

RADIO TEST REPORT – 414172-1TRFWL

Type of assessment:

Final product testing

Applicant:

Neutron Automotive Controls Inc.

Product:

915MHz Wi-SUN Node

Model:

NCF-SQRR-915-WSUN-CAN-NFC-SANT-5V-A01

FCC ID:

2A4B6-S915WSN

IC Registration number:

28166-S915WSN

Specifications:

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

Date of issue: **March 22, 2022**

Andrey Adelberg, Senior EMC/RF Specialist

Tested by



Signature

David Duchesne, EMC/RF Lab Manager

Reviewed by



Signature

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SCC File Number: 15064 (Ottawa/Almonte); 151100 (Montreal); 151097 (Cambridge)

Lab locations

Company name	Nemko Canada Inc.			
Facilities	<i>Ottawa site:</i>	<i>Montréal site:</i>	<i>Cambridge site:</i>	<i>Almonte site:</i>
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Test site identifier	Organization	Ottawa/Almonte	Montreal	Cambridge
	FCC:	CA2040	CA2041	CA0101
	ISED:	2040A-4	2040G-5	24676
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	March 22, 2022	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

None

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 $\pm 5\%$, 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

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

Section 5 Information provided by the applicant

5.1 Disclaimer

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

5.2 Applicant and Manufacturer

Applicant name	Neutron Automotive Controls Inc.
Applicant address	350 Palladium Drive #102; Ottawa, Ontario; K2V 1A8; Canada
Manufacturer name	Microart Services Inc
Manufacturer address	4412 14th Ave, Markham, ON, L6G 1C6, Canada

5.3 EUT information

Product	915MHz Wi-SUN Node
Model	NCF-SQRRL-915-WSUN-CAN-NFC-SANT-5V-A01
Serial number	TBD
Power supply requirements	DC: 5 V
Product description and theory of operation	ISM radio node that operates in 915 MHz ISM band and can associate with a wireless mesh network and periodically send data that is present on its CAN bus. The SQRRL when powered will automatically look for an existing Wi-SUN based network to join. Once joined, it will periodically read data being sent to it via CAN interface and relay that data through the network to the local gateway.

5.4 Radio technical information

Category of Wideband Data Transmission equipment	Frequency Hopping Spread Spectrum (FHSS) equipment
Frequency band	902–928 MHz
Frequency Min (MHz)	902.2 (for 50 kbps), 902.4 (for 150 kbps)
Frequency Max (MHz)	927.8 (for 50 kbps), 927.6 (for 150 kbps)
Number of Channels	129 (for 50 kbps), 64 (for 150 kbps)
RF power Max (W), Conducted	0.0158 (for 50 kbps), 0.0158 (for 150 kbps)
Field strength, dBμV/m @ 3 m	N/A
Measured BW (kHz), 99% OBW	89.566 (for 50 kbps), 162.903 (for 150 kbps)
Type of modulation	FSK
Emission classification	F1D
Transmitter spurious, dBμV/m @ 3 m	46.8 at 5413.2 MHz
Antenna information	Rod antenna by Taoglass, MN: FW.95.B, Gain: 2.30 dBi (at 902 MHz), 2.71 dBi (at 915 MHz), 3.75 dBi (at 928 MHz)

5.5 EUT setup details

5.5.1 Radio exercise details

Operating conditions	Software version 1.0.0 Test Sequence version 1.6
Transmitter state	Transmitter set into continuous mode at low, mid or high channels with 50 kbps or 150 kbps bit rate. Hopping was also turned on for some tests.

5.5.2 EUT setup configuration

Table 5.5-1: EUT interface ports

Description	Qty.
Antenna port	1
DC+I/O	1
USB (internal)	1

Table 5.5-2: Support equipment

Description	Brand name	Model, Part number, Serial number, Revision level
Laptop	Lenovo	MN: ThinkPad T440s, SN: 73B84FB4-F14D-4F15-9019-2AEA032ED310
DC Power supply	Agilent	MN: E3642A, SN: KR00300021

Table 5.5-3: Inter-connection cables

Cable description	From	To	Length (m)
DC+I/O	EUT	DC power supply	2.0
USB	EUT	Laptop	0.2

EUT setup configuration, continued

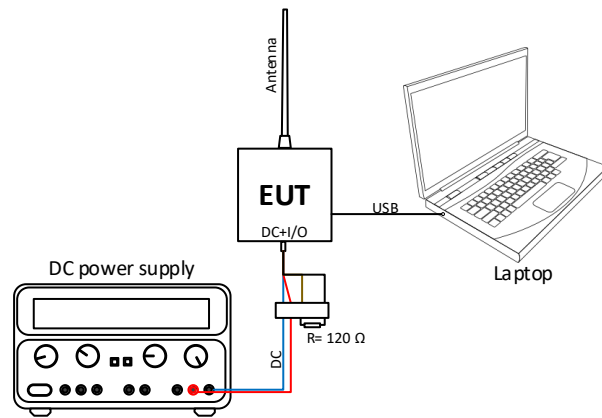


Figure 5.5-1: Radiated testing block diagram

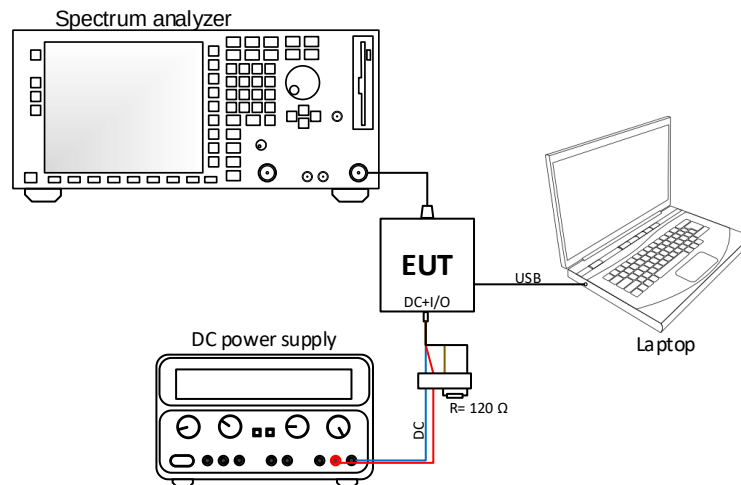


Figure 5.5-2: Antenna port testing block diagram

Section 6 Summary of test results

6.1 Testing location

Test location (s) Ottawa

6.2 Testing period

Test start date January 18, 2021 Test end date January 20, 2021

6.3 Sample information

Receipt date January 18, 2021 Nemko sample ID number(s) 1, 2

6.4 FCC Part 15 Subpart A and C, general requirements test results

Table 6.4-1: FCC general requirements results

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

6.5 FCC Part §15.247 test results for frequency hopping spread spectrum systems (FHSS)

Table 6.5-1: FCC FHSS requirements results

Part	Test description	Verdict
§15.247(a)(1)(i)	Requirements for operation in the 902–928 MHz band	Pass
§15.247(b)(2)	Maximum peak output power in the 902–928 MHz band	Pass
§15.247l(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247(f)	Time of occupancy for hybrid systems	Not applicable

6.6 ISED RSS-Gen, Issue 5, test results

Table 6.6-1: RSS-Gen requirements results

Part	Test description	Verdict
7.3	Receiver radiated emission limits ¹	Not applicable
7.4	Receiver conducted emission limits ¹	Not applicable
6.9	Operating bands and selection of test frequencies	Pass
8.8	AC power-line conducted emissions limits	Pass

Notes: ¹According 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.

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

Table 6.7-1: ISED FHSS requirements results

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
5.4	Transmitter output power and e.i.r.p. requirements	
5.4 (a)	Systems operating in the 902–928 MHz band	Pass
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	FA002047	1 year	January 24, 2021
Flush mount turntable	Sunol	FM2022	FA002082	—	NCR
Controller	Sunol	SC104V	FA002060	—	NCR
Antenna mast	Sunol	TLT2	FA002061	—	NCR
Receiver/spectrum analyzer	Rohde & Schwarz	ESU 26	FA002043	1 year	November 6, 2021
Biconical antenna (30–300 MHz)	Sunol	BC2	FA002078	1 year	April 30, 2021
Log periodic antenna (200–5000 MHz)	Sunol	LP5	FA002077	1 year	April 30, 2021
Horn (1–18 GHz)	ETS Lindgren	3117	FA002840	1 year	February 2, 2022
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002873	1 year	September 22, 2022
915 MHz ISM band notch filter	Microwave Circuits	N03916M1	FA003305	—	VOU
Signal and Spectrum Analyzer	Rhode&Schwarz	FSW50	FA003267	1 year	December 7, 2021

Notes: NCR - no calibration required

Section 8 Testing data

8.1 Variation of power source

8.1.1 References, definitions and limits

FCC §15.31 (e):

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	Andrey Adelberg	Test date	January 19, 2021

8.1.3 Observations, settings and special notes

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

- 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.
- For devices, where operating at a supply voltage deviating $\pm 15\%$ 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.
- 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.
- 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 Number of frequencies

8.2.1 References, definitions and limits

FCC §15.31:

- (m) 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.

RSS-Gen, Clause 6.9:

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

Notes: “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	Andrey Adelberg	Test date	January 19, 2021

8.2.3 Observations, settings and special notes

ANSI C63.10, Clause 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:

- 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.
- 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.
- 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.

ANSI C63.10, Clause 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:

- 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).
- 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).
- 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*

Bit rate, kbps	Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
50	902	928	26	902.4	915.0	927.8
150	902	928	26	902.6	915.0	927.6

8.3 Antenna requirement

8.3.1 References, definitions and limits

FCC §15.203:

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

RSS-Gen, Clause 6.8:

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	Andrey Adelberg	Test date	January 19, 2021

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
Rod	Taoglass	FW.95.B	2.3–3.75 dBi	SMA

8.4 AC power line conducted emissions limits

8.4.1 References, definitions and limits

FCC §15.207:

- (a) 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 μ H/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, Clause 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.

RSS-Gen, Clause 8.8:

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 emissions limit, dB μ V	
	Quasi-peak	Average**
0.15–0.5	66 to 56*	56 to 46*
0.5–5	56	46
5–30	60	50

Notes: * - 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	Andrey Adelberg	Test date	January 19, 2021

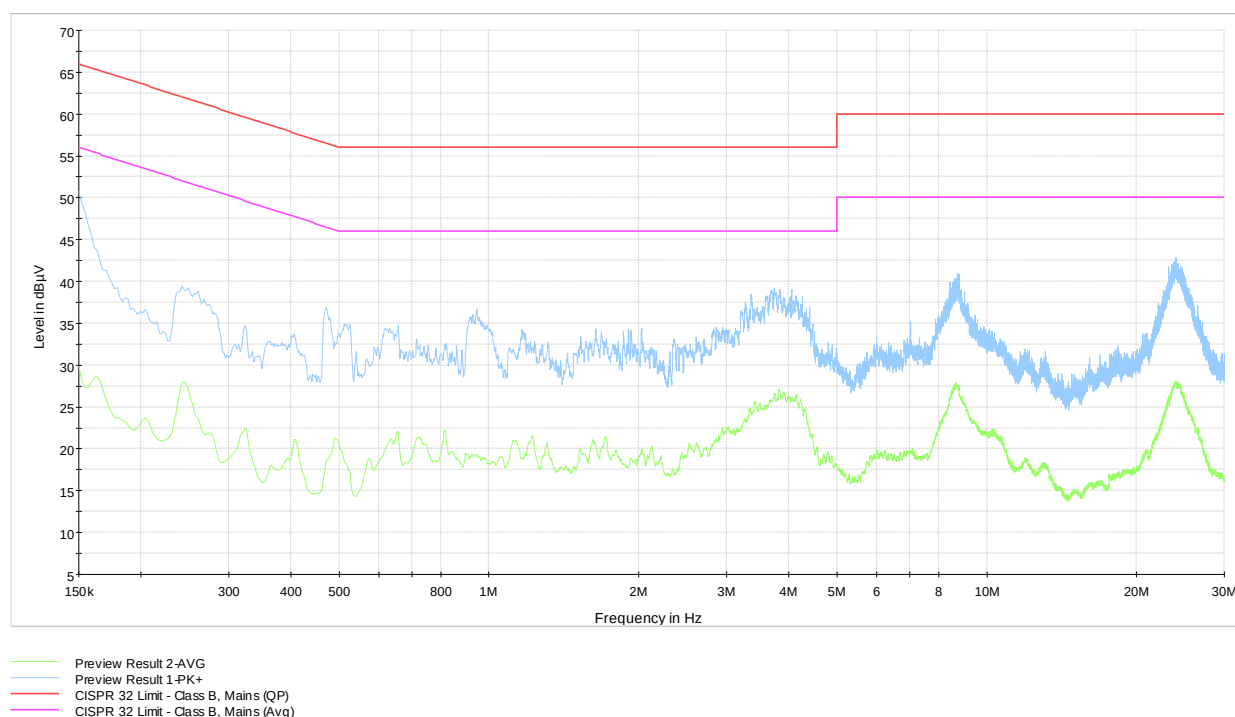
8.4.3 Observations, settings and special notes

Port under test – Coupling device	AC power of Lab Power supply – Artificial Mains Network (AMN)
EUT power input during test	5 V _{DC} (via external 120 V _{AC} , 60 Hz lab power supply)
EUT setup configuration	Table top
Measurement details	A preview measurement was generated with the receiver in continuous scan mode. Emissions detected within 10 dB or above the limit were re-measured with the appropriate detector against the correlating limit and recorded as the final measurement.
Additional 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. Correction factor (dB) = LISN factor IL (dB) + cable loss (dB) + attenuator (dB) – Emissions that were continuously present for a minimum of 1 second and occurred more than once for every 15 seconds observation period were considered valid emissions. The maximum value of valid emissions has been recorded.

Receiver settings:

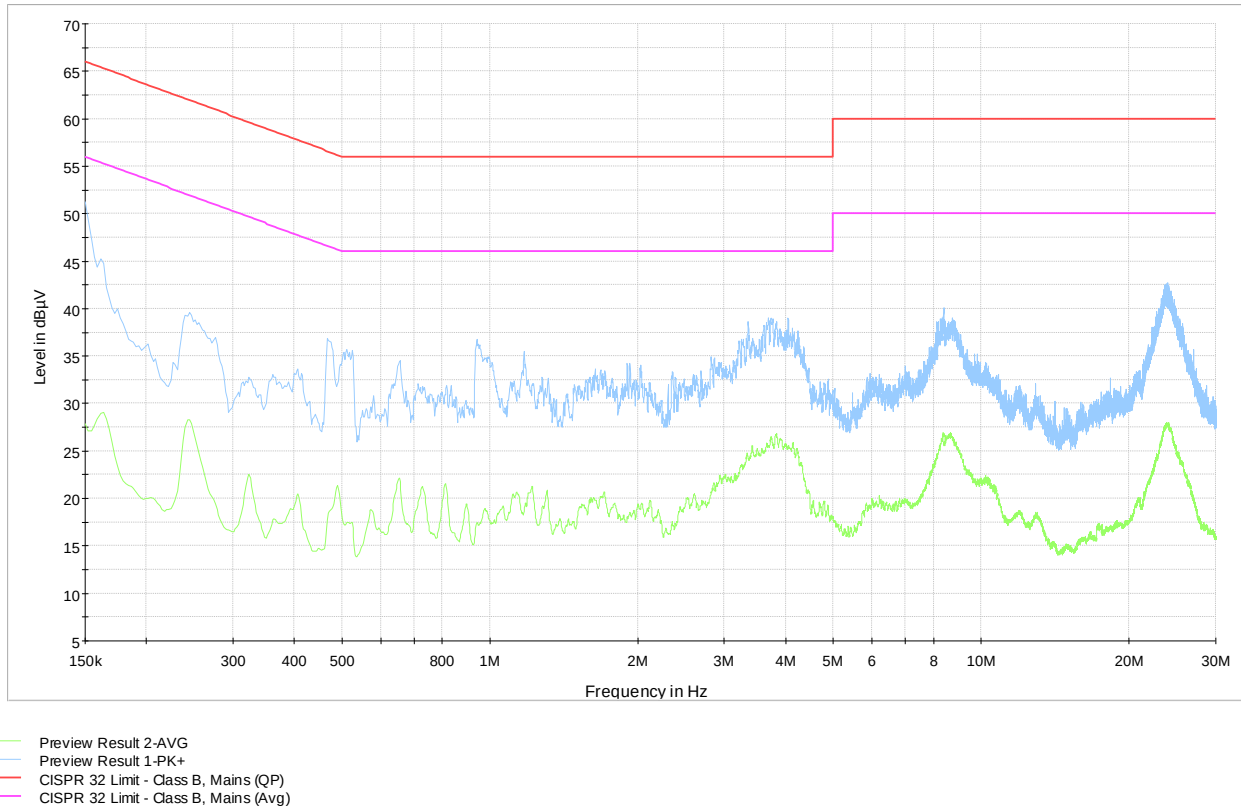
Resolution bandwidth	9 kHz
Video bandwidth	30 kHz
Detector mode	Peak and Average (Preview), Quasi-peak and CAverage (Final)
Trace mode	Max Hold
Measurement time	100 ms (Preview), 160 ms (Final)

8.4.4 Test data



Plot 8.4-1: Conducted emissions on phase line

Test data, continued



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

8.5 Frequency Hopping Systems requirements, 900 MHz operation

8.5.1 References, definitions and limits

FCC §15.247:

- (a) Operation under the provisions of this Section is limited to frequency hopping and digitally modulated intentional radiators that comply with the following provisions:
- (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. [...] 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

$P_{\text{max-pk}} \leq 1 \text{ W}$	$P_{\text{max-pk}} \leq 0.125 \text{ W}$
$N_{\text{ch}} \geq 75$	$N_{\text{ch}} \geq 15$
$\Delta f \geq \text{MAX} \{ 25 \text{ kHz}, BW_{20 \text{ dB}} \}$	$\Delta f \geq \text{MAX} \{ \text{MAX} \{ 25 \text{ kHz}, 0.67 \times BW_{20 \text{ dB}} \} \text{ OR } \text{MAX} \{ 25 \text{ kHz}, BW_{20 \text{ dB}} \} \}$
max. $BW_{20 \text{ dB}}$ not specified	max. $BW_{20 \text{ dB}}$ not specified
$t_{\text{ch}} \leq 0.4 \text{ s for } T = 0.4 \times N_{\text{ch}}$	$t_{\text{ch}} \leq 0.4 \text{ s for } T = 0.4 \times N_{\text{ch}}$

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

RSS-247, Clause 5.1:

- 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.

RSS-247, Clause 5.3:

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	Andrey Adelberg	Test date	January 20, 2021

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 $\gg 1/T$, 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

Table 8.5-2: 20 dB bandwidth results

Bit rate, kbps	Frequency, MHz	20 dB bandwidth, kHz	Maximum limit, kHz	Margin, kHz
50	902.2	103.90	500.00	396.10
	915.0	104.40	500.00	395.60
	927.8	102.90	500.00	397.10
150	902.4	185.80	500.00	314.20
	915.0	178.80	500.00	321.20
	927.6	185.80	500.00	314.20

Test data, continued

Table 8.5-3: 99% occupied bandwidth results

Bit rate, kbps	Frequency, MHz	99% occupied bandwidth, kHz
50	902.2	89.566
	915.0	89.207
	927.8	89.539
150	902.4	162.903
	915.0	162.562
	927.6	162.545

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

Table 8.5-4: Carrier frequency separation results

Bit rate, kbps	Carrier frequency separation, kHz	Minimum limit, kHz	Margin, kHz
50	200.00	104.40	95.6
150	400.80	185.80	215.0

Table 8.5-5: Number of hopping frequencies results

Bit rate, kbps	Number of hopping frequencies	Minimum limit	Margin
50	129	15	114
150	64	15	49

Table 8.5-6: Average time of occupancy results

Bit rate, kbps	Dwell time of each pulse, ms	Number of pulses within period	Total dwell time within period, ms	Limit, ms	Margin, ms
50	10.8	12	129.6	400.0	270.4
150	3.8	51	193.8	400.0	206.2

Notes: -20 dBc BW is less than 250 kHz, therefore the measurement period is 20 s

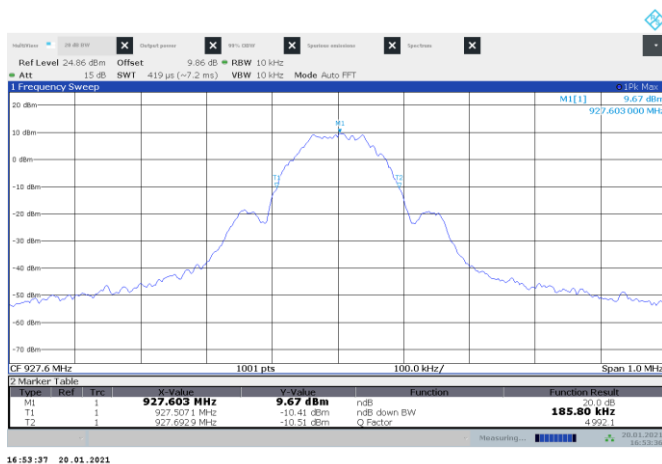


Figure 8.5-1: 20 dB bandwidth, sample plot

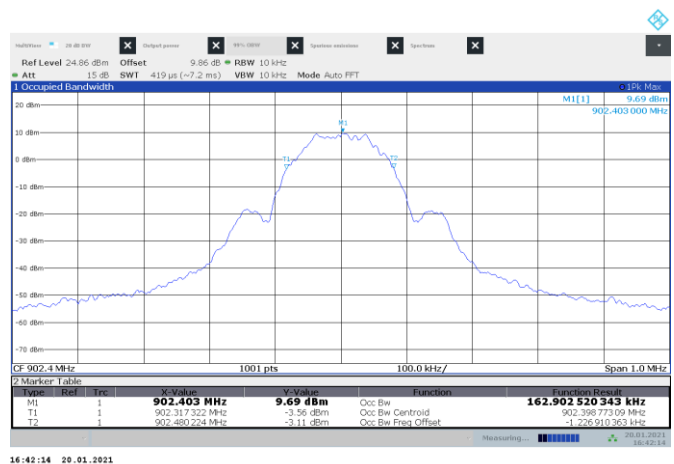


Figure 8.5-2: 99% occupied bandwidth, sample plot

Test data, continued

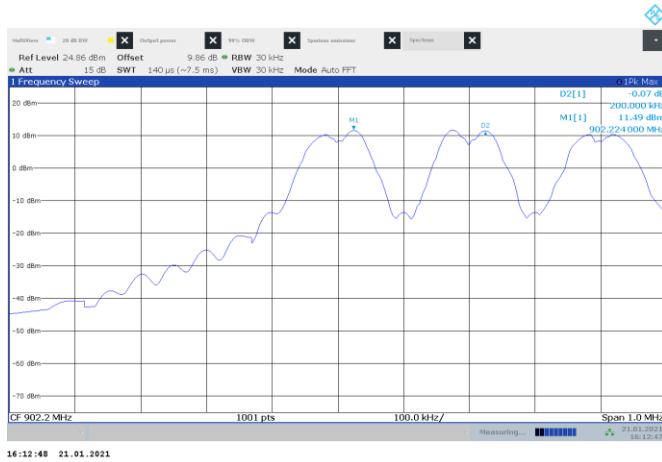


Figure 8.5-3: Carrier frequency separation, sample plot

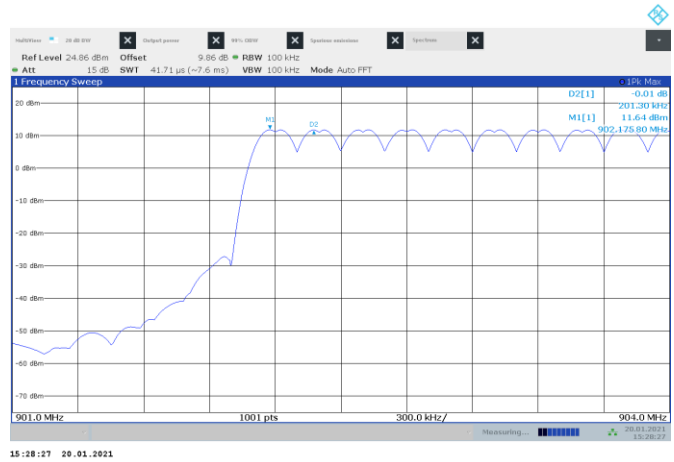


Figure 8.5-4: Number of channels within 901–904 MHz (9.5 of 129), sample plot

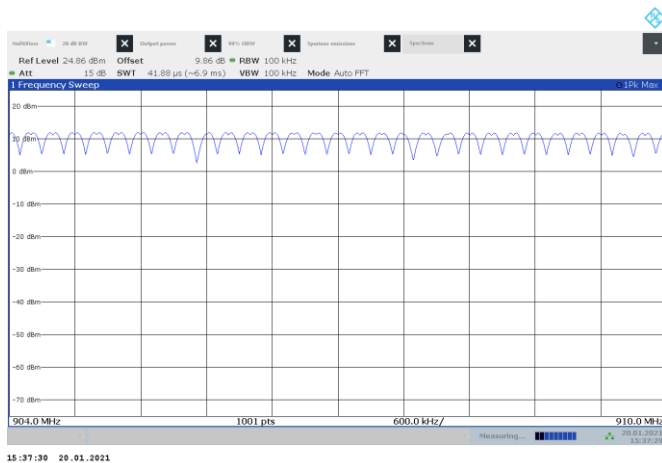


Figure 8.5-5: Number of channels within 904–910 MHz (30 of 129), sample plot

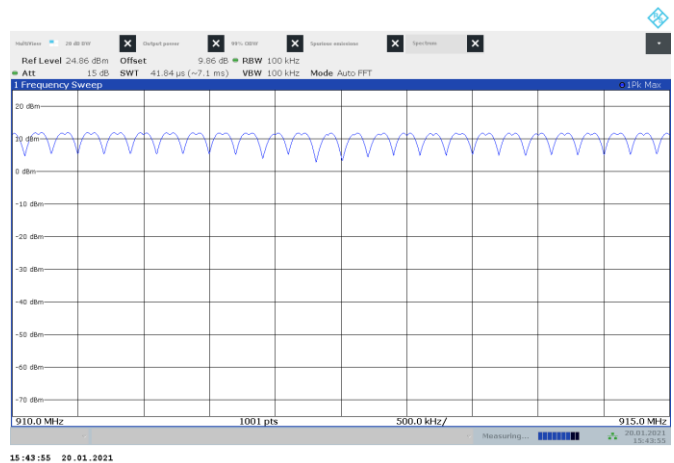


Figure 8.5-6: Number of channels within 910–915 MHz (25 of 129), sample plot

Test data, continued

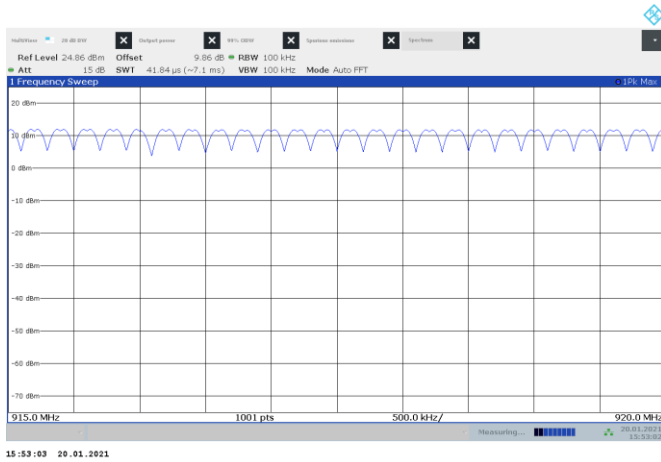


Figure 8.5-7: Number of channels within 915–920 MHz (25 of 129), sample plot

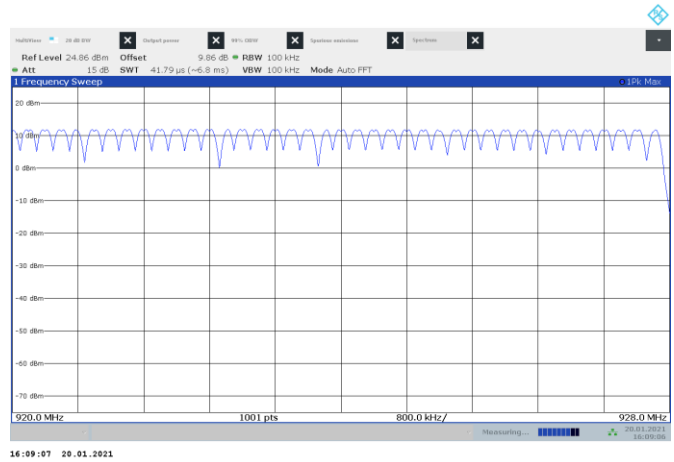


Figure 8.5-8: Number of channels within 920–928 MHz (39.5 of 129), sample plot

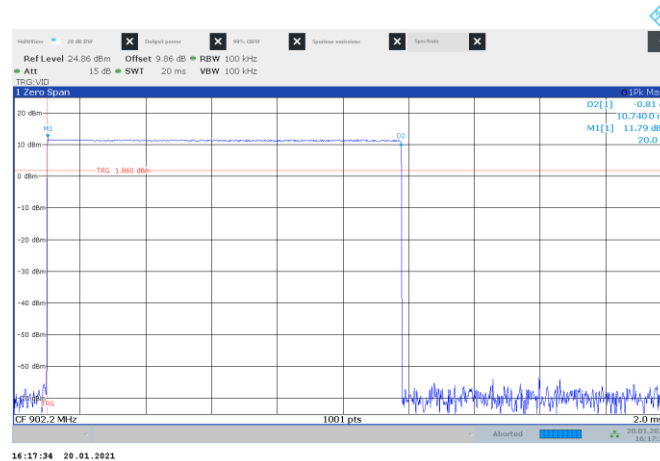


Figure 8.5-9: Pulse width, sample plot

8.6 Transmitter output power and e.i.r.p. requirements for FHSS 900 MHz

8.6.1 References, definitions and limits

FCC §15.247:

- (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.

RSS-247, Clause 5.4:

Devices shall comply with the following requirements, where applicable:

- a. 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.

8.6.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	January 19, 2021

8.6.3 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:

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

8.6.4 Test data

Table 8.6-1: Output power and EIRP results

Bit rate, kbps	Frequency, MHz	Output power, W	Output power, dBm	Output	Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
				power limit, dBm					
50	902.2	0.0157	11.95	30.00	18.05	2.30	14.25	36.00	21.75
	915.0	0.0158	12.00	30.00	18.00	2.71	14.71	36.00	21.29
	927.8	0.0156	11.92	30.00	18.08	3.75	15.67	36.00	20.33
150	902.4	0.0157	11.95	30.00	18.05	2.30	14.25	36.00	21.75
	915.0	0.0158	11.98	30.00	18.02	2.71	14.69	36.00	21.31
	927.6	0.0156	11.94	30.00	18.06	3.75	15.69	36.00	20.31

Notes: EIRP = Output power + Antenna gain

Test data, continued

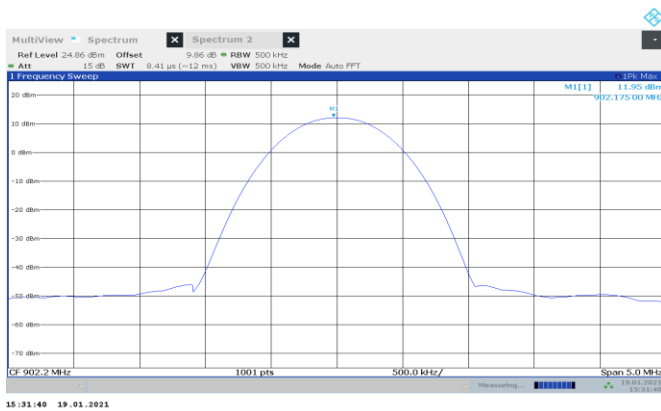


Figure 8.6-1: Output power on low channel, 50 kbps

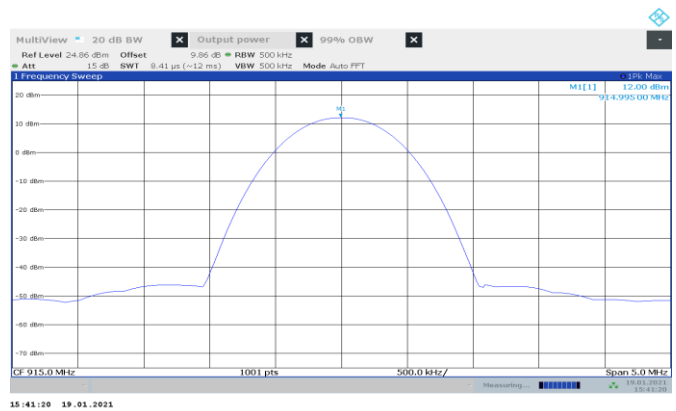


Figure 8.6-2: Output power on mid channel, 50 kbps

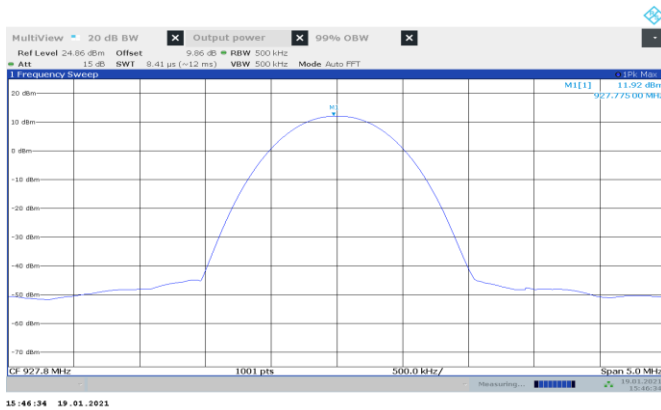


Figure 8.6-3: Output power on high channel, 50 kbps

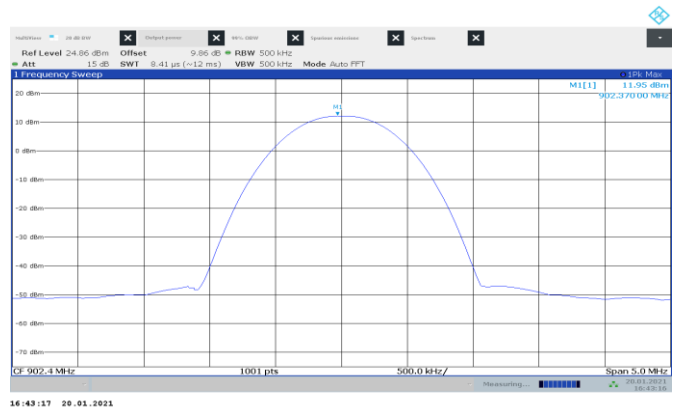


Figure 8.6-4: Output power on low channel, 150 kbps

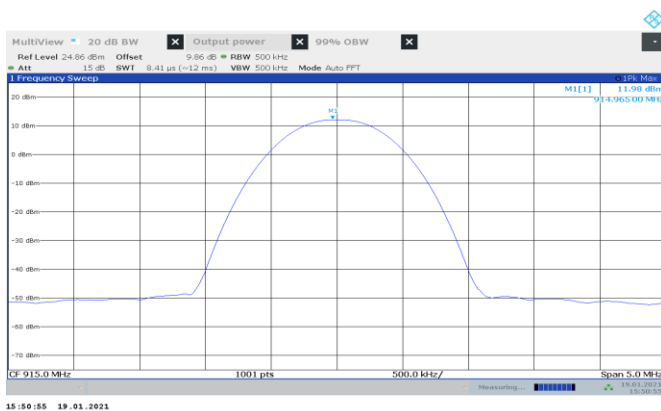


Figure 8.6-5: Output power on mid channel, 150 kbps

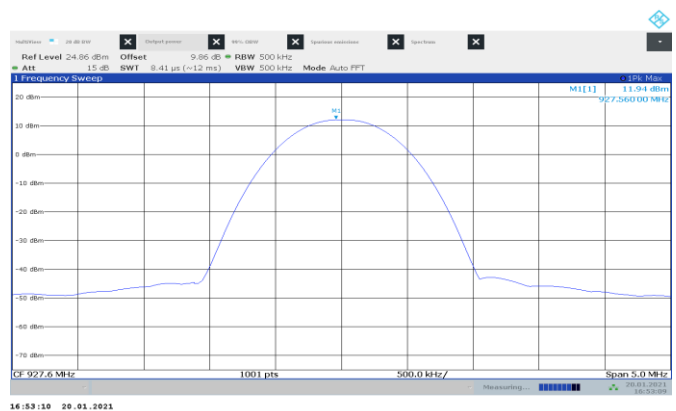


Figure 8.6-6: Output power on high channel, 150 kbps

8.7 Spurious (out-of-band) unwanted emissions

8.7.1 References, definitions and limits

FCC §15.247:

- (d) 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)).

RSS-247, Clause 5.5:

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

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

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

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

References, definitions and limits, continued

Table 8.7-2: ISED restricted frequency bands

MHz	MHz	MHz	GHz
0.090–0.110	12.57675–12.57725	399.9–410	7.25–7.75
0.495–0.505	13.36–13.41	608–614	8.025–8.5
2.1735–2.1905	16.42–16.423	960–1427	9.0–9.2
3.020–3.026	16.69475–16.69525	1435–1626.5	9.3–9.5
4.125–4.128	16.80425–16.80475	1645.5–1646.5	10.6–12.7
4.17725–4.17775	25.5–25.67	1660–1710	13.25–13.4
4.20725–4.20775	37.5–38.25	1718.8–1722.2	14.47–14.5
5.677–5.683	73–74.6	2200–2300	15.35–16.2
6.215–6.218	74.8–75.2	2310–2390	17.7–21.4
6.26775–6.26825	108–138	2483.5–2500	22.01–23.12
6.31175–6.31225	149.9–150.05	2655–2900	23.6–24.0
8.291–8.294	156.52475–156.52525	3260–3267	31.2–31.8
8.362–8.366	156.7–156.9	3332–3339	36.43–36.5
8.37625–8.38675	162.0125–167.17	3345.8–3358	
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 8.7-2 and above 38.6 GHz are designated for licence-exempt applications. These frequency bands and the requirements that apply to related devices are set out in the 200 and 300 series of RSSs.

Table 8.7-3: FCC restricted frequency bands

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

8.7.2 Test summary

Verdict	Pass		
Tested by	Andrey Adelberg	Test date	January 18, 2021

8.7.3 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.
- 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.
- Emissions in restricted frequency bands test was performed as per KDB 558074, section 8.6 with reference to ANSI C63.10 subclause 11.12.
- 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 average radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	10 Hz
Detector mode:	Peak
Trace mode:	Max Hold

Spectrum analyser settings for conducted spurious emissions measurements:

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

8.7.4 Test data

Table 8.7-4: Radiated field strength measurement results

Channel	Frequency, MHz	Peak Field strength, dBμV/m		Margin, dB	Average Field strength, dBμV/m		Margin, dB
		Measured	Limit		Measured*	Limit	
Low	4511.0	46.00	74.00	28.00	46.00	54.00	8.00
Low	5413.2	46.80	74.00	27.20	46.80	54.00	7.20
Mid	5490.0	45.95	74.00	28.05	45.95	54.00	8.05

Notes: Field strength includes correction factor of antenna, cable loss, amplifier, and attenuators where applicable.

*Peak levels were below Average limit line; therefore no additional Average measurements were performed.

Test data, continued

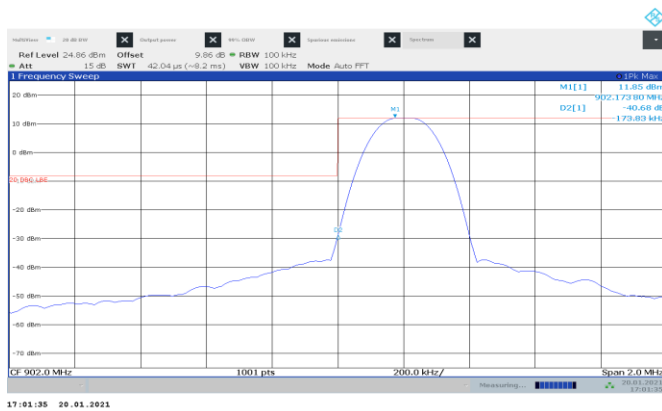


Figure 8.7-1: Band edge spurious emissions at 902 MHz, 50 kbps

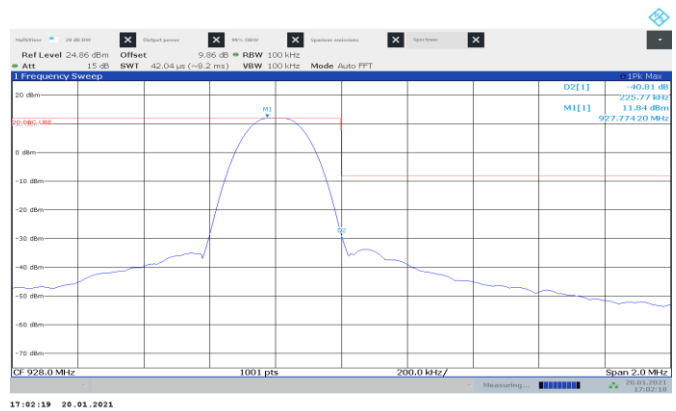


Figure 8.7-2: Band edge spurious emissions at 928 MHz, 50 kbps

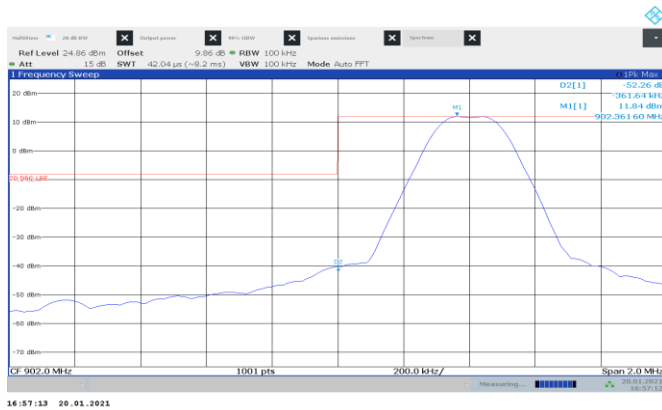


Figure 8.7-3: Band edge spurious emissions at 902 MHz, 150 kbps

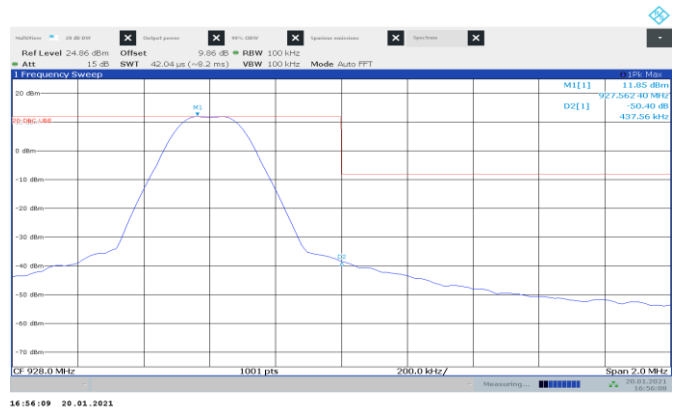


Figure 8.7-4: Band edge spurious emissions at 928 MHz, 150 kbps

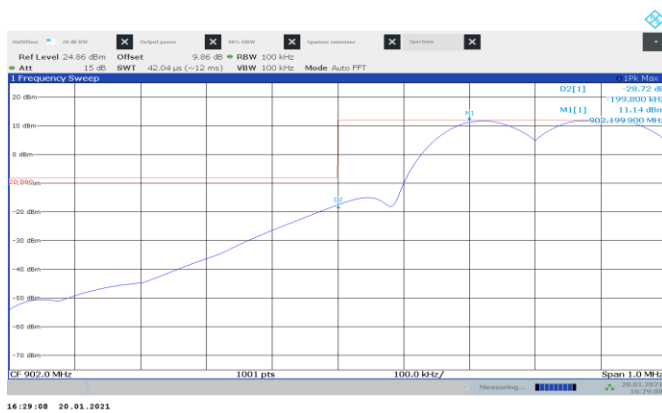


Figure 8.7-5: Band edge spurious emissions at 902 MHz, hopping on

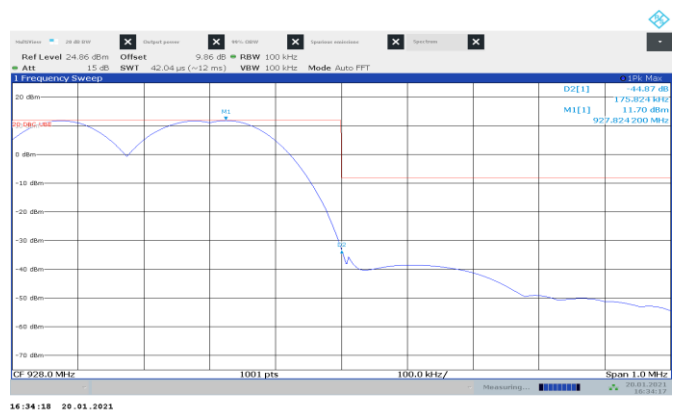


Figure 8.7-6: Band edge spurious emissions at 928 MHz, hopping on

Test data, continued

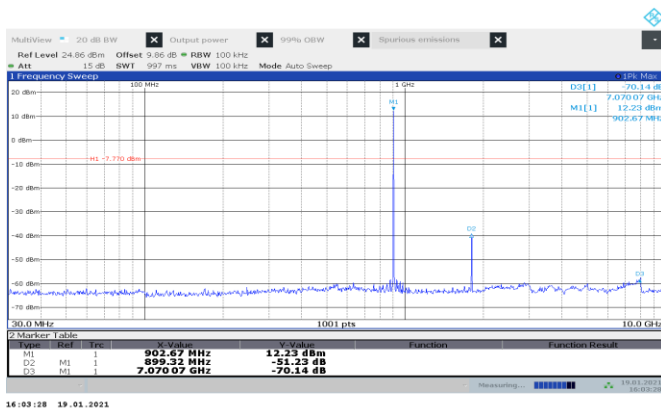


Figure 8.7-7: Conducted spurious emissions on low channel at 50 kbps



Figure 8.7-8: Conducted spurious emissions on mid channel at 50 kbps

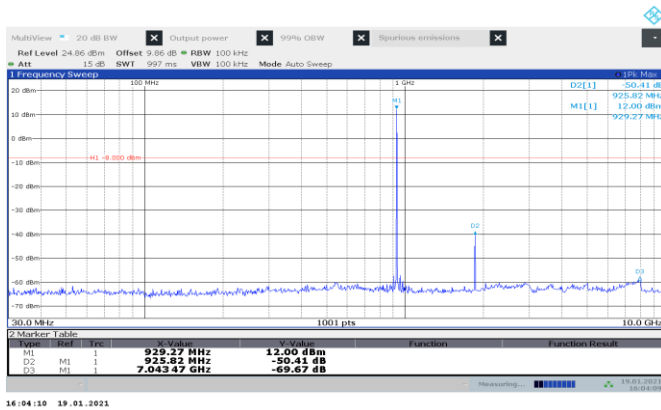


Figure 8.7-9: Conducted spurious emissions on high channel at 50 kbps



Figure 8.7-10: Conducted spurious emissions on low channel at 150 kbps

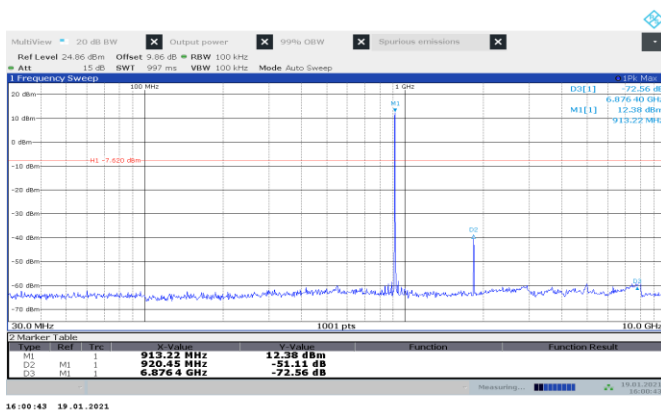


Figure 8.7-11: Conducted spurious emissions on mid channel at 150 kbps

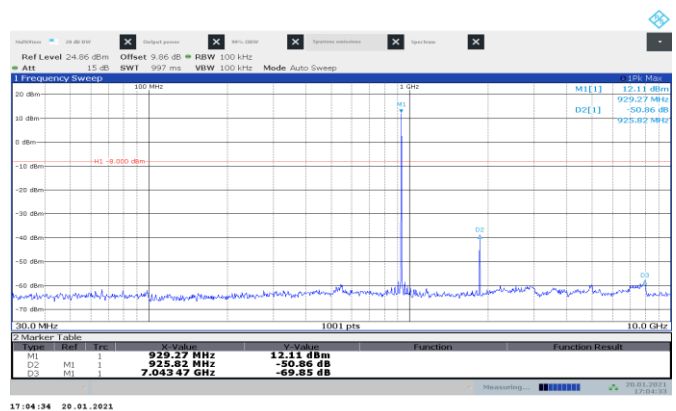


Figure 8.7-12: Conducted spurious emissions on high channel at 150 kbps

Test data, continued

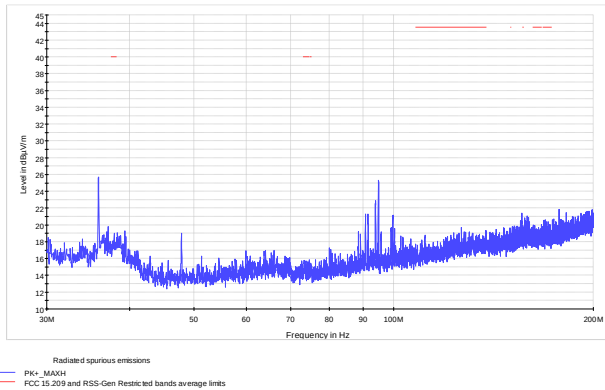


Figure 8.7-13: Radiated spurious emissions within 30–200 MHz on low channel

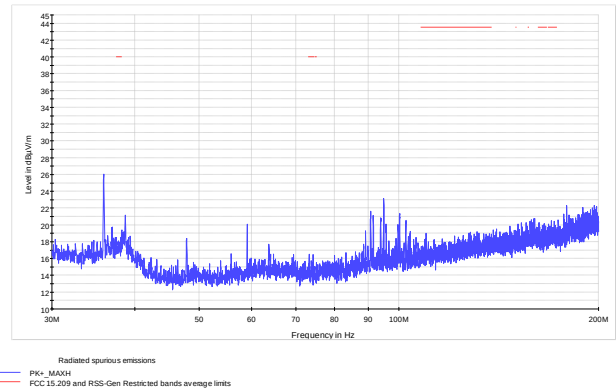


Figure 8.7-14: Radiated spurious emissions within 30–200 MHz on mid channel

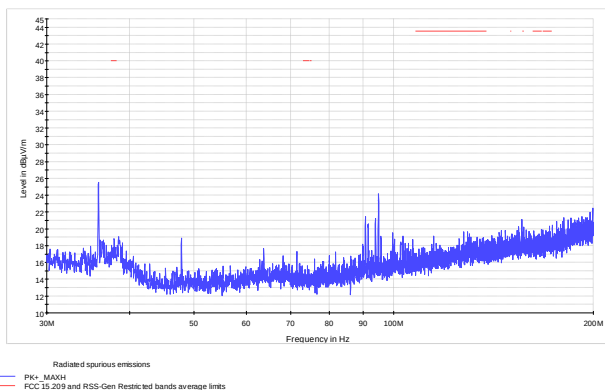


Figure 8.7-15: Radiated spurious emissions within 30–200 MHz on high channel

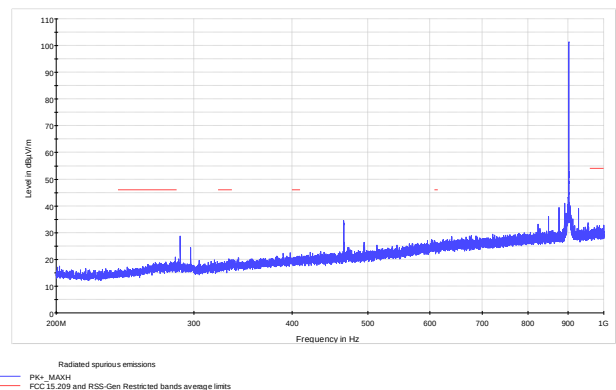


Figure 8.7-16: Radiated spurious emissions within 200–1000 MHz on low channel

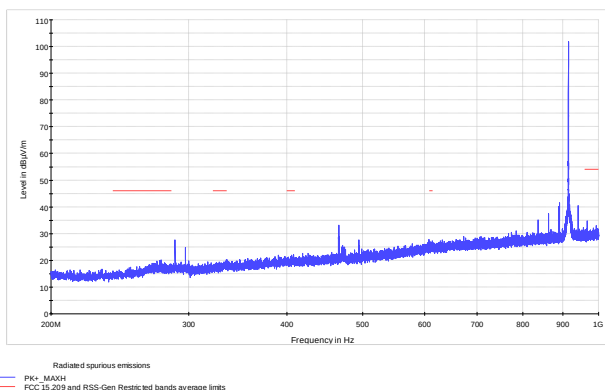


Figure 8.7-17: Radiated spurious emissions within 200–1000 MHz on mid channel

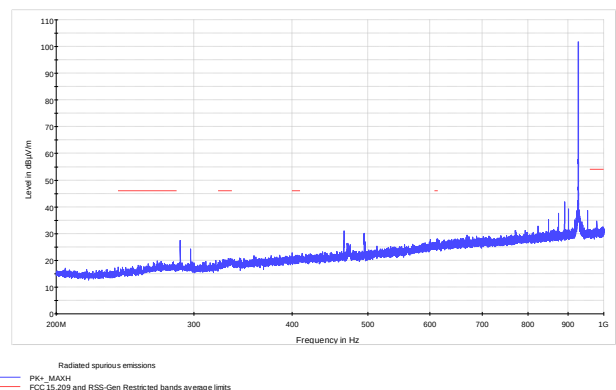


Figure 8.7-18: Radiated spurious emissions within 200–1000 MHz on high channel

Test data, continued

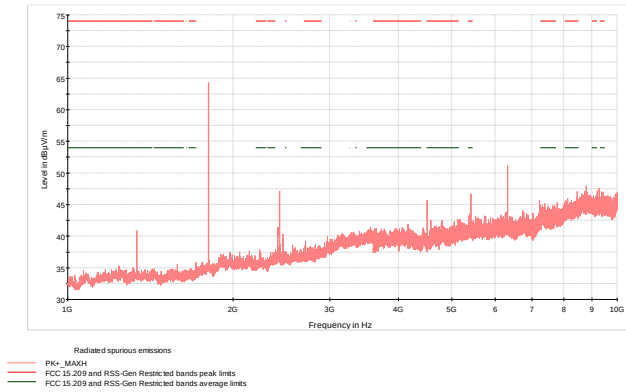


Figure 8.7-19: Radiated spurious emissions within 1–10 GHz on low channel

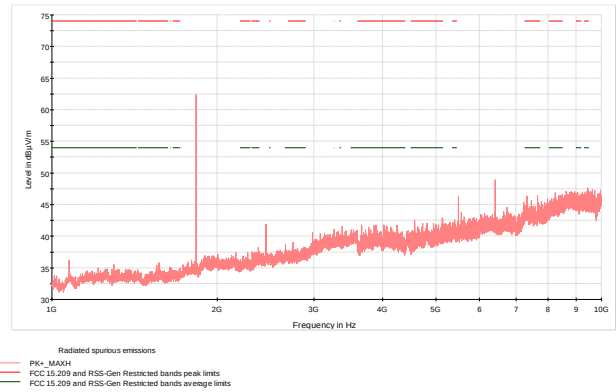


Figure 8.7-20: Radiated spurious emissions within 1–10 GHz on mid channel

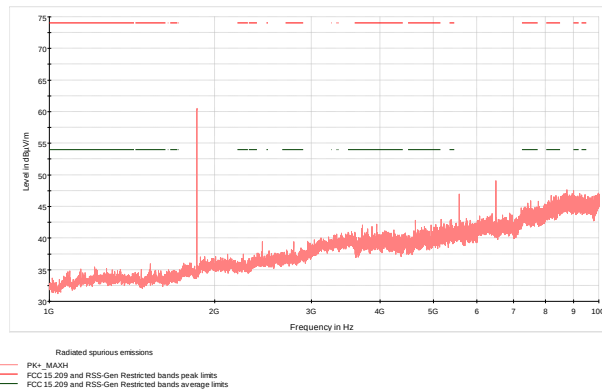


Figure 8.7-21: Radiated spurious emissions within 1–10 GHz on high channel

Section 9 EUT photos

9.1 External photos



Figure 9.1-1: Top view photo



Figure 9.1-2: Bottom view photo



Figure 9.1-3: Antenna port side view photo



Figure 9.1-4: I/O side view photo



Figure 9.1-5: Side view photo



Figure 9.1-6: Side view photo

End of the test report