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FCC RF Test Report

Test Report Number	SUB-23071961-LC-FCC-DSS
FCC ID	2AS4H-BLINC2
Applicant	Subeca, Inc.
Applicant Address	4514 Cole Avenue Suite 600, Dallas, TX 75205
Product Name	Subeca BLINC
Model (s)	BLINC
Date of Receipt	08/15/2023
Date of Test	08/15/2023- 08/21/2023
Report Issue Date	02/27/2024
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

Devin Tai (Test Engineer)

David Zhang (Technical Manager)

REVISION HISTORY

Report Number	Version	Description	Issued Date
SUB-23071961-LC-FCC-DSS	01	Initial report	02/27/2024

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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
Product Description	Subeca BLINC
Model Number	BLINC
Family Models	N/A
Serial Number	N/A
Frequency Band	BLE: 2402-2480MHz LoRA: 902.3-914.9MHz
Type of modulation	GFSK (BLE), LoRA
Equipment Class	DTS, DSS
Antenna Information	FPC Antenna: WPANT10148-S1A (BLE anenna), peak gain: 2 dBi WPANT10144-S2A (LoRA antenna), peak gain: -1 dBi WPANT10129-S1A (LoRA antenna), peak gain: 2 dBi
Clock Frequencies	N/A
Input Power	DC 3.7V
Power Adapter Manufacturer/Model	N/A
Power Adapter SN	N/A
Hardware version	N/A
Software version	N/A
Simultaneous Transmission	BLE and LoRa can transmit simultaneously
Additional Info	N/A

2.3 Test standard and method

Test standard	47 CFR Part 15.247
Test method	ANSI C63.10-2013 558074 D01 15.247 Meas Guidance v05r02

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

5.2 Supporting Equipment

Description	Manufacturer	Model #	Serial #
Development board	Subeca	PCB-00017	N/A
Power adapter	GNARBOX	KYTW40P01	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 removable FPC antennas which connect to the main board through unique U.FL RF connectors. One for BLE and one for LoRa.
- Both main board and antenna are equipped with U.FL connector. No standard RF connector is used.

Conclusion:

- EUT complies with antenna requirement in § 15.203.

7.2 Conducted Emissions

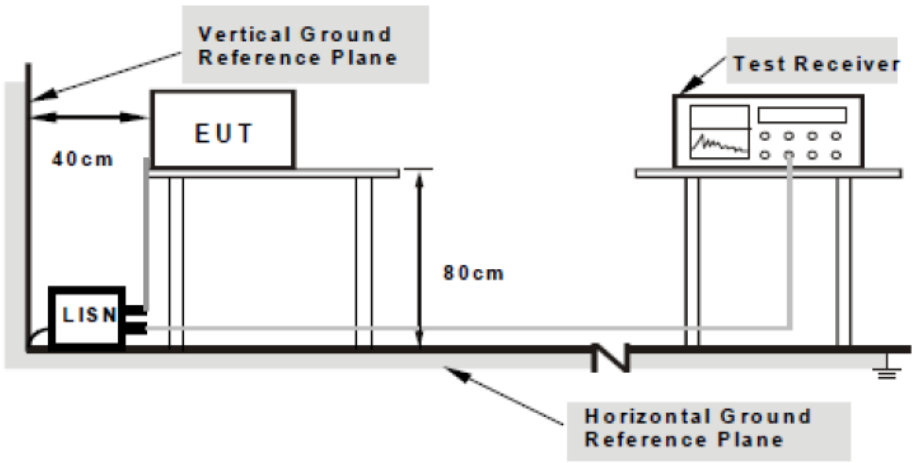
7.2.1 Requirement

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



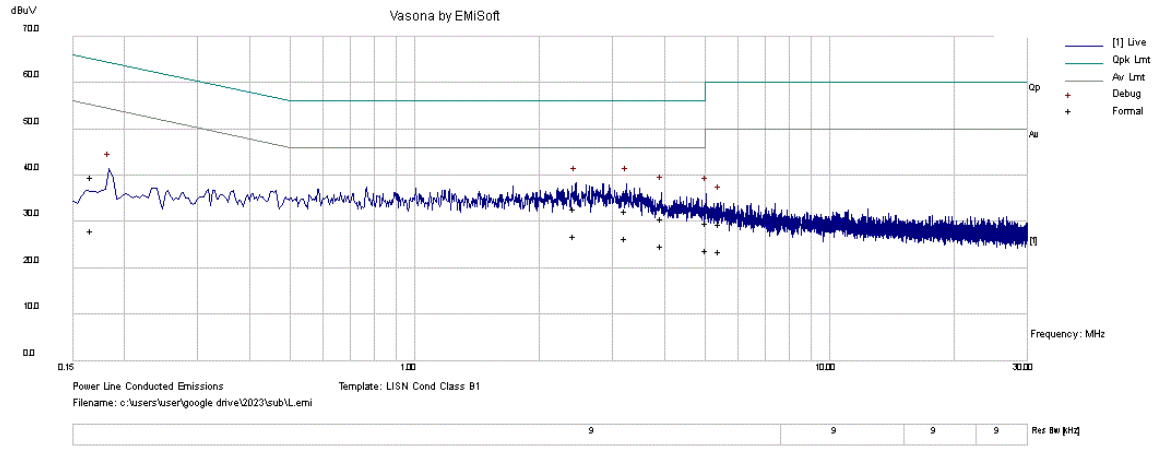
Note: 1.Support units were connected to second LISN.
2.Both of LISNs (AMN) are 80cm from EUT and at least 80cm from other units and other metal planes support units.

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:	08/21/2023
Antenna Type/Polarity:	N/A	Test Personnel:	Devin Tai
Remark:	Class B, 120VAC, 60Hz	Test Result:	Pass

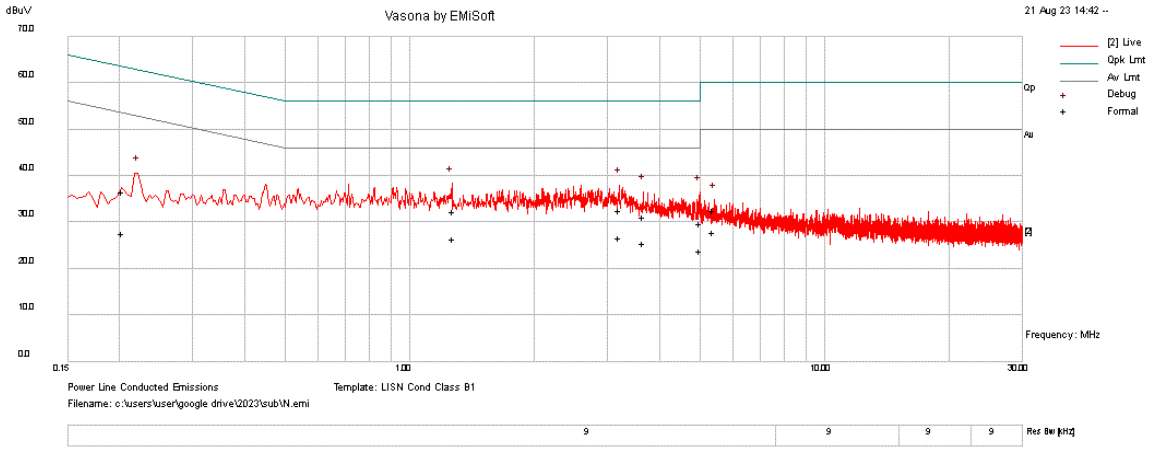


No.	Frequency (MHz)	Raw (dBuV)	Cable Loss (dB)	Factors (dB)	Level (dBuV)	Meas. Type	Line	Limit (dBuV)	Margin (dB)	Pass /Fail
1	2.432	22.4	10.2	0.1	32.7	Quasi Peak	Live	56	-23.3	Pass
2	3.223	22.1	10.3	0.1	32.5	Quasi Peak	Live	56	-23.5	Pass
3	3.95	20.3	10.3	0.1	30.7	Quasi Peak	Live	56	-25.3	Pass
4	0.166	29.5	10.1	0.2	39.8	Quasi Peak	Live	65.1	-25.3	Pass
5	5.046	19.3	10.4	0.1	29.8	Quasi Peak	Live	60	-30.2	Pass
6	5.439	18.9	10.4	0.1	29.4	Quasi Peak	Live	60	-30.6	Pass
7	2.432	16.5	10.2	0.1	26.8	Average	Live	46	-19.2	Pass
8	3.223	16.2	10.3	0.1	26.6	Average	Live	46	-19.4	Pass
9	3.95	14.4	10.3	0.1	24.8	Average	Live	46	-21.2	Pass
10	0.166	17.8	10.1	0.2	28.1	Average	Live	55.1	-27	Pass
11	5.046	13.4	10.4	0.1	23.9	Average	Live	50	-26.1	Pass
12	5.439	13.1	10.4	0.1	23.6	Average	Live	50	-26.4	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:	08/21/2023
Antenna Type/Polarity:	N/A	Test Personnel:	Devin Tai
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	1.274	22	10.2	0.1	32.3	Quasi Peak	Neutral	56	-23.7	Pass
2	3.207	22.2	10.3	0.1	32.6	Quasi Peak	Neutral	56	-23.4	Pass
3	3.656	20.9	10.3	0.1	31.3	Quasi Peak	Neutral	56	-24.7	Pass
4	0.204	26.3	10.1	0.2	36.6	Quasi Peak	Neutral	63.4	-26.8	Pass
5	5.018	19.3	10.4	0.1	29.8	Quasi Peak	Neutral	60	-30.2	Pass
6	5.414	22	10.4	0.2	32.6	Quasi Peak	Neutral	60	-27.4	Pass
7	1.274	16.2	10.2	0.1	26.5	Average	Neutral	46	-19.5	Pass
8	3.207	16.3	10.3	0.1	26.7	Average	Neutral	46	-19.3	Pass
9	3.656	15	10.3	0.1	25.4	Average	Neutral	46	-20.6	Pass
10	0.204	17.5	10.1	0.2	27.8	Average	Neutral	53.4	-25.6	Pass
11	5.018	13.5	10.4	0.1	24	Average	Neutral	50	-26	Pass
12	5.414	17.3	10.4	0.2	27.9	Average	Neutral	50	-22.1	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.

7.3 20 dB Bandwidth

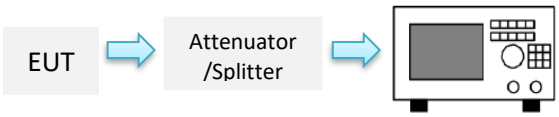
7.3.1 Requirement

§ 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

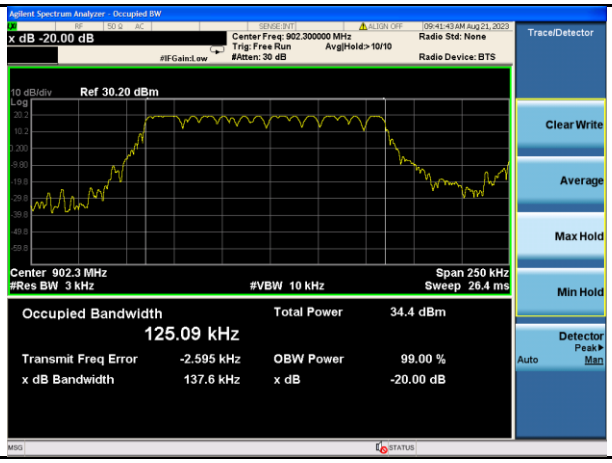
According to section 6.9.2, in ANSI C63.10-2013:

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

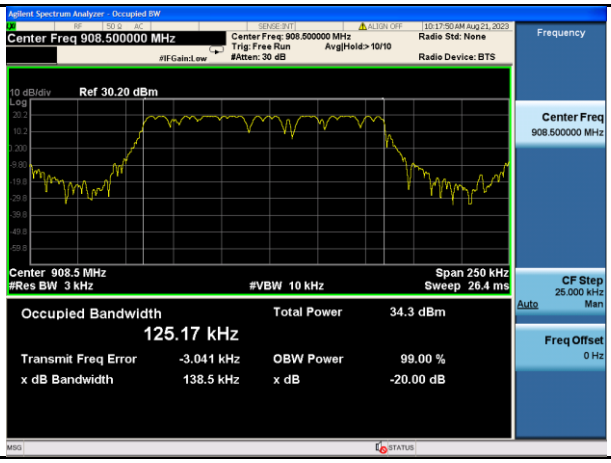
1. Set Center Frequency = Nominal EUT channel center frequency.
2. Set Span to be between two times and five times of the OBW.
3. RBW shall be in the range of 1% to 5% of the OBW, and VBW shall be approximately three times RBW.
4. Set detection mode to peak and trace mode to max hold.
5. Use the occupied 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

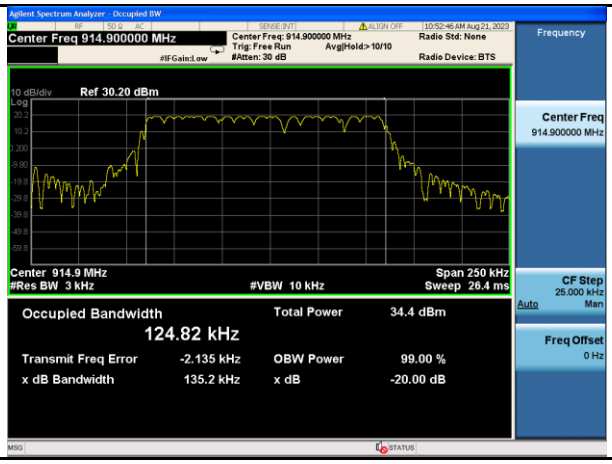
Mode/ Bandwidth	Frequency (MHz)	Measured Bandwidth (KHz)	Bandwidth Limit (KHz)	Result
LoRA	902.3	137.6	250	Pass
LoRA	908.4	138.5	250	Pass
LoRA	914.9	135.2	250	Pass



20dB BW - Low CH



20dB BW - Mid CH



20dB BW - High CH

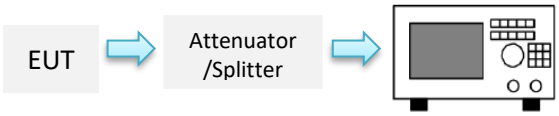
7.4 Maximum Output Power

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



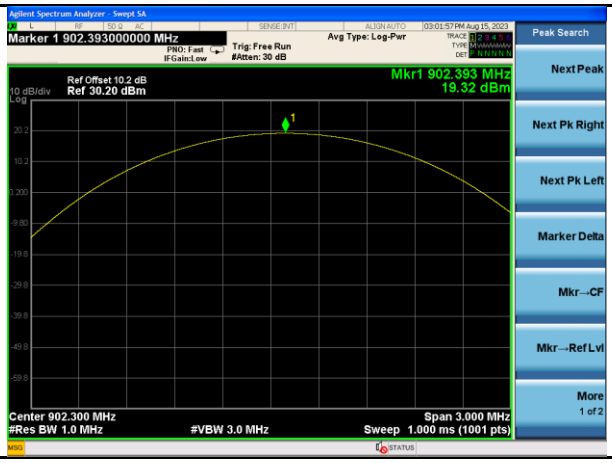
7.4.3 Test Procedure

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.

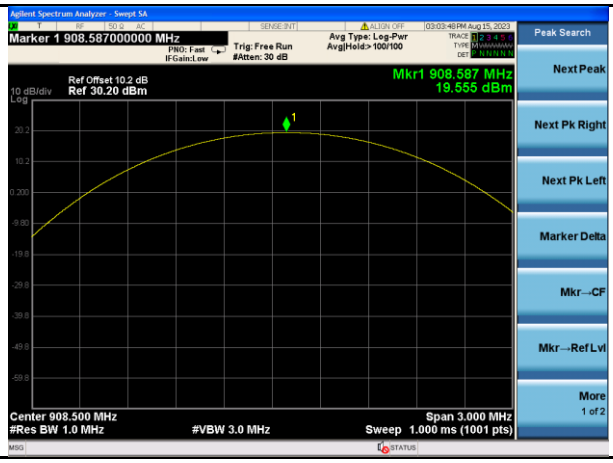
1. Set the RBW > 20 dB BW
2. Set VBW ≥ RBW.
3. Set span to approximately five times the 20 dB bandwidth, centered on a hopping channel.
4. Sweep time = auto couple.
5. Detector = peak.
6. Trace mode = max hold.
7. Allow trace to fully stabilize.
8. Use peak marker function to determine the peak amplitude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

7.4.4 Test Result

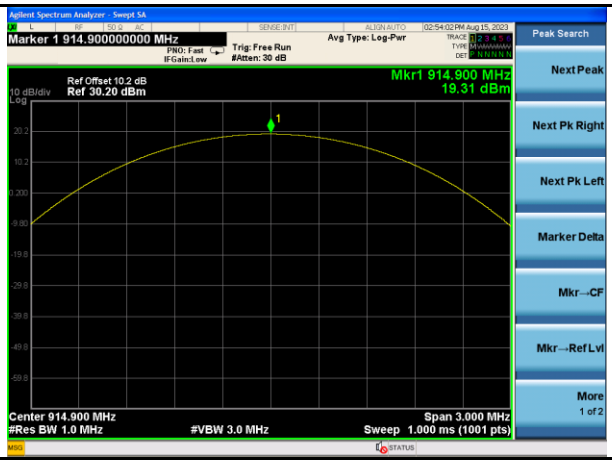
Mode/ Bandwidth	Frequency (MHz)	Measured Output Power (dBm)	Max Output Power (dBm)	Result
LoRA	902.3	19.32	30	Pass
LoRA	908.5	19.56	30	Pass
LoRA	914.9	19.31	30	Pass



OP - Low CH



OP - Mid CH



OP - High CH

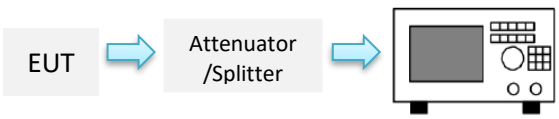
7.5 Number of Hopping Channel

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

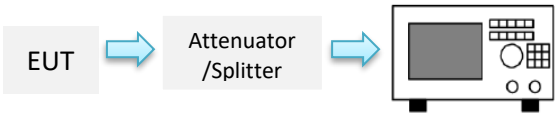
7.6 Channel Separation

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



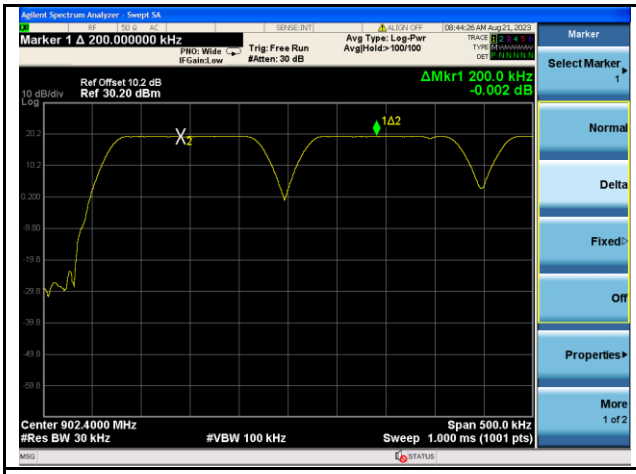
7.6.3 Test Procedure

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

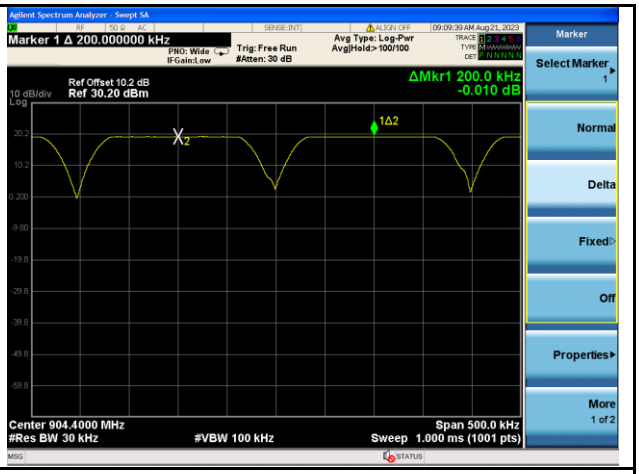
1. Set Span to wide enough to capture the peaks of two adjacent channels.
2. RBW: Start with the RBW set to approximately 30% of the channel spacing
3. VBW ≥ RBW.
5. Detector = peak.
6. Sweep time = auto couple.
7. Trace mode = max hold.
8. Allow trace to fully stabilize.
9. Use the peak marker function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

7.6.4 Test Result

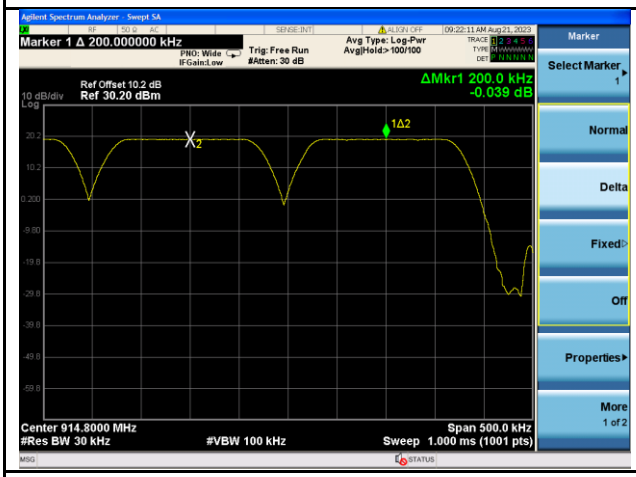
Mode/ Bandwidth	Frequency (MHz)	Channel Separation (KHz)	Max 20 dB Bandwidth (KHz)	Result
LoRA	902.3	200	137.6	Pass
LoRA	908.5	200	138.5	Pass
LoRA	914.9	200	135.2	Pass



CH Sep - Low CH



CH Sep - Mid CH



CH Sep - High CH

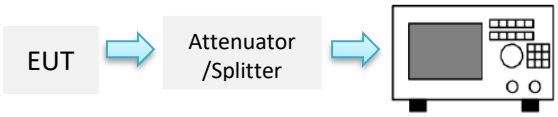
7.7 Time of Occupancy

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



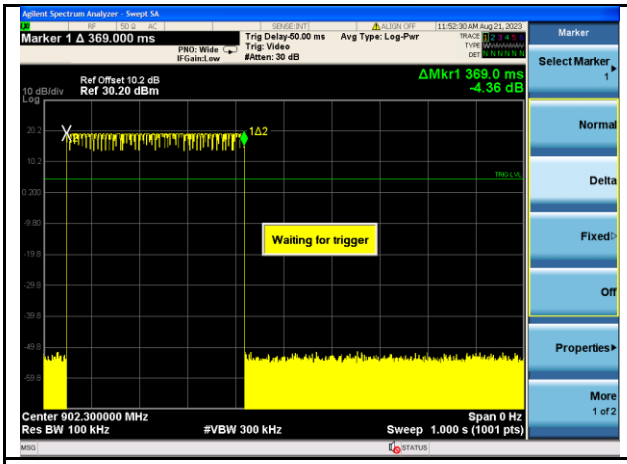
7.7.3 Test Procedure

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

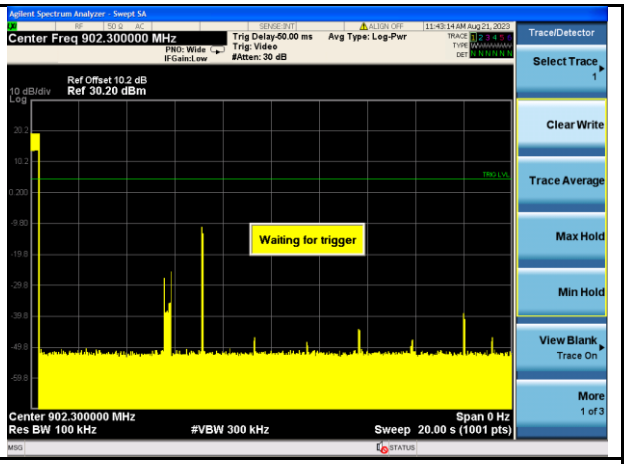
1. Set Span to zero, centered on a hopping channel.
2. RBW shall be ≤ channel spacing.
3. VBW ≥ RBW.
5. Detector = peak.
6. Sweep time = auto couple. As necessary to capture the entire dwell time per hopping channel; where possible use a video trigger and trigger delay so that the transmitted signal 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

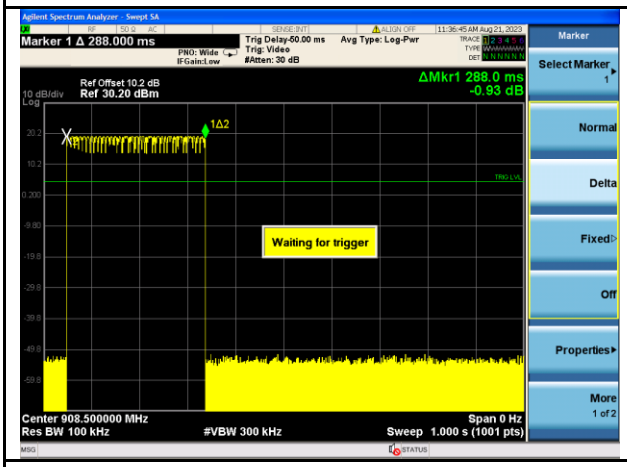
Mode/ Bandwidth	Frequency (MHz)	Burst Width (ms)	Number of transmissions in 20 sec	Dwell Time (ms)	Limit (ms)	Result
LoRA	902.3	369	1	369	≤ 400	Pass
LoRA	908.5	288	1	288	≤ 400	Pass
LoRA	914.9	288	1	288	≤ 400	Pass



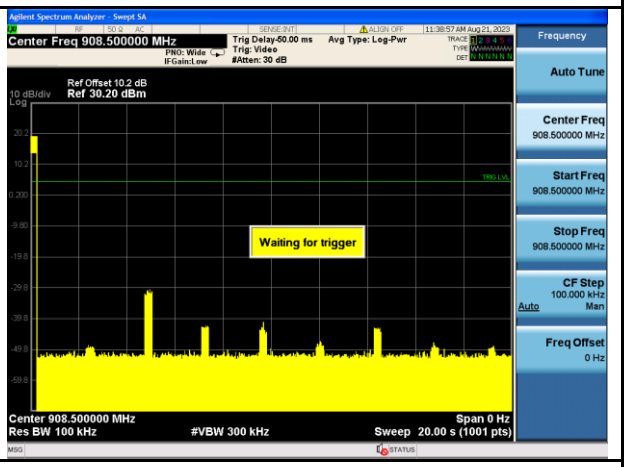
Dwell Time - Low CH (Single Pulse)



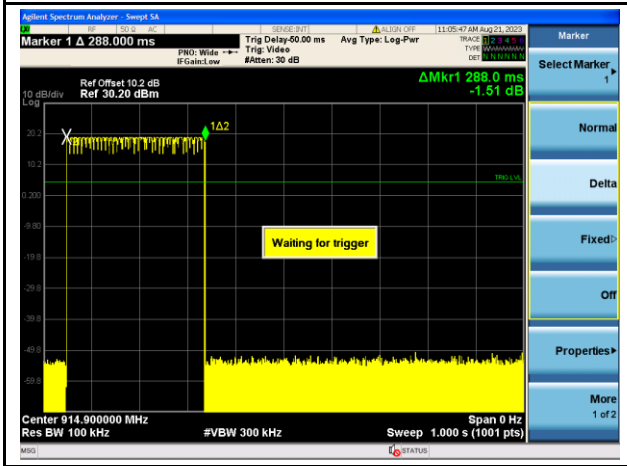
Dwell Time - Low CH (Cycle)



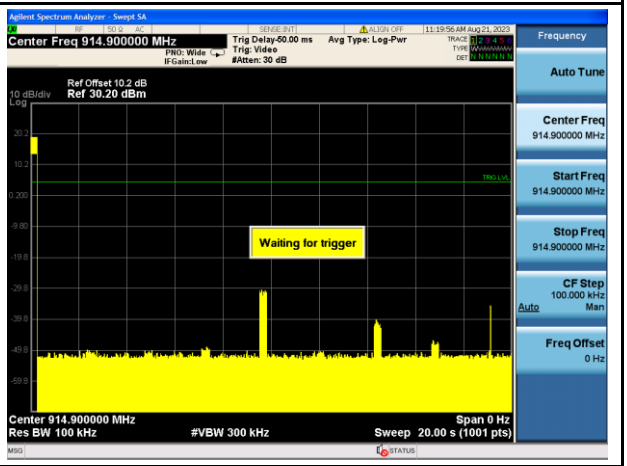
Dwell Time - Mid CH (Single Pulse)



Dwell Time - Mid CH (Cycle)



Dwell Time - High CH (Single Pulse)



Dwell Time - High CH (Cycle)

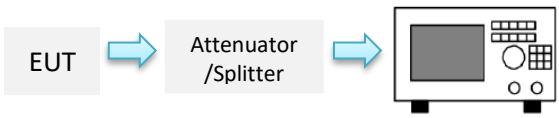
7.8 Conducted Band-Edge

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.

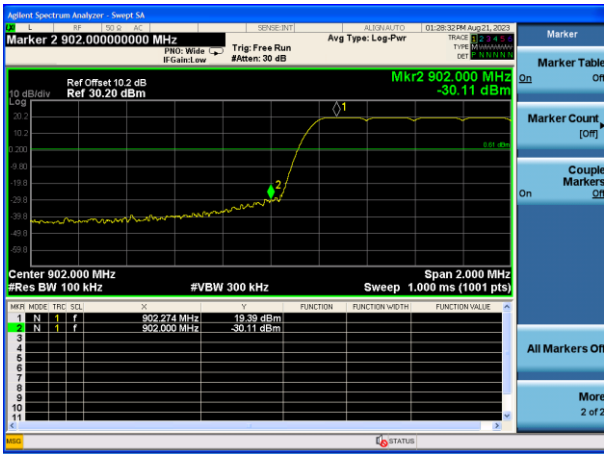
g. Detector: Peak.
h. Trace: Max hold.
i. Allow the trace to stabilize. For the test with the hopping function turned ON, this can take several minutes to achieve a reasonable probability of intercepting any emissions due to oscillator overshoot.

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).

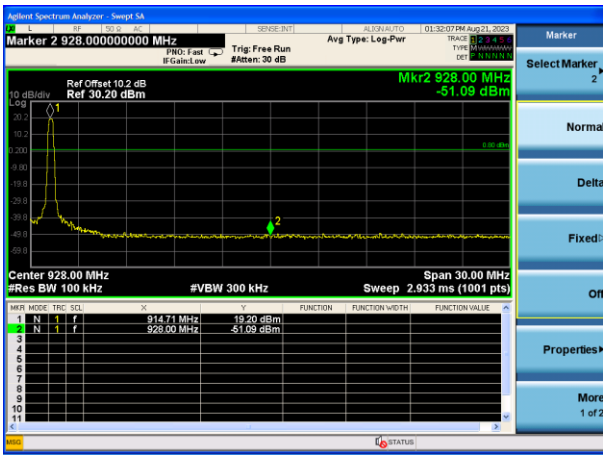
7.8.4 Test Result

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

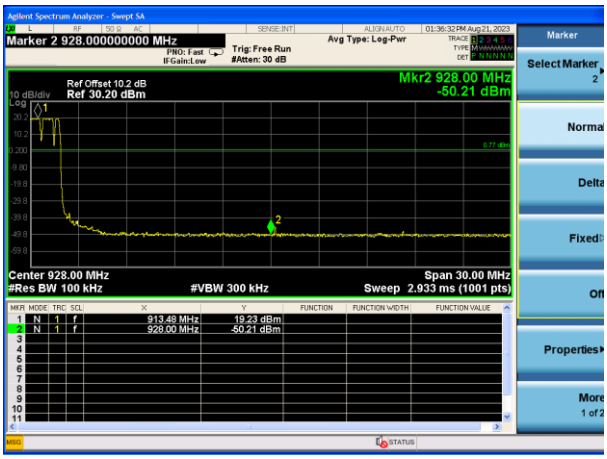
Band Edge-Low CH-Non hopping



Band Edge-Band Edge-Low CH-Hopping



Band Edge-High CH-Non hopping



Band Edge-High CH-Hopping

7.9 Radiated Spurious Emissions into Restricted Frequency Bands

7.9.1 Requirement

Per § 15.247 (d)

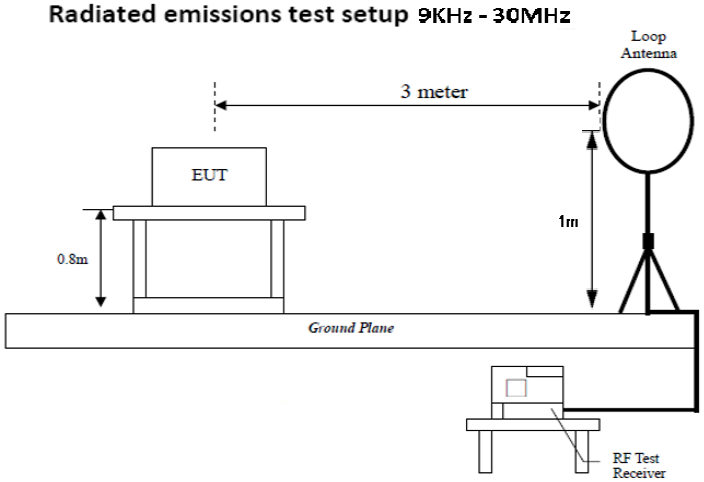
In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the 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)).

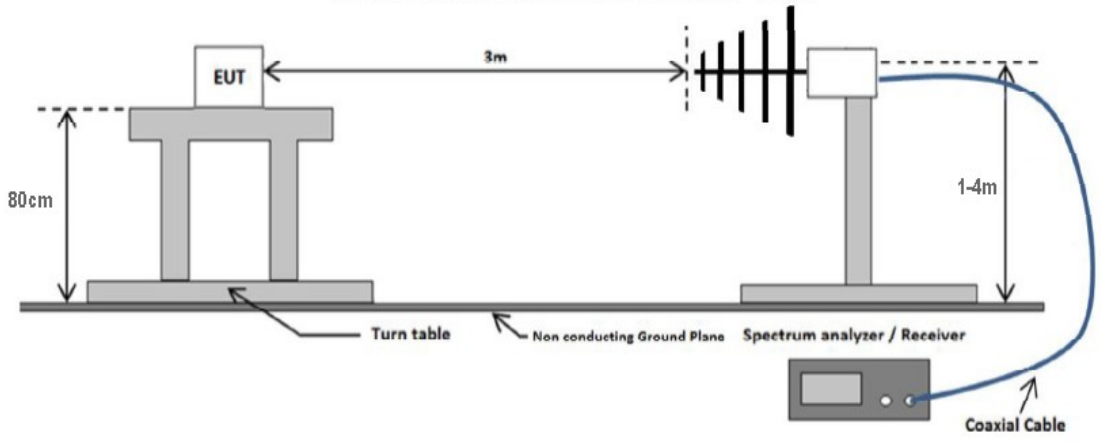
Frequency Range (MHZ)	Field Strength (μV/m)
0.009~0.490	2400/F(KHz)
0.490~1.705	24000/F(KHz)
1.705~30.0	30
30 – 88	100
88 – 216	150
216 960	200
Above 960	500

7.9.2 Test Setup

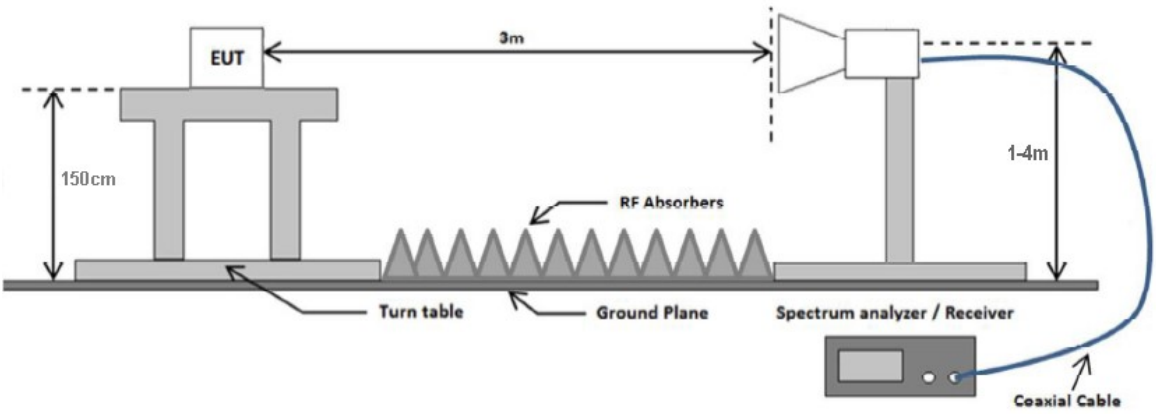
Radiated emissions test setup 9KHz - 30MHz



Radiated emissions test setup 30 MHz - 1 GHz



Radiated emissions test setup above 1 GHz



7.9.3 Test Procedure

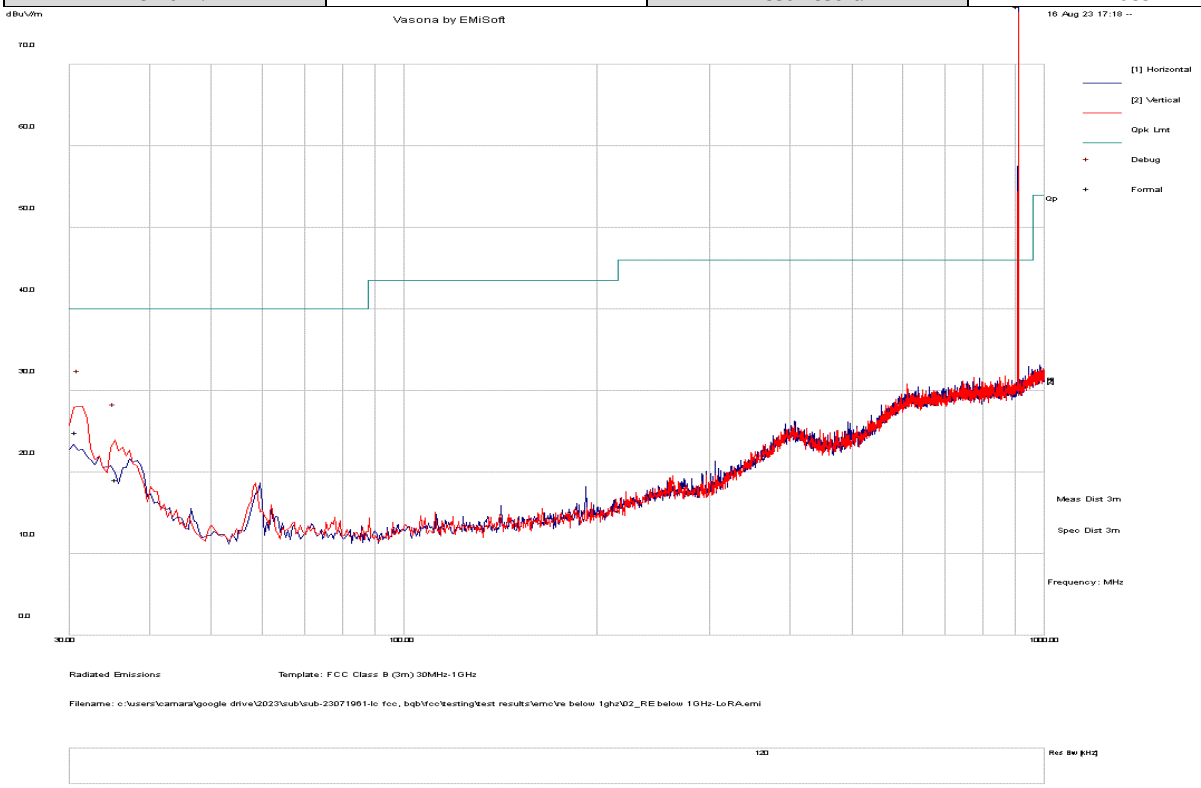
According to subclause 6.4, 6.5 and 6.6 of Radiated spurious emission measurements in ANSI C63.10-2013 as well as the procedures for maximizing and measuring radiated emissions that are described in ANSI C63.10 was followed. Boresight antenna mast was used during the scanning to point to EUT to maximize 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:	08/16/2023
Antenna Type/Polarity:	Bi-Log/Hor & Ver	Test Personnel:	Devin Tai
Remark:	N/A	Test Result:	Pass



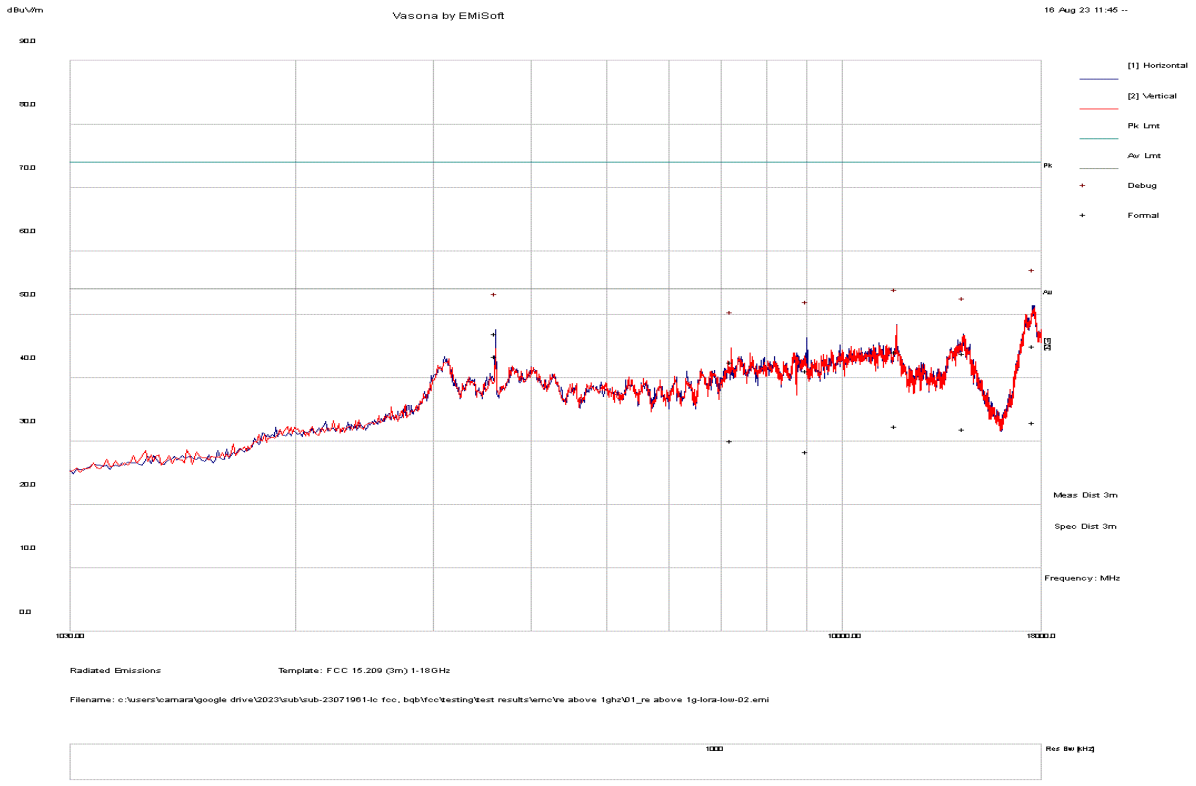
No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	30.817	34.7	2.3	-12	25	Quasi Max	V	375	170	40	-15	Pass
2	35.506	31.3	2.4	-14.6	19.1	Quasi Max	V	163	266	40	-20.9	Pass

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:	08/16/2023
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Devin Tai
Remark:	N/A	Test Result:	Pass

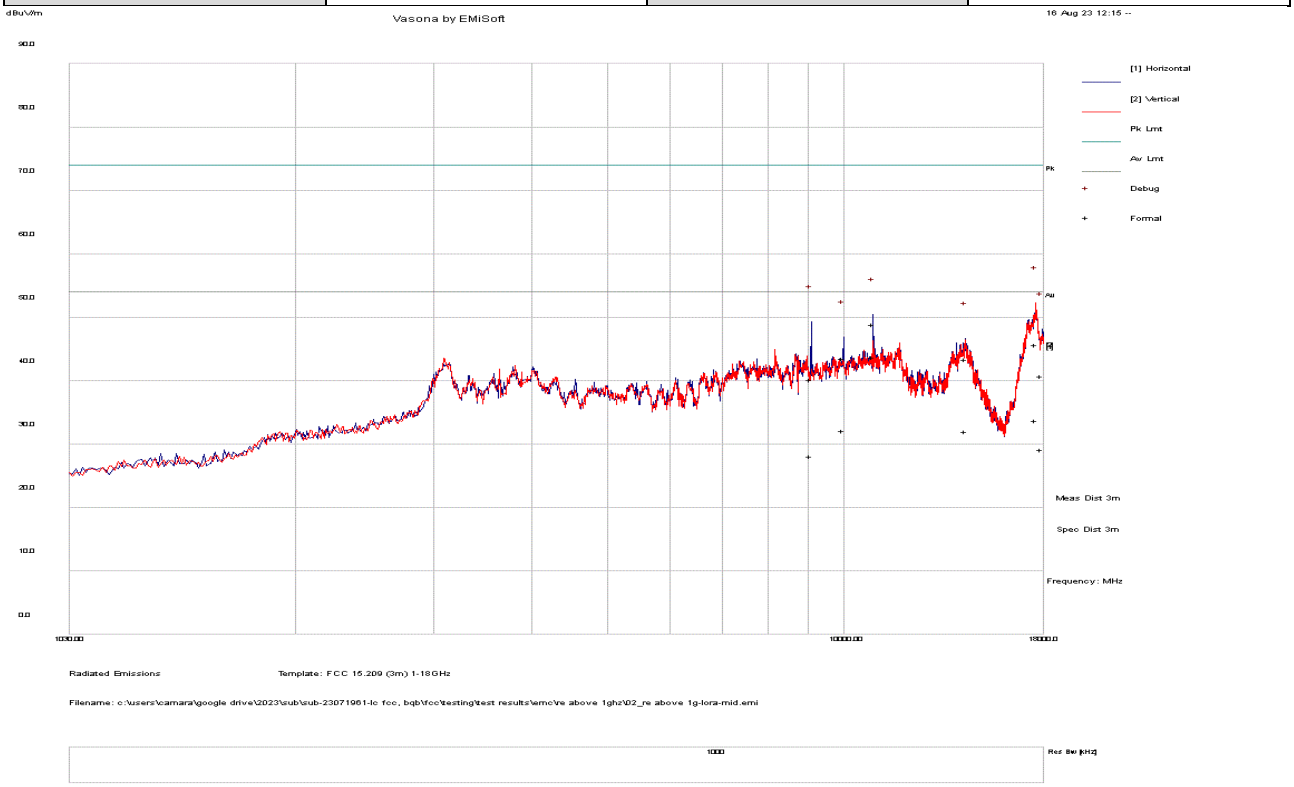


No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	17573.853	19	22	4.1	45.1	Peak Max	H	253	87	74	-28.9	Pass
2	11732.286	29.9	18.3	-4.2	44	Peak Max	H	215	0	74	-30	Pass
3	3609.299	36.7	8.5	1.8	47	Peak Max	H	100	308	74	-27	Pass
4	14300.084	26.4	16.4	1.1	43.9	Peak Max	H	343	298	74	-30.1	Pass
5	9025.575	31.8	15.1	-5.8	41.1	Peak Max	H	100	278	74	-32.9	Pass
6	7222.188	35.4	12.7	-5.5	42.6	Peak Max	V	405	0	74	-31.4	Pass
7	17573.853	6.9	22	4.1	33	Average Max	H	253	87	54	-21	Pass
8	11732.286	18.3	18.3	-4.2	32.4	Average Max	H	215	0	54	-21.6	Pass
9	3609.299	33.2	8.5	1.8	43.5	Average Max	H	100	308	54	-10.5	Pass
10	14300.084	14.4	16.4	1.1	31.9	Average Max	H	343	298	54	-22.1	Pass
11	9025.575	19.1	15.1	-5.8	28.4	Average Max	H	100	278	54	-25.6	Pass
12	7222.188	23	12.7	-5.5	30.2	Average Max	V	405	0	54	-23.8	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)

Test Standard:	15.247, 15.209	Mode:	Mid CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/16/2023
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Devin Tai
Remark:	N/A	Test Result:	Pass

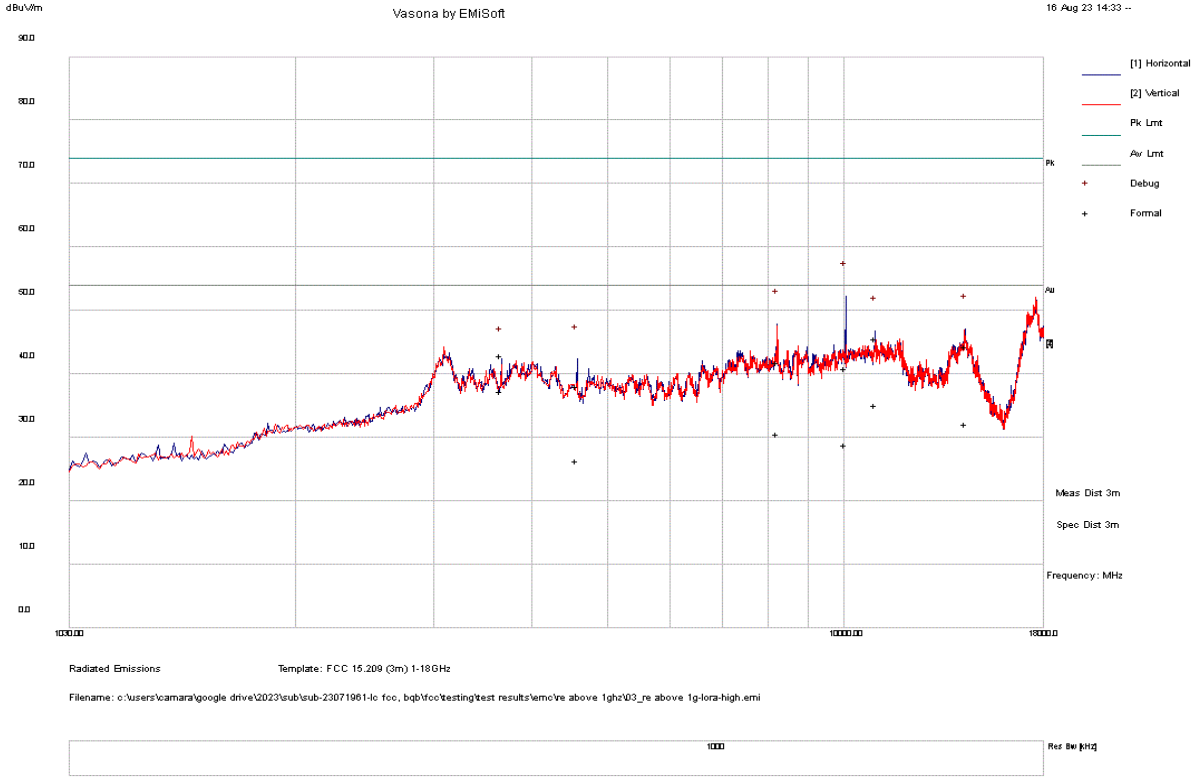


No.	Frequency MHz	Raw dBuV	Cable Loss dB	AF dB/m	Level dBuV/m	Measurement Type	Pol	Hgt cm	Azt Deg	Limit dBuV/m	Margin dB	Pass/Fail
1	17598.8	19.3	22	4.4	45.7	Peak Max	V	178	36	74	-28.3	Pass
2	10903.584	36.6	17.2	-4.8	49	Peak Max	H	192	210	74	-25	Pass
3	9088.783	31	15.1	-5.8	40.3	Peak Max	H	298	96	74	-33.7	Pass
4	17905.231	17.3	21.7	1.8	40.8	Peak Max	H	227	194	74	-33.2	Pass
5	9990.514	32.3	16.7	-5.5	43.5	Peak Max	H	371	102	74	-30.5	Pass
6	14318.069	26	16.4	1.1	43.5	Peak Max	H	326	252	74	-30.5	Pass
7	17598.8	7.4	22	4.4	33.8	Average Max	V	178	36	54	-20.2	Pass
8	10903.584	31.4	17.2	-4.8	43.8	Average Max	H	192	210	54	-10.2	Pass
9	9088.783	18.9	15.1	-5.8	28.2	Average Max	H	298	96	54	-25.8	Pass
10	17905.231	5.8	21.7	1.8	29.3	Average Max	H	227	194	54	-24.7	Pass
11	9990.514	20.9	16.7	-5.5	32.1	Average Max	H	371	102	54	-21.9	Pass
12	14318.069	14.5	16.4	1.1	32	Average Max	H	326	252	54	-22	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)

Test Standard:	15.247, 15.209	Mode:	High CH
Frequency Range:	1 GHz – 18 GHz	Test Date:	08/16/2023
Antenna Type/Polarity:	Horn/Hor & Ver	Test Personnel:	Devin Tai
Remark:	N/A	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	10065.128	29.6	16.7	-5.4	40.9	Peak Max	H	394	133	74	-33.1	Pass
2	8233.279	33.1	14.2	-5.5	41.8	Peak Max	H	275	65	74	-32.2	Pass
3	14310.628	26.8	16.4	1.1	44.3	Peak Max	H	130	65	74	-29.7	Pass
4	10978.935	33	17.2	-4.6	45.6	Peak Max	H	240	202	74	-28.4	Pass
5	4571.857	31.3	8.7	-1.8	38.2	Peak Max	V	267	80	74	-35.8	Pass
6	3659.912	31.6	8.6	2.8	43	Peak Max	V	116	232	74	-31	Pass
7	10065.128	17.5	16.7	-5.4	28.8	Average Max	H	394	133	54	-25.2	Pass
8	8233.279	21.9	14.2	-5.5	30.6	Average Max	H	275	65	54	-23.4	Pass
9	14310.628	14.7	16.4	1.1	32.2	Average Max	H	130	65	54	-21.8	Pass
10	10978.935	22.5	17.2	-4.6	35.1	Average Max	H	240	202	54	-18.9	Pass
11	4571.857	19.5	8.7	-1.8	26.4	Average Max	V	267	80	54	-27.6	Pass
12	3659.912	25.9	8.6	2.8	37.3	Average Max	V	116	232	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)

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 hopsets 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	10/18/2022	10/18/2023
Shielding Control Room	ETS-Lindgren	Series 81	VL006	N/A1)	N/A1)
Spectrum Analyzer	Keysight	N9020A	MY50110074	06/09/2023	06/09/2024
EMC Test Receiver	R&S	ESL6	100230	06/07/2023	06/07/2024
LISN (9KHz – 30MHz)	EMCO	3816/2	9705-1066	07/12/2023	07/12/2024
Bi-Log Antenna	ETS-Lindgren	3142E	217921	07/19/2023	07/19/2024
Horn Antenna (1-18GHz)	Electro-Metrics	EM-6961	6292	07/21/2023	07/21/2024
Horn Antenna (18-40GHz)	Com-Power	AH-840	101109	07/21/2023	07/21/2024
Preamplifier	RF Bay, Inc.	LPA-10-20	11180621	07/16/2023	07/16/2024
True RMS Multi-meter	UNI-T	UT181A	C173014829	06/07/2023	06/07/2024
Temp / Humidity / Pressure Meter	PCE Instruments	PCE-THB 40	R062028	06/07/2023	06/07/2024
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	06/09/2023	06/09/2024
RE test cable (below 6GHz)	Vista	RE-6GHz-01	RE-6GHz-01	07/16/2023	07/16/2024
RE test cable (1-18GHz)	PhaseTrack	II-240	RE-18GHz-01	07/16/2023	07/16/2024
RE test cable (>18GHz)	Sucoflex	104	344903/4	07/16/2023	07/16/2024
Pulse limiter	Com-Power	LIT-930A	531727	07/16/2023	07/16/2024
CE test cable #1	FIRST RF	FRF-C-1002-001	CE-6GHz-01	07/16/2023	07/16/2024
CE test cable#2	FIRST RF	FRF-C-1002-001	CE-6GHz-02	07/16/2023	07/16/2024

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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