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RADIO TEST REPORT

Report ID:
REP029561

Project number:
PRJ52103466

Type of assessment:
Final product testing

Type of radio equipment:
Spread Spectrum/Digital Device (902–928 MHz)

Equipment class:
DSS, DTS

Applicant:
Eleven-X Inc.

Description of product:
SPS-X Surface Mount Sensor (Second Generation), SPS-X Subsurface Sensor (Second Generation)

Model(s)/HVIN(s):
PRK002001 rev A, PRK001002 rev A

Product marketing name (PMN):
SPS-X

FCC identifier:
FCC ID: 2AOX5PRK002001

ISED certification number:
IC: 22369-PRK002001

Specifications:

- FCC 47 CFR Part 15 Subpart C, §15.247
- RSS-247, Issue 3, August 2023, Section 5

Date of issue: April 7, 2024

Tarek Elkholy, EMC/RF Specialist
Tested by

Tarek Elkholy
Signature

Ketav Jani, EMC/RF Specialist
Reviewed by

Signature

Lab locations

Company name	Nemko Canada Inc.			
Facilities	*Ottawa site:* 303 River Road Ottawa, Ontario Canada K1V 1H2 Tel: +1 613 737 9680 Fax: +1 613 737 9691		*Montréal site:* 292 Labrosse Avenue Pointe-Claire, Québec Canada H9R 5L8 Tel: +1 514 694 2684 Fax: +1 514 694 3528	*Cambridge site:* 1-130 Saltsman Drive Cambridge, Ontario Canada N3E 0B2 Tel: +1 519 650 4811
Test site identifier	**Organization**	**Ottawa**	**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.

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
RSS-247, Issue 3, August 2023, 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
RSS-Gen, Issue 5, April 2018	General Requirements for Compliance of Radio Apparatus
ANSI C63.10 v2013	American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices

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.
Determining compliance is based on the results of the compliance measurement, not taking into account measurement uncertainty, in accordance with section 1.3 of ANSI C63.10 v2013.

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
REP029561	April 7, 2024	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 Model variant declaration

As declared by the applicant, the EUT model PRK002001 rev A has been chosen to be representative for the other model in the model family. The model family, and the description of the variations, are as follows:
PRK001002 rev A is the variant.
Both models contain the exact same radio module and antenna, the only difference is the non-conductive area around the antenna, only for different enclosure installation requirements.
The radiated emissions tests were performed for both variants, the worst-case test data are included in this report.

2.4 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 Information provided by the applicant

4.1 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.

4.2 FCC Applicant / Manufacturer

Applicant name	Eleven-X Inc.
Applicant address	375 Hagey Blvd, Suite 311, Waterloo, ON N2L 6R5, Canada
Manufacturer name	Same as applicant
Manufacturer address	Same as applicant

4.3 ISED Applicant

Applicant name	Eleven-X Inc.
Applicant address	460 Phillip Street, Suite 300, Waterloo, ON N2L 5J2, Canada

4.4 EUT information

Product description	SPS-X Surface Mount Sensor (Second Generation)
Model / HVIN	PRK002001 rev A, PRK001002 rev A
Serial number	70B3B514900B5FF5 (radiated sample) 70B3B514900B5FEA (conducted sample)
Power supply requirements	Battery: 3.6 V(DC)
Product description and theory of operation	The eleven smart parking sensor is an innovative patent-pending LoRaWAN®-based device that utilizes multiple technologies including magnetic sensing, 60 GHz radar, Bluetooth and AI that provides: • Real-time stall occupancy status and monitoring • Industry leading accuracy based on multiple sensing technologies backed by advanced AI • Designed and engineered for maximum reliability and robustness • Leverages standards-based low power wireless technology • Ultra-long battery life The rugged sensor is designed to function in all conditions. This variant is installed on the parking surface. Surface installation is done using a combination of high strength adhesive and screws. For details see the eleven-x installation guide. The sensor sends parking events over LoRaWAN to the eleven-x SPS analytics platform where the data provides key analytics and insight to help parking manager understand the usage of the parking assets.

4.5 Radio technical information

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
Channel width	Narrow (FHSS - 125 kHz), Wide (DTS - 500 kHz)
Frequency Min	902.3 MHz (narrow), 903.0 MHz (wide)
Frequency Max	914.9 MHz(narrow), 914.2 MHz (wide)
RF power Max (W), Conducted	141.3 mW and (21.5 dBm)
Measured BW (kHz), 99% OBW	126.4 kHz (narrow), 511.4 kHz (wide)
Type of modulation	LoRa (Chirp-Spread-Spectrum)
Emission classification	F1D, W7D
Transmitter spurious, dBµV/m @ 3 m	Peak, 47.6 dBµV/m @ 9.4 GHz
Antenna information	Manufacturer: Eleven-x Inc. Type: Monopole MN: PCB-2001931 Rev2 Connector type: Spring Contact Peak gain: 2.4 dBi

4.6 EUT setup details

4.6.1 Radio exercise details

Operating conditions	Using a laptop loaded with (mcu_cmdr_mini) application, USB cable and Eleven-X Debugger rev4 (PCB-180515-004), and via Tag connect interface at the EUT side, the EUT was controlled and forced into either continuous transmission or hopping mode at power level of 22 dBm.
Transmitter state	Transmitter set into continuous mode.

4.6.2 EUT setup configuration

Table 4.6-1: *EUT interface ports*

Description	Qty.
Tag connect, control port	1

Table 4.6-2: *Support equipment*

Description	Brand name	Model, Part number, Serial number, Revision level
Laptop	Dell	MN: Inspiron P93G, DPN: R08RD A00 DPC
Mini Debugger	Eleven-X	MN: Debugger rev4 (PCB-180515-004), SN: 017A1F86

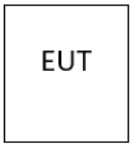


Figure 4.6-1: *Radiated testing block diagram*

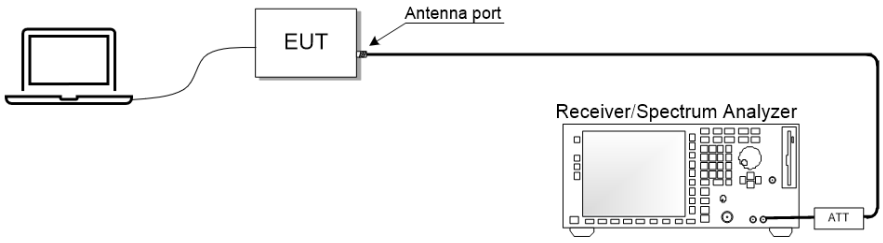


Figure 4.6-2: *Antenna port testing block diagram*

Section 5 Summary of test results

5.1 Testing period

Test start date	February 26, 2024	Test end date	February 28, 2024

5.2 Sample information

Receipt date	February 26, 2024	Nemko sample ID number(s)	PRJ521034660001, PRJ521034660002, PRJ521034660003, PRJ521034660004

5.3 FCC test results

Table 5.3-1: *FCC requirements results*

Part	Test description	Verdict
Generic requirements		
§15.207(a)	Conducted limits	Not applicable
§15.31(e)	Variation of power source	Not applicable
§15.31(m)	Number of tested frequencies	Pass
§15.203	Antenna requirement	Pass
§15.247(c)(1)	Fixed point-to-point operation with directional antenna gains greater than 6 dBi	Not applicable
§15.247(c)(2)	Transmitters operating in the 2400–2483.5 MHz band that emit multiple directional beams	Not applicable
§15.247(d)	Spurious emissions	Pass
§15.247(f)	Time of occupancy for hybrid systems	Pass
FHSS specific requirements		
§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
DTS specific requirements		
§15.247(a)(2)	Minimum 6 dB bandwidth	Pass
§15.247(b)(3)	Maximum peak output power	Pass
§15.247(e)	Power spectral density	Pass

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

5.4 ISED test results

Table 5.4-1: *ISED requirements results*

Part	Test description	Verdict
Generic requirements		
RSS-Gen, 7.3	Receiver radiated emission limits[1]	Not applicable
RSS-Gen, 7.4	Receiver conducted emission limits[1]	Not applicable
RSS-Gen, 6.9	Operating bands and selection of test frequencies	Pass
RSS-Gen, 8.8	AC powerline conducted emissions limits	Not applicable
RSS-247, 5.5	Unwanted emissions	Pass
RSS-247, 5.3	Hybrid Systems	
RSS-247, 5.3 (a)	Digital modulation turned off	Pass
RSS-247, 5.3 (b)	Frequency hopping turned off	Pass
FHSS specific requirements		
RSS-247, 5.1 (b)	Minimum channel spacing	Pass
RSS-247, 5.1 (c)	Number of hopping channels, dwell time and occupied channel bandwidth in the 902–928 MHz band	Pass
RSS-247, 5.1 (d)	Number of hopping channels, dwell time and occupied channel bandwidth in the 2400–2483.5 MHz band	Not applicable
RSS-247, 5.1 (e)	Number of hopping channels, dwell time and occupied channel bandwidth in the 5725–5850 MHz band	Not applicable
RSS-247, 5.4 (a)	Transmitter output power and e.i.r.p. requirements in the 902–928 MHz band	Pass
RSS-247, 5.4 (b)	Transmitter output power and e.i.r.p. requirements in the 2400–2483.5 MHz band	Not applicable
RSS-247, 5.4 (c)	Transmitter output power and e.i.r.p. requirements in the 5725–5850 MHz	Not applicable
RSS-247, 5.4 (e)	Transmitter e.i.r.p. requirements for point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band	Not applicable
RSS-247, 5.4 (f)	Transmitter requirements for operation in the 2400–2483.5 MHz band with multiple directional beams	Not applicable
DTS specific requirements		
RSS-247, 5.2 (a)	Minimum 6 dB bandwidth	Pass
RSS-247, 5.2 (b)	Maximum power spectral density	Pass
RSS-247, 5.4 (d)	Transmitter output power and e.i.r.p. requirements for systems employing digital modulation techniques	Pass
RSS-247, 5.4 (e)	Transmitter e.i.r.p. requirements for point-to-point systems in 2400–2483.5 MHz and 5725–5850 MHz band	Not applicable
RSS-247, 5.4 (f)	Transmitter requirements for operation in the 2400–2483.5 MHz band with multiple directional beams	Not applicable

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

Section 6 Test equipment

6.1 Test equipment list

Table 6.1-1: *Equipment list*

Equipment	Manufacturer	Model no.	Asset no.	Cal cycle	Next cal.
3 m EMI test chamber	TDK	SAC-3	FA003012	1 year	January 22, 2025
Flush mount turntable	SUNAR	FM2022	FA003006	—	NCR
Controller	SUNAR	SC110V	FA002976	—	NCR
Antenna mast	SUNAR	TLT2	FA003007	—	NCR
AC Power source	Chroma	61605	FA003034	—	NCR
Receiver/spectrum analyzer	Rohde & Schwarz	ESR26	FA002969	1 year	May 9, 2024
Bilog antenna (30–2000 MHz)	SUNAR	JB1	FA003010	1 year	July 14, 2024
Horn antenna (1–18 GHz)	ETS Lindgren	3117	FA002911	1 year	May 31, 2024
Preamp (1–18 GHz)	ETS Lindgren	124334	FA002956	1 year	March 27, 2024
Spectrum analyzer	Rohde & Schwarz	FSW43	FA002971	1 year	November 30, 2024
Vector signal generator	Rohde & Schwarz	SMW200A	FA002970	1 Year	December 8, 2024
Notch filter (902-928 MHz)	Microwave circuits	N03916M1	FA003032	1 year	NCR
50 Ω coax cable	Huber + Suhner	None	FA003047	1 year	July 27, 2024
50 Ω coax cable	Huber + Suhner	None	FA003402	1 year	July 27, 2024
50 Ω SMA coaxial attenuator, DC-18 GHz, 5 Watts, 20 dB	Weinschel	WA7	FA003495	1 year	Feb 20, 2025
50 Ω coax cable	Huber + Suhner	None	FA003056	1 year	Feb 20, 2025

Note: NCR - no calibration required
All equipment related to the contribution of measurement has been included in this list. Such items include, but are not limited to, cables, attenuators, directional couplers, and pre-amps.

Table 6.1-2: *Automation software details*

Test description	Manufacturer of Software	Details
Radio/EMC test software	Rohde & Schwarz	EMC32, Software for EMC Measurements, Version 10.60. 00

Table 6.1-3: *Measurement uncertainty calculations based on equipment list*

Measurement	Measurement uncertainty, ±dB
Radiated spurious emissions (30 MHz to 1 GHz)	4.27
Radiated spurious emissions (1 GHz to 6 GHz)	4.74
Radiated spurious emissions (6 GHz to 18 GHz)	5.04
RF Output power measurement using Spectrum Analyzer	0.71
Conducted spurious emissions	0.90
Other antenna port measurements	0.81

Notes: UKAS Lab 34, TIA-603 and ETSI TR 100 028-1&2 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 calculations assume a coverage factor of K = 2 with 95% certainty.

Section 7 Testing data

7.1 Variation of power source

7.1.1 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.

7.1.2 Test summary

Verdict	Pass		
Test date	February 26, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.1.3 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.
e) For battery-operated equipment, the equipment tests shall be performed using a variable power supply.

7.1.4 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

7.2 Number of frequencies

7.2.1 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 7.2-1: *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.

7.2.2 Test summary

Verdict	Pass		
Test date	February 26, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.2.3 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:

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.

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:

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.

7.2.4 Test data

Table 7.2-2: *Test channels selection – 125 kHz signal*

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

Table 7.2-3: *Test channels selection – 500 kHz signal*

Start of Frequency range, MHz	End of Frequency range, MHz	Frequency range bandwidth, MHz	Low channel, MHz	Mid channel, MHz	High channel, MHz
902	928	26	903.0	907.8	914.2

7.3 Antenna requirement

7.3.1 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.

7.3.2 Test summary

Verdict	Pass		
Test date	February 26, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.3.3 Observations, settings and special notes

None

7.3.4 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 7.3-1: *Antenna information*

Antenna type	Manufacturer	Model number	Maximum gain	Connector type
Monopole	Eleven-x Inc.	PCB-2001931 Rev2	2.4 dBi	Spring Contact

7.4 Frequency Hopping Systems requirements, 900 MHz operation

7.4.1 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. 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 7.4-1: *Summary of the basic requirements*

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

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.

b. FHSs 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.

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.

7.4.2 Test summary

Verdict	Pass		
Test date	February 28, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.4.3 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

7.4.4 Test data

Table 7.4-2: *20 dB bandwidth results*

Frequency, MHz	20 dB bandwidth, kHz
902.3	144.9
908.7	143.9
914.9	144.1

Test data, continued

Table 7.4-3: *99% occupied bandwidth results*

Frequency, MHz	99% occupied bandwidth, kHz
902.3	126.4
908.7	125.9
914.9	126.1

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

Table 7.4-4: *Carrier frequency separation results*

Carrier frequency separation, kHz	Minimum limit, kHz	Margin, kHz
202	145	57

Notes: 20 dB bandwidth is 145 kHz

Table 7.4-5: *Number of hopping frequencies results*

Number of hopping frequencies	Minimum limit	Margin
64	50	14

Table 7.4-6: *Average time of occupancy results*

Dwell time of each pulse, ms	Number of pulses within period	Total dwell time within period, ms	Limit, ms	Margin, ms
370	1	370	400	30

Notes: Measurement Period is 20 s

Figure 7.4-1: *20 dB bandwidth on low channel*

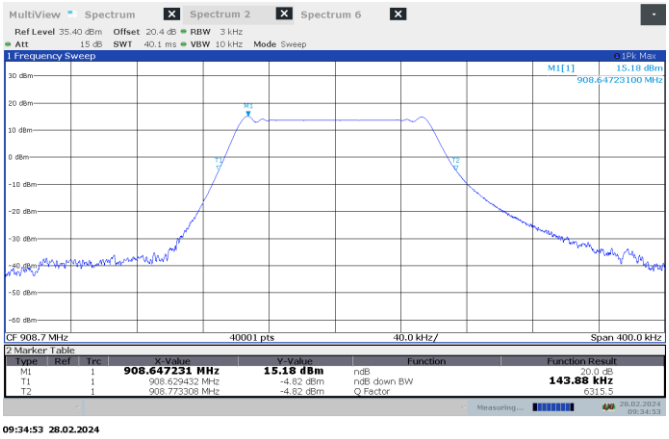


Figure 7.4-2: *20 dB bandwidth on mid channel*

Test data, continued

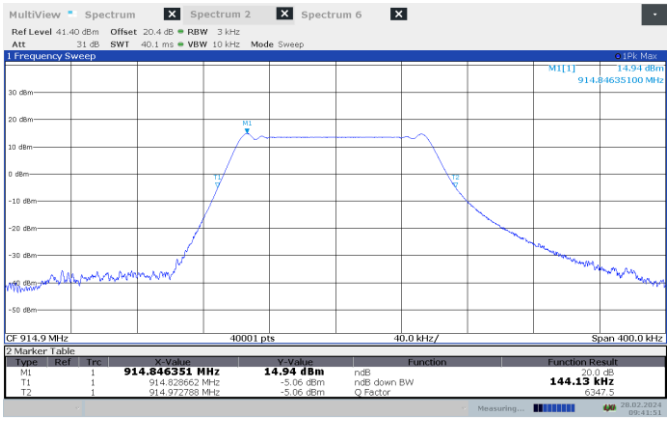


Figure 7.4-3: *20 dB bandwidth on high channel*

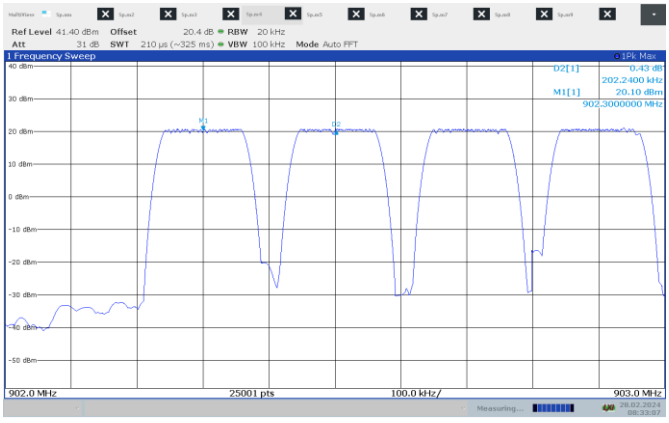


Figure 7.4-4: *Carrier frequency separation*

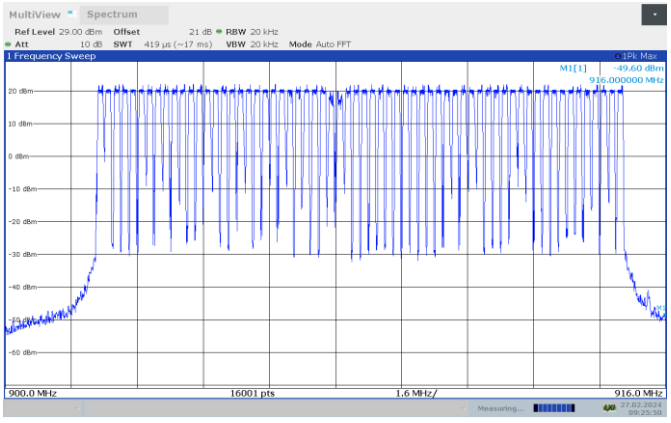


Figure 7.4-5: *Number of hopping channels*

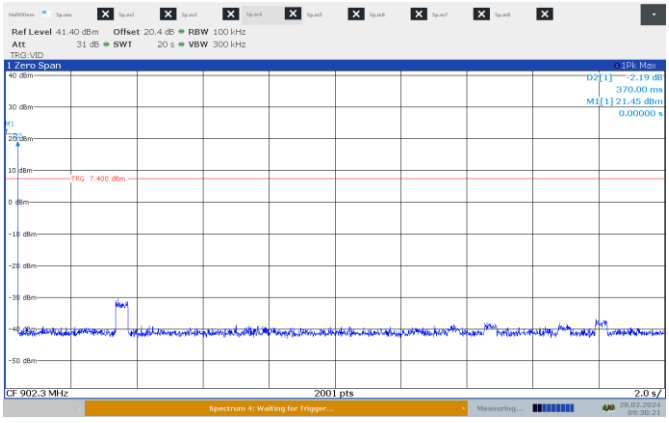


Figure 7.4-6: *Dwell time*

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

7.5.1 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.

7.5.2 Test summary

Verdict	Pass		
Test date	February 28, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.5.3 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:

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

7.5.4 Test data

Table 7.5-1: *Output power and EIRP results*

Frequency, MHz	Output power, dBm	Output power limit, dBm	Margin, dB	Antenna gain, dBi	EIRP, dBm	EIRP limit, dBm	EIRP margin, dB
902.3	21.5	30.0	8.5	2.4	23.9	36.0	12.1
908.7	21.5	30.0	8.5	2.4	23.9	36.0	12.1
914.9	21.3	30.0	8.7	2.4	23.7	36.0	12.3

Notes: EIRP = Output power + Antenna gain

Test data, continued

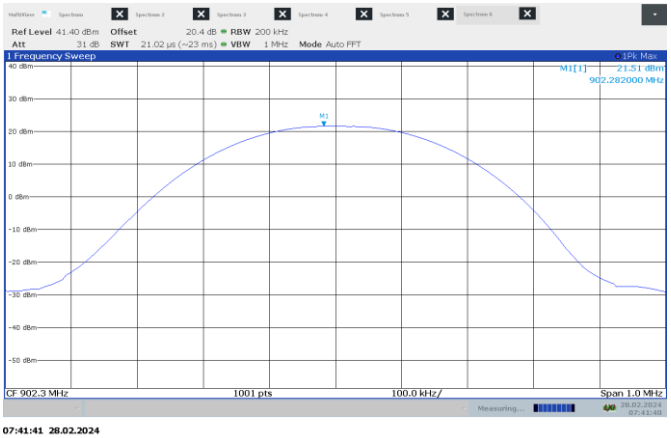


Figure 7.5-1: *Output power on low channel*

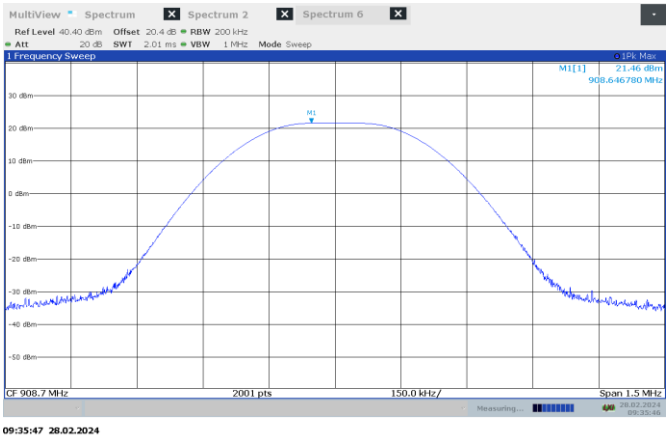


Figure 7.5-2: *Output power on mid channel*

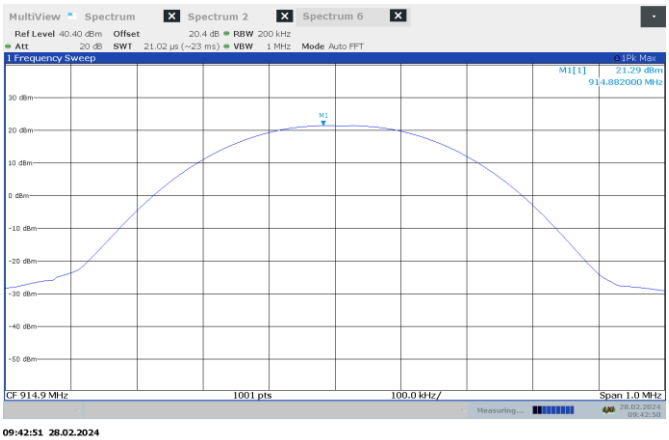


Figure 7.5-3: *Output power on high channel*

7.6 Minimum 6 dB bandwidth for DTS systems

7.6.1 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:

(2) 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.

RSS-247, Clause 5.2:

DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400-2483.5 MHz:

a. The minimum 6 dB bandwidth shall be 500 kHz.

RSS-Gen, Clause 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).

7.6.2 Test summary

Verdict	Pass		
Test date	February 28, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.6.3 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	3 MHz
Detector mode	Peak
Trace mode	Max Hold

7.6.4 Test data

Table 7.6-1: *99% occupied bandwidth results*

Modulation	Frequency, MHz	99% occupied bandwidth, kHz
LoRa (Chirp-Spread-Spectrum)	903.0	508.2
	907.8	511.4
	914.2	509.4

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

Table 7.6-2: *6 dB bandwidth results*

Modulation	Frequency, MHz	6 dB bandwidth, MHz	Minimum limit, MHz	Margin, MHz
LoRa (Chirp-Spread-Spectrum)	903.0	0.631	0.500	0.131
	907.8	0.635	0.500	0.135
	914.2	0.628	0.500	0.128

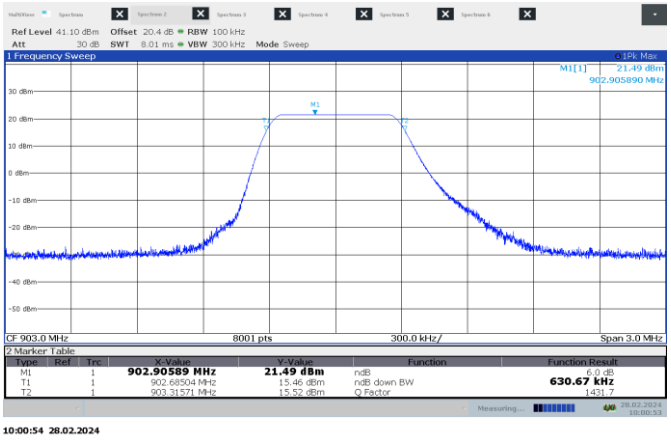


Figure 7.6-1: *6 dB bandwidth on low channel*

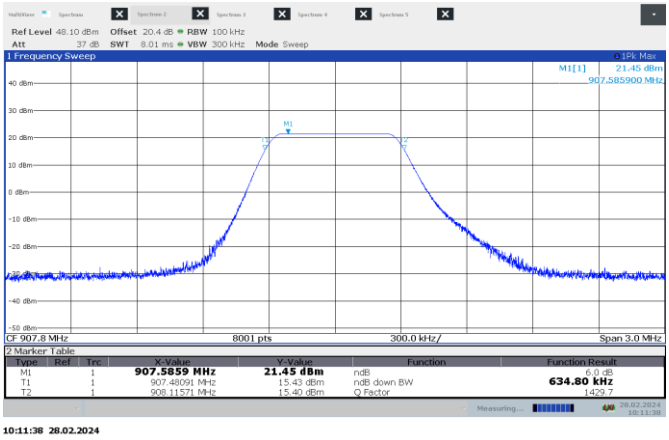


Figure 7.6-2: *6 dB bandwidth on mid channel*

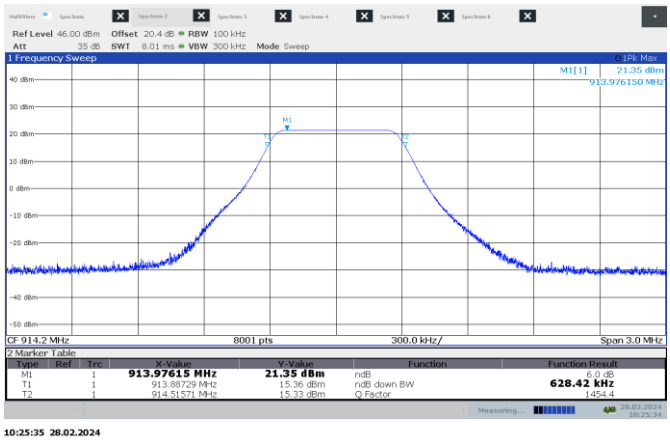


Figure 7.6-3: *6 dB bandwidth on high channel*

Test data, continued

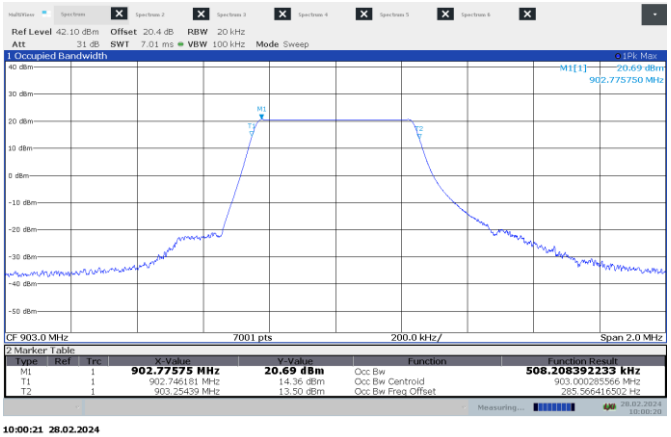


Figure 7.6-4: *99% occupied bandwidth on low channel*

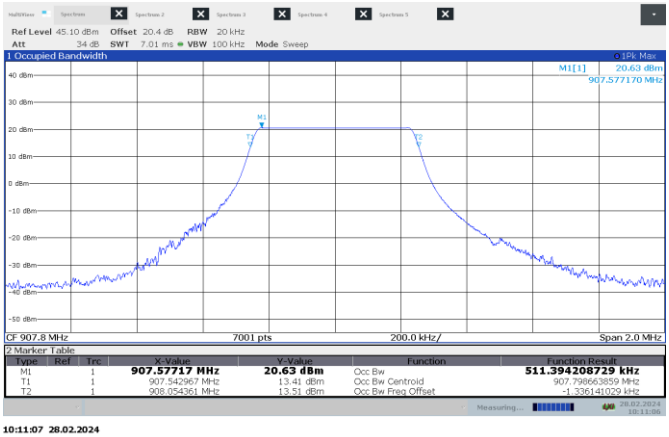


Figure 7.6-5: *99% occupied bandwidth on mid channel*

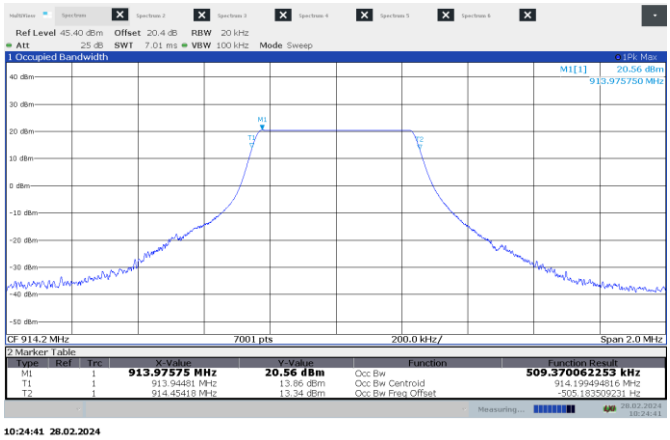


Figure 7.6-6: *99% occupied bandwidth on high channel*

7.7 Transmitter output power and e.i.r.p. requirements for DTS in 900 MHz

7.7.1 References, definitions and limits

FCC §15.247:

(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.

RSS-247, Clause 5.4:

Devices shall comply with the following requirements, where applicable:

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.

7.7.2 Test summary

Verdict	Pass		
Test date	February 28, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.7.3 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	1 MHz
Video bandwidth	≥3 × RBW
Frequency span	5 MHz
Detector mode	Peak
Trace mode	Max Hold

7.7.4 Test data

Table 7.7-1: *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
903.0	21.5	30.0	8.5	2.4	23.9	36.0	12.1
907.8	21.5	30.0	8.5	2.4	23.9	36.0	12.1
914.2	21.4	30.0	8.6	2.4	23.8	36.0	12.2

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

Test data, continued

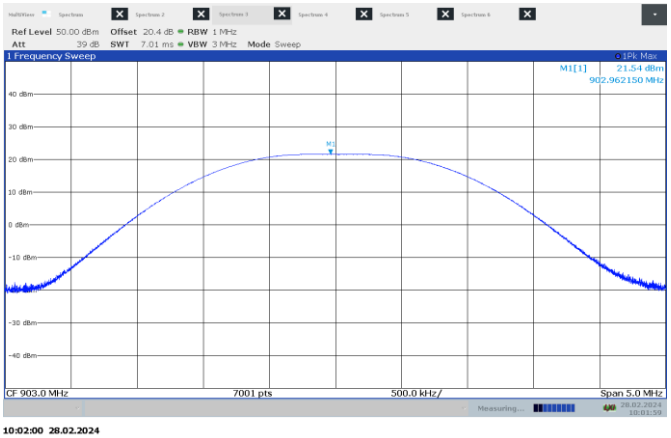


Figure 7.7-1: *Output power on low channel*

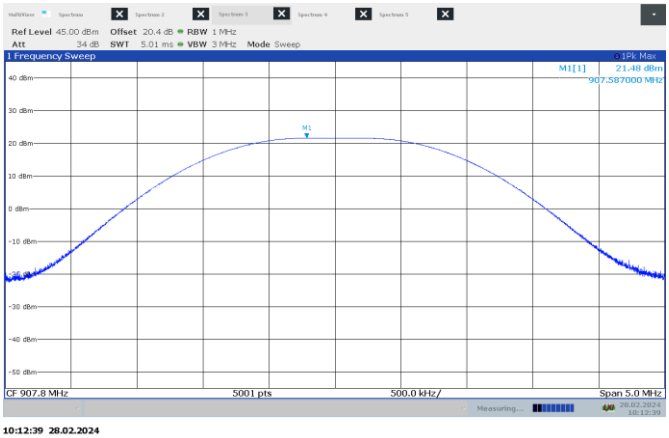


Figure 7.7-2: *Output power on mid channel*

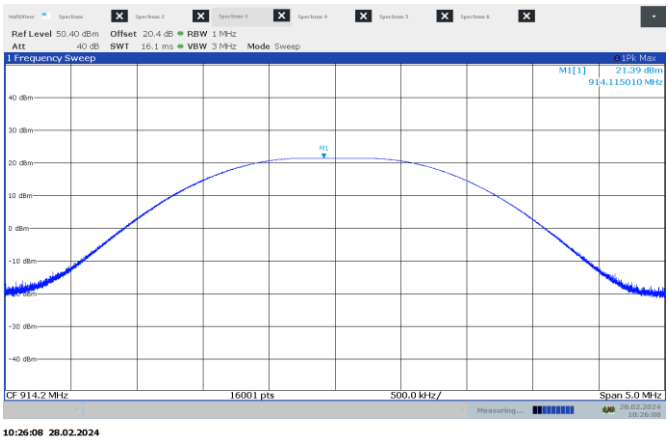


Figure 7.7-3: *Output power on high channel*

7.8 Spurious (out-of-band) unwanted emissions

7.8.1 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.

RSS-Gen:

8.9 Except where otherwise indicated in the applicable RSS, radiated emissions shall comply with the field strength limits shown in table below.

8.10 Restricted frequency bands are designated primarily for safety-of-life services (distress calling and certain aeronautical activities), certain satellite downlinks, radio astronomy and some government uses. The following conditions related to the restricted frequency bands apply:

a The transmit frequency, including fundamental components of modulation, of licence-exempt radio apparatus shall not fall within the restricted frequency bands.

b Unwanted emissions that fall into restricted frequency bands listed in table 7 shall comply with the limits specified in table below.

c Unwanted emissions that do not fall within the restricted frequency bands shall comply either with the limits specified in the applicable RSS or with those specified in table below.

Table 7.8-1: *FCC §15.209 and RSS-Gen – Radiated emission limits*

	Field strength of emissions		
Frequency, MHz	**µV/m**	**dBµV/m**	**Measurement distance, 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 7.8-2: *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 7.8-2 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 7.8-3: *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			

7.8.2 Test summary

Verdict	Pass		
Test date	February 26, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.8.3 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 average radiated measurements within restricted bands above 1 GHz:

Resolution bandwidth:	1 MHz
Video bandwidth:	3 MHz
Detector mode:	RMS
Trace mode:	Avergae

Spectrum analyser settings for conducted spurious emissions measurements:

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

7.8.4 Test data

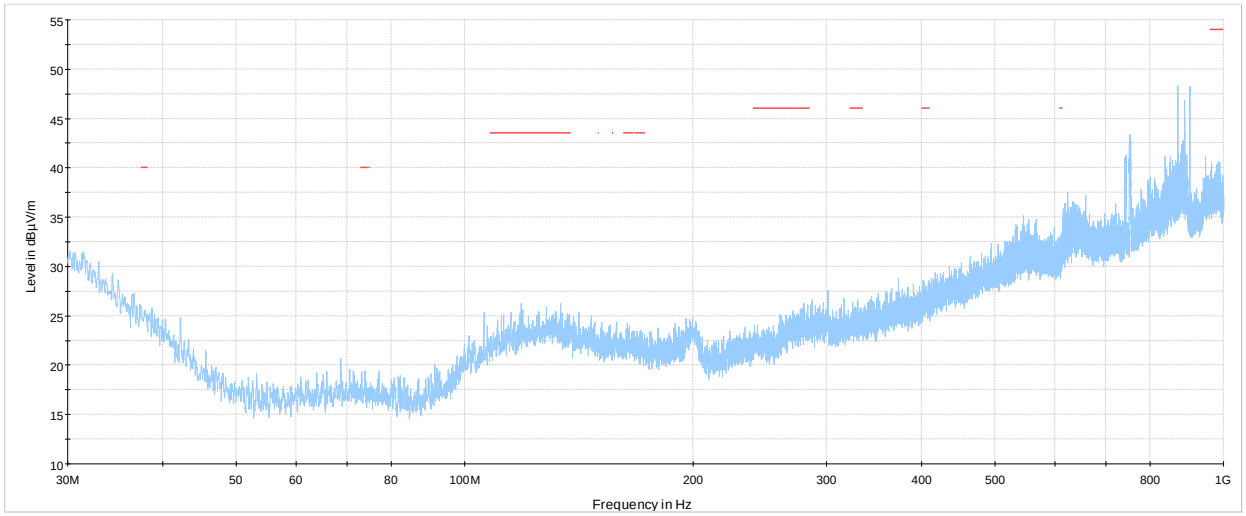


Figure 7.8-1: *Radiated spurious emissions 30-1000 MHz low channel, LoRA 125 kHz*

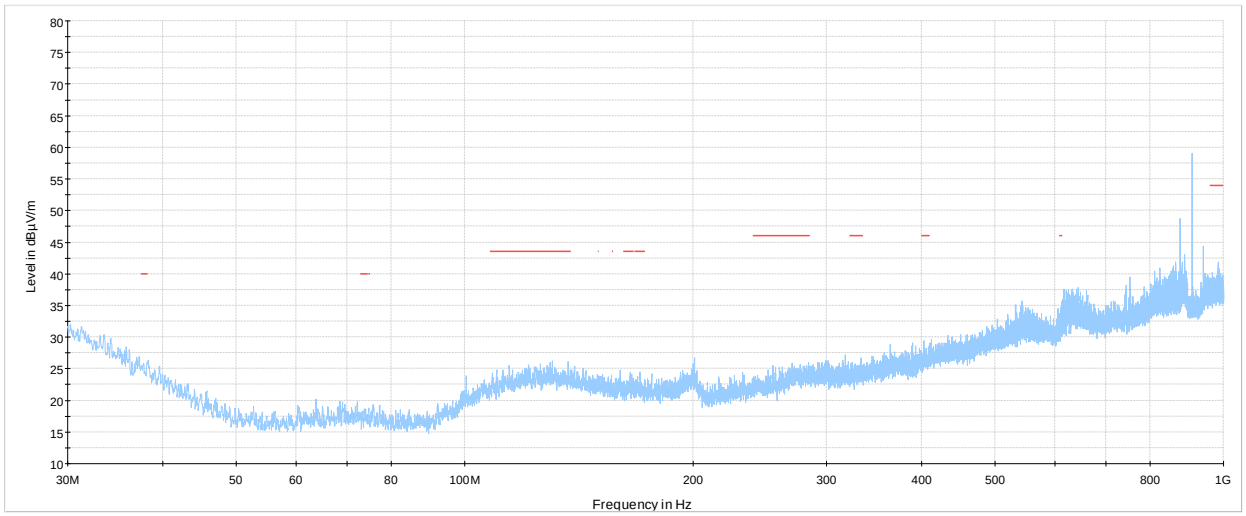


Figure 7.8-2: *Radiated spurious emissions 30-1000 MHz mid channel, LoRA 125 kHz*

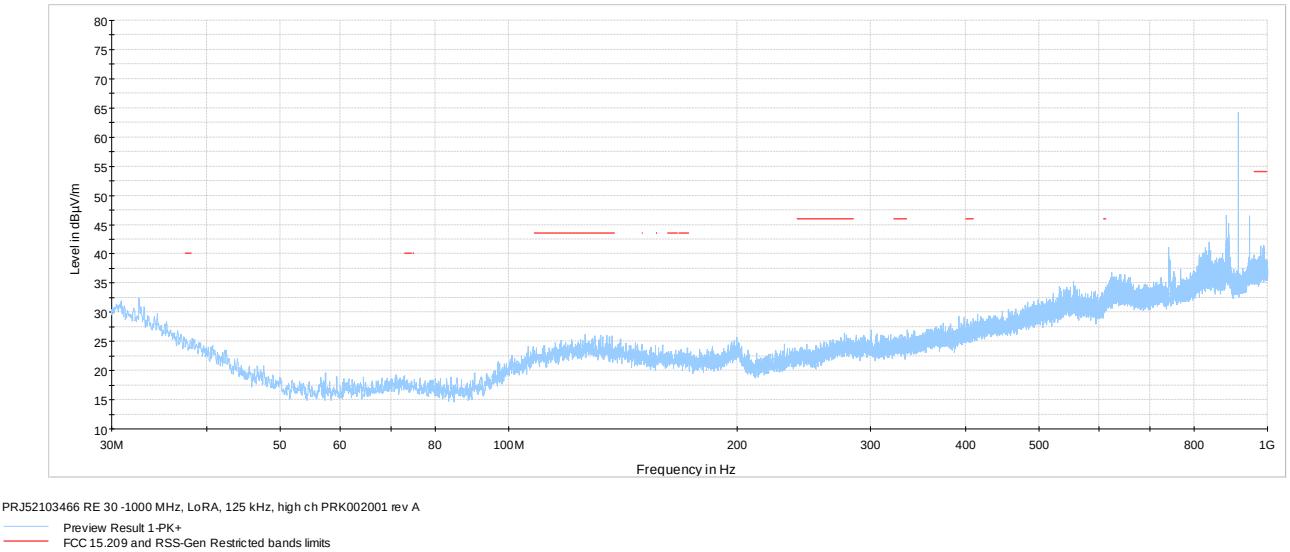


Figure 7.8-3: *Radiated spurious emissions 30-1000 MHz high channel, LoRA 125 kHz*

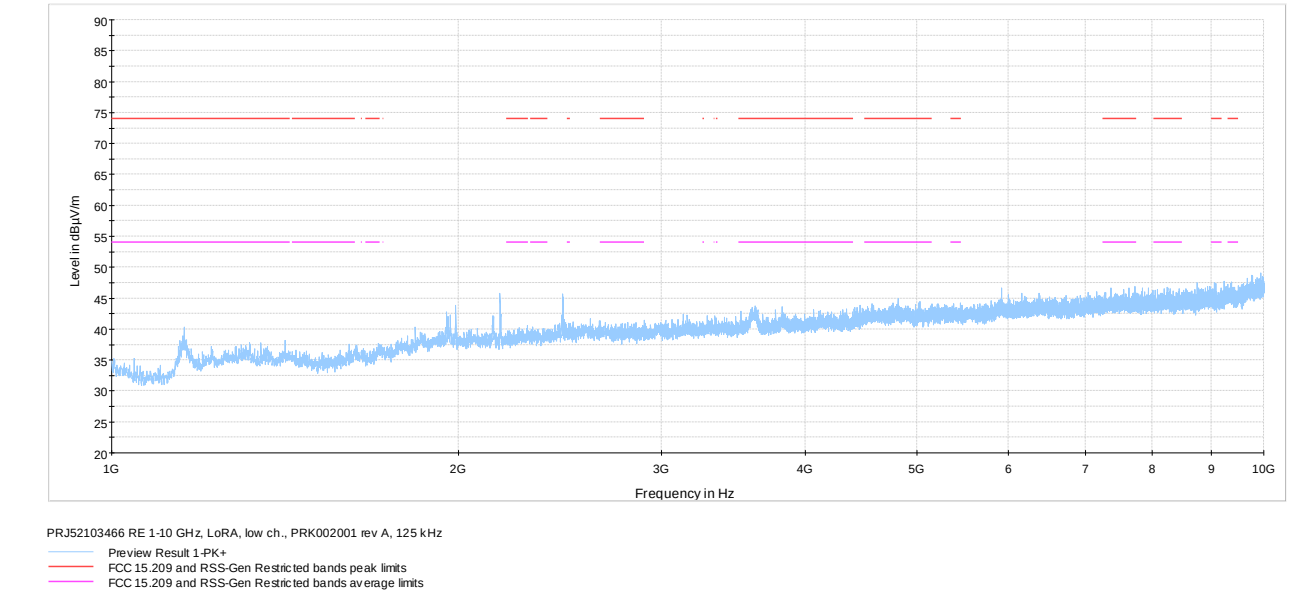
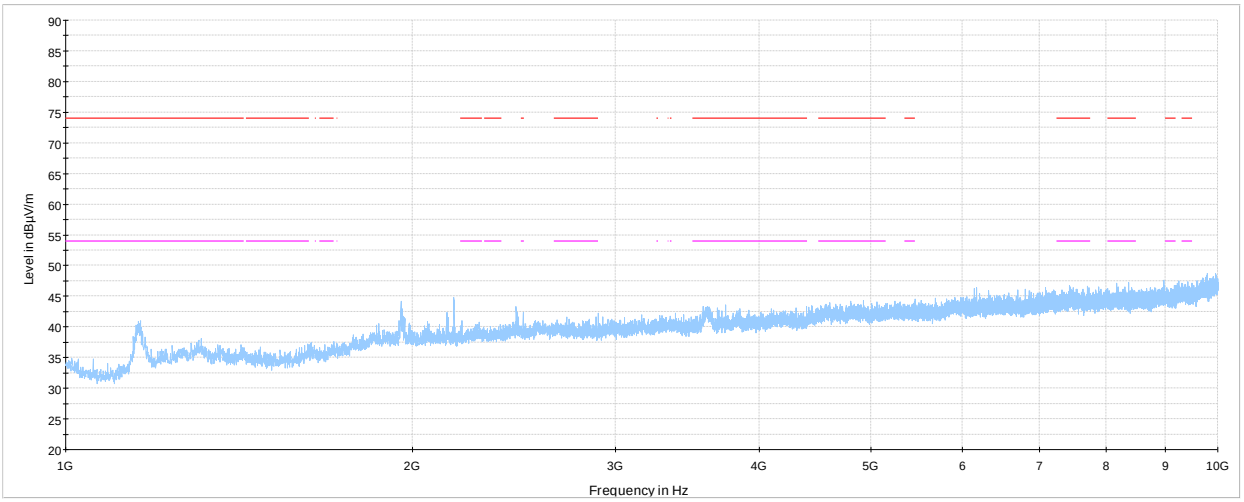


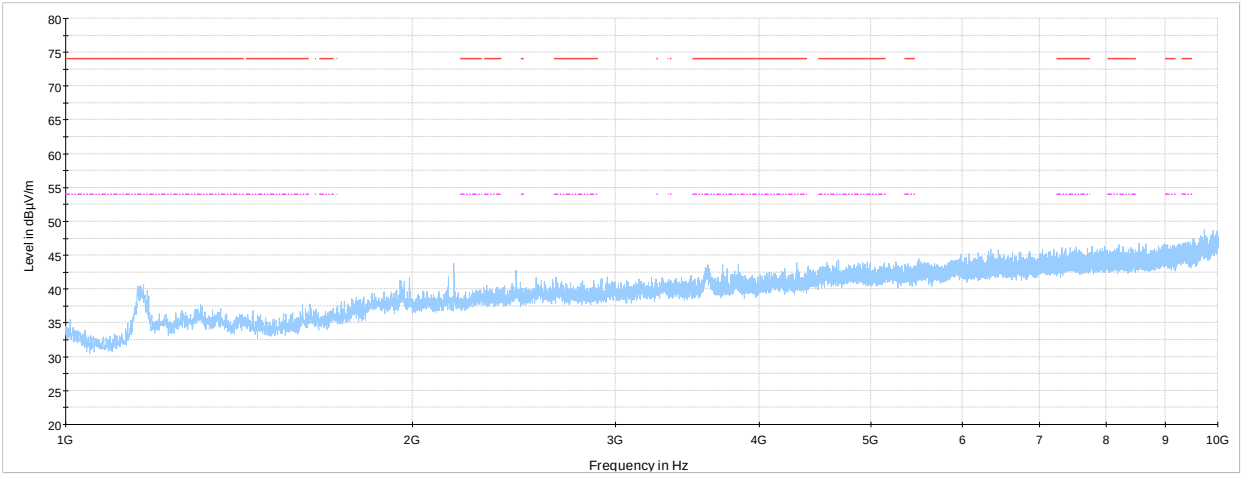
Figure 7.8-4: *Radiated spurious emissions 1-10 GHz low channel, LoRA 125 kHz*

Test data, continued



PRJ52103466 RE 1-10 GHz, LoRA, mid ch., PRK002001 rev A, 125 kHz
Preview Result 1-PK+
FCC 15.209 and RSS-Gen Restricted bands peak limits
FCC 15.209 and RSS-Gen Restricted bands average limits

Figure 7.8-5: *Radiated spurious emissions 1-10 GHz mid channel, LoRA 125 kHz*



PRJ52103466 RE 1-10 GHz, LoRA, high ch., PRK002001 rev A, 125 kHz
Preview Result 1-PK+
FCC 15.209 and RSS-Gen Restricted bands peak limits
FCC 15.209 and RSS-Gen Restricted bands average limits

Figure 7.8-6: *Radiated spurious emissions 1-10 GHz high channel, LoRA 125 kHz*

Test data, continued

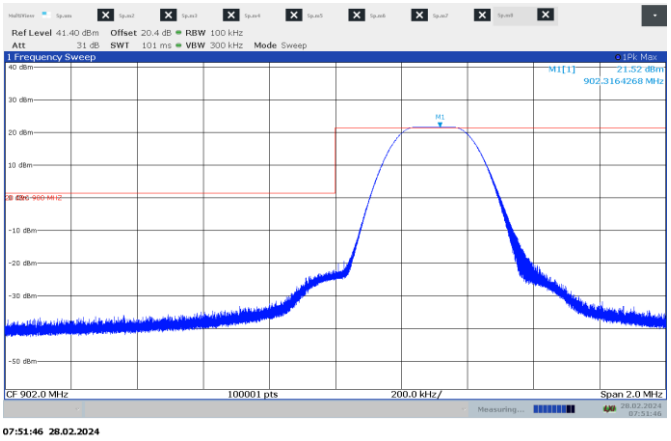


Figure 7.8-7: *Band edge spurious emissions at 902 MHz – Hopping OFF – low channel, LoRA 125 kHz*

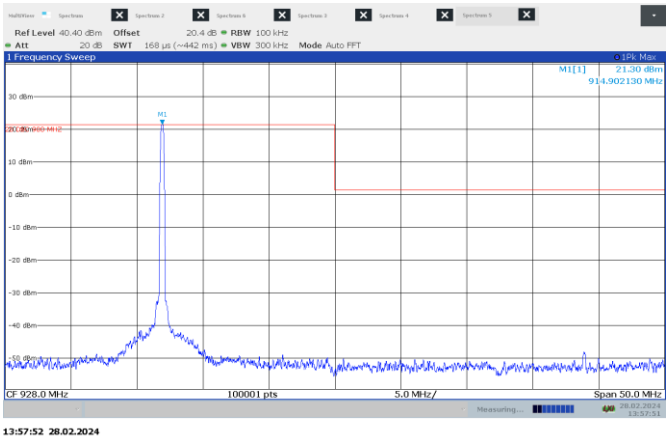


Figure 7.8-8: *Band edge spurious emissions at 928 MHz – Hopping OFF – high channel, LoRA 125 kHz*

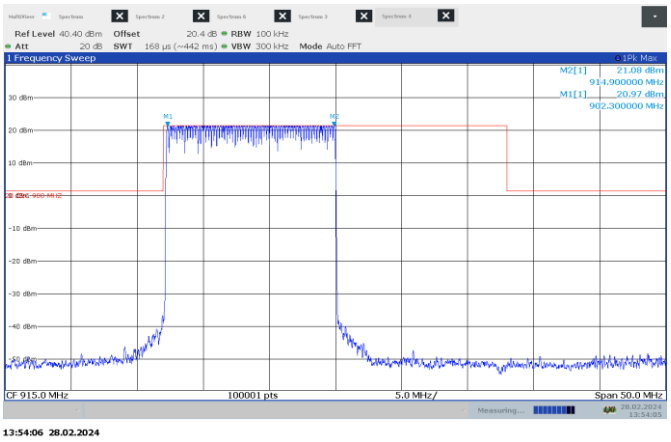


Figure 7.8-9: *Band edge spurious emissions at 902-928 MHz Peak – Hopping ON, LoRA 125 kHz*

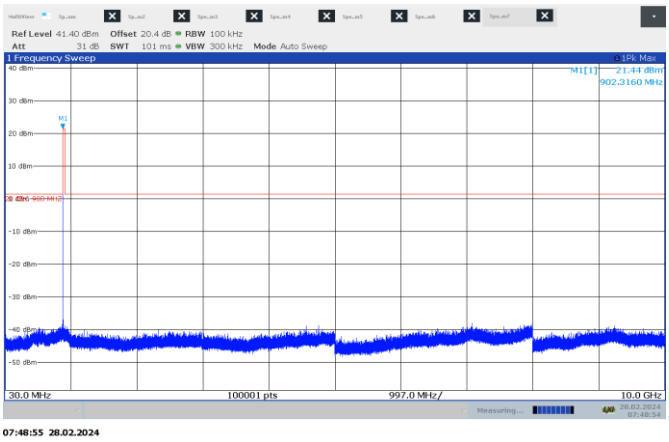


Figure 7.8-10: *Conducted spurious emissions on low channel, LoRA 125 kHz*

Test data, continued

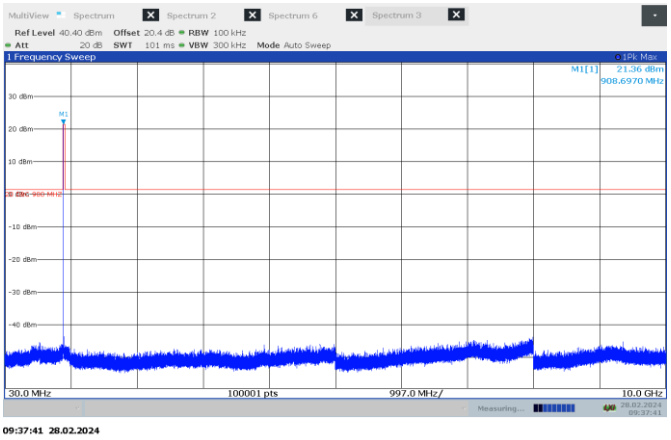


Figure 7.8-11: *Conducted spurious emissions on mid channel, LoRA 125 kHz*

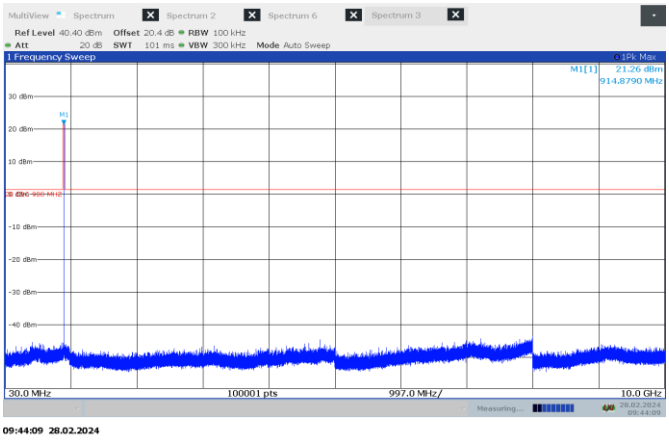


Figure 7.8-12: *Conducted spurious emissions on high channel, LoRA 125 kHz*

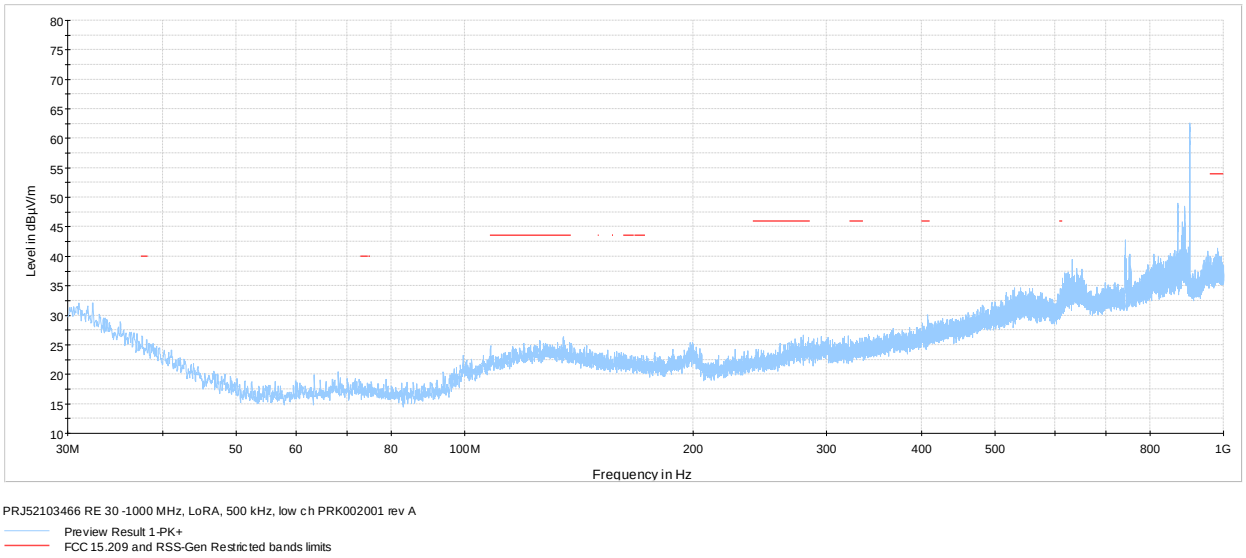


Figure 7.8-13: *Radiated spurious emissions 30-1000 MHz low channel, LoRA 500 kHz*

Test data, continued

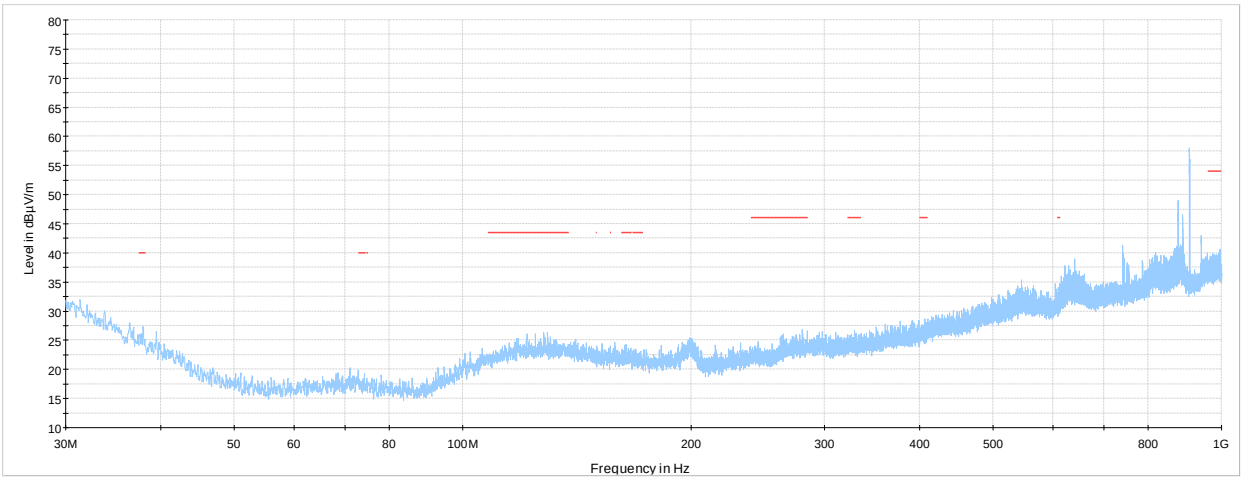


Figure 7.8-14: *Radiated spurious emissions 30-1000 MHz mid channel, LoRA 500 kHz*

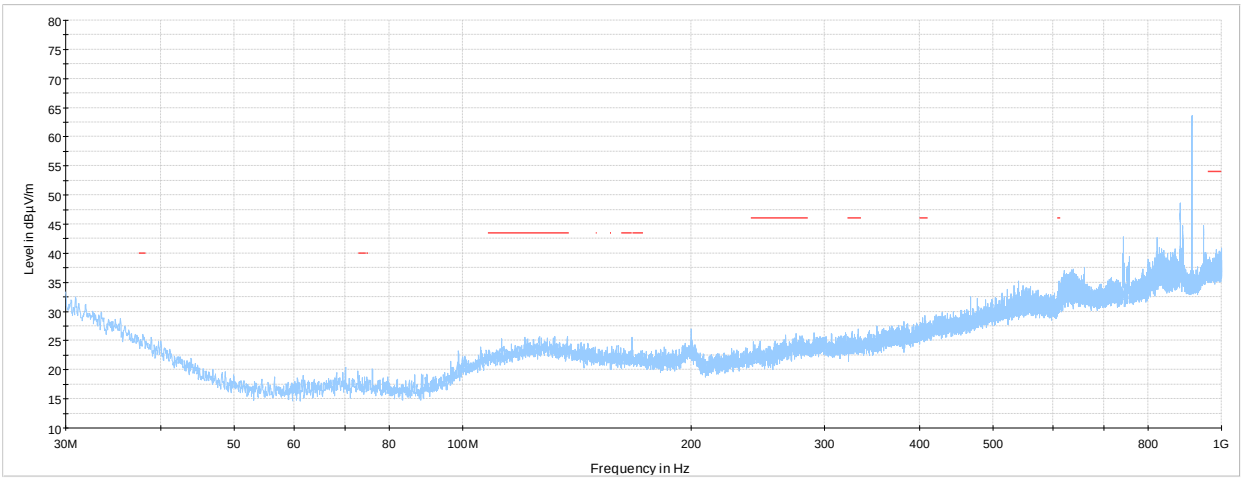


Figure 7.8-15: *Radiated spurious emissions 30-1000 MHz high channel, LoRA 500 kHz*

Test data, continued

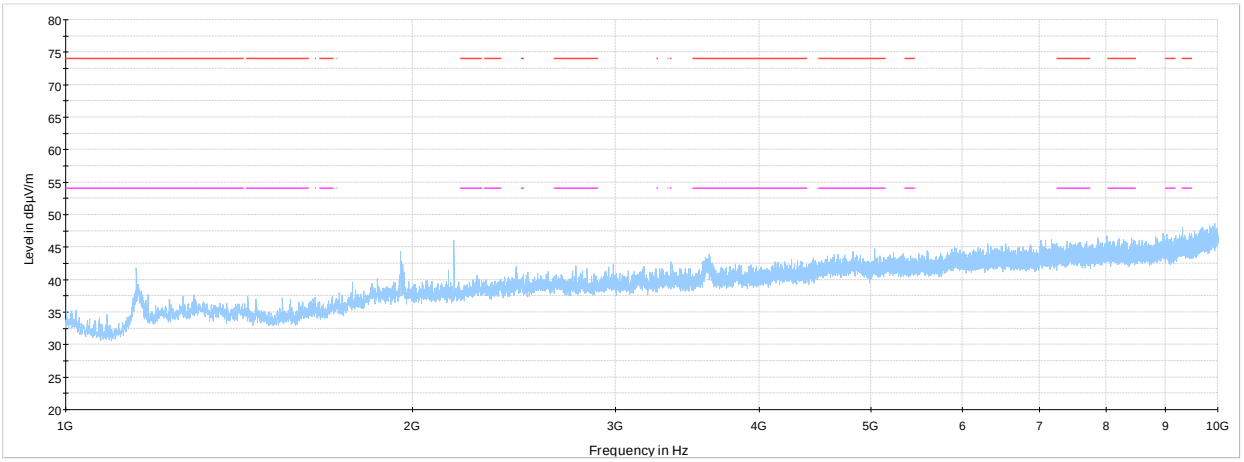


Figure 7.8-16: *Radiated spurious emissions 1-10 GHz low channel, LoRA 500 kHz*

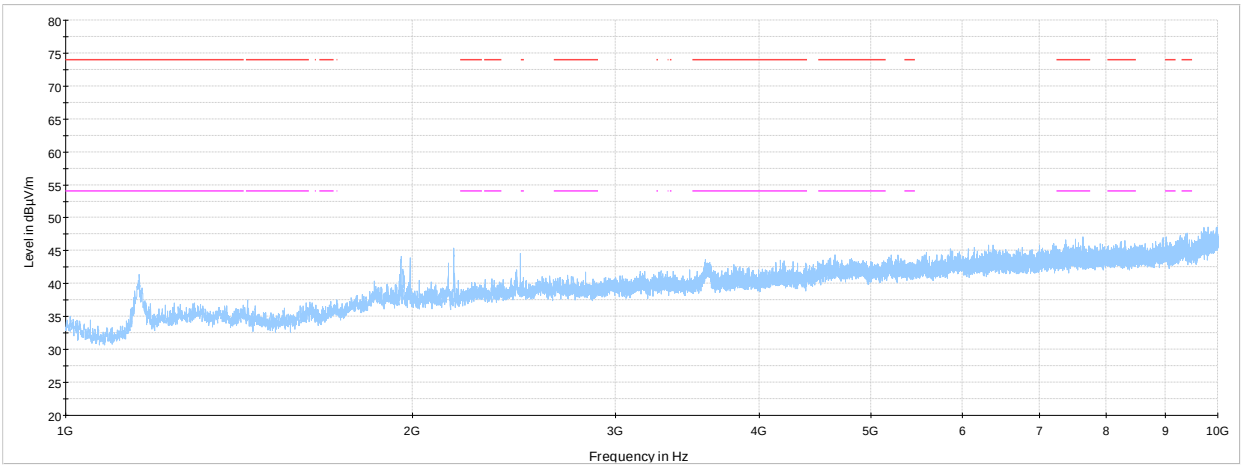


Figure 7.8-17 *Radiated spurious emissions 1-10 GHz mid channel, LoRA 500 kHz*

Test data, continued

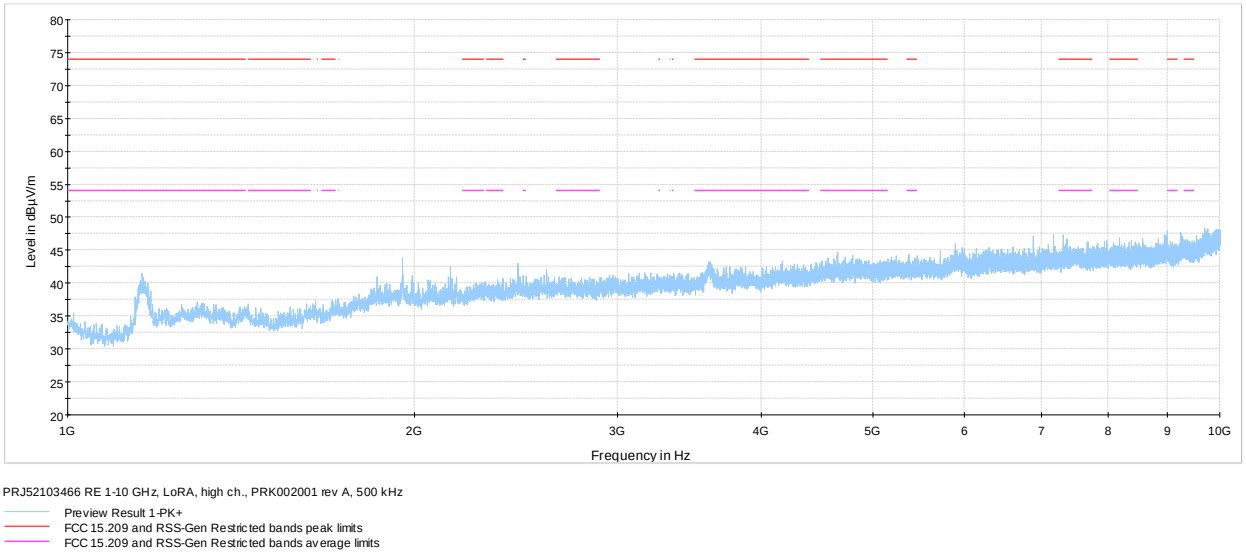


Figure 7.8-18: *Radiated spurious emissions 1-10 GHz high channel, LoRA 500 kHz*

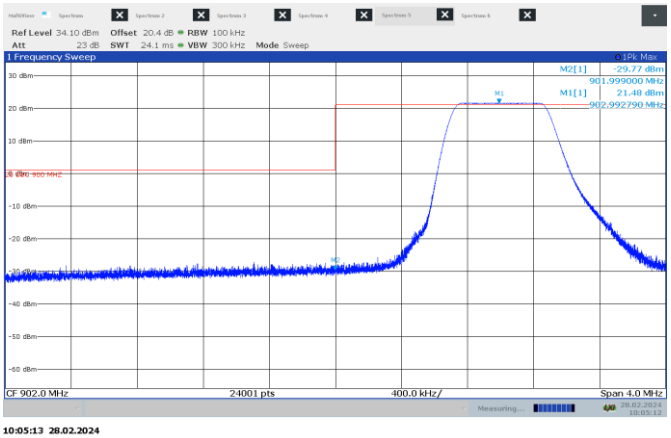


Figure 7.8-19: *Band edge spurious emissions at 902 MHz– low channel, LoRA 500 kHz*

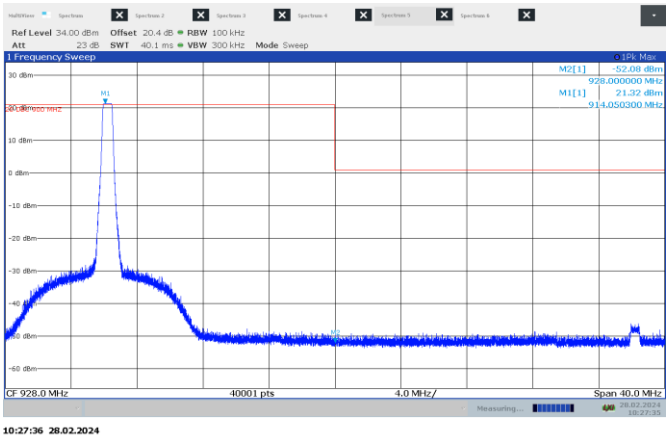


Figure 7.8-20: *Band edge spurious emissions at 928 MHz– high channel, LoRA 500 kHz*

Test data, continued

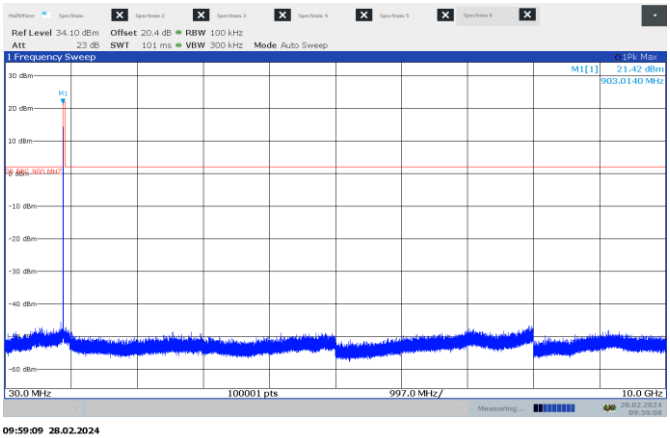


Figure 7.8-21: *Conducted spurious emissions at low channel – LoRA 500 kHz*

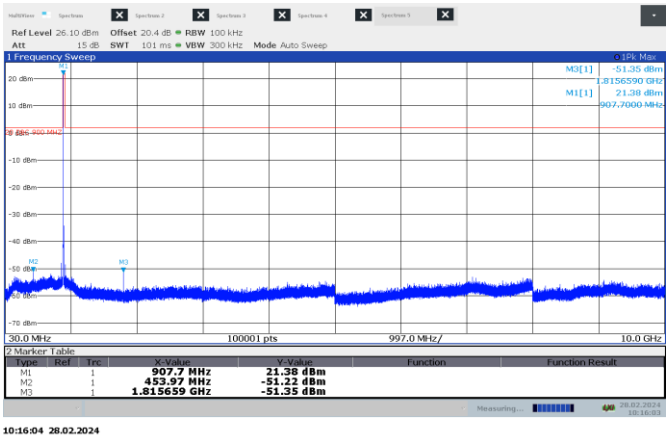


Figure 7.8-22: *Conducted spurious emissions at mid channel – LoRA 500 kHz*

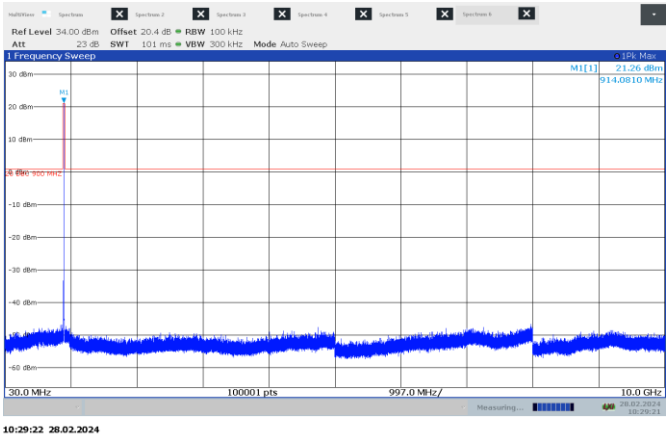


Figure 7.8-23: *Conducted spurious emissions at high channel – LoRA 500 kHz*

7.9 Power spectral density for digitally modulated devices

7.9.1 References, definitions and limits

FCC §15.247:

(e) 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.

RSS-247, Clause 5.2:

DTSs include systems that employ digital modulation techniques resulting in spectral characteristics similar to direct sequence systems. The following applies to the bands 902-928 MHz and 2400-2483.5 MHz:

b. 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).

RSS-247, Clause 5.3:

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

b. 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.

7.9.2 Test summary

Verdict	Pass		
Test date	February 28, 2024	Temperature	22.5 °C
Tested by	Tarek Elkholy	Air pressure	957 mbar
Test location	Cambridge	Relative humidity	52 %

7.9.3 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 × OBW
Detector mode:	Peak
Trace mode:	Max Hold

7.9.4 Test data

Table 7.9-1: *PSD results (antenna port measurement)*

Frequency, MHz	PSD, dBm/3 kHz	PSD limit, dBm/3 kHz	Margin, dB
903.0	6.5	8.0	1.5
907.8	6.2	8.0	1.8
914.2	6.2	8.0	1.8

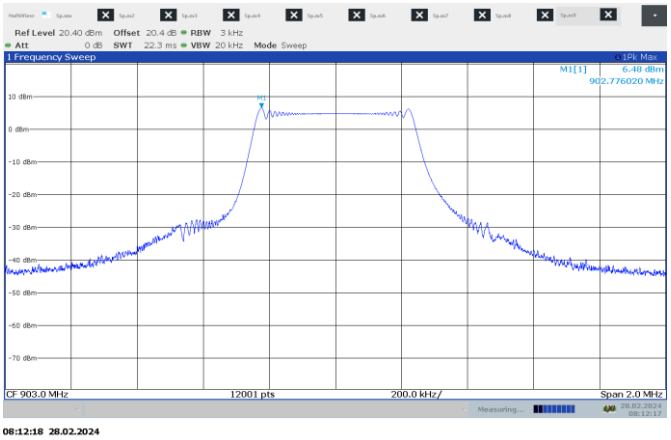


Figure 7.9-1: *PSD on low channel*

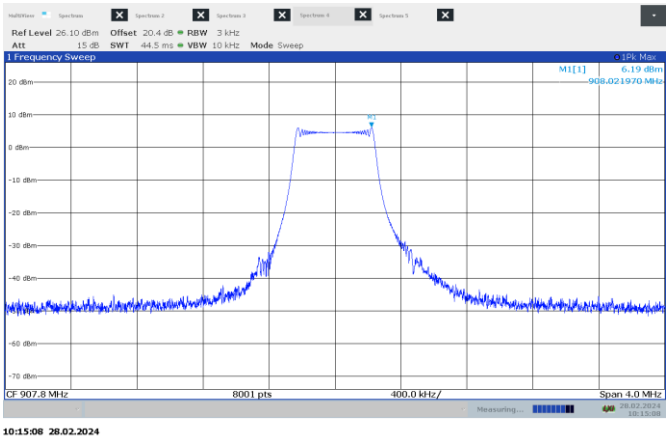


Figure 7.9-2: *PSD on mid channel*

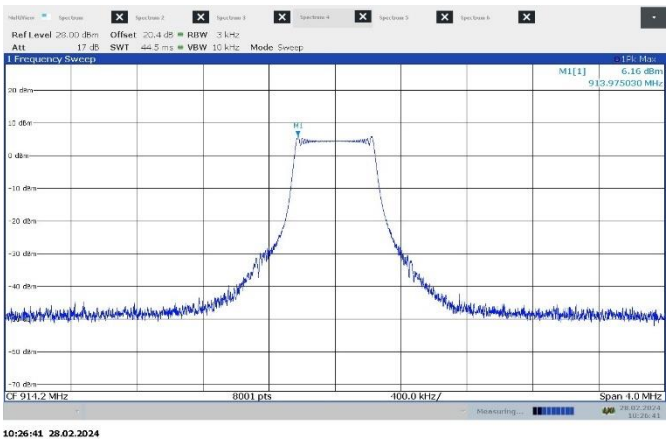
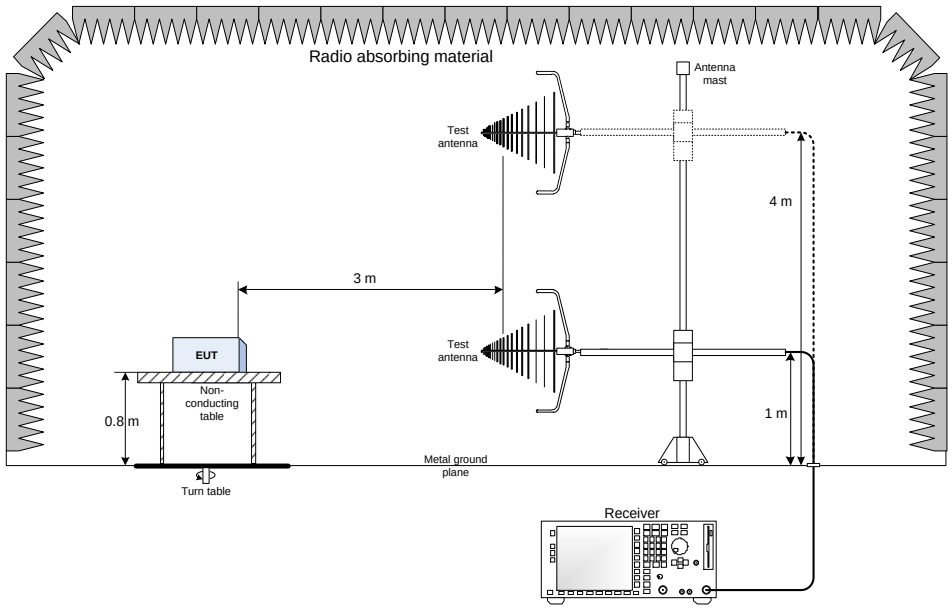


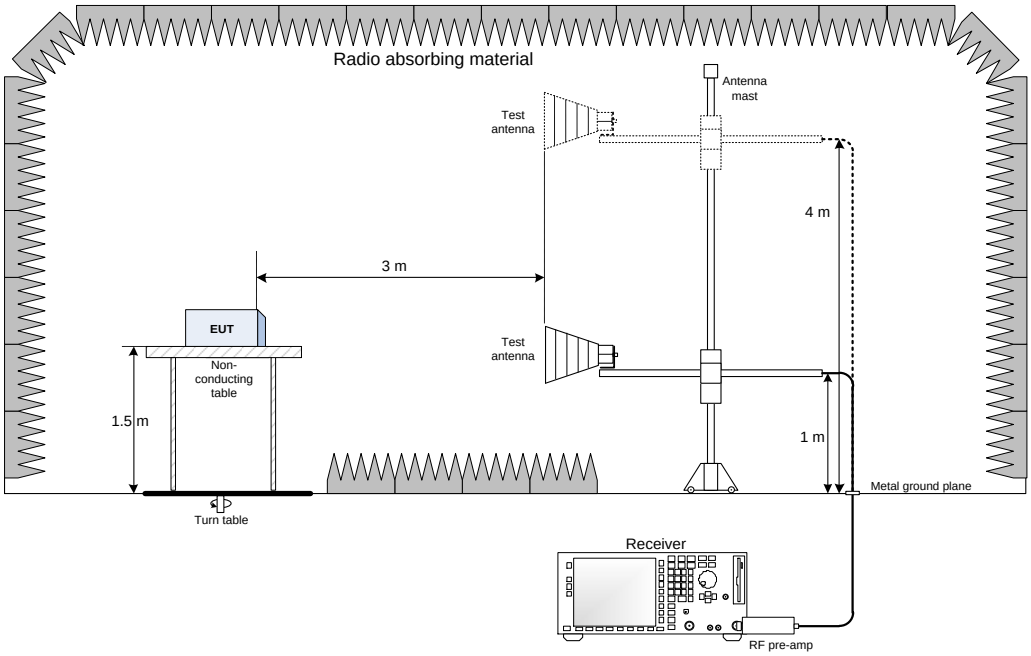
Figure 7.9-3: *PSD on high channel*

Section 8 Test setup diagrams

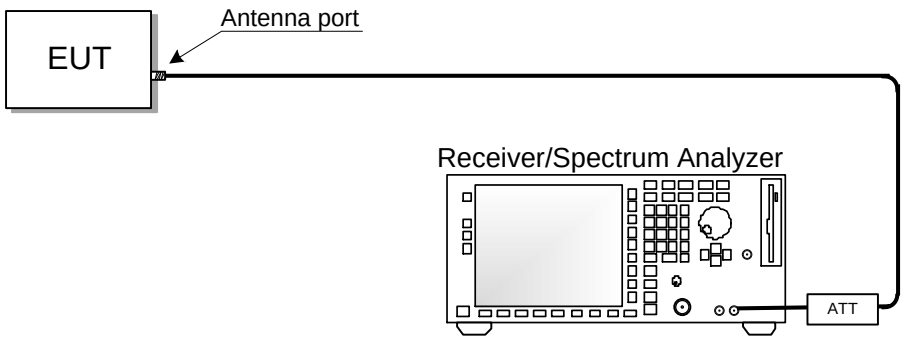
8.1 Radiated emissions set-up for frequencies below 1 GHz



8.2 Radiated emissions set-up for frequencies above 1 GHz



8.3 Antenna port set-up



End of the test report