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RADIO TEST REPORT – 403703-1TRFWL

Type of assessment:

Final product testing

Applicant:

Ring LLC

Product name (type):

Range Extender

Model:

5AT2S8

FCC ID:

2AEUP5AT2S8

IC Registration number:

20271-5AT2S8

Specifications:

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

Date of issue: January 28, 2021

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Tested by	Signature
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Reviewed by	Signature

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

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.

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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/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	Range extender
Model	5AT2S8
Model variant(s)	None
Serial number	G7Q1D002019400K2 (Conducted), None (Radiated)
Part number	None
Operating conditions	firmware revision v1.11
Product description and theory of operation	The range extender is only re-transmit signals that are uniquely identified as originating from a transmitter, or set of transmitters, with which the repeater is authorized to operate.

5.4 Technical information

Applicant IC company number	20271
IC UPN number	5AT2S8
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: 0.0126 (11.0 dBm) @ 902.2 MHz 150 kbps, FHSS: 0.0158 (12.0 dBm) @ 902.4 MHz 250 kbps, FHSS: 0.0158 (12.0 dBm) @ 902.5 MHz DTS: 0.0182 (12.6 dBm) @ 912 MHz
Field strength, dBµV/m @ 3 m	N/A
Measured BW (kHz), 99% OBW	50 kbps, FHSS: 97.7 @ 915.2 MHz 150 kbps, FHSS: 320.2 @ 902.4 MHz 250 kbps, FHSS: 386.8 @ 902.5 MHz DTS: 932.1 @ 920 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: 47.3 dBµV/m (Average) @ 1.8556 GHz 150 kbps, FHSS: 46.4 dBµV/m (Average) @ 1.8548 GHz 250 kbps, FHSS: 45.9 dBµV/m (Average) @ 1.8544GHz DTS: 65.7 dBµV/m (Average) @ 1.84 GHz
Power supply requirements	100 - 240 V_{AC}, 50/60 Hz
Antenna information	Monopole antenna Peak gain = 0.8 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 interface ports*

Description	Qty.
10 pin I/O header	1
AC Mains	1

Table 5.5-2: *Support equipment*

Description	Brand name	Model, Part number, Serial number, Revision level
Laptop	Dell Latitude	MN: E6420, SN: FA002705
Development board	Silicon Labs	MN: PCB4001 Rev A03, SN: 195057645

Table 5.5-3: *Inter-connection cables*

Cable description	From	To	Length (m)
10 pin I/O cable	EUT	Laptop	> 1

5.6 EUT setup details, continued

5.5.2 EUT test configuration, continued

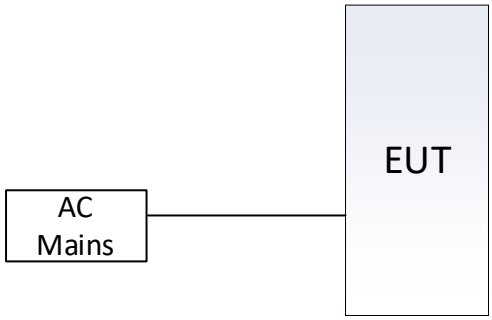


Figure 5.5-1: *Radiated testing block diagram*

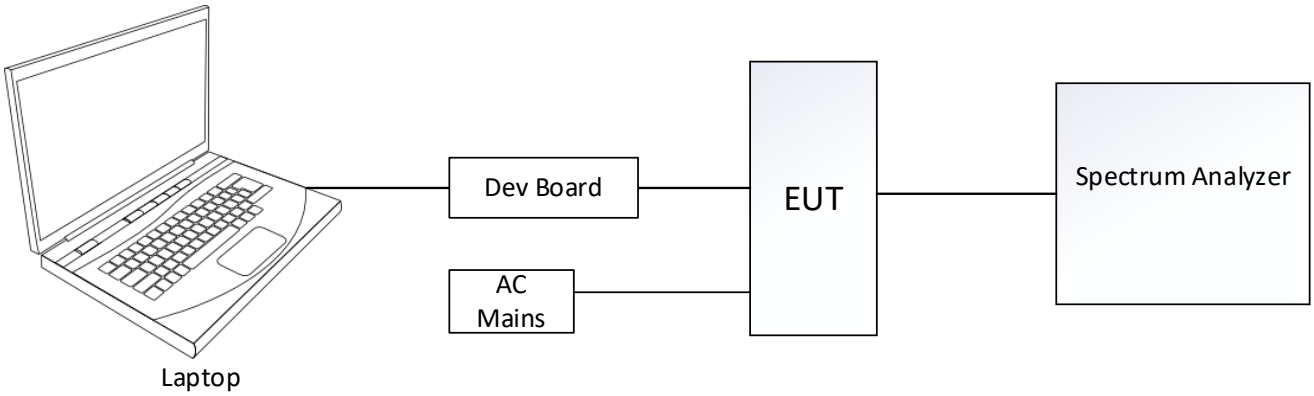


Figure 5.5-2: *Antenna port testing block diagram*

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
Monopole	Jucheng	N/A	0.8 dBi	N/A

8.4 FCC 15.207(a) and RSS-Gen 8.8 AC power line conducted emissions limits

8.4.1 References, definitions and limits

FCC:
Except as shown in paragraphs (b) and (c) of this section, for an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 µH/50 Ω line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

ANSI: C63.10 subclause 6.2
If the EUT normally receives power from another device that in turn connects to the public utility ac power lines, measurements shall be made on that device with the EUT in operation to demonstrate that the device continues to comply with the appropriate limits while providing the EUT with power. If the EUT is
operated only from internal or dedicated batteries, with no provisions for connection to the public utility ac power lines (600 VAC or less) to operate the EUT (such as an adapter), then ac power-line conducted measurements are not required.
For direct current (dc) powered devices where the ac power adapter is not supplied with the device, an “off-the-shelf” unmodified ac power adapter shall be used. If the device is supposed to be installed in a host (e.g., the device is a module or PC card), then it is tested in a typical compliant host.

IC:
A radio apparatus that is designed to be connected to the public utility (AC) power line shall ensure that the radio frequency voltage, which is conducted back onto the AC power line on any frequency or frequencies within the band 150 kHz to 30 MHz, shall not exceed the limits in table below.

Unless the requirements applicable to a given device state otherwise, for any radio apparatus equipped to operate from the public utility AC power supply either directly or indirectly (such as with a battery charger), the radio frequency voltage of emissions conducted back onto the AC power lines in the frequency range of 0.15 MHz to 30 MHz shall not exceed the limits shown in table below. The more stringent limit applies at the frequency range boundaries.

Table 8.4-1: *Conducted emissions limit*

Frequency of emission, MHz	Conducted limit, dBµV	
	Quasi-peak	Average**
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

Note: * - The level decreases linearly with the logarithm of the frequency.
** - A linear average detector is required.

8.4.2 Test summary

Verdict	Pass		
Tested by	Mark Libbrecht	Test date	January 11, 2021

8.4.3 Observations, settings and special notes

The EUT was set up as tabletop configuration per ANSI C63.10-2013 measurement procedure.

The spectral scan has been corrected with transducer factors (i.e. cable loss, LISN factors, and attenuators) for determination of compliance.

A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 6 dB or above limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.

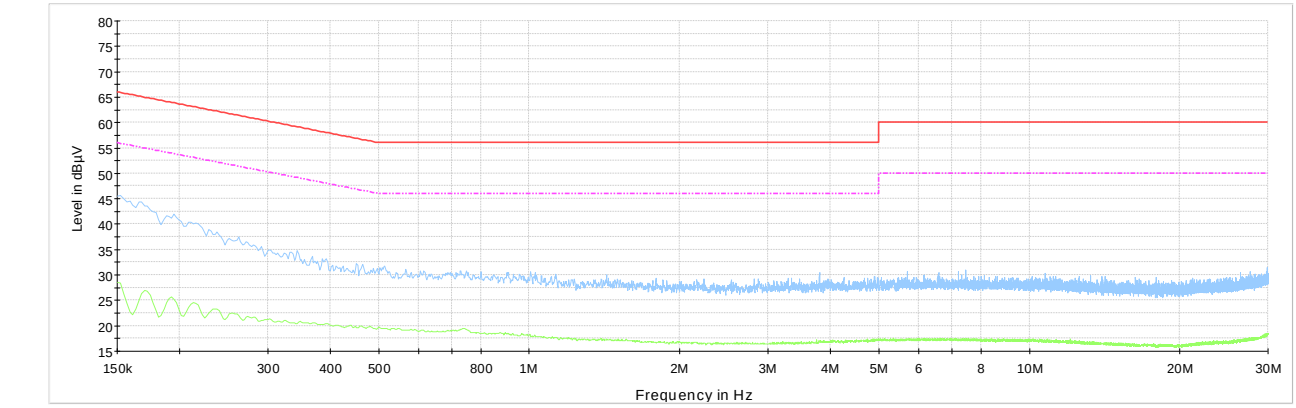
EMI Receiver settings for preview measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

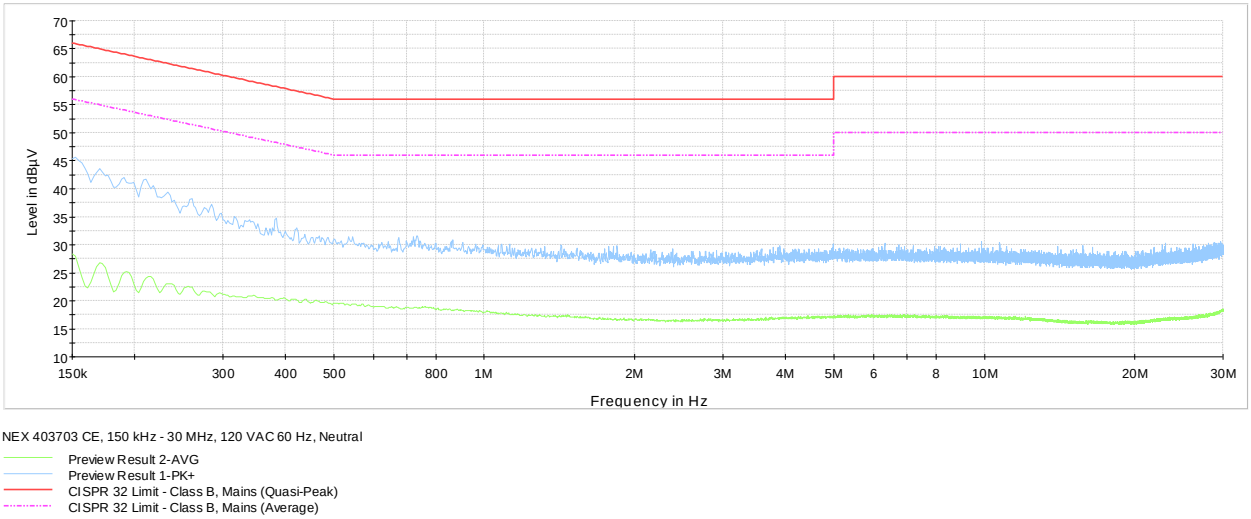
Receiver settings for final measurements:

Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Quasi-Peak and Average
Trace mode	Max Hold
Measurement time	1000 ms

8.4.4 Test data



Plot 8.4-1: *Conducted emissions on phase line*



Plot 8.4-2: *Conducted emissions on neutral line*

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

8.5.1 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 8.5-1: *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.

8.5.2 Test summary

Verdict	Pass		
Tested by	Mark Libbrecht	Test date	October 9, 2020

8.5.3 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

8.5.4 Test data, 50 kbps

Table 8.5-2: *20 dB bandwidth results, 50 kbps*

Frequency, MHz	20 dB bandwidth, kHz	Max 20 dB bandwidth limit, kHz	Margin, kHz
902.2	84.2	500	415.8
915.2	84.1	500	415.9
927.8	84.3	500	415.7

Figure 8.5-1: *20 dB bandwidth on low channel, 50 kbps*

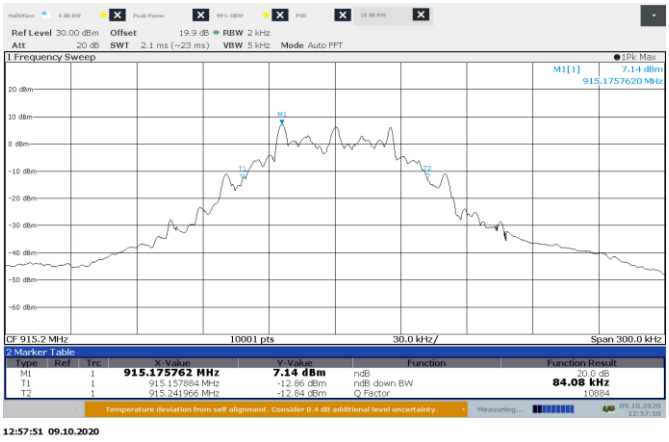


Figure 8.5-2: *20 dB bandwidth on mid channel, 50 kbps*

Figure 8.5-3: *20 dB bandwidth on high channel, 50 kbps*

Test data continued, 50 kbps

Table 8.5-3: *99% occupied bandwidth results, 50 kbps*

Frequency, MHz	99% occupied bandwidth, kHz
902.2	86.4
915.2	87.7
927.8	86.5

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

Figure 8.5-4: *99% OBW on low channel, 50 kbps*

Figure 8.5-5: *99% OBW on mid channel, 50 kbps*

Figure 8.5-6: *99% OBW bandwidth on high channel, 50 kbps*

Test data continued, 50 kbps

Table 8.5-4: *Carrier frequency separation results, 50 kbps*

Carrier frequency separation, kHz	Minimum limit, kHz	Margin, kHz
200.8	84.3	116.5

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

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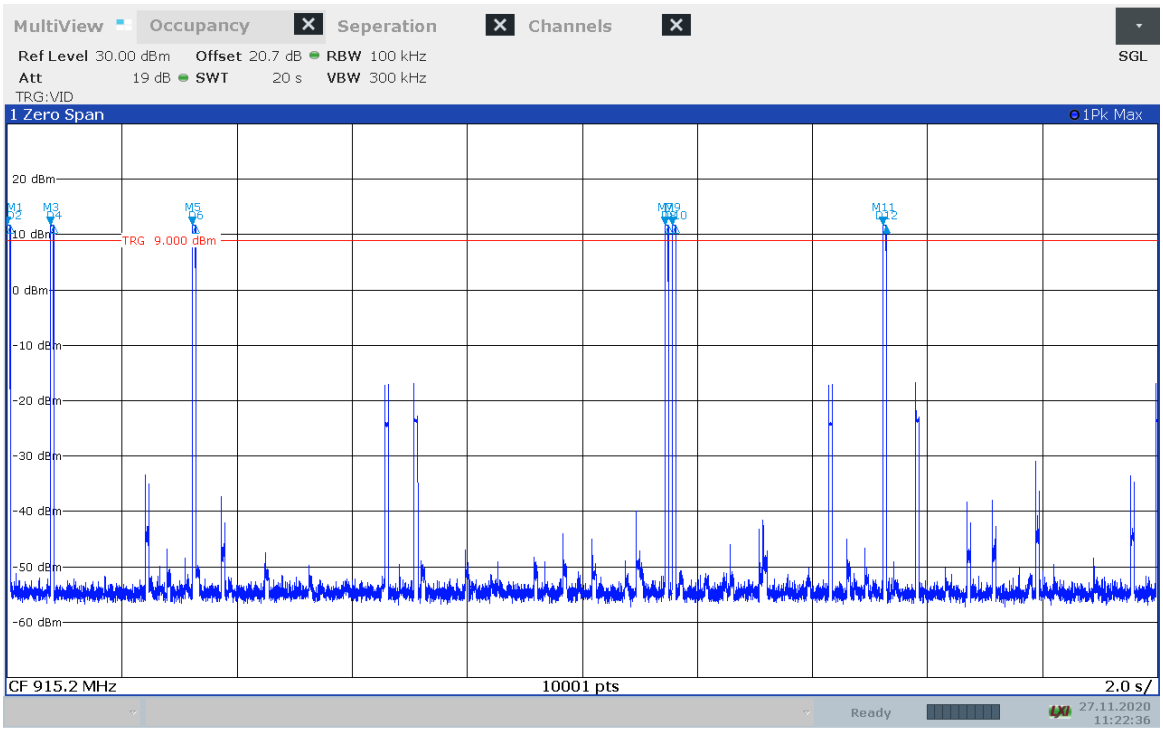
Figure 8.5-7: *Carrier frequency separation*

Test data continued, 50 kbps

Table 8.5-5: *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	6	372	400	28

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



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2 Marker Table

Type	Ref	Trc	X-Value	Y-Value	Function	Function Result
M1		1	**0.0 s**	**11.70 dBm**		
D2	M1	1	**62.0 ms**	**-0.04 dB**		
M3		1	**758.0 ms**	**11.70 dBm**		
D4	M3	1	**62.0 ms**	**-0.04 dB**		
M5		1	**3.222 s**	**11.70 dBm**		
D6	M5	1	**62.0 ms**	**-0.04 dB**		
M7		1	**11.436 s**	**11.70 dBm**		
D8	M7	1	**62.0 ms**	**-0.04 dB**		
M9		1	**11.564 s**	**11.66 dBm**		
D10	M9	1	**62.0 ms**	**-0.00 dB**		
M11		1	**15.228 s**	**11.70 dBm**		
D12	M11	1	**62.0 ms**	**-0.04 dB**		

Figure 8.5-8: *Dwell time*

Test data continued, 50 kbps

Table 8.5-6: *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

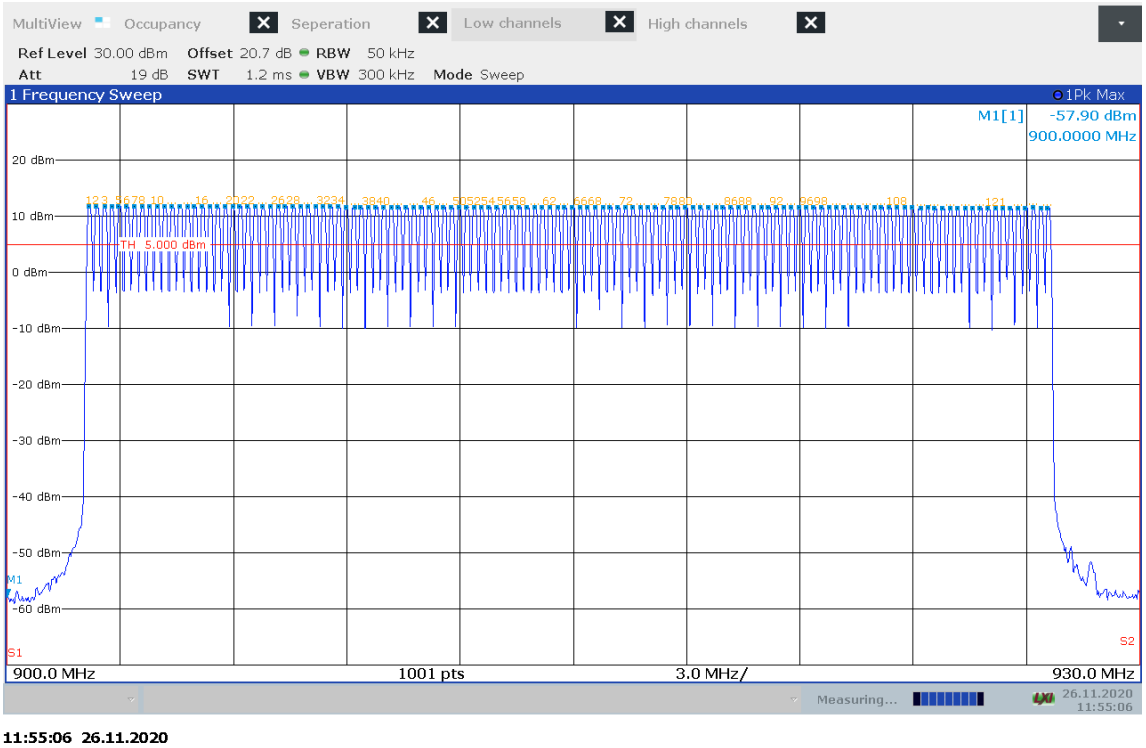

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Figure 8.5-9: *Number of hopping frequncies = 128*

Test data continued, 50 kbps

2 Marker Peak List

No	X-Value	Y-Value	No	X-Value	Y-Value
1	902.203000 MHz	11.720 dBm	65	914.970000 MHz	11.624 dBm
2	902.383000 MHz	11.729 dBm	66	915.180000 MHz	11.619 dBm
3	902.592000 MHz	11.708 dBm	67	915.360000 MHz	11.613 dBm
4	902.772000 MHz	11.710 dBm	68	915.569000 MHz	11.609 dBm
5	903.012000 MHz	11.698 dBm	69	915.779000 MHz	11.607 dBm
6	903.162000 MHz	11.699 dBm	70	915.959000 MHz	11.603 dBm
7	903.372000 MHz	11.695 dBm	71	916.169000 MHz	11.605 dBm
8	903.581000 MHz	11.692 dBm	72	916.379000 MHz	11.599 dBm
9	903.761000 MHz	11.694 dBm	73	916.558000 MHz	11.596 dBm
10	903.971000 MHz	11.687 dBm	74	916.768000 MHz	11.595 dBm
11	904.181000 MHz	11.686 dBm	75	916.978000 MHz	11.611 dBm
12	904.391000 MHz	11.692 dBm	76	917.158000 MHz	11.606 dBm
13	904.570000 MHz	11.686 dBm	77	917.368000 MHz	11.597 dBm
14	904.780000 MHz	11.685 dBm	78	917.577000 MHz	11.590 dBm
15	904.960000 MHz	11.687 dBm	79	917.757000 MHz	11.586 dBm
16	905.170000 MHz	11.689 dBm	80	917.967000 MHz	11.571 dBm
17	905.380000 MHz	11.688 dBm	81	918.177000 MHz	11.575 dBm
18	905.559000 MHz	11.682 dBm	82	918.357000 MHz	11.566 dBm
19	905.769000 MHz	11.694 dBm	83	918.566000 MHz	11.565 dBm
20	905.979000 MHz	11.685 dBm	84	918.776000 MHz	11.556 dBm
21	906.159000 MHz	11.687 dBm	85	918.956000 MHz	11.554 dBm
22	906.369000 MHz	11.690 dBm	86	919.166000 MHz	11.553 dBm
23	906.578000 MHz	11.686 dBm	87	919.376000 MHz	11.550 dBm
24	906.758000 MHz	11.689 dBm	88	919.555000 MHz	11.552 dBm
25	906.968000 MHz	11.691 dBm	89	919.765000 MHz	11.547 dBm
26	907.178000 MHz	11.695 dBm	90	919.975000 MHz	11.545 dBm
27	907.358000 MHz	11.688 dBm	91	920.155000 MHz	11.549 dBm
28	907.567000 MHz	11.691 dBm	92	920.365000 MHz	11.545 dBm
29	907.777000 MHz	11.690 dBm	93	920.574000 MHz	11.554 dBm
30	907.957000 MHz	11.689 dBm	94	920.754000 MHz	11.550 dBm
31	908.167000 MHz	11.686 dBm	95	920.964000 MHz	11.548 dBm
32	908.377000 MHz	11.681 dBm	96	921.174000 MHz	11.545 dBm
33	908.556000 MHz	11.677 dBm	97	921.354000 MHz	11.543 dBm
34	908.766000 MHz	11.677 dBm	98	921.563000 MHz	11.546 dBm
35	908.976000 MHz	11.661 dBm	99	921.773000 MHz	11.553 dBm
36	909.156000 MHz	11.663 dBm	100	921.953000 MHz	11.549 dBm
37	909.366000 MHz	11.661 dBm	101	922.163000 MHz	11.550 dBm
38	909.575000 MHz	11.663 dBm	102	922.373000 MHz	11.545 dBm
39	909.755000 MHz	11.660 dBm	103	922.552000 MHz	11.538 dBm
40	909.965000 MHz	11.653 dBm	104	922.762000 MHz	11.545 dBm
41	910.175000 MHz	11.647 dBm	105	922.972000 MHz	11.538 dBm
42	910.355000 MHz	11.642 dBm	106	923.152000 MHz	11.528 dBm
43	910.564000 MHz	11.636 dBm	107	923.362000 MHz	11.570 dBm
44	910.774000 MHz	11.630 dBm	108	923.571000 MHz	11.531 dBm
45	910.954000 MHz	11.627 dBm	109	923.781000 MHz	11.521 dBm
46	911.164000 MHz	11.620 dBm	110	923.961000 MHz	11.517 dBm
47	911.374000 MHz	11.623 dBm	111	924.171000 MHz	11.498 dBm
48	911.553000 MHz	11.613 dBm	112	924.381000 MHz	11.550 dBm
49	911.793000 MHz	11.618 dBm	113	924.560000 MHz	11.498 dBm
50	911.973000 MHz	11.616 dBm	114	924.770000 MHz	11.505 dBm
51	912.153000 MHz	11.616 dBm	115	924.980000 MHz	11.494 dBm
52	912.363000 MHz	11.609 dBm	116	925.160000 MHz	11.489 dBm
53	912.572000 MHz	11.644 dBm	117	925.370000 MHz	11.509 dBm
54	912.782000 MHz	11.613 dBm	118	925.579000 MHz	11.483 dBm
55	912.962000 MHz	11.604 dBm	119	925.759000 MHz	11.484 dBm
56	913.172000 MHz	11.640 dBm	120	925.969000 MHz	11.478 dBm
57	913.352000 MHz	11.616 dBm	121	926.179000 MHz	11.474 dBm
58	913.561000 MHz	11.615 dBm	122	926.359000 MHz	11.474 dBm
59	913.771000 MHz	11.616 dBm	123	926.568000 MHz	11.476 dBm
60	913.981000 MHz	11.615 dBm	124	926.778000 MHz	11.474 dBm
61	914.161000 MHz	11.615 dBm	125	926.958000 MHz	11.472 dBm
62	914.371000 MHz	11.618 dBm	126	927.168000 MHz	11.509 dBm
63	914.580000 MHz	11.620 dBm	127	927.378000 MHz	11.467 dBm
64	914.760000 MHz	11.620 dBm	128	927.557000 MHz	11.473 dBm

Figure 8.5-10: *List of hopping frequencies*