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FCC RF Test Report

Test Report Number	SUB-24041751-C-FCC-DSS-900M
FCC ID	2AS4H-BLINC3
Applicant	Subeca, Inc.
Applicant Address	4514 Cole Avenue Suite 600, Dallas, TX 75205
Product Name	Subeca BLINC S2
Model (s)	BLINC S2
Date of Receipt	06/11/2024
Date of Test	06/15/2024- 08/08/2024
Report Issue Date	08/16/2024
Test Standards	47 CFR Part 15.247
Test Result	**PASS**

Issued by:

Vista Compliance Laboratories
1261 Puerta Del Sol, San Clemente, CA 92673 USA
www.vista-compliance.com

Minoush Niknam (Test Engineer)

David Zhang (Technical Manager)

REVISION HISTORY

Report Number	Version	Description	Issued Date
SUB-24041751-C-FCC-DSS-LoRa	01	Initial report	08/16/2024

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1 Test Summary

Test Item	Test Requirement	Test Method	Result
Antenna Requirement	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
AC Power Line Conducted Emissions	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
20dB Channel Bandwidth	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Number of Hopping Channel	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Conducted Maximum Output Power	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Chanel Separation	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Time of Occupancy	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Conducted Band-Edge & Unwanted Emissions	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Frequency Hopping System Requirement	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass
Radiated Emissions & Unwanted Emissions into Restricted Frequency Bands	47 CFR Part 15.247	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02	Pass

2 General Information

2.1 Applicant

Applicant	Subeca, Inc.
Applicant address	4514 Cole Avenue Suite 600, Dallas, TX 75205
Manufacturer	Subeca, Inc.
Manufacturer Address	4514 Cole Avenue Suite 600, Dallas, TX 75205

2.2 Product information

Product Name	Subeca BLINC S2
Product Description	Subeca BLINC S2
Model Number	BLINC S2
Family Models	N/A
Serial Number	N/A
Frequency Band	LoRA: 902.3-914.9MHz
Type of modulation	LoRA
Equipment Class	DSS
Antenna Information	P/N: Taoglas PC91.07.0100A, db(915 MHz PCB antenna), peak gain: 2.67 dBi P/N: Taoglas iLA.09 (915 MHz Ceramic loop antenna), Chip Antenna, Peak gain: 1.57 dBi
Clock Frequencies	N/A
Input Power	DC 3.6V
Power Adapter Manufacturer/Model	N/A
Power Adapter SN	N/A
Hardware version	N/A
Software version	N/A
Simultaneous Transmission	BLE and 900MHz can transmit simultaneously
Additional Info	EUT supports BLE and 900 MHz LoRA/Sidewalk procotols. The 900MHz LoRA is under DSS equpment class as hopping device; the 900MHz Sidewalk is under DTS equipment class as digital modulation device. EUT is soldered onto a devleopment board for testing purpose.

2.3 Test standard and method

Test standard	47 CFR Part 15.247
Test method	ANSI C63.10-2013

3 Test Site Information

Lab performing tests	Vista Laboratories, Inc.
Lab Address	1261 Puerta Del Sol, San Clemente, CA 92673 USA
Phone Number	+1 (949) 393-1123
Website	www.vista-compliance.com

Test Condition	Temperature	Humidity	Atmospheric Pressure
RF Testing	23.5°C	55.1%	996 mbar
Radiated Emission Testing	23.5°C	55.1%	996 mbar

4 Modification of EUT / Deviations from Standards

The EUT is an engineering test sample loaded with RF testing firmware specifically designed to support the RF TX/RX measurement in different aspects.

5 Test Configuration and Operation

5.1 EUT Test Configuration

The EUT is mounted onto a development board to support testing. EUT is set to different transmission mode in terms of radio mode bandwidth, power level, test channel, etc.

The following software was used for testing and to monitor EUT performance

Software	Description
EMISoft Vasona	EMC/RF Spurious emission test software used during testing
Tera Term	Set EUT into RF test mode

5.2 Supporting Equipment

Description	Manufacturer	Model #	Serial #
Development board	Subeca	PROP PLUG	N/A

6 Uncertainty of Measurement

Test item	Measurement Uncertainty (dB)
RF Output Power (Conducted)	±1.2 dB
Power Spectral Density	±0.9 dB
Unwanted Emission (conducted)	±2.6 dB
Occupied Channel Bandwidth	±5 %
Radiated Emission (9KHz-30MHz)	±3.5 dB
Radiated Emission (30MHz-1GHz)	±4.6 dB
Radiated Emission (1-18GHz)	±4.9 dB
Radiated Emission (18-40GHz)	±3.5 dB

7 Test Results

7.1 Antenna Requirement

7.1.1 Requirement

Per § 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.

7.1.2 Result

Analysis:

- EUT has two types of antennas connection: one is using on board unique u.FL connector, for connecting to a external PCB antenna (peak gain: 2.67 dBi); one is a on board ceramic loop antenna (1.57 dBi), which is soldered to the mainboard and considered permantely attached.

Conclusion:

- EUT complies with antenna requirement in § 15.203.

7.2 Conducted Emissions

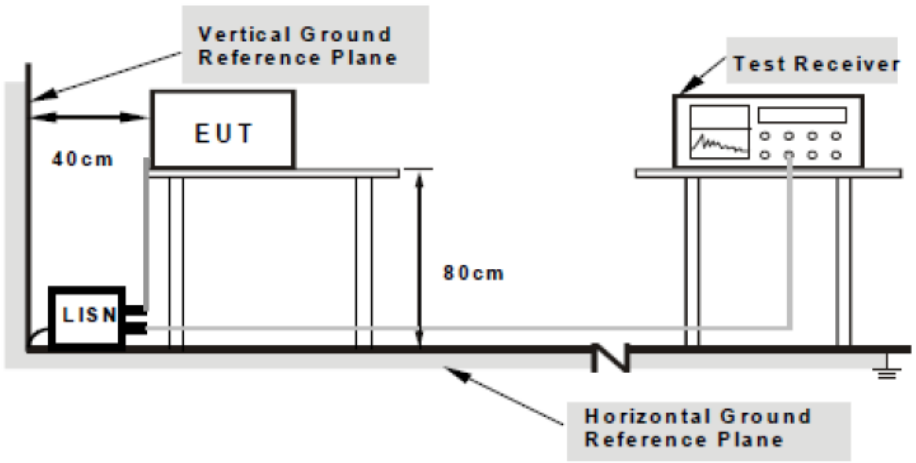
7.2.1 Requirement

Per § 15.207 (a), an intentional radiator that is designed to be connected to the public utility (AC) power line, the radio frequency voltage that is conducted back onto the AC power line on any frequency or frequencies, within the band 150 kHz to 30 MHz, shall not exceed the limits in the following table, as measured using a 50 μH/50 ohms line impedance stabilization network (LISN). Compliance with the provisions of this paragraph shall be based on the measurement of the radio frequency voltage between each power line and ground at the power terminal. The lower limit applies at the boundary between the frequency ranges.

Limits for Conducted Emissions at the Mains Ports

Section	Frequency ranges (MHz)	Limit (dBuV)	
		QP	Average
Class B devices	0.15 – 0.5	66 – 56	56 – 46
	0.5 – 5	56	46
	5 - 30	60	50
NOTE 1 The lower limit shall apply at the transition frequencies.			

7.2.2 Test setup



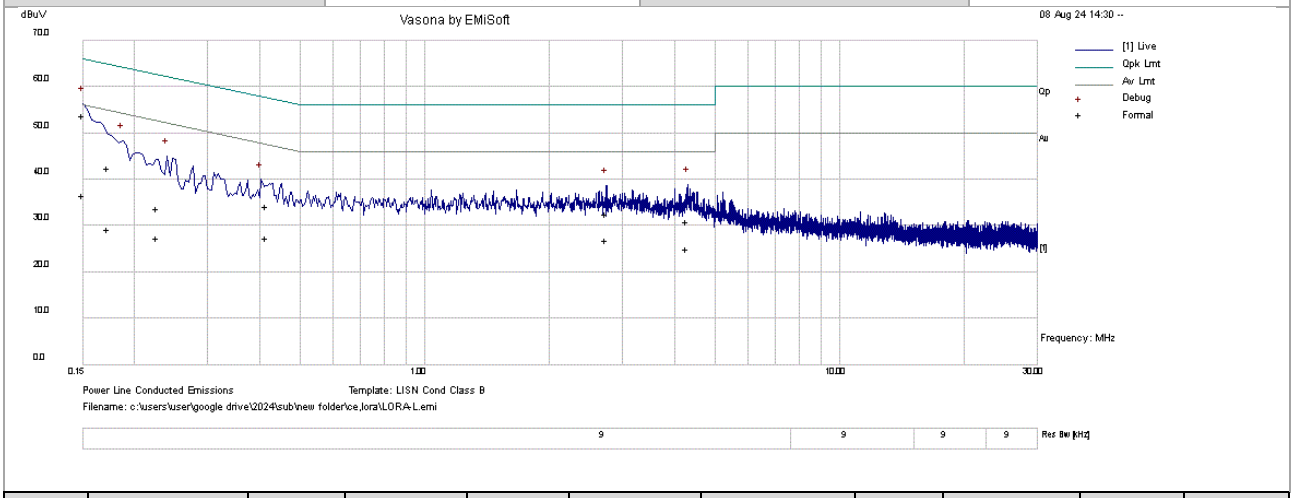
Note: 1.Support units were connected to second LISN.
2.Both of LISNs (AMN) are 80cm from EUT and at least 80cm from other units and other metal planes support units.

7.2.3 Test Procedure

1. The EUT and supporting equipment were set up in accordance with the requirements of the standard on top of a 1.5m x 1m x 0.8m high, non-metallic table.
2. The power supply for the EUT was fed through a 50Ω/50µH EUT LISN, connected to filtered mains.
3. The RF OUT of the EUT LISN was connected to the EMI test receiver via a low-loss coaxial cable.
4. All other supporting equipment was powered separately from another main supply.
5. The EUT was switched on and allowed to warm up to its normal operating condition.
6. A scan was made on the NEUTRAL line (for AC mains) or Earth line (for DC power) over the required frequency range using an EMI test receiver.
7. High peaks, relative to the limit line, were then selected.
8. The EMI test receiver was then tuned to the selected frequencies and the necessary measurements made with a receiver bandwidth setting of 10 kHz. For FCC tests, only Quasi-peak measurements were made; while for CISPR/EN tests, both Quasi-peak and Average measurements were made
9. All possible modes of operation were investigated. Only the worst-case emissions were measured and reported. All other emissions were relatively insignificant.

7.2.4 Test Result

Test Standard:	Part 15.207	Mode:	TX, Live
Frequency Range:	0.15-30MHz	Test Date:	08/08/2024
Antenna Type/Polarity:	N/A	Test Personnel:	Minoush Niknam
Remark:	Class B, 120VAC, 60Hz	Test Result:	Pass

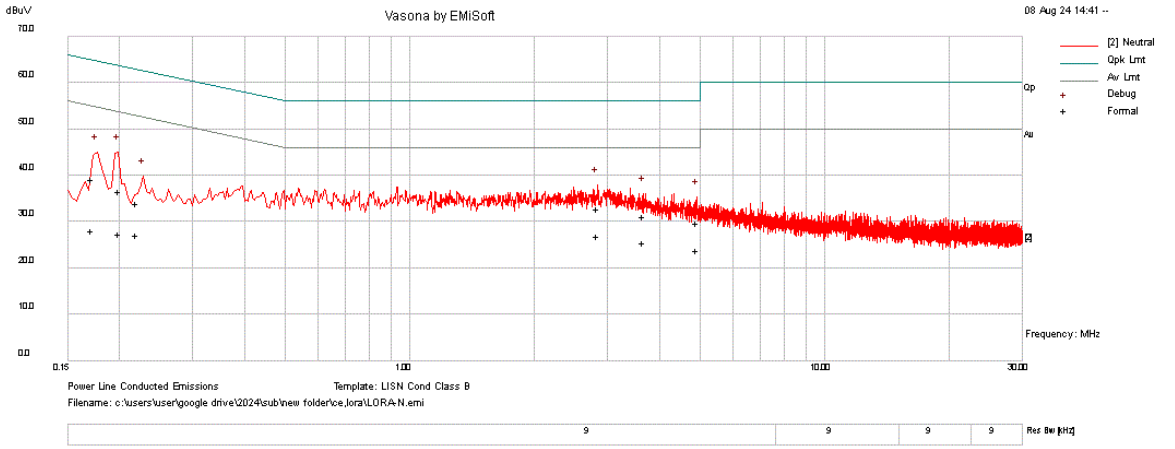


No.	Frequency (MHz)	Raw (dBuV)	Cable Loss (dB)	Factors (dB)	Level (dBuV)	Meas. Type	Line	Limit (dBuV)	Margin (dB)	Pass /Fail
1	0.150	43.5	10.0	0.2	53.8	Quasi Peak	Live	66.0	-12.2	Pass
2	0.173	32.2	10.0	0.2	42.4	Quasi Peak	Live	64.8	-22.4	Pass
3	4.297	20.8	10.1	0.1	31.0	Quasi Peak	Live	56.0	-25.0	Pass
4	0.227	23.7	10.0	0.2	33.9	Quasi Peak	Live	62.6	-28.7	Pass
5	2.739	22.5	10.1	0.1	32.7	Quasi Peak	Live	56.0	-23.3	Pass
6	0.417	24.0	10.0	0.1	34.2	Quasi Peak	Live	57.5	-23.3	Pass
7	0.150	26.4	10.0	0.2	36.6	Average	Live	56.0	-19.4	Pass
8	0.173	19.1	10.0	0.2	29.3	Average	Live	54.8	-25.5	Pass
9	4.297	14.9	10.1	0.1	25.1	Average	Live	46.0	-20.9	Pass
10	0.227	17.2	10.0	0.2	27.4	Average	Live	52.6	-25.1	Pass
11	2.739	16.7	10.1	0.1	26.9	Average	Live	46.0	-19.1	Pass
12	0.417	17.2	10.0	0.1	27.4	Average	Live	47.5	-20.1	Pass

REMARKS:

1. The emission levels of other frequencies were very low against the limit.
2. Factor = Inert loss of LISN
3. Margin value = Emission level - Limit value
4. Emission Level = Raw Value + Cable loss + Factors Value.

Test Standard:	Part 15.207	Mode:	TX, Neutral
Frequency Range:	0.15-30MHz	Test Date:	08/08/202
Antenna Type/Polarity:	N/A	Test Personnel:	Minoush Niknam
Remark:	Class B, 120VAC, 60Hz	Test Result:	Pass



No.	Frequency (MHz)	Raw (dBuV)	Cable Loss (dB)	Factors (dB)	Level (dBuV)	Meas. Type	Line	Limit (dBuV)	Margin (dB)	Pass /Fail
1	2.833	22.6	10.1	0.1	32.8	Quasi Peak	Neutral	56.0	-23.2	Pass
2	0.200	26.3	10.0	0.2	36.5	Quasi Peak	Neutral	63.6	-27.1	Pass
3	0.171	28.8	10.0	0.2	39.1	Quasi Peak	Neutral	64.9	-25.8	Pass
4	3.656	21.1	10.1	0.1	31.3	Quasi Peak	Neutral	56.0	-24.7	Pass
5	4.921	19.6	10.1	0.2	29.9	Quasi Peak	Neutral	56.0	-26.1	Pass
6	0.220	23.7	10.0	0.2	34.0	Quasi Peak	Neutral	62.8	-28.9	Pass
7	2.833	16.7	10.1	0.1	26.9	Average	Neutral	46.0	-19.1	Pass
8	0.200	17.3	10.0	0.2	27.5	Average	Neutral	53.6	-26.1	Pass
9	0.171	17.8	10.0	0.2	28.1	Average	Neutral	54.9	-26.8	Pass
10	3.656	15.2	10.1	0.1	25.4	Average	Neutral	46.0	-20.6	Pass
11	4.921	13.8	10.1	0.2	24.0	Average	Neutral	46.0	-22.0	Pass
12	0.220	17.0	10.0	0.2	27.2	Average	Neutral	52.8	-25.6	Pass

REMARKS:

1. The emission levels of other frequencies were very low against the limit.
2. Factor = Inert loss of LISN
3. Margin value = Emission level - Limit value
4. Emission Level = Raw Value + Cable loss + Factors Value.

7.3 20 dB Bandwidth

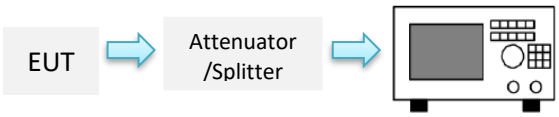
7.3.1 Requirement

§ 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. 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.

7.3.2 Test Setup



7.3.3 Test Procedure

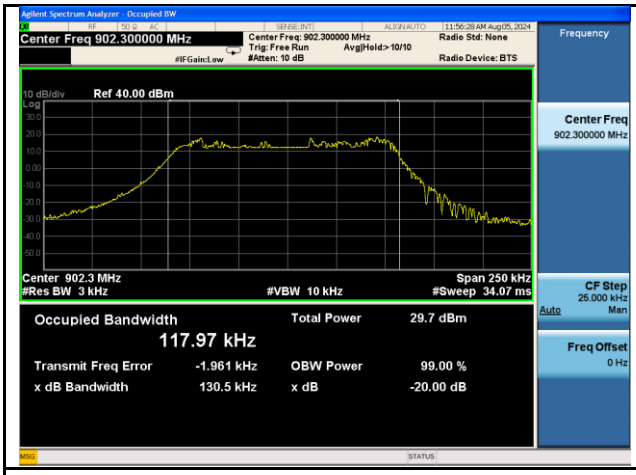
According to section 6.9.2, in ANSI C63.10-2013:

Measurement is made with the occupied bandwidth measurement function incorporated in spectrum analyzer. The following setting are used per ANSI C63.10-2013.

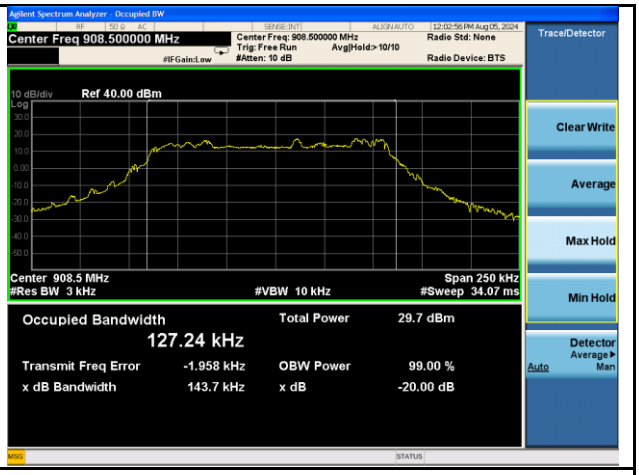
1. Set center Frequency = Nominal EUT channel center frequency.
2. Set Span to be between two times and five times of the OBW.
3. RBW shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times RBW.
4. Set detection mode to peak and trace mode to max hold.
5. Use the occupied bandwidth measurement function to place two markers, one at the lowest frequency and the other at the highest frequency of the envelope of the spectral display, such that each marker is at or slightly below the "-xx dB down amplitude" determined.
6. The occupied bandwidth shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labelled. Tabular data may be reported in addition to the plot(s).

7.3.4 Test Result

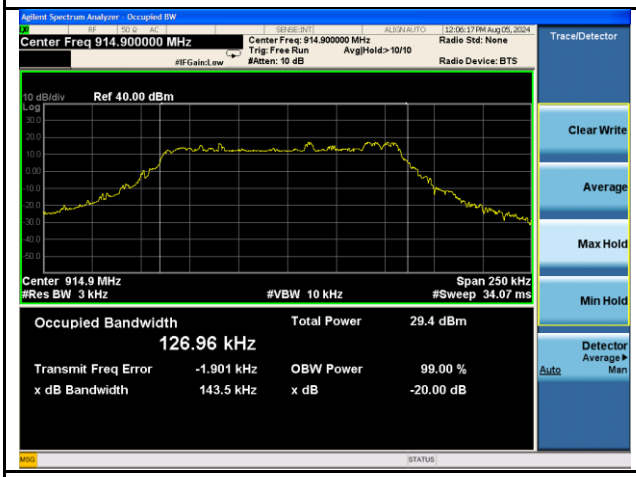
Mode/ Bandwidth	Frequency (MHz)	Measured Bandwidth (KHz)	Bandwidth Limit (KHz)	Result
LoRA	902.3	130.5	250	Pass
LoRA	908.5	143.7	250	Pass
LoRA	914.9	143.5	250	Pass



20dB BW - Low CH



20dB BW - Mid CH



20dB BW - High CH

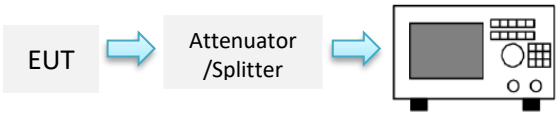
7.4 Maximum Output Power

7.4.1 Requirement

§ 15.247 (b)(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.

7.4.2 Test Setup



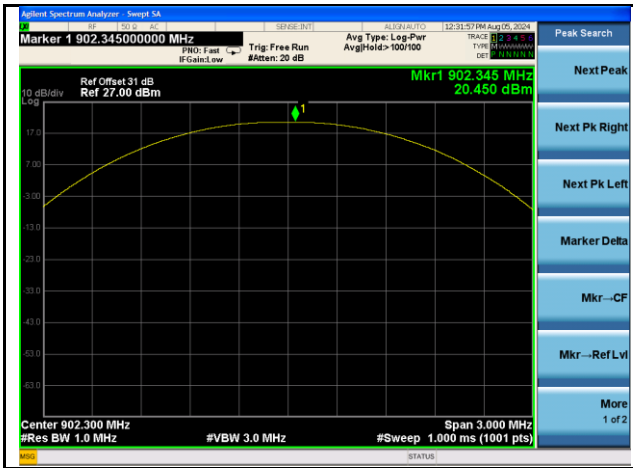
7.4.3 Test Procedure

According to section 7.8.5 of ANSI C63.10-2013. The measurement was made with EUT directly connected to spectrum analyzer. The following setting is used.

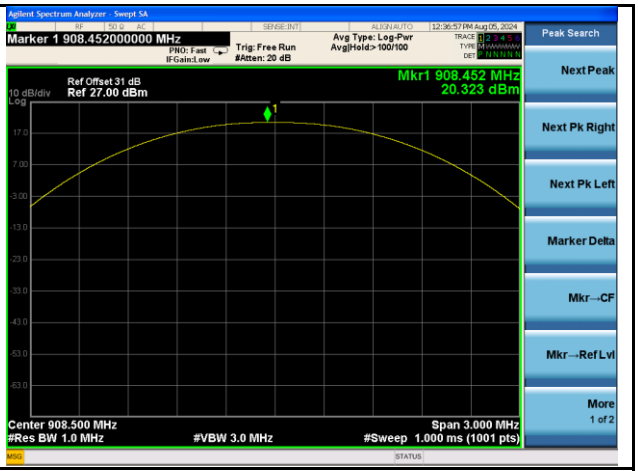
1. Set the RBW > 20 dB BW
2. Set VBW ≥ RBW.
3. Set span to approximately five times the 20 dB bandwidth, centered on a hopping channel.
4. Sweep time = auto couple.
5. Detector = peak.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use peak marker function to determine the peak amplitude level.

7.4.4 Test Result

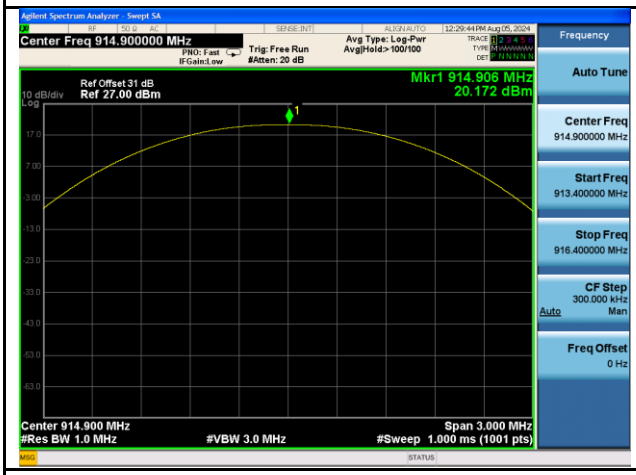
Mode/ Bandwidth	Frequency (MHz)	Measured Output Power (dBm)	Max Output Power (dBm)	Result
LoRA	902.3	20.450	30	Pass
LoRA	908.5	20.323	30	Pass
LoRA	914.9	20.172	30	Pass



OP - Low CH



OP - Mid CH



OP - High CH

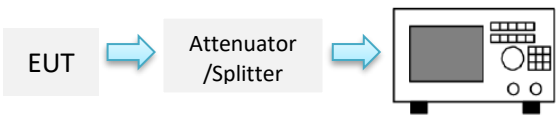
7.5 Number of Hopping Channel

7.5.1 Requirement

Per § 15.247 (a) (1) (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.

7.5.2 Test setup



7.5.3 Test Procedure

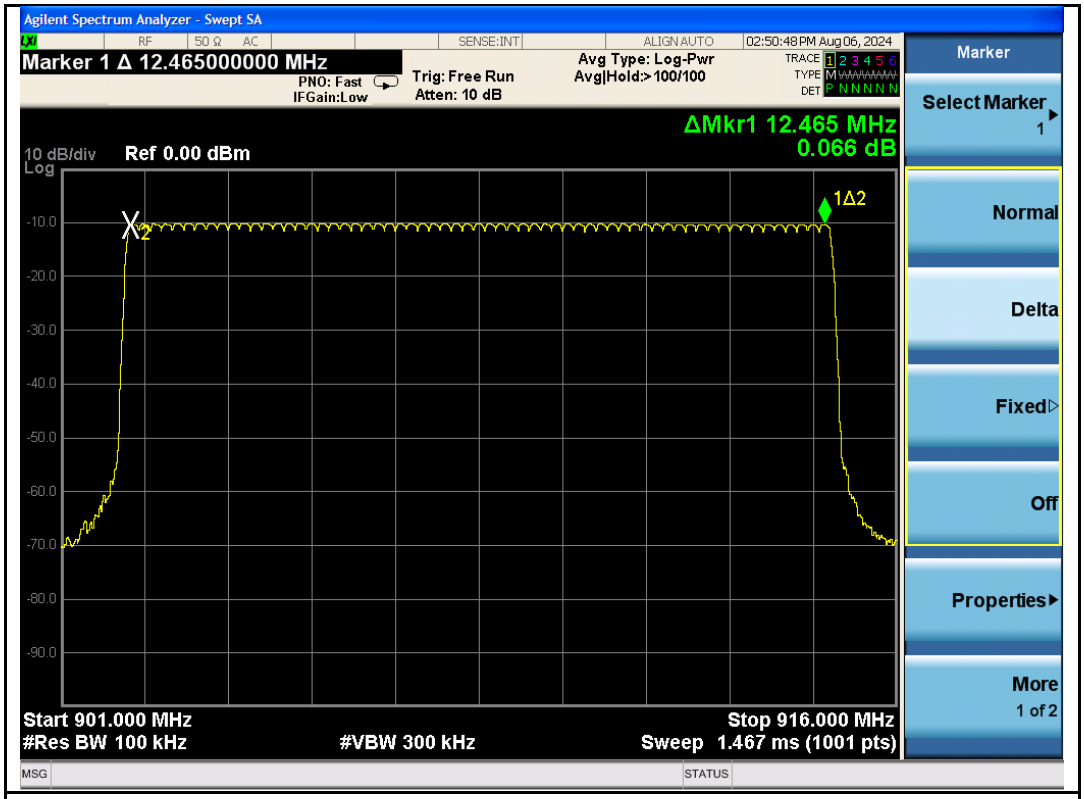
According to section 7.8.3, in ANSI C63.10-2013:

Measurement is made with spectrum analyzer. The following setting is used.

1. Set Span to be the frequency band of operation.
2. Set RBW to less 30% of the channel spacing or the 20 dB bandwidth, whichever is smaller.
3. VBW ≥ RBW.
4. Sweep: Auto.
5. Detector function: Peak.
6. Trace: Max hold.
7. Allow the trace to stabilize.

7.5.4 Test Result

Mode/ Bandwidth	Frequency (MHz)	Channel Number	Minimum Limit	Result
LoRA	902.3 – 914.9	64	50	Pass



Hopping Channel Number

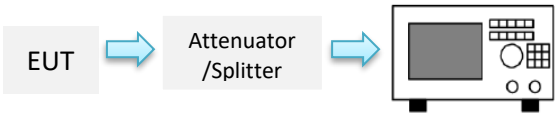
7.6 Channel Separation

7.6.1 Requirement

Per § 15.247 (a) (1), RSS-247 §5.1, b)

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.

7.6.2 Test setup



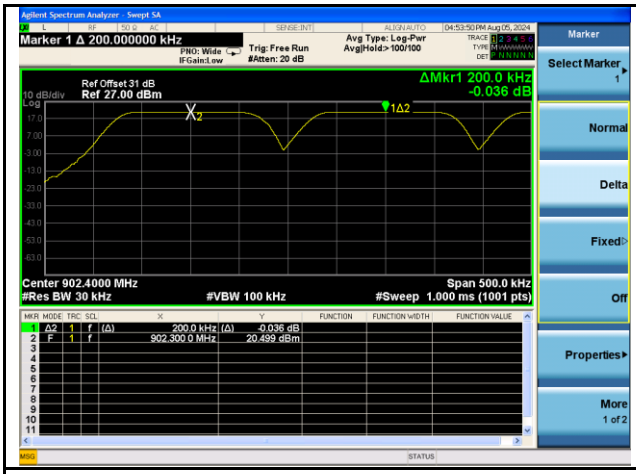
7.6.3 Test Procedure

According to section 7.8.2 of ANSI C63.10-2013. The measurement was made with spectrum analyzer. The following setting is used.

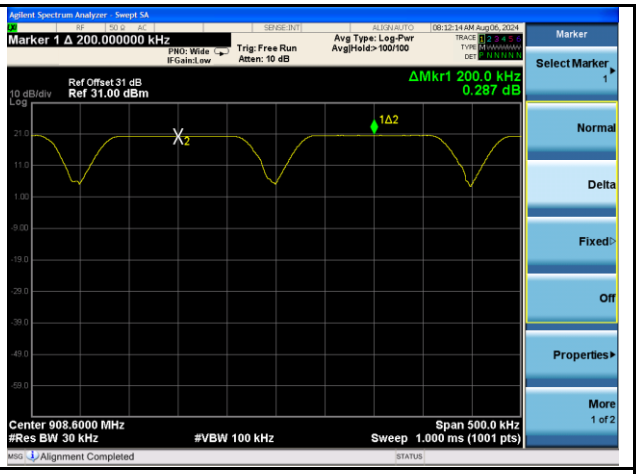
1. Set Span to wide enough to capture the peaks of two adjacent channels.
2. RBW: Start with the RBW set to approximately 30% of the channel spacing
3. VBW ≥ RBW.
5. Detector = peak.
6. Sweep time = auto couple.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function to determine separation between the peaks of adjacent channels.

7.6.4 Test Result

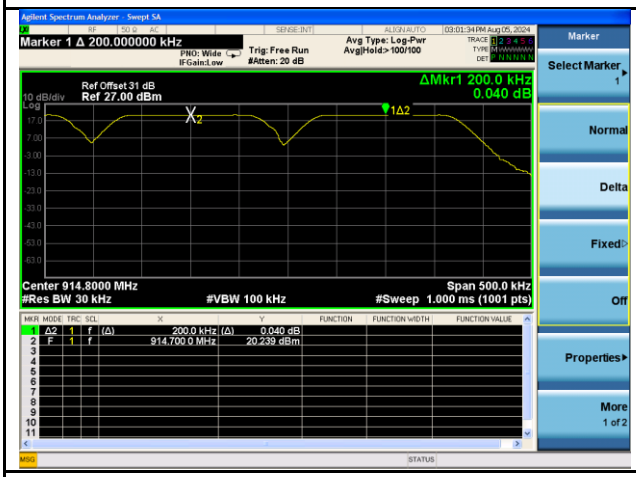
Mode/ Bandwidth	Frequency (MHz)	Channel Separation (KHz)	Max 20 dB Bandwidth (KHz)	Result
LoRA	902.3	200	130.5	Pass
LoRA	908.5	200	143.7	Pass
LoRA	914.9	200	143.5	Pass



CH Sep - Low CH



CH Sep - Mid CH



CH Sep - High CH

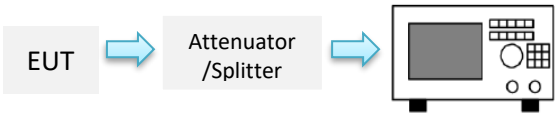
7.7 Time of Occupancy

7.7.1 Requirement

Per § 15.247 (a) (1) (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.

7.7.2 Test setup



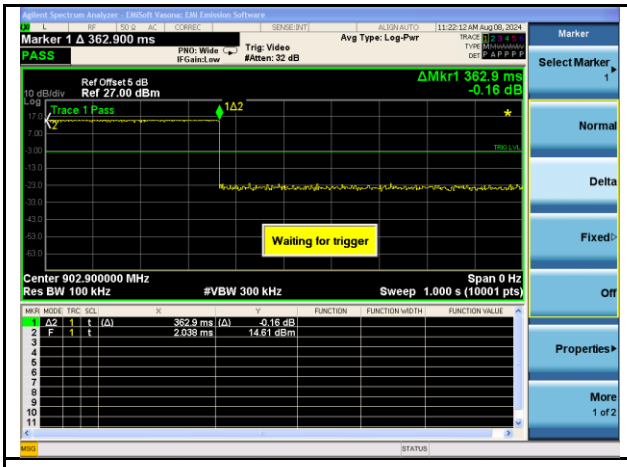
7.7.3 Test Procedure

According to section 7.8.4 of ANSI C63.10-2013. The measurement was made with spectrum analyzer. The following setting is used.

1. Set Span to zero, centered on a hopping channel.
2. RBW shall be ≤ channel spacing.
3. VBW ≥ RBW.
5. Detector = peak.
6. Sweep time = auto couple. As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal starts a little to the right of the start of the plot. The trigger level might need slight adjustment to prevent triggering when the system hops on an adjacent channel; a second plot might be needed with a longer sweep time to show two successive hops on a channel.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the marker-delta function to determine the transmit time per hop.

7.7.4 Test Result

Mode/ Bandwidth	Frequency (MHz)	Burst Width (ms)	Number of transmissions in 20 sec	Dwell Time (ms)	Limit (ms)	Result
LoRA	902.9	362.9	1	362.9	≤ 400	Pass



Dwell Time (Single Pulse)

Dwell Time (Cycle)

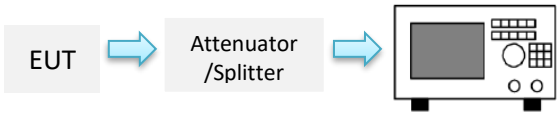
7.8 Conducted Band-Edge and conducted spurious emission

7.8.1 Requirement

Per § 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.

7.8.2 Test setup



7.8.3 Test Procedure

According to section 6.10 and 7.8.6 of ANSI C63.10-2013.

1. Connect the EMI receiver or spectrum analyzer to the EUT using an appropriate RF cable connected to the EUT output. Configure the spectrum analyzer settings as described in step e) (be sure to enter all losses between the unlicensed wireless device output and the spectrum analyzer).
2. Set the EUT to the lowest frequency channel (for the hopping on test, the hopping sequence shall include the lowest frequency channel).
3. Set the EUT to operate at maximum output power and 100% duty cycle, or equivalent “normal mode of operation” as specified in 6.10.3.
4. If using the radiated method, then use the applicable procedure(s) of 6.4, 6.5, or 6.6, and orient the EUT and measurement antenna positions to produce the highest emission level.
5. Perform the test as follows:
    a. Span: Wide enough to capture the peak level of the emission operating on the channel closest to the band edge, as well as any modulation products that fall outside of the authorized band of operation.
    b. Reference level: As required to keep the signal from exceeding the maximum instrument input mixer level for linear operation. In general, the peak of the spectral envelope shall be more than [10 log (OBW/RBW)] below the reference level. Specific guidance is given in 4.1.5.2.
    c. Attenuation: Auto (at least 10 dB preferred).
    d. Sweep time: Coupled.
    e. Resolution bandwidth: 100 kHz.

f. Video bandwidth: 300 kHz.
g. Detector: Peak.
h. Trace: Max hold.
i. Allow the trace to stabilize. For the test with the hopping function turned ON, this can take several minutes to achieve a reasonable probability of intercepting any emissions due to oscillator overshoot.

6. Set the marker on the emission at the band edge, or on the highest modulation product outside of the band, if this level is greater than that at the band edge. Enable the marker-delta function, and then use the marker-to-peak function to move the marker to the peak of the in-band emission.
7. Repeat step c) through step e) for every applicable modulation.
8. Set the EUT to the highest frequency channel (for the hopping on test, the hopping sequence shall include the highest frequency channel) and repeat step c) through step d).
9. The band-edge measurement shall be reported by providing plot(s) of the measuring instrument display; the plot axes and the scale units per division shall be clearly labeled. Tabular data may be reported in addition to the plot(s).

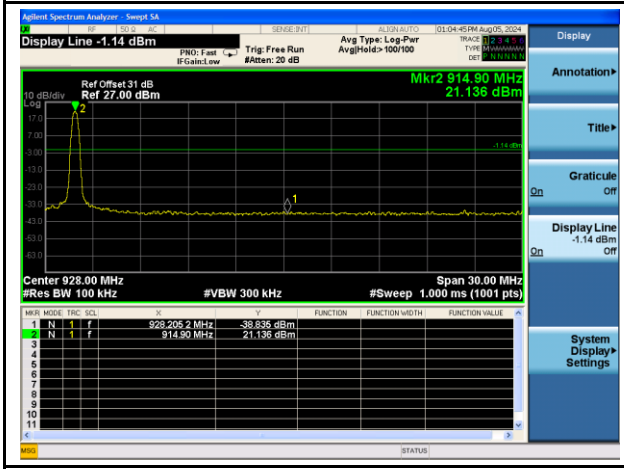
7.8.4 Test Result

The spectrum plots are attached on the following images. It shows compliance with the requirement.

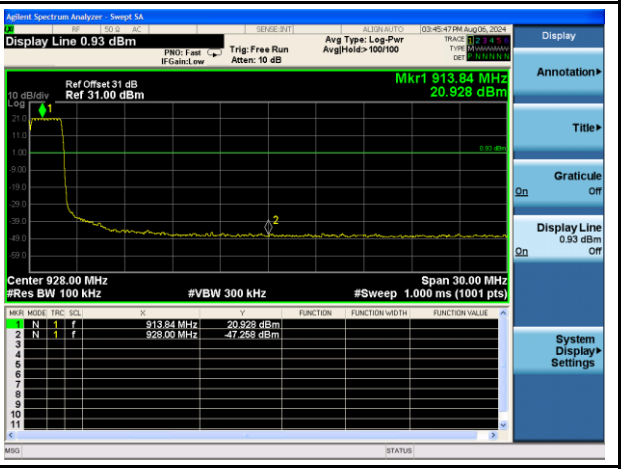
Band Edge test results

Band Edge-Low CH-Non hopping

Band Edge-Band Edge-Low CH-Hopping

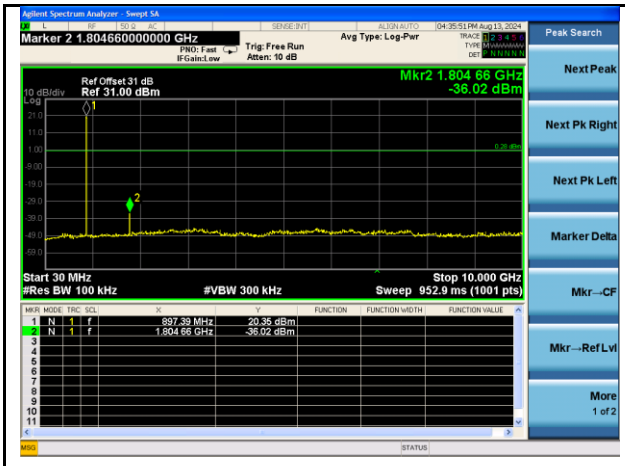


Band Edge-High CH-Non hopping

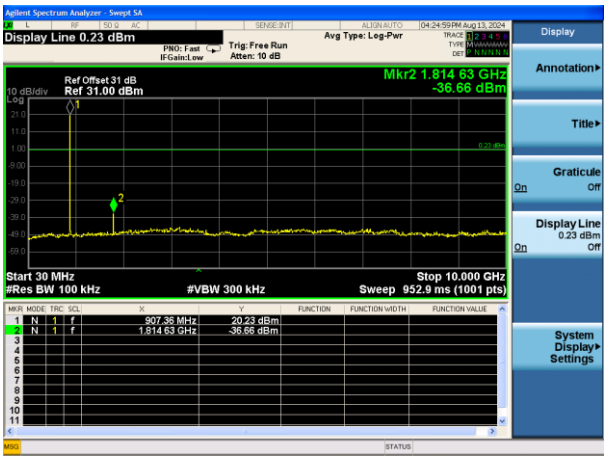


Band Edge-High CH-Hopping

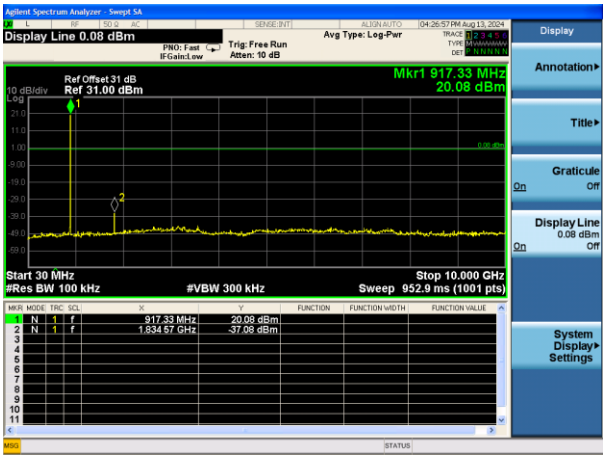
Conducted spurious emission test results



CSE-Low CH



CSE-Mid CH



CSE-High CH

7.9 Radiated Spurious Emissions into Restricted Frequency Bands

7.9.1 Requirement

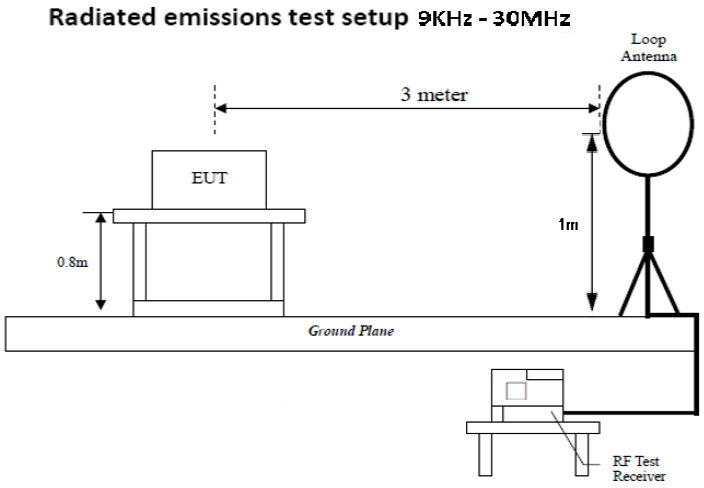
Per § 15.247 (d)

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, the attenuation required under this paragraph shall be 30 dB instead of 20 dB.

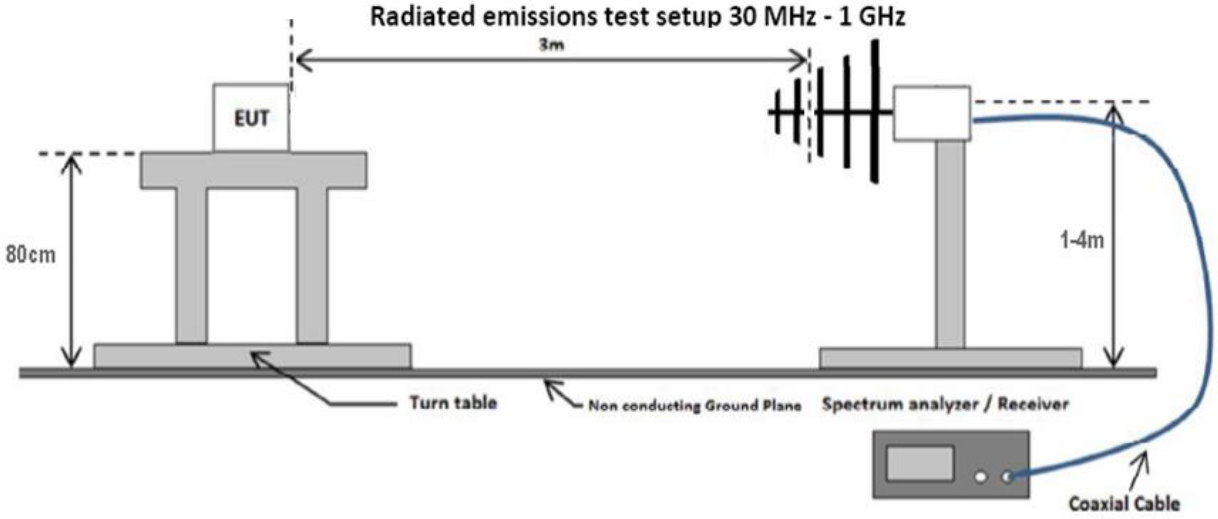
Attenuation below the general limits specified in §15.209(a) and RSS-Gen is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).

Frequency Range (MHZ)	Field Strength (μV/m)
0.009~0.490	2400/F(KHz)
0.490~1.705	24000/F(KHz)
1.705~30.0	30
30 – 88	100
88 – 216	150
216 960	200
Above 960	500

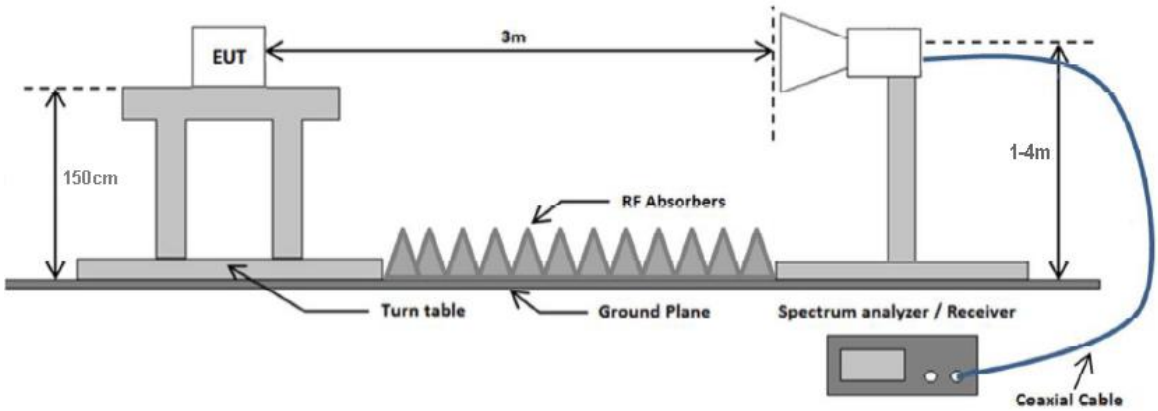
7.9.2 Test Setup



Radiated emissions test setup 30 MHz - 1 GHz



Radiated emissions test setup above 1 GHz



7.9.3 Test Procedure

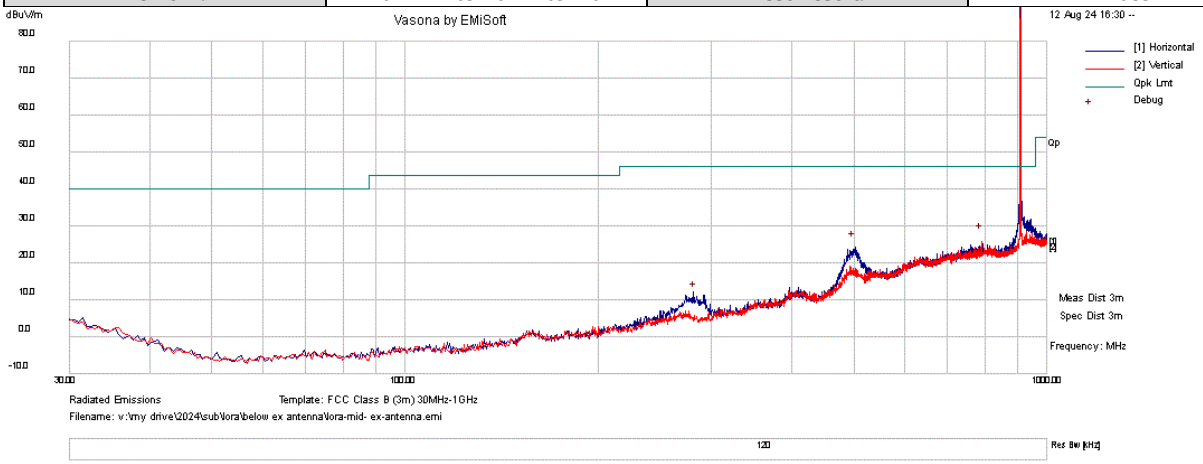
According to subclause 6.4, 6.5 and 6.6 of Radiated spurious emission measurements in ANSI C63.10-2013 as well as the procedures for maximizing and measuring radiated emissions that are described in ANSI C63.10 was followed. Boresight antenna mast was used during the scanning to point to EUT to maximize the emission. The process will be repeated in three EUT orientations.

1. The EUT was switched on and allowed to warm up to its normal operating condition.
2. The test was carried out at the selected frequency points obtained from the EUT characterization. Maximization of the emissions, was carried out by rotating the EUT, changing the antenna polarization, and adjusting the antenna height in the following manner:
   a. Vertical or horizontal polarization (whichever gave the higher emission level over a full rotation of the EUT) was chosen.
   b. The EUT was then rotated to the direction that gave the maximum emission.
   c. Finally, the antenna height was adjusted to the height that gave the maximum emission.
3. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 300 Hz for frequency below 150KHz.
4. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 10 kHz for frequency between 150KHz – 30MHz.
5. The resolution bandwidth and video bandwidth of test receiver/spectrum analyzer is 120 kHz for Quasi-Peak detection at frequency between 30MHz - 1GHz.
6. The resolution bandwidth of test receiver/spectrum analyzer is 1MHz and video bandwidth is 3MHz with Peak detection for Peak and average measurement at frequency above 1GHz.
7. Steps 2 and 3 were repeated for the next frequency point, until all selected frequency points were measured.

7.9.4 Test Result

RADIATED EMISSIONS BELOW 1 GHZ

Test Standard:	15.247, 15.209	Mode:	Transmit Mode
Frequency Range:	30 MHz - 1 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Bi-Log/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LoRA- External Antenna	Test Result:	Pass



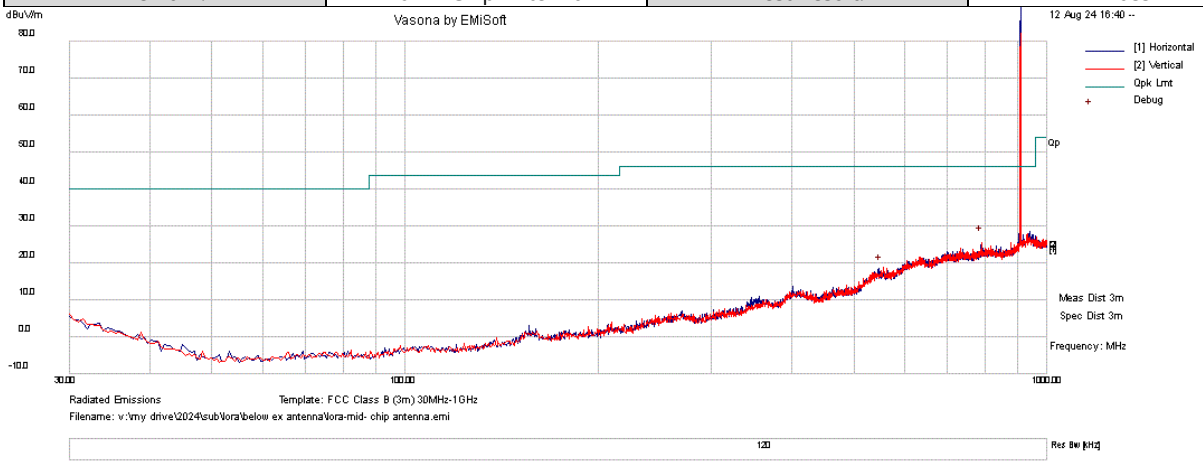
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	499.516	17.8	6.1	-0.2	23.6	Peak [Scan]	H	100	0	46	-22.4	Pass
2	282.489	12.2	5.5	-7.6	10.1	Peak [Scan]	H	100	0	46	-35.9	Pass
	790.007	12.1	7.3	6.4	25.8	Peak [Scan]	V	100	0	46	-20.2	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. Emission at around 900MHz is LoRA fundamental emission.

RADIATED EMISSIONS BELOW 1 GHZ

Test Standard:	15.247, 15.209	Mode:	Transmit Mode
Frequency Range:	30 MHz - 1 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Bi-Log/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LoRA- Chip Antenna	Test Result:	Pass



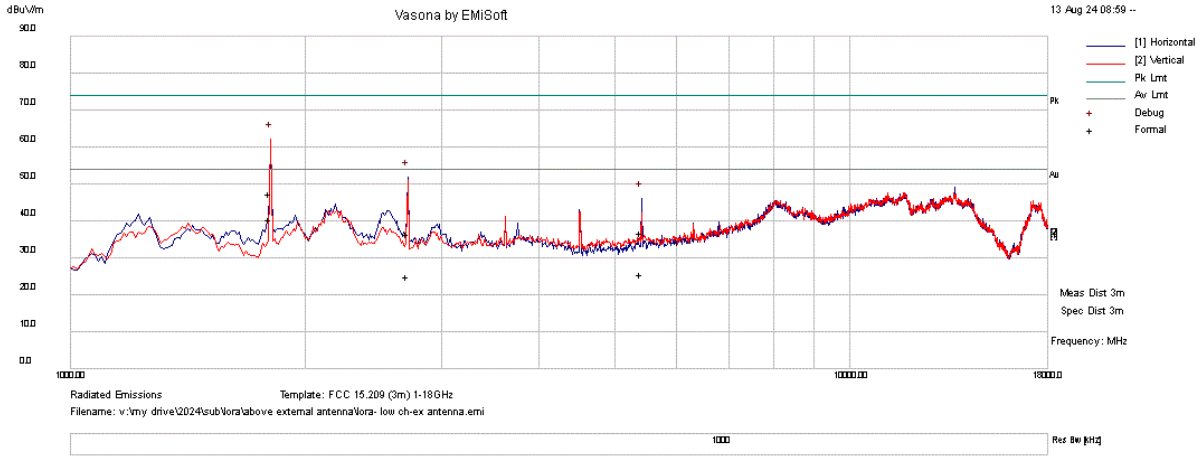
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	549.946	7.6	6.6	3	17.3	Peak [Scan]	V	100	0	46	-28.7	Pass
2	790.02	11.6	7.3	6.4	25.2	Peak [Scan]	V	100	0	46	-20.8	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. Emission at around 900MHz is LoRA fundamental emission.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	Low CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LORA-Low Ch-Ex Antenna	Test Result:	Pass



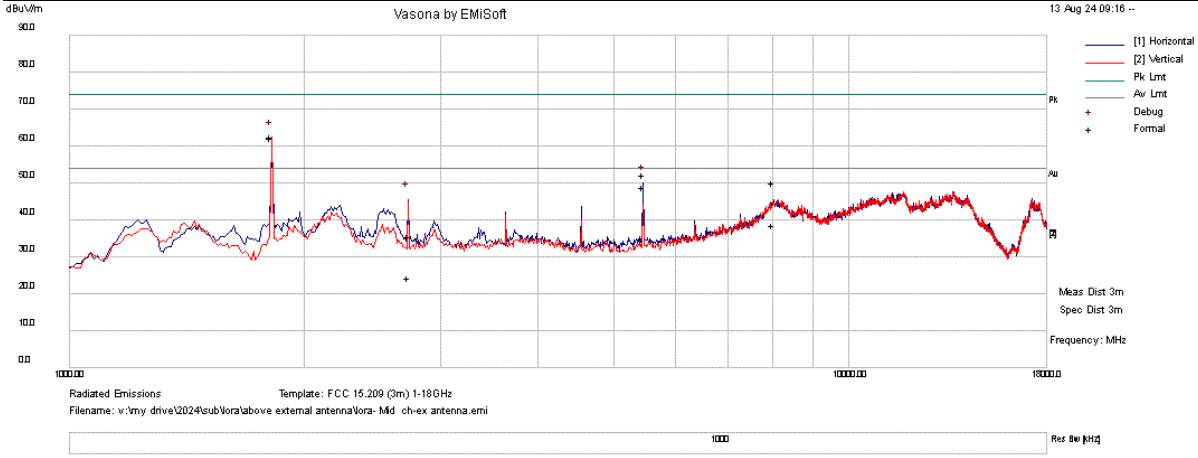
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1805.5	41.7	6.1	-0.2	47.5	Peak Max	V	158	30	74	-26.5	Pass
2	2710.38	28.2	7.2	1.1	36.5	Peak Max	H	174	1	74	-37.5	Pass
3	5408.67	20	10.5	6.1	36.7	Peak Max	H	172	102	74	-37.3	Pass
4	1805.5	34.6	6.1	-0.2	40.4	Average Max	V	158	30	54	-13.6	Pass
5	2710.38	16.8	7.2	1.1	25.1	Average Max	H	174	1	54	-28.9	Pass
6	5408.67	8.8	10.5	6.1	25.5	Average Max	H	172	102	54	-28.5	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1805 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	Mid CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Devin Tai
Remark:	LoRA-Mid Ch-EX Antenna	Test Result:	Pass



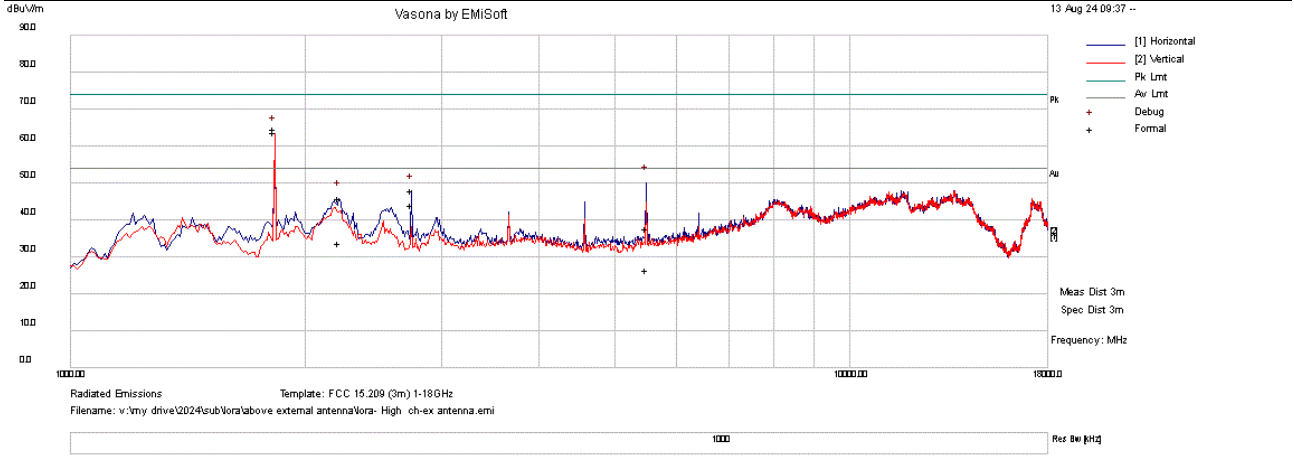
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1816.993	56.5	6.1	0	62.6	Peak Max	V	197	0	74	-11.4	Pass
2	5451.045	35.5	10.6	6	52.2	Peak Max	H	174	40	74	-21.8	Pass
3	2722.138	27.3	7.2	1.1	35.6	Peak Max	H	195	53	74	-38.4	Pass
4	8010.523	19.9	14.3	15.9	50	Peak Max	H	126	0	74	-24	Pass
5	1816.993	56.2	6.1	0	62.3	Average Max	V	197	0	54	8.3	Fail*
6	5451.045	32.2	10.6	6	48.9	Average Max	H	174	40	54	-5.1	Pass
7	2722.138	15.9	7.2	1.1	24.2	Average Max	H	195	53	54	-29.8	Pass
8	8010.523	8.6	14.3	15.9	38.7	Average Max	H	126	0	54	-15.3	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1816 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	High CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LORA-High CH-EX Antenna	Test Result:	Pass



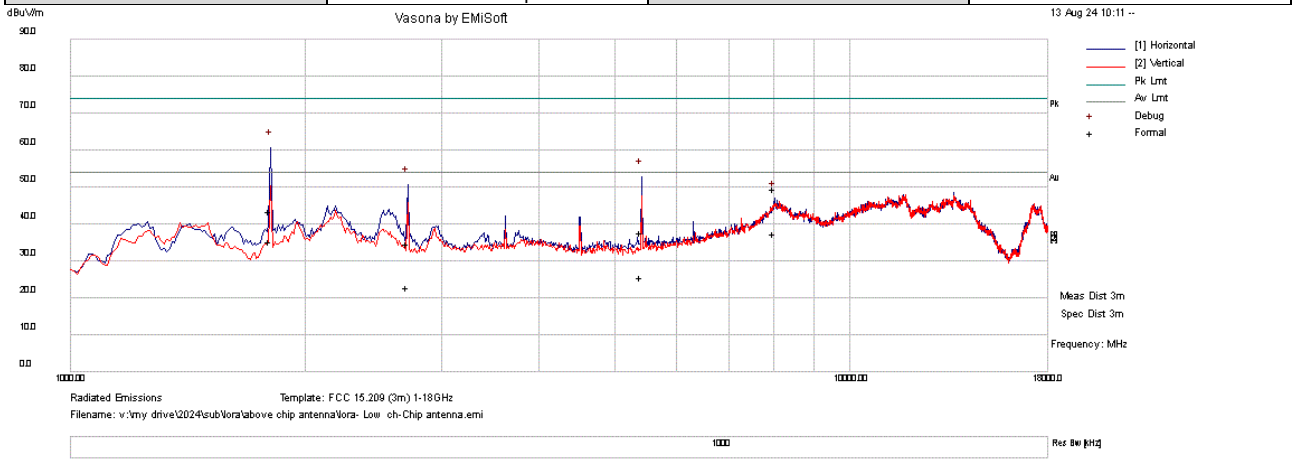
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1829.893	58.3	6.1	0.1	64.6	Peak Max	V	170	1	74	-9.4	Pass
2	5494.803	21	10.8	5.9	37.7	Peak Max	H	117	0	74	-36.3	Pass
3	2744.42	39.6	7.2	1.2	48	Peak Max	H	173	10	74	-26	Pass
4	2212.573	39.1	6.5	0.2	45.8	Peak Max	H	140	48	74	-28.2	Pass
5	1829.893	57.6	6.1	0.1	63.9	Average Max	V	170	1	54	9.9	Fail*
6	5494.803	9.8	10.8	5.9	26.5	Average Max	H	117	0	54	-27.5	Pass
7	2744.42	35.6	7.2	1.2	44	Average Max	H	173	10	54	-10	Pass
8	2212.573	27	6.5	0.2	33.6	Average Max	H	140	48	54	-20.4	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1829 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	Low CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LORA-Low CH-Chip Antenna	Test Result:	Pass



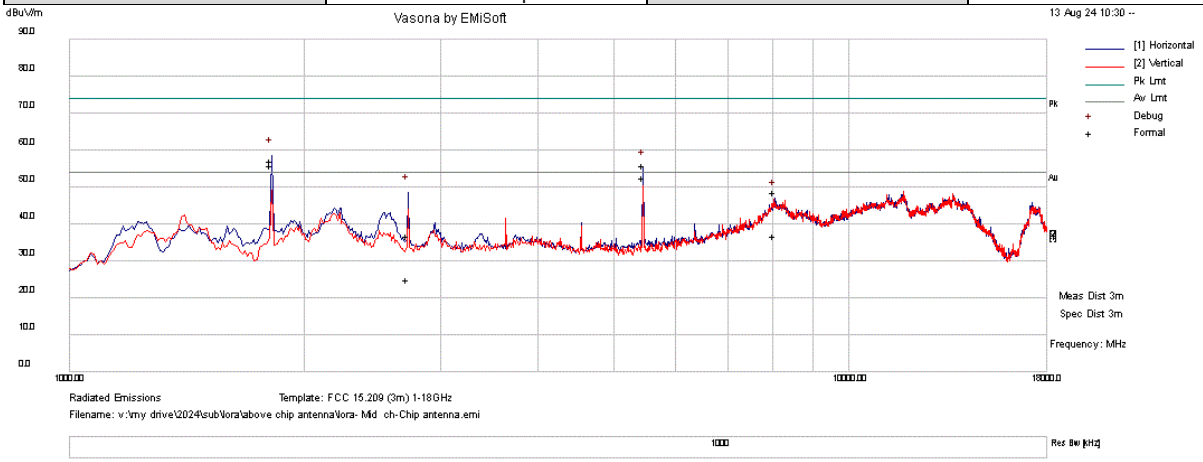
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1805.513	37.7	6.1	-0.2	43.6	Peak Max	H	132	17	74	-30.4	Pass
2	5407.608	21	10.5	6.1	37.7	Peak Max	H	164	160	74	-36.3	Pass
3	2712.008	26.5	7.2	1.1	34.8	Peak Max	H	167	46	74	-39.2	Pass
4	8012.038	19.3	14.3	15.9	49.4	Peak Max	H	207	165	74	-24.6	Pass
5	1805.513	29.4	6.1	-0.2	35.2	Average Max	H	132	17	54	-18.8	Pass
6	5407.608	9	10.5	6.1	25.7	Average Max	H	164	160	54	-28.3	Pass
7	2712.008	14.5	7.2	1.1	22.8	Average Max	H	167	46	54	-31.2	Pass
8	8012.038	7.3	14.3	15.9	37.4	Average Max	H	207	165	54	-16.6	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1805 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	Mid CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LORA-Mid CH-Chip Antenna	Test Result:	Pass



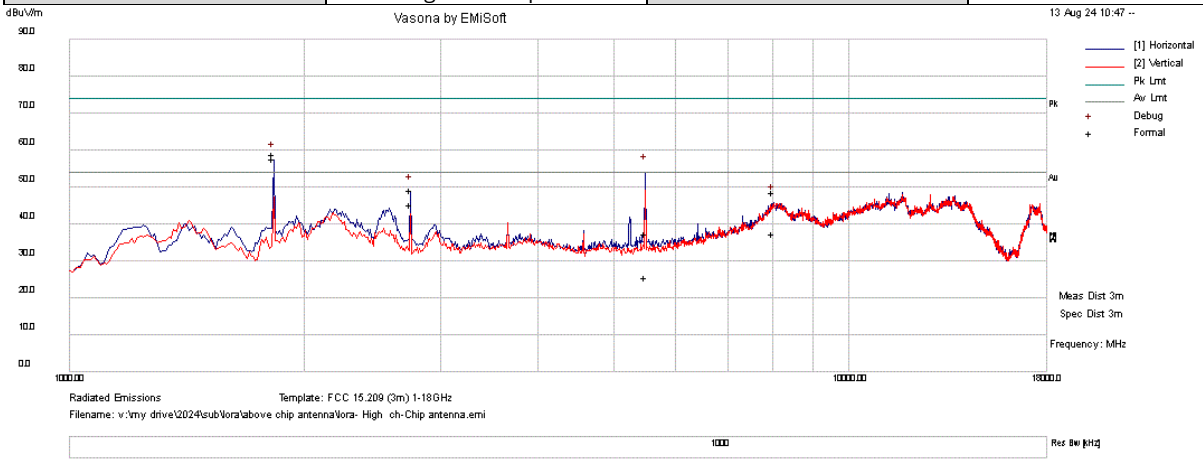
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1816.95	51	6.1	0	57.1	Peak Max	H	174	12	74	-16.9	Pass
2	5451.195	39.3	10.6	6	56	Peak Max	H	151	29	74	-18	Pass
3	2720.263	28.4	7.2	1.1	36.7	Peak Max	H	143	0	74	-37.3	Pass
4	8042.888	18.5	14.3	15.8	48.6	Peak Max	H	144	88	74	-25.4	Pass
5	1816.95	49.9	6.1	0	55.9	Average Max	H	174	12	54	1.9	Fail*
6	5451.195	35.9	10.6	6	52.6	Average Max	H	151	29	54	-1.4	Pass
7	2720.263	16.7	7.2	1.1	25.1	Average Max	H	143	0	54	-28.9	Pass
8	8042.888	6.8	14.3	15.8	36.9	Average Max	H	144	88	54	-17.1	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1816 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

RADIATED EMISSIONS 1 - 18 GHZ

Test Standard:	15.247, 15.209	Mode:	High CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/13/2024
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Minoush Niknam
Remark:	LORA-High CH- Chip Antenna	Test Result:	Pass



No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	1829.788	52.6	6.1	0.1	58.9	Peak Max	H	190	12	74	-15.1	Pass
2	5493.885	20.8	10.8	5.9	37.5	Peak Max	H	121	166	74	-36.5	Pass
3	2744.44	40.8	7.2	1.2	49.2	Peak Max	H	153	0	74	-24.8	Pass
4	8012.638	18.4	14.3	15.9	48.5	Peak Max	H	177	180	74	-25.5	Pass
5	1829.788	51.3	6.1	0.1	57.6	Average Max	H	190	12	54	3.6	Fail*
6	5493.885	8.9	10.8	5.9	25.6	Average Max	H	121	166	54	-28.4	Pass
7	2744.44	36.9	7.2	1.2	45.3	Average Max	H	153	0	54	-8.7	Pass
8	8012.638	7.2	14.3	15.9	37.3	Average Max	H	177	180	54	-16.7	Pass

Remarks:

1. Level (dBuV/m) = Raw (dBuV) + Cable loss(dB) + AF (dB/m).
2. AF (dB/m) = Antenna Factor (dB) – Preamplifier Gain (dB)
3. Margin = Level (dBuV/m) - Limit value(dBuV/m)
4. The 2nd harmonics of frequency 1829 MHz is not in the restricted band. The limit of FCC 15.209 is not required. For more information, please refer to section 7.8.4 conducted spurious emission result.

Radiated Emission between 9KHz – 30MHz test result

Note: no substantial emission is found other than the noise floor. Different modes have been verified.

Radiated Emission between 18GHz – 40GHz test result

Note: no substantial emission is found other than the noise floor. Different modes have been verified.

7.10 Frequency Hopping System Requirement

7.10.1 Requirement

Per § 15.247 (a) (1), 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.

Per § 15.247 (g), frequency hopping spread spectrum systems are not required to employ all available hopping channels during each transmission. However, the system, consisting of both the transmitter and the receiver, must be designed to comply with all of the regulations in this section should the transmitter be presented with a continuous data (or information) stream. In addition, a system employing short transmission bursts must comply with the definition of a frequency hopping system and must distribute its transmissions over the minimum number of hopping channels specified in this section.

Per § 15.247 (h), the incorporation of intelligence within a frequency hopping spread spectrum system that permits the system to recognize other users within the spectrum band so that it individually and independently chooses and adapts its hop-sets to avoid hopping on occupied channels is permitted. The coordination of frequency hopping systems in any other manner for the express purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters is not permitted.

7.10.2 Result

Analysis:

This system, consisting of both the transmitter and the receiver, is designed to comply with all of the regulations defined per § 15.247. This system also complies with the definition of a frequency hopping system and distribute its transmissions over the 64 channels which meets § 15.247 requirement.

The hopping sequence for the channel is based on a pseudo random sequence of channels defined in the code. The pseudorandom sequence is always followed and no other effort for adaptation or coordination is used.

An example of Pseudorandom Frequency Hopping Sequence Table as below:

05 49 23 33 27 02 54 31 29 21 07 28 41 62 52 46 57 06 06 12 52 42 39 13 21 49 44 06 29 06 50 53 29 47 12 53 05 13 63 10 15 41 16 57 46 25 33 48 26 49 28 04 28 01 52 50 61 41 46 01 51 56 63 33, etc.

The pseudorandom sequence of frequencies is followed by each receiver and each channel frequency within the sequence is listened to for a uniform dwell period. The transmitter syncs to a receiver's sequence and transmits on each channel within the sequence for dwell time. The device continues to cycle through each frequency and repeats the sequence in a regular period. This ensures that a constant transmitter uniformly spreads transmission equally across its frequency set. The system uses a uniformly distributed transmission scheme so the transmissions will on average occupy each transmission equally.

The system transmitters match the hopping channel sequence of the receiver. The input bandwidth matches the channel hopping and shift frequencies in synchronization with the transmitted signals.

The system receiver's listen on channels according to their pseudorandom channel sequence and dwell period. The input bandwidth is determined by this sequence and the system transmitters shift frequencies in synchronization with the receivers.

Conclusion:

EUT complies with frequency hopping system requirement in § 15.247.

8 EUT and Test Setup Photos

See FCC exhibits

9 Test Instrument List

Equipment	Manufacturer	Model	Instrument Number	Cal. Date	Cal. Due
Semi-Anechoic Chamber	ETS-Lindgren	10M	VL001	10/18/2023	10/18/2024
Shielding Control Room	ETS-Lindgren	Series 81	VL006	N/A1)	N/A1)
Spectrum Analyzer	Keysight	N9020A	MY50110074	06/09/2024	06/09/2025
EMC Test Receiver	R&S	ESL6	100230	06/07/2024	06/07/2025
LISN (9KHz – 30MHz)	EMCO	3816/2	9705-1066	07/12/2024	07/12/2025
Bi-Log Antenna	ETS-Lindgren	3142E	217921	07/19/2024	07/19/2025
Horn Antenna (1-18GHz)	Electro-Metrics	EM-6961	6292	07/21/2024	07/21/2025
Horn Antenna (18-40GHz)	Com-Power	AH-840	101109	07/21/2024	07/21/2025
Preamplifier	RF Bay, Inc.	LPA-10-20	11180621	07/16/2024	07/16/2025
True RMS Multi-meter	UNI-T	UT181A	C173014829	06/07/2024	06/07/2025
Temp / Humidity / Pressure Meter	PCE Instruments	PCE-THB 40	R062028	06/07/2024	06/07/2025
RF Attenuator	Pasternack	PE7005-3	VL061	N/A2)	N/A2)
EM Center Control	ETS-Lindgren	7006-001	160136	N/A1)	N/A1)
Turn Table	ETS-Lindgren	2181-3.03	VL002	N/A1)	N/A1)
Boresight Antenna Tower	ETS-Lindgren	2171B	VL003	N/A1)	N/A1)
Loop Antenna (9k-30MHz)	Com-Power	AL-130	121012	06/09/2024	06/09/2025
RE test cable (below 6GHz)	Vista	RE-6GHz-01	RE-6GHz-01	07/16/2024	07/16/2025
RE test cable (1-18GHz)	PhaseTrack	II-240	RE-18GHz-01	07/16/2024	07/16/2025
RE test cable (>18GHz)	Sucoflex	104	344903/4	07/16/2024	07/16/2025
Pulse limiter	Com-Power	LIT-930A	531727	07/16/2024	07/16/2025
CE test cable #1	FIRST RF	FRF-C-1002-001	CE-6GHz-01	07/16/2024	07/16/2025
CE test cable#2	FIRST RF	FRF-C-1002-001	CE-6GHz-02	07/16/2024	07/16/2025

Note:

1) This equipment is not for measurement purposes and only require functional verification. Calibration is not required.
2) This equipment is part of test system that to be calibrated as a system. It's verified together with the test system prior to testing.

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