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RADIO TEST REPORT – 403700-1R1TRFWL

Type of assessment:

Final product testing

Applicant:

Ring LLC

Product name (type):

Contact Sensor

Model:

5AT3S2

FCC ID:

2AEUP5AT3S2

IC Registration number:

20271-5AT3S2

Specifications:

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

Date of issue: January 29, 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:* 1-130 Saltsman Drive Cambridge, Ontario Canada N3E 0B2 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
1RTRF	January 29, 2021	Update battery information section 2.2 and 5.4

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
The EUT will be powered by 2 × CR 2032, 3.0 V_{DC} Batteries in normal operation. For testing purposes only 1 × 3.0 V_{DC} battery was required to power the EUT in combination with the external Laptop.

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/Manufacture

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	Contact Sensor
Model	5AT3S2
Model variant(s)	None
Serial number	G7Q1D202018505QN (Radiated), G7Q1D2020113OOOM (Conducted)
Part number	None
Operating conditions	Firmware revision V1.15
Product description and theory of operation	When activated, the contact sensor will send a message to the Base Station that the door has been opened. It can also be placed on a window frame and window to achieve the same function.

5.4 Technical information

Applicant IC company number	20271
IC UPN number	5AT3S2
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 ☒ 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: 0.0135 (11.3 dBm) @ 927.8 MHz 150 kbps, FHSS: 0.0138 (11.4 dBm) @ 927.6 MHz 250 kbps, FHSS: 0.0135 (11.3 dBm) @ 927.5 MHz DTS: 0.0126 (11.0 dBm) @ 920 MHz
Field strength, dBµV/m @ 3 m	N/A
Measured BW (kHz), 99% OBW	50 kbps, FHSS: 88.0 @ 915.2 MHz 150 kbps, FHSS: 317.2 @ 927.6 MHz 250 kbps, FHSS: 386.7 @ 927.5 MHz DTS: 933.5 @ 912 MHz
Type of modulation	Equipment class DSS: (FSK FHSS) Equipment class DXX: DSSS-OQPSK
Emission classification	F1D, W7D
Transmitter spurious, dBµV/m @ 3 m	50 kbps, FHSS: 51.3 dBµV/m (Average) @ 1.8044 GHz 150 kbps, FHSS: 44.4 dBµV/m (Average) @ 1.8552 GHz 250 kbps, FHSS: 42.5 dBµV/m (Average) @ 1.855 GHz DTS: 64.1 dBµV/m (Average) @ 1.84 GHz
Power supply requirements	Battery: 2 × 3.0 V_{DC}
Antenna information	IFA Antenna Peak gain = −1 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
3.0 VDC Battery	Duracell	MN: DL/CR 2032, SN: None

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

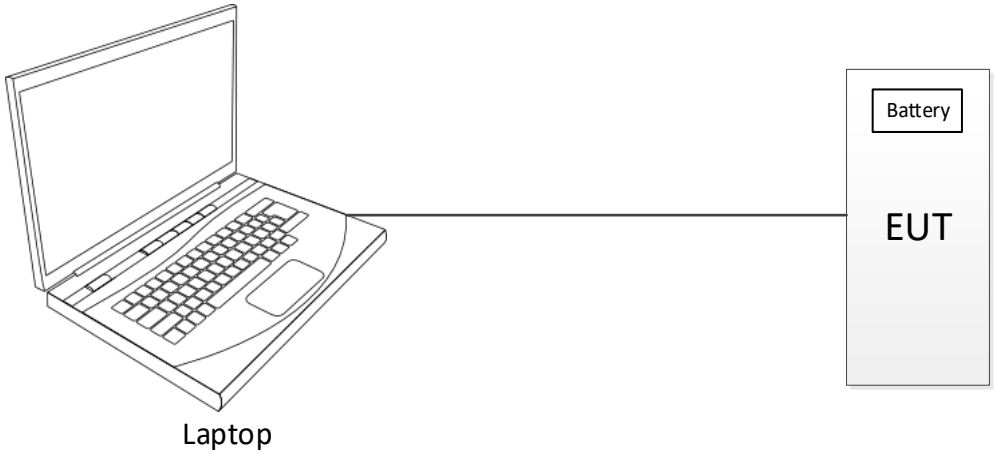


Figure 5.5-1: *Radiated testing block diagram*

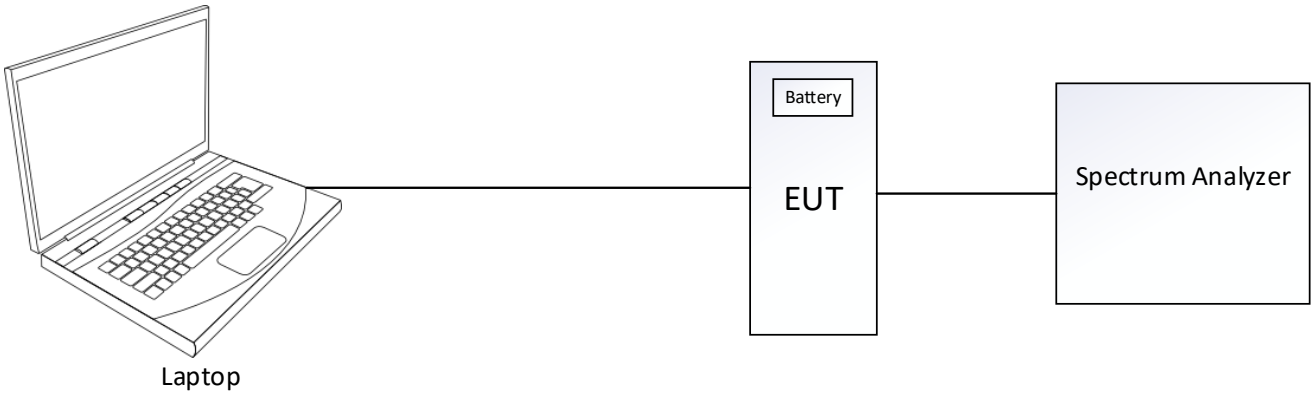


Figure 5.5-2: *Antenna port testing block diagram*

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 5, 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
IFA Antenna	Jucheng	N/A	-1 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; Δf = 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	102.5	500	397.5
915.2	101.9	500	398.1
927.8	102.6	500	397.4

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	86.3
915.2	88.0
927.8	86.0

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

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

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

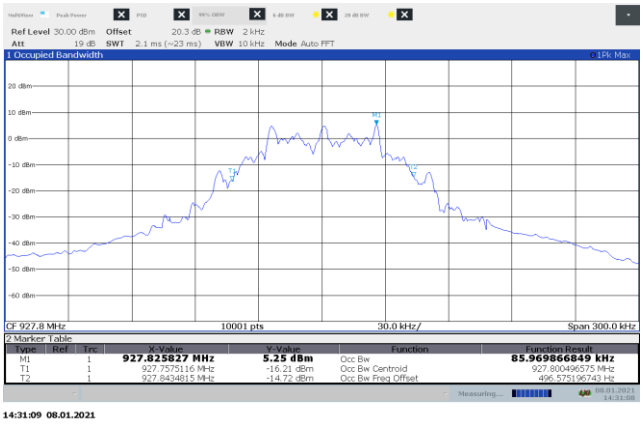


Figure 8.4-6: *99% OBW bandwidth on high channel, 50 kbps*

Test data continued, 50 kbps

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

Carrier frequency separation, kHz	Minimum limit, kHz	Margin, kHz
198.1	102.6	95.5

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

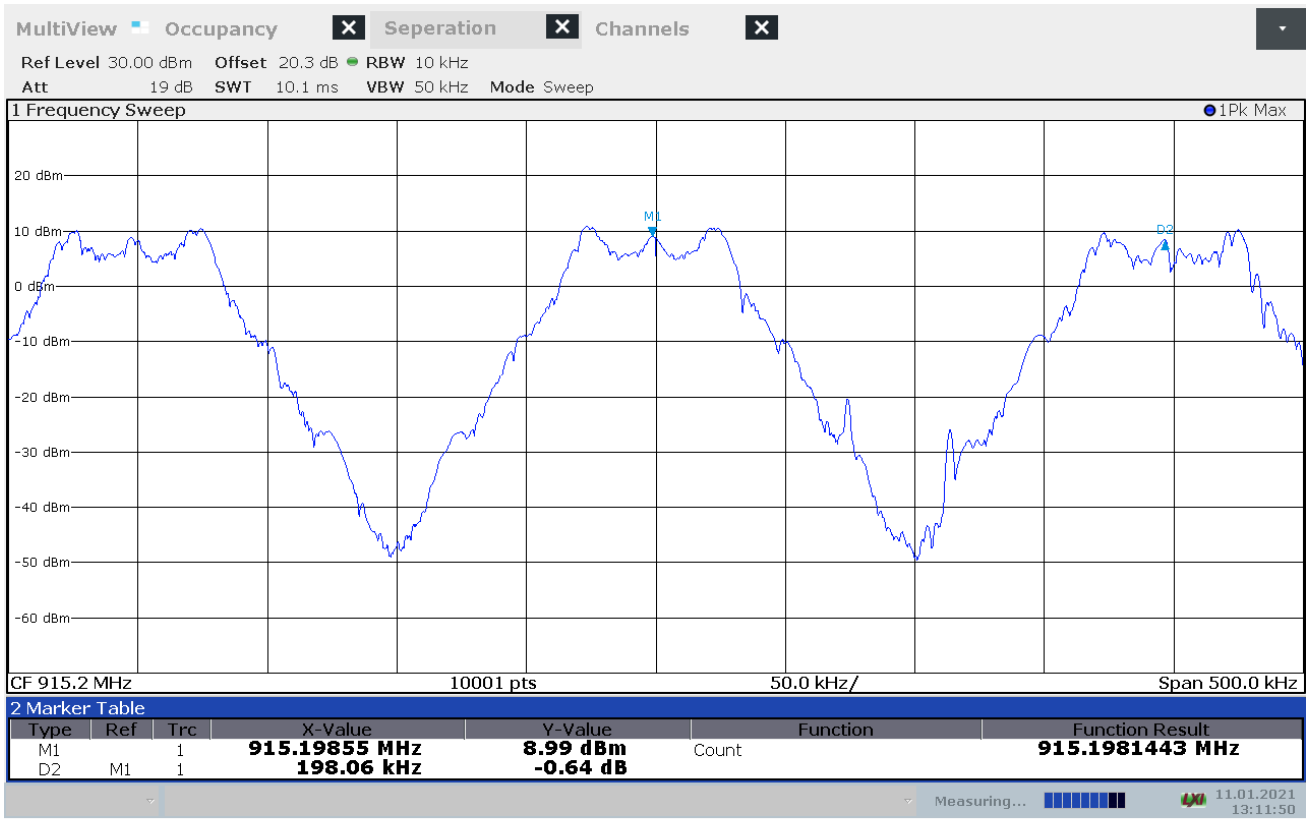


Figure 8.4-7: *Carrier frequency separation*

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
63	6	378	400	22

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

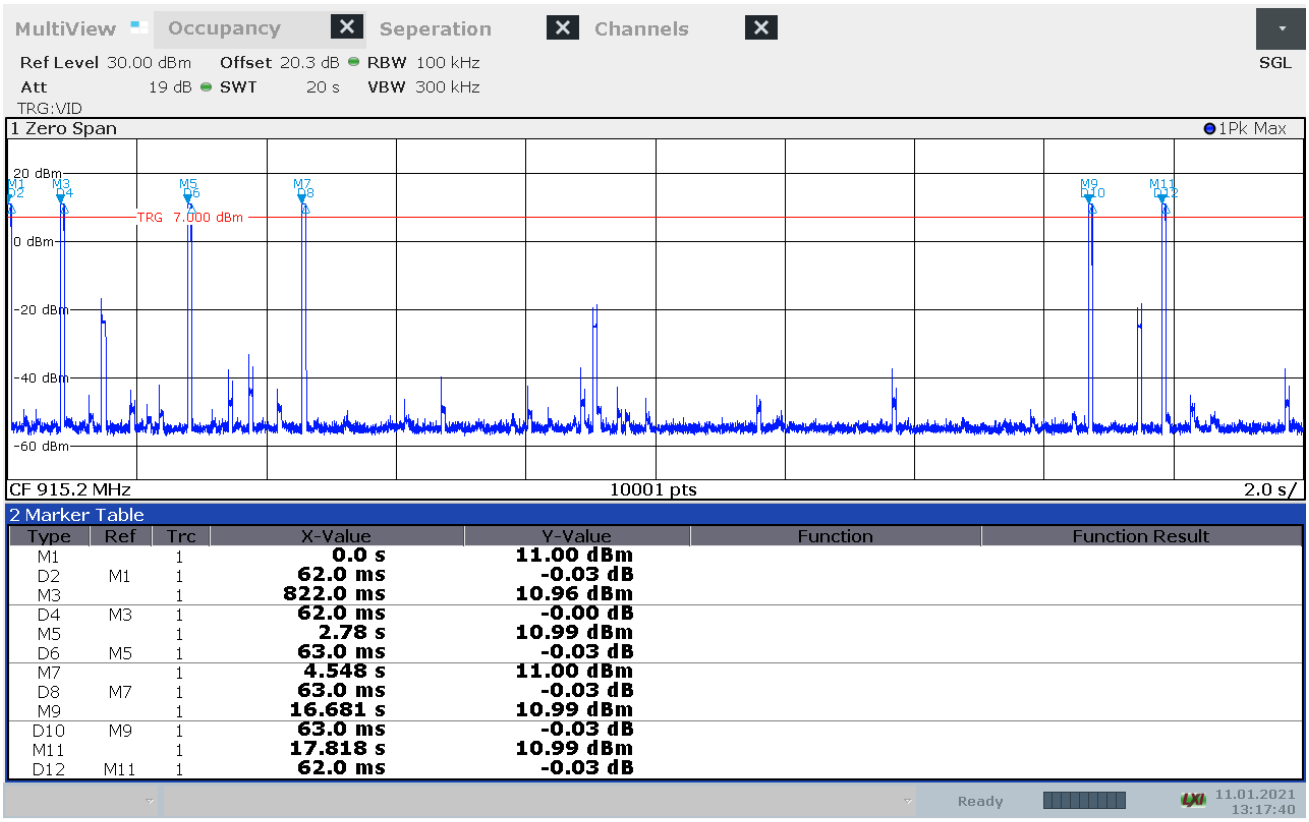


Figure 8.4-8: *Dwell time*

Test data continued, 50 kbps

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

Number of hopping frequencies	Minimum limit	Margin
128	50	78

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

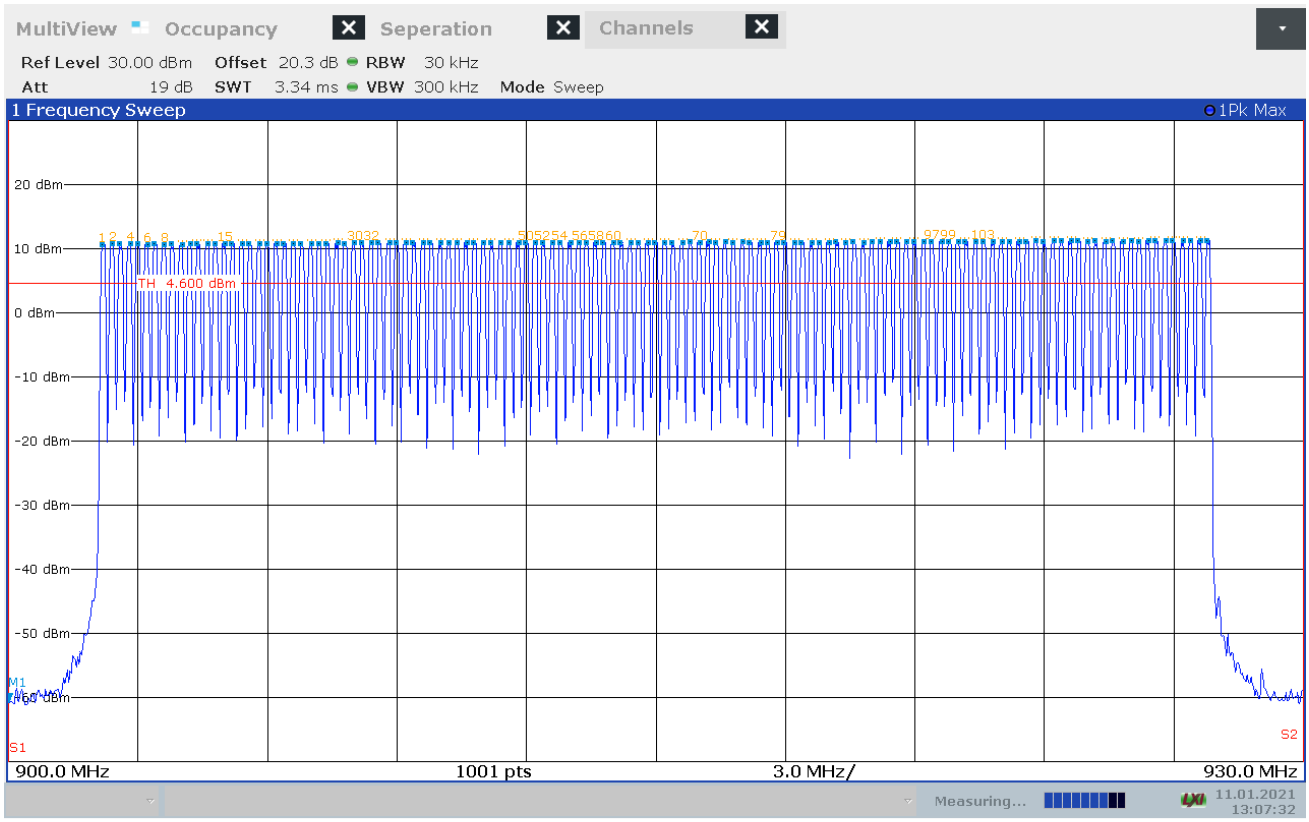


Figure 8.4-9: *Number of hopping frequencies = 128*

Test data continued, 50 kbps

2 Marker Peak List

No	X-Value	Y-Value	No	X-Value	Y-Value
1	902.173000 MHz	10.705 dBm	66	915.210000 MHz	11.010 dBm
2	902.413000 MHz	10.722 dBm	67	915.360000 MHz	11.028 dBm
3	902.562000 MHz	10.717 dBm	68	915.629000 MHz	11.011 dBm
4	902.832000 MHz	10.724 dBm	69	915.779000 MHz	11.036 dBm
5	902.982000 MHz	10.726 dBm	70	916.019000 MHz	11.008 dBm
6	903.222000 MHz	10.719 dBm	71	916.169000 MHz	11.046 dBm
7	903.372000 MHz	10.736 dBm	72	916.379000 MHz	11.013 dBm
8	903.611000 MHz	10.718 dBm	73	916.618000 MHz	11.049 dBm
9	903.761000 MHz	10.744 dBm	74	916.768000 MHz	11.029 dBm
10	904.031000 MHz	10.720 dBm	75	917.008000 MHz	11.053 dBm
11	904.211000 MHz	10.759 dBm	76	917.158000 MHz	10.988 dBm
12	904.361000 MHz	10.720 dBm	77	917.428000 MHz	11.004 dBm
13	904.630000 MHz	10.766 dBm	78	917.577000 MHz	10.991 dBm
14	904.780000 MHz	10.750 dBm	79	917.817000 MHz	11.010 dBm
15	905.020000 MHz	10.785 dBm	80	917.967000 MHz	10.999 dBm
16	905.170000 MHz	10.768 dBm	81	918.207000 MHz	11.012 dBm
17	905.410000 MHz	10.792 dBm	82	918.357000 MHz	11.013 dBm
18	905.559000 MHz	10.795 dBm	83	918.626000 MHz	11.014 dBm
19	905.829000 MHz	10.806 dBm	84	918.776000 MHz	11.025 dBm
20	905.979000 MHz	10.810 dBm	85	919.016000 MHz	11.017 dBm
21	906.219000 MHz	10.815 dBm	86	919.166000 MHz	11.037 dBm
22	906.369000 MHz	10.832 dBm	87	919.406000 MHz	11.020 dBm
23	906.608000 MHz	10.822 dBm	88	919.555000 MHz	11.049 dBm
24	906.758000 MHz	10.849 dBm	89	919.825000 MHz	11.023 dBm
25	907.028000 MHz	10.823 dBm	90	919.975000 MHz	11.064 dBm
26	907.208000 MHz	10.867 dBm	91	920.185000 MHz	11.034 dBm
27	907.358000 MHz	10.832 dBm	92	920.425000 MHz	11.083 dBm
28	907.627000 MHz	10.877 dBm	93	920.574000 MHz	11.061 dBm
29	907.777000 MHz	10.850 dBm	94	920.814000 MHz	11.098 dBm
30	908.017000 MHz	10.892 dBm	95	920.964000 MHz	11.090 dBm
31	908.167000 MHz	10.881 dBm	96	921.204000 MHz	11.114 dBm
32	908.407000 MHz	10.894 dBm	97	921.384000 MHz	11.113 dBm
33	908.556000 MHz	10.886 dBm	98	921.623000 MHz	11.127 dBm
34	908.826000 MHz	10.899 dBm	99	921.773000 MHz	11.138 dBm
35	908.976000 MHz	10.906 dBm	100	922.013000 MHz	11.133 dBm
36	909.216000 MHz	10.900 dBm	101	922.163000 MHz	11.153 dBm
37	909.366000 MHz	10.913 dBm	102	922.403000 MHz	11.137 dBm
38	909.605000 MHz	10.894 dBm	103	922.582000 MHz	11.168 dBm
39	909.755000 MHz	10.918 dBm	104	922.822000 MHz	11.137 dBm
40	910.025000 MHz	10.886 dBm	105	923.032000 MHz	11.178 dBm
41	910.205000 MHz	10.920 dBm	106	923.182000 MHz	11.148 dBm
42	910.385000 MHz	10.889 dBm	107	923.422000 MHz	11.189 dBm
43	910.624000 MHz	10.922 dBm	108	923.571000 MHz	11.173 dBm
44	910.774000 MHz	10.900 dBm	109	923.811000 MHz	11.195 dBm
45	911.014000 MHz	10.924 dBm	110	923.961000 MHz	11.185 dBm
46	911.164000 MHz	10.907 dBm	111	924.231000 MHz	11.200 dBm
47	911.404000 MHz	10.926 dBm	112	924.381000 MHz	11.196 dBm
48	911.583000 MHz	10.919 dBm	113	924.620000 MHz	11.198 dBm
49	911.823000 MHz	10.928 dBm	114	924.770000 MHz	11.205 dBm
50	911.973000 MHz	10.933 dBm	115	925.010000 MHz	11.190 dBm
51	912.213000 MHz	10.930 dBm	116	925.160000 MHz	11.209 dBm
52	912.363000 MHz	10.944 dBm	117	925.430000 MHz	11.193 dBm
53	912.602000 MHz	10.929 dBm	118	925.579000 MHz	11.214 dBm
54	912.782000 MHz	10.956 dBm	119	925.819000 MHz	11.179 dBm
55	913.022000 MHz	10.928 dBm	120	925.969000 MHz	11.220 dBm
56	913.232000 MHz	10.969 dBm	121	926.179000 MHz	11.186 dBm
57	913.382000 MHz	10.937 dBm	122	926.359000 MHz	11.229 dBm
58	913.621000 MHz	10.984 dBm	123	926.568000 MHz	11.212 dBm
59	913.771000 MHz	10.957 dBm	124	926.808000 MHz	11.239 dBm
60	914.011000 MHz	10.996 dBm	125	926.958000 MHz	11.222 dBm
61	914.161000 MHz	10.985 dBm	126	927.228000 MHz	11.246 dBm
62	914.431000 MHz	11.007 dBm	127	927.378000 MHz	11.247 dBm
63	914.580000 MHz	11.003 dBm	128	927.617000 MHz	11.250 dBm
64	914.820000 MHz	11.008 dBm	129	927.767000 MHz	11.256 dBm
65	914.970000 MHz	11.016 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	354.9	500	145.1
914.8	353.3	500	146.7
927.6	349.7	500	150.3

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	316.1
914.8	314.1
927.6	317.2

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

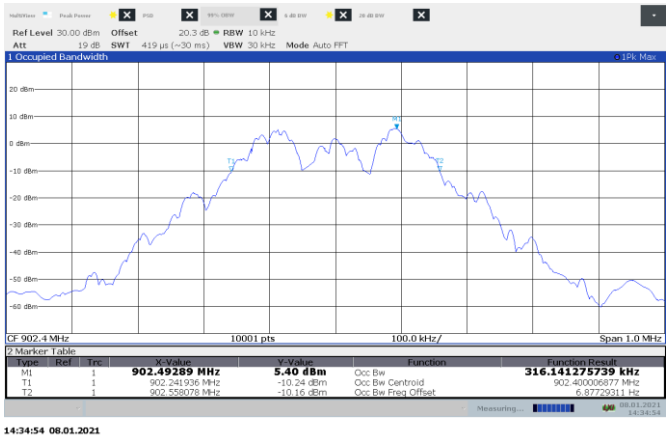


Figure 8.4-14: *99% OBW on low channel, 150 kbps*

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
402.9	354.9	48.0

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

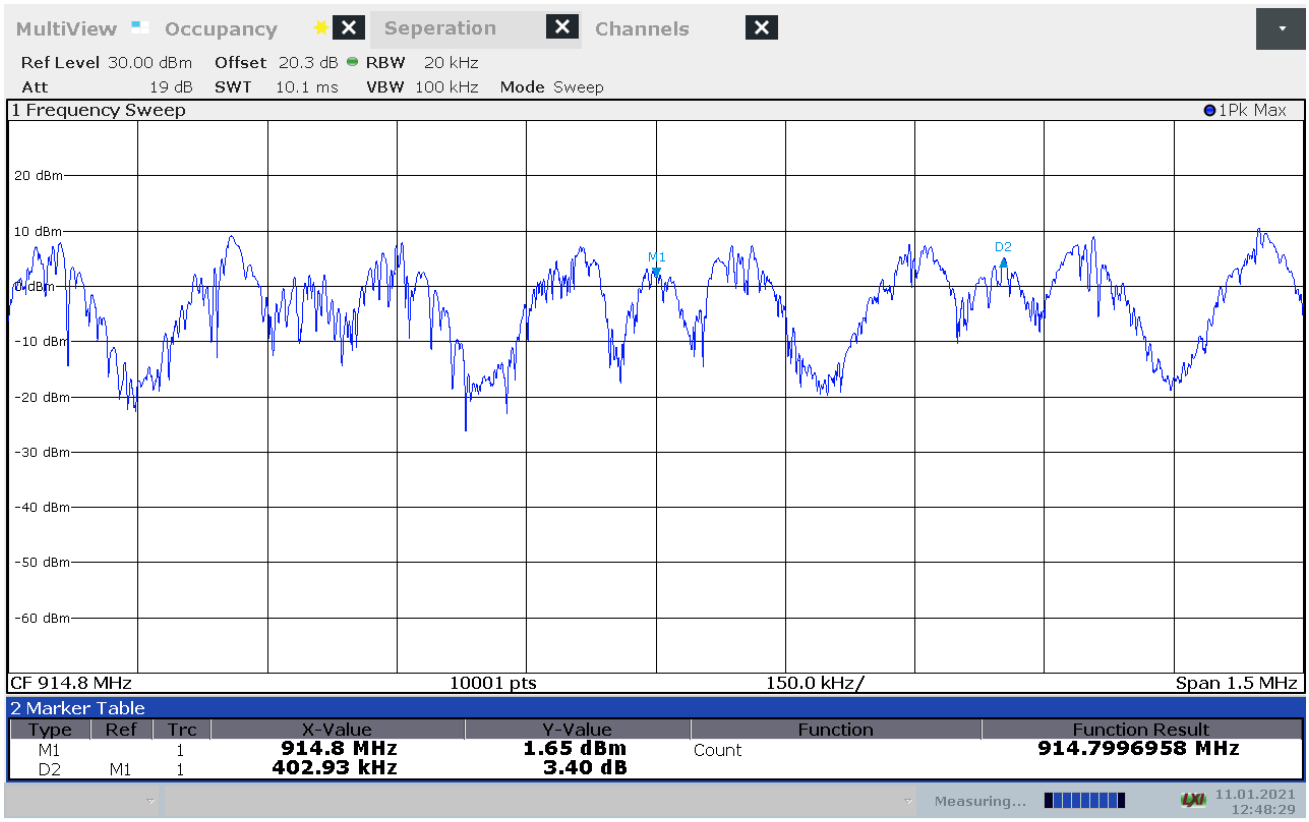


Figure 8.4-17: *Carrier frequency separation*

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

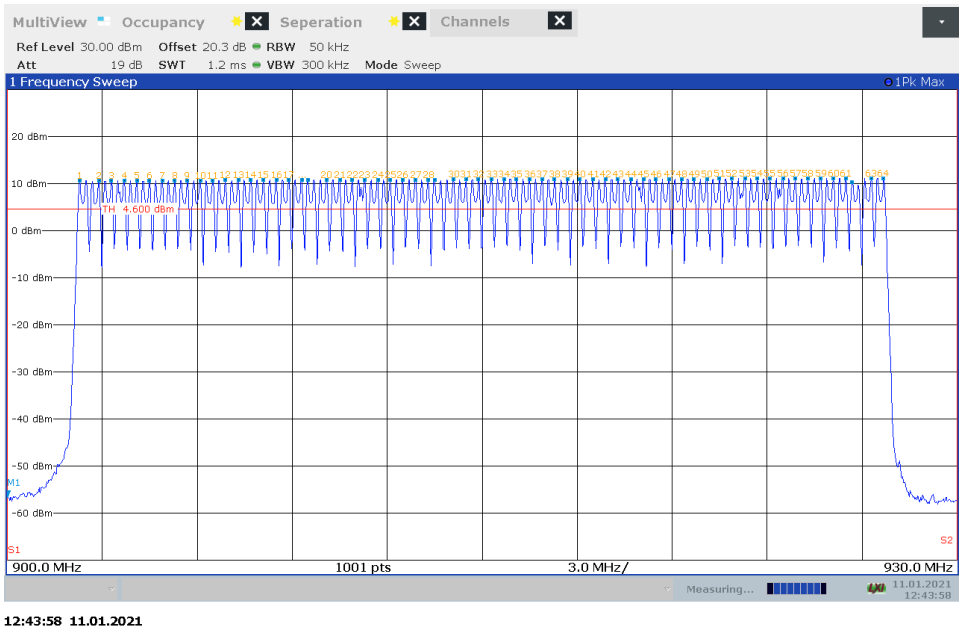
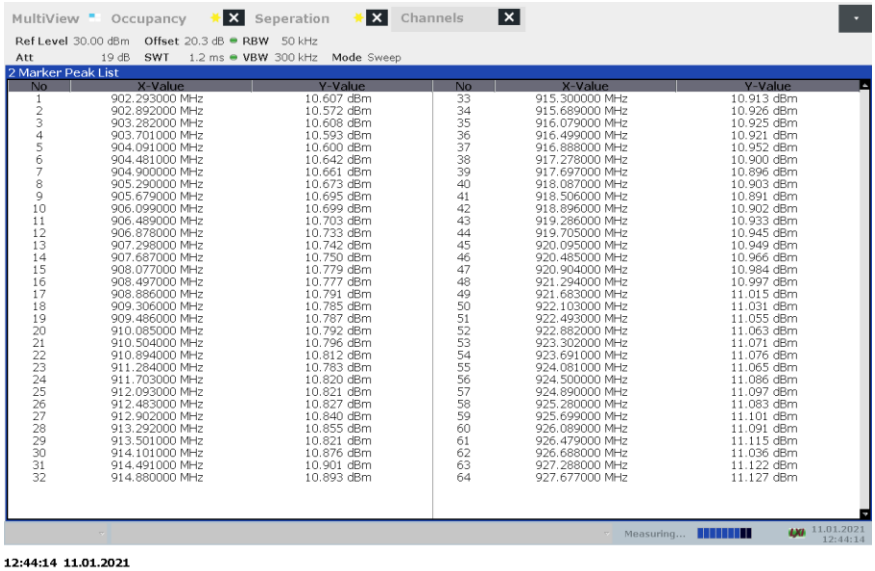


Figure 8.4-18: *Number of hopping frequencies = 64*



No	X-Value	Y-Value	No	X-Value	Y-Value
1	902.293000 MHz	10.607 dBm	33	915.300000 MHz	10.913 dBm
2	902.892000 MHz	10.572 dBm	34	915.689000 MHz	10.926 dBm
3	903.282000 MHz	10.608 dBm	35	916.079000 MHz	10.925 dBm
4	903.701000 MHz	10.593 dBm	36	916.499000 MHz	10.921 dBm
5	904.091000 MHz	10.600 dBm	37	916.888000 MHz	10.952 dBm
6	904.481000 MHz	10.642 dBm	38	917.278000 MHz	10.900 dBm
7	904.900000 MHz	10.661 dBm	39	917.697000 MHz	10.896 dBm
8	905.290000 MHz	10.673 dBm	40	918.087000 MHz	10.903 dBm
9	905.679000 MHz	10.695 dBm	41	918.506000 MHz	10.891 dBm
10	906.099000 MHz	10.699 dBm	42	918.896000 MHz	10.902 dBm
11	906.489000 MHz	10.703 dBm	43	919.286000 MHz	10.933 dBm
12	906.878000 MHz	10.733 dBm	44	919.705000 MHz	10.945 dBm
13	907.298000 MHz	10.742 dBm	45	920.095000 MHz	10.949 dBm
14	907.687000 MHz	10.750 dBm	46	920.485000 MHz	10.966 dBm
15	908.077000 MHz	10.779 dBm	47	920.904000 MHz	10.984 dBm
16	908.497000 MHz	10.777 dBm	48	921.294000 MHz	10.997 dBm
17	908.886000 MHz	10.791 dBm	49	921.683000 MHz	11.015 dBm
18	909.306000 MHz	10.785 dBm	50	922.103000 MHz	11.031 dBm
19	909.486000 MHz	10.787 dBm	51	922.493000 MHz	11.055 dBm
20	910.085000 MHz	10.792 dBm	52	922.882000 MHz	11.063 dBm
21	910.504000 MHz	10.796 dBm	53	923.302000 MHz	11.071 dBm
22	910.894000 MHz	10.812 dBm	54	923.691000 MHz	11.076 dBm
23	911.284000 MHz	10.783 dBm	55	924.081000 MHz	11.065 dBm
24	911.703000 MHz	10.820 dBm	56	924.500000 MHz	11.086 dBm
25	912.093000 MHz	10.821 dBm	57	924.890000 MHz	11.097 dBm
26	912.483000 MHz	10.827 dBm	58	925.280000 MHz	11.083 dBm
27	912.902000 MHz	10.840 dBm	59	925.699000 MHz	11.101 dBm
28	913.292000 MHz	10.855 dBm	60	926.089000 MHz	11.091 dBm
29	913.501000 MHz	10.821 dBm	61	926.479000 MHz	11.115 dBm
30	914.101000 MHz	10.876 dBm	62	926.688000 MHz	11.036 dBm
31	914.491000 MHz	10.901 dBm	63	927.288000 MHz	11.122 dBm
32	914.880000 MHz	10.893 dBm	64	927.677000 MHz	11.127 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

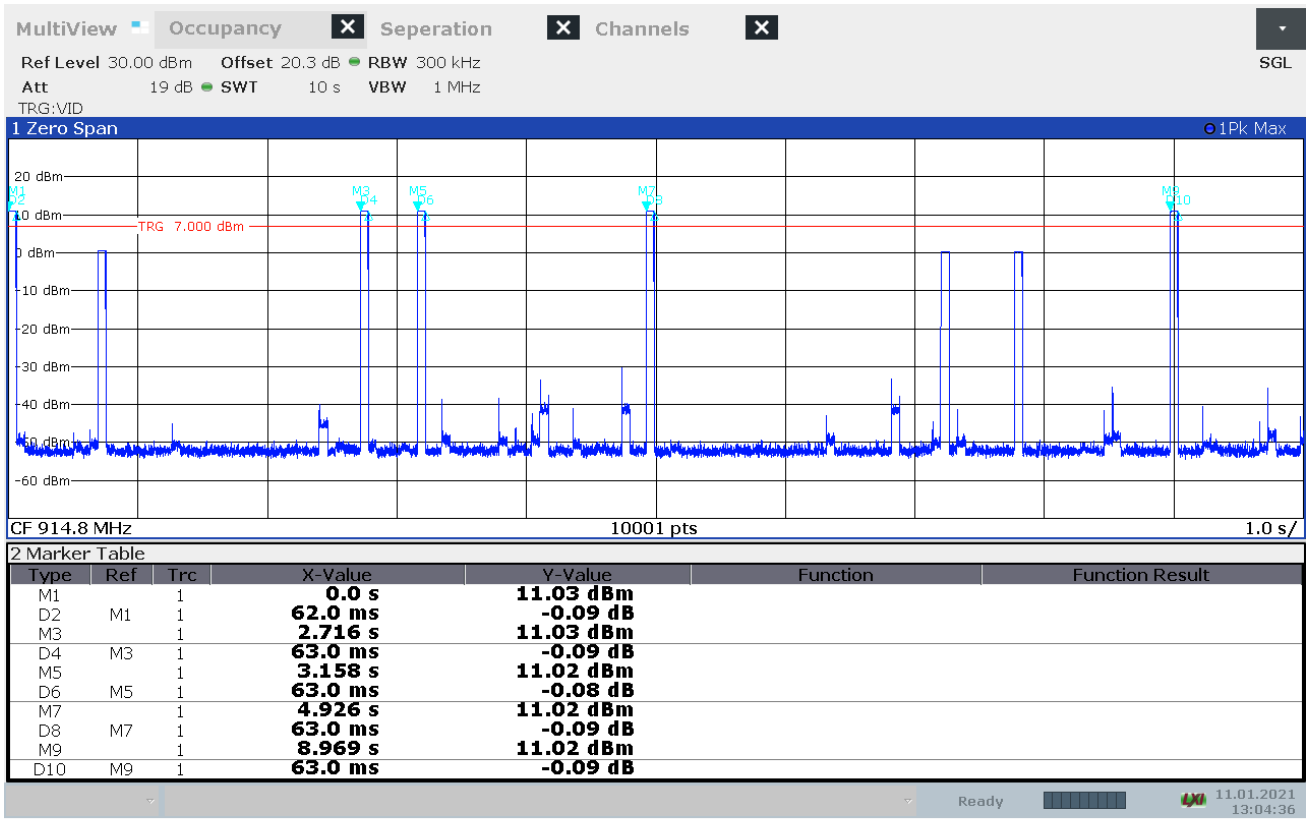


Figure 8.4-20: *Dwell time*

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	409.3	500	90.7
915.0	408.5	500	91.5
927.5	406.2	500	93.8

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

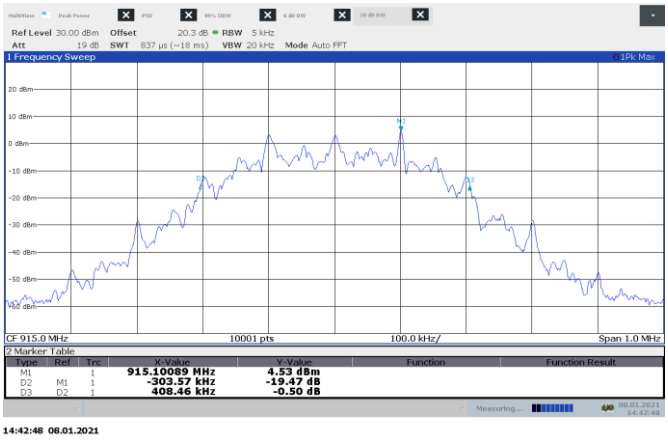


Figure 8.4-22: *20 dB bandwidth on mid channel, 250 kbps*

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	383.2
915.0	378.3
927.5	386.7

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

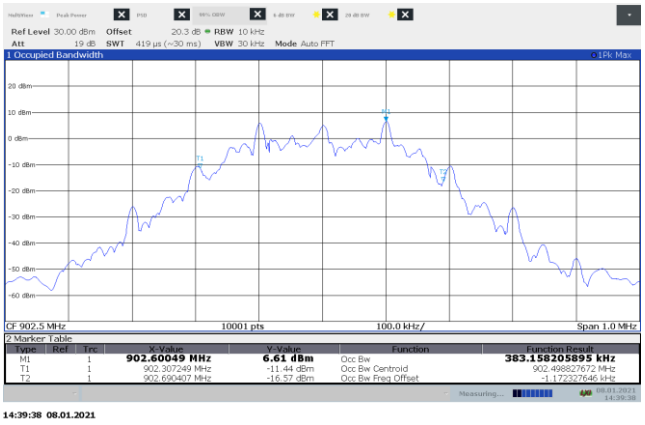


Figure 8.4-24: *99% OBW on low channel, 250 kbps*

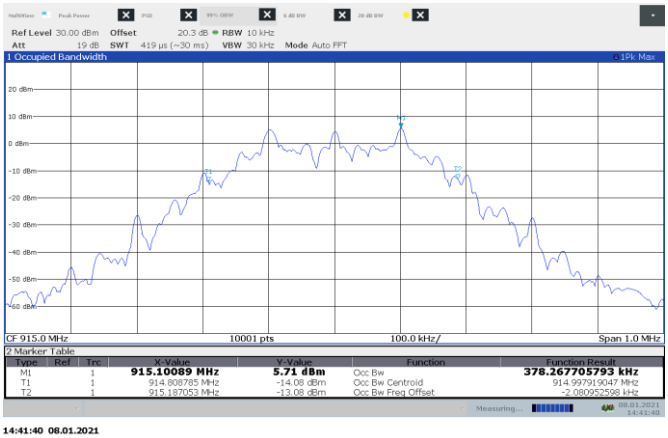


Figure 8.4-25: *99% OBW on mid channel, 250 kbps*

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
493.9	409.3	84.6

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

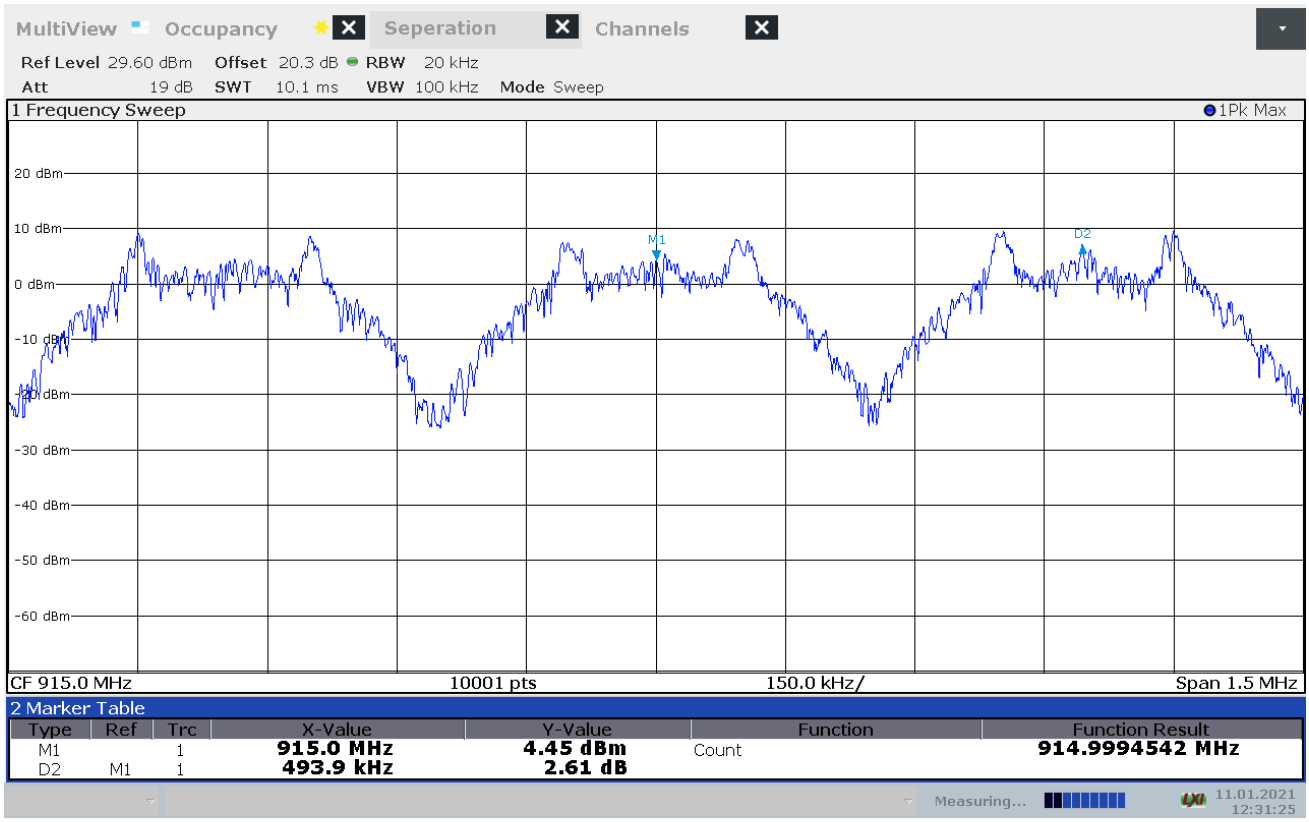


Figure 8.4-27: *Carrier frequency separation*

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

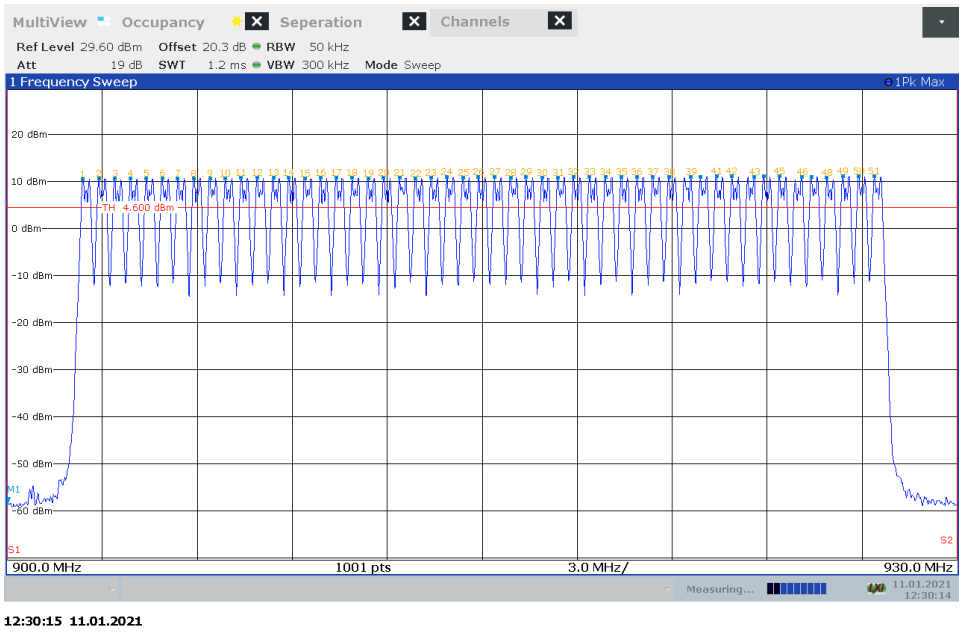
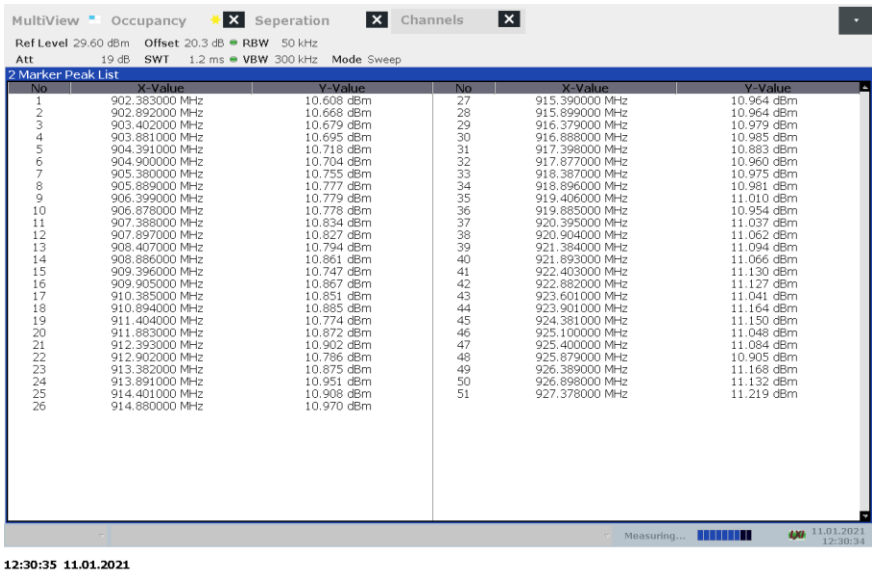


Figure 8.4-28: *Number of hopping frequencies = 51*



No	X-Value	Y-Value	No	X-Value	Y-Value
1	902.383000 MHz	10.608 dBm	27	915.390000 MHz	10.964 dBm
2	902.892000 MHz	10.668 dBm	28	915.899000 MHz	10.964 dBm
3	903.402000 MHz	10.679 dBm	29	916.379000 MHz	10.979 dBm
4	903.881000 MHz	10.695 dBm	30	916.888000 MHz	10.985 dBm
5	904.391000 MHz	10.718 dBm	31	917.398000 MHz	10.883 dBm
6	904.900000 MHz	10.704 dBm	32	917.877000 MHz	10.960 dBm
7	905.380000 MHz	10.755 dBm	33	918.387000 MHz	10.975 dBm
8	905.889000 MHz	10.777 dBm	34	918.896000 MHz	10.981 dBm
9	906.399000 MHz	10.779 dBm	35	919.406000 MHz	11.010 dBm
10	906.878000 MHz	10.778 dBm	36	919.865000 MHz	10.954 dBm
11	907.388000 MHz	10.834 dBm	37	920.395000 MHz	11.037 dBm
12	907.897000 MHz	10.827 dBm	38	920.904000 MHz	11.062 dBm
13	908.407000 MHz	10.794 dBm	39	921.384000 MHz	11.094 dBm
14	908.886000 MHz	10.861 dBm	40	921.893000 MHz	11.066 dBm
15	909.396000 MHz	10.747 dBm	41	922.403000 MHz	11.130 dBm
16	909.905000 MHz	10.867 dBm	42	922.882000 MHz	11.127 dBm
17	910.385000 MHz	10.851 dBm	43	923.601000 MHz	11.041 dBm
18	910.894000 MHz	10.885 dBm	44	923.901000 MHz	11.164 dBm
19	911.404000 MHz	10.774 dBm	45	924.381000 MHz	11.150 dBm
20	911.883000 MHz	10.872 dBm	46	925.100000 MHz	11.048 dBm
21	912.393000 MHz	10.902 dBm	47	925.400000 MHz	11.084 dBm
22	912.902000 MHz	10.786 dBm	48	925.879000 MHz	10.905 dBm
23	913.382000 MHz	10.875 dBm	49	926.389000 MHz	11.168 dBm
24	913.891000 MHz	10.951 dBm	50	926.898000 MHz	11.132 dBm
25	914.401000 MHz	10.908 dBm	51	927.378000 MHz	11.219 dBm
26	914.880000 MHz	10.970 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	2	126	400	274

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

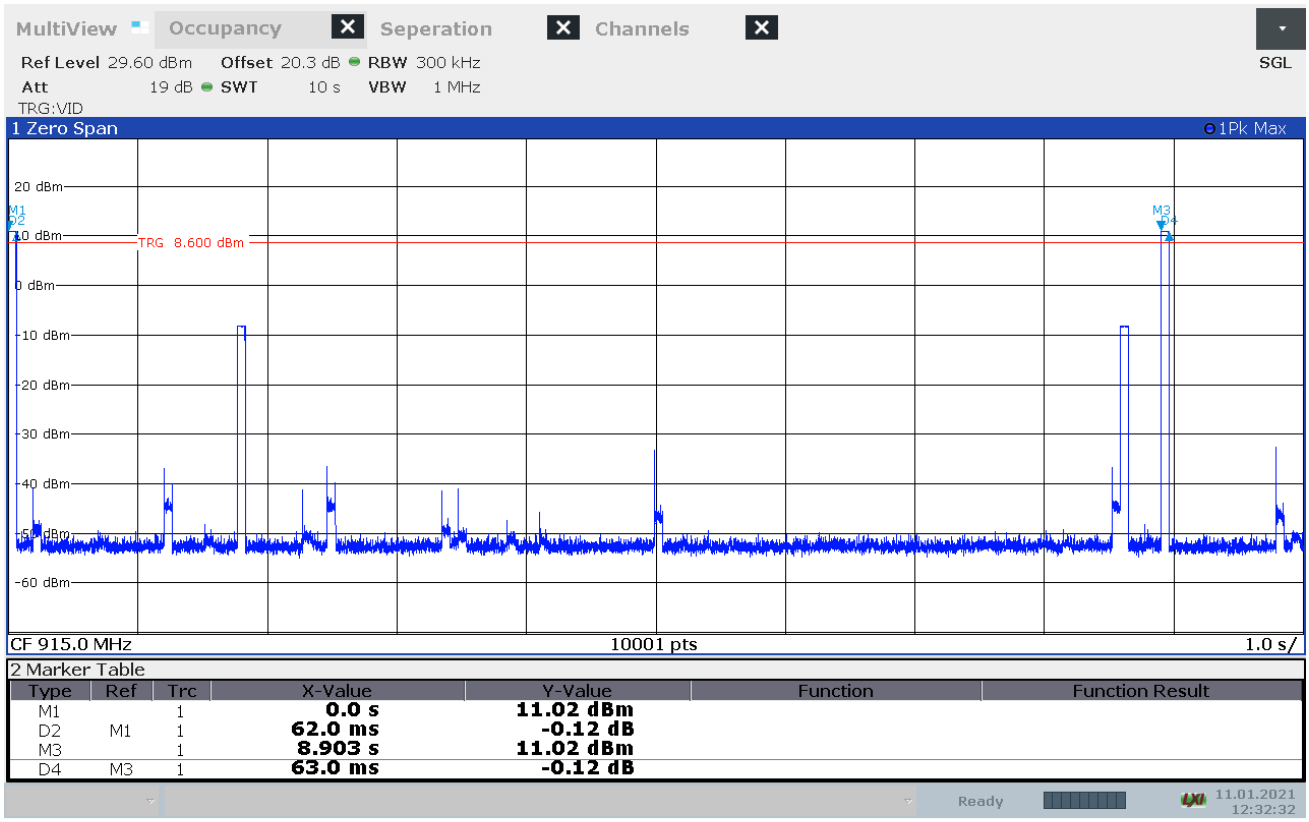


Figure 8.4-30: *Dwell time*

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	10.9	30.0	19.1	-1.0	9.9	36.0	26.1
915.2	11.1	30.0	18.9	-1.0	10.1	36.0	25.9
927.8	11.3	30.0	18.7	-1.0	10.3	36.0	25.7

EIRP = Output power + Antenna gain

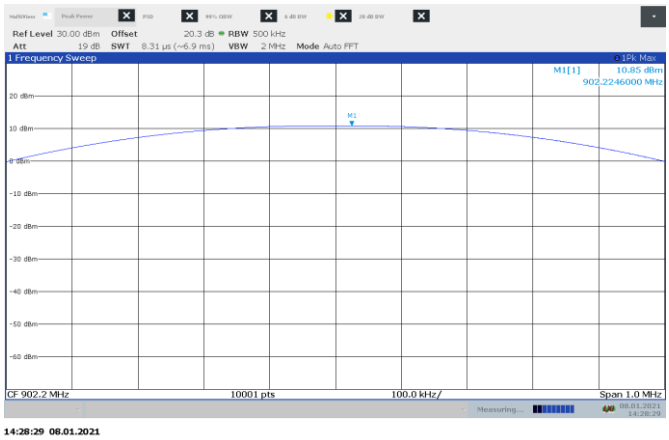


Figure 8.5-1: *Output power on low channel, 50 kbps*

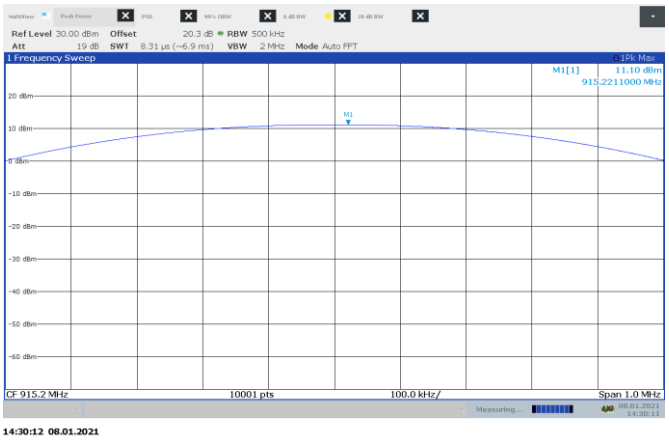


Figure 8.5-2: *Output power on mid channel, 50 kbps*

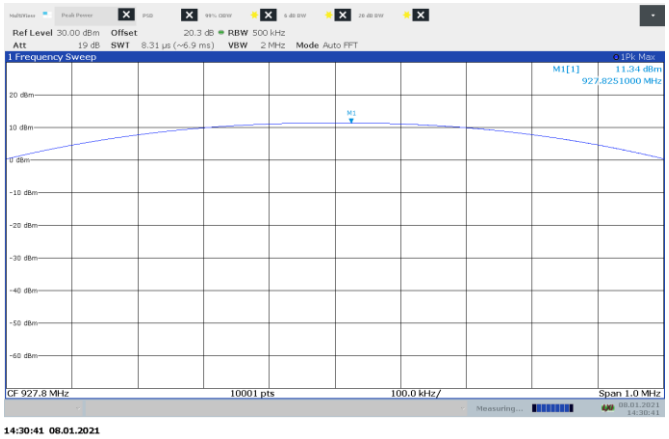


Figure 8.5-3: *Output power on high channel, 50 kbps*

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	10.9	30.0	19.1	-1.0	9.9	36.0	26.1
914.8	11.1	30.0	18.9	-1.0	10.1	36.0	25.9
927.6	11.4	30.0	18.6	-1.0	10.4	36.0	25.6

EIRP = Output power + Antenna gain

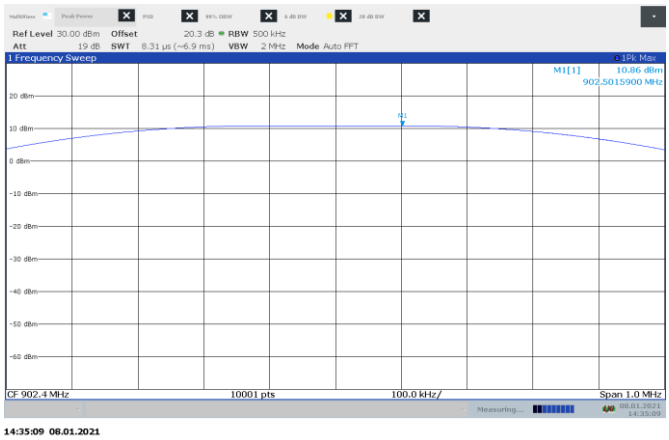


Figure 8.5-4: *Output power on low channel, 150 kbps*

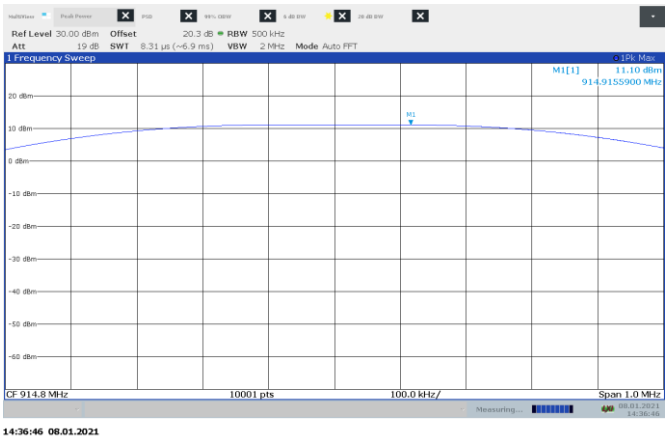


Figure 8.5-5: *Output power on mid channel, 150 kbps*

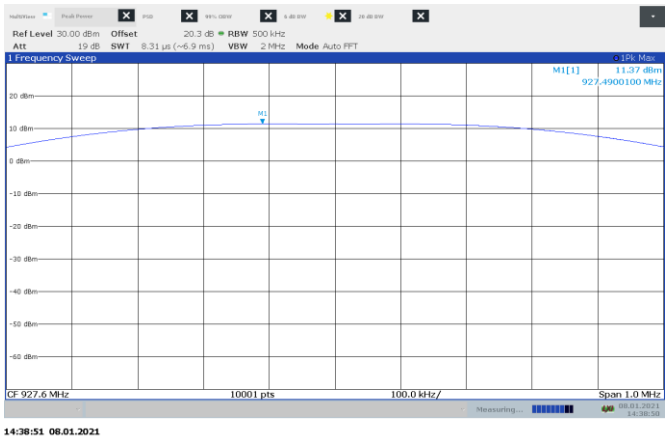


Figure 8.5-6: *Output power on high channel, 150 kbps*

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	10.9	30.0	19.1	-1.0	9.9	36.0	26.1
915.0	11.1	30.0	18.9	-1.0	10.1	36.0	25.9
927.5	11.3	30.0	18.7	-1.0	10.3	36.0	25.7

EIRP = Output power + Antenna gain

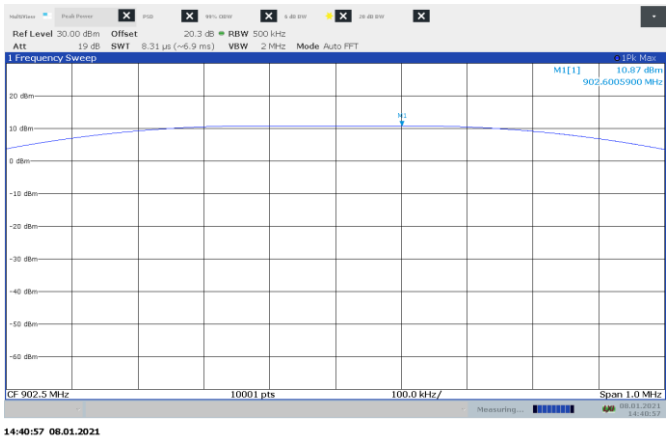


Figure 8.5-7: *Output power on low channel, 250 kbps*

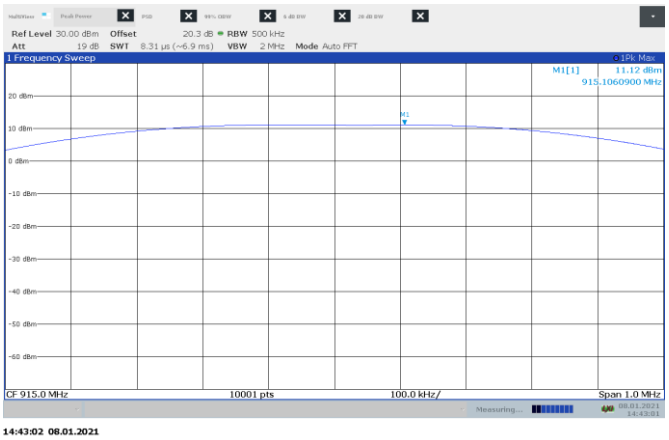


Figure 8.5-8: *Output power on mid channel, 250 kbps*

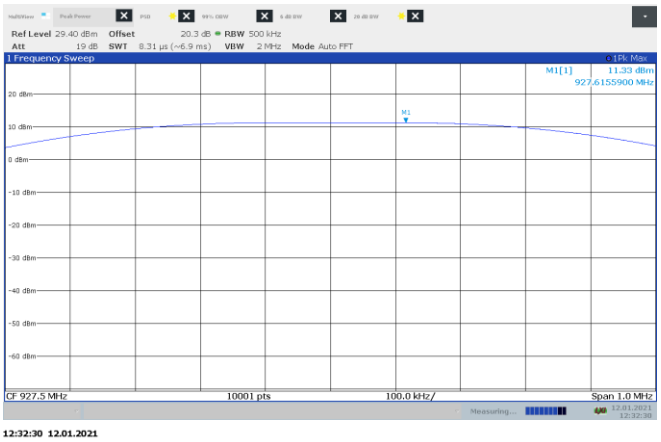


Figure 8.5-9: *Output power on high channel, 250 kbps*

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	639.7	500	139.7
DSSS-OQPSK	920.0	640.5	500	140.5

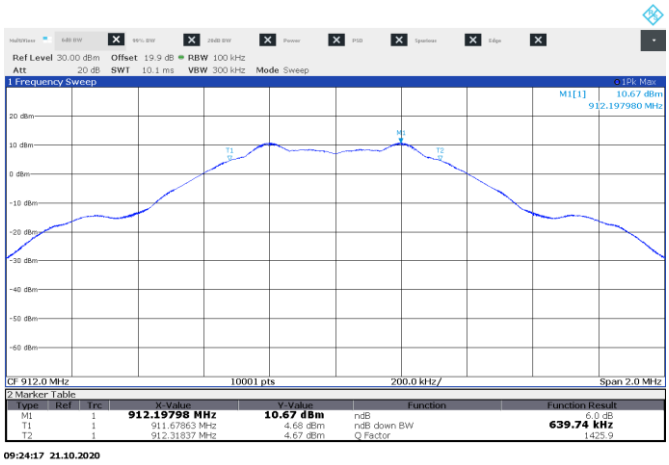


Figure 8.6-1: *6 dB bandwidth on 912 MHz channel, Z-Wave Long Range*

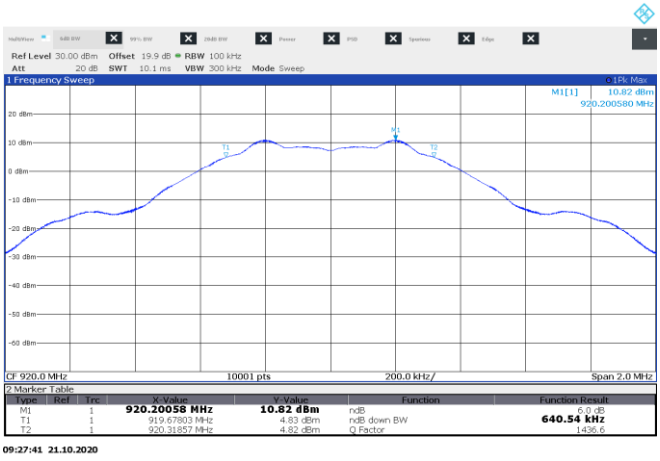


Figure 8.6-2: *6 dB bandwidth on 920 MHz channel, Z-Wave Long Range*

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

Frequency, MHz	99% occupied bandwidth, kHz
912.0	933.5
920.0	933.3

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	10.9	30.0	19.1	-1.0	9.9	36.0	26.1
920	11.0	30.0	19.0	-1.0	10.0	36.0	26.0

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

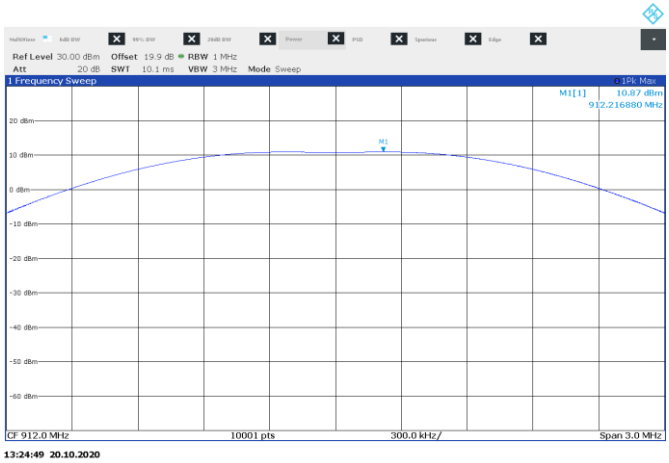


Figure 8.7-1: *Output power on 912 MHz channel*

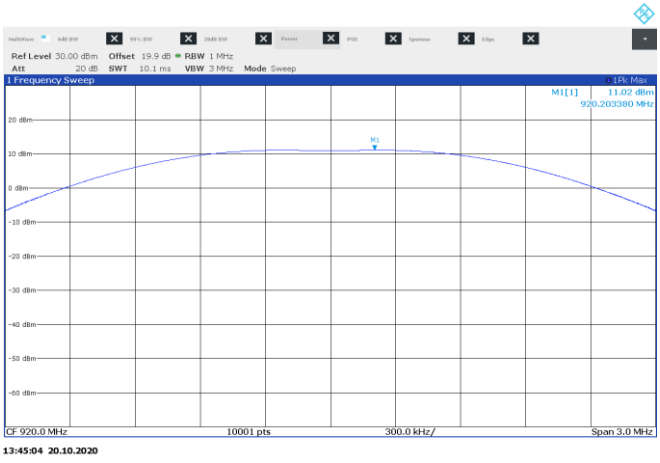


Figure 8.7-2: *Output power on 920 MHz channel*

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

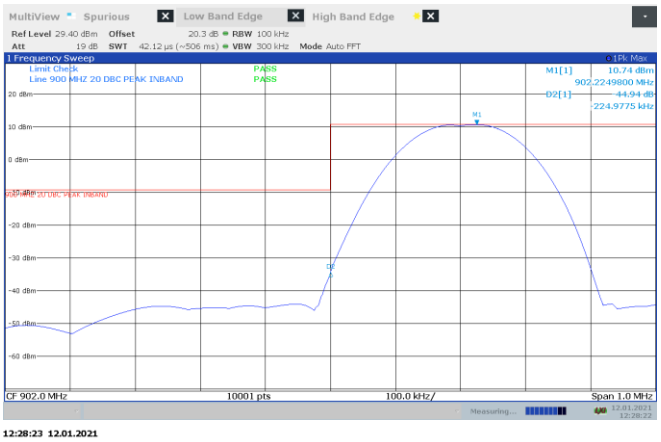


Figure 8.8-1: *Conducted Band-edge on low channel, FSK 50kbps*

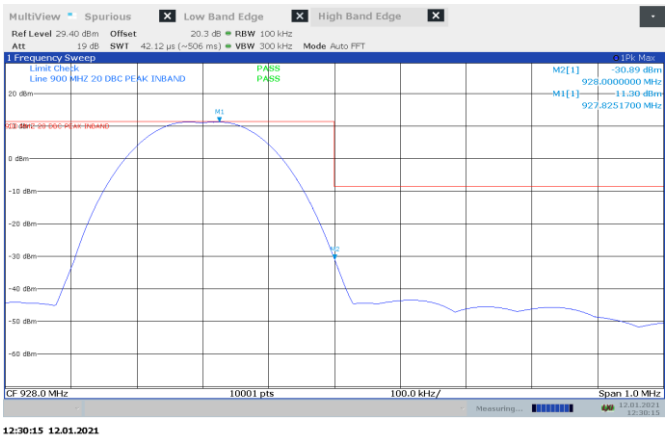


Figure 8.8-2: *Conducted Band-edge on high channel, FSK 50kbps*

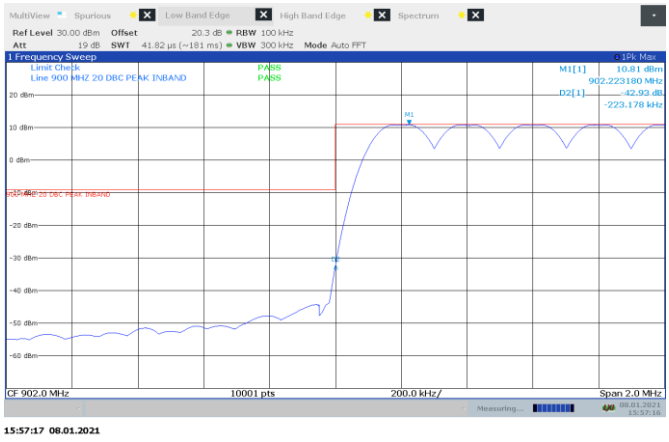


Figure 8.8-3: *Conducted Low Band-edge on hopping, FSK 50kbps*

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

Test data, continued

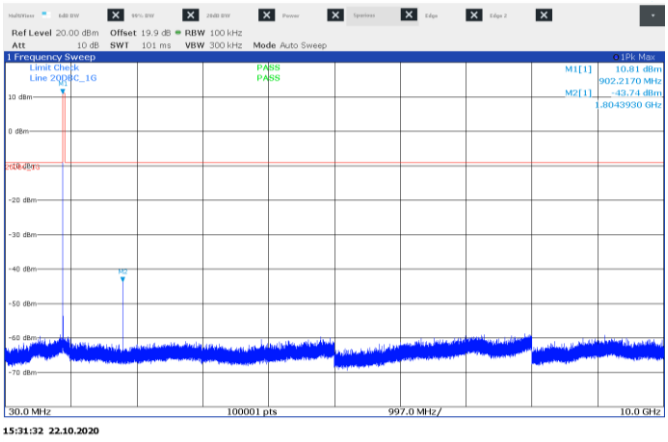


Figure 8.8-5: *Conducted spurious emissions on low channel, FSK 50kbps*

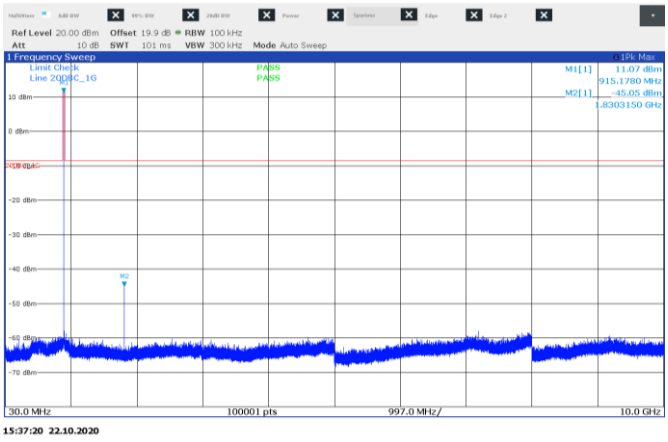


Figure 8.8-6: *Conducted spurious emissions on mid channel, FSK 50kbps*

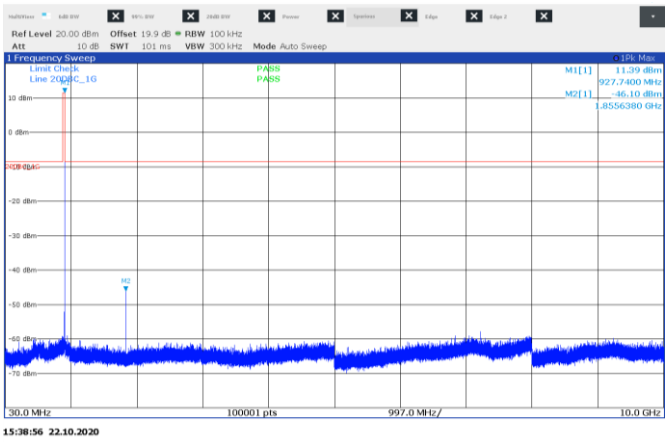


Figure 8.8-7: *Conducted spurious emissions on high channel, FSK 50kbps*

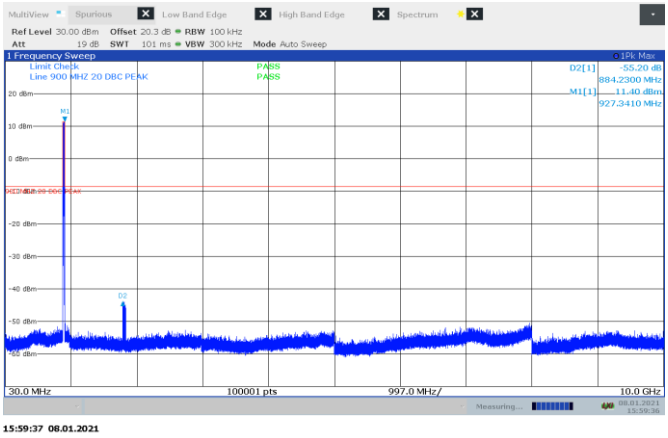


Figure 8.8-8: *Conducted spurious emissions on Hopping, FSK 50kbps*

Test data, continued

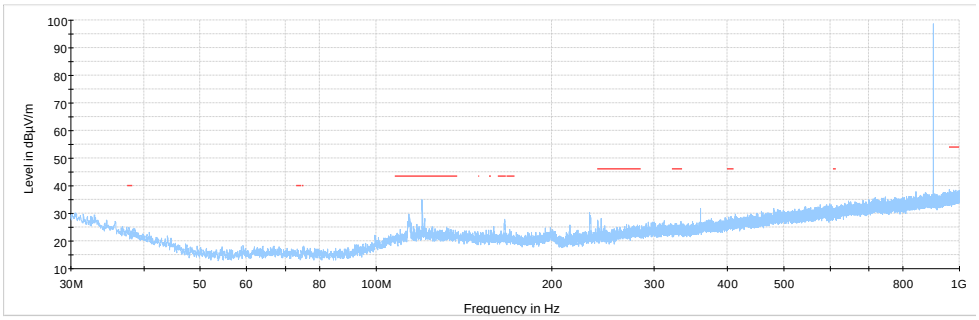


Figure 8.8-9: *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 50kbps*

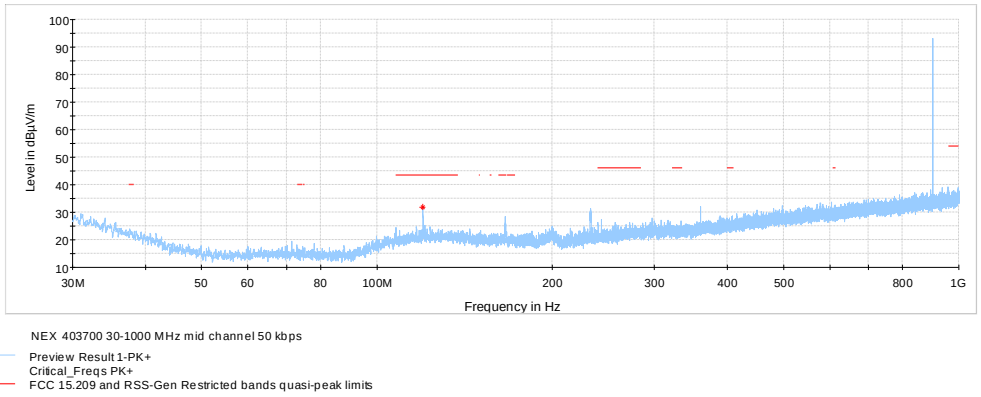


Figure 8.8-10: *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 50kbps*

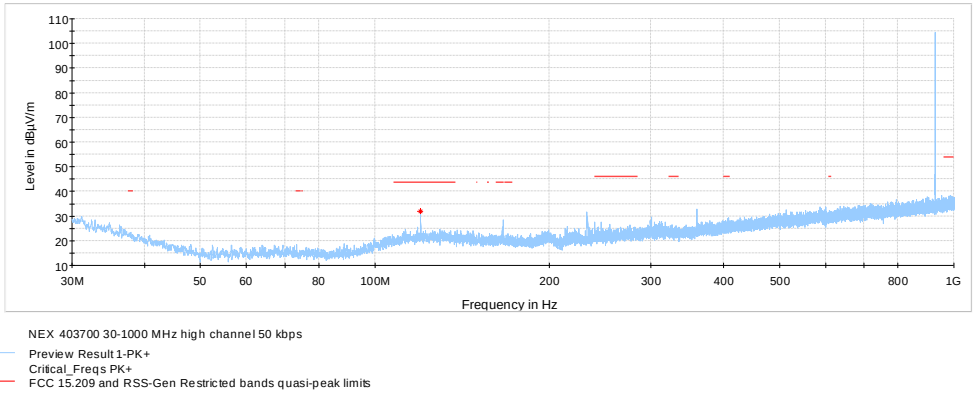


Figure 8.8-11: *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 50kbps*

Test data, continued

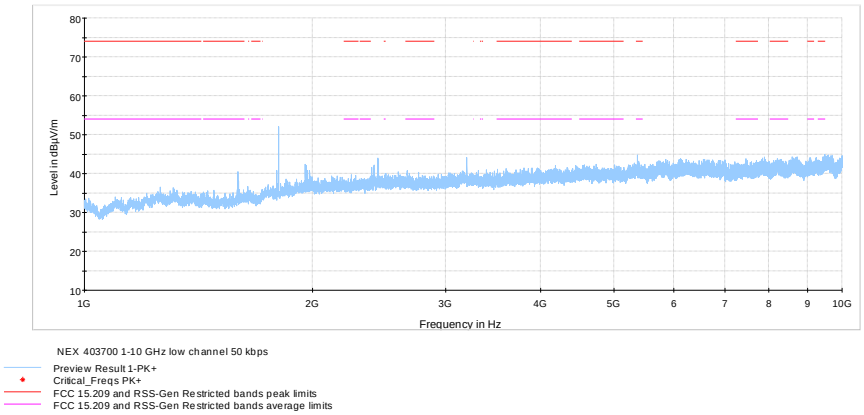


Figure 8.8-12: *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 50kbps*

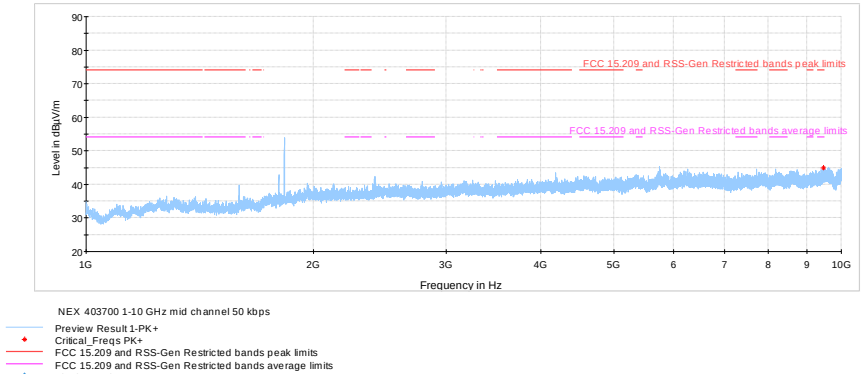


Figure 8.8-13: *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 50kbps*

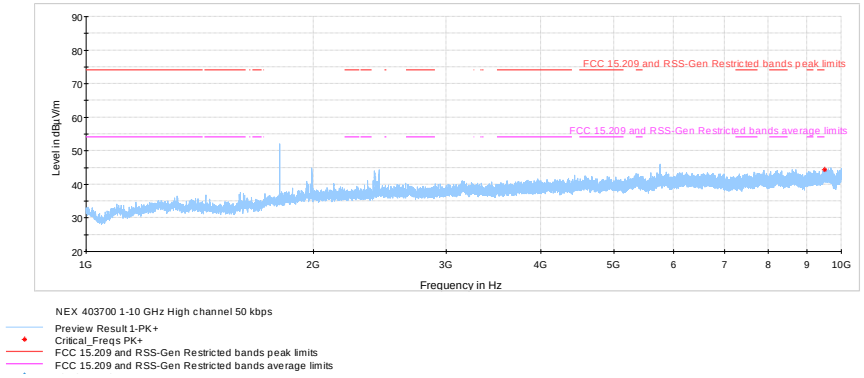


Figure 8.8-14: *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 50kbps*

Test data, continued

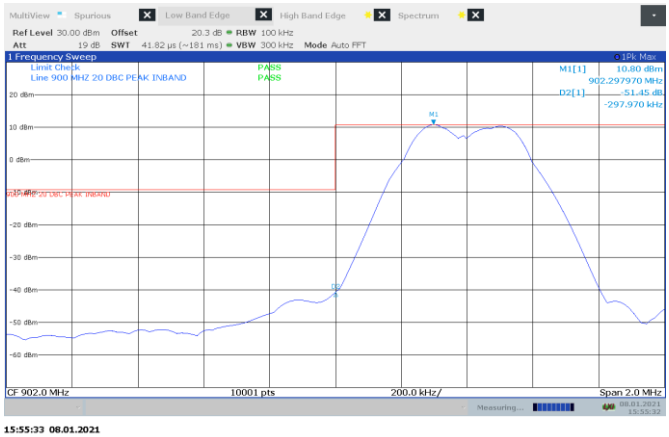


Figure 8.8-15: *Conducted Band-edge on low channel, FSK 150kbps*

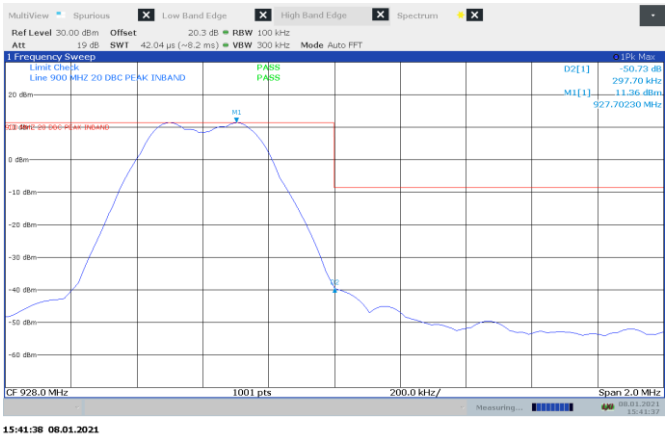


Figure 8.8-16: *Conducted Band-edge on high channel, FSK 150kbps*

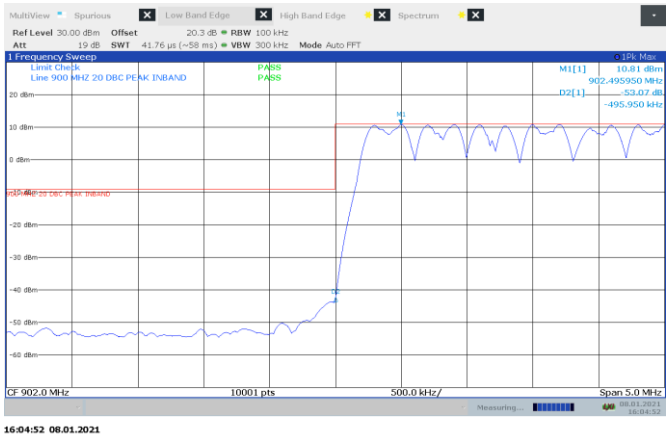


Figure 8.8-17: *Conducted Low Band-edge on Hopping, FSK 150kbps*

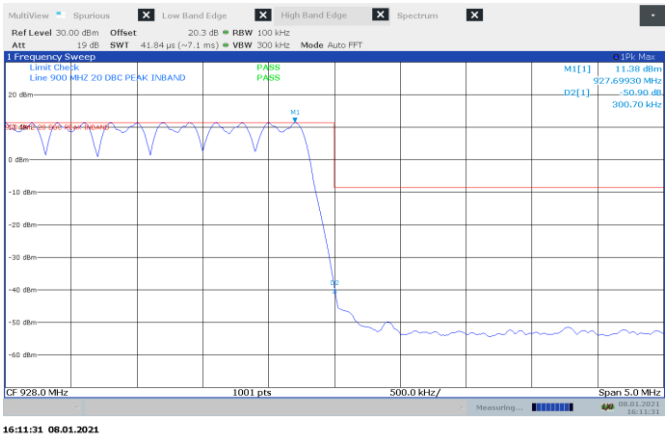


Figure 8.8-18: *Conducted High Band-edge on Hopping, FSK 150kbps*

Test data, continued

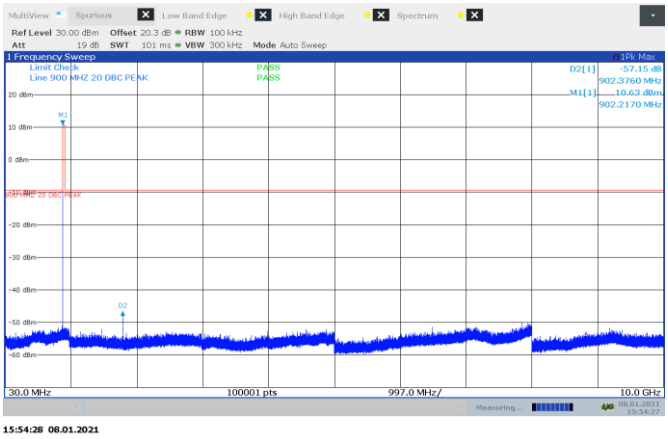


Figure 8.8-19: *Conducted spurious emissions on low channel, FSK 150kbps*

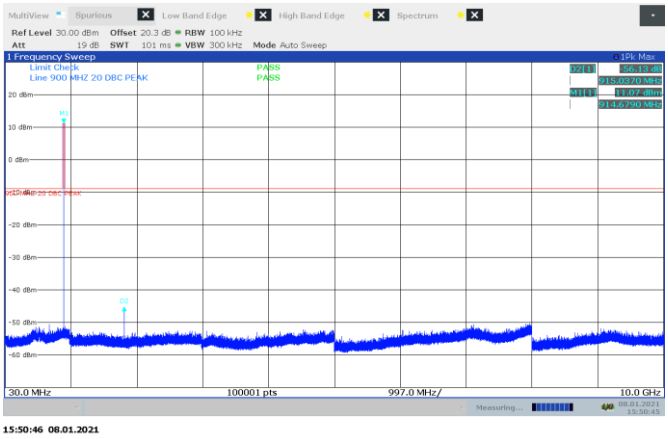


Figure 8.8-20: *Conducted spurious emissions on mid channel, FSK 150kbps*

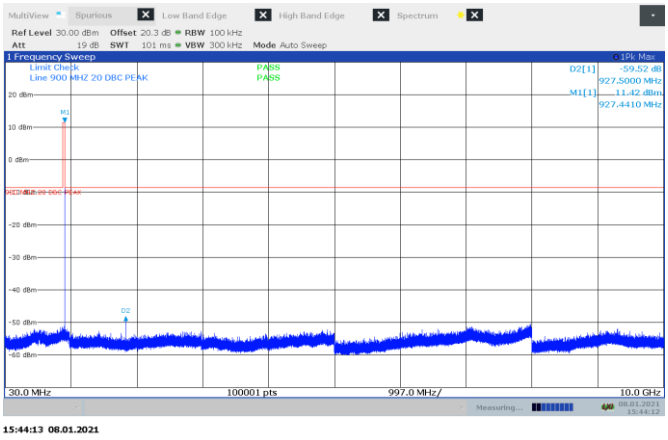


Figure 8.8-21: *Conducted spurious emissions on high channel, FSK 150kbps*

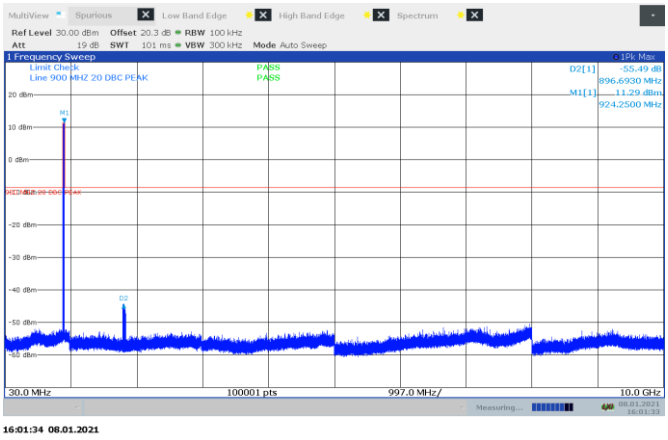


Figure 8.8-22: *Conducted spurious emissions on Hopping, FSK 150kbps*

Test data, continued

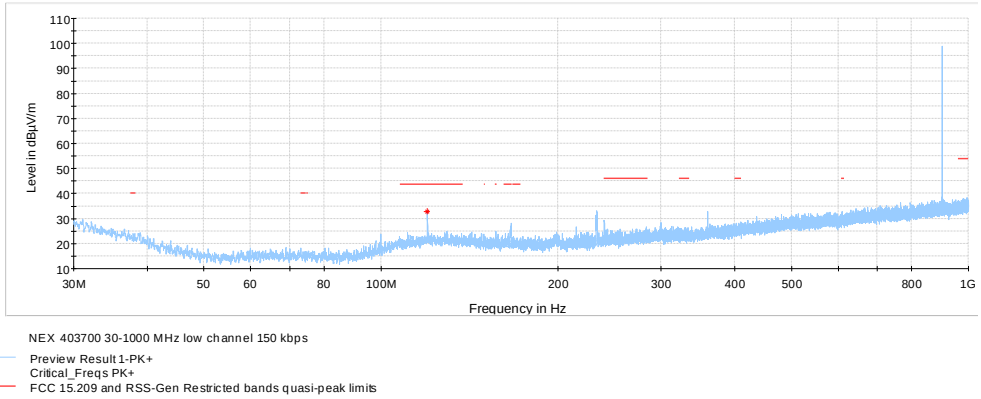


Figure 8.8-23: *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 150kbps*

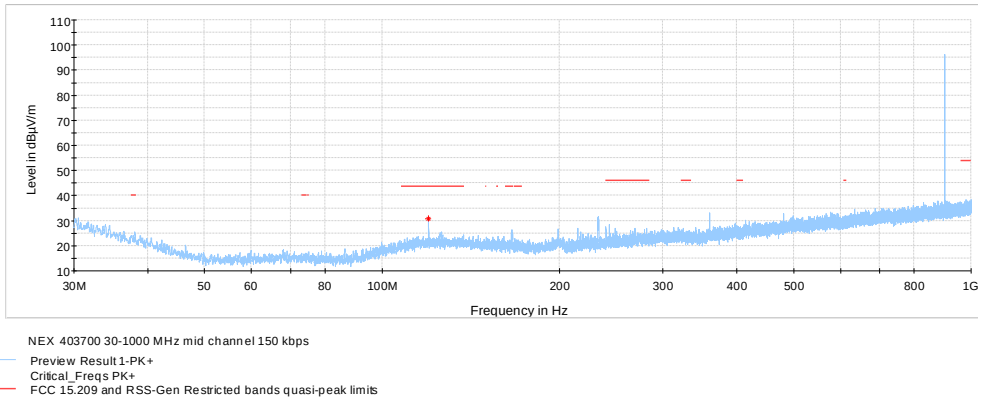


Figure 8.8-24: *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 150kbps*

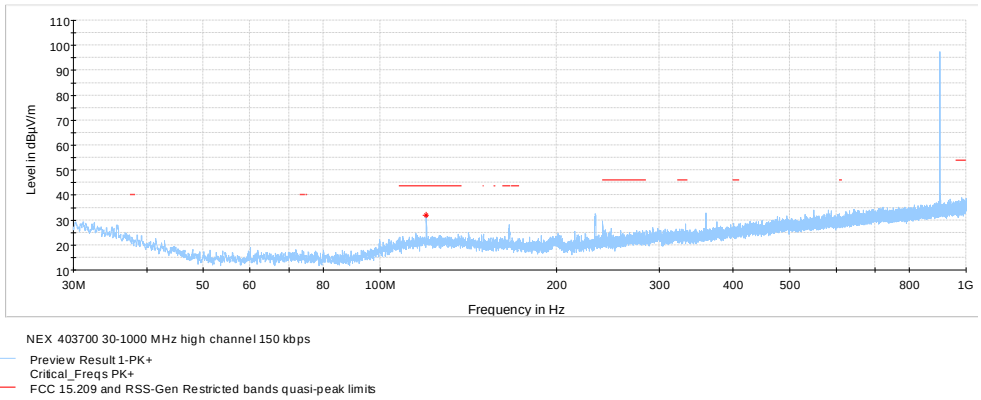


Figure 8.8-25: *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 150kbps*

Test data, continued

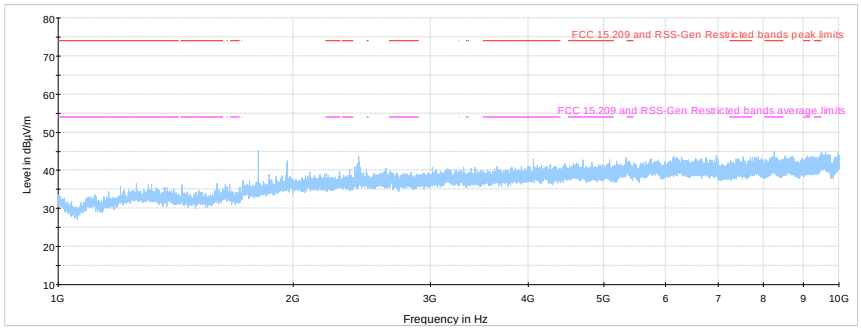


Figure 8.8-26: *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 150kbps*

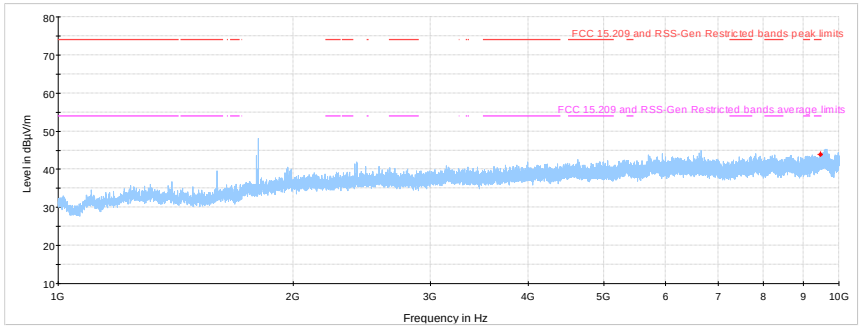


Figure 8.8-27: *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 150kbps*

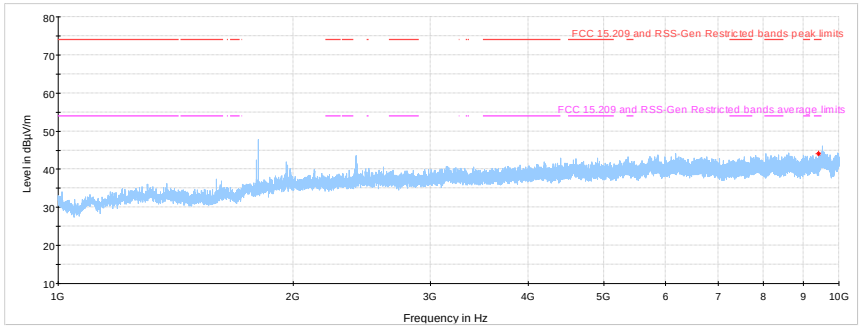
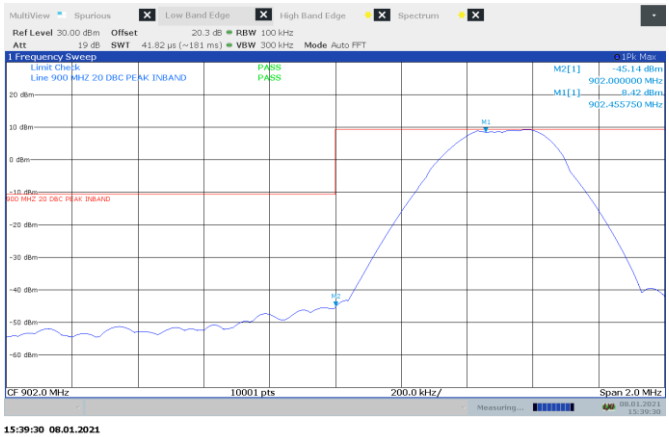


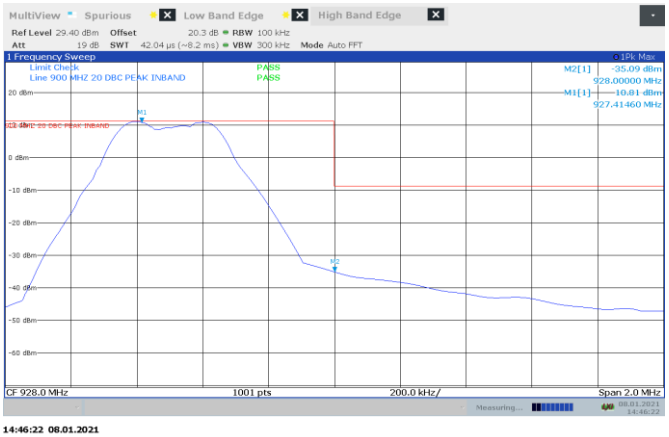
Figure 8.8-28: *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 150kbps*

Test data, continued



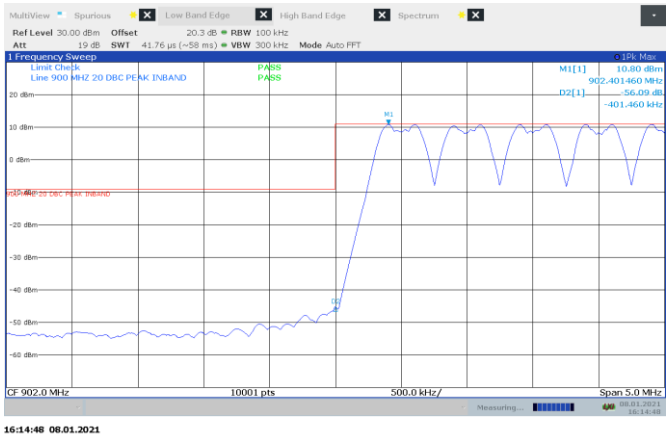
15:39:30 08.01.2021

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



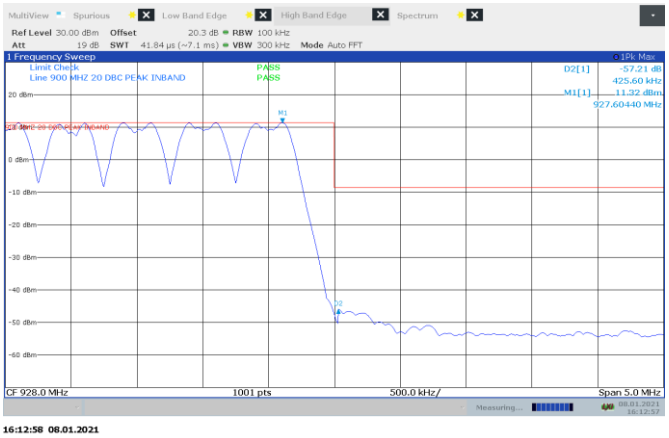
14:46:22 08.01.2021

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



16:14:48 08.01.2021

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



16:12:58 08.01.2021

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

Test data, continued

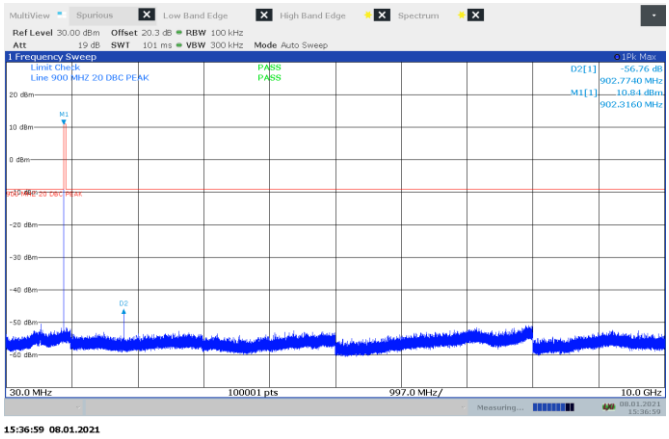


Figure 8.8-33: *Conducted spurious emissions on low channel, FSK 250kbps*

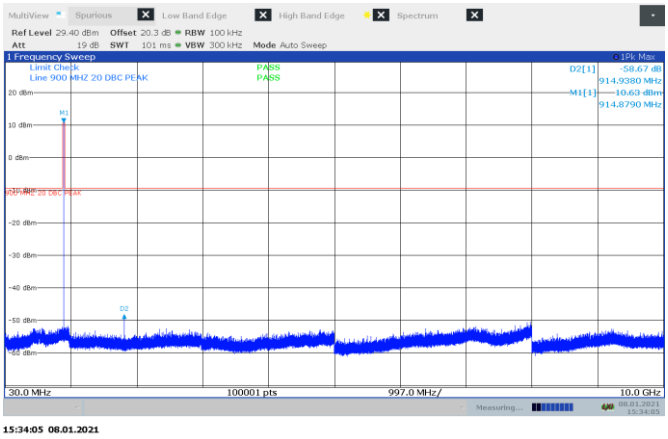


Figure 8.8-34: *Conducted spurious emissions on mid channel, FSK 250kbps*

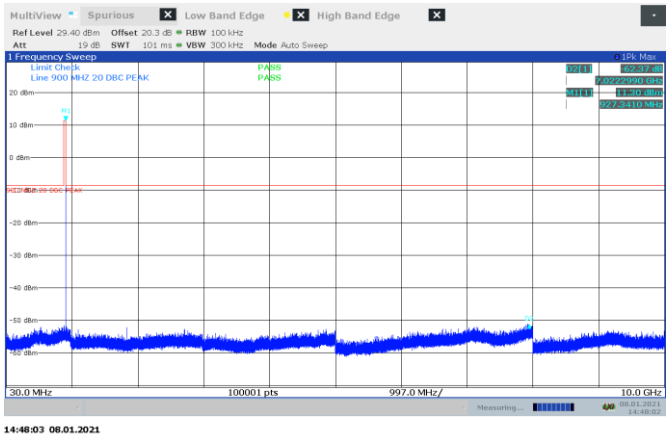


Figure 8.8-35: *Conducted spurious emissions on high channel, FSK 250kbps*

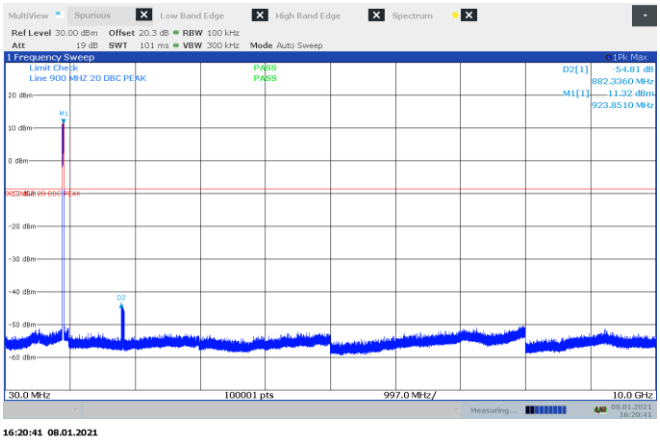


Figure 8.8-36: *Conducted spurious emissions on hopping, FSK 250kbps*

Test data, continued

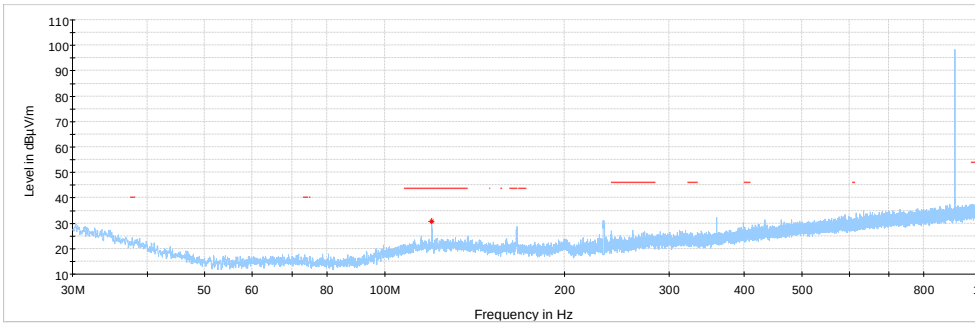


Figure 8.8-37: *Radiated spurious emissions 30 MHz – 1 GHz on low channel, FSK 250kbps*

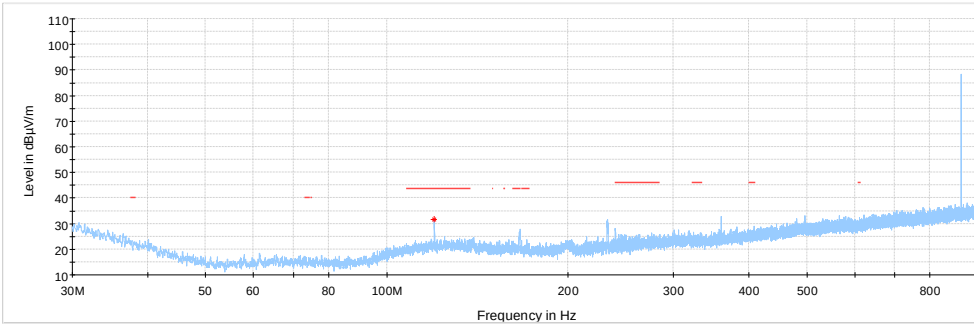


Figure 8.8-38: *Radiated spurious emissions 30 MHz – 1 GHz on mid channel, FSK 250kbps*

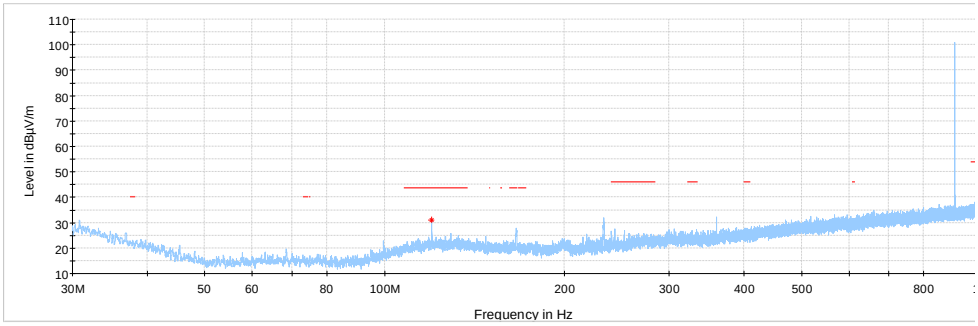


Figure 8.8-39: *Radiated spurious emissions 30 MHz – 1 GHz on high channel, FSK 250kbps*

Test data, continued

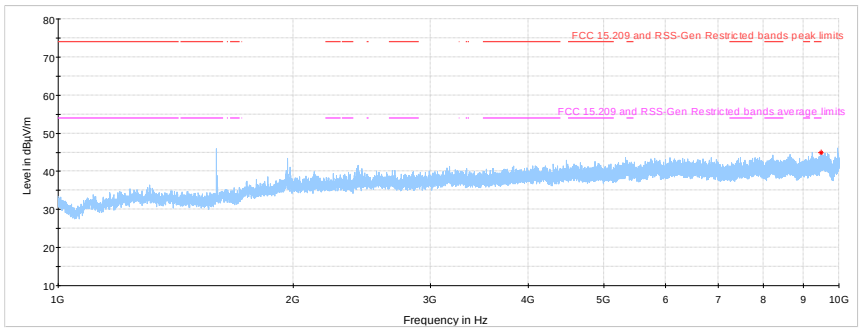


Figure 8.8-40: *Radiated spurious emissions 1 – 10 GHz on low channel, FSK 250kbps*

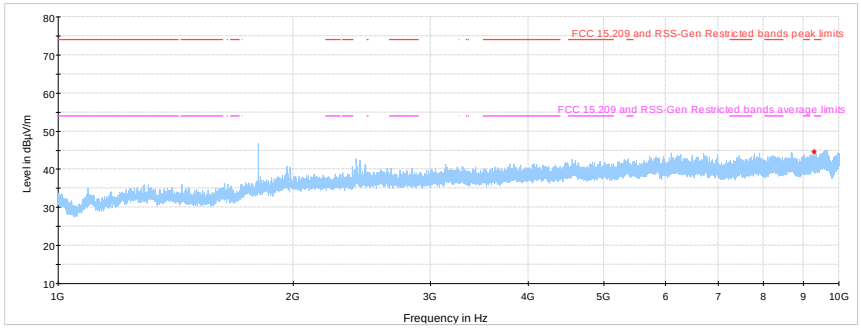


Figure 8.8-41: *Radiated spurious emissions 1 – 10 GHz on mid channel, FSK 250kbps*

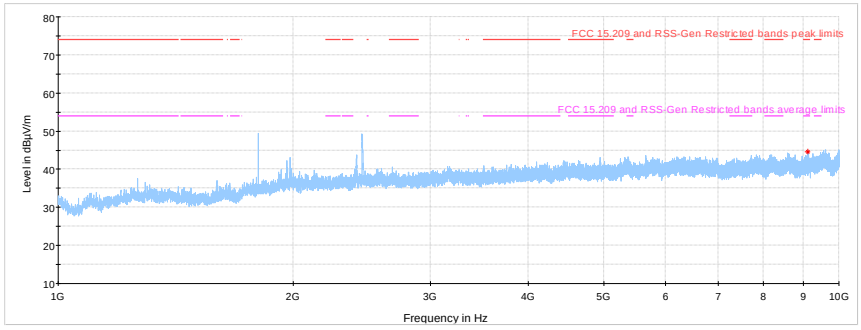


Figure 8.8-42: *Radiated spurious emissions 1 – 10 GHz on high channel, FSK 250kbps*

Test data, continued

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

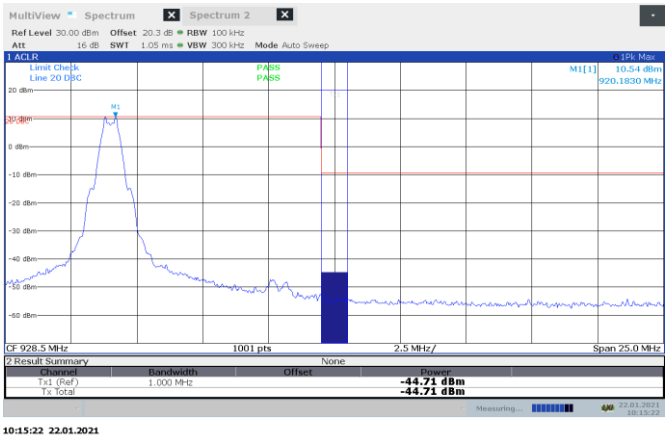


Figure 8.8-44: *Conducted Band-edge on 920 MHz channel, Z-Wave Long Range*

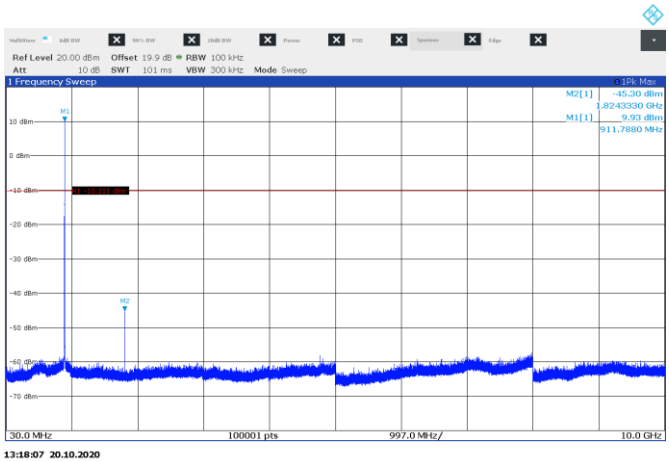


Figure 8.8-45: *Conducted spurious emissions on 912 MHz channel, Z-Wave Long Range*

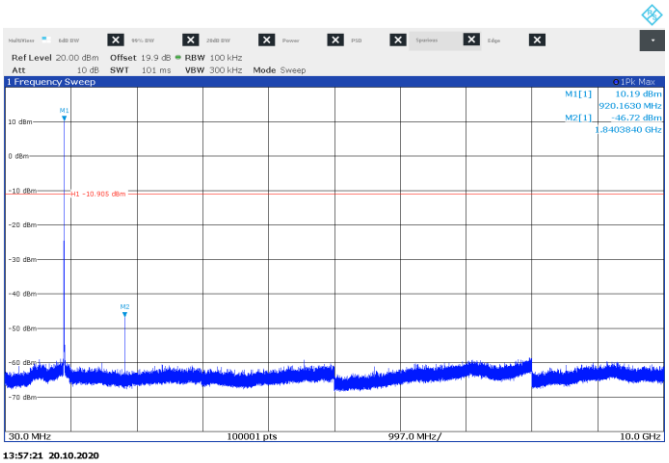


Figure 8.8-46: *Conducted spurious emissions on 920 MHz channel, Z-Wave Long Range*

Test data, continued

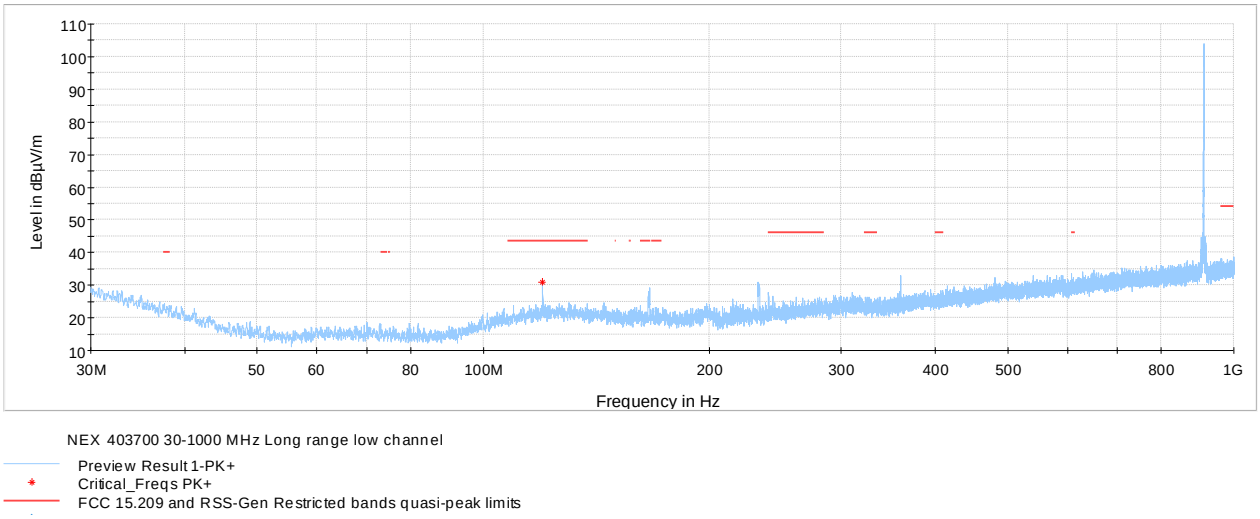


Figure 8.8-47: *Radiated spurious emissions 30 MHz – 1 GHz, on 912 MHz channel, Z-Wave Long Range*

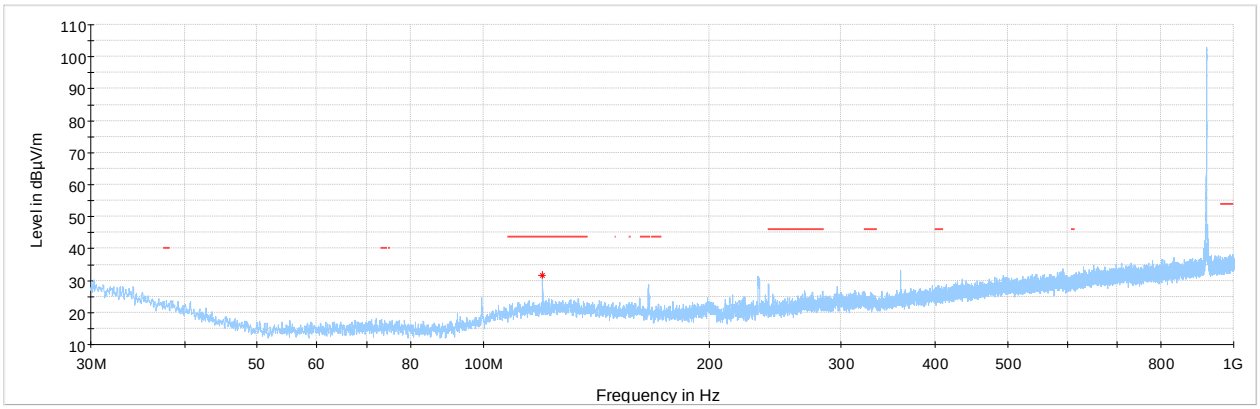


Figure 8.8-48: *Radiated spurious emissions 30 MHz – 1 GHz, on 920 MHz channel, Z-Wave Long Range*

Test data, continued

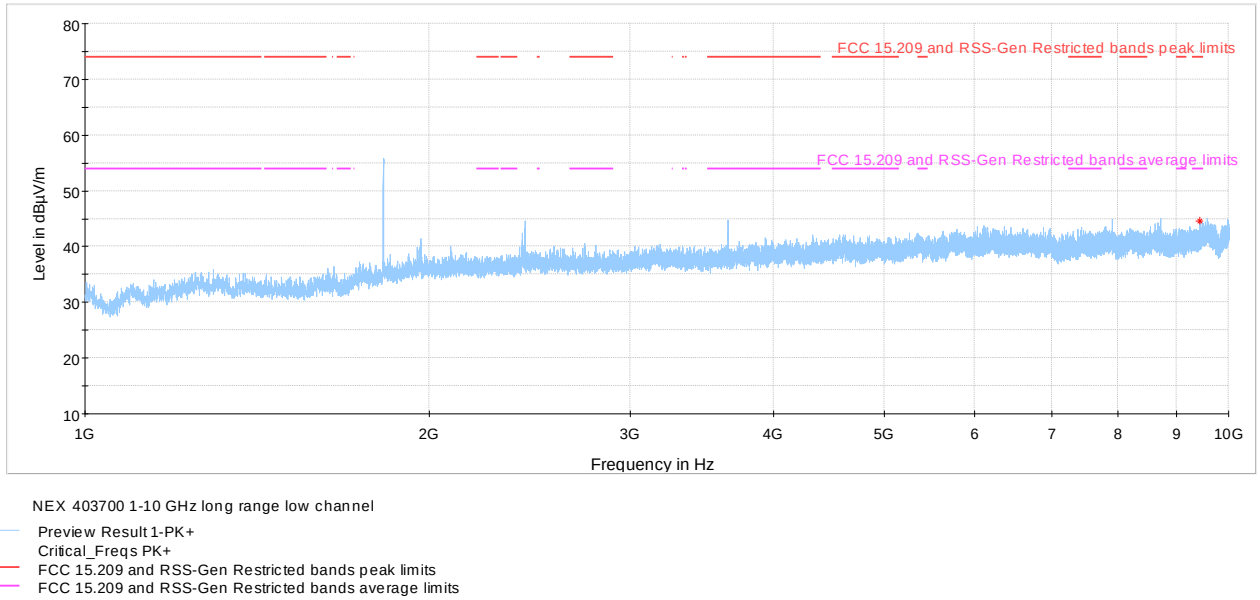


Figure 8.8-49: *Radiated spurious emissions 1 - 10 GHz, on 912 MHz channel, Z-Wave Long Range*

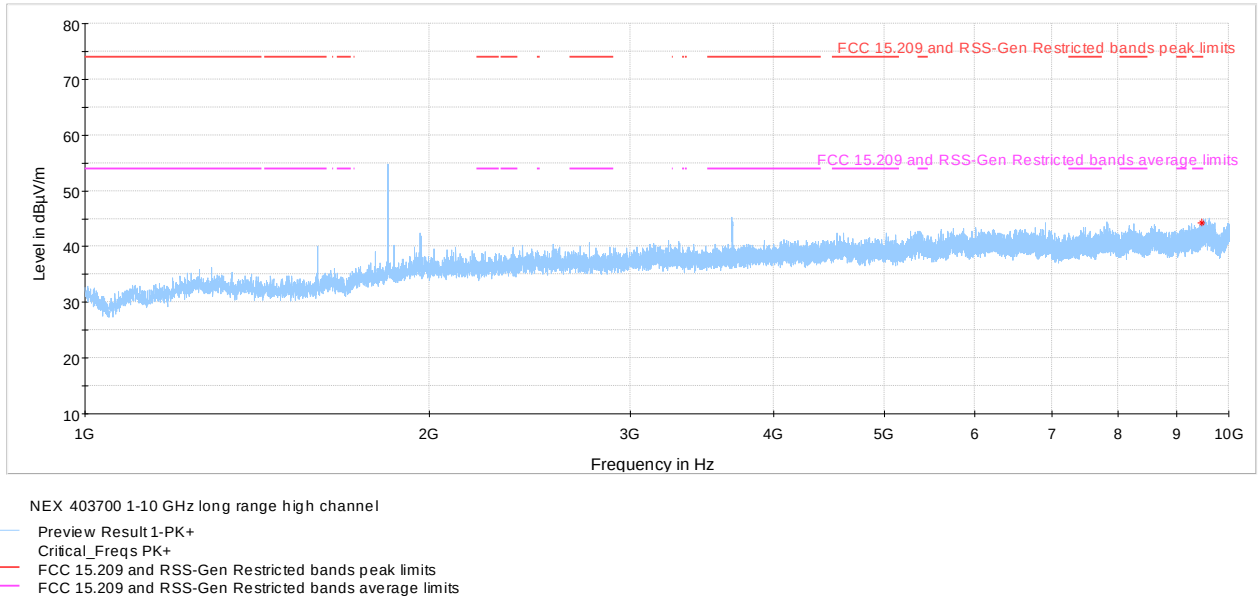


Figure 8.8-50: *Radiated spurious emissions 1 - 10 GHz, on 920 MHz channel, Z-Wave Long Range*

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	-1.2	8.0	9.2
920	-1.1	8.0	9.1

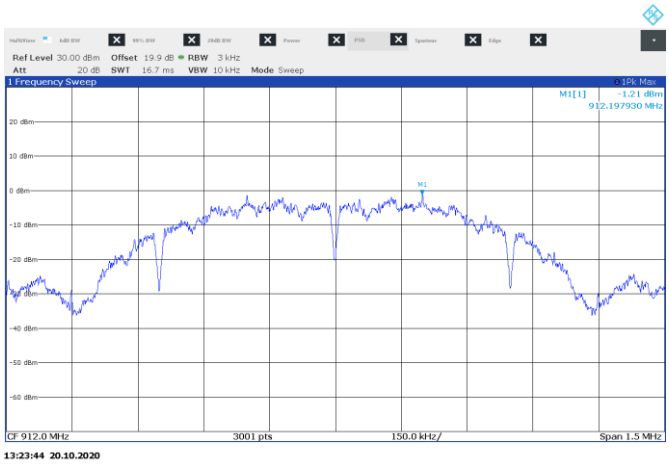


Figure 8.9-1: *PSD on 912 MHz channel, Z-Wave Long Range*

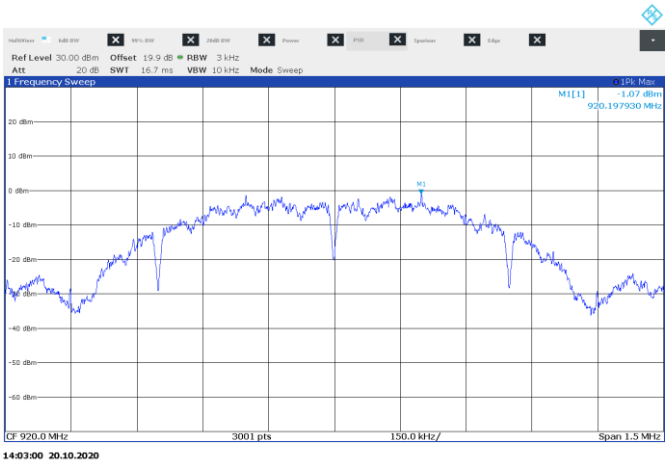


Figure 8.9-2: *PSD on 920 MHz channel, Z-Wave Long Range*

End of Test Report