Testing Tomorrow's Technology

Application

For

Part 2, Subpart J, Paragraph 2.907 Equipment Authorization of Certification for an Intentional Radiator per Part 15, Subpart C, paragraphs 15.207, 15.209 and 15.247

And

ISED Radio Standards Specification: RSS-Gen Issue 5 and RSS-247 Issue 3

For the

Mueller Systems, LLC

Model: MINODE6A

FCC ID: SM6-MINODE6A
IC: 9235A-MINODE6A

UST Project: 24-0031
Issue Date: March 19, 2024

Total Pages in This Report: 47

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I certify that I am authorized to sign for the Test Agency and that all of the statements in this report and in the Exhibits attached hereto are true and correct to the best of my knowledge and belief:

US TECH (Agent Responsible For Test):

By: Alan Ghasiani

Name: 

Title: Compliance Engineer – President

Date March 19, 2024

NVLAP LAB CODE 200162-0

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MEASUREMENT TECHNICAL REPORT

COMPANYS NAME: Mueller Systems, LLC

MODEL: MINODE6A

FCC ID: SM6-MINODE6A

IC: 9235A-MINODE6A

DATE: March 19, 2024

This report concerns (check one): Original grant [X]
Class II change

Equipment type: 902-928MHz FHSS Transmitter device

FCC Rule	Description of Test	Result
15.247(b)(2)	Peak Output Power	PASS
15.247(a)(1)(i)	20 dB Bandwidth	PASS
15.247(d)	Conducted & Radiated Spurious Emissions	PASS
15.247(a)	Channel Separation	PASS
15.247(a)(i)	Number of Channels/ Occupancy Time	PASS
15.247(b)	Output power	PASS
15.209	Spurious Radiated Emissions	PASS
15.207	Power line Conducted Emissions	N/A

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1 General Information

1.1 Purpose of this Report

This report is prepared as a means of conveying test results and information concerning the suitability of this exact product for public distribution according to the FCC Rules and Regulations Part 15, Section 247 and IC RSS 247 Issue 2.

1.2 Characterization of Test Sample

The sample used for testing was received by US Tech on February 7, 2024 in good operating condition.

1.3 Product Description

The Equipment under Test (EUT) is the Mueller Systems, LLC. Model MINODE6A. The EUT is an RF transceiver module. It operates in the unlicensed 902 to 928 MHz ISM band. The device offers three modes Frequency Hopping Spread Spectrum (FHSS), Digital Transmission Systems (DTS) and a cross between both these modes called Hybrid mode of operation.

The EUT uses RFV4 and LoRAWAN protocols. The protocol is dependent on the mode of operation.

This report is written to evaluate the FHSS mode. The DTS and Hybrid modes have been evaluated in a separate test report.

Mode of operation: FHSS
Frequency Range: 902.3 MHz – 927.012451 MHz
Protocals: RFV4, LoRaWAN
Antenna: Monopole, 4.0 dBi Peak Gain @ 915 MHz
Modulation: CSS
Maximum Output Power: +28.38 dBm (measured)

1.4 Configuration of Tested System

The Test Sample was tested per ANSI C63.4:2014 and ANSI C63.4:2013, Methods of Measurement of Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz for FCC subpart A Digital equipment Verification requirements and per ANSI C63.10-2013, American National Standard of Procedures for Compliance Testing of Unlicensed Wireless Devices for FCC subpart C Intentional Radiators.

A list of EUT and Peripherals is found in Table 1 below. A block diagram of the tested system is shown in Figure 1. Test configuration photographs are provided in separate Appendices.

1.5 Test Facility

Testing was performed at US Tech's measurement facility at 3505 Francis Circle, Alpharetta, GA 30004. This site has been fully described and registered with the FCC. Its designation number is US5301. Additionally, this site has also been fully described and submitted to Industry Canada (ISED), and has been approved under file number 9900A-1.

1.6 Related Submittals

1.6.1 The EUT is subject to the following FCC authorizations:

a) Certification under section 15.247 as a transmitter.
b) Verification under 15.101 as a digital device and receiver.

1.6.2 Verification of the Digital apparatus

The Verification requirement shares many common report elements with the Certification report. Therefore, though this report is mostly intended to provide data for the Certification process, the Verification authorization report (part 15.107 and 15.109) for the EUT is included herein.

Table 1. EUT and Peripherals

PERIPHERAL MANUFACTURER.	MODEL NUMBER	SERIAL NUMBER	FCC ID:	CABLES P/D
Mueller Systems, LLC	MINODE6A	Engineering Sample	FCC ID: SM6-MINODE6A IC:9235A-MINODE6A	None
Antenna See antenna details	--	--	--	--

U= Unshielded S= Shielded P= Power D= Data

2 Tests and Measurements

2.1 Test Equipment

The table below lists test equipment used to evaluate this product. Model numbers, serial numbers and their calibration status are indicated.

Table 2. Test Instruments

TEST INSTRUMENT	MODEL NUMBER	MANUFACTURER	SERIAL NUMBER	CALIBRATION DUE DATE
SPECTRUM ANALYZER	E4407B	AGILENT	US41442935	09/21/2024 2 yr.
SPECTRUM ANALYZER	E4440A	AGILENT TECHNOLOGIES INC	MY45304803	07/21/2025 2 yr.
SPECTRUM ANALYZER	DSA815	RIGOL	DSA8A180300138	01/06/2024 2 yr.
BICONICAL ANTENNA	EMCO	EMCO	9307-1431	01/13/2025 2 yr.
HORN ANTENNA	SAS-571	A. H. SYSTEMS	605	04/28/2024 2 yr.
LOG PERIODIC ANTENNA	3146	EMCO	9110-3236	Extended 3/13/2024 2 yr.
LOOP ANTENNA	6502	ETS LINDGREN	9810-3246	12/7/2024 2 yr.
PREAMP	8449B	HEWLETT PACKARD	3008A00914	3/3/2024
PREAMP	8447D	HEWLETT-PACKARD	1937A01611	7/20/2024
HIGH PASS FILTER	H3R020G2	Microwave Circuits	001DC9528	8/2/2024
HIGH PASS FILTER	VHF-1320 15542	Mini-Circuits Inc.	3 0843	8/2/2024

Note: The calibration interval of the above test instruments are 12 months unless stated otherwise and all calibrations are traceable to NIST/USA.

2.2 Modifications to EUT Hardware

No physical modifications were made by US Tech in order to bring the EUT into compliance with FCC Part 15, Subpart C Intentional Radiator Limits for the transmitter portion of the EUT or the Subpart B Unintentional Radiator Limits (Receiver and Digital Device) Requirements.

2.3 Number of Measurements for Intentional Radiators (15.31(m))

Measurements of intentional radiators or receivers shall be performed and 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 Table 3 below.

Table 3. Number of Test Frequencies for Intentional Radiators

Frequency Range over which the device operates	Number of Frequencies	Location in the Range of operation
1 MHz or less	1	Middle
1 to 10 MHz	2	1 near the top 1 near the bottom
Greater than 10 MHz	3	1 near top 1 near middle 1 near bottom

Because the EUT operates over 10 MHz span, 3 test frequencies were used.

2.4 Frequency Range of Radiated Measurements (Part 15.33)

2.4.1 Intentional Radiator

The spectrum shall be investigated for the intentional radiator from the lowest RF signal generated in the EUT, without going below 9 kHz to the 10th harmonic of the highest fundamental frequency generated or 40 GHz, whichever is the lowest.

2.4.2 Unintentional Radiator

For the digital device, an unintentional radiator, the frequency range shall be 30 MHz to 1000 MHz, or to 5 times the highest internal clock frequency.

2.5 Measurement Detector Function and Bandwidth (CFR 15.35)

The radiated and conducted emissions limits shown herein are based on the following.

2.5.1 Detector Function and Associated Bandwidth

On frequencies below 1000 MHz, the limits herein are based upon measurement equipment employing a CISPR Quasi-peak detector function and related measurement bandwidths (i.e., 9 kHz from 150 kHz to 30 MHz and 120 kHz from 30 MHz to 1000 MHz). Alternatively, measurements may be made with equipment employing a peak detector function as long as the same bandwidths specified for the Quasi-peak device are used.

2.5.2 Corresponding Peak and Average Requirements

Above 1000 MHz, radiated limits are based on measuring instrumentation employing an average detector function. When average radiated emissions are specified, there is also a corresponding Peak requirement, as measured using a peak detector, of 20 dB greater than the average limit. For all measurements above 1000 MHz the Resolution Bandwidth shall be at least 1 MHz .

2.5.3 Pulsed Transmitter Averaging

When the radiated emissions limit is expressed as an average value, and the transmitter is pulsed, the measured field strength shall be determined by applying a Duty Cycle Correction Factor based upon dividing the total ON time during the first 100 ms period by 100 ms (or by the period if less than 100 ms). The duty cycle may be expressed logarithmically in dB.

NOTE: If the transmitter was programmed to transmit at >98% duty cycle, then, wherever applicable (where the detection mode was AVG) the duty cycle factor calculated will be applied.

2.7 EUT Antenna Requirements (CFR 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. Only the antenna(s) listed in Table 4 will be used with this module.

Table 4. Allowed Antenna(s)

REPORT REFERENCE	MANUFACTURER	TYPE OF ANTENNA	MODEL	GAIN dB_i	TYPE OF CONNECTOR
Antenna	Mueller Systems, LLC	¼ Monopole	145-0037-001	4.0	Permanent

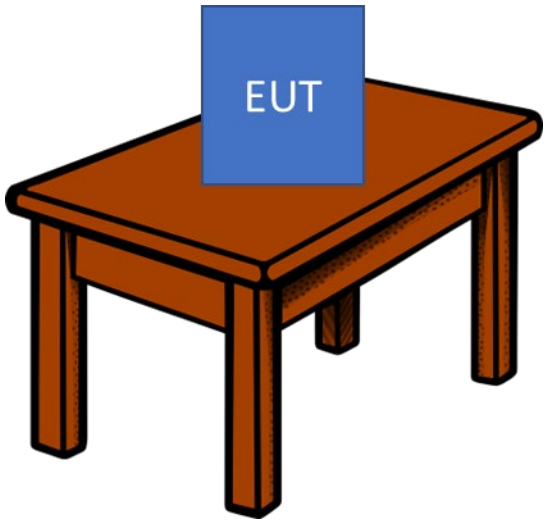

Figure 1. Test Configuration

2.9 Power Line Conducted Emissions (CFR 15.207)

Since the EUT is battery powered, this test was not applied.

2.10 Intentional Radiator, Radiated Emissions (CFR 15.209, 15.247(d)) (IC RSS 247 5.1 & 5.2)

Radiated Spurious measurements: The EUT was placed into a continuous transmit mode of operation (>98%) duty cycle) and tested per FCC Public Notice DA 00-705 and ANSI C63.10:2013. A preliminary scan was performed on the EUT to find signal frequencies that were caused by the transmitter part of the device. A preliminary scan was performed on the EUT to find the worse case results the EUT was tested in X, Y, and Z axes or in the orientation of normal operation if the device is designed to operate in a fixed position.

Radiated measurements were then conducted between the frequency range of 9 kHz (or lowest frequency used/generated by the device) up to the tenth harmonic of the device (no greater than 40 GHz). In the band below 30 MHz a resolution bandwidth (RBW) of 9 kHz was used, emissions below 1 GHz were tested with a RBW of 120 kHz and emissions above 1 GHz were tested with a RBW of 1 MHz . All video bandwidth settings were at least three times the RBW value.

The EUT was investigated to CFR 15.209, General requirements for unwanted spurious emissions. The conducted spurious method as described below was used to investigate all other emissions emanating from the antenna port.

Conducted Spurious measurements: The EUT was put into a continuous-transmit mode of operation (>98% duty cycle) and tested per FCC Public Notice DA 00-705 for conducted out of band emissions emanating from the antenna port over the frequency range of 30 MHz to 25 GHz. A conducted scan was performed on the EUT to identify and record the spurious signals that were related to the transmitter.

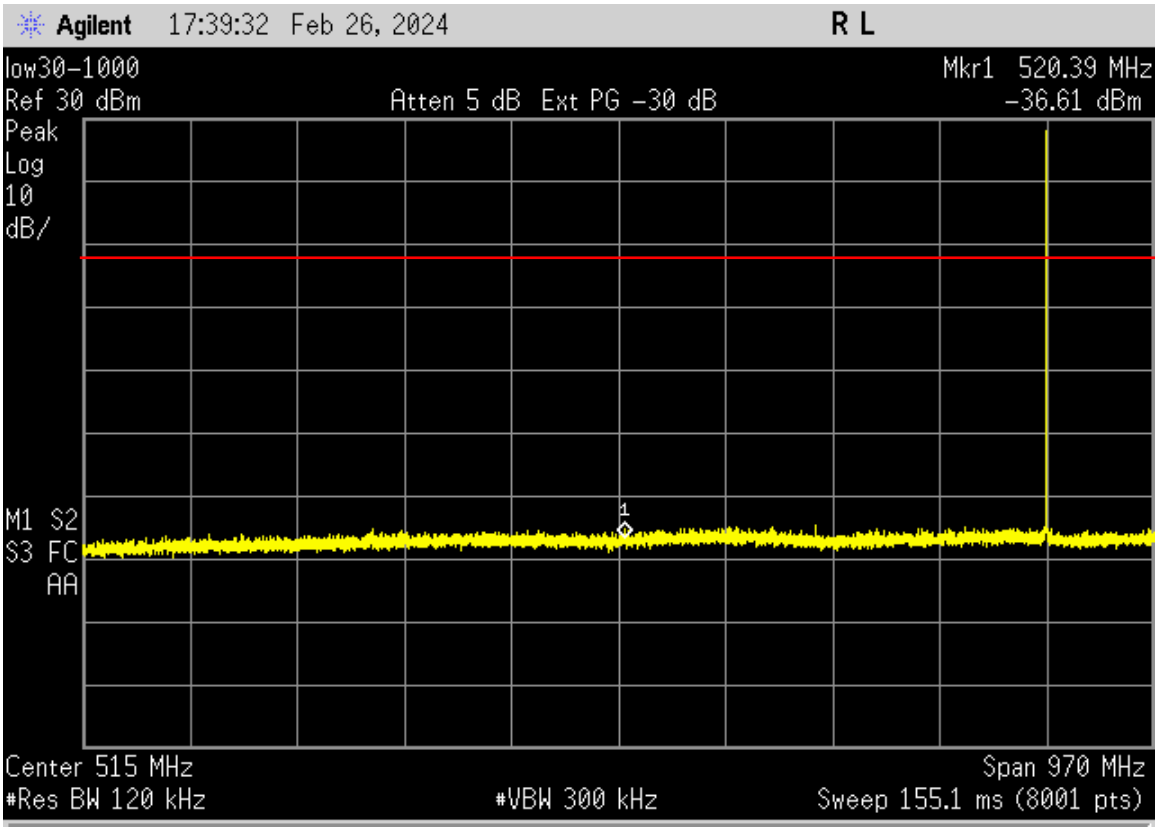

Figure 2. Conducted Spurious Emissions-Low Channel, 30MHz – 1 GHz

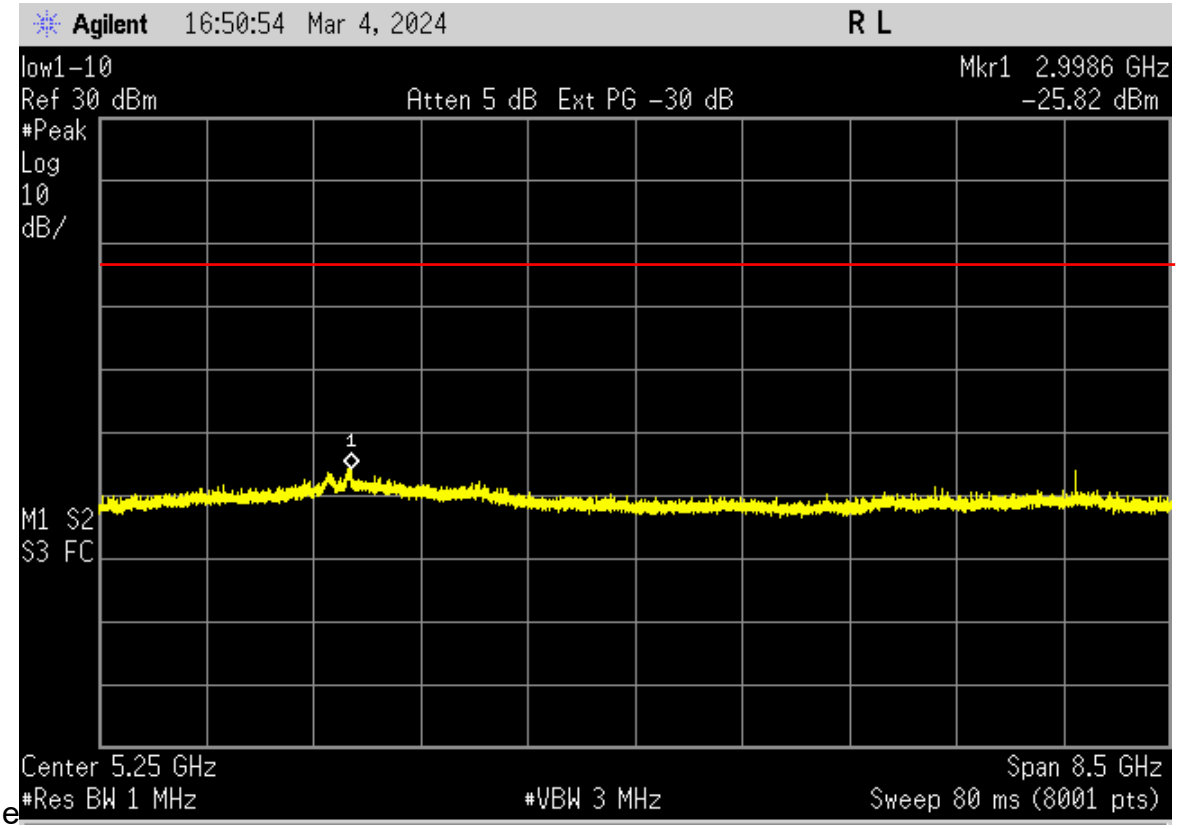

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Figure 3. Conducted Spurious Emissions - Low Channel, 1 GHz – 10 GHz

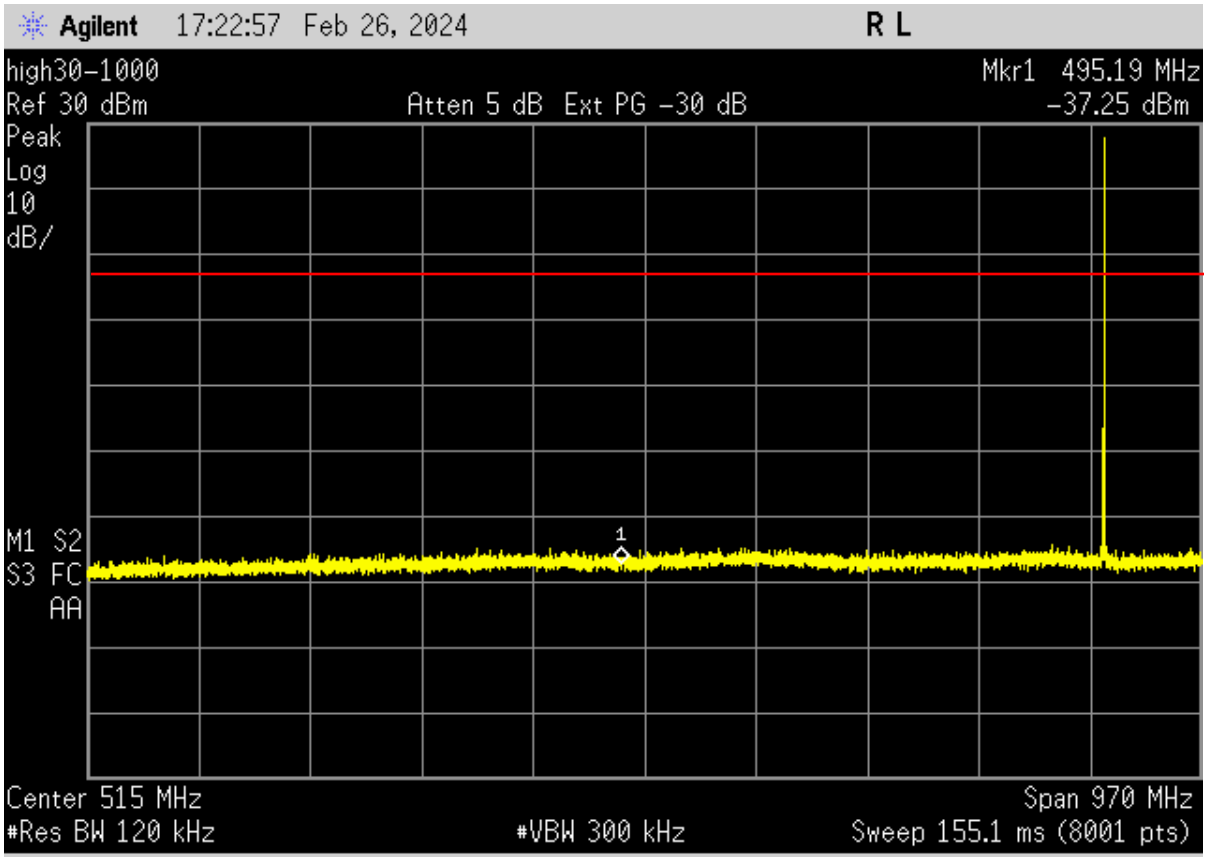

Figure 4. Conducted Spurious Emissions - Mid Channel, 30MHz – 1 GHz

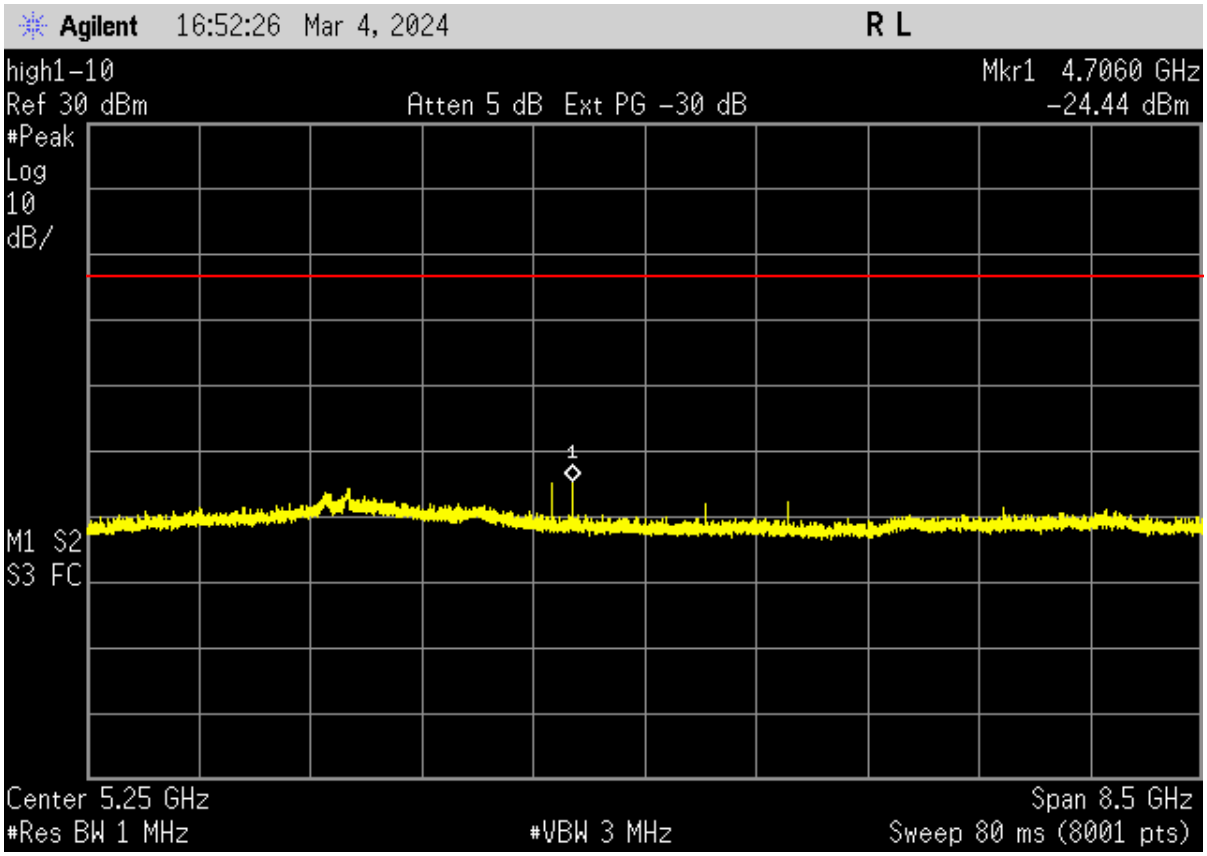

Figure 5. Conducted Spurious Emissions - Mid Channel, 1 GHz – 10 GHz

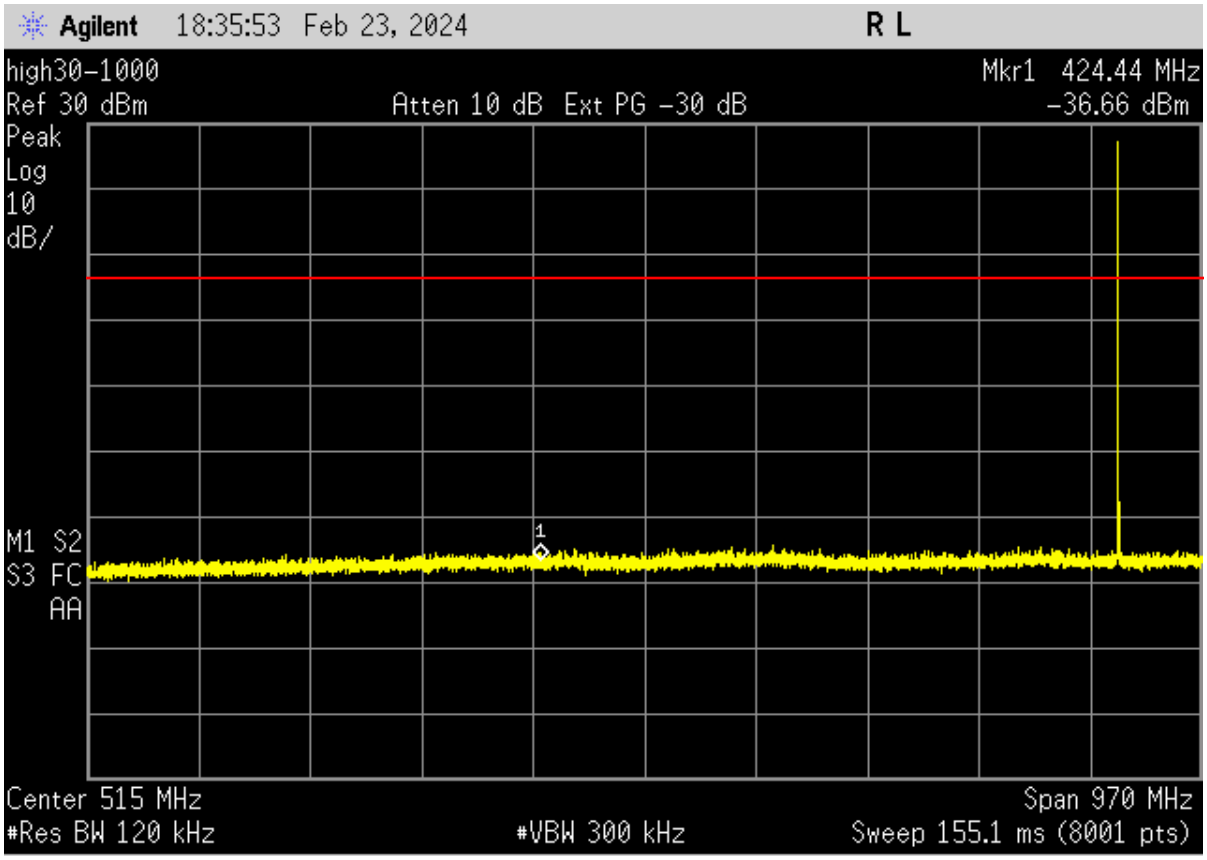

Figure 6. Conducted Spurious Emissions - High Channel, 30 MHz – 1 GHz

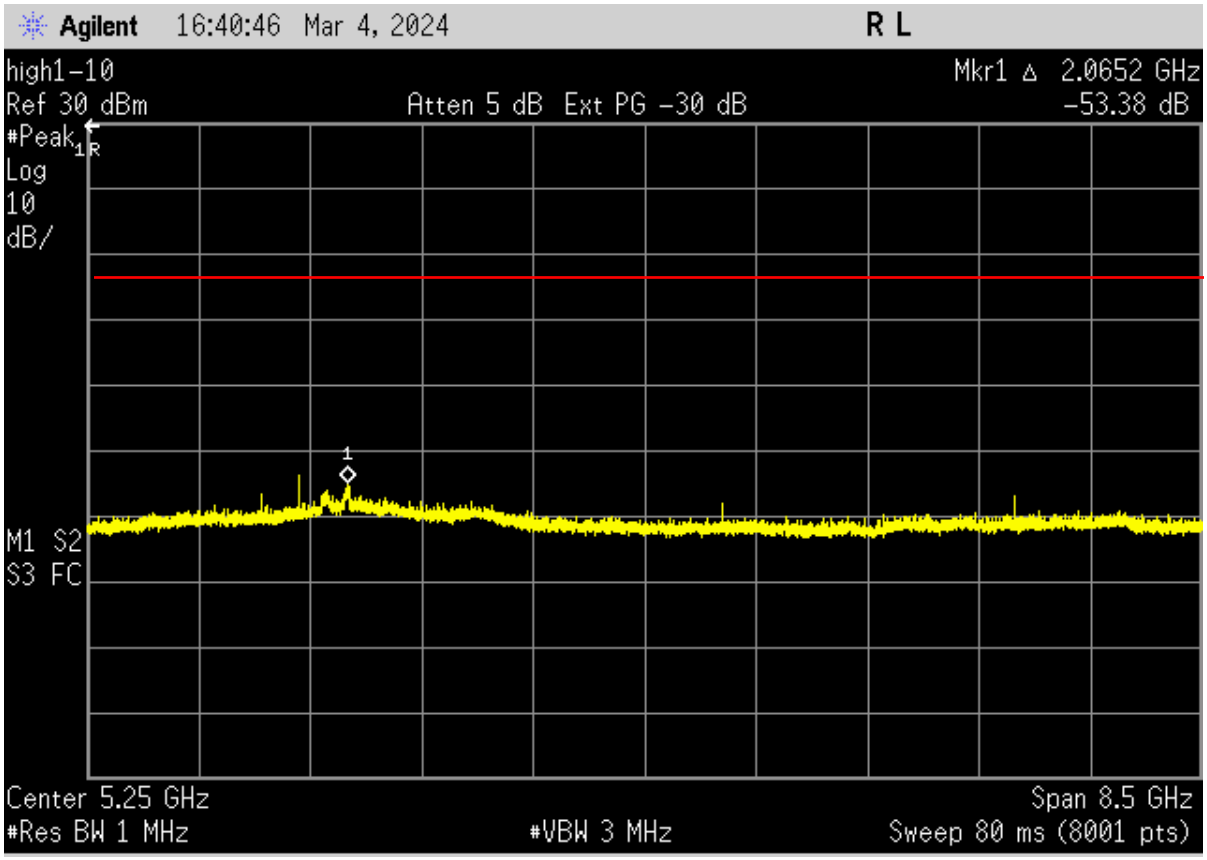

Figure 7. Conducted Spurious Emissions - High Channel, 1 GHz – 10 GHz

Table 5. Peak Radiated Fundamental & Harmonic Emissions

Test: FCC Part 15, Para 15.209, 15.247(d)								
Frequency (MHz)	**Test Data (dBuV)**	**Factor (dB)**	**AF+CA -AMP (dB/m)**	**Results (dBuV/m)**	**Limits (dBuV/m)**	**Antenna Distance/ Polarization**	**Margin (dB)**	**Detector Mode**
Low Channel								
902.30	102.24	--	26.15	128.39	--	3.0m/HORZ	--	**PK**
1804.76	49.96	--	-7.44	42.53	104.00	3.0m/HORZ	61.47	**PK**
*2707.06	49.75	--	-4.11	45.65	74.00	3.0m/HORZ	28.35	**PK**
*3608.92	42.04	--	-1.44	40.61	74.00	3.0m/HORZ	33.39	**PK**
*4511.35	44.41	--	0.90	45.31	74.00	3.0m/HORZ	28.69	**PK**
*5413.88	42.84	--	5.92	48.76	74.00	3.0m/HORZ	25.24	**PK**
6316.21	41.06	--	9.56	50.62	104.00	3.0m/HORZ	53.38	**PK**
7218.41	43.56	--	12.13	55.69	104.00	3.0m/HORZ	48.31	**PK**
*8120.84	41.84	--	11.79	53.63	74.00	3.0m/HORZ	20.37	**PK**
*9024.82	38.22	--	13.71	51.93	74.00	3.0m/HORZ	22.07	**PK**
Mid Channel								
914.90	102.26	--	26.17	128.42	--	3.0m/HORZ	--	**PK**
1829.69	52.51	--	-7.48	45.04	104.00	3.0m/HORZ	58.96	**PK**
*2744.88	52.75	--	-3.99	48.77	74.00	3.0m/HORZ	25.23	**PK**
*3659.8	41.86	--	-0.94	40.92	74.00	3.0m/HORZ	33.08	**PK**
*4574.35	45.41	--	1.18	46.59	74.00	3.0m/HORZ	27.41	**PK**
5489.07	42.92	--	6.03	48.95	104.00	3.0m/HORZ	55.05	**PK**
6404.18	43.10	--	9.31	52.41	104.00	3.0m/HORZ	51.59	**PK**
*7318.92	41.51	--	11.92	53.43	74.00	3.0m/HORZ	20.57	**PK**
*8233.7	41.41	--	13.54	54.96	74.00	3.0m/HORZ	19.04	**PK**
*9152.94	37.95	--	14.16	52.10	74.00	3.0m/HORZ	21.90	**PK**
High Channel								
927.0125	101.90	--	26.18	128.08	--	3.0m/HORZ	--	**PK**
1853.98	54.78	--	-7.20	47.58	104.00	3.0m/HORZ	56.42	**PK**
*2780.86	50.44	--	-4.02	46.42	74.00	3.0m/HORZ	27.58	**PK**
*3707.82	45.68	--	-0.86	44.82	74.00	3.0m/HORZ	29.18	**PK**
*4634.91	47.57	--	1.28	48.85	74.00	3.0m/HORZ	25.15	**PK**
5562.23	41.21	--	6.27	47.48	104.00	3.0m/HORZ	56.52	**PK**
6489.15	46.14	--	9.64	55.79	104.00	3.0m/HORZ	48.21	**PK**
*7415.7	43.98	--	11.37	55.35	74.00	3.0m/HORZ	18.65	**PK**
*8343.21	40.65	--	13.74	54.39	74.00	3.0m/HORZ	19.61	**PK**
9267.94	38.45	--	13.30	51.75	104.00	3.0m/HORZ	52.25	**PK**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209 & 20 dB relaxation for peak measurements of CFR 15.35.
2. The EUT was placed in two orthogonal positions and the transmitter was in constant broadcast mode, with a duty cycle of greater than 98%. The emissions were measured with the receive antenna in vertical and horizontal polarizations. The data listed in the above table was worst case.

Sample Calculation at 902.30 MHz:

Magnitude of Measured Frequency	102.24	dBuV
+Antenna Factor + Cable Loss+ Amplifier Gain	26.15	dB/m
1 meter to 3-meter extrapolation	0.00	dB
Corrected Result	128.39	dBuV/m

Test Date: February 8-26, 2024

Tested By
Signature: Ian Charboneau Name: Ian Charboneau

Table 6. Average Radiated Fundamental & Harmonic Emissions

Test: FCC Part 15, Para 15.209, 15.247(d)								
Frequency (MHz)	**Test Data (dBuV)**	**Factor (dB)**	**AF+CA -AMP (dB/m)**	**Results (dBuV/m)**	**Limits (dBuV/m)**	**Antenna Distance/ Polarization**	**Margin (dB)**	**Detector Mode**
Low Channel								
902.30	99.17	--	26.15	125.32	--	3.0m/HORZ	--	**AVG**
1804.76	44.64	--	-7.44	37.20	104.00	3.0m/HORZ	66.8	**AVG**
*2707.06	45.07	--	-4.11	40.96	54.00	3.0m/HORZ	13.04	**AVG**
*3608.92	28.32	--	-1.44	26.88	54.00	3.0m/HORZ	27.12	**AVG**
*4511.35	31.92	--	0.90	32.82	54.00	3.0m/HORZ	21.18	**AVG**
*5413.88	34.47	--	5.92	40.39	54.00	3.0m/HORZ	13.61	**AVG**
6316.21	32.39	--	9.56	41.95	104.00	3.0m/HORZ	62.05	**AVG**
7218.41	35.14	--	12.13	47.27	104.00	3.0m/HORZ	56.73	**AVG**
*8120.84	31.32	--	11.79	43.11	54.00	3.0m/HORZ	10.89	**AVG**
*9024.82	23.99	--	13.71	37.70	54.00	3.0m/HORZ	16.3	**AVG**
Mid Channel								
914.90	99.35	--	26.17	125.52	--	3.0m/HORZ	--	**AVG**
1829.69	48.08	--	-7.48	40.60	104.00	3.0m/HORZ	63.4	**AVG**
*2744.88	40.66	--	-3.99	36.67	54.00	3.0m/HORZ	17.33	**AVG**
*3659.8	28.99	--	-0.94	28.05	54.00	3.0m/HORZ	25.95	**AVG**
*4574.35	40.40	--	1.18	41.58	54.00	3.0m/HORZ	12.42	**AVG**
5489.07	35.65	--	6.03	41.68	104.00	3.0m/HORZ	62.32	**AVG**
6404.18	37.70	--	9.31	47.01	104.00	3.0m/HORZ	56.99	**AVG**
*7318.92	28.96	--	11.92	40.88	54.00	3.0m/HORZ	13.12	**AVG**
*8233.7	28.88	--	13.54	42.42	54.00	3.0m/HORZ	11.58	**AVG**
*9152.94	23.75	--	14.16	37.91	54.00	3.0m/HORZ	16.09	**AVG**
High Channel								
927.0125	98.81	--	26.19	125.00	--	3.0m/HORZ	--	**AVG**
1853.98	52.27	--	-7.20	45.07	104.00	3.0m/HORZ	58.93	**AVG**
*2780.86	46.02	--	-4.02	42.00	54.00	3.0m/HORZ	12	**AVG**
*3707.82	27.52	--	-0.86	26.66	54.00	3.0m/HORZ	27.34	**AVG**
*4634.91	43.59	--	1.28	44.87	54.00	3.0m/HORZ	9.13	**AVG**
5562.23	31.86	--	6.27	38.13	104.00	3.0m/HORZ	65.87	**AVG**
6489.15	37.19	--	9.64	46.83	104.00	3.0m/HORZ	57.17	**AVG**
*7415.7	35.45	--	11.37	46.82	54.00	3.0m/HORZ	7.18	**AVG**
*8343.21	29.53	--	13.74	43.27	54.00	3.0m/HORZ	10.73	**AVG**
9267.94	23.53	--	13.30	36.83	104.00	3.0m/HORZ	67.17	**AVG**

1. (*) Falls within the restricted bands of CFR 15.205. Limits based on CFR15.209 & 20 dB relaxation for peak measurements of CFR 15.35.
2. The EUT was placed in three orthogonal positions and the transmitter was in constant broadcast mode, with a duty cycle of greater than 98%. The emissions were measured with the receive antenna in vertical and horizontal polarizations. The data listed in the above table was worst case.

Sample Calculation at 902.16 MHz:

Magnitude of Measured Frequency	99.17	dBuV
+Antenna Factor + Cable Loss+ Amplifier Gain	26.15	dB/m
1 meter to 3-meter extrapolation	0.00	dB
Corrected Result	125.32	dBuV/m

Test Date: February 8-26, 2024

Tested By
Signature: Ian Charboneau Name: Ian Charboneau

2.11 Band Edge Measurements – (CFR 15.247 (d))

Band Edge measurements are made following the guidelines in FCC KDB Publication No. DA 00-705 with the EUT initially operating on the Lowest Channel and then operating on the Highest Channel within its band of operation. Antenna port conducted measurements are performed to demonstrate compliance with the requirement of 15.247(d) that all emissions outside of the band edges be attenuated by at least 20 dB when compared to its highest in-band value (contained in a 100 kHz band).

To capture the band edge set the Spectrum Analyzer frequency span large enough (usually around 3 MHz) to capture the peak level of the emission operating on the channel closest to the band edge as well as any modulation products falling outside of the authorized band of operation. Conducted measurements are performed with RBW ≥1% of the frequency span. In all cases, the VBW is set ≥ RBW. See figure and calculations below for more detail. This measurement was performed with the EUT continuously transmitting on the low and high channels as well as in normal use mode (frequency hopping ON).

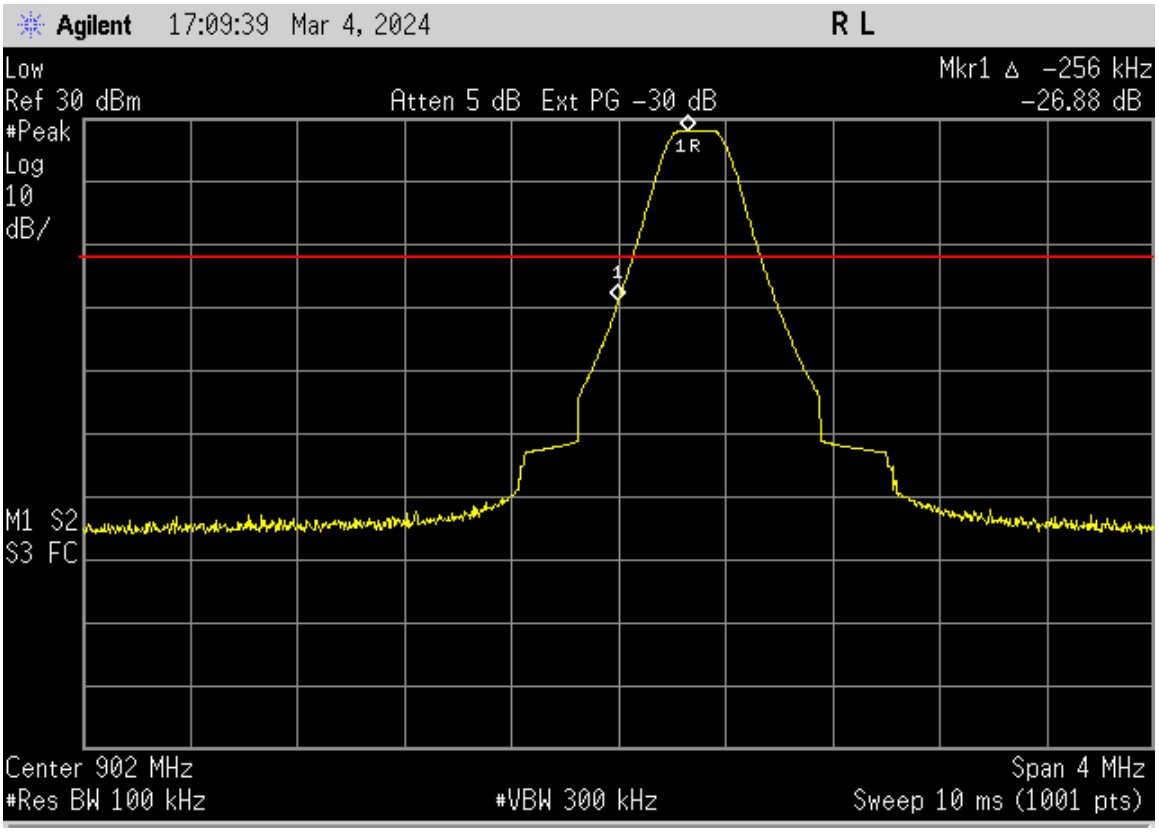

Figure 8. Band Edge Compliance, Low Channel Delta - Peak

All emissions greater than 100 kHz bandwidth outside the frequency band in which the FHSS intentional radiator is operating is at least 20 dB below the fundamental.

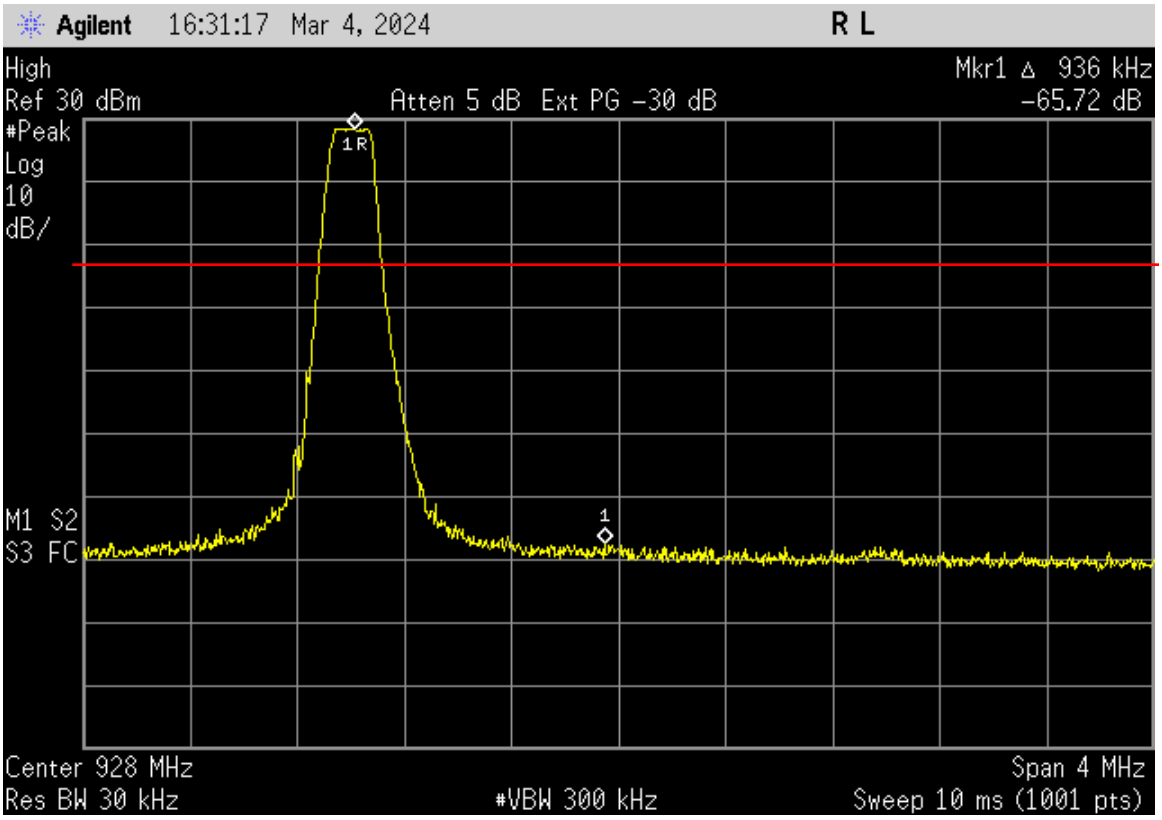

Figure 9. Band Edge Compliance, High Channel Delta – Peak

All emissions greater than 100 kHz bandwidth outside the frequency band in which the FHSS intentional radiator is operating is at least 20 dB below the fundamental.

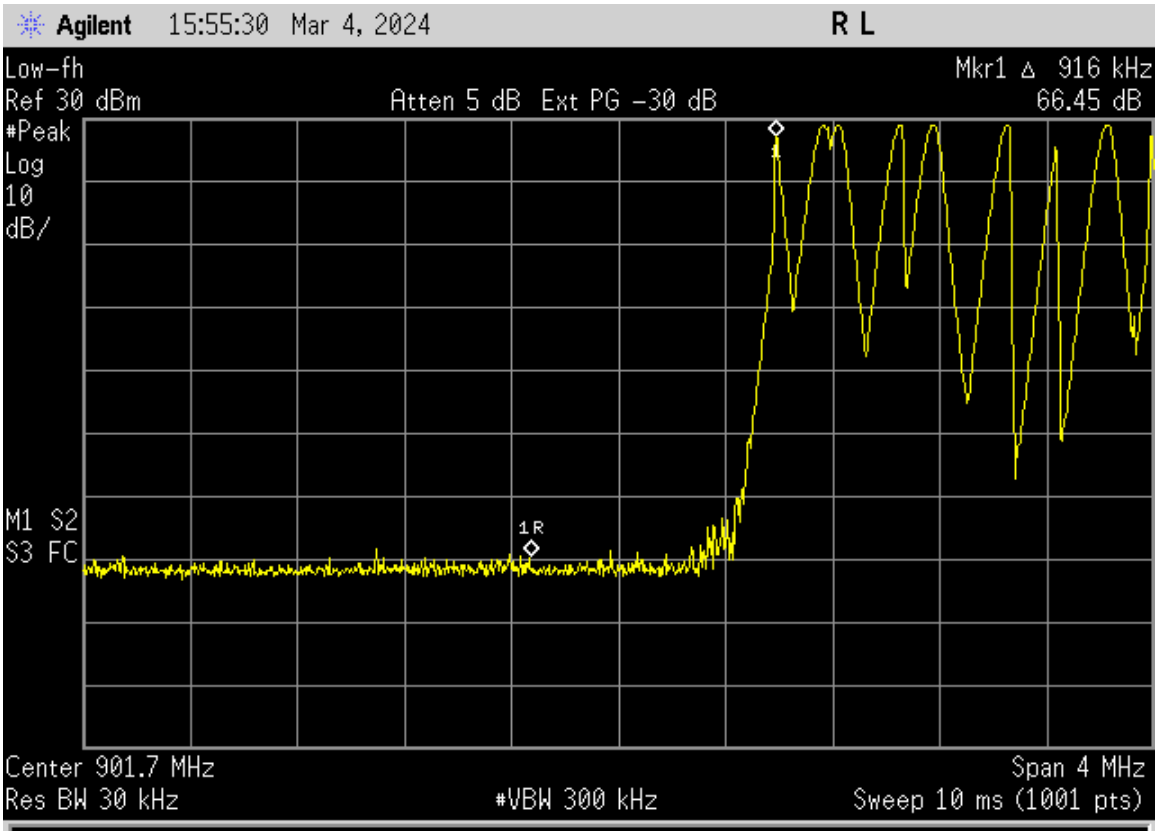

Figure 10. Band Edge Compliance, Low Hopping Delta – Peak

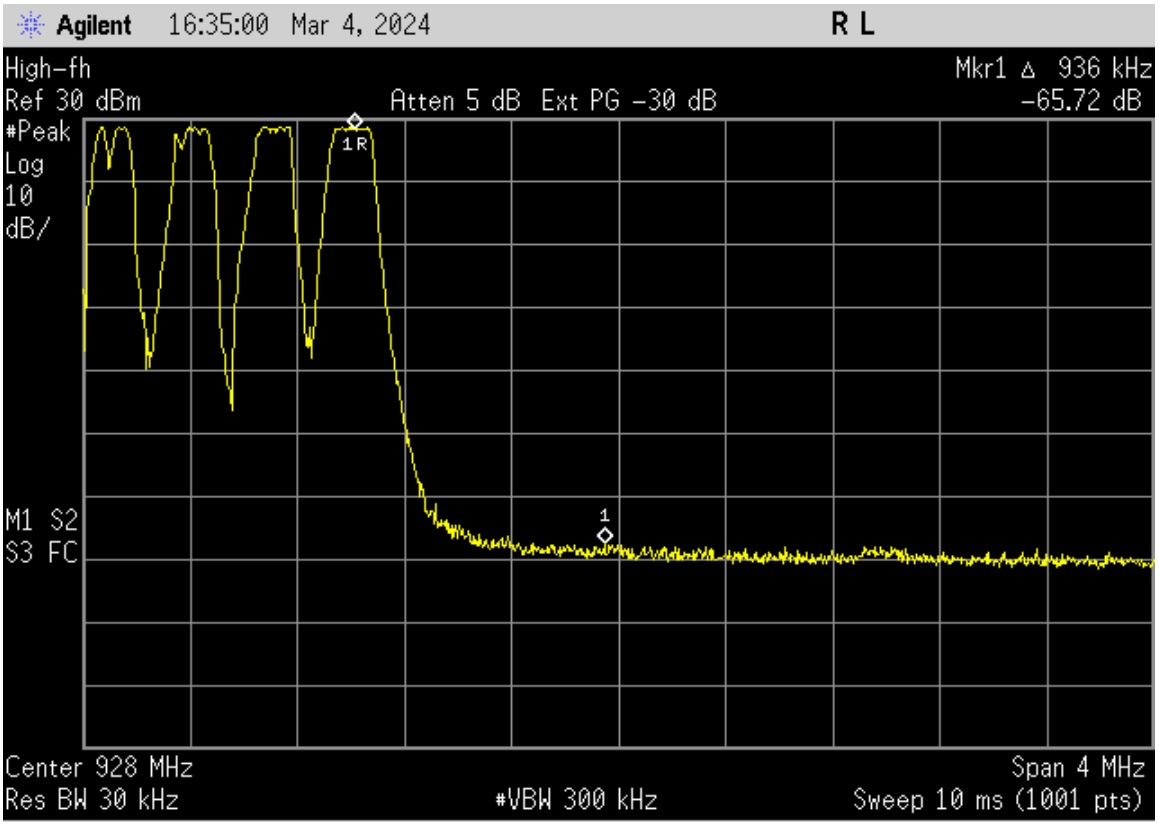

Figure 11. Band Edge Compliance, High Hopping Delta – Peak

2.12 99% Occupied Bandwidth (IC RSS 247 5.1 & 5.2,CFR 15.247 (a) (1) (i))

For frequency hopping systems operating in the 902-928 MHz band the maximum allowed 20 dB bandwidth is 500 kHz.

These measurements were performed while the EUT was in a constant transmit mode. A method similar to the marker delta method was used to capture the points. The RBW was set to approximately 1/100 of the manufacturers claimed RBW and with the VBW ≥ RBW. The results of this test are given in Table 12 and Figures 21-23.

Table 7. 20 dB Bandwidth and 99% Occupied Bandwidth

Frequency (MHz)	20 dB Bandwidth (kHz)	99% Occupied Bandwidth (kHz)
902.30	148.47	129.88
914.90	144.76	130.25
927.0125	142.22	129.49

Test Date: February 8-26, 2024

Tested By
Signature: Ian Charboneau Name: Ian Charboneau

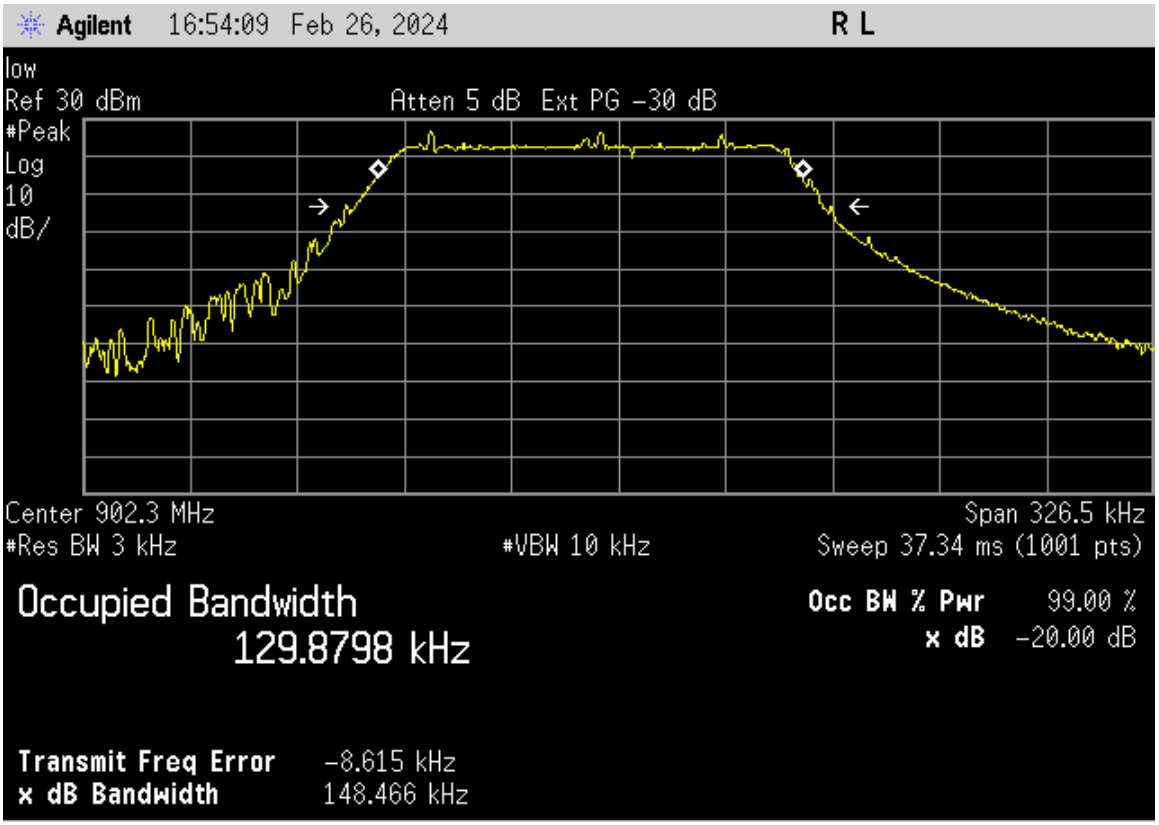

Figure 12. Bandwidth – Low Channel

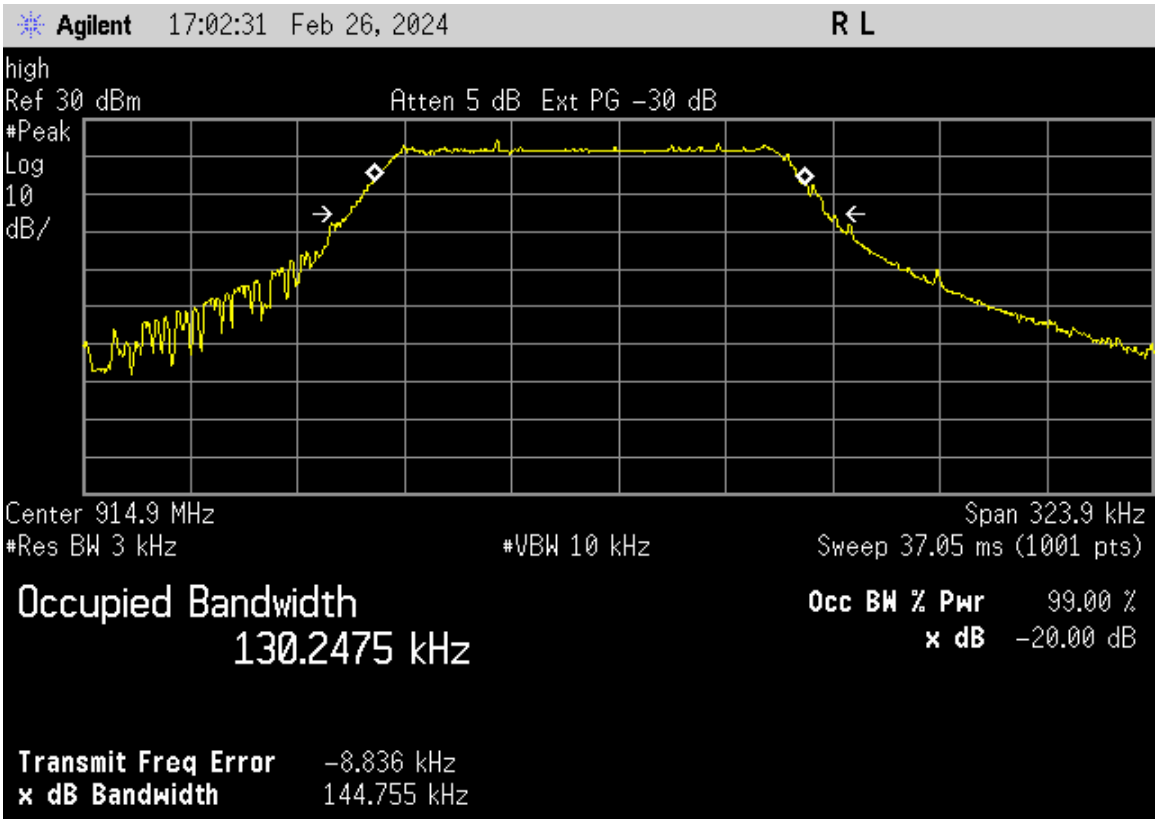

Figure 13. Bandwidth – Mid Channel

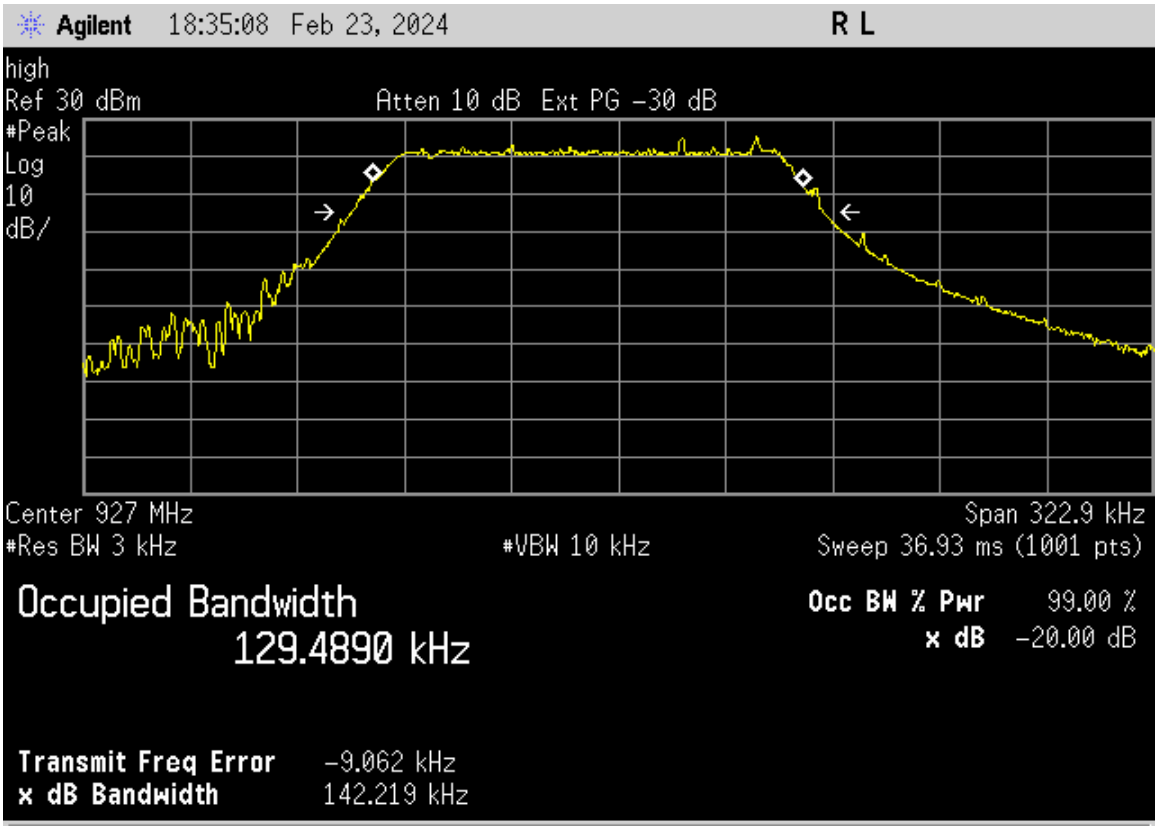

Figure 14. Bandwidth – High Channel

2.13 Number of Hopping Frequencies (CFR 15.247 (a)(1)) (CRF 15.247(b)(1))

Frequency hopping systems in the 902-928 MHz band shall have at least 50 hopping frequencies if the 20 dB bandwidth is less than 250 kHz. If the 20 dB bandwidth is 250 kHz or greater, then the system shall have at least 25 hopping frequencies. Since the EUT has a 20 dB bandwidth less than 250 kHz, then at least 50 hopping frequencies shall be used.

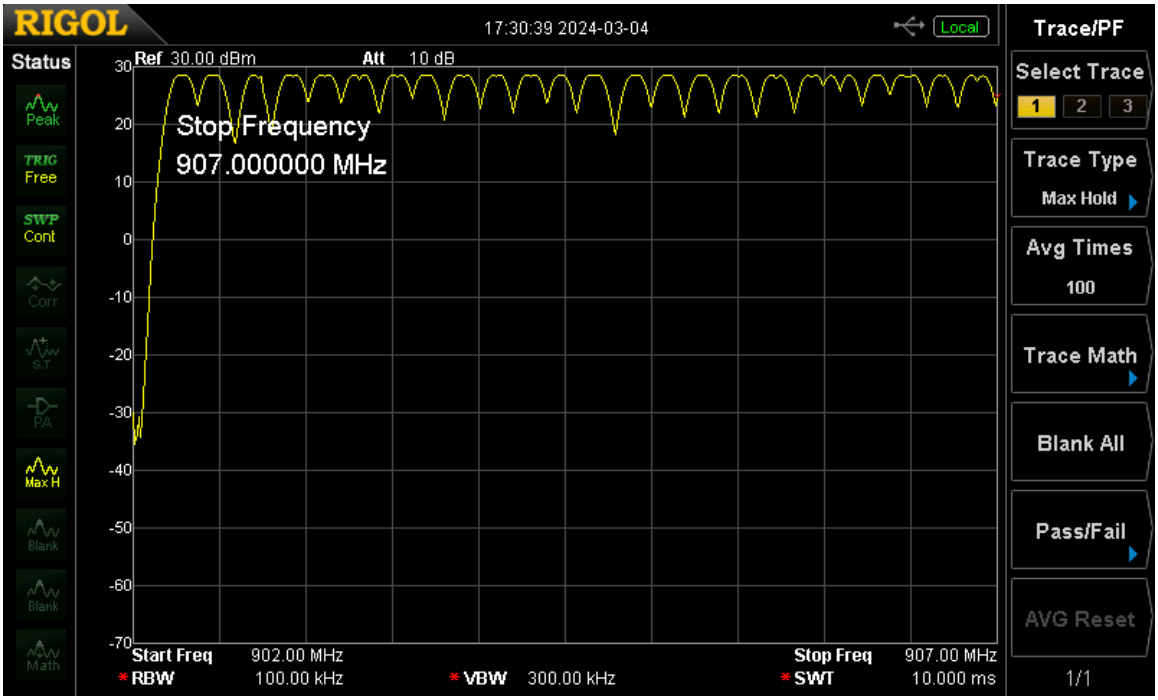

Figure 15. Hopping Channels LoRa 181 through 204

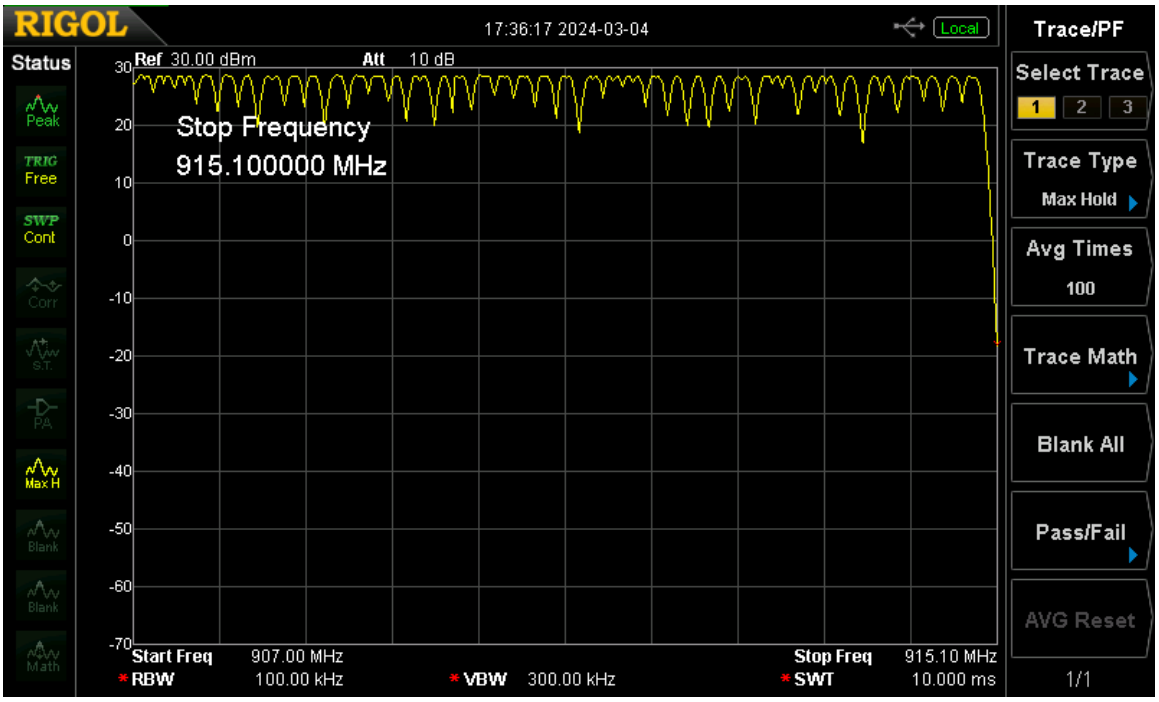

Figure 16. Hopping Channels LoRa 205 through 244

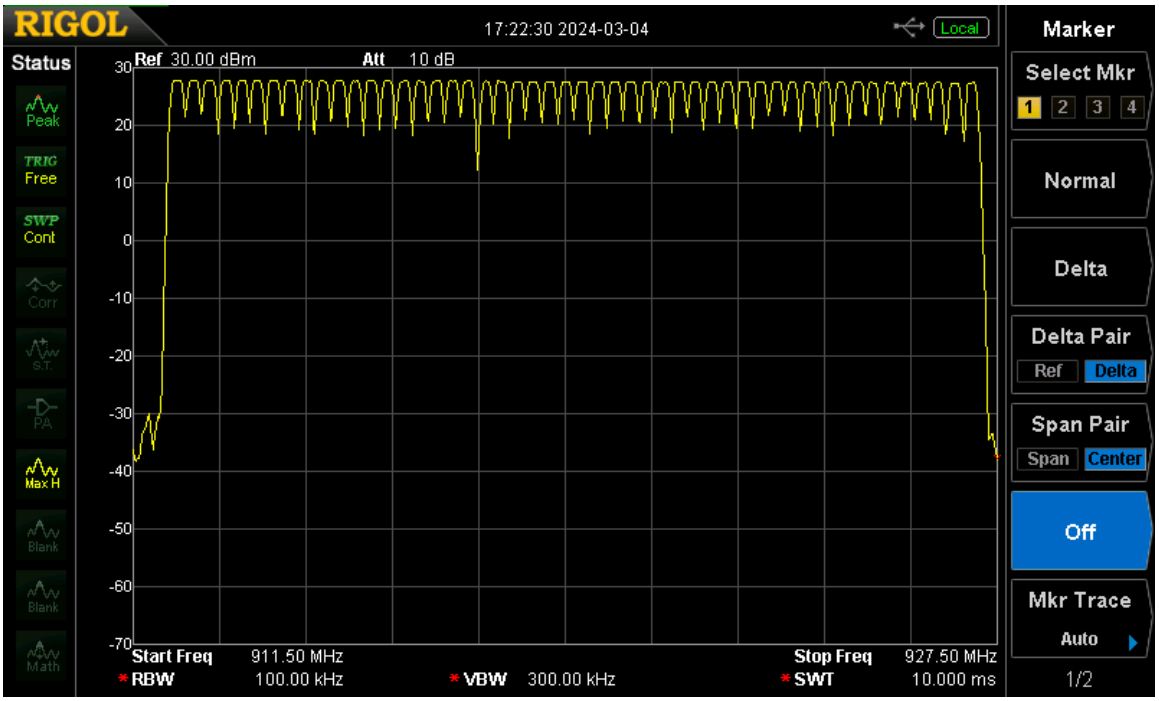

Figure 17. Hopping Channels 102 through 151

2.14 Maximum Peak Conducted Output Power (CFR 15.247 (b) (2))

For frequency hopping systems in the 902-928 MHz band with at least 50 hopping channels, the maximum peak conducted output power of the intentional radiator shall not exceed 1 watt. Systems with less than 50 hopping channels, but at least 25 hopping channels, the maximum peak conducted output power of the intentional radiator shall not exceed .25 watts. Since the EUT has 50(rfv4) and 64(lora) hopping channels, the maximum peak conducted output power shall not exceed 1 watt.

Peak power within the band 902.125 MHz to 927.80 MHz was measured per FCC KDB Publication DA 00-705 as an Antenna Conducted test with a spectrum analyzer by connecting the spectrum analyzer directly, via a short RF cable, and attenuators to the antenna output terminals on the EUT. The spectrum analyzer was set for an impedance of 50 Ω with the RBW set greater than the 6 dB bandwidth of the EUT, and the VBW ≥ RBW. Peak antenna conducted output power is tabulated in the table below.

Table 8. Peak Antenna Conducted Output Power per Part 15.247 (b) (3)

Frequency of Fundamental (MHz)	Raw Test Data dBm	Converted Data (mW)	FCC Limit (mW Maximum)
902.30	28.38	688.65	1000
914.90	27.58	572.79	1000
927.0125	27.14	517.61	1000

Test Date: February 8-26, 2024

Tested By
Signature: Ian Charboneau Name: Ian Charboneau

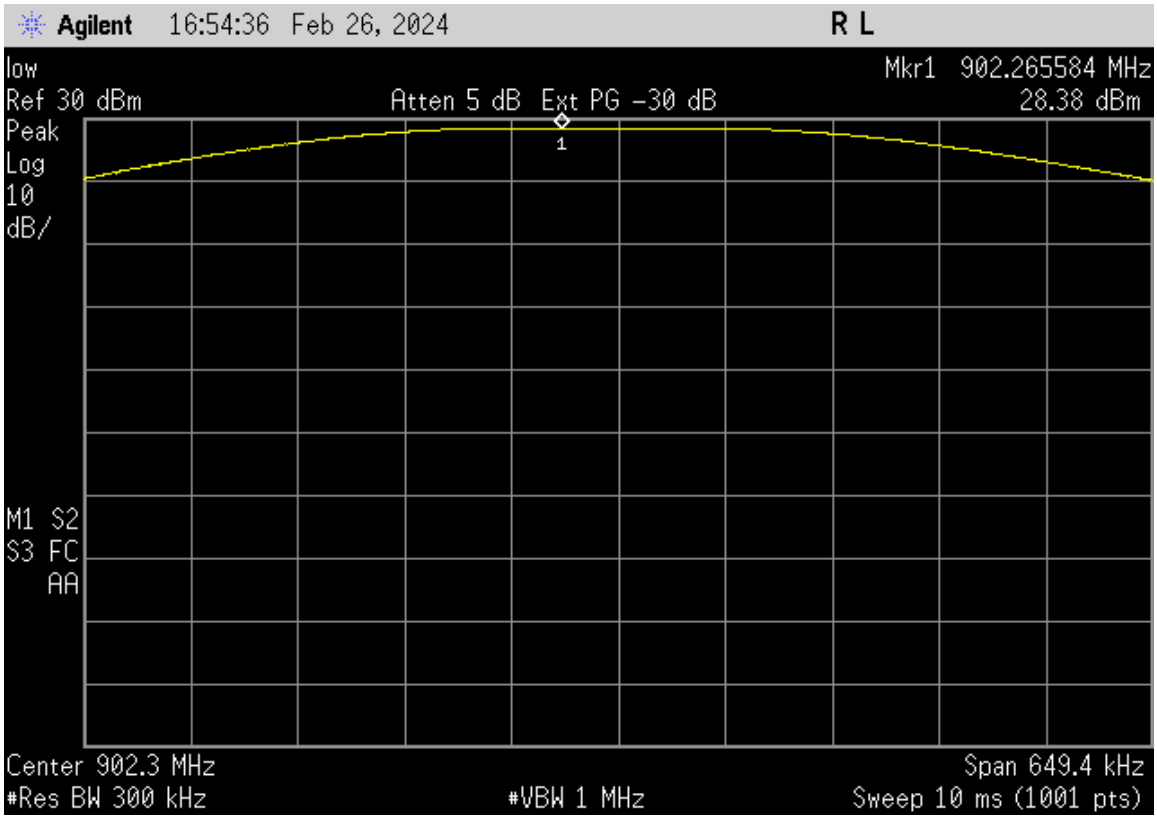

Figure 18. Peak Antenna Conducted Output Power, Low Channel

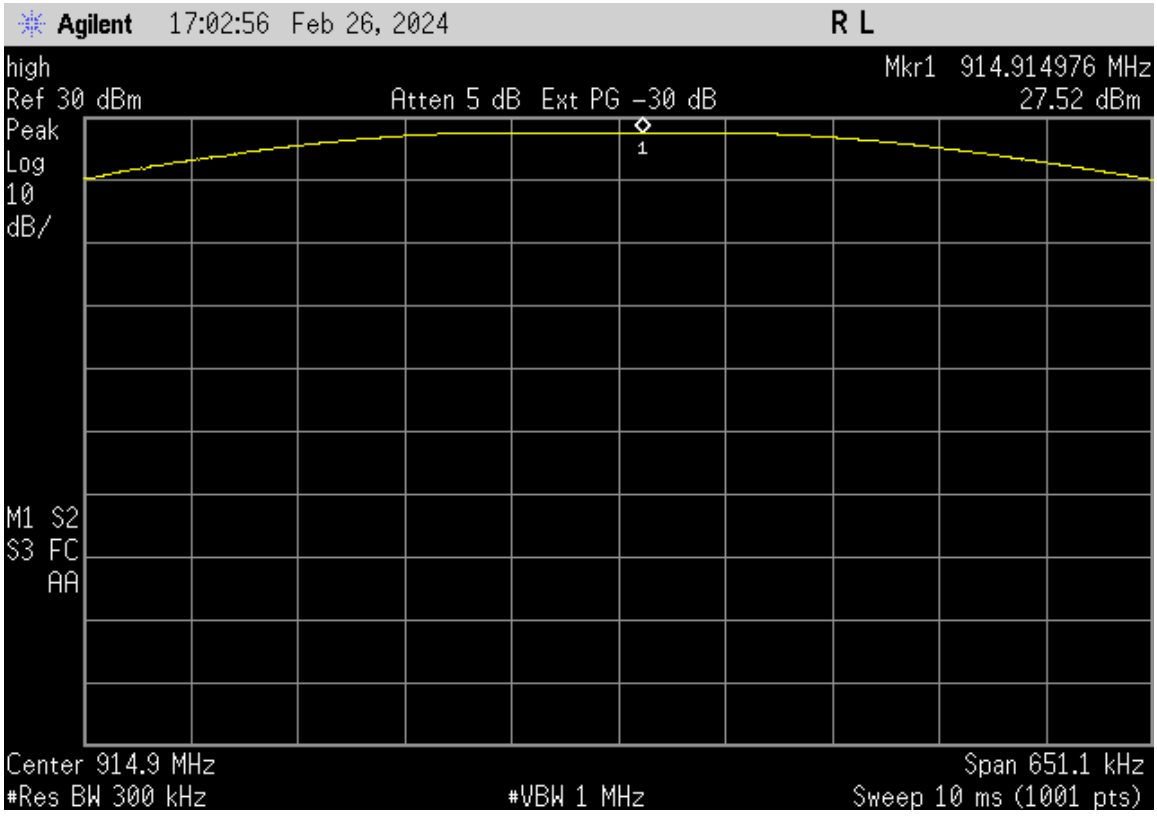

Figure 19. Peak Antenna Conducted Output Power, Mid Channel

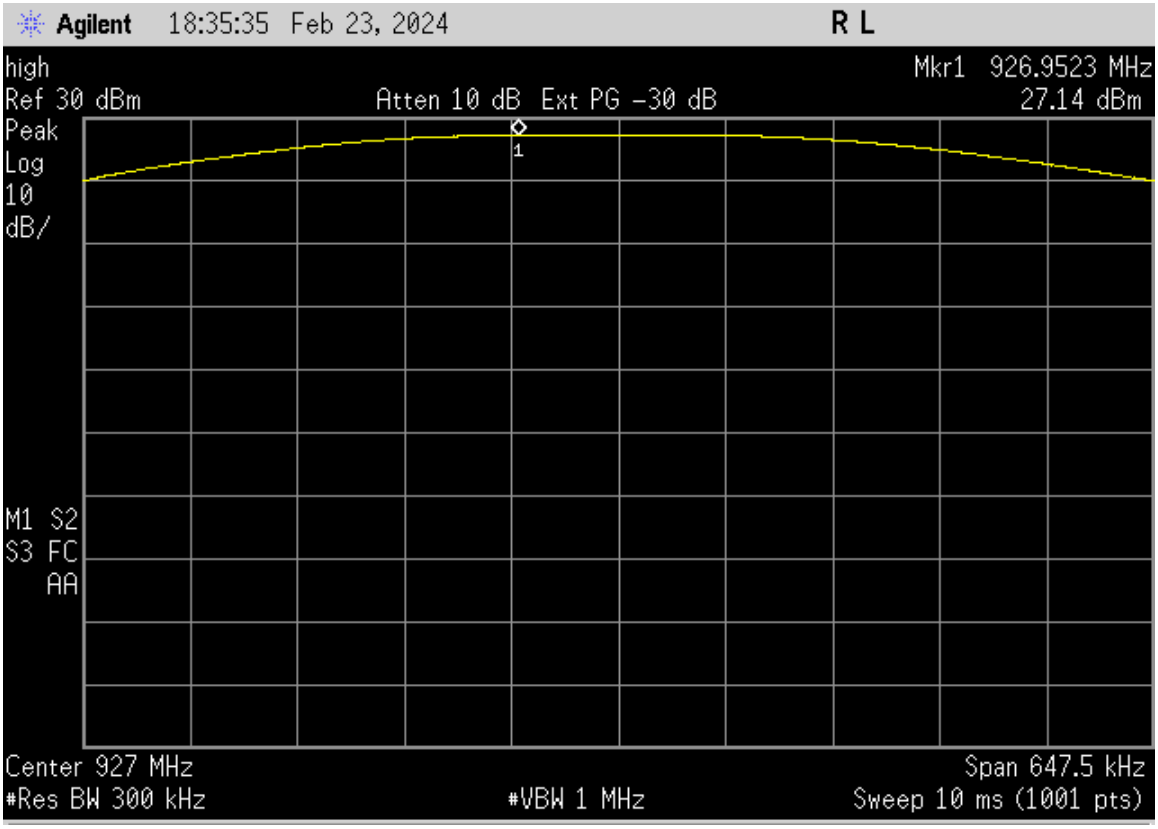

Figure 20. Peak Antenna Conducted Output Power, High Channel

2.15 Frequency Separation (CRF 15.247(a)(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. In this case, the 20 dB bandwidth of the hopping channel is 148.7 kHz, so the minimum requirement used was 148.7 kHz**.**

The EUT met the frequency separation requirement.

The test procedures outlined in Clause 7.8 of ANSI C63.10-2013 were used to conduct measurements. The EUT hopping function was enabled during the testing.

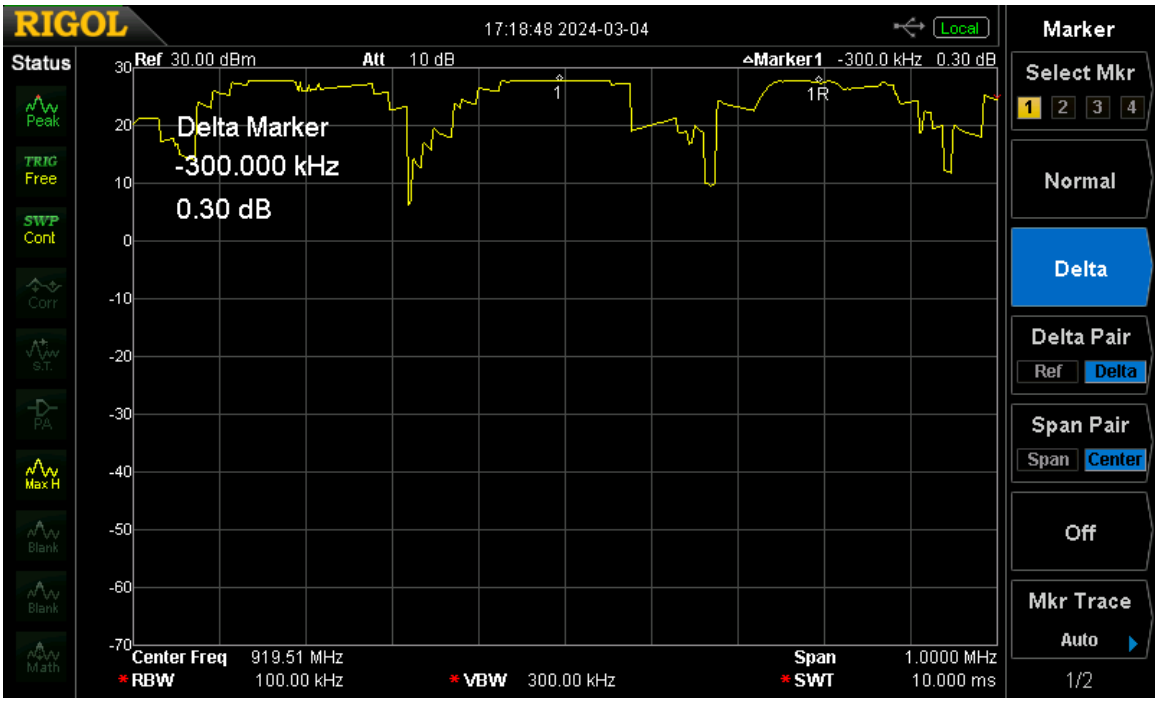

Figure 21. Channel Separation RFV4

Measured Delta (Figure 27)	300.0 kHz
-Limit (20db BW)	148.7 kHz
Margin	151.3 kHz

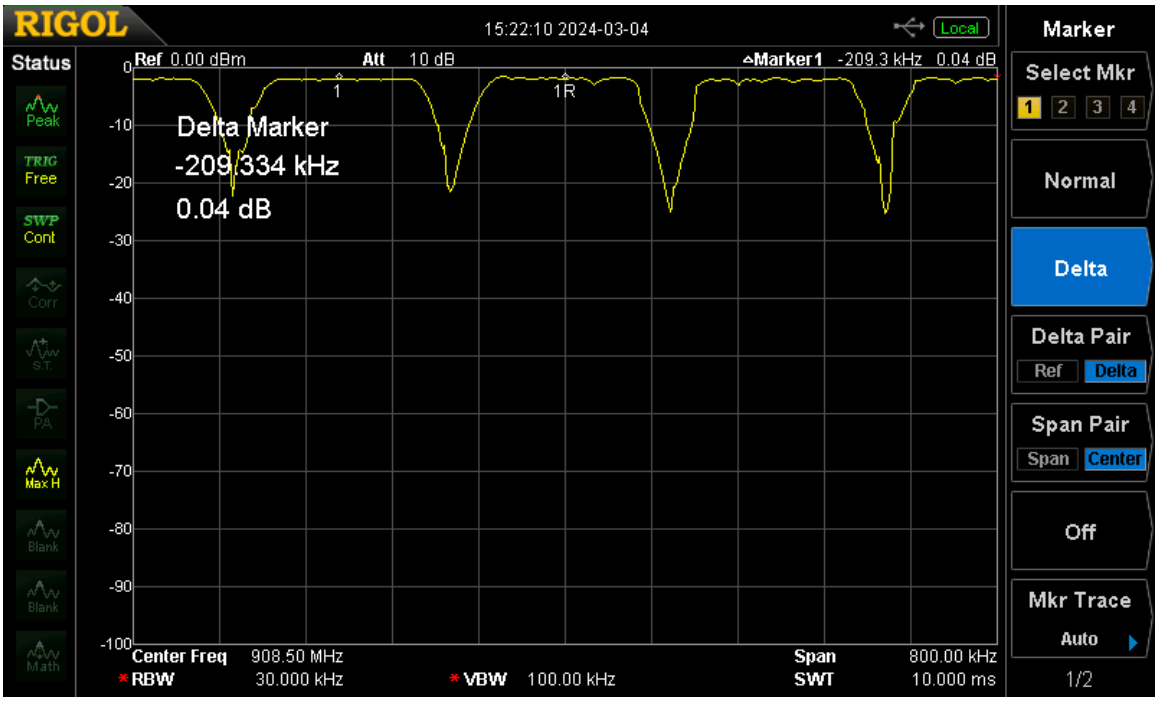

Figure 22. Channel Separation LoRa

Measured Delta (Figure 27)	209.3 kHz
-Limit (20db BW)	148.7 kHz
Margin	60.6 kHz

2.16 Average Time of Occupancy (CFR 15.247(a)(1))

Frequency hopping system in the 902-928 MHz bands with a 20 dB bandwidth less than 250 kHz shall have an average time occupancy not greater than 0.4 seconds within a 20 second period. If the 20 dB bandwidth of the hopping channels is 250 kHz or greater, than the average time of occupancy shall not be greater than 0.4 seconds within a 10 second period. In this case, since the 20 dB bandwidth was less than 250 kHz the average time of occupancy shall not be greater than 0.4 seconds.

In this case the radio uses 50 channels, therefore the maximum occupancy time I 0.4 seconds in a 20 second period.

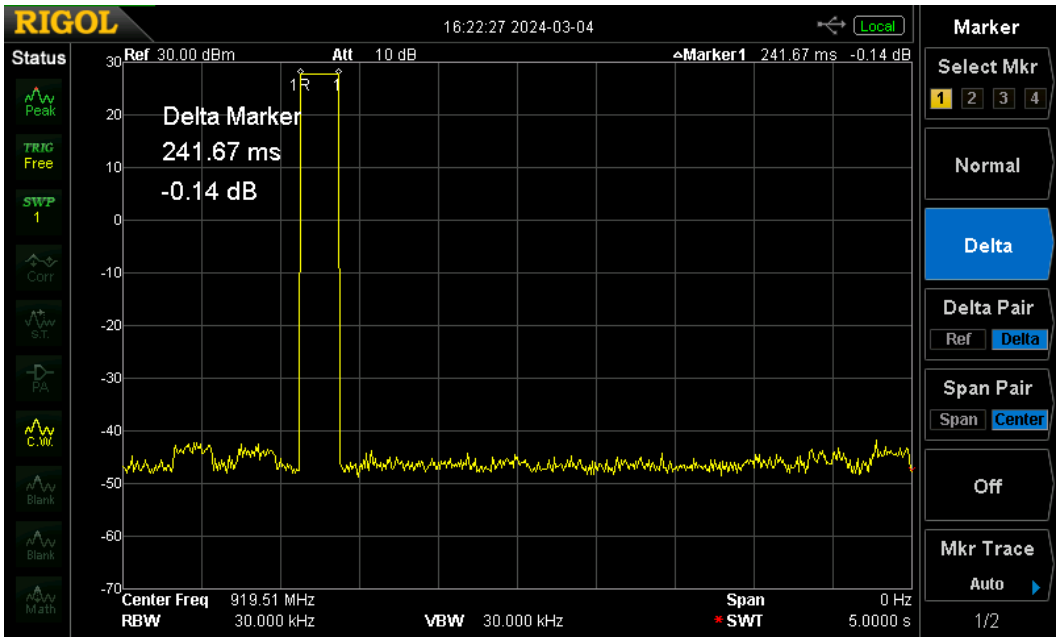

Figure 23. Average Time of Occupancy, On Time, RFV4

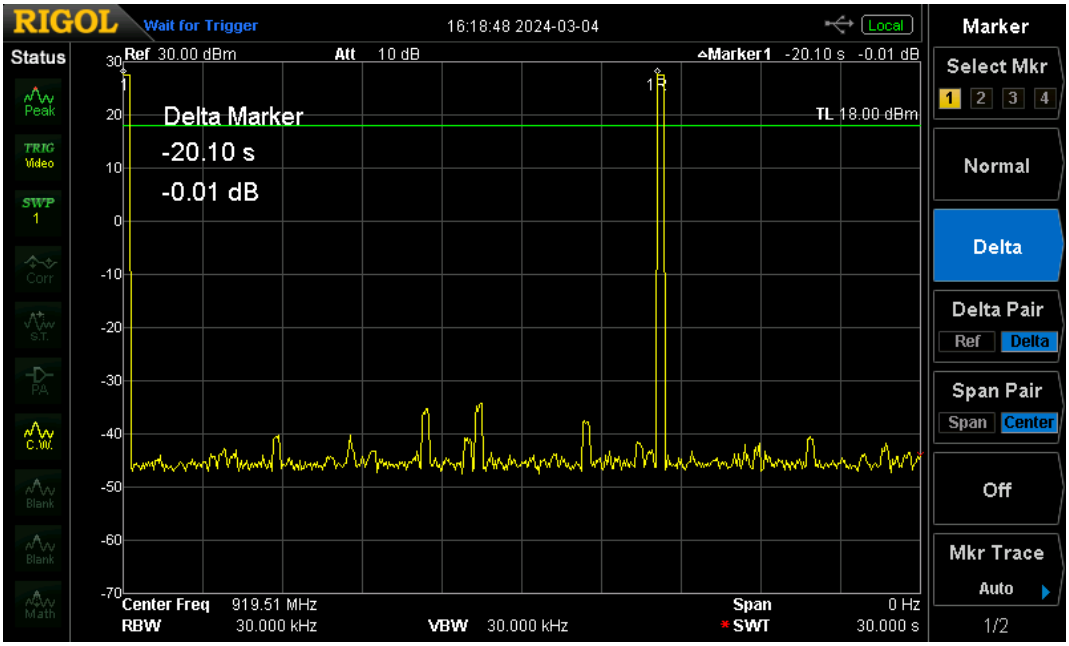

Figure 24. Average Time of Occupancy, Off Time, RFV4

Limit	400.0 ms
-Total Time on (Figure above)	241.5 ms
Margin	158.5 ms

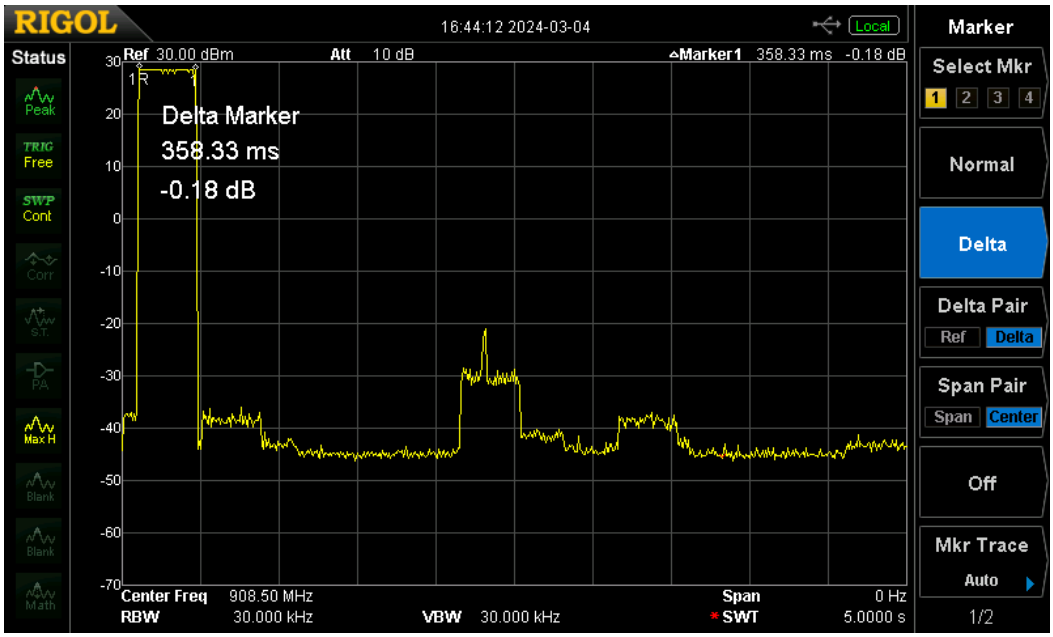

Figure 25. Average Time of Occupancy, On Time, LoRa

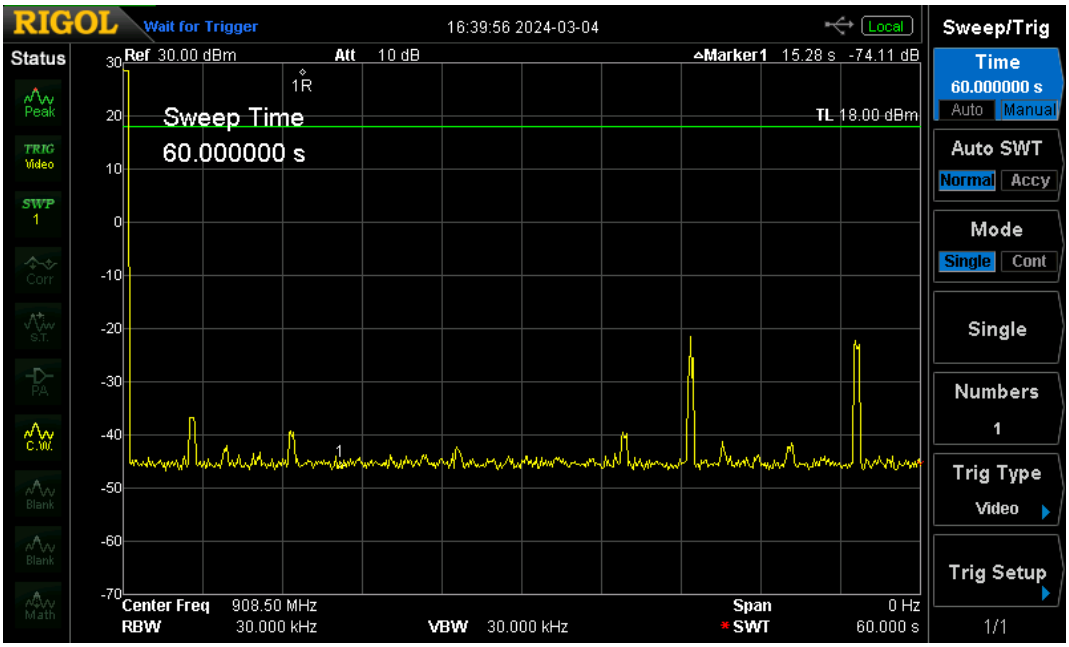

Figure 26. Average Time of Occupancy, Off Time, LoRa

Limit	400.0 ms
-Total Time on (Figure above)	358.3 ms
Margin	41.7 ms

2.17 Powerline Emissions (CFR 15.207)

The power line conducted voltage emission measurements have been carried out in accordance with CFR 15.107, per ANSI C63.4:2014, Paragraph 7, with a spectrum analyzer connected to a LISN and the EUT placed into a continuous mode of transmission.

The EUT was battery powered; therefore, this test was not applied.

Table 9. Transmitter Power Line Conducted Emissions Test Data, Part 15.107

150KHz to 30 MHz with Class A Limits						
Frequency (MHz)	**Test Data (dBuV)**	**LISN+CL-PA (dB)**	**Results (dBuV)**	**AVG Limits (dBuV)**	**Margin (dB)**	**Detector PK, QP, or AVG**
This test is not applicable to this EUT. The host device will be powered exclusively by a battery pack. No means for AC mains connection.						

Sample calculation: N/A

Test Date: February 29, 2024

Tested By
Signature:  Name: Ian Charboneau

2.18 Intentional Radiator, Radiated Emissions (CFR 15.209)

Radiated emissions disturbance Measurements were performed with an instrument having both peak and quasi-peak detectors over the frequency range of 9 KHz to 10 GHz. Measurements of the radiated emissions were made with the receiver antenna at a distance of 3 m from the boundary of the test unit.

The test antenna was varied from 1 m to 4 m in height while watching the analyzers' display for the maximum magnitude of the signal at the test frequency. The antenna polarization (horizontal or vertical) and test sample azimuth were varied during the measurements to find the maximum field strength readings to record.

Table 10. Radiated Emissions, 9 kHz - 30 MHz

9 kHz to 30 MHz, 15.209 limits							
Frequency (MHz)	**Test Data (dBuV)**	**AF+CA-AMP (dB/m)**	**Results (dBuV/m)**	**QP Limits (dBuV/m)**	**Antenna Distance/ Polarization**	**Margin (dB)**	**Detector PK, or AVG**
All emissions were more than 20 dB below the limit							

Sample Calculation: N/A

Test Date: February 12, 2024

Tested By
Signature:  Name: Ian Charboneau

Table 11. Radiated Emissions 30 MHz to 1000 MHz (CFR 15.209)

30 MHz to 1000 MHz, 15.209 limits							
Frequency (MHz)	**Test Data (dBuV)**	**AF+CA-AMP (dB/m)**	**Results (dBuV/m)**	**QP Limits (dBuV/m)**	**Antenna Distance/ Polarization**	**Margin (dB)**	**Detector PK, or QP**
All emissions were more than 20 dB below the limit							

Sample calculation: N/A

Test Date: February 12, 2024

Tested By
Signature:  Name: Ian Charboneau

Table 12. Radiated Emissions 1 GHz to 10 GHz (CFR 15.209)

1 GHz to 10 GHz, 15.209 limits							
Frequency (MHz)	**Test Data (dBuV)**	**AF+CA-AMP (dB/m)**	**Results (dBuV/m)**	**AVG Limits (dBuV/m)**	**Antenna Distance/ Polarization**	**Margin (dB)**	**Detector PK, or AVG**
All emissions were more than 20 dB below the limit							

Sample calculation: N/A

Test Date: February 12, 2024

Tested By
Signature:  Name: Ian Charboneau

2.19 Measurement Uncertainty

The measurement uncertainties given were calculated using the method detailed in CISPR 16-4. A coverage factor of k=2 was used to give a level of confidence of approximately 95%.

219.1 Conducted Emissions Measurement Uncertainty

Measurement Uncertainty (within a 95% confidence level) for this test is ± 2.78 dB.

2.19.2 Radiated Emissions Measurement Uncertainty

For a measurement distance of 3 m the measurement uncertainty (with a 95% confidence level) for this test using a Biconical Antenna (30 MHz to 200 MHz) is ± 5.39 dB. This value includes all elements of measurement.

The measurement uncertainty (with a 95% confidence level) for this test using a Log Periodic Antenna (200 MHz to 1000 MHz) is ± 5.18 dB.

The measurement uncertainty (with a 95% confidence level) for this test using a Horn Antenna (1 GHz to 18 GHz) is ± 5.21dB.

3 Conclusion

The EUT is deemed to have met the requirements of this subpart as tested and presented in this test report.