidth > 250 kHz, therefore Measurement Period is 10 s

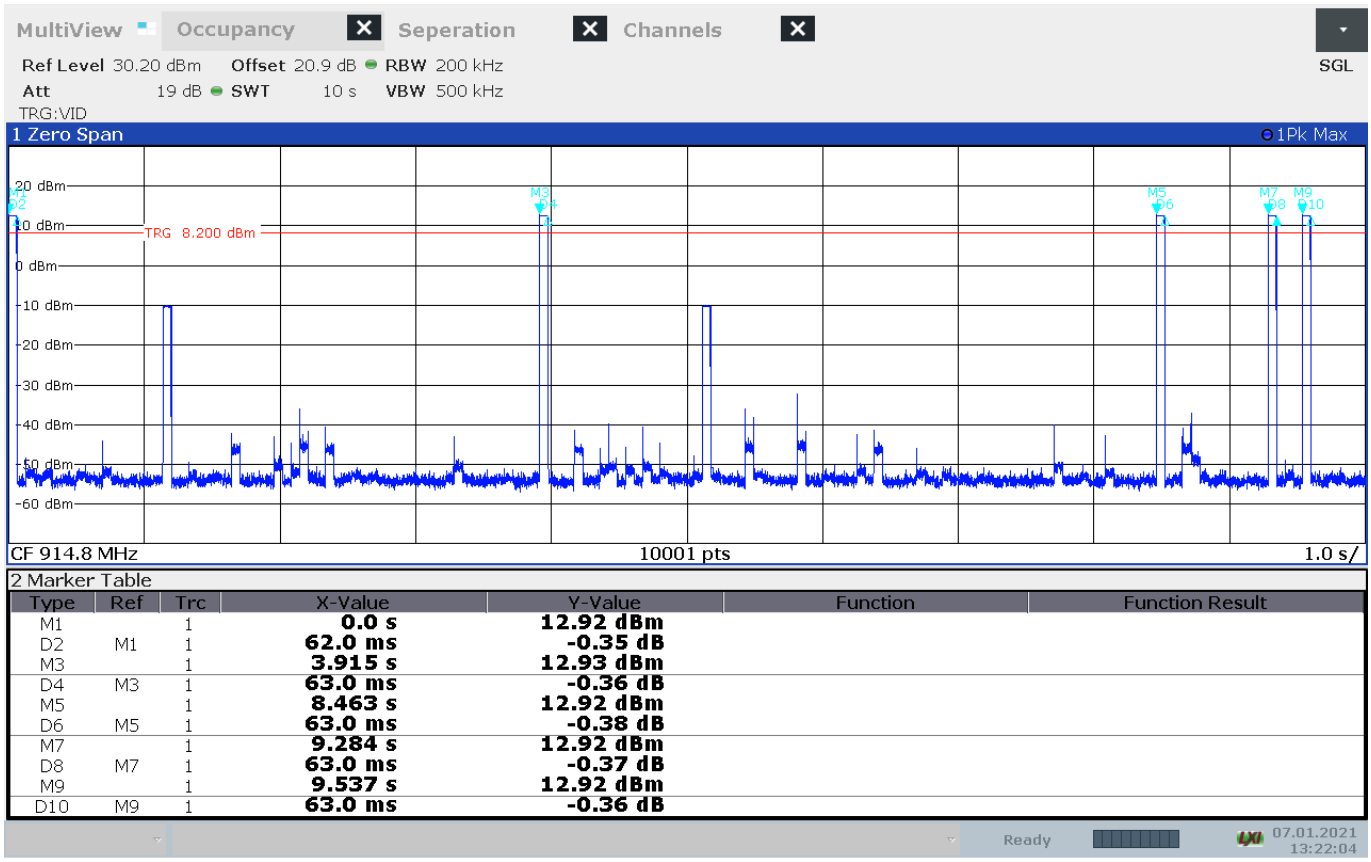



***Figure 8.4-20:*** *Dwell time*

### 8.4.1 Test data, 250 kbps

***Table 8.4-12:*** *20 dB bandwidth results, 250 kbps*

| Frequency, MHz | 20 dB bandwidth, kHz | Max 20 dB bandwidth limit, kHz | Margin, kHz |
|---|---|---|---|
| 902.5 | 408.1 | 500 | 91.9 |
| 915.0 | 409.0 | 500 | 91.0 |
| 927.5 | 405.5 | 500 | 94.5 |

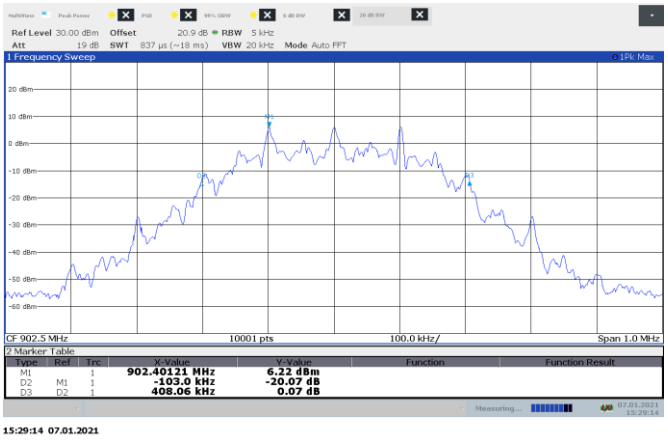



***Figure 8.4-21:*** *20 dB bandwidth on low channel, 250 kbps*

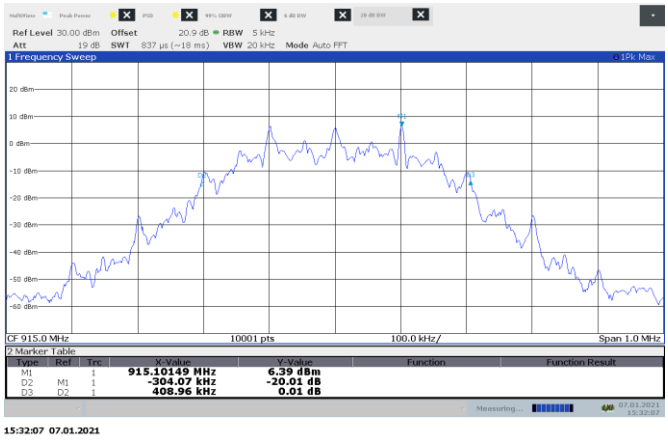



***Figure 8.4-22:*** *20 dB bandwidth on mid channel, 250 kbps*

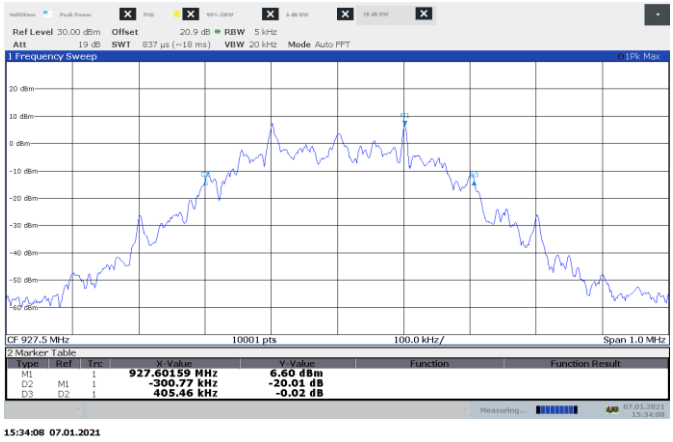



***Figure 8.4-23:*** *20 dB bandwidth on high channel, 250 kbps*

Test data continued, 250 kbps

***Table 8.4-13:*** *99% occupied bandwidth results, 250 kbps*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 902.5 | 380.8 |
| 915.0 | 364.8 |
| 927.5 | 373.9 |

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


***Figure 8.4-24:*** *99% OBW on low channel, 250 kbps*

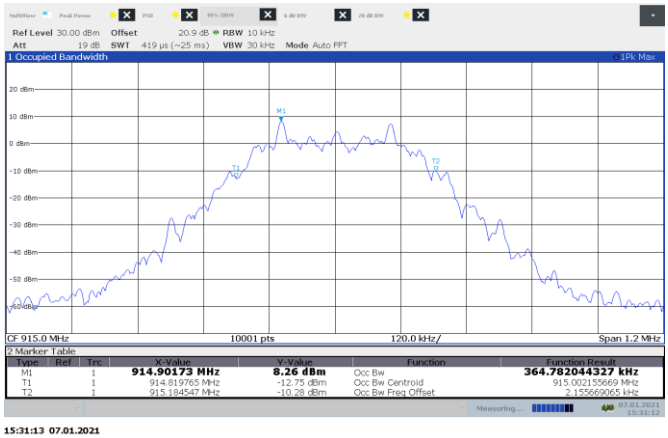



***Figure 8.4-25:*** *99% OBW on mid channel, 250 kbps*

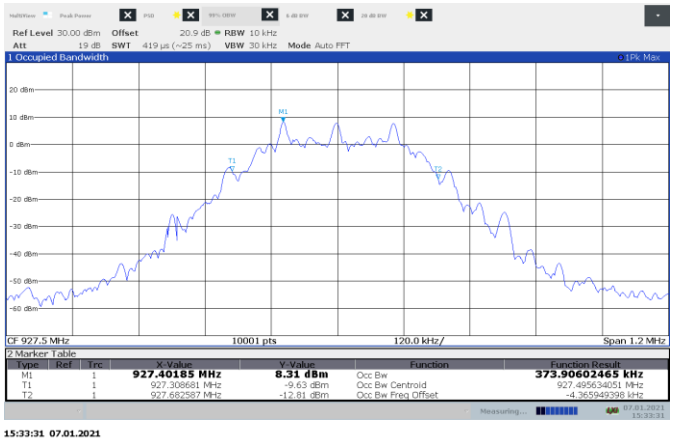



***Figure 8.4-26:*** *99% OBW bandwidth on high channel, 250 kbps*

Test data continued, 250 kbps

***Table 8.4-14:*** *Carrier frequency separation results, 250 kbps*

| Carrier frequency separation, kHz | Minimum limit, kHz | Margin, kHz |
|---|---|---|
| 502.6 | 409.0 | 93.6 |

Note: Minimum limit = 25 kHz or the 20 dB BW whichever is greater

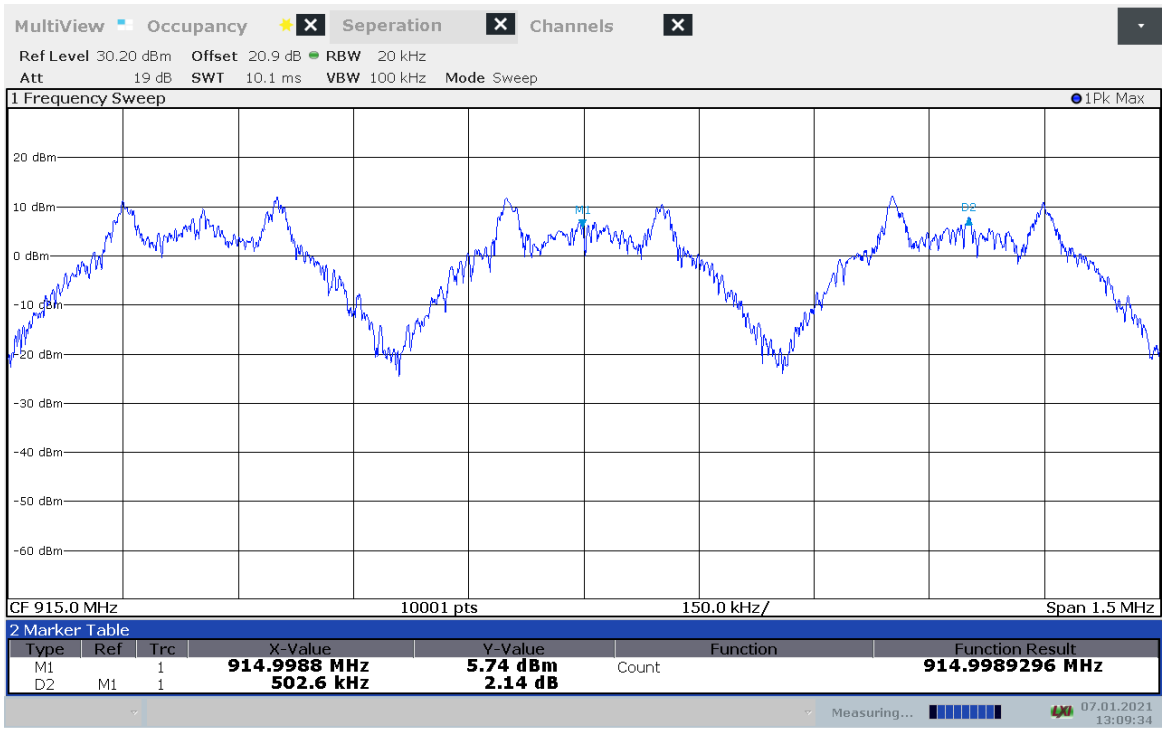



***Figure 8.4-27:*** *Carrier frequency separation*

Test data continued, 250 kbps

***Table 8.4-15:*** *Number of hopping frequencies results, 250 kbps*

| Number of hopping frequencies | Minimum limit | Margin |
|---|---|---|
| 51 | 25 | 26 |

Note: 20 dB bandwidth > 250 kHz, Minimum limit = 25 hopping frequencies

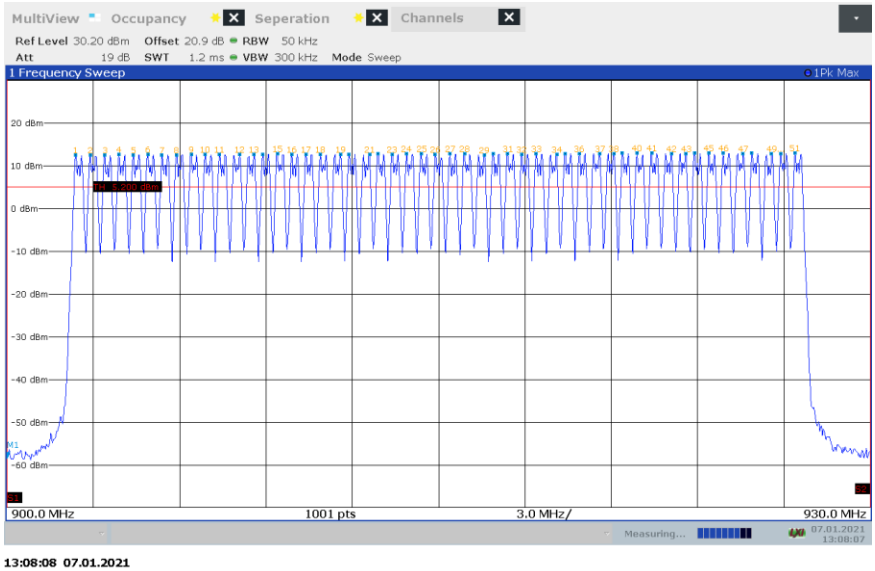
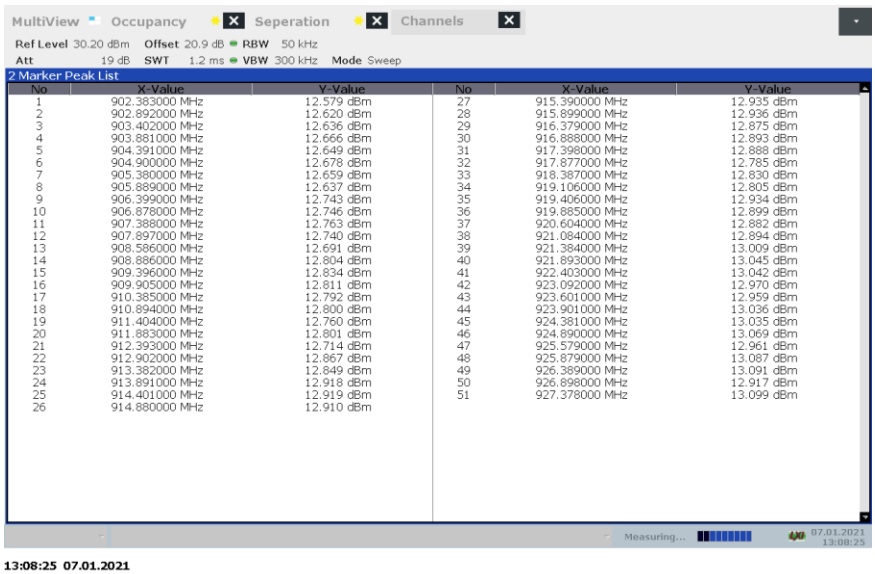



***Figure 8.4-28:*** *Number of hopping frequencies = 51*




| No | X-Value | Y-Value | No | X-Value | Y-Value |
|---|---|---|---|---|---|
| 1 | 902.383000 MHz | 12.579 dBm | 27 | 915.390000 MHz | 12.935 dBm |
| 2 | 902.892000 MHz | 12.620 dBm | 28 | 915.899000 MHz | 12.936 dBm |
| 3 | 903.402000 MHz | 12.636 dBm | 29 | 916.379000 MHz | 12.875 dBm |
| 4 | 903.881000 MHz | 12.666 dBm | 30 | 916.888000 MHz | 12.893 dBm |
| 5 | 904.391000 MHz | 12.649 dBm | 31 | 917.398000 MHz | 12.888 dBm |
| 6 | 904.900000 MHz | 12.678 dBm | 32 | 917.877000 MHz | 12.785 dBm |
| 7 | 905.380000 MHz | 12.659 dBm | 33 | 918.387000 MHz | 12.830 dBm |
| 8 | 905.889000 MHz | 12.637 dBm | 34 | 919.106000 MHz | 12.805 dBm |
| 9 | 906.399000 MHz | 12.743 dBm | 35 | 919.406000 MHz | 12.934 dBm |
| 10 | 906.878000 MHz | 12.746 dBm | 36 | 919.885000 MHz | 12.899 dBm |
| 11 | 907.388000 MHz | 12.763 dBm | 37 | 920.604000 MHz | 12.882 dBm |
| 12 | 907.897000 MHz | 12.740 dBm | 38 | 921.084000 MHz | 12.894 dBm |
| 13 | 908.586000 MHz | 12.691 dBm | 39 | 921.384000 MHz | 13.009 dBm |
| 14 | 908.886000 MHz | 12.804 dBm | 40 | 921.893000 MHz | 13.045 dBm |
| 15 | 909.396000 MHz | 12.834 dBm | 41 | 922.403000 MHz | 13.042 dBm |
| 16 | 909.905000 MHz | 12.811 dBm | 42 | 923.092000 MHz | 12.970 dBm |
| 17 | 910.385000 MHz | 12.792 dBm | 43 | 923.601000 MHz | 12.959 dBm |
| 18 | 910.894000 MHz | 12.800 dBm | 44 | 923.901000 MHz | 13.036 dBm |
| 19 | 911.404000 MHz | 12.760 dBm | 45 | 924.381000 MHz | 13.035 dBm |
| 20 | 911.883000 MHz | 12.801 dBm | 46 | 924.890000 MHz | 13.069 dBm |
| 21 | 912.393000 MHz | 12.714 dBm | 47 | 925.579000 MHz | 12.961 dBm |
| 22 | 912.902000 MHz | 12.867 dBm | 48 | 925.879000 MHz | 13.087 dBm |
| 23 | 913.382000 MHz | 12.849 dBm | 49 | 926.389000 MHz | 13.091 dBm |
| 24 | 913.891000 MHz | 12.918 dBm | 50 | 926.898000 MHz | 12.917 dBm |
| 25 | 914.401000 MHz | 12.919 dBm | 51 | 927.378000 MHz | 13.099 dBm |
| 26 | 914.880000 MHz | 12.910 dBm | | | |

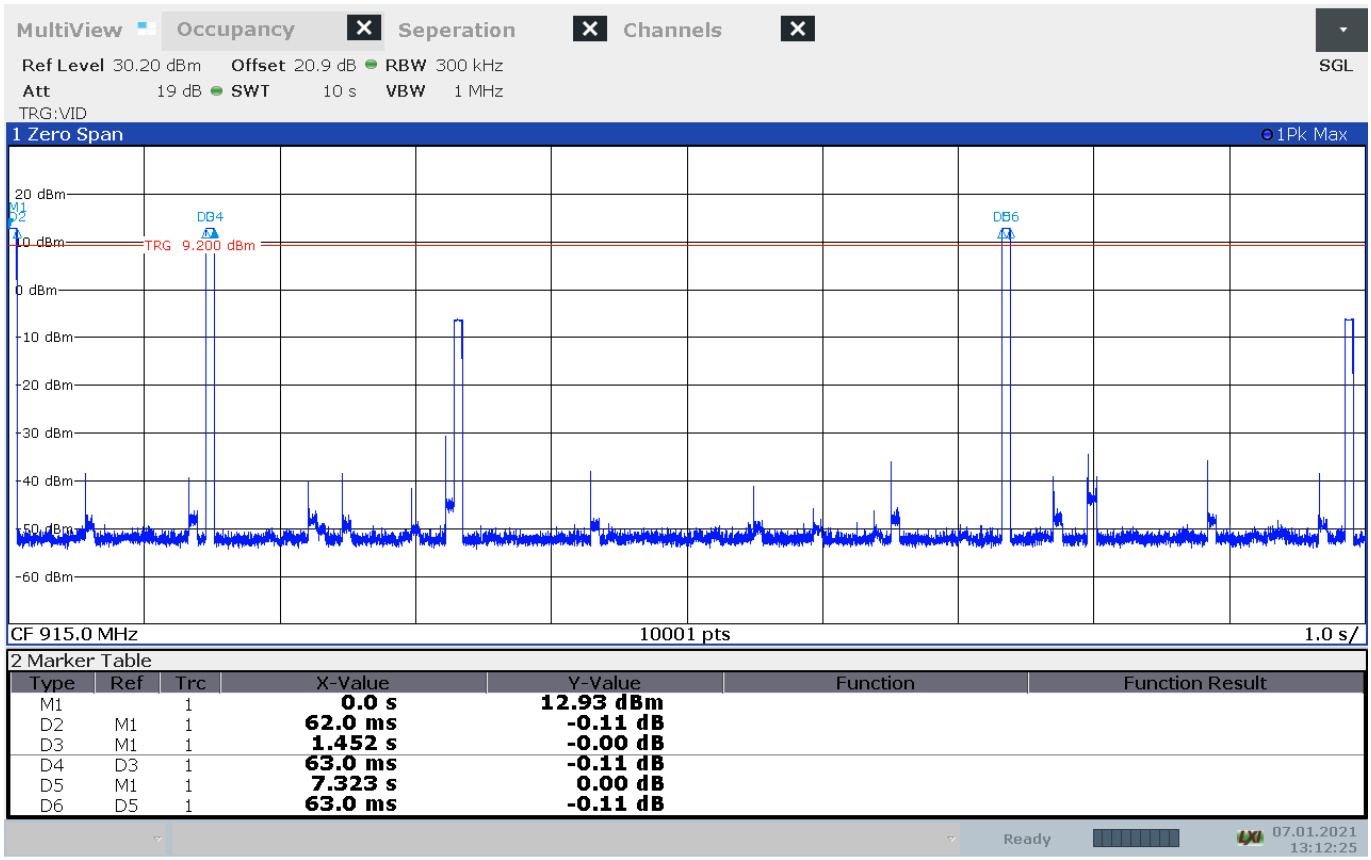
***Figure 8.4-29:*** *List of hopping frequencies*

Test data continued, 250 kbps

***Table 8.4-16:*** *Average time of occupancy results, 250 kbps*

| Dwell time of each pulse, ms | Number of pulses within period | Total dwell time within period, ms | Limit, ms | Margin, ms |
|---|---|---|---|---|
| 63 | 3 | 189 | 400 | 211 |

Note: 20 dB bandwidth > 250 kHz, therefore Measurement Period is 10 s




**13:12:26 07.01.2021**

***Figure 8.4-30:*** *Dwell time*

## 8.5 FCC 15.247(b) and RSS-247 5.4(a) Transmitter output power and e.i.r.p. requirements for FHSS 900 MHz

### 8.5.1 References, definitions and limits

**FCC:**

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

(2) For frequency hopping systems operating in the 902–928 MHz band: 1 watt for systems employing at least 50 hopping channels; and, 0.25 watts for systems employing less than 50 hopping channels, but at least 25 hopping channels, as permitted under paragraph (a)(1)(i) of this section.

(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.

**ISED:**

For FHSs operating in the band 902–928 MHz, the maximum peak conducted output power shall not exceed 1.0 W, and the e.i.r.p. shall not exceed 4 W if the hopset uses 50 or more hopping channels; the maximum peak conducted output power shall not exceed 0.25 W and the e.i.r.p. shall not exceed 1 W if the hopset uses less than 50 hopping channels.

### 8.5.2 Test summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | November 30, 2020 |

### 8.5.3 Observations, settings and special notes

Conducted output power was tested per ANSI C63.10 subclause 7.8.5. The hopping shall be disabled for this test. Spectrum analyser settings:
EUT utilizes > 50 hopping frequencies for all modulations

| | |
|---|---|
| Resolution bandwidth | > 20 dB bandwidth of the emission being measured |
| Video bandwidth | ≥ RBW |
| Frequency span | approximately 5 times the 20 dB bandwidth, centered on a hopping channel |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.5.4 Test data, 50 kbps

***Table 8.5-1:*** *Output power and EIRP results, 50 kbps*

| Frequency, MHz | Output power, dBm | Output power limit, dBm | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 902.2 | 11.9 | 30.0 | 18.1 | 0.26 | 12.2 | 36.0 | 23.8 |
| 915.2 | 12.1 | 30.0 | 17.9 | 0.26 | 12.4 | 36.0 | 23.6 |
| 927.8 | 12.4 | 30.0 | 17.6 | 0.26 | 12.7 | 36.0 | 23.3 |

EIRP = Output power + Antenna gain

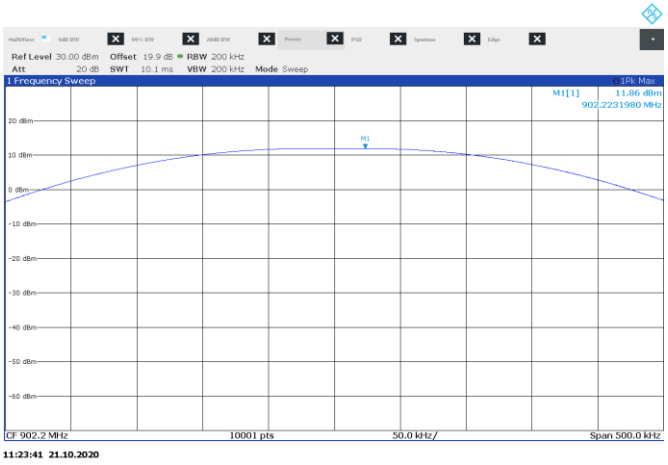



***Figure 8.5-1:*** *Output power on low channel, 50 kbps*

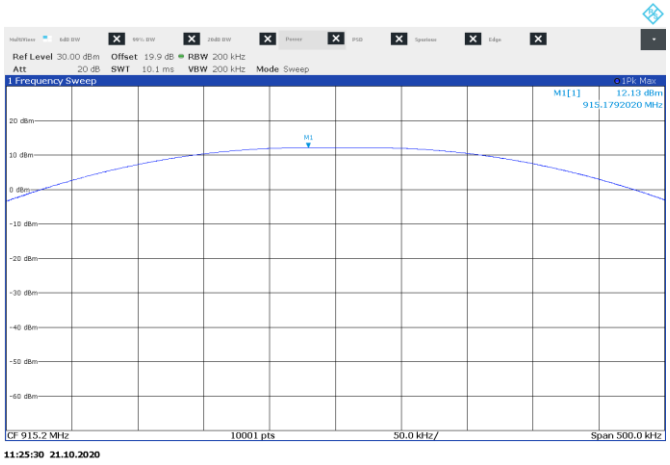



***Figure 8.5-2:*** *Output power on mid channel, 50 kbps*

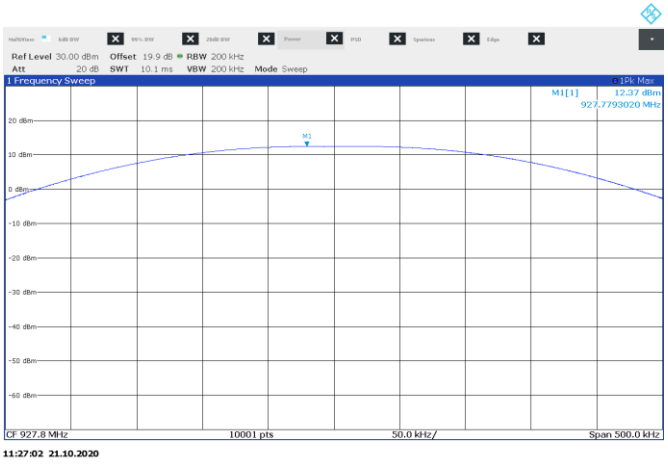



***Figure 8.5-3:*** *Output power on high channel, 50 kbps*

### 8.5.1 Test data, 150 kbps

***Table 8.5-2:*** *Output power and EIRP results, 150 kbps*

| Frequency, MHz | Output power, dBm | Output power limit, dBm | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 902.4 | 12.7 | 30.0 | 17.3 | 0.26 | 13.0 | 36.0 | 23.0 |
| 914.8 | 13.0 | 30.0 | 17.0 | 0.26 | 13.3 | 36.0 | 22.7 |
| 927.6 | 13.2 | 30.0 | 16.8 | 0.26 | 13.5 | 36.0 | 22.5 |

EIRP = Output power + Antenna gain

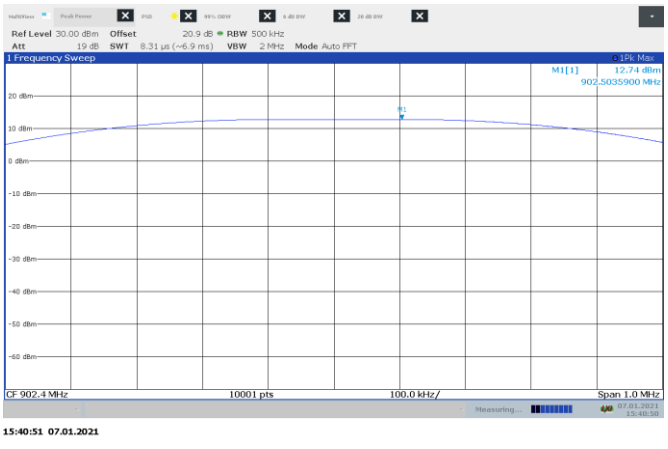



***Figure 8.5-4:*** *Output power on low channel, 150 kbps*

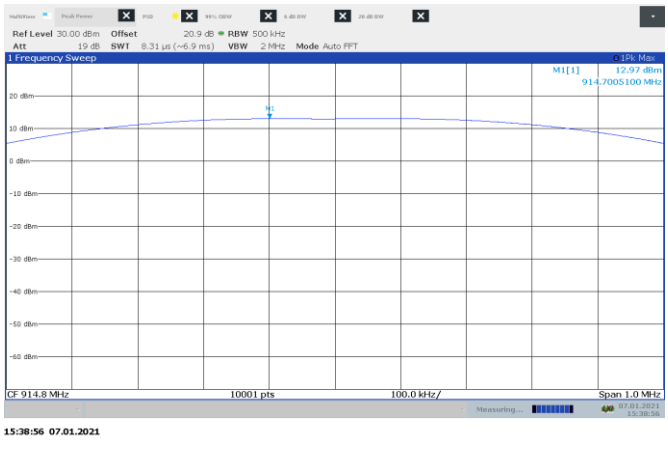



***Figure 8.5-5:*** *Output power on mid channel, 150 kbps*

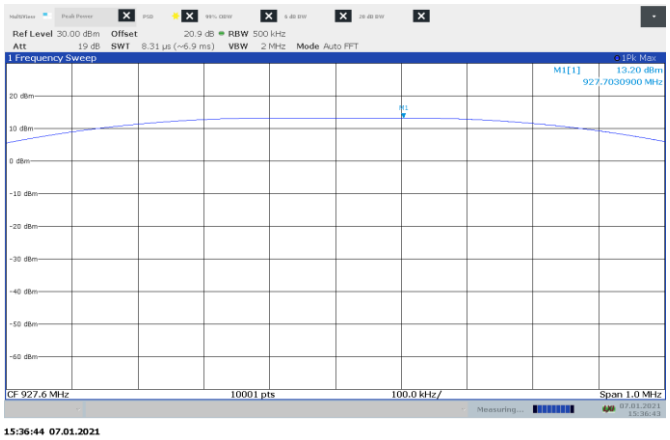



***Figure 8.5-6:*** *Output power on high channel, 150 kbps*

### 8.5.1 Test data, 250 kbps

***Table 8.5-3:*** *Output power and EIRP results, 250 kbps*

| Frequency, MHz | Output power, dBm | Output power limit, dBm | Margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 902.5 | 12.7 | 30.0 | 17.3 | 0.26 | 13.0 | 36.0 | 23.0 |
| 915.0 | 13.0 | 30.0 | 17.0 | 0.26 | 13.3 | 36.0 | 22.7 |
| 927.5 | 13.2 | 30.0 | 16.8 | 0.26 | 13.5 | 36.0 | 22.5 |

EIRP = Output power + Antenna gain

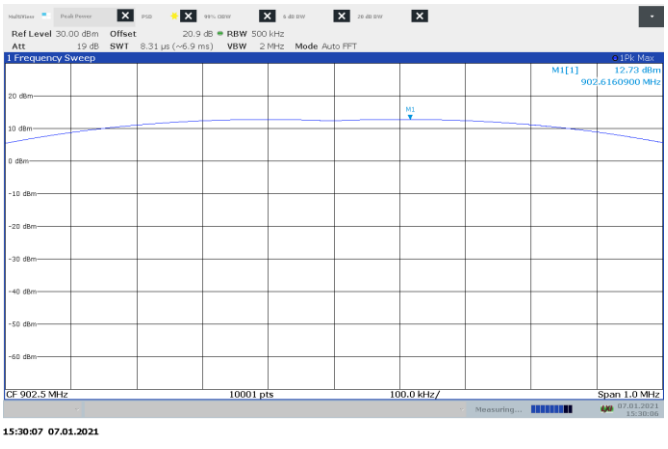



***Figure 8.5-7:*** *Output power on low channel, 250 kbps*

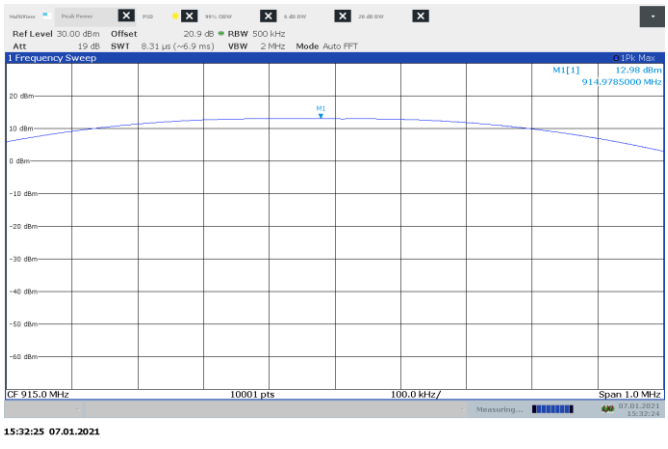



***Figure 8.5-8:*** *Output power on mid channel, 250 kbps*

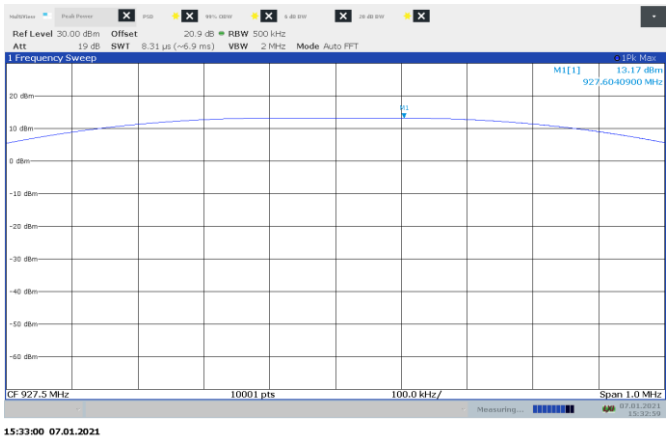



***Figure 8.5-9:*** *Output power on high channel, 250 kbps*

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

### 8.6.1 References, 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.
**RSS-GEN, Section 6.7:**
6 dB bandwidth is defined as the frequency range between two points, one at the lowest frequency below and one at the highest frequency above the carrier frequency, at which the maximum power level of the transmitted emission is attenuated 6 dB below the maximum in-band power level of the modulated signal, where the two points are on the outskirts of the in-band emission.
For the 99% emission bandwidth, the trace data points are recovered and directly summed in linear power level terms. The recovered amplitude data points, beginning at the lowest frequency, are placed in a running sum until 0.5% of the total is reached, and that frequency recorded. The process is repeated for the highest frequency data points (starting at the highest frequency, at the right side of the span, and going down in frequency). This frequency is then recorded. The difference between the two recorded frequencies is the occupied bandwidth (or the 99% emission bandwidth).

### 8.6.2 Test summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Alvin Liu | Test date | November 11, 2020 |

### 8.6.3 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 | 6 dB BW: 100 kHz; 99% OBW: 1–5% of OBW |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 1 – 5 × OBW |
| Detector mode | Peak |
| Trace mode | Max Hold |

## 8.6.4 Test data

***Table 8.6-1:*** *6 dB bandwidth results, Z-Wave Long Range*

| Modulation | Frequency, MHz | 6 dB bandwidth, kHz | Minimum limit, kHz | Margin, kHz |
|---|---|---|---|---|
| DSSS-OQPSK | 912.0 | 635.6 | 500 | 135.6 |
| DSSS-OQPSK | 920.0 | 638.6 | 500 | 138.6 |

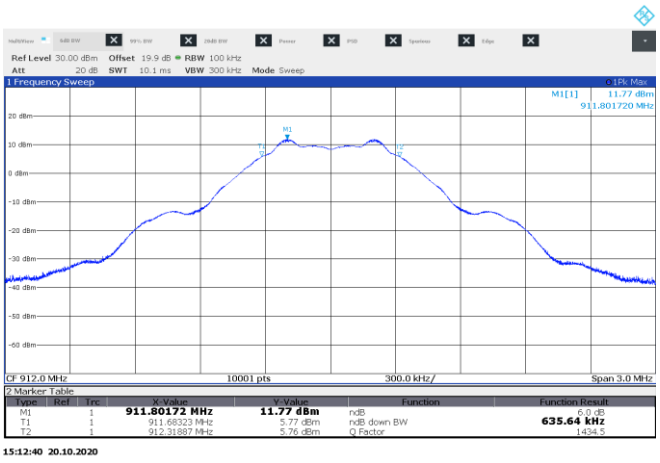



***Figure 8.6-1:*** *6 dB bandwidth on 912 MHz channel, Z-Wave Long Range*

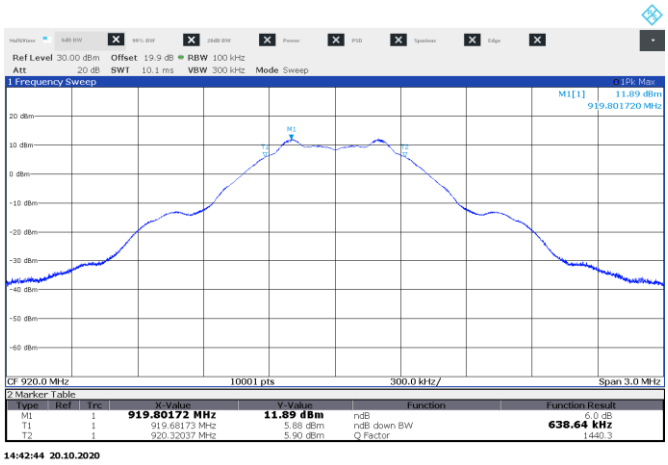



***Figure 8.6-2:*** *6 dB bandwidth on 920 MHz channel, Z-Wave Long Range*

***Table 8.6-2:*** *99% occupied bandwidth results, Z-Wave Long Range*

| Frequency, MHz | 99% occupied bandwidth, kHz |
|---|---|
| 912.0 | 928.0 |
| 920.0 | 932.1 |

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


***Figure 8.6-3:*** *99% OBW on 912 MHz channel, Z-Wave Long Range*

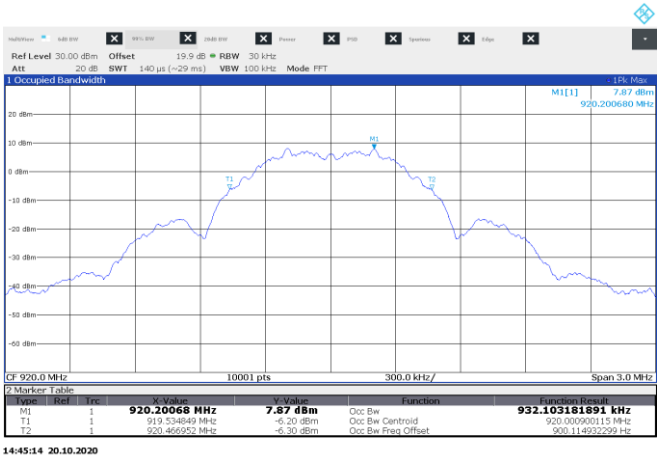



***Figure 8.6-4:*** *99% OBW on 920 MHz channel, Z-Wave Long Range*

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

### 8.7.1 References, 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.

### 8.7.2 Test summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Alvin Liu | Test date | November 11, 2020 |

### 8.7.3 Observations, settings and special notes

The test was performed as per KDB 558074, section 8.3 with reference to ANSI C63.10 subclause 11.9.1 (peak power) using method RBW≥DTS bandwidth (Maximum peak conducted output power).
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth | ≥ OBW |
| Video bandwidth | ≥3 × RBW |
| Frequency span | 2 – 5 × OBW |
| Detector mode | Peak |
| Trace mode | Max Hold |

### 8.7.4 Test data

***Table 8.7-1:*** *Output power and EIRP results (antenna port measurement)*

| Frequency, MHz | Conducted output power, dBm | Output power limit, dBm | Output power margin, dB | Antenna gain, dBi | EIRP, dBm | EIRP limit, dBm | EIRP margin, dB |
|---|---|---|---|---|---|---|---|
| 912 | 12.1 | 30.0 | 17.9 | 0.26 | 12.4 | 36.0 | 23.6 |
| 920 | 12.2 | 30.0 | 17.8 | 0.26 | 12.5 | 36.0 | 23.5 |

*Note: EIRP [dBm] = Conducted output power [dBm] + Antenna gain [dBi]*

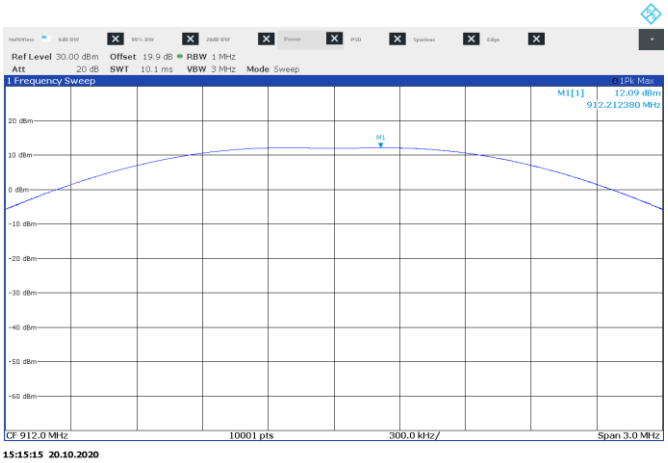



***Figure 8.7-1:*** *Output power on 912 MHz channel*

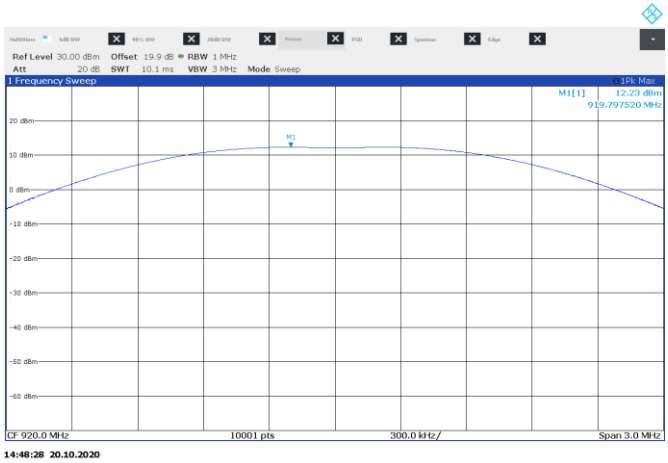



***Figure 8.7-2:*** *Output power on 920 MHz channel*

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

### 8.8.1 References, 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 8.8-1:*** *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 8.8-2:*** *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 | |
| 8.41425–8.41475 | 167.72–173.2 | 3500–4400 | Above 38.6 |
| 12.29–12.293 | 240–285 | 4500–5150 | |
| 12.51975–12.52025 | 322–335.4 | 5350–5460 | |

Note: Certain frequency bands listed in Table 8.8-2 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 8.8-3:*** *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 | | | |

## 8.8.2 Test summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Mark Libbrecht | Test date | October 20, 2020 |

### 8.8.3 Observations, settings and special notes

As part of the current assessment, the test range of 9 kHz to 10th harmonic has been fully considered and compared to the actual frequencies utilized within the EUT. Since the EUT contains a transmitter in the GHz range, the EUT has been deemed compliant without formal testing in the 9 kHz to 30 MHz test range, therefore formal test results (tabular data and/or plots) are not provided within this test report.
EUT was set to transmit with 100 % duty cycle.
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 the maximum peak conducted output power procedure to demonstrate compliance, the spurious emissions limit is −20 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 peak radiated measurements within restricted bands above 1 GHz:

| | |
|---|---|
| Resolution bandwidth: | 1 MHz |
| Video bandwidth: | 3 MHz |
| 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 |

## 8.8.4 Test data

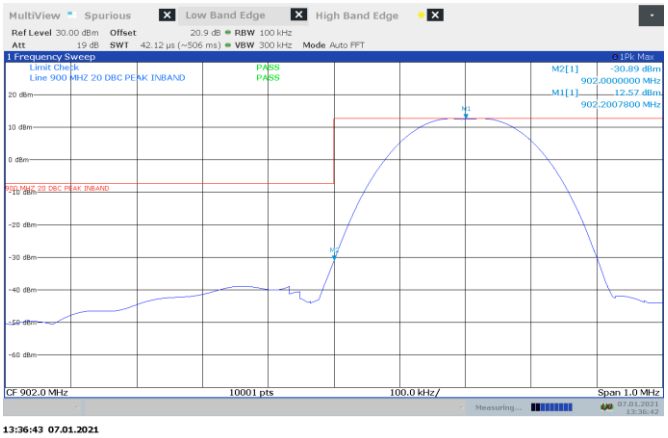



***Figure 8.8-1:*** *Conducted Band-edge on low channel, FSK 50kbps*

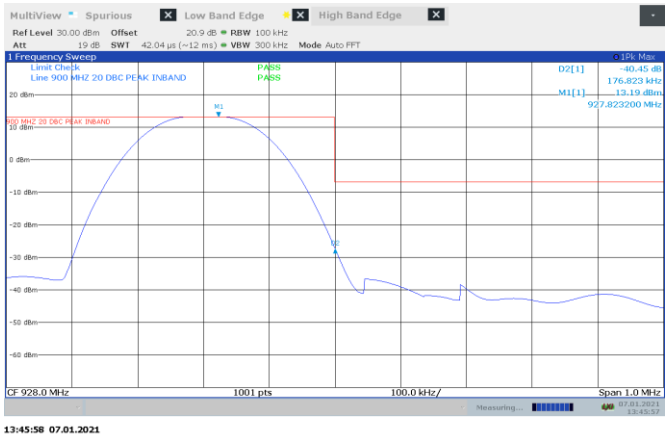



***Figure 8.8-2:*** *Conducted Band-edge on high channel, FSK 50kbps*

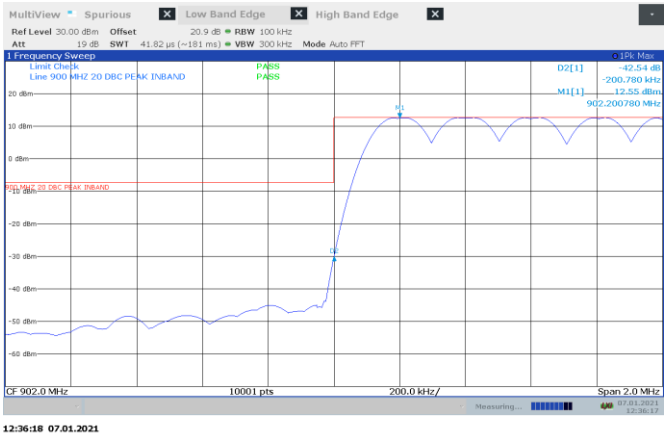



***Figure 8.8-3:*** *Conducted Low Band-edge on hopping, FSK 50kbps*


***Figure 8.8-4:*** *Conducted High Band-edge on hopping, FSK 50kbps*

Test data, continued

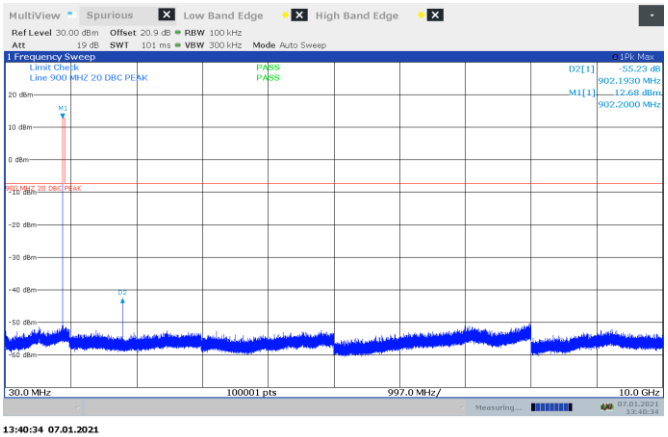



***Figure 8.8-5:*** *Conducted spurious emissions on low channel, FSK 50kbps*

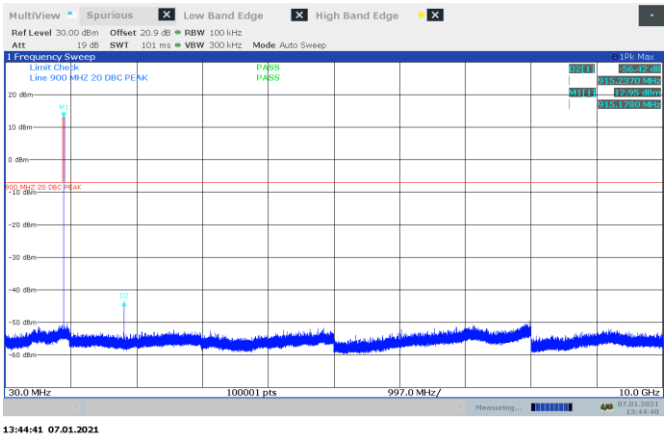



***Figure 8.8-6:*** *Conducted spurious emissions on mid channel, FSK 50kbps*

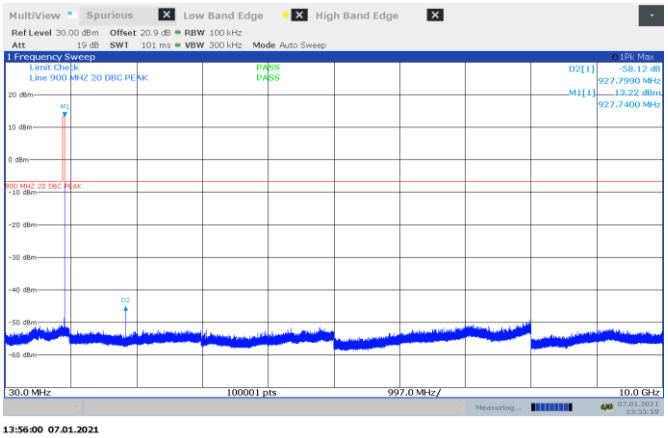



***Figure 8.8-7:*** *Conducted spurious emissions on high channel, FSK 50kbps*

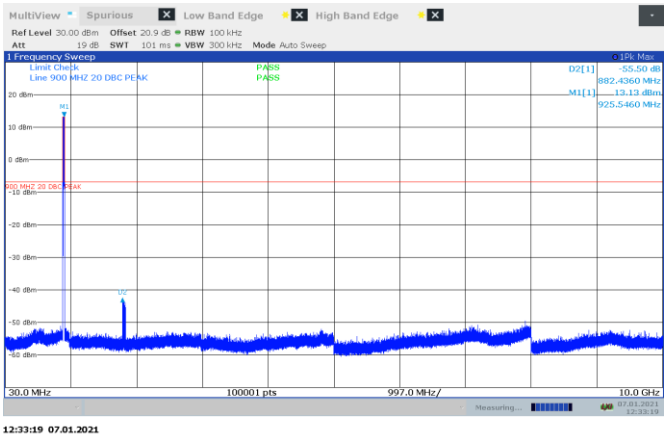



***Figure 8.8-8:*** *Conducted spurious emissions on Hopping, FSK 50kbps*

Test data, continued

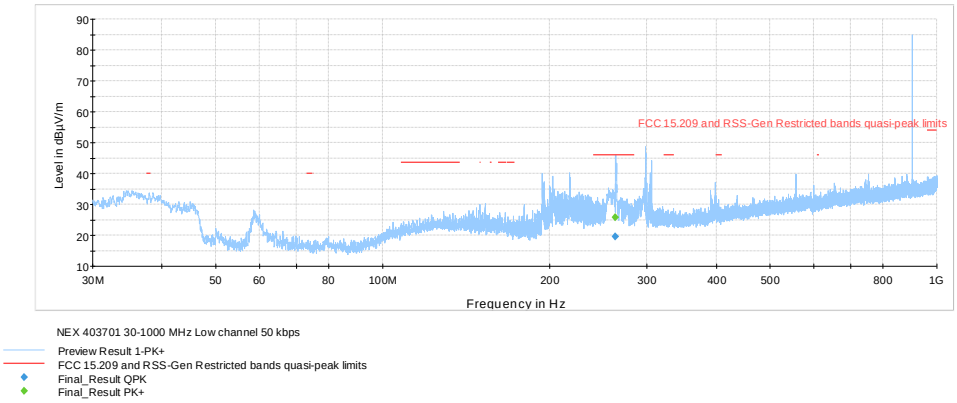



***Figure 8.8-9:*** *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 50kbps*

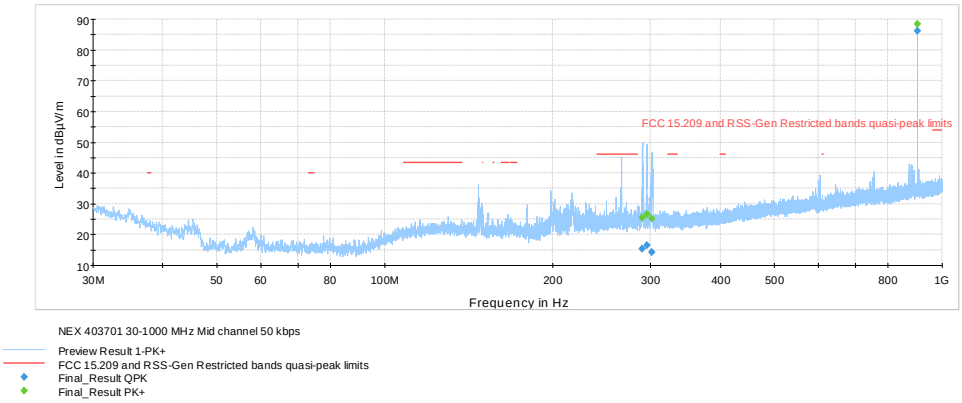



***Figure 8.8-10:*** *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 50kbps*

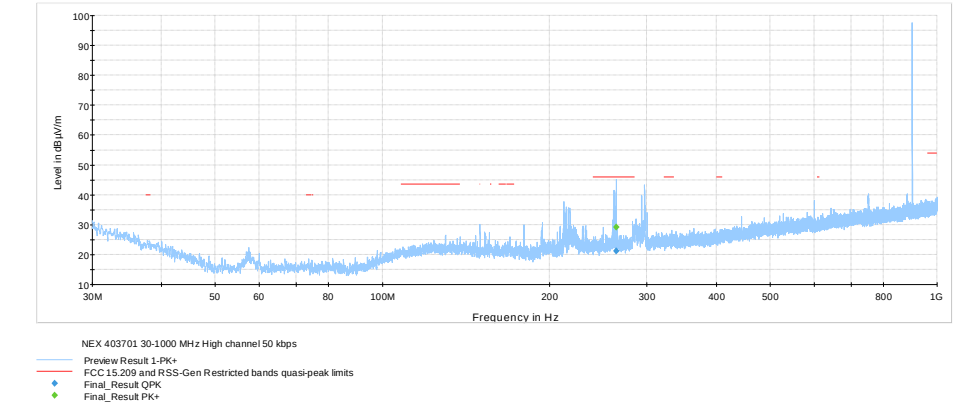



***Figure 8.8-11:*** *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 50kbps*

Test data, continued

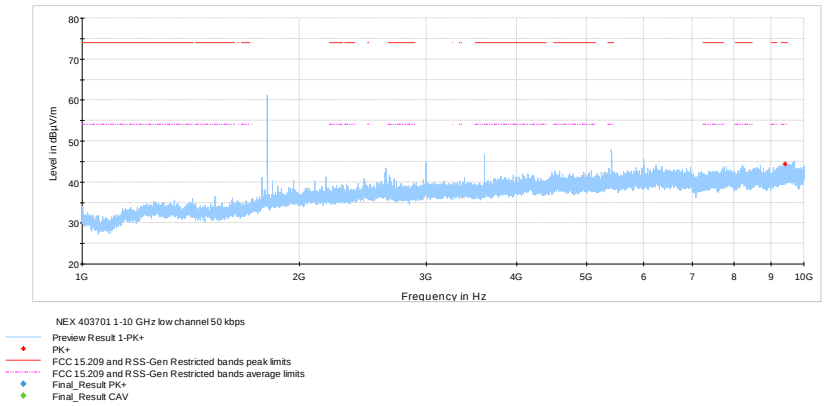



***Figure 8.8-12:*** *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 50kbps*

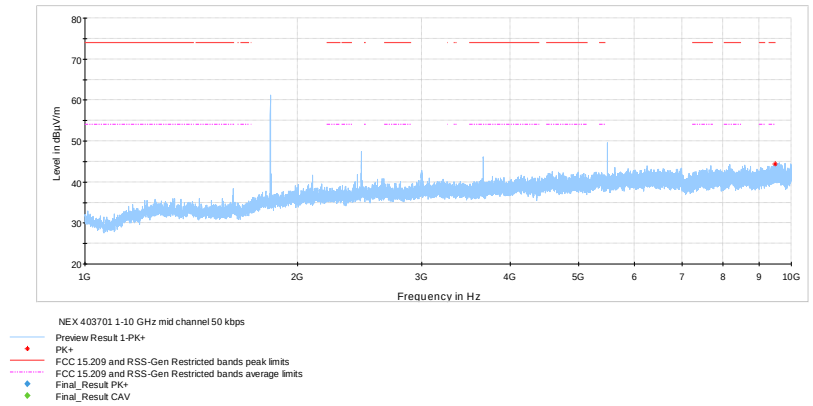



***Figure 8.8-13:*** *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 50kbps*

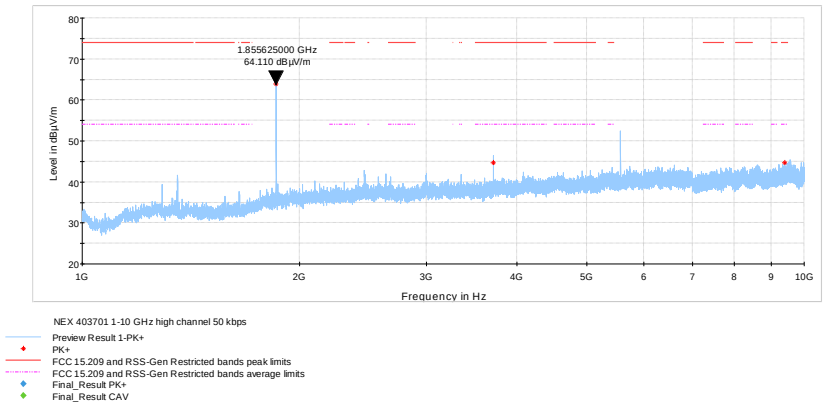



***Figure 8.8-14:*** *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 50kbps*

Test data, continued

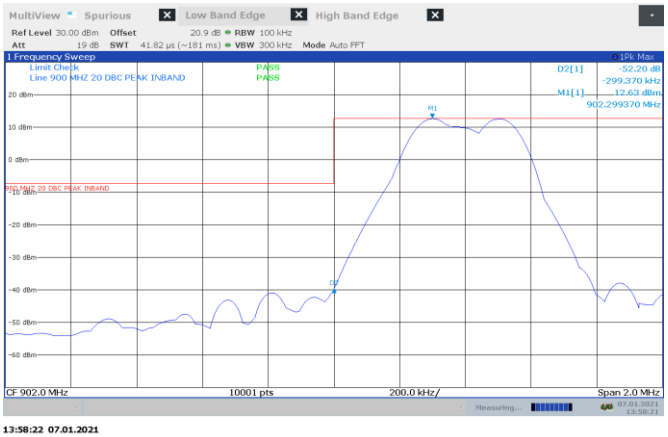



***Figure 8.8-15:*** *Conducted Band-edge on low channel, FSK 150kbps*

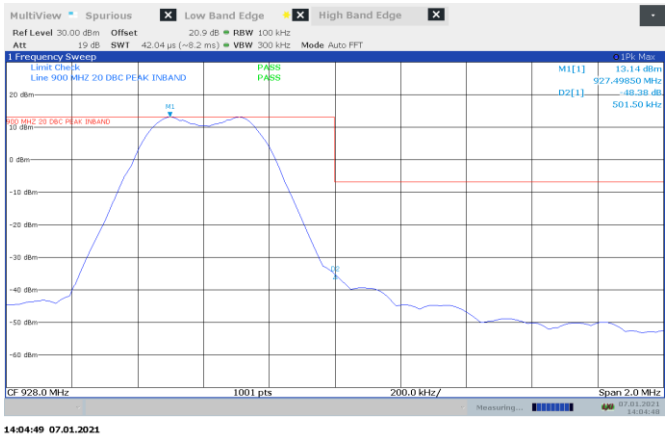



***Figure 8.8-16:*** *Conducted Band-edge on high channel, FSK 150kbps*

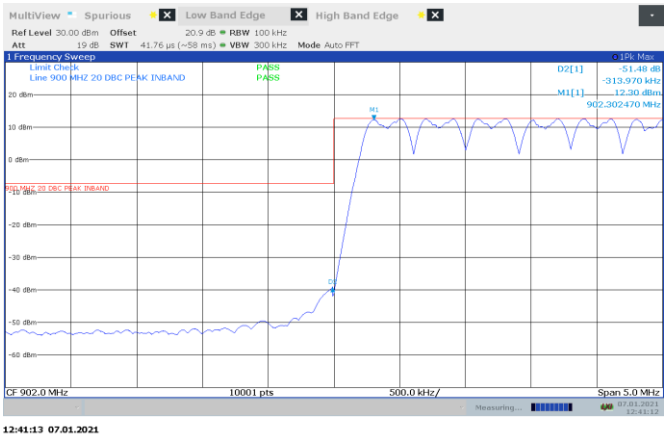



***Figure 8.8-17:*** *Conducted Low Band-edge on Hopping, FSK 150kbps*


***Figure 8.8-18:*** *Conducted High Band-edge on Hopping, FSK 150kbps*

Test data, continued

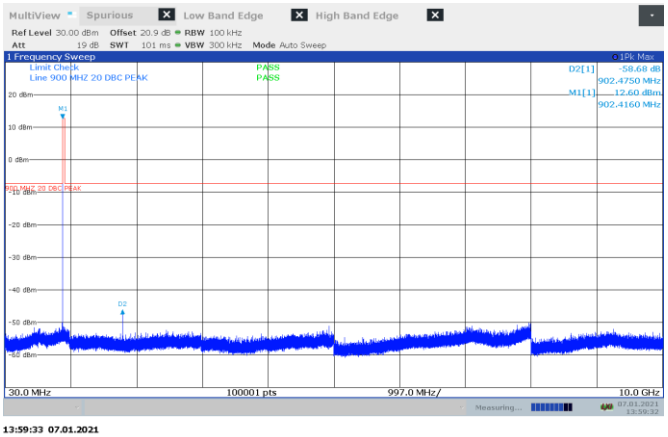



***Figure 8.8-19:*** *Conducted spurious emissions on low channel, FSK 150kbps*

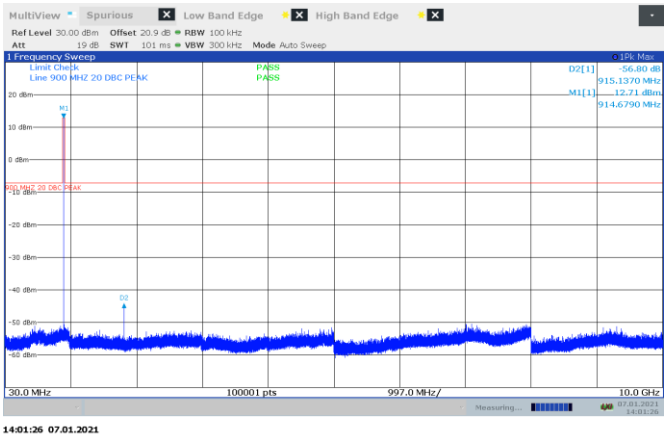



***Figure 8.8-20:*** *Conducted spurious emissions on mid channel, FSK 150kbps*

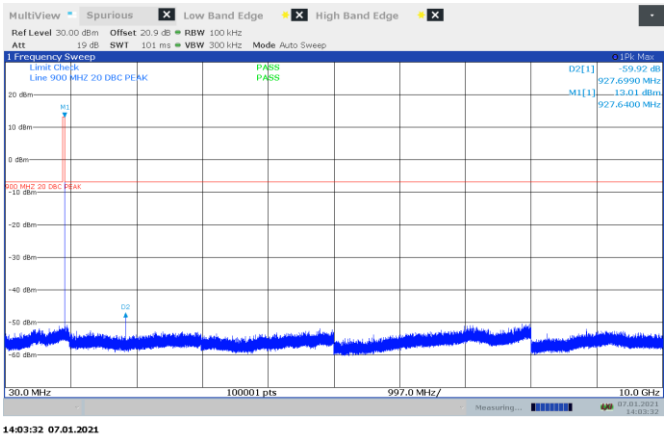



***Figure 8.8-21:*** *Conducted spurious emissions on high channel, FSK 150kbps*

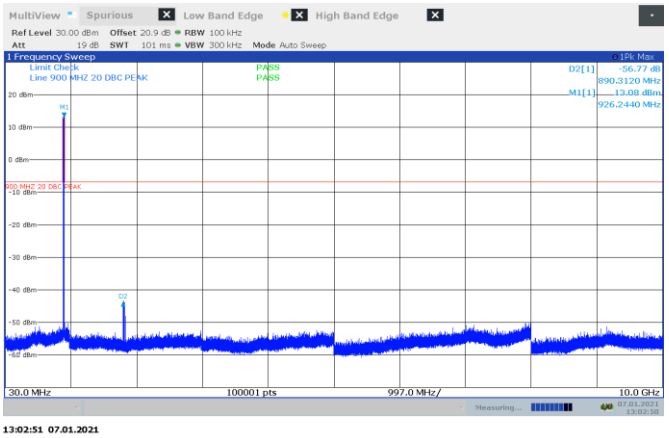



***Figure 8.8-22:*** *Conducted spurious emissions on Hopping, FSK 150kbps*

Test data, continued

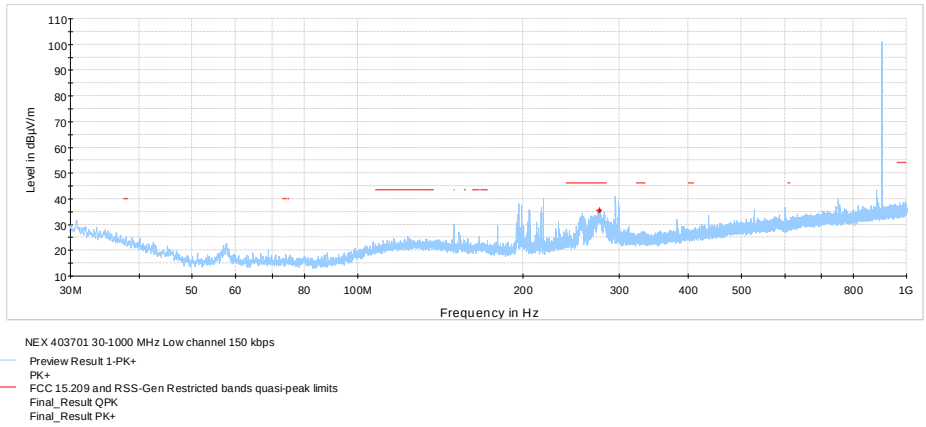



***Figure 8.8-23:*** *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 150kbps*

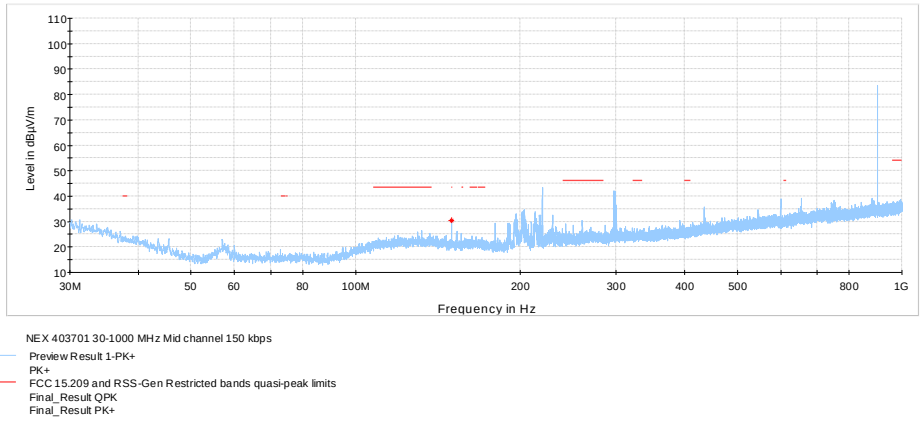



***Figure 8.8-24:*** *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 150kbps*

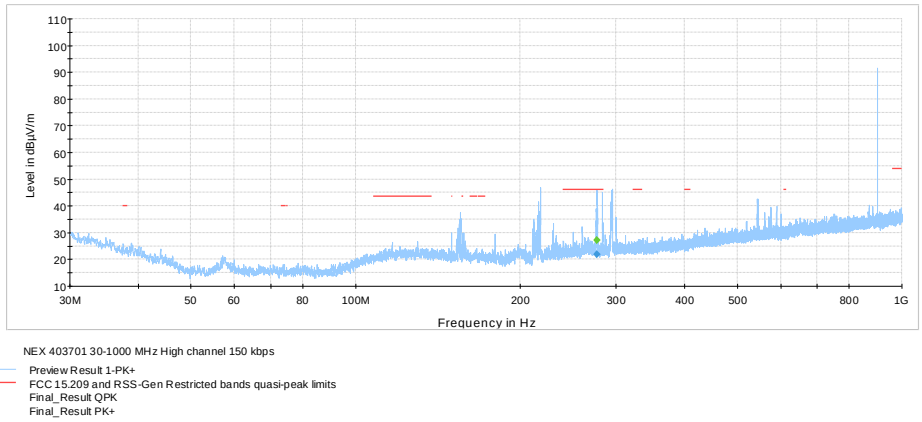



***Figure 8.8-25:*** *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 150kbps*

Test data, continued

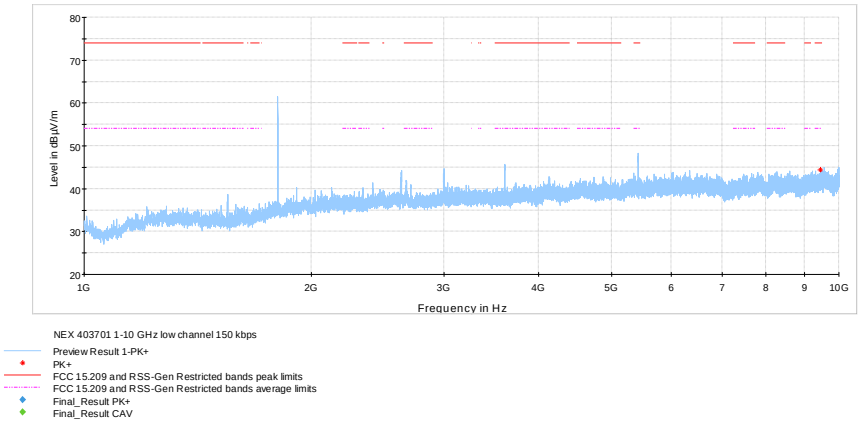



***Figure 8.8-26:*** *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 150kbps*

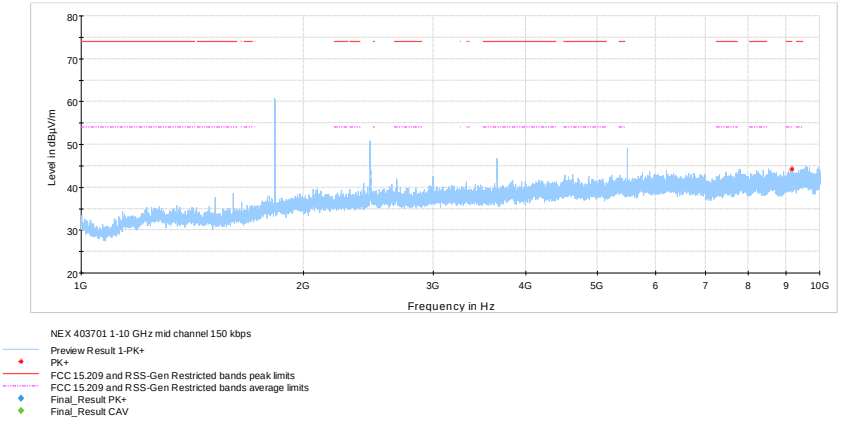



***Figure 8.8-27:*** *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 150kbps*

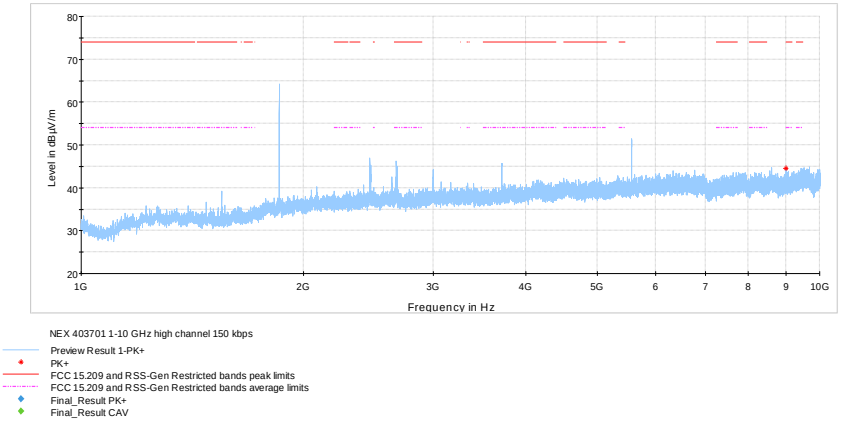



***Figure 8.8-28:*** *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 150kbps*

Test data, continued


***Figure 8.8-29:*** *Conducted Band-edge on low channel, FSK 250kbps*

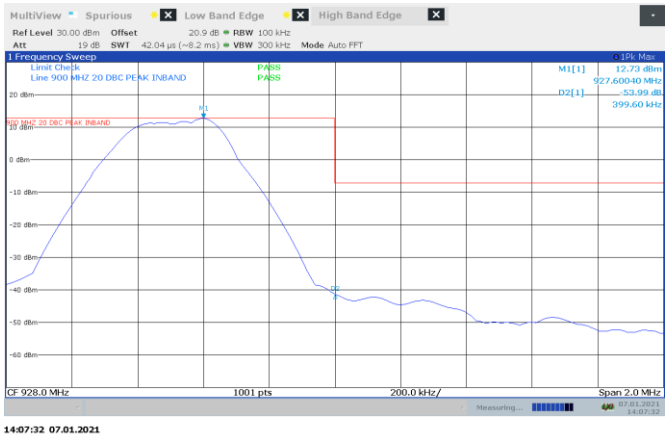



***Figure 8.8-30:*** *Conducted Band-edge on high channel, FSK 250kbps*

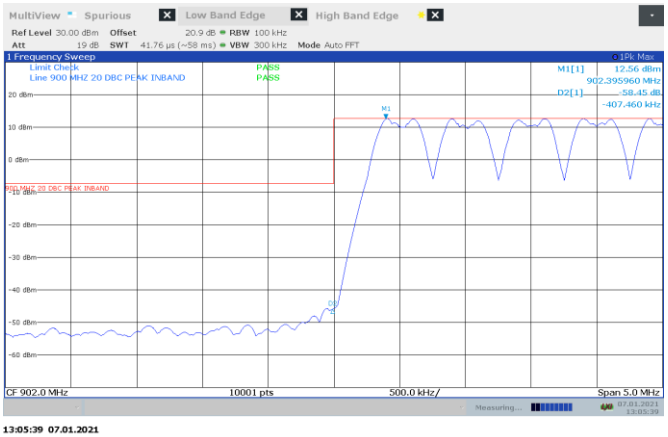



***Figure 8.8-31:*** *Conducted Low Band-edge on hopping, FSK 250kbps*

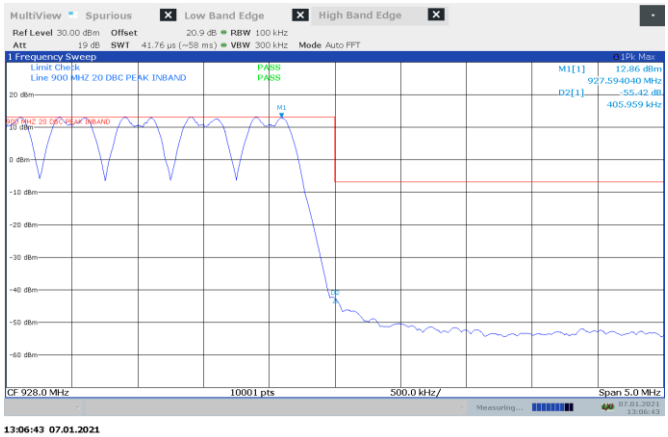



***Figure 8.8-32:*** *Conducted High Band-edge on hopping, FSK 250kbps*

Test data, continued

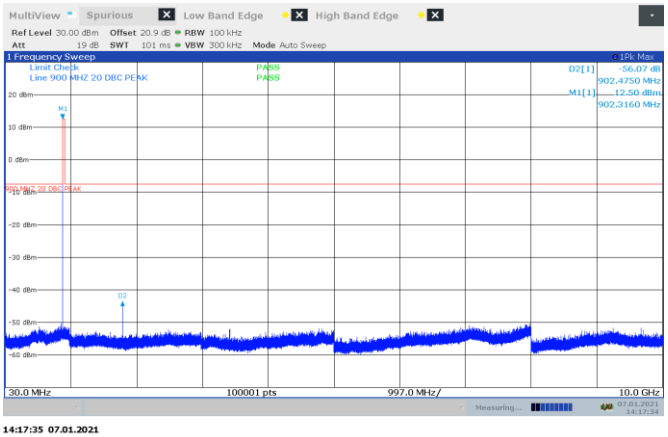



***Figure 8.8-33:*** *Conducted spurious emissions on low channel, FSK 250kbps*

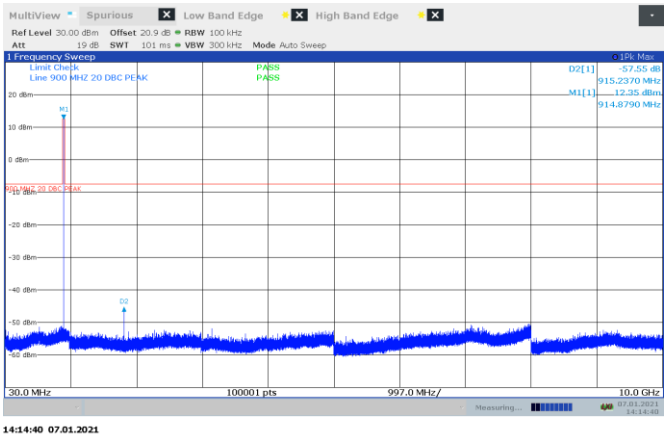



***Figure 8.8-34:*** *Conducted spurious emissions on mid channel, FSK 250kbps*

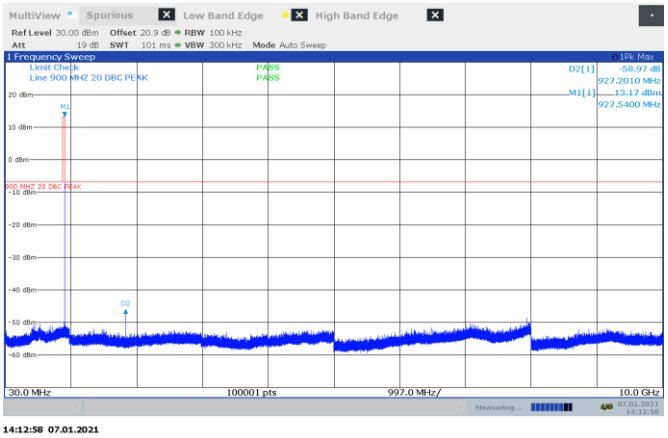



***Figure 8.8-35:*** *Conducted spurious emissions on high channel, FSK 250kbps*

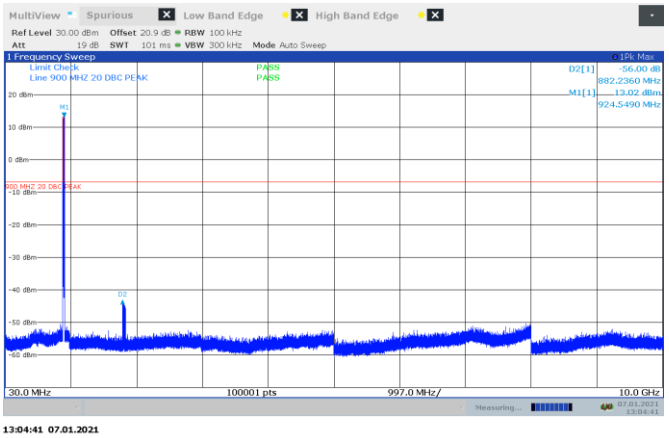



***Figure 8.8-36:*** *Conducted spurious emissions on hopping, FSK 250kbps*

Test data, continued

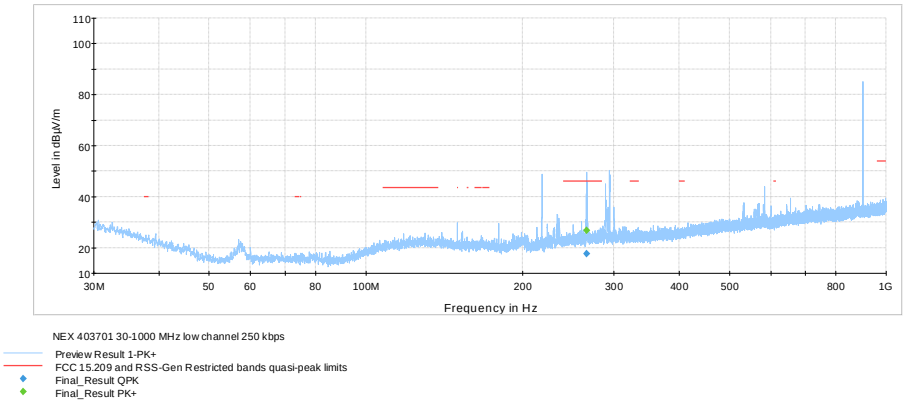



***Figure 8.8-37:*** *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 250kbps*

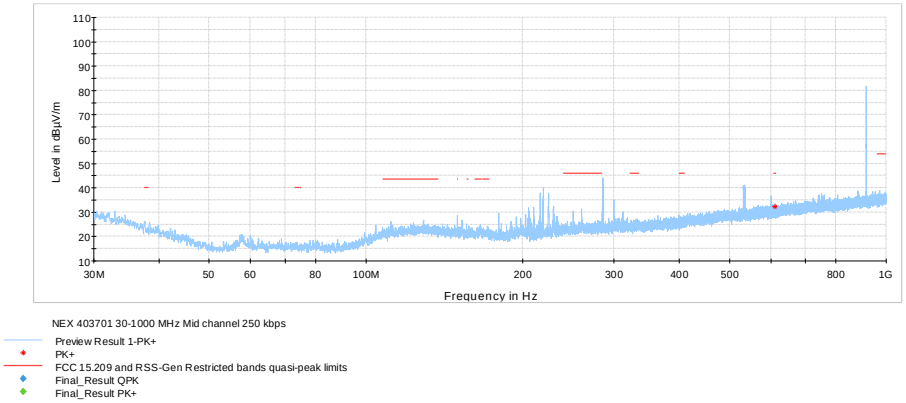



***Figure 8.8-38:*** *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 250kbps*

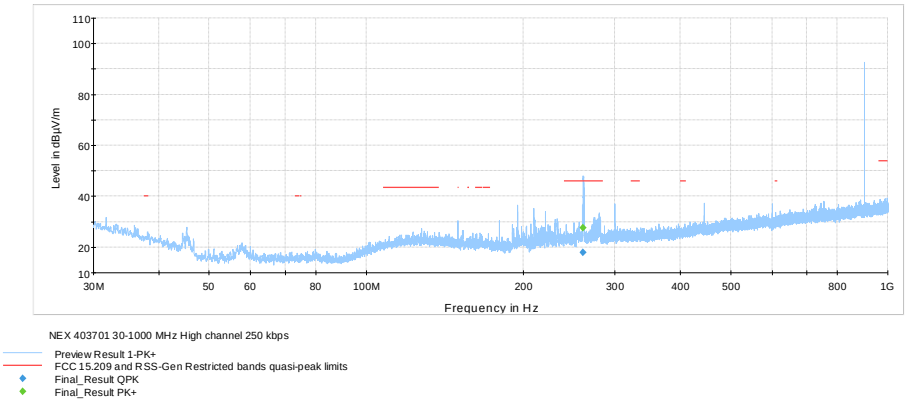



***Figure 8.8-39:*** *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 250kbps*

Test data, continued

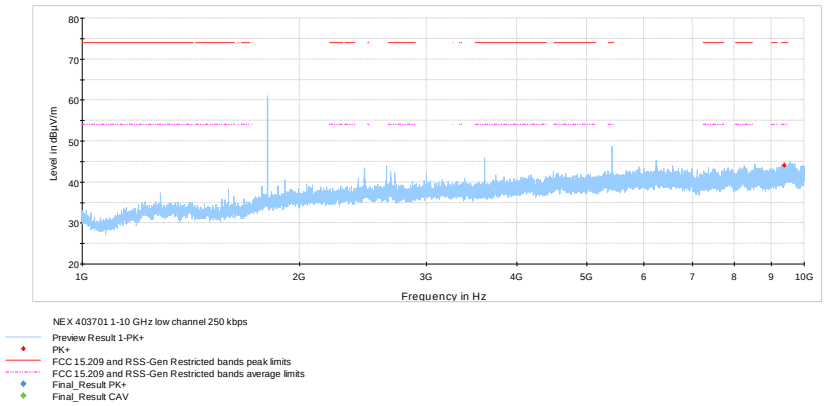



***Figure 8.8-40:*** *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 250kbps*

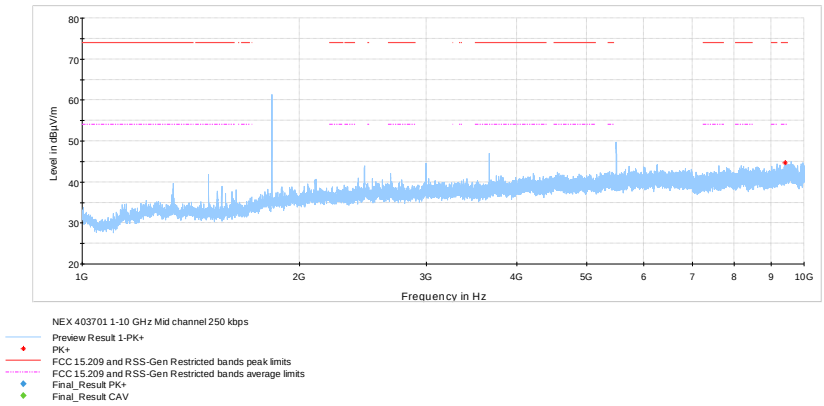



***Figure 8.8-41:*** *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 250kbps*

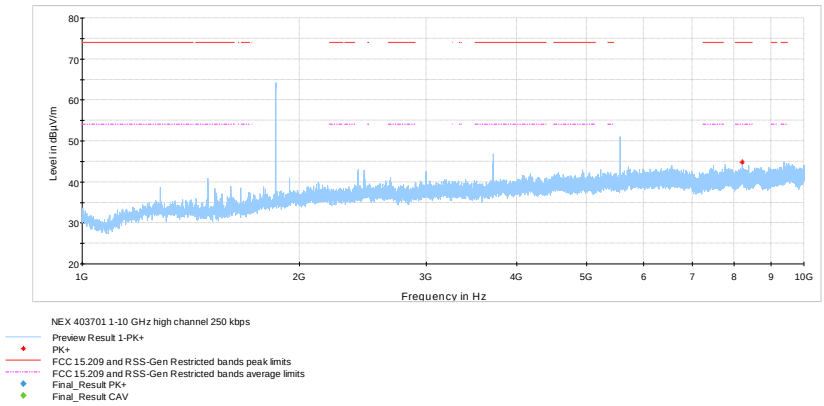



***Figure 8.8-42:*** *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 250kbps*

Test data, continued


***Figure 8.8-43:*** *Conducted Band-edge on 912 MHz channel, Z-Wave Long Range*

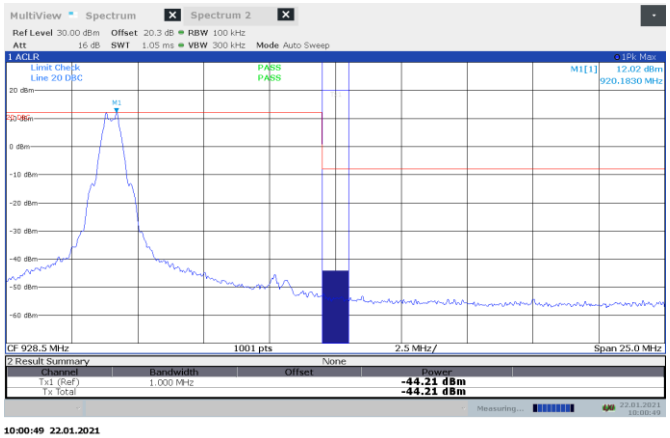



***Figure 8.8-44:*** *Conducted Band-edge on 920 MHz channel, Z-Wave Long Range*

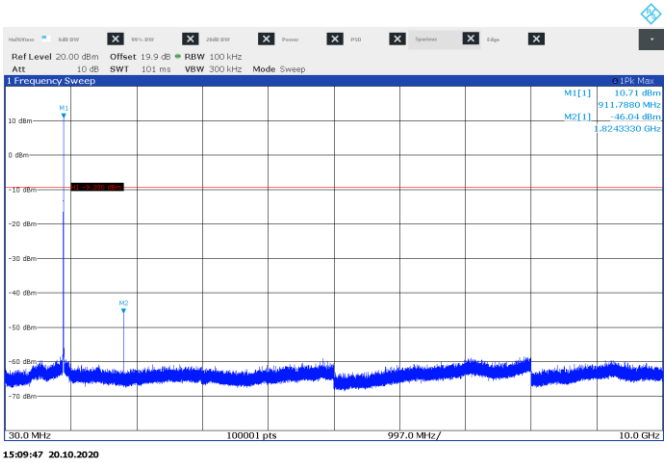



***Figure 8.8-45:*** *Conducted spurious emissions on 912 MHz channel, Z-Wave Long Range*

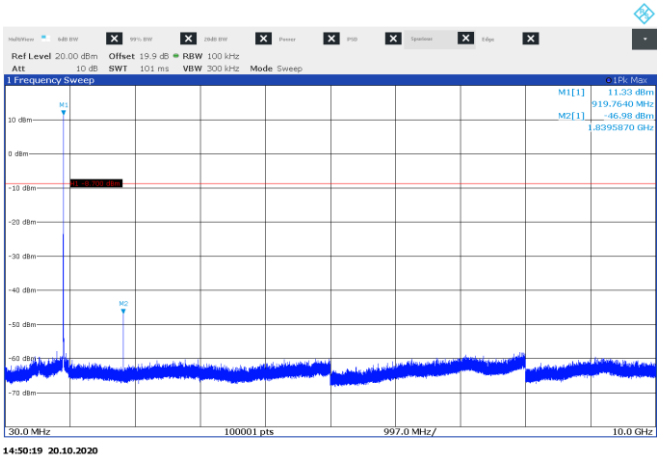



***Figure 8.8-46:*** *Conducted spurious emissions on 920 MHz channel, Z-Wave Long Range*

Test data, continued

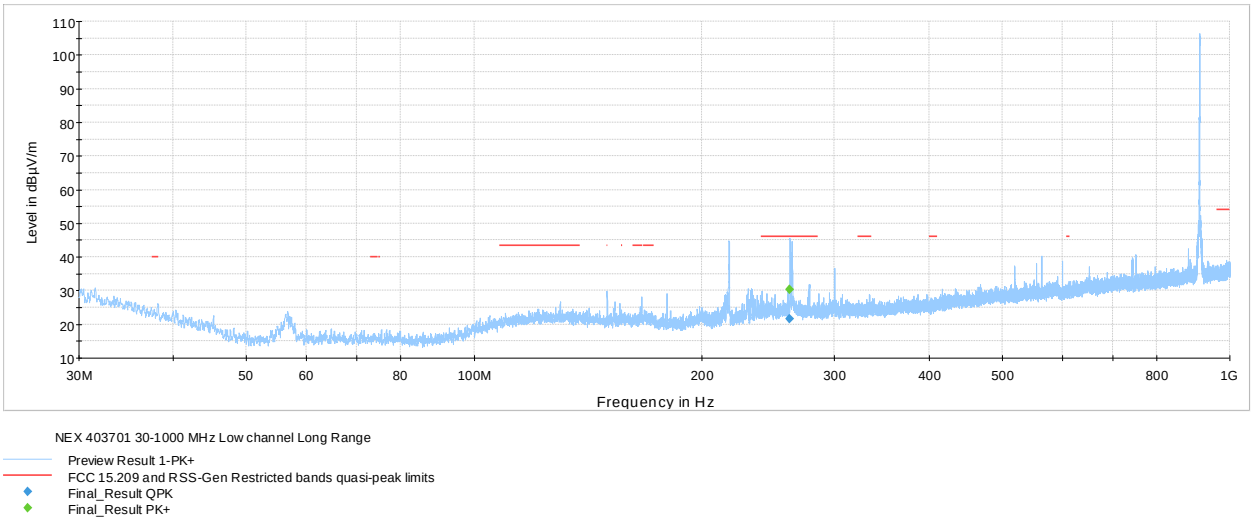



***Figure 8.8-47:*** *Radiated spurious emissions 30 MHz – 1 GHz, on 912 MHz channel, Z-Wave Long Range*

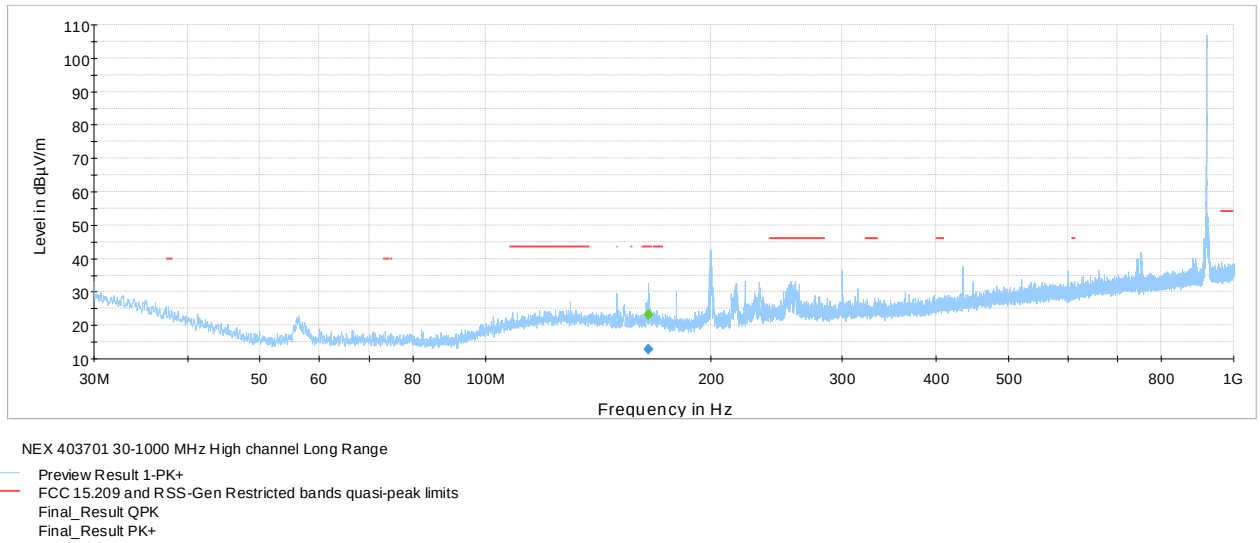
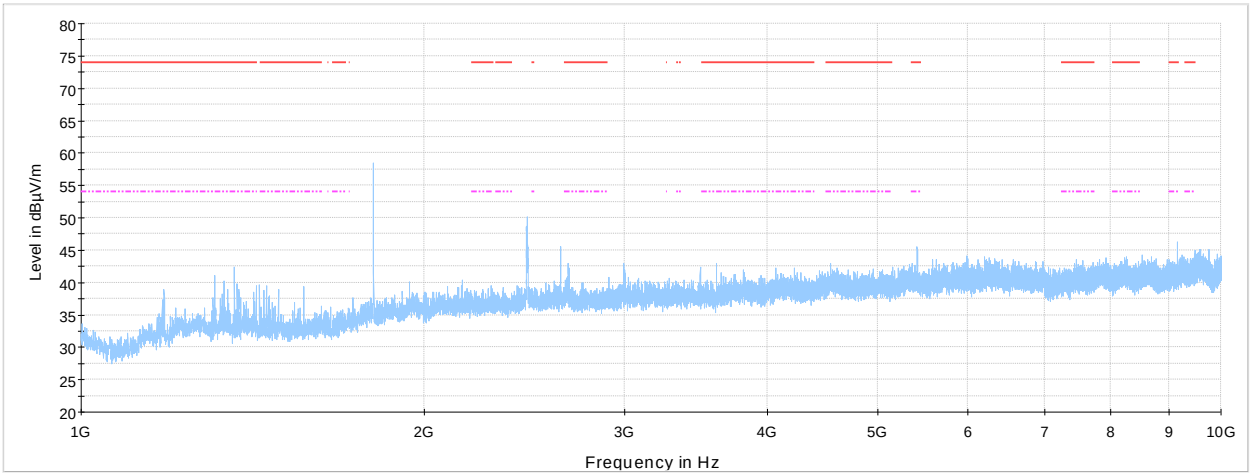


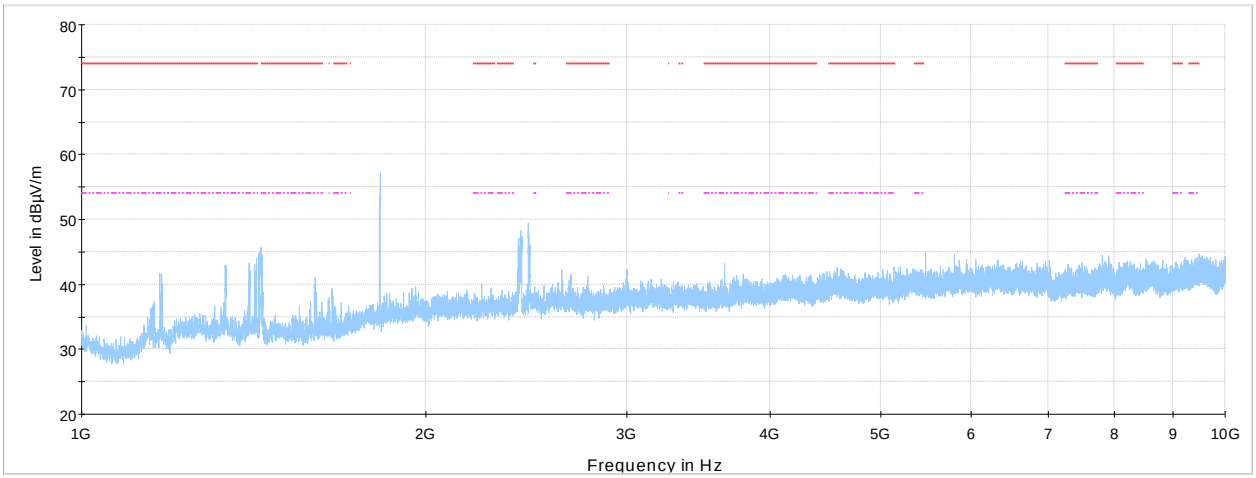

***Figure 8.8-48:*** *Radiated spurious emissions 30 MHz – 1 GHz, on 920 MHz channel, Z-Wave Long Range*

Test data, continued




NEX 403701 1-10 GHz Low channel Long Range
Preview Result 1-PK+
PK+
FCC 15.209 and RSS-Gen Restricted bands peak limits
FCC 15.209 and RSS-Gen Restricted bands average limits
Final_Result PK+
Final_Result CAV

***Figure 8.8-49:*** *Radiated spurious emissions 1 - 10 GHz, on 912 MHz channel, Z-Wave Long Range*




NEX 403701 1-10 GHz High channel Long Range
Preview Result 1-PK+
PK+
FCC 15.209 and RSS-Gen Restricted bands peak limits
FCC 15.209 and RSS-Gen Restricted bands average limits
Final_Result PK+
Final_Result CAV

***Figure 8.8-50:*** *Radiated spurious emissions 1 - 10 GHz, on 920 MHz channel, Z-Wave Long Range*

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

### 8.9.1 References, 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:
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.

### 8.9.2 Test summary

| | | | |
|---|---|---|---|
| Verdict | Pass | | |
| Tested by | Alvin Liu | Test date | October 20, 2020 |

### 8.9.3 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 PKPSD (peak PSD).
Spectrum analyser settings:

| | |
|---|---|
| Resolution bandwidth: | 3 kHz |
| Video bandwidth: | ≥3 × RBW |
| Frequency span: | 1.5 times the DTS BW (Peak) |
| Detector mode: | Peak |
| Trace mode: | Max Hold |

## 8.9.4 Test data

***Table 8.9-1:*** *PSD results (antenna port measurement)*

| Frequency, MHz | PSD, dBm/3 kHz | PSD limit, dBm/3 kHz | Margin, dB |
|---|---|---|---|
| 912 | -0.1 | 8.0 | 8.1 |
| 920 | 0.1 | 8.0 | 7.9 |

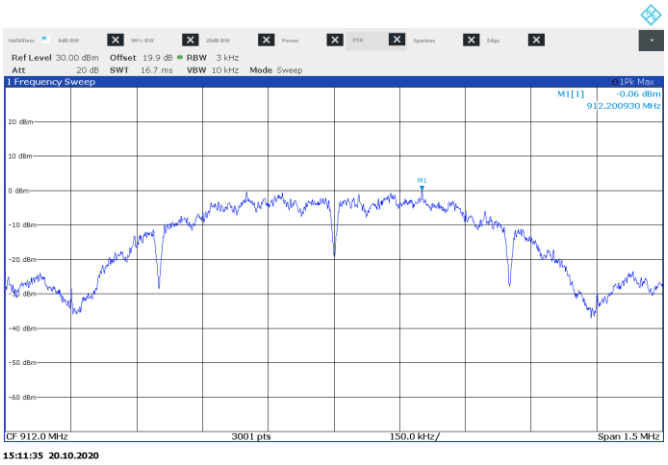



***Figure 8.9-1:*** *PSD on 912 MHz channel, Z-Wave Long Range*

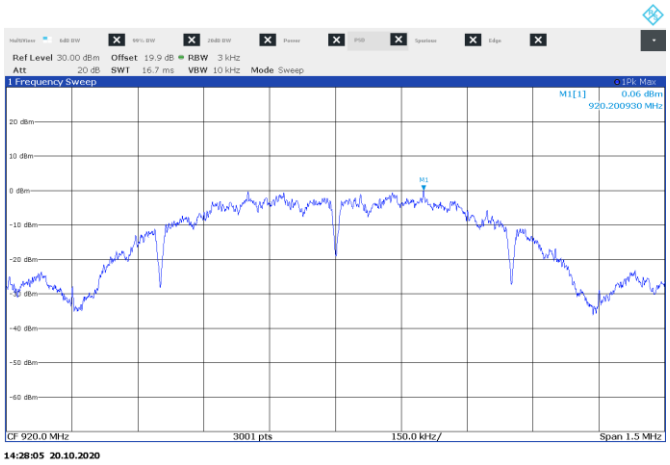



***Figure 8.9-2:*** *PSD on 920 MHz channel, Z-Wave Long Range*

**End of the test report**